# On the low-frequency relationship between public deficits and inflation*

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**Abstract**

We estimate the low-frequency relationship between fiscal deficits and inflation and pay special attention to its potential time variation by estimating a time-varying VAR model for U.S. data from 1900 to 2011. We find the strongest relationship neither in times of crisis nor in times of high public deficits, but from the mid-1960s up to 1980. Our results suggest that the low-frequency relationship between fiscal deficits and inflation is strongly related to the conduct of monetary policy and its interaction with fiscal policy after World War II.

**JEL classification**: E42, E58, E61
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# 1 Introduction

The recent economic crisis has led to an enormous increase in fiscal deficits. This upsurge was caused either by automatic stabilizers or by discretionary fiscal actions aiming to stabilize the economy. Concerns that high deficits are inflationary in the medium run or in the long run originate in economic theory developed by Sargent and Wallace (1981), Leeper (1991), Sims (1994), Woodford (1994, 1995), and Cochrane (2001). Although their work differs in important aspects, they have in common the idea that if the current debt is not entirely backed by future primary surpluses, inflation will follow.

Despite these theoretical results there is as of now no clear empirical evidence of co-movement between inflation and the fiscal deficit. For instance, King and Plosser (1985) conclude "[...] that it is difficult to find an objective basis for the strongly held popular beliefs about the inflationary effects of the deficit in the post-war experience[...]". More recently, Catão and Terrones (2005) find a positive relationship between inflation and fiscal deficits only among developing, high-inflation countries, but not for low-inflation, advanced economies.

In the spirit of Lucas (1980) and Sargent and Surico (2011), we re-investigate the relationship between fiscal stance and inflation , thereby focusing on their low-frequency relationship. We measure fiscal stance by real debt growth minus the gross real interest rate which is defined as primary deficits over debt (see Sims, 2011). In contrast to the existing literature, we pay special attention to potential time variation of this low-frequency relationship for the U.S. between 1900 and 2011. This extensive data set is beneficial in many ways. Firstly, it includes periods of even higher debt growth than the one the US faces today. Secondly, it contains periods like the Great Depression, which are of current interest as they also involved financial crises. Thirdly, it comprises episodes of different policy regimes which are accompanied by different degrees of central bank independence or different kinds of fiscal-monetary policy regimes. To accommodate the different time episodes and structural changes in a single empirical framework, we estimate a time-varying parameter Vector-Autoregression (TVP-VAR) model.

We find a positive low-frequency relationship between public deficits over debt and inflation for the U.S. which is time-varying. In the first half of the 20th century, the low-frequency relationship is volatile and only partly positive. After WWII, the relationship is stable and significantly positive up to 1980. It reaches its highest value in the years between 1973, the end of the Bretton Woods system, and 1979, the year in which Paul Volcker became Chairman of the Federal Reserve system. After 1980, the low-frequency relationship is stable and insignificantly different from zero.

Taking at face value, the results are suggestive that, especially, the change in the early 1980s is driven by structural changes in the economy. However, it may, in principle, equally well be the case that innovations have driven this result. To shed light on this, we employ a counterfactual analysis. We demonstrate that the movements in the low-frequency relationship up to the end of WWII and its aftermath are due to the volatilities of the underlying shocks or their impact on the economy. For most of the period after WWII, the low-frequency relationship between inflation and primary deficit over debt is determined by the systematic behavior of the economy. In particular, the period of the highest low-frequency relationship between 1973 to 1979 would not have occurred if the economy had responded systematically as in 1995. Instead, the low-frequency relationship would have been stable and insignificantly different from zero from 1960 onwards.

We interpret our findings and the counterfactual analysis using narrative evidence and the evidence provided by the related literature. The period of the 1970s is usually characterized by a central bank not responding strongly to inflation (e.g. Clarida, Gali, and Gertler, 1998; Lubik and Schorfheide, 2004) and the fiscal authority playing a dominant role (e.g. Davig and Leeper, 2007; Bianchi and Ilut, 2012). Similarly, our results are in line with the narrative description by Meltzer (2010, p. 485) that the Federal Reserve had "accepted its role as a junior partner by agreeing to coordinate actions with the administration's fiscal policy" up to 1979. The high low-frequency relationship breaks down in 1980 and becomes insignificant shortly afterwards, which corresponds to the beginning of the chairmanship of Paul Volcker in the fourth quarter of 1979. As Meltzer (2010) points out, Volcker rebuilt much of the independence and credibility, which the Federal reserve had lost over the two proceeding decades (see also, for example Taylor, 2011). From this we deduce that the low-frequency relationship between fiscal deficits and inflation is strongly related to the conduct and the independence of monetary policy. In a policy regime where the central bank accommodates the action of the fiscal authority, and the central bank is willing to accept high inflation rates, high deficits are related with inflation in the long run.

The relationship between fiscal deficits and inflation has been studied extensively. This includes studies that investigate the relationship between fiscal deficits and seignorage, since it was assumed that seignorage always translates into inflation. The findings in the literature are mixed. While Niskanen (1978), McMillin and Beard (1982), King and Plosser (1985), and Joines (1985) find no empirical evidence of a relationship between fiscal deficits and inflation; the work of Hamburger and Zwick (1981) finds evidence for the period from 1961 to 1974. In a related article, Hamburger and Zwick (1982) stress that this relationship is likely to be time-varying, especially following the change in the conduct of monetary policy after Paul Volcker became Chairman of the Federal Reserve System. More recently, Giannitsarou and

Scott (2008) find "extremely modest statistical interactions" between deficits and inflation for the United States. However, another strand of the literature with a more international focus finds a significant relationship for high-inflation countries (see, for example Catão and Terrones, 2005; Lin and Chu, 2013). Similarly, De Haan and Zelhorst (1990) and Fischer, Sahay, and Vegh (2002) find evidence of a co-movement between deficits and inflation for developing countries during highly inflationary episodes. To the best of our knowledge, the present paper is the first which takes explicitly into account the possible time variation of the low-frequency relationship by investigating long time series for the United States.

The remainder of the paper is organized as follows. Section two illustrates our measure of low-frequency relationship in a simple two-variable approach for different sub-samples. In Section three, we present the TVP-VAR framework and its estimation. Section four presents and discusses the estimation results, before section five concludes.

## 2 The measurement of the low-frequency relationship

In this section, we introduce our two main variables, inflation and primary deficits over debt, and describe how we measure the low-frequency relationship between them.

Both time series range from 1875 to 2011. Following Sargent and Surico (2011), inflation ($\pi$) is measured as year-to-year first differences of the logarithmic GDP deflator, where the data is taken from the FRED II database starting in 1947Q1 and from Balke and Gordon (1986) before then.[1] As a measure for fiscal stance, we consider the variable primary deficits over debt ($d$). This measures debt growth minus the gross real interest rate. In contrast to the debt over output ratio or debt growth, this measure is not influenced by variables which are not controlled directly by the fiscal authority, for example output or the real interest rate. In order to gain intuition for the measure of fiscal stance, consider the opposite of primary deficits over debt - government's primary surplus over debt. This summarizes the net payments to bondholders either through interest rates or through retirement of the bonds. Thus, a change in the primary deficits over debt measures the change in the fiscal authority's future liabilities. Furthermore, choosing this variable allows us to interpret our measure of the low-frequency relationship. If the measure is equal to one, the increase in primary deficit is matched by an increase in inflation and, thus, the real debt remains constant. The time series for primary deficit and government debt held by the public are taken from Bohn (2008).[2] The time series is of annual frequency. Since the remaining time

[1] Appendix A describes the data construction in more detail.

[2] See http://www.econ.ucsb.edu/~bohn/morepapers.html for more details and recent updates of these time series.

series employed in this paper are of quarterly frequency, we decide to interpolate the annual data using the cubic-spline approach. While this allows us to include all observations and to obtain more precise estimates, this approach introduces the possibility of an approximation error when interpolating a time series. In order to control for the approximation error, we consider two additional interpolation techniques. Moreover, we also perform a robustness exercise with respect to the measure of fiscal stance by considering debt growth instead of primary deficits over debt.[3]

We employ the same approach as Lucas (1980) and Sargent and Surico (2011) to gauge the low-frequency relationship between two variables. In particular, this measure can be interpreted as the slope in a scatter plot of the low-frequency components of two filtered time series. To illustrate the measure, we filter inflation and primary deficits over debt by the filter suggested by Lucas (1980).[4] In Figure 1 we plot the filtered time series. The plot suggests that there are periods in which both time series share a co-movement. Figure 2(a)

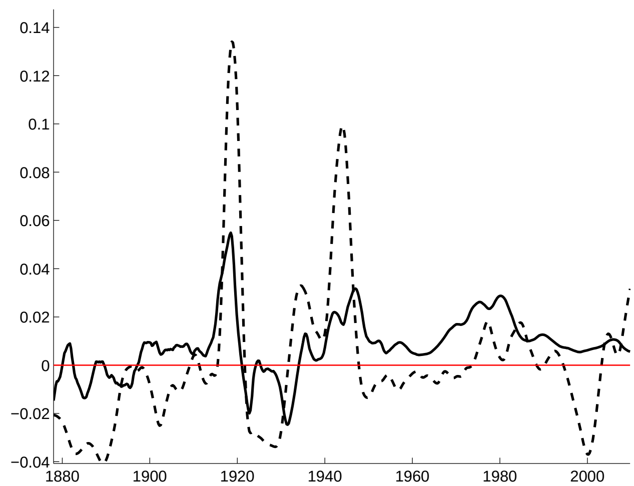



Figure 1: Filtered time series of inflation (solid) and primary deficit over debt (dashed). $\beta = 0.95$

shows a scatter plot for the two time series. To keep the plot clearly arranged, we consider only the first quarter of each year. Using different quarters or even all observations does not affect the illustrative results.

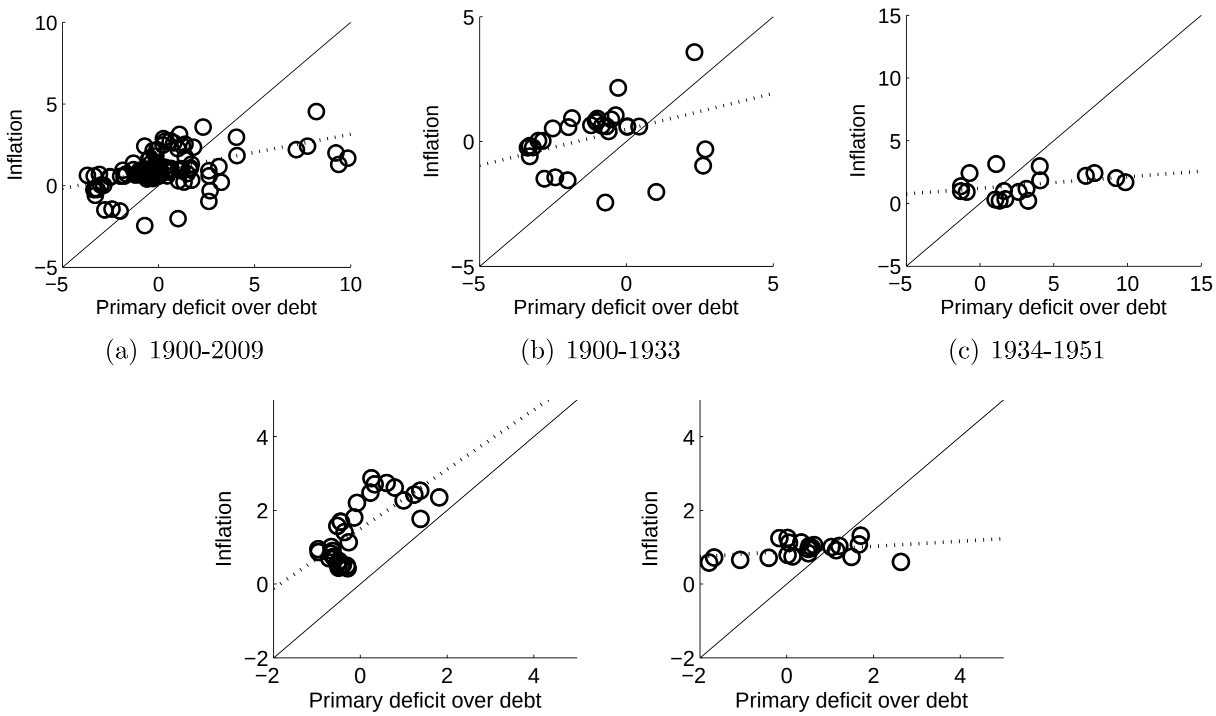
To investigate potential time variation in the data, we divide the sample into four sub-samples: 1900-1933, 1934-1951, 1952-1983, and 1984-2009. The distinctive events for the sub-samples are the New Deal policy in 1934 and the abandonment of the gold standard one year earlier, the Treasury-Federal Reserve Accord of 1951, and, finally, the end of the

[3]See Appendix E.3. for both robustness exercises.

[4]The filter is defined as $x(\beta)_t = \alpha \sum_{k=-n}^{n} \beta^{|k|} x_{t+k}$, where $\alpha = \frac{(1-\beta)^2}{(1-\beta^2-2\beta^{(k+1)}(1-\beta^2)}$ is chosen such that the sum of weights equals one. $n$ is set to eight and $\beta = 0.95$.

deflationary policy to combat inflation and expectations of high inflation, and the beginning of the Great Moderation (Kim and Nelson, 1999; Perez-Quiros and McConnell, 2000).

The results are depicted in the scatter plots 2(b) to 2(e). The dotted line in each plot is our measure of the low-frequency relationship between inflation and primary deficits over debt. We compute the slope coefficient by ordinary least squares (OLS). The scatter plots point to the following characteristics of the low-frequency relationship: first, the co-movement checnges over time, i.e. it is different in each sub-sample. Second, the slope of the dotted line is especially steep in the 1952–1983 sub-sample (Figure 2(d)). In the 1984–2009 sub-sample (Figure 2(e)) the dotted line is almost flat.




(a) 1900-2009 (b) 1900-1933 (c) 1934-1951

(d) 1952-1983 (e) 1984-2009

Figure 2: Scatter plots of filtered time series ($\beta = 0.95$) of inflation and primary deficits over debt. The dashed line indicates the slope of the scatter and the solid line is the 45° line.

In order to accommodate the time-variation of the relationship, potential omitted variables, and in order to allow for lagged inflation in the estimation we estimate the slope coefficient using a TVP-VAR model. Since the TVP-VAR model contains unfiltered data, we follow Sargent and Surico (2011) and make use of the finding by Whiteman (1984) and calculate the low-frequency relationship via the spectrum. For completeness, an alternative approach to estimate the low-frequency relationship directly from unfiltered data would be the dynamic OLS estimator as proposed by Stock and Watson (1993).

# 3 The TVP-VAR model

Next to inflation ($\pi_t$) and primary deficits over debt ($d_t$), we consider real output growth ($\Delta x_t$), money growth ($\Delta m_t$), and nominal interest rates ($R_t$) as additional observable variables. All variables are of quarterly frequency and range from 1875Q1 until 2011Q4. In doing so, we employ the same VAR model as Sargent and Surico (2011), but augment the VAR model by the measure of fiscal stance, primary deficits over debt.

The vector of observable variables comprises $\mathbf{y}_t = [d_t, \Delta M_t, \pi_t, R_t, \Delta x_t]$. The TVP-VAR model with time-varying coefficients and stochastic volatilities is defined as

$$\mathbf{y}_t = \mathbf{c}_t + \sum_{j=1}^{p} \mathbf{A}_{j,t}\mathbf{y}_{t-j} + \mathbf{u}_t = \mathbf{X}_t'\mathbf{A}_t + \mathbf{B}_t^{-1}\mathbf{H}_t^{\frac{1}{2}}\epsilon_t \ , \tag{1}$$

where $\mathbf{y}_t$ is a $n \times 1$ vector of macroeconomic time series, $\mathbf{c}_t$ is a time-varying $n \times 1$ vector of constants, and $\mathbf{A}_{j,t}$ are $p$ time-varying $n \times n$ coefficient matrices, and $\mathbf{u}_t$ is a $n \times 1$ vector of disturbances with time-varying variance-covariance matrix $\mathbf{\Omega}_t = \mathbf{B}_t^{-1}\mathbf{H}_t\left(\mathbf{B}_t^{-1}\right)'$. The time-varying matrices $\mathbf{H_t}$ and $\mathbf{B_t}$ are defined as

$$\mathbf{H_t} = \begin{bmatrix} h_{1,t} & 0 & \cdots & 0 \\ 0 & h_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & h_{n,t} \end{bmatrix} \qquad \mathbf{B}_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ b_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ b_{n1,t} & \dots & b_{n(n-1),t} & 1 \end{bmatrix}. \tag{2}$$

The time-varying coefficients are assumed to follow independent random walks with fixed variance covariance matrices. In particular, laws of motions for the vector $\mathbf{a}_t = \text{vec}[\mathbf{c}_t \ \mathbf{A}_{1,t} \ ... \ \mathbf{A}_{p,t}]$, $\mathbf{h}_t = \text{diag}(\mathbf{H_t})$, and the vector $\mathbf{b}_t = [b_{21,t}, (b_{31,t} \ b_{32,t}), ..., (b_{n1,t} \ ... \ b_{n(n-1),t})]'$ containing the equation-wise stacked free parameters of $\mathbf{B}_t$ are given by

$$\mathbf{a}_t = \mathbf{a}_{t-1} + \nu_t, \tag{3}$$

$$\mathbf{b}_t = \mathbf{b}_{t-1} + \zeta_t, \tag{4}$$

$$\log \mathbf{h}_t = \log \mathbf{h}_{t-1} + \eta_t. \tag{5}$$

Finally, we assume that the variance-covariance matrix of the innovations is block diagonal:

$$\begin{bmatrix} \epsilon_t \\ \nu_t \\ \zeta_t \\ \eta_t \end{bmatrix} \sim N(0, V) \text{ , with } \mathbf{V} = \begin{bmatrix} \mathbf{I}_n & 0 & 0 & 0 \\ 0 & \mathbf{Q} & 0 & 0 \\ 0 & 0 & \mathbf{S} & 0 \\ 0 & 0 & 0 & \mathbf{W} \end{bmatrix} \text{ and } \mathbf{W} = \begin{bmatrix} \sigma_1^2 & 0 & \cdots & 0 \\ 0 & \sigma_2^2 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & \sigma_n^2 \end{bmatrix} , \tag{6}$$

where $\mathbf{I}_n$ is an n-dimensional identity matrix, $\mathbf{Q}$, $\mathbf{S}$, and $\mathbf{W}$ are positive definite matrices. Moreover, it is assumed that matrix $\mathbf{S}$ is also block-diagonal with respect to the parameter blocks for each equation and $\mathbf{W}$ is diagonal.[5]

To estimate the model, we employ a Metropolis-within-Gibbs sampling algorithm. For a more detailed discussion of the estimation procedure, we refer the reader to Primiceri (2005) and Cogley and Sargent (2005). However, in contrast to the former papers, we use a multi-move sampler to sample stochastic volatility as suggested by Shephard and Pitt (1997) and modified by Watanabe and Omori (2004).[6] During the simulation, we ensure stationarity of the VAR-coefficients in the posterior distribution. We choose a lag length $p = 2$. The prior distributions for the VAR-coefficients are calibrated based on a training sample from 1876Q1 to 1899Q1. The remaining prior specifications are borrowed from Cogley and Sargent (2005) or Primiceri (2005). A detailed description can be found in Appendix B. Finally, we take 100,000 draws with a burn-in phase of 80,000 draws. After the burn-in phase, we keep only each 10th draw to reduce autocorrelation. [7]

Given the estimated TVP-VAR model, we calculate the spectral density at time $t$ to investigate the variation of the sum of lagged regression coefficient as shown in (16) over time. To do so, we write the TVP-VAR model in state space form:

$$\begin{aligned} \mathbf{X}_t &= \hat{\mathbf{A}}_{t|T}\mathbf{X}_{t-1} + \hat{\mathbf{B}}_{t|T}\mathbf{w}_t \\ \mathbf{y}_t &= \hat{\mathbf{C}}_{t|T}\mathbf{X}_t \ , \end{aligned} \tag{7}$$

where $\mathbf{X}_t$ is the $n_x \times 1$ state vector, $\mathbf{y}_t$ is an $n_y \times 1$ vector of observables, $\mathbf{w}_t$ is an $n_w \times 1$ Gaussian random vector with mean zero and unit covariance matrix that is distributed identically and independently across time. The matrices $\hat{\mathbf{A}}$, $\hat{\mathbf{B}}$, and $\hat{\mathbf{C}}$ are functions of a vector of the time-varying structural model parameters. Given this representation, the

[5]See Primiceri (2005) for a discussion about relaxing these assumptions.
[6]See also Nakajima (2011) for a comparison and detailed description of this sampling algorithm.
[7]Detailed convergence statistics and diagnostics can be found in Appendix C.

corresponding temporary spectral density at time $\mathbf{t}$ of matrix $Y$ is

$$S_{Y,t|T}(\omega) = \hat{\mathbf{C}}_{t|T}\left(I - \hat{\mathbf{A}}_{t|T}e^{-i\omega}\right)^{-1}\hat{\mathbf{B}}_{t|T}\hat{\mathbf{B}}'_{t|T}\left(I - \hat{\mathbf{A}}'_{t|T}e^{i\omega}\right)^{-1}\hat{\mathbf{C}}'_{t|T} \tag{8}$$

and the time-varying sum of lagged regression coefficients between deficits and inflation at time $t$ is computed as

$$\hat{b}_{f,t|T} = \frac{S_{\pi,d,t|T}(0)}{S_{d,t|T}(0)} \tag{9}$$

The measure of fit is defined as coherency squared:

$$H_{\pi d,t|T}(0) = \frac{|S_{\pi d,t|T}(0)|^2}{S_{\pi,t|T}(0)S_{d,t|T}(0)} \tag{10}$$

We follow Sargent and Surico (2011) and the discussion therein and do not account for the fact that the parameter drift is going forward beyond time $t$. More precisely, we calculate $b_{f,t|T}$ using the updated parameter of the matrices $\mathbf{H}_t$, $\mathbf{A}_t$, and $\mathbf{B}_t$ in $t$ and assuming that they remain constant.

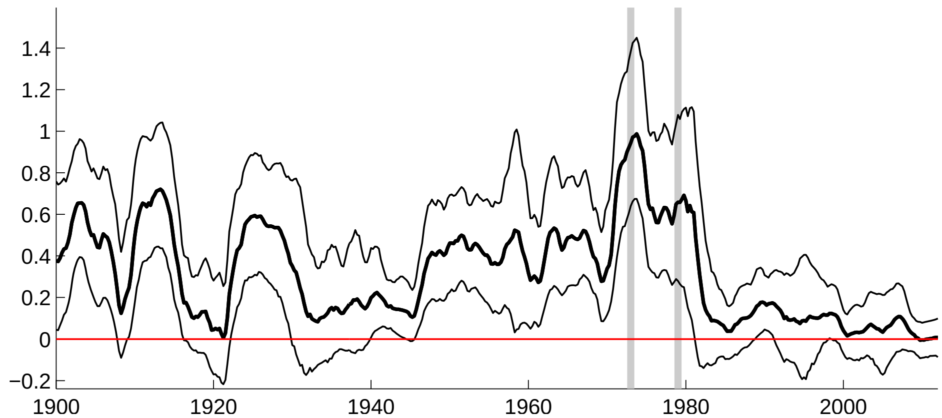
# 4 Results

## 4.1 Estimation results

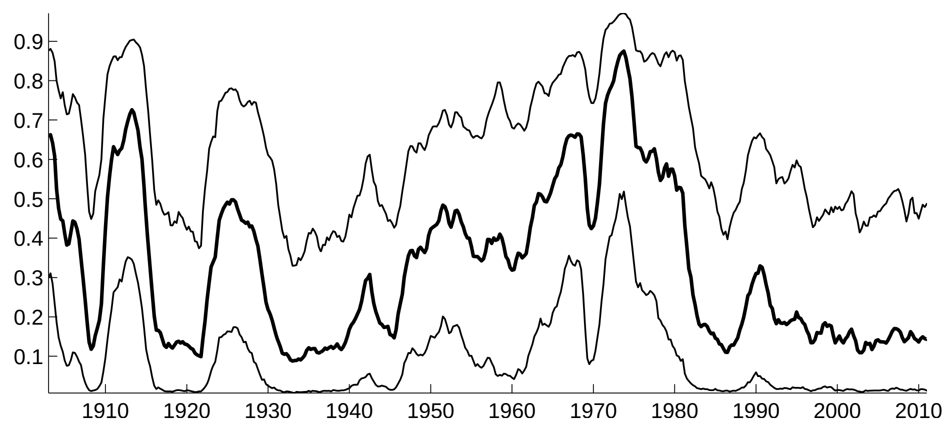
The results of the TVP-VAR model are illustrated in Figure 3, where sub-plots show the evolution of the low-frequency relationship between inflation and the primary deficit-to-debt ratio (Figure 3(a)) and the corresponding measure of fit (Figure 3(b)).

Our first main finding is that the low-frequency relationship between the variables of interest is time-varying. Except for a short period after WWI and the times around the great depression, this relationship is significantly positive until 1980. While the relationship in the first part of the 20th century is rather volatile, it is stable in the period from 1945 to the end of the Bretton Woods system. In the year the Bretton Woods system ends, the low-frequency relationship increases to its highest value around one. It decreases sharply in 1979 when Paul Volcker became Chairman of the Federal Reserve System. After 1980, zero is included in the probability band most of the time. This period from 1960 to 1980 is also the time of the highest $R^2$. Moreover, the time-variation of the low-frequency relationship is in line with our analysis in Section 2. By comparing Figure 3(a) with the results from the OLS estimation of the filtered data in Section 2, we conclude that the spectrum is well approximated by the TVP-VAR model.[8]

[8]To further investigate how well the low-frequency spectrum is approximated, we compare the estimation




(a) $\hat{b}_f$: Median and 68% central posterior bands for the time-varying regression coefficient inflation on primary deficits over debt. Grey lines depict the years 1973 (end of the Bretton Woods system) and 1979 (Volcker becomes Chairman of the Federal Reserve System).




(b) $R^2$: Inflation on Primary deficits over debt

Figure 3: Median and 68% central posterior bands for $\hat{b}_f$ and corresponding $R^2$

## 4.2 Counterfactual analysis and narrative evidence

In order to further disentangle the determinants of the low-frequency relationship we perform a counterfactual analysis. We investigate whether the movements of the low-frequency relationship are due to changes in the variance-covariance matrix of the shocks or whether the changes in the low-frequency can be attributed to the changes in the systematic behavior of the economy.

We start by fixing the systematic behavior of the economy ($\mathbf{A}_t$) to the first quarter in 1995, i.e. we draw realizations for ($\mathbf{A}_{1995.1}$) out of its posterior distributions. For every draw, the matrices ($\mathbf{B}_t$) and ($\mathbf{H}_t$) are drawn from their posterior distribution at each point in time and we calculate the low-frequency relationship using equation 9. Figure 4 displays the result of the counterfactual experiment.

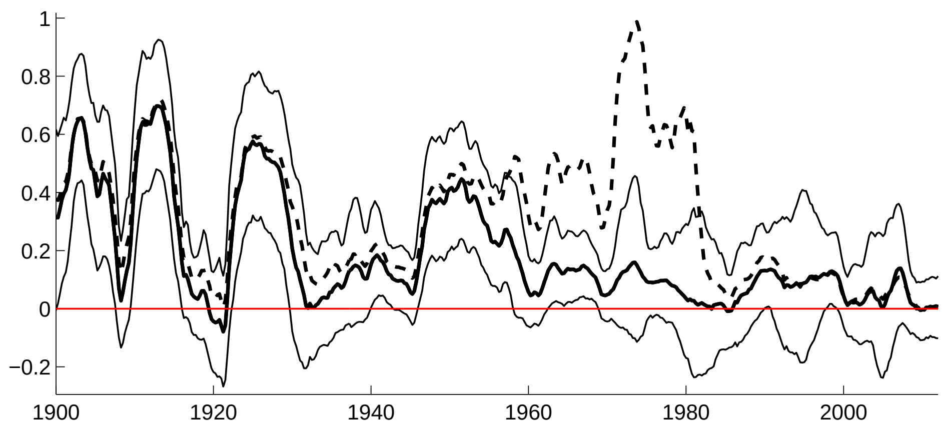



Figure 4: Counterfactual experiment: Median and 68% central posterior bands for $\hat{b}_f$ for fixed VAR model coefficients ($\mathbf{A}_{1995.1}$). The dashed line represents the median of $\hat{b}_f$ without fixing the VAR model coefficients.

In comparison to Figure 3(a), we first deduce that the movements of the low-frequency relationship in the first part of the 20th century are mostly attributable to the changes in the variance-covariance matrix of the shocks on the economy. Thus, the low-frequency relationship after 1950 is driven much more by the systematic behavior than by the innovations. Furthermore, we infer that the significantly positive low-frequency relationship after 1965 and, especially, the period of the highest relationship would not have occurred if the systematic behavior of the economy of 1995 had been in place.[9]

Given the counterfactual analysis, we cannot be sure that the strong low-frequency relationship in the 1970s and the sharp decline after Paul Volcker became Chairman of the

results of the VAR model with DOLS regression estimation results in Appendix E.1.

[9]Alternatively, by fixing the systematic behavior of the economy ($\mathbf{A}_t$) to the first quarter in 1975, we obtain a similar high low-frequency relationship as in 1975 also for the period after 1980.

Federal Reserve is due to changes in the policy regime. Nevertheless, the fact that the relationship reaches is highest value in the year in which the Bretton Woods system ends and stays high until 1979 would tend to suggest this explanation. For further evidence, we turn to narrative sources. One source is the book by Meltzer (2010). He characterizes the period as the Fed accepting "its role as a junior partner by agreeing to coordinate actions with the administration's fiscal policy." Similarly, it is argued by Greider (1987) that Arthur Burns ran an unusually expansionary policy because he believed it would increase his chances of being nominated for another term. However, the strong low-frequency relationship declines sharply after 1980, i.e. after Paul Volcker became Chairman of the Fed. As Meltzer (2010) points out, Volcker rebuilt much of the independence and credibility the Federal reserve had lost during the two previous decades.

Given this anecdotal evidence, Martin (2012) proxies central bank independence by the number of meetings at the White House between the U.S. President and the Fed Chairman. He shows that the number of meetings with Presidents Nixon and Ford (1969-1977) were quite frequent and took place four times more often than the next four presidents put together. Additionally, Martin (2012) shows that President Johnson (1963-1969) met with the Fed Chairmen 300 times during his five years in office. Another instance of empirical support for this interpretation is given by Demertzis, Marcellino, and Viegi (2008).

We find further support in the literature for our interpretation that the change in the low-frequency relationship is due to a change in policy regime. Bianchi and Ilut (2012) and Davig and Leeper (2007) categorize the period 1973-1979 as an active fiscal and passive monetary policy regime. Lubik and Schorfheide (2004) and Clarida et al. (1998) associate the 1970s with a low response by the central bank to inflation. Additionally, a variety of papers has estimated a change in the conduct of monetary policy in connection with the beginning of the chairmanship of Paul Volcker (e.g. Clarida et al., 1998; Lubik and Schorfheide, 2004; Davig and Leeper, 2007; Bianchi and Ilut, 2012). They find that the period after 1980 are associated with an independent central bank that responds strongly to inflation. Thus, we interpret the significant low-frequency relationship between primary deficits over debt and inflation from 1965 onwards and its disappearance in the early 1980s as strongly related to a change in the conduct or independence of monetary policy.

# 5 Conclusion

The low-frequency relationship between inflation and primary deficits over debt for the U.S. is time-varying and mostly positive between 1900 and 1980. After 1980 it becomes insignificantly different from zero. We document that, while the movements in the first half of the century are due to changes in the variance-covariance matrix of the shocks on the economy, the movements in the second half are attributable to changes in the systematic behavior of the economy. We estimate the highest relationship at the end of the Bretton Woods system in 1973 and show that this relationship breaks down after Paul Volcker becomes Chairman of the Federal Reserve System. Using narrative evidence, we conclude that the relationship depends on the policy regime which is in place. In a policy regime in which the central bank accommodates the action of the fiscal authority which is willing to put up with high inflation rates, high deficits are associated with inflation in the long run.

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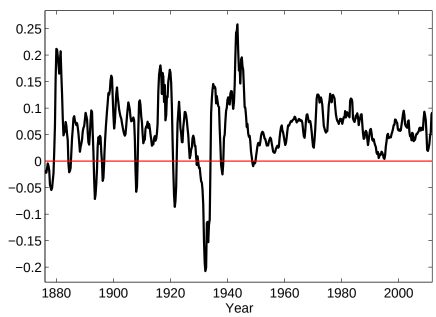
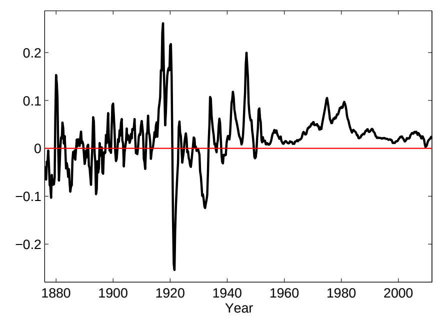
# A Data

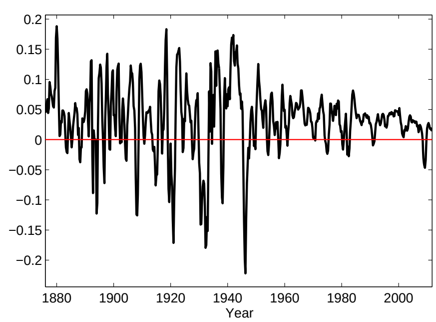
Next to primary deficits over debt we build up on data recently investigated by Sargent and Surico (2011), which are quarterly U.S. data from 1875Q1 until 2011Q4. Real output growth is defined as year-to-year first differences of the logarithm of real GDP. From 1947Q1 onward, real GDP (in chained 2005 Dollars) is taken from the FRED II database of the Federal Reserve Bank of St. Louis. For the period before 1947, we employ the growth rates of the real GNP series provided by Balke and Gordon (1986) to construct the time series. We apply the same procedure for money growth to the M2 stock series from FRED II database starting in 1959Q1. Similarly, inflation is measured as year-to-year first differences of the logarithmic GDP deflator, where the data is taken from the FRED II database starting in 1947Q1 and from Balke and Gordon (1986) before then. For the period from 1875Q1 until 1981Q4, the nominal interest rate is defined as the six-month commercial paper rate given by Balke and Gordon (1986). From 1982Q1 onward, we use the quarterly averages of the weekly six-month Treasury Constant Maturity Rate available on the FRED II database.



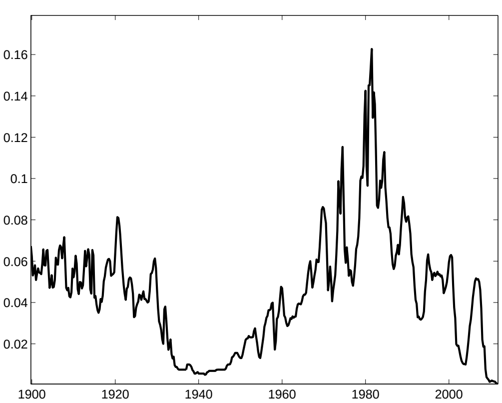

(a) Money Growth




(b) Inflation




(c) GDP growth




(d) Interest rate

Figure 5: Data between 1976Q1 and 20011Q4.

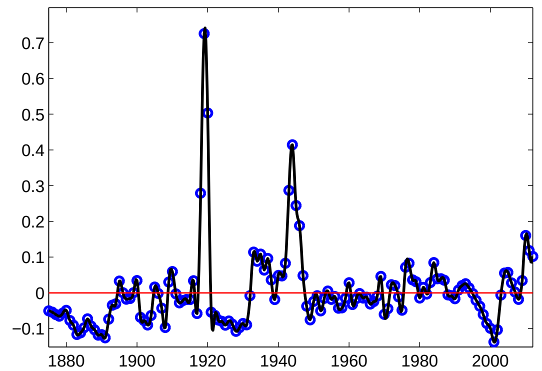



Figure 6: Primary deficits over debt between 1976Q1 and 2011Q4, the *o* indicate the original data by Bohn (2008) while the solid line indicates the final interpolated data.

# B Prior specification

Some of the prior specifications of the VAR-coefficients are based on estimates from a time-invariant VAR using a training sample of 93 observations between 1876Q1 and 1899Q1. The prior choices can be summarized as follows.

$$\begin{aligned}
\mathbf{a}_0 &\sim N(\hat{a}^{OLS}, 4\ Var(\hat{a}^{OLS})) \\
\mathbf{b}_0 &\sim N(\hat{b}^{OLS}, k_b^2\ I_4) \\
\log h_0 &\sim N(\log h^{OLS}, 10\ I_n) \\
\mathbf{Q} &\sim IW(k_Q^2\ 93\ Var(\hat{a}^{OLS}),\ 93) \\
\sigma_i^2 &\sim IG(\frac{k_w^2 \cdot 6}{2},\ \frac{6}{2}) \\
\mathbf{S}_1 &\sim IW(k_S^2\ 2\ I_1,\ 2) \\
\mathbf{S}_2 &\sim IW(k_S^2\ 3\ I_2,\ 3) \\
\mathbf{S}_3 &\sim IW(k_S^2\ 4\ I_3,\ 4) \\
\mathbf{S}_4 &\sim IW(k_S^2\ 5\ I_4,\ 5),
\end{aligned} \tag{11}$$

where $k_Q$ and $k_W$ are set to 0.01 and $k_b$ and $k_S$ to 0.1.

# C Convergence Checks

To check the convergence of our sampler, we have used visual inspections and numerical convergence diagnostics. The visual inspections illustrate how the parameters move through the parameter space, thereby allowing us to check wether the chain gets stuck in certain areas. To visualize the evolution of our parameters, we use running mean plots and trace plots. For lack of space, we present only running mean plots and trace plots for the trace of the variance covariance matrices Q, W, and S. As can be seen in Figure 7, and Figure 8 running mean plots and trace plots both show that the mean of the parameter values stabilize as the number of iterations increases and that the chains are mixing quite well.

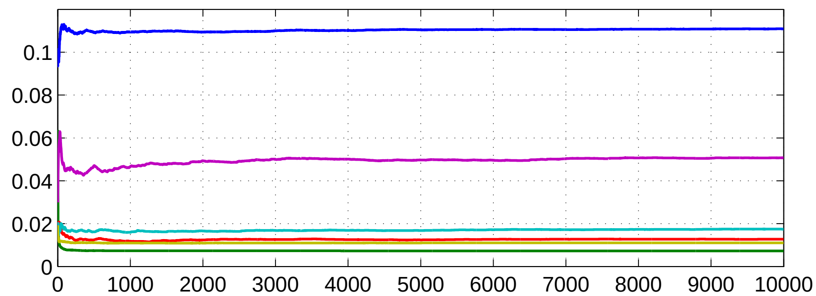


Figure 7: Running Mean Plot.

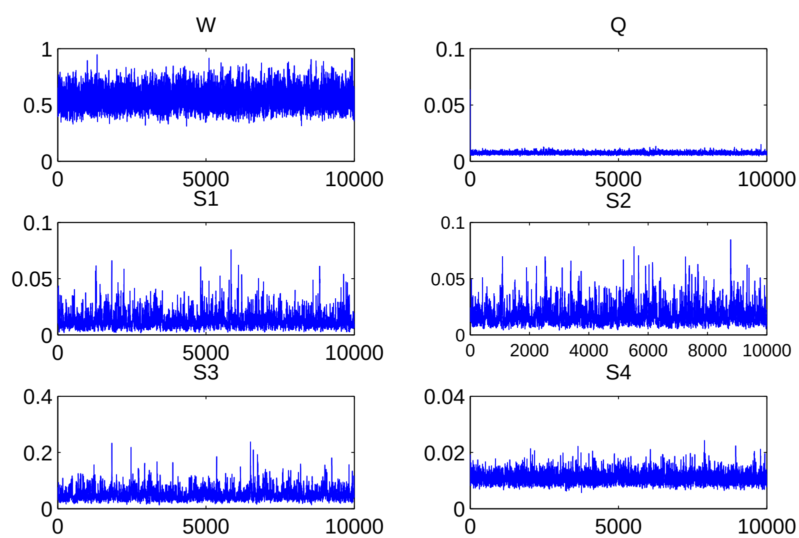
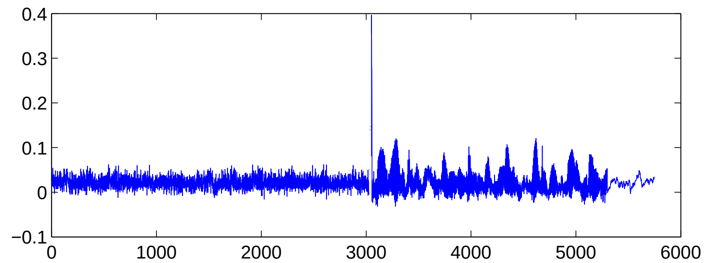
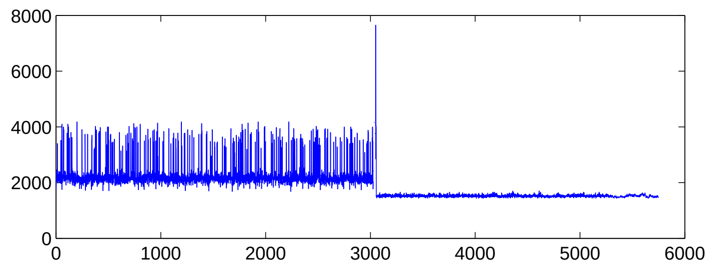



Figure 8: Trace Plot.

Additionally, we have calculated autocorrelations at the 10th lag as a numerical measure of the mixing characteristics of the Markov chain. High autocorrelations indicate a bad mixing of the chain that would exacerbate the convergence of the sampler. We have also computed the total number of draws needed to obtain a certain precision as suggested by Raftery and Lewis (1992).




(a) Autocorrelation at 10th draw.



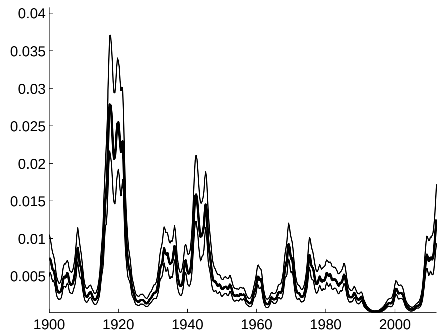

(b) Minimum Number of Draws.

Figure 9: Convergency diagnostics.

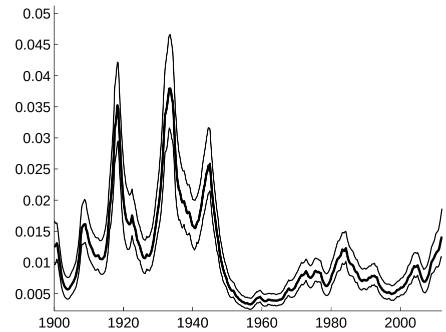
Figure 9 depicts the convergence diagnostics for all hyperparameters (points 1-3055), the stochastic volatilities (points 3056-5300) and the absolute maximum eigenvalue of the parameter matrix $\mathbf{A_t}$ (points 5301-5749). As can be seen in Figure 9(a), most of the autocorrelations are below 0.1 indicating that the chain mixes quite well and that the sampler performs efficiently. Moreover, as can be seen in Figure 9(b), the number of draws suggested by the Raftery and Lewis (1992) diagnostic is far below our actual number of draws (we used 0.025 for the quantile, 0.025 for the level of precision, and the 0.95 for probability of obtaining the required precision). To summarize, according to convergence tests conducted the sampler seems to be converged.

# D Supplementary estimation results

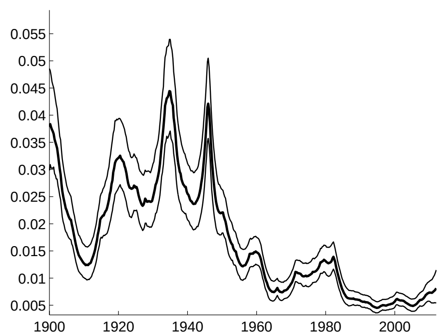
## D.1 Stochastic Volatility



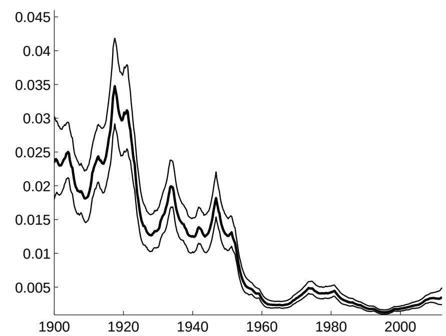

(a) Primary deficits over Debt



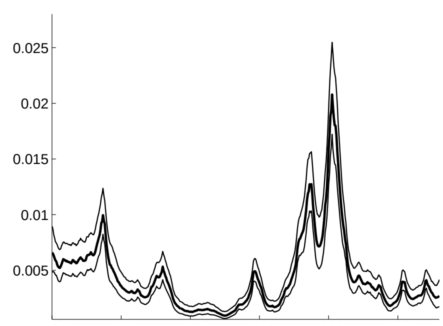

(b) $\Delta$ Money




(c) $\Delta$ GDP



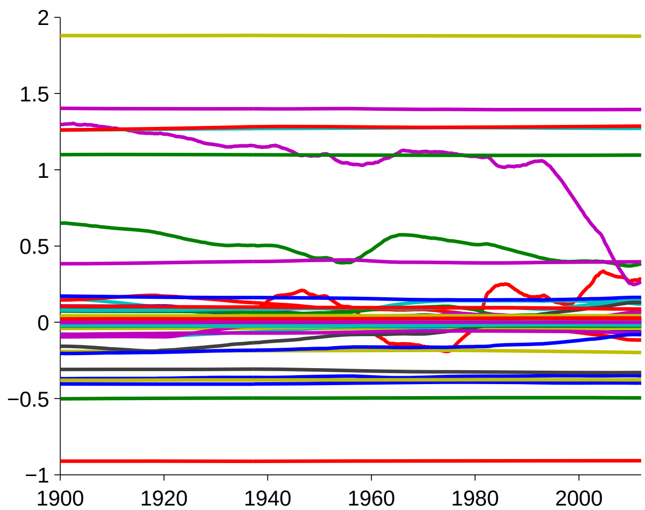

(d) Inflation



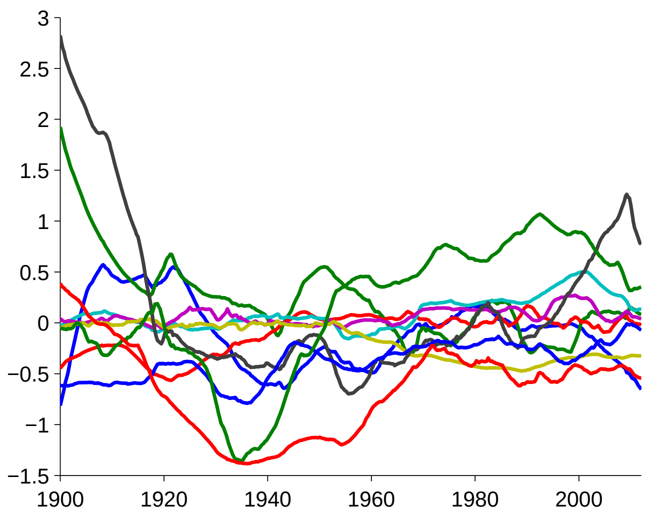

(e) 6m Interest Rate

Figure 10: Square roots of stochastic volatility.

## D.2 Parameter Estimates



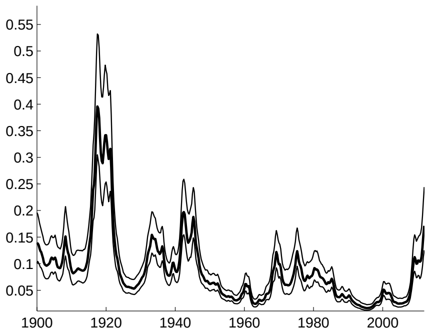

(a) Matrix A



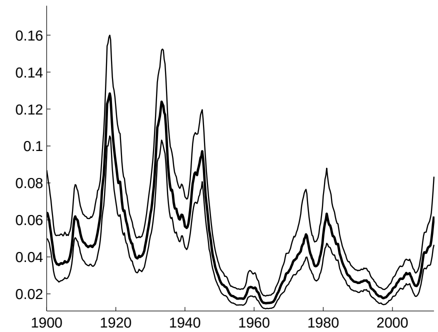

(b) Matrix B

Figure 11: Time-varying parameter estimates.

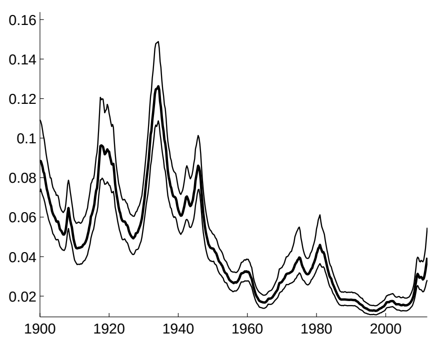
## D.3 Macroeconomic Volatility



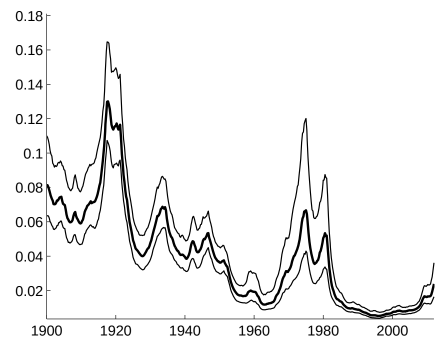

(a) Primary deficits over Debt



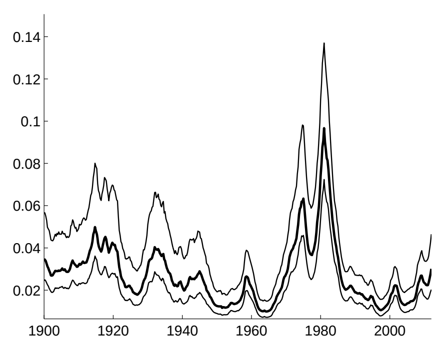

(b) $\Delta$ Money




(c) $\Delta$ GDP




(d) Inflation




(e) Short-term Interest Rate

Figure 12: Standard deviations of the variables.

# E Robustness

## E.1 Alternative measures

In Section 2 we illustrate the low-frequency relationship between inflation and primary deficits over debt by presenting scatter plots of the corresponding filtered time series, where the filter is defined as $x_t(\beta) = \alpha \sum_{k=-n}^{n} \beta^{|k|} x_{t+k}$ with $\alpha = \frac{(1-\beta)^2}{(1-\beta^2-2\beta^{(k+1)}(1-\beta^2)}$ is beingchosen such that the sum of weights equals one. The number of leads and lags $n$ is set to 8 and $\beta = 0.95$. The slope of the scatter plots is equal to the OLS estimate of the following regression

$$\pi_t(\beta) = const + b_f d_t(\beta) + error, \tag{12}$$

where we assume orthogonality between $d_t(\beta)$ and the error term.

Alternatively, we can calculate the low-frequency relationship directly without filtering the data by employing the efficient lead/lag estimator postulated by Stock and Watson (1993). The corresponding regression formula using unfiltered data is given by

$$\pi_t = const + b_f d_t + \sum_{i=-n}^{n} \gamma_i \Delta d_{t-i} + error, \tag{13}$$

where $b_f$ is the dynamic OLS estimator (DOLS). The number of leads and lags is chosen to be 8. Finally, we employ Newey-West HAC standard errors for both estimation approaches. Table 1 presents the estimation results for both regression for different sub-samples, as discussed in Section 2. Both methodologies show similar patterns, we find a low-frequency relationship for the time between 1952 and 1983, but not for the period, for example, from 1984 onward.

In the present paper, we follow another alternative to estimate the low-frequency relationship by employing the method suggested by Sargent and Surico (2011). In particular, we estimate the TVP-VAR model and use its coefficients to compute the low-frequency relationship. The TVP-VAR model contains unfiltered data instead of filtered data. Hence, we follow Sargent and Surico (2011) and make use of one result provided by Whiteman (1984). In particular, Whiteman (1984) shows that for $\beta$ close to 1, the regression coefficient in equation (12) can be approximated by the sum of lagged regression coefficients of a projection of $\pi$ on $d$. Formally, define the projection as

$$\pi_t = \sum_{j=-\infty}^{\infty} h_j d_{t-j} + \epsilon_t, \tag{14}$$

with the orthogonality assumption $E[d_{t-j}\epsilon_t] = 0$. The regression coefficient is approximated

| Sample | OLS | DOLS |
|---|---|---|
| 1900-1933 | 0.2882 | 0.2879 |
| | (0.0499) | (0.0570) |
| 1934-1951 | 0.0909 | 0.2999 |
| | (0.0350) | (0.1585) |
| 1952-1983 | 0.8076 | 1.0604 |
| | (0.1214) | (0.1108) |
| 1984-2009 | 0.0691 | 0.0913 |
| | (0.0242) | (0.0244) |
| 1900-2009 | 0.2212 | 0.2455 |
| | (0.0395) | (0.0791) |

Table 1: OLS and DOLS estimates and corresponding Newey-West HAC standard errors.

as

$$b_f \approx \sum_{j=-\infty}^{\infty} h_j \tag{15}$$

Sargent (1987) shows that the sum of lagged regression coefficients is equal to the cross spectrum of $\pi$ and $d$ ($S_{\pi d}$) divided by the spectrum of $d$ ($S_d$) at frequency zero:

$$\sum_{j=-\infty}^{\infty} h_j = \frac{S_{\pi d}(0)}{S_d(0)} \tag{16}$$

Given the estimates of the TVP-VAR model, we use the results (16) and (15) to obtain estimates of the time-varying regression coefficient.

Figure 13 shows the low-frequency relationship calculated via the TVP-VAR and the spectrum and the low-frequency relationship based on the OLS regression coefficient of the filtered data. Both measures present similar results, which gives us confidence that our VAR gives a good approximation of the spectrum. Finally, we also calculated time-varying estimates of equation (12) and (13) by employing a rolling sample with a fixed window length of 120 quarters. Figure 14 presents the time-varying estimates of $b_f$. The results of both time-varying estimation approaches are similar and indeed comparable to our main result presented in Figure 13.

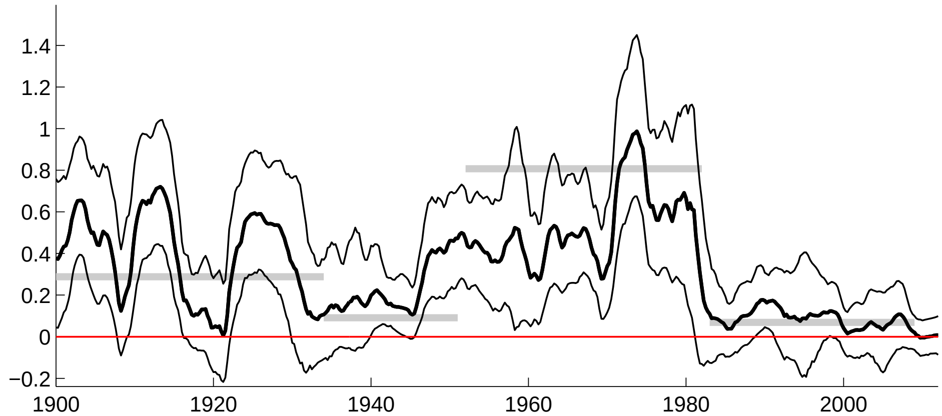
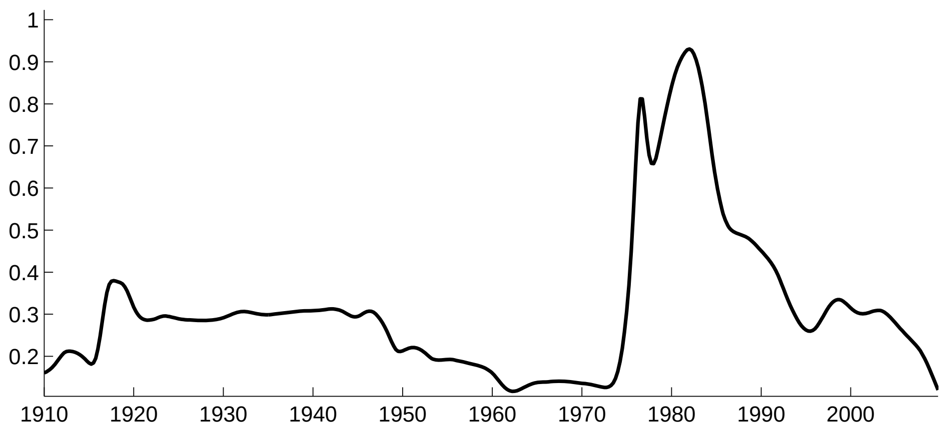
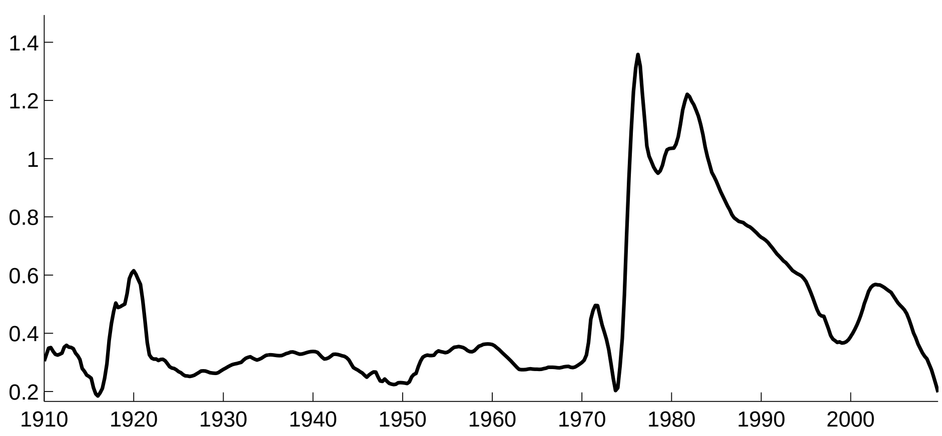



Figure 13: $\hat{b}_f$: Median and 68% central posterior bands for the time-varying regression coefficient inflation on primary deficits over debt. Grey lines correspond to the heteroscedastic-serial consistent OLS regression coefficient of the filtered data from Table 1.




(a) OLS estimate

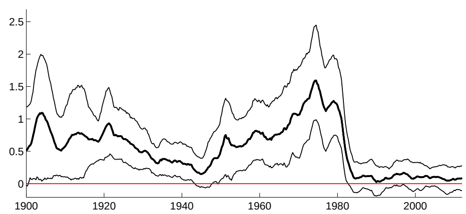



(b) DOLS estimate

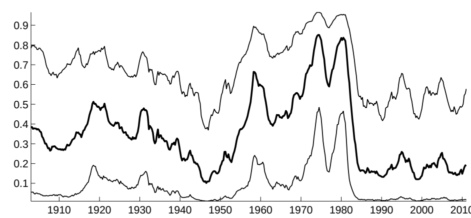
Figure 14: Rolling sample (fixed window) regression coefficients.

## E.2 Further low-frequency relationships

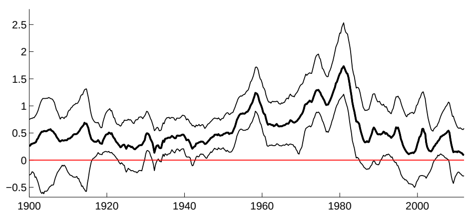
Below we analyze whether the low-frequency relationship between inflation and the primary deficits over debt ratio diminishes or even cancels out other well established low-frequency relationships. More precisely, we investigate the low-frequency relationship between inflation and money and between money and interest rates as postulated by Lucas (1980) and recently investigated by Sargent and Surico (2011). As Figures 15(a) and 15(c) show, we obtain results similar to those of Sargent and Surico (2011), i.e. our finding of an additional positive relationship does not crowd out the existing relationships.



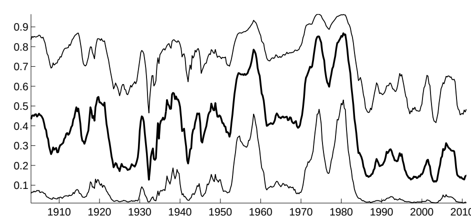

(a) $\hat{b}_f$: Inflation on money




(b) $\hat{R}^2$: Inflation on money




(c) $\hat{b}_f$: Interest rate on money




(d) $\hat{R}^2$: Interest rate on money

Figure 15: Selected low-frequency relationships.

## E.3 Alternative TVP-VAR Specifications

In the following, we describe different robustness checks we employ to investigate the sensitivity of our results. First, we change the interpolation method for the primary deficits over debt time series. In particular, we employ the methods proposed by Chow and Lin (1971) and Litterman (1983) next to the cubic-spline approach. Figure 16 presents the interpolated time series.

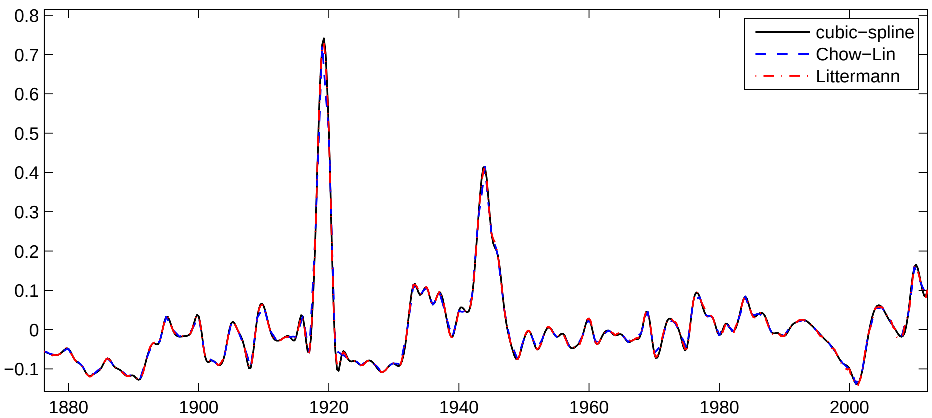



Figure 16: Interpolated time series for primary deficits over debt using different interpolation methods.

We use for both methods, Chow and Lin (1971) and Litterman (1983), as related time series for the interpolation real GDP and the Price index as described in Section A. The results for all methods are quite similar. We decide to use the interpolated time series based on the cubic-spline method for our baseline estimation. This is based on the fact that next to the time series employed in the VAR model, we have no other suitable long time series available whose information can be exploited to interpolate the primary deficit-over debt time series. But this is necessary for the application of the methods proposed by Chow and Lin (1971) and Litterman (1983). Using the same time series for interpolation and estimation of the TVP-VAR would imply that we use the data twice. Therefore, we only show that the interpolated time series are similar, but do not employ the different interpolated time series in the estimation.

Next, we calculate the low-frequency relationship between inflation and primary deficits over debt for different VAR specifications. In particular, we check the robustness of our result with respect to other interest rates measures, and another measure of fiscal stance. Figures 17 to 19 show the main result of the present paper based on different VAR specifications. While different interest rates have almost no impact on our result, the change of the fiscal variable also changes the estimated relationship slightly. Also, our main finding of an high relationship in the 1970s, which deteriorates after 1980, still exists.

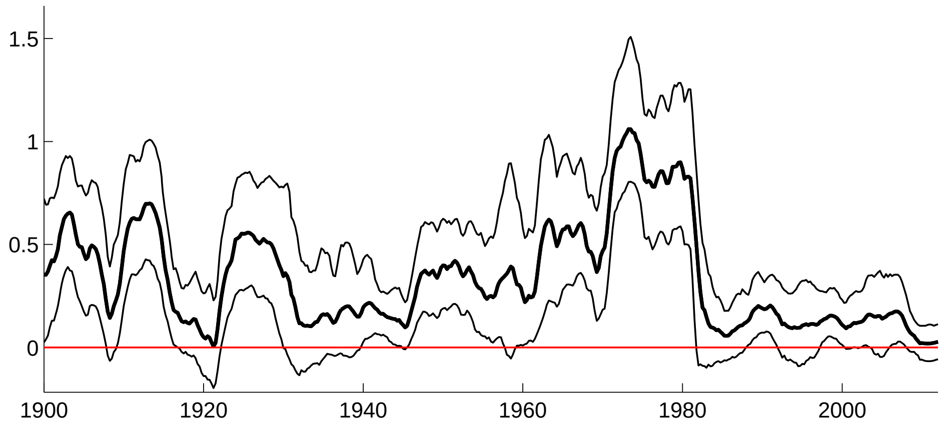



Figure 17: $\hat{b}_f$: Median and 68% central posterior bands for the time-varying regression coefficient inflation on primary deficits over debt. Robustness check with 3m nominal interest rates instead of 6m interest rates.

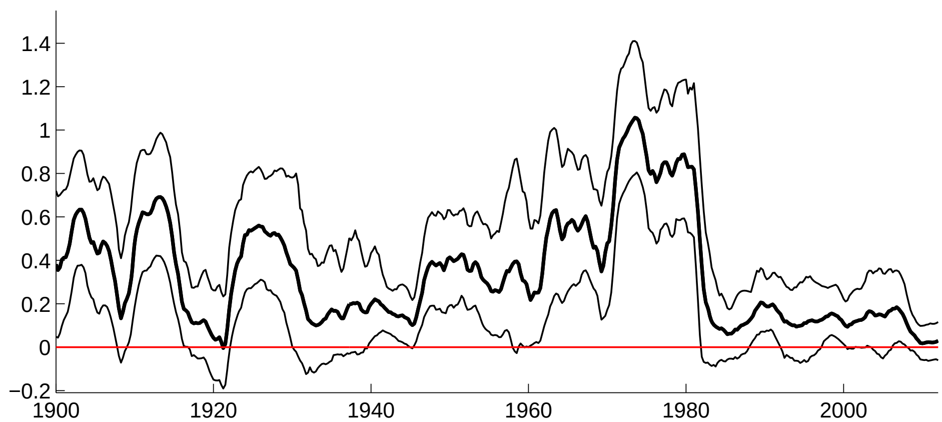



Figure 18: $\hat{b}_f$: Median and 68% central posterior bands for the time-varying regression coefficient inflation on primary deficits over debt. Robustness check with 3m real interest rates instead of 6m interest rates.

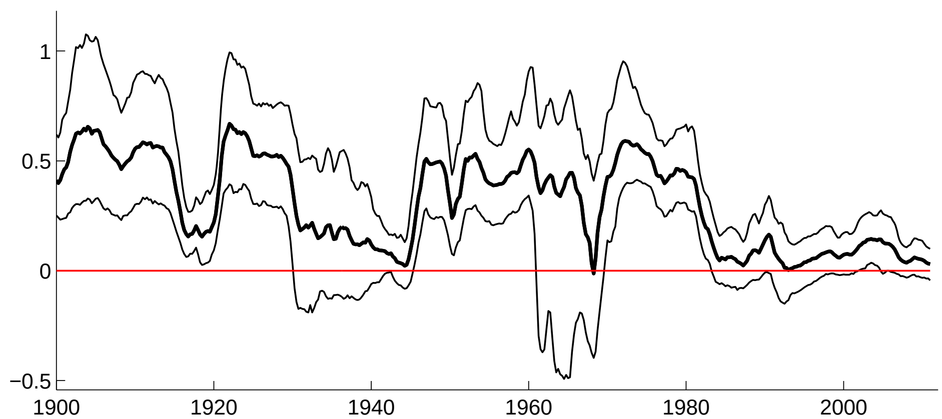



Figure 19: $\hat{b}_f$: Median and 68% central posterior bands for the time-varying regression coefficient inflation on debt growth. Robustness check with real debt growth instead of primary deficits over debt.