## Appendix

## Majority Rule, Consensus Building, and the Power of the Chairman: Arthur Burns and the FOMC

### Section 1. Data Coding Procedures

The *Memoranda of Discussion* (1970-1976) and Ford Library transcripts (1976-1978) provide detailed records of FOMC deliberations on monetary policy. Transcripts were very lightly edited; the *Memoranda* slightly more so. Both sources summarize the statements made by individuals within the meetings.

During the 1970s, the FOMC met at approximately monthly intervals. In each meeting it adopted a directive to guide the conduct of monetary policy over the next inter-meeting period. Monetary policy directives are short, sometimes vaguely worded documents, but in the Burns era directives included specific target ranges for the federal funds rate. We measure the adopted policy outcome as the midpoint of the federal funds rate range associated with the directive. In a few cases, policies with "asymmetric midpoints" were explicitly proposed or adopted. An asymmetric midpoint represents the primary target value for policymakers, even though it is not strictly the midpoint within the proposed target range. Whenever asymmetric midpoints were explicitly mentioned, we regarded those as the targets for the given proposals.

In each meeting, the Federal Reserve staff presented the Committee with alternative policy options and associated forecasts, which usually became a focus of subsequent discussion. After the presentation of the staff report, the Chairman called for the "policy go-around," in which members of the Committee, including both voting and non-voting district Reserve Bank presidents, presented views on appropriate policy choices. At this stage, members usually identified themselves with one of the staff proposals or offered an alternative position. Frequently, members were explicit about desired ranges for the federal funds rate. Based on the textual record contained in the *Memoranda of Discussion* and the Ford Library transcripts, we have attributed desired federal funds rate targets to individuals when any of the following circumstances prevailed:

(1) The individual explicitly stated a desired range for the federal funds rate.

(2) The individual stated a preference for a staff policy scenario that had an explicit target range for the federal funds rate.

(3) The individual stated that his preference coincided with that of another member of the Committee whose desired funds rate could be inferred by way of (1) or (2) above.

We then calculated each individual's desired funds rate as the midpoint of the reported range. For our 99-meeting sample, we were able to code a desired funds rate for 1427 (80.1%) of the 1782 member observations (including both voting and non-voting member observations).

For observations where individuals failed to state an explicit funds rate range, we instead coded a qualitative variable to describe preferences. To do so, we first established a benchmark policy with which members' preferences could be compared in each meeting. We used a Board staff proposal for this purpose. Although the Board staff usually presented several policy scenarios ranging from "easier" to "tighter," we defined a composite proposal as our benchmark. When the staff presented an odd number of scenarios, our benchmark was the midpoint of the range prescribed by the median proposal. When the staff presented an even number of proposals, our benchmark was the midpoint of the range defined by the union of the ranges in the two median proposals.

In the policy go-around which follows the staff presentation, members' comments can indicate (1) a preference for a policy which is "easier" than the staff proposal, (2) a preference for a policy which is "tighter" than the staff proposal, or (3) no clear direction of preference relative to the staff proposal. For each Committee member who did not state a desired interest rate, we have used the textual record of Committee deliberations to code member policy positions into these three categories. Members either "lean toward ease," "lean toward tightness," or "assent."

In practice, members' statements are frequently framed in comparison to staff proposals, so with few exceptions, classifying positions is straightforward. One can think of the staff proposals as points on an interest rate number line. Members' comments typically place them in particular intervals along that line. For example, the staff may offer scenarios A, B, and C, ranging from easiest to tightest. Without stating a specific target, a member may indicate a preference "close to A, but shaded in the direction of B." This verbal statement indicates a desire for ease relative to the benchmark staff proposal, which in this case is B. The original transcripts have in all cases been read and coded at least twice by graduate student assistants and once by the authors. Final coding decisions were made by the authors. Of the 355 member observations (again including non-voting Bank presidents) where desired funds rates were not directly inferred, leans for ease were coded in 88 (24.8%) cases, leans for tightness were coded in 81 (22.8%) cases, and assents were coded in the remaining 186 (52.4%) cases.

