Was the Gold Standard Really Destabilizing?

Gabriel Fagan[*], James R. Lothian[†], and Paul D. McNelis[‡]

September 2009

Abstract

No. This paper investigates the extent to which the high macroeconomic volatility experienced in the classical Gold-Standard era of US history can be attributed to the monetary policy regime *per se* as distinct from other shocks. For this purpose, we estimate a small Dynamic Stochastic General Equilibrium model for the classical Gold-Standard era. We use this model to conduct a counterfactual experiment to assess whether a monetary policy conducted on the basis of a Taylor rule characterizing the Great-Moderation data would have led to different outcomes for macroeconomic volatility and welfare in the Gold-Standard era. The counterfactual Taylor rule significantly reduces inflation volatility, but at the cost of higher real money and interest rate volatility. There is no unambiguous welfare improvement.

1 Introduction

There is an emerging consensus that, from the mid-1980s up until 2008, the US economy experienced a period of unusually low volatility in output accompanied by low and stable inflation [see, for example, Stock and Watson (2003)]. This stands in contrast to the high levels of macroeconomic instability which characterized the late 1960s and 1970s, now called the Great Inflation. There is an ongoing debate as to the sources of the improved performance, which has been dubbed the Great Moderation. Is it due to luck, reflected in the fact that the magnitude of the shocks hitting the economy have been much smaller, as Sims and Zha (2006) and Ahmed, Levin and Wilson (2004) argue? Alternatively, does it reflect the improved conduct of monetary policy, reflected in a stronger response of interest rates to inflation, as Clarida, Gali and Gertler (2000) and Benati and Surico (2008) suggest?

The studies which address this question make use of historical counterfactual simulations: by means of stochastic simulation of the respective models, they ask how the economy would have performed in the Great-Inflation era if the policy

---

[*] Directorate General Research, European Central Bank

[†] Department of Finance, Fordham University

[‡] Department of Finance, Fordham University

rule of the Great-Moderation era had been in place. Volcker and Greenspan thus go back in time.

The current discussion has interesting parallels with a debate which has long been underway among economic historians. Numerous studies have documented the fact that the classical Gold-Standard era (from 1879 to the start of World War I), although it delivered a low long-term average rate of inflation, was characterized by higher levels of volatility of output, shorter term inflation and interest rates relative to the post World War II era (see Bordo and Schwartz (1999)[1].

One influential line of argument holds that the Gold-Standard regime itself was responsible for the high degree of macroeconomic instability that was observed in this period since, as Niehans (1978) argued, the pure Gold Standard left no room for monetary policy to stabilize output.

Irving Fisher (1920, p. 65) was particularly vehement in this regard, stating that:

> The chief indictment, then, of our present dollar is that it is uncertain. As long as it is used as a measuring stick, every contract is necessarily a lottery; and every contracting party is compelled to be a gambler in gold without his own consent.
>
> Business is always injured by uncertainty. Uncertainty paralyzes effort. And uncertainty in the purchasing power of the dollar is the worst of all business uncertainties.

Fisher went on to say that (1920, p. 65):

> One of the results of such uncertainty is that price fluctuations cause alternate fluctuations in business; that is, booms and crises, followed by contractions and depressions.

More recently, in a somewhat similar vein Gramlich (1998) argued that:

> Monetary policy was not set consciously in terms of the economic needs of the country, but by the world gold market. The world gold stock would fluctuate in line with international discoveries, while the stock in particular countries reflected trade flows. There was no automatic provision for money or liquidity to grow in line with the normal production levels in the economy... this regime was responsible for large fluctuations in real output, much less stability in real output than has been achieved in the post gold standard era.

---

[1] There is some controversy as to whether output in the Gold-Standard era was in fact more volatilie than in the post World War II era and conclusions depend on the data sets used (see Romer (1990). Nonetheless, regardless of the data sets employed, macroeconomic volatility was clearly higher than what has been recorded in the Great-Moderation era.

This view seems now to be an accepted wisdom, and is even reflected in some undergraduate textbooks. [2]

However, the recent debate about the sources of the Great Moderation highlights the need for caution in attributing high levels of macroeconomic volatility solely to the monetary policy regime in place. Indeed, there is some evidence to suggest that the US economy was subject to highly volatile demand and supply shocks in the Gold-Standard era (Bordo and Schwartz, 1999). As an example of a different view, for example, Chernyshoff, Jacks and Taylor (2005) argue that the Classical Gold Standard was an effective shock absorber.

In line with the literature on the Great Moderation, we address the question of the extent to which the macroeconomic volatility experienced during the gold standard era was due to the monetary regime by conducting a counterfactual experiment. Specifically, using Bayesian techniques, we estimate a dynamic stochastic general equilibrium (DSGE) model for the period of the classical Gold Standard (1879 to 1914). We then proceed to conduct our counterfactual experiment. Taking the parameters, including the estimated shock volatilities, from the Gold-Standard era, we simulate the model under two alternative monetary policy rules: first, the estimated historical rule for the Gold Standard era and, second, the Taylor rule estimated for the Great-Moderation era. Finally, we compare the properties of the classical Gold-Standard economy under these different rules. This allows us to assess how macroeconomic outcomes would have been different had a Taylor rule characterizing the Great-Moderation era been in place instead of the Gold-Standard regime.

The remainder of this paper is structured as follows. The next section examines the data from the classical Gold Standard and compares key properties with corresponding data from the Great Moderation. Section 3 presents the model we use for our Bayesian estimation and subsequent counter-factual simulation. The following section then examines the welfare and volatility distributions of key macroeconomic variables under the actual and counterfactual monetary regimes in the Gold-Standard Era.

2 The Data

The data we use for the Gold-Standard era come from Balke and Gordon (1989b), and are based on quarterly interpolations of the annual data reported in Balke and Gordon (1989a)[3]. In our estimation, we use quarterly data

---

[2] Burda and Wyplosz (1997, p.515), for example, state in an undergraduate macro textbook aimed at a European audience: "While average growth was comparable to the postwar experience and inflation was lower, the table also shows that both measures were more variable under the gold standard. Unstable economic conditions imposed serious costs on individuals at the time, as is made clear by the unemployment rates... Was it just a coincidence? In fact, the very automatic mechanisms that are often considered the main advantage of the gold standard imply such an outcome."

[3] In order to derive an estimated policy rule for our counterfactual experiment, we also estimate the model for the Great-Moderation era. For this purpose, we use the FRED database of the Federal Reserve Bank of St. Louis.

for four macroeconomic variables: real GDP (y), the rate of change of the GDP deflator (π), a short-term interest rate (the interest rate on commercial paper) (r), and nominal base money . We transform the logarithm of real GDP with the Hodrik-Prescot filter. For the other variables we simply detrend the variables by taking deviations from a log-linear time trend. Figures 1-A to 1-D picture these four variables for the classical Gold Standard period.

Figure 1-A

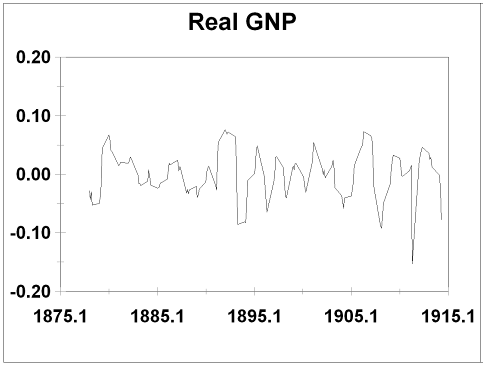


Figure 1-B

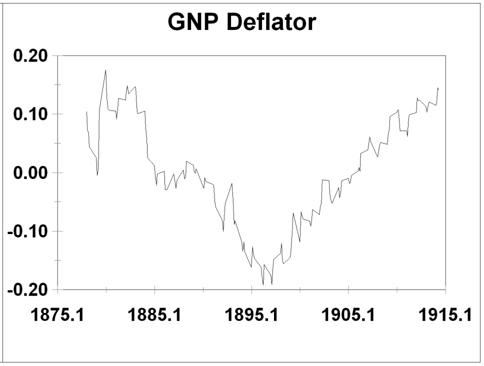


Figure 1-C

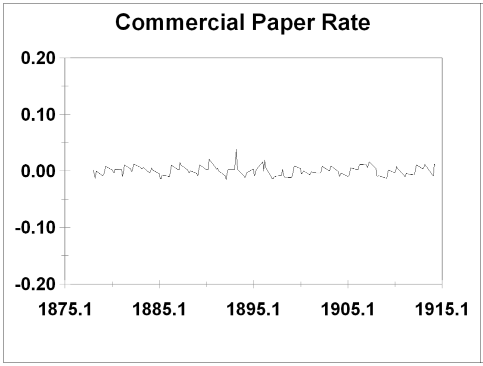


Figure 1-D

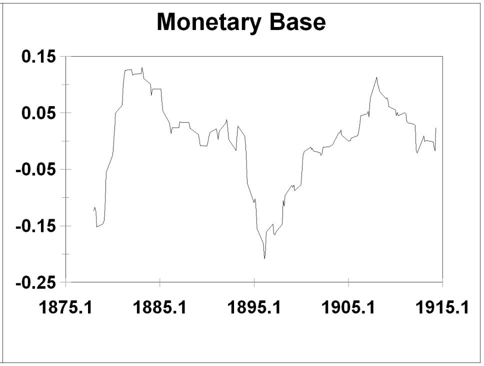


Table 1 shows the means and standard deviations of the raw data on the rate of growth of output, inflation, interest rates and nominal base money. We also show the standard deviations for the filtered variables which we will use in the model estimation.

Table 1. Statistics for Gold Standard and Great Moderation

Means

.	Δy	π	r	Δm
Gold Std.	3.48	0.35	5.94	6.37
Great Mod.	2.97	2.48	4.75	5.16

Std. Deviation-Actual Data

	Δy	π	r	Δm
Gold Std.	2.33	2.15	0.22	3.36
Great Mod.	0.49	0.24	0.50	0.74

Std. Deviation - Filtered Data

	$\widehat{y}$	$\widehat{\pi}$	$\widehat{r}$	$\widehat{m}$
Gold Std.	0.037	0.021	0.002	0.077
Great Mod.	0.009	0.002	0.005	0.036

As regards the means, the following well known features can be highlighted. Output growth rates in the two periods are broadly comparable. Notwithstanding the good inflation performance in the Great-Moderation period, it is notable that inflation in the period 1879-1914 was almost zero, implying a modest rise in the price level over the whole period. Of course, this average masks the fact there was alternation between deflation and inflation over the period. The main feature of interest from the point of view of this paper, however, is the relative volatilities of the key variables. When measured in terms of growth rates, the standard deviation of output is practically four times larger in the Gold Standard compared to the Great Moderation, while inflation is 10 times more volatile. Nominal money growth rates are almost three times as volatile. Interestingly, interest rates are less volatile in the Gold Standard era. The same picture emerges when we use standard deviations of the filtered data. These statistics confirm the conventional wisdom that the Gold Standard era was a much more volatile era than the Great Moderation. Is this difference due to the monetary policy regime or are other factors at play? In the remainder of this paper, we will address this question using a microfounded DSGE model.

3 The Model

3.1 Theoretical Framework

Given the paucity of data for the Gold-Standard era, and in line with much of the existing literature, we confine ourselves to a relatively small-scale workhorse model. The model comprises four linearized equations: an Euler equation for consumption, a Phillips curve, a money-demand relation and a stochastic process for money supply. The periodicity of the model is quarterly.

Specifically, we employ the model put forth by Andrés, López-Salido and Vallés (2006). This model is representative of the New Keynesian approach in macroeconomic dynamic stochastic general equilibrium modelling. For our purposes, the advantage of this model, in contrast to other New Keynesian models is that it explicitly incorporates money. Thus it can be used straightforwardly to analyse a monetary regime such as the Gold Standard in which interest rates are determined by the interaction of the supply and demand for money rather than being explicitly set by a central bank policy rule. Given the empirical evidence reported in that paper and by Ireland (2004), we employ the version which assumes linear separability between money and consumption in preferences (ie, the utility function). The model incorporates a number of frictions which in principle allow it to match the dynamics of the data: internal habit formation in consumption and sticky prices à la Calvo combined with indexation. For estimation and simulation, we take the log-linearized model, expressed as percentage deviation of each variable from its steady-state.

We now turn to the derivation of the model. We start by assuming that there is a representative household in the model that maximizes the following intertemporal welfare with respect to the choice of real consumption expenditures C_t, labor N_t, nominal money holdings M_t, and nominal bonds B_t :

$$\max_{C_t,N_t,M_t,B_t} V_0 = \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t a_t \left[\Psi\left(C_t^*, \frac{M_t}{e_t P_t} \right) - \gamma_N \left(\frac{N_t^{1+\varphi}}{1+\varphi} \right) \right], \tag{1}$$

$$C_t^* = \frac{C_t}{C_{t-1}^h}, \tag{2}$$

$$\Psi\left(C_t^*, \frac{M_t}{e_t P_t} \right) = \frac{1}{1-\sigma} \left(\frac{C_t}{C_{t-1}^h} \right)^{1-\sigma} + \gamma_M \left(\frac{1}{1-\delta} \right) \left(\frac{M_t}{e_t P_t} \right)^{1-\delta}. \tag{3}$$

The variables C_t and P_t are the CES aggregators of the quantities and prices of the different goods consumed:

$$C_t = \left(\int_0^1 C_t(j)^{\frac{\epsilon}{\epsilon-1}} dj \right)^{\frac{\epsilon-1}{\epsilon}},$$

$$P_t = \left(\int_0^1 P_t(j)^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}.$$

The variable a_t is a preference shock and e_t is a liquidity-preference or money-demand shock. The parameter $\beta \in (0,1)$ is the discount factor and $\varphi \geq 0$ is the inverse of the Frisch labor supply elasticity. The parameter h represents the importance of habit persistence in the utility function (with $h = 0$ we obtain the standard CRRA function). The symbol γ_N is the coefficient of the disutility of labor, while γ_M is the coefficient for the utility of real balances.

The budget constraint of the household has the following form:

$$\frac{M_{t-1} + B_{t-1} + W_t N_t + T_t + D_t}{P_t} = C_t + \frac{B_t/r_t + M_t}{P_t}. \tag{4}$$

Households receive nominal government transfers T_t from the government, as well as nominal dividends D_t and nominal labor income $W_t N_t$ from firms. They enter period t with money and bond holdings, M_{t-1} and B_{t-1}. They can use these resources for consumption or to purchase bonds at cost B_t/r_t. The firm produces a differentiated output with the following production function:

$$Y_t(j) = z_t N_t(j)^{1-\alpha}. \tag{5}$$

The variable z_t is an economy-wide technology shock while $1-\alpha$ is the elasticity of labor with respect to output. Aggregate output is obtained by the following CES aggregation function:

$$Y_t = \left(\int_0^1 Y_t(j)^{\frac{\epsilon}{\epsilon-1}} dj \right)^{\frac{\epsilon-1}{\epsilon}}.$$

Market clearing requires, of course, $Y_t = C_t$.

Prices are sticky. Firms set their prices through the familiar Calvo mechanism. Each firm resets its price with probability $(1-\theta)$ each period, while a fraction θ leave their price unchanged. Of those firms which change prices in a given quarter, a fraction ω sets their price in a fully forward-looking manner while the remainder set prices in a backward-looking manner, updating their previous price using the observed rate of inflation. In the special case of no constraints on price adjustment ($\theta = 0$), firm j would sets its price as a mark-up over marginal cost $MC_t(j)$, defined as the ratio of the economy-wide nominal wage divided by the marginal product of labor in firm j:

$$P_t(j) = \left[\frac{\epsilon}{\epsilon - 1} \right] MC_t(j), \tag{6}$$

$$MC_t(j) = \frac{W_t}{\partial Y_t(j)/\partial N_t(j)}. \tag{7}$$

The following equations summarize this price-setting mechanism:

$$P_t^b = P_{t-1}\pi_{t-1}, \tag{8}$$

$$\pi_{t-1} = \frac{P_{t-1}}{P_{t-2}}, \tag{9}$$

$$P_t^f = \frac{E_t \sum\limits_{i=0}^{\infty} \beta^i \theta^i Y_{t+i} \left[\frac{\epsilon}{\epsilon-1}\right] MC_{t+i}}{E_t \sum\limits_{i=0}^{\infty} \beta^i \theta^i Y_{t+i}^j}, \tag{10}$$

$$P_t^* = \left(P_t^f\right)^{(1-\omega)} \left(P_t^b\right)^{\omega} \tag{11}$$

$$P_t = \left[\theta P_{t-1}^{(1-\epsilon)} + (1-\theta) P_t^{*(1-\epsilon)}\right]^{\frac{1}{1-\epsilon}}. \tag{12}$$

3.2 Log-linearized System

The following equations summarize log-linearized Euler equations for the Taylor-rule era with endogenous money supply. Lower-case variables capped with the symbol $\widehat{}$ represent logarithmic or percentage deviations from the steady-state values of the respected variables.

$$\begin{aligned}
\widehat{y}_t &= \frac{\phi_1}{\phi_1+\phi_2}\widehat{y}_{t-1} + \frac{\beta\phi_1+\phi_2}{\phi_1+\phi_2}\widehat{y}_{t+1} - \frac{1}{\phi_1+\phi_2}\left(\widehat{r}_t - \widehat{\pi}_{t+1}\right) \\
&\quad - \frac{\beta\phi_1}{\phi_1+\phi_2}\widehat{y}_{t+2} + \frac{1-\beta h\rho_a}{(1-\beta h)}\frac{1-\rho_a}{\phi_1+\phi_2}\widehat{a}_t, \qquad (13) \\
\widehat{m}_t - \widehat{p}_t &= -\frac{\phi_1}{\delta}\widehat{y}_{t-1} + \frac{\phi_2}{\delta}\widehat{y}_t - \frac{\beta\phi_1}{\delta}\widehat{y}_{t+1} \\
&\quad - \frac{1}{\delta(r-1)}\widehat{r}_t + \frac{1-\beta h\rho_a}{(1-\beta h)\delta}\widehat{a}_t + \frac{\delta-1}{\delta}\widehat{e}_t, \qquad (14) \\
\widehat{mc}_t &= -\phi_1\widehat{y}_{t-1} + (\chi+\phi_2)\widehat{y}_t - \beta\phi_1\widehat{y}_{t+1} \\
&\quad - (1+\chi)\widehat{z}_t - \left[\frac{\beta h(1-\rho_a)}{1-\beta h}\right]\widehat{a}_t, \qquad (15) \\
\widehat{\pi}_t &= \gamma_f\widehat{\pi}_{t+1} + \gamma_b\widehat{\pi}_{t-1} + \lambda\widehat{mc}_t. \qquad (16)
\end{aligned}$$

The first equation, given by (13), describes real GDP $\widehat{y}_t$ as a function of past and future GDP, as well as the expected real interest rate $(\widehat{r}_t - \widehat{\pi}_{t+1})$, and the current period demand shock, $\widehat{a}_t$.

Real money demand , $\widehat{m}_t - \widehat{p}_t$, given by equation (14), depends on past, present and future output, as well as the interest rate $\widehat{r}_t$, the demand shock, $\widehat{a}_t$, and the exogenous liquidity preference shock, $\widehat{e}_t$.

Marginal cost changes, $\widehat{mc}_t$, in equation (15), are a function of past, present and future output, productivity shocks $\widehat{z}_t$, and demand shocks, $\widehat{a}_t$.

Current inflation, $\widehat{\pi}_t$, in equation (16), responds both to past and expected future inflation as well as to marginal cost changes, $\widehat{mc}_t$. The parameter λ gives the sensitivity of inflation to the output gap. As shown by Andres, Lópes-Salido, and Vallés (2006, p. 462), this coefficient in turn depends on the other deep parameters of the model:

$$\begin{aligned}
\lambda &= (1-\theta)(1-\beta\theta)(1-\omega)\xi \\
\xi &= \frac{(1-\alpha)}{1+\alpha(\epsilon-1)}\{\theta+\omega[1-\theta(1-\beta)]\}^{-1}
\end{aligned}$$

Four key parameters in the above model, ϕ_1,ϕ_2, γ_f and γ_b are themselves functions, of deep structural parameters, the constant relative risk aversion coefficient σ, the habit persistence parameter h, the discount parameter β, the Calvo forward-looking pricing parameter θ and the Calvo backward-looking indexing coefficient, ω :

$$\begin{aligned}
\phi_1 &= \frac{(\sigma-1)h}{1-\beta h}, \\
\phi_2 &= \frac{\sigma+(\sigma-1)\beta h^2-\beta h}{1-\beta h}, \\
\gamma_f &= \frac{\beta\theta}{\theta+\omega[1-\theta(1-\beta)]}, \\
\gamma_b &= \frac{\omega}{\theta+\omega[1-\theta(1-\beta)]}.
\end{aligned}$$

The three exogenous shock processes, for demand $(\widehat{a}_t)$, liquidity $(\widehat{e}_t)$, and productivity $(\widehat{z}_t)$ follow first order autoregressive processes with normally distributed innovations and constant variances..

$$\begin{aligned}
\widehat{a}_t &= \rho_a \widehat{a}_{t-1} + \epsilon_{a,t}, \\
\epsilon_{a,t} &\tilde{} N(0, \sigma_a^2), \\
\widehat{e}_t &= \rho_e \widehat{e}_{t-1} + \epsilon_{e,t}, \\
\epsilon_{e,t} &\tilde{} N(0, \sigma_e^2), \\
\widehat{z}_t &= \rho_z \widehat{z}_{t-1} + \epsilon_{z,t}, \\
\epsilon_{z,t} &\tilde{} N(0, \sigma_z^2).
\end{aligned}$$

3.3 Modelling monetary policy

In order to close the model, we need to add an equation which captures the determination of interest rates.

Monetary policy is traditionally modelled in terms of a policy rule which expresses the interest rate as a function of a number of macroeconomic variables. As the various papers in the volume edited by Taylor (1999) show, this approach provides a good description of US monetary policy over the last 30 years. However, in the same volume, Taylor shows that such a rule is poor description of interest rate determination for the classical gold standard period. This is not surprising. Since the Federal Reserve was only established by the Federal Reserve Act of 1913 and only started operations in 1914, it is clear that interest rates in our sample period were not the outcome of decisions by a central bank.

Instead, in order to model interest rates in this era, our approach is based on the theory of the working of the classical gold standard (see, for example, Niehans (1978), for a survey). In this approach, interest rates, and ultimately the price level, are determined by the interaction of the demand for, and the supply of, money. The model outlined above already contains a money demand function, equation (14). The model can be closed by adding a process for the money supply. From an econometric point of view, this approach will be valid provided the money supply is largely exogenous. Cagan's (1965) classic study on the determinants of money stock has addressed this issue. He shows that changes in the stock of base money during this period was largely due to exogenous causes, in particular changes in the gold stock (reflecting new discoveries and improved production techniques as well as capital flows). In contrast, changes in broader measures of money (e.g. $M2$) reflected, in addition to the change in base money, movements the currency and reserve ratios. These ratios, though strongly influenced by banking panics, which Cagan argues were themselves exogenous events, arguably contain important endogenous responses to the business cycle. In order to minimize the effects of this endogeneity, we choose to model the demand and supply of base money rather than M2. Given the evidence provided by Cagan, we approximate the monetary regime by an exogenous stochastic process for nominal base money growth, $\widehat{dM}_t$, given by (17).

$$\widehat{dM}_t = \rho_m \widehat{dM}_{t-1} + \epsilon_{m,t}, \tag{17}$$

$$\epsilon_{m,t}\tilde{} N(0, \sigma_m^2). \tag{18}$$

In this setup, the evolution of real money balances $(\widehat{m}_t - \widehat{p}_t)$ is given by the identity:

$$\widehat{m}_t - \widehat{p}_t = \widehat{m}_{t-1} - \widehat{p}_{t-1} + \widehat{dM}_t - \widehat{\pi}_t.$$

In this regime, the nominal interest rate is given by the inversion of the demand for money in equation (14).

In order to derive a monetary policy rule for our counterfactual analysis, we follow the existing literature (summarised, for example, in the NBER volume edited by Taylor (1999)) by assuming that the behaviour of the Federal Reserve can be adequately captured by a Taylor rule formulation with interest smoothing:

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + (1 - \rho_r)\rho_y \widehat{y}_t + (1 - \rho_r)\rho_\pi \widehat{\pi}_t + \epsilon_{m,t}, \tag{19}$$

$$\epsilon_{m,t}\tilde{} N(0, \sigma_\nu^2).$$

In this case, the interest rate equation $\widehat{r}_t$, in equation (19), shows that current interest rates respond to past interest rates with a smoothing parameter ρ_r, and well as to output and inflation, $\widehat{\pi}_t$. The interest rate is also affected by an exogenous policy shock, given by $\widehat{v}_t$.

In order to derive estimates for the policy rule for the counterfactual experiment, we estimate a modified version of our model for the Great Moderation era. The modification consists of replacing the money supply process ((17)) by (19). The parameters of the rule are obtained as part of the estimation of the whole model.

Note the change in the interpretation of the stochastic shocks $\epsilon_{v,t}$. In the Taylor-rule framework, these shocks are the shocks to the interest rate, often referred to as monetary policy shocks. In the Gold Standard, these are the shocks to the rate of growth of the nominal money stock, reflecting the factors mentioned earlier (changes in the gold stock due to discoveries etc.).

3.4 Bayesian Estimation

Table 2 presents the priors for Bayesian estimation.. For each volatility and coefficient, we specify the distribution, the mean, as well as the standard deviation, supremum and infimum. The volatility priors have inverse gamma distributions. Parameters restricted to fall between zero and one have a beta distribution, while coefficients outside this range are specified with a normal distribution with restrictions on their infimum and supremum. The choice of prior distributions as well as their mean and standard deviation values closely match those used by Smets and Wouters (2003).

We have also incorporated a measurement error term, relating observed real output to the model generated output with a stochastic term $\epsilon_{y,t}$, normally distributed with variance σ_y^2. Our objective here is to allow for possible differences in the magnitude of such errors across regimes.

$$\widehat{y}_t^o = \widehat{y}_t + \epsilon_{y,t}$$
$$\epsilon_{y,t}\tilde{\ }N(0,\sigma_y^2)$$

Table 2

Priors: Distributions and Parameters

	Distribution	Mean	Std. Dev.	Inf	Sup
Volatility.					
σ_a	Inv. Gamma	.01	2	.005	4
σ_e	Inv. Gamma	.01	2	.005	4
σ_z	Inv. Gamma	.01	2	.005	4
σ_m	Inv. Gamma	.01	2	.005	4
σ_y	Inv. Gamma	.01	2	.005	4
Coefficient					
h	Beta	.7	.1	.2	.95
σ	Normal	1.25	.1	1.1	1.5
χ	Normal	.5	.05	.1	1.5
λ	Normal	1.15	.05	1	1.25
θ	Beta	.5	.1	.1	.85
ω	Beta	.1	.1	.1	.85
ρ_a	Beta	.5	.2	.1	.95
ρ_e	Beta	.5	.2	.1	.95
ρ_z	Beta	.5	.2	.1	.95
ρ_v	Beta	.5	.2	.1	.95
ρ_r	Beta	.5	.2	.1	.95
ρ_y	Beta	.5	.2	.1	.95
ρ_π	Normal	1.5	.2	1.1	2.5
δ	Normal	10	3	3	50

Table 3 shows the Bayesian posterior estimates of the model for the classical Gold Standard.. We present the mean, median and standard deviation of the posterior distributions. The estimates come from Metropolis-Hastings Monte Carlo Markov Chain replications with ten sets of 500,000 draws.

Table 3

Posterior Estimates

	Mean	Median	Std Dev.
Volatility			
σ_a	0.021	0.027	0.008
σ_e	0.051	0.078	0.029
σ_z	0.029	0.031	0.003
σ_m	0.012	0.013	0.001
σ_y	0.004	0.007	0.002
Coefficient			
	Mean	Median	Std Dev.
h	0.815	0.751	0.08
σ	1.250	1.34	0.109
χ	0.488	0.471	0.054
λ	1.138	1.134	0.05
θ	0.593	0.537	0.10
ω	0.355	0.448	0.132
ρ_a	0.762	0.698	0.004
ρ_e	0.931	0.866	0.066
ρ_z	0.784	0.725	0.08
ρ_v	0.473	0.452	0.047
δ	4.711	5.231	0.989

The volatility estimates show that the largest sources are in money demand and in productivity. This result contrasts with the Euro Area estimates reported by Andres, Lópes-Salido, and Vallés, who find that the dominating source of volatility is in demand, σ_a. The habit persistence parameter h is only slightly lower than those reported by Andres, Lópes-Salido, and Vallés.

In Appendix Table A-1, we present the corresponding estimates for the Great Moderlation. The reason for estimating the model for the Great Moderation, of course, is to obtain the parameters for the Taylor rule. The posterior mean for the coefficient on inflation is ρ_π is 1.51, confirming that the Taylor principle was respected in this period. The coefficient on the output gap ρ_y is 0.25 while the mean smoothing parameter is ρ_r is 0.66. The estimated volatiltiy for the shocks to the Taylor rule, with σ_m at .001. These Taylor rule estimates fall within the range of commonly reported estimates for the Great Moderation [see, for example, Clarida, Gali, and Gertler (2000)].

Analyzing these structural parameters individually or in small subsets, of course, does not give much information about the implications of the fully-estimated model for inflation and output volatility. This is the subject of the next section.

4 Simulations

We first simulate the model with random draws for the underlying parameters and standard deviations for the innovations, to assess the performance of the model in replicating the actual volatilities during the Gold Standard era. We simulate the model 1000 times, each time with a sample size of 500.

4.1 Benchmark Volatility

Table 4 gives the standard deviations of the actual data on real GDP, inflation, the nominal interest rate, and nominal money for the Gold Standard era. The table also shows values for the corresponding statistics implied by the stochastic simulation of our model. Specifically, we show the posterior mean and the supremum and infinum estimates based on 95% highest posterior density intervals).

Table 4

Volatility Estimates:
Fully Stochastic Posterior Simulations

	$\widehat{y}$	$\widehat{\pi}$	$\widehat{r}$	$\widehat{m}$
Actual	0.037	0.021	0.002	0.077
Mean	0.045	0.038	0.006	0.099
Sup	0.053	0.042	0.008	0.121
Inf	0.035	0.033	0.004	0.057

The overall assessment of these simulations is that they slightly overpredict inflation volatility and underpredict real money stock and interest rate volatility. However, these estimates are on target for real GDP, the centerpiece of the discussion, since actual output volatility falls within the 95% confidence interval obtained from the stochastic simulations.

4.2 Impulse Response Functions

Figures 2 and 3 picture the impulse response functions of output and inflation following shocks to output demand A, liquidity preference E, productivity Z,and M, representing supply in the Gold Standard era. We leave out the measurement error shock for the sake of expositional clarity.

The qualitative responses show that output rises with an increase in demand, productivity and money, and falls with an increase in liquidity preference. As expected, inflation rises temporarily with a positive shock to demand and money and falls with a shock to productivity and liquidity preference.

4.3 Variance Decomposition

Table 5 presents the variance decomposition after twenty periods for output and inflation. Given the long-run horizon, productivity shocks dominate the

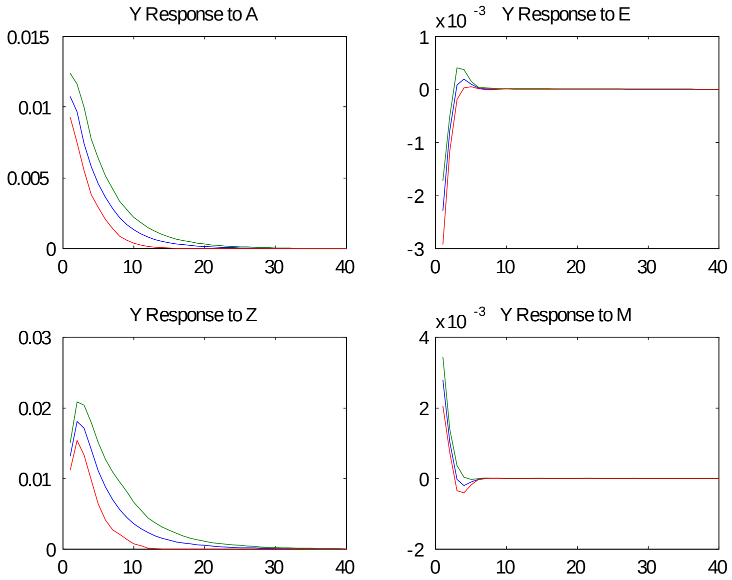


Figure 1: Output Response to Shocks under the Gold Standard

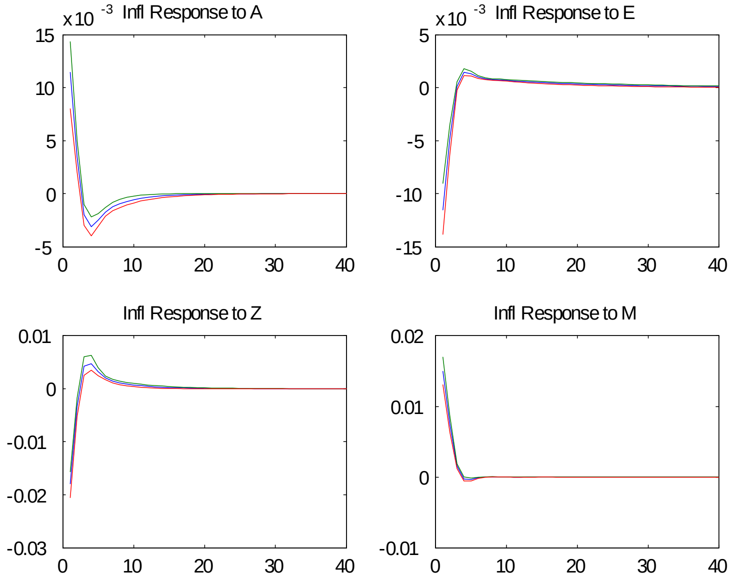


Figure 2: Inflation Response to Shocks under the Gold Standard

variance of output.Both money and productivity shocks dominate the effects of demand shocks for the evolution of inflation. The finding that technology shocks dominate the variance of output in the Gold Standard era may at first glance seem surprising. However, this period was one of rapid transformation of the US economy, characterized by dramatic technical change, a major expansion in the labor force, driven by immigration, and a shift from an agricultural economy to an industrial economy[4]. The result is also consistent with existing evidence. For example, Bordo and Schwartz (1999) used a structural VAR methodology to examine the sources of volatility in the US over different monetary regimes. They report that technology shocks were much larger in the Gold Standard than in the post World War II era and, moreover, they were the dominant source of output volatility during the Gold Standard era.

Table 5

Variance Decomposition of Output and Inflation

Shocks:	Demand **A**	Liquidity **E**	Productivity. **Z**	Money **M**
	Output			
Mean	0.207	0.004	0.784	0.006
Sup	0.327	0.006	0.888	0.009
Inf	0.109	0.001	0.665	0.002
	Inflation			
Mean	0.172	0.164	0.383	0.281
Sup	0.245	0.234	0.457	0.337
Inf	0.095	0.094	0.310	0.224

4.4 Counterfactual Simulations

We now turn to our counterfactual experiment. This involves using our model for the Gold Standard era to answer the question: how would macroeconomic outcomes have been different if instead of the money supply process (14) by the Taylor rule (19) estimated for the Great Moderation.

Figure 4 pictures the Epanechnikov densities of the distribution of inflation and output/consumption growth volatility of 1000 simulations for the actual Gold Standard money supply process and the counterfactual Taylor rule. We see quite clearly that transporting Volcker and Greenspan back in time would have decreased the volatility of inflation but it would have lessened only sightly the volatility of output. The mean of the distribution under the counterfactual simulation for inflation volatility is slightly less than half of the actual policy regime. The distributions of real GDP growth, however, are much closer, with considerable overlap.

Figure 5 pictures the corresponding densities for the real money stock, employment, and interest rates based on the same simulations. We see that the

---

[4] To give some examples, comparing 1880 and 1910, the labour force rose from 18.7 million to 37 million while the share of workers employed in agriculture fell from 48% to 35%. All data is taken from Bureau of the Census (1975),

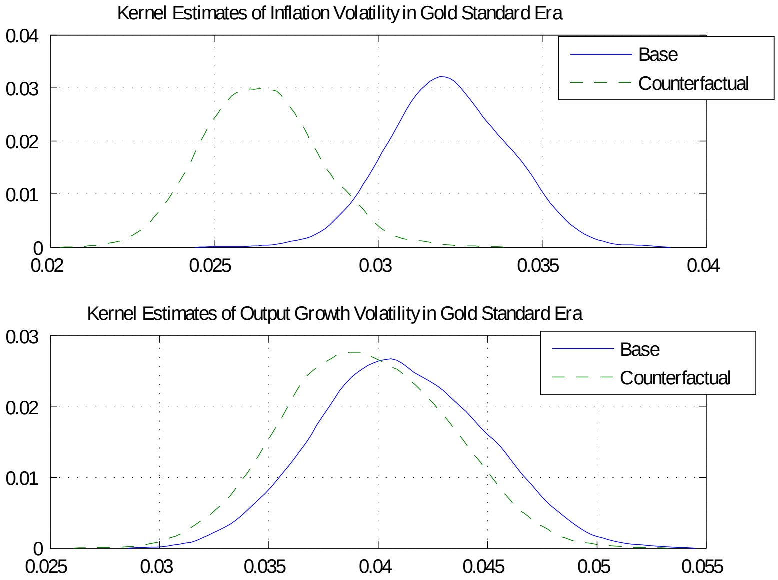


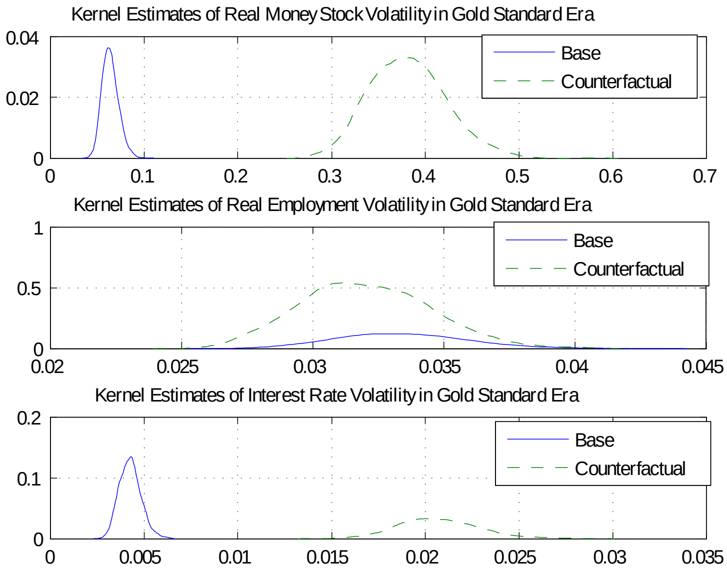
Figure 3: Actual and Counterfactual Simulations in the Gold Standard: Real GDP Growth and Inflation

actual and counterfactual show little or no difference in the distribution of employment volatility. However, there is a much more noticeable and significant difference in the distributions for real balances and interest rates. While Figure 4 shows that the counterfactual Taylor rule reduces the volatility of inflation, it does so at the cost of higher volatility in real balances and interest rates.

4.5 Welfare Comparison

While the above distributions pictured inflation, output, money, interest and employment volatilities, we need a suitable metric to judge the difference in economic outcomes. For this purpose, since we have a micro-founded model with an explicit utility function for the representative agent, we can compute overall welfare measures for both the baseline and counterfactual simulations. Our measure of welfare is based on expected value of the discounted utility function in equation (1).

Figure 6 pictures the distribution of overall welfare differences under the actual and counterfactual policy simulations. We see no unambiguous improvement in welfare, due to the reduction in inflation volatility. As shown in Figures 4 and 5, the counterfactual regime delivers lower inflation volatility but it does so at a cost of significantly higher real-balance and interest rate volatility.


Kernel Estimates of Real Money Stock Volatility in Gold Standard Era

Kernel Estimates of Real Employment Volatility in Gold Standard Era

Kernel Estimates of Interest Rate Volatility in Gold Standard Era

Figure 4: Actual and Counterfactual Simulations in the Gold Standard: Real Balances and Employment

5 Conclusion

This paper makes use of counter-factual simulations to assess the extent to which a different monetary policy - the estimated Taylor rule from the Great-Moderation period - would have led to differences in the behaviour of the economy in the classical Gold-Standard period. The results show that sending Volcker and Greenspan back to the Gold-Standard era would not have improved welfare. Inflation volatility would have decreased, while output and employment volatility would not have fallen very much. and real money stock and interest rate volatility would have increased. In short, there would have been no clearcut welfare gain from pursuing a Taylor-rule policy of the sort that has characterized the Great-Moderation era in the Gold-Standard era.

6 Appendix

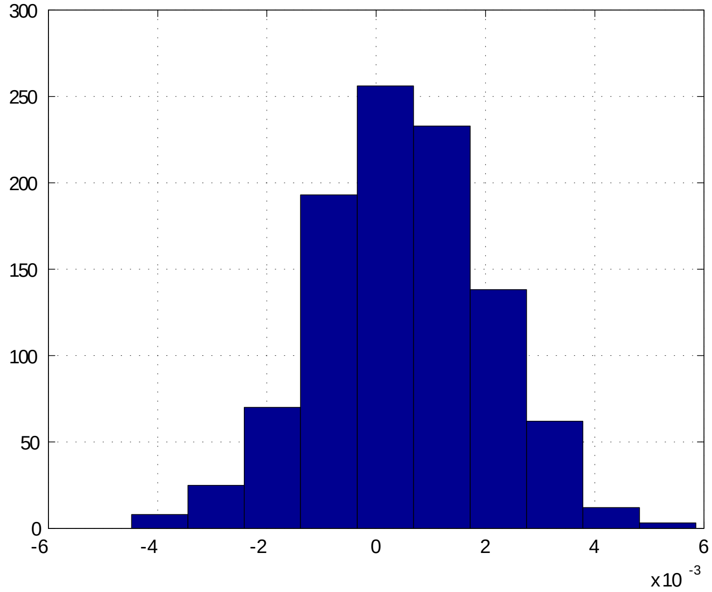


Figure 5: Historgram of Differences in Welfare under the Gold Standard and Counterfactual Regime

Table A-1

Posterior Estimates

Great Moderation

	Mean	Median	Std Dev.
Volatility			
σ_a	0.009	0.014	0.006
σ_e	0.009	0.010	0.001
σ_z	0.002	0.003	0.000
σ_m	0.002	0.002	0.000
σ_y	0.002	0.003	0.000
Coefficient			
σ	1.269	1.279	0.047
χ	0.506	0.508	0.050
λ	1.147	1.139	0.051
θ	0.554	0.516	0.099
ω	0.433	0.468	0.109
h	0.898	0.873	0.031
ρ_a	0.869	0.799	0.080
ρ_e	0.936	0.914	0.024
ρ_z	0.914	0.861	0.058
ρ_r	0.668	0.608	0.069
ρ_y	0.242	0.303	0.081
ρ_π	1.514	1.515	0.020
δ	57.136	66.079	15.006

References

[1] Ahmed, S., A. Levin and B.Wilson. 2004. Recent U.S. Macroeconomic Stability: Good Luck, Good Policies, or Good Practices? Review of Economics and Statistics 86(3): 824-32.

[2] Andolfatto D. and P. Gomme. 2003. "Monetary Policy Regimes and Beliefs." International Economic Review 44: 1-30.

[3] Andres, J,D. Lópes-Salido, and J. Vallés. 2006. Money in an Estimated Business Cycle Model of the Euro Area. The Economic Journal 116, 457-477.

[4] Arias, A., G. Hansen, and L. Ohanian. 2006. "Why Have Business Cycle Fluctuations Become Less Volatile?" NBER Working Paper #12079.

[5] Aruoba, S.B., J. Fernandez-Villaverde, and J.F. Rubio-Ramirez. 2006. "Comparing Solution Methods for Dynamic Equilibrium Economies." Journal of Economic Dynamics and Control, 30: 2477-2508.

[6] N.S. Balke and R.J. Gordon. 1989a. The Estimation of Pre-War Gross National Product: Methodology and New Evidence. Journal of Political Economy 97: 38-92.

[7] Balke N.S. and R. J. Gordon. 1989b. Appendix B, Historical data, in R. J. Gordon (ed.) *The American Business Cycle, Continuity and Change* Chicago: The University of Chicago Press, 781-783.

[8] Benati, L. and P. Surico. 2008. VAR analysis and the Great Moderation. ECB Working Paper No. 866.

[9] Bordo, M. and R. MacDonald. 1997. Violations of the Rules of the Game and the Classical Gold Standard, 1880-1914. NBER Working Paper 6115.

[10] Bordo, M. and A.J. Schwartz. 1999.Monetary policy regimes and economic performance: The historical record. in J.B. Taylor and M. Woodford (eds) *Handbook of Macroeconomics.* Elsevier. Chapter 3.

[11] Bullard, J. and A. Singh. 2007. Learning and the Great Moderation. Manuscript, FRB St. Louis.

[12] Bureau of the Census, 1975. *Historical Statistics of the United States: Bicentennial Edition.*

[13] M. Burda and C. Wyplosz .1997. Macroeconomics: A European Text. Oxford: Oxford University Press.

[14] Cagan, P. 1965. *Determinants and Effects of Changes in the Stock of Money 1875-1960.* National Bureau of EconomicsResearch. Studies in Business Cycles. Vol 13.

[15] Cagan, P. 1984. The Report of the Gold Commission (1982). Carnegie Conference Series on Public Policy.20: 247-268.

[16] Chernyshoff, N., D. Jacks and A. Taylor. 2005. Stuck on Gold: Real Exchange Rate Volatility and the Rise and Fall of the Gold Standard. National Bureau of Economic Research: Working Paper 11795.

[17] Christiano, L.J., Eichenbaum, M. and C. L. Evans. 2005. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. Journal of Political Economy. 113:1-45.

[18] Clarida, R., J. Gali, and M. Gertler. 2000. Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory. Quarterly Journal of Economics. 115: 147-80.

[19] De Long, J.B. and L. Summers. 1984. The Changing Cyclical Variability of Economic Variability in the United States. NBER Working Paper 1450.

[20] Fisher, I.. 1920. Stabilizing the Dollar. New York: MacMillan.

[21] Gramlich, E.M. 1998. The Samuelson Lecture , given before the 24th Annual Conference of the Eastern Economic Association, New York. available at: www.federalreserve.gov/Boarddocs/speeches/1998/199802272.htm.

[22] Ireland, P. 2004. Money's role in the monetary business cycle. Journal of Money Credit and Banking. 36:969-984.

[23] Justiniano, A., and G. Primiceri. 2006. "The Time-Varying Volatility of Macroeconomic Fluctuations." NBER Working Paper 12022.

[24] Kahn, J., M. McConnell, and G. Perez-Quiros. 2002. "The Reduced Volatility of the U.S. Economy: Policy or Progress?" Manuscript, FRB New York.

[25] Kim, C.-J., and C. Nelson. 1999a. "Has the U.S. Economy become more Stable? A Bayesian Approach Based on a Markov-Switching Model of the Business Cycle." The Review of Economics and Statistics 81(4): 608-616.

[26] McConnell, M., and G. Perez-Quiros. 2000. "Output Fluctuations in the United States: What Has Changed Since the Early 1980s?" American Economic Review 90: 1464-1476.

[27] Niehans, J. 1978. *The Theory of Money.* Baltimore: Johns Hopkins Press.

[28] Romer, Paul. 1990. Endogenous Technological Change. Journal of Political Economy, 98, S71-102.

[29] Sims, C., and T. Zha. 2006. "Were There Regime Switches in U.S. Monetary Policy?" American Economic Review 91: 54-81.

[30] Stock, J., and M. Watson. 2003. “Has the Business Cycle Changed and Why?” NBER Macroeconomics Annual 2002 17: 159-218.

[31] Svensson, L. 1994. Why Exchange Rate Bands? Journal of Monetary Economics. 33:157-199.

[32] Smets, F. and R.Wouters. 2003. An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area/ Journal of the European Economic Association. 1:1123-1175.

[33] Stock, J. and M. Watson. 2003. Has the Business Cycle Changed? Evidence and Explanations. prepared for the Federal Reserve Bank of Kansas City symposium, Monetary Policy and Uncertainty, Jackson Hole, Wyoming, August 28-30.

[34] Taylor, J. (ed.), 1999, *Monetary Policy Rules.* Chicago: University of Chicago Press for the National Bureau of Economic Research.