## Section II. The Likelihood Function for Individual Reaction Function Estimation

In this section we present the likelihood function for the estimation of the reaction function for member *i*, using a sample in which desired interest rates may or may not be observed. We derive the likelihood functions for observations falling into each of four categories: (1) $R_{it}^*$ is not observed and member *i* leans for tightness, (2) $R_{it}^*$ is not observed and member *i* leans for ease, (3) $R_{it}^*$ is not observed and member *i* assents, and (4) $R_{it}^*$ is observed.

*Case I. $R_{it}^*$ is Not Observed and Member i Leans for Tightness*

Because $V_{it} = 1$, we know that $R_{it}^* - \tilde{R}_t > l_i$, or equivalently, that $e_{it} > a_{it}$ , where $a_{it} = \dfrac{l_i + \tilde{R}_t - \mathbf{X}_t b_i}{s_i}$. The likelihood for the observation is given by the probability that we observe this case given the parameter values:

$$L_{I,it} = \text{Prob}\left(e_{it} > a_{it}\right)$$

$$= 1\text{-}\ F\left(a_{it}\right),$$

where $F$ is the standard normal cumulative distribution function.

*Case II. $R_{it}^*$ is Not Observed and Member i Leans for Ease*

Because $V_{it} = -1$, we know that $R_{it}^* - \tilde{R}_t < -l_i$, or equivalently, that $e_{it} < b_{it}$, where $b_{it} = \dfrac{-l_i + \tilde{R}_t - \mathbf{X}_t b_i}{s_i}$. The likelihood for this observation is given by:

$$L_{II,it} = \text{Prob}\left(e_{it} < b_{it}\right)$$

$$= F\left(b_{it}\right).$$

*Case III. $R_{it}^*$ is Not Observed and Member i Assents*

Because $V_{it} = 0$, we know that $-l_i \le R_{it}^* - \tilde{R}_t \le l_i$, or equivalently, that $b_{it} \le e_{it} \le a_{it}$. The likelihood for this observation is given by:

$$L_{III,it} = \text{Prob}\left(b_{it} \le e_{it} \le a_{it}\right)$$

$$= F\left(a_{it}\right) - F\left(b_{it}\right).$$

*Case IV. $R_{it}^*$ is Observed*

In this case the likelihood function for observation $t$ is identical to that for an ordinary least squares regression:

$$L_{IV,it} = \frac{1}{\sqrt{2p}\,s_i} \exp\left[ -\left(\frac{1}{2}\right)\left(\frac{R_{it}^* - \mathbf{X}_t b_i}{s_i}\right)^2 \right].$$

The likelihood function for the sample of observations $t = 1,\ldots,T$ for member $i$ is given by:

$$L_i = \prod_{t=1}^{T} \left( D_{I,it} L_{I,it} + D_{II,it} L_{II,it} + D_{III,it} L_{III,it} + D_{IV,it} L_{IV,it} \right),$$

where the variables $D_I, D_{II}$, etc., are dummy variables equal to one for the indicated case and otherwise equal to zero.

## Section III. Imputing Desired Interest Rates

For the three cases where an individual's desired interest rate is not observed, we describe how to calculate the expected value of that desired interest rate. We will consider three cases corresponding to the three possible qualitative categorizations of a member's preference relative to the proposed policy of the Federal Reserve staff.

*Case I. Member i Leans Toward Tightness*

Recall that member *i*'s desired interest rate reaction function is given by:

(A.1) $R_{it}^* = \mathbf{X}_t b_i + s_i e_{it} \qquad e_{it} \sim N(0,1)$.

Given values for the exogenous variables and for the parameters of the reaction function, and taking expected values on each side of (A.1), we obtain:

(A.2) $E\left(R_{it}^*\right) = \mathbf{X}_t b_i + s_i E\left(e_{it}\right)$.

Because we have observed a lean toward tightness, we know that $R_{it}^* - \tilde{R}_t > l_i$, or, equivalently, that $e_{it} > a_{it}$, where $a_{it}$ is defined as before. Applying Bayes' Rule, the expected value of $e_{it}$ is given by:

(A.3) $E\left(e_{it}\right) = \dfrac{\int_{a_{it}}^{\infty} x f(x) dx}{1 - F\left(a_{it}\right)}$.

For a normal density, $f'(x) = -xf(x)$, so

$$\int_{a_{it}}^{\infty} xf(x)dx = -\int_{a_{it}}^{\infty} f'(x)dx$$

$$= -\left[f(x)\right]_{a_{it}}^{\infty}$$

$$= f(a_{it}).$$

Substituting this result into (A.3), we obtain:

$$E(e_{it}) = \frac{f(a_{it})}{1 - F(a_{it})}.$$

Then, substituting into (A.2) yields:

$$E(R_{it}^{*}) = \mathbf{X}_t b_i + s_i \frac{f(a_{it})}{1 - F(a_{it})}.$$

*Case II. Member i Leans Toward Ease*

Again, we have:

(A.2) $E(R_{it}^{*}) = \mathbf{X}_t b_i + s_i E(e_{it}).$

Because we have observed a lean toward ease, we know that $R_{it}^{*} - \tilde{R}_t < -l_i$, or, equivalently, that $e_{it} < b_{it}$, where $b_{it}$ is defined as before. Applying Bayes' Rule, the expected value of $e_{it}$ is given by:

$$E(e_{it}) = \frac{\int_{-\infty}^{b_{it}} xf(x)dx}{F(b_{it})}.$$

Using the condition $f'(x) = -xf(x)$ and integrating yields:

$$E(e_{it}) = -\frac{f(b_{it})}{F(b_{it})}.$$

Finally, substituting into (A.2) we obtain:

$$E\left(R_{it}^{*}\right) = \mathbf{X}_t b_i - s_i \frac{f\left(b_{it}\right)}{F\left(b_{it}\right)}.$$

*Case III. Member i Assents*

Once again, we have:

(A.2) $E\left(R_{it}^{*}\right) = \mathbf{X}_t b_i + s_i E\left(e_{it}\right).$

Because member *i* assents, we know that $-l_i \leq R_{it}^{*} - \tilde{R}_t \leq l_i$, or equivalently, that

$b_{it} \leq e_{it} \leq a_{it}$.

Making use of Bayes' Rule, $E\left(e_{it}\right)$ is given by:

$$E\left(e_{it}\right) = \frac{\int_{b_{it}}^{a_{it}} xf(x)dx}{F\left(a_{it}\right) - F\left(b_{it}\right)}.$$

Then employing the condition $f'(x) = -xf(x)$ and integrating, we obtain:

$$E\left(e_{it}\right) = \frac{f\left(b_{it}\right) - f\left(a_{it}\right)}{F\left(a_{it}\right) - F\left(b_{it}\right)}.$$

Finally, substituting into (A.2), the expected value of $R_{it}^{*}$ is given by:

$$E\left(R_{it}^{*}\right) = \mathbf{X}_t b_i + s_i \frac{f\left(b_{it}\right) - f\left(a_{it}\right)}{F\left(a_{it}\right) - F\left(b_{it}\right)}.$$

**Section IV. Unit Root and Cointegration Tests**

We tested each of our interest rate measures for a unit root using an augmented Dickey-Fuller test. Time plots of our data are shown in Figures A1-A3. Because of the high correlations between our interest rate measures we plot only two series per figure: in A1, Burns's preferred funds rate and the

Committee's adopted target funds rate; A2, the Committee mean and median funds rates; and A3, the Governors' mean and the voting Bank Presidents' mean. An inspection of Figures A1-A3 does not indicate a trend in any of our interest rate measures. Our unit root tests were therefore conducted using augmented Dickey-Fuller regressions of the form

$$\Delta y_t = a_0 + g\, y_{t-1} + \sum_{i=2}^{p} b_i \Delta y_{t-i+1} + e_t \,,$$

where $y$ denotes each interest rate measure in turn. The test of the unit root null in this specification is a test of the null hypothesis that $g = 0$. The results are presented in Table A1. For each interest rate measure, we report the test statistic for the unit root null, the *p*-value associated with the test statistic, and the number of lagged augmentation terms *p* included in the test regression. We cannot reject the unit root null at the 0.05 significance level for any of our interest rate measures.

We then proceeded, under the assumption that our interest rate measures are I(1), to test for cointegration in each of the specifications we report in Tables 3 and 4 of the text for cointegration. To do this, we use the Engle-Granger approach, which involves testing for a unit root in a specification of the form

$$\Delta \hat{u}_t = g\, \hat{u}_{t-1} + \sum_{i=2}^{p} b_i\, \Delta \hat{u}_{t-i+1} + e_t \,,$$

where $\hat{u}$ denotes the residual from an OLS regression estimating the relevant committee decision-making model. The unit root null in this case is equivalent to the null hypothesis of no cointegration; thus, rejecting a unit root would suggest that the particular combination of variables considered is cointegrated. Because we are not able to conduct these tests when there are gaps in the series, as would be the case in the 63- and 43-observation sub-samples, we report the results for only the 99-observation sample.

Table A2 presents the Engle-Granger cointegration test for each specification in Tables 3 and 4. As in Table A1, we report the test statistic for the unit root null, the *p*-value associated with the test statistic, and the number of lagged augmentation terms *p* included in the test regression. The results suggest that each combination of interest rate measures is cointegrated. This implies that OLS estimates of our committee decision-making models, with variables expressed in level form, are consistent. However, although coefficient estimates are consistent, standard inference procedures are not appropriate for some of the hypotheses we test. Specifically, with a single I(1) regressor, standard inference procedures are not appropriate for testing the null hypothesis that $f_1$ equals one, nor are they appropriate for testing the null hypothesis that the coefficients sum to one in specifications in which we have two or more I(1) regressors. In the latter case, though, it is possible to interpret the individual *t*-statistics in the usual way; Hamilton (1994, pp. 602-608), Sims, Stock, and Watson (1990), and West (1988) discuss this special case.

## Section V. Bootstrapping Methods for Hypothesis Testing

For those specifications in which standard inference procedures are inappropriate, we carry out Monte Carlo simulations to calculate bootstrapped critical values and *p*-values associated with our hypothesis tests. We describe our bootstrapping procedures in this section.

*Case I. Regressions with a Single Right-Hand-Side Variable*

Consider the case of a 1-variable regression:

(A.4) $y_{0t} = b_0 + b_1 y_{1t} + u_t$

where we permit serial correlation in $u_t$:

(A.5) $u_t = r u_{t-1} + v_t$ .

Further, $y_{1t}$ is specified to follow the process:

(A.6) $y_{1t} = y_{1t-1} + e_t$ .

The error terms, $u_t$, $v_t$, and $e_t$ are normally distributed white-noise disturbances.

To test hypotheses, we first estimate the variances $s_u$ and $s_v$. To do so, we impose the null hypothesis that $b_0 = 0$ and $b_1 = 1$; an estimate of $s_u$ can then be obtained as the variance of the residuals in (A.4). Then (A.5) is estimated using the residuals from (A.4), providing estimates of $r$ and $s_v$. Using data available for $y_{1t}$, we are able to estimate the variance $s_e$ from (A.6).

We then begin the bootstrapping procedure. Using the estimated error variances, we draw values for each of the random errors, $u_t$, $v_t$, and $e_t$, for a sample of 99 observations (corresponding to our 99-observation data set of FOMC meetings). Using historical data for initial values of $y_0$ and $y_1$, we then use the process described by (A.4)-(A.6) to generate a 99-observation sample of pseudo-data for each of those two variables. Next, using that sample, we estimate equation (A.4), saving values of the parameter estimates for $b_0$ and $b_1$. We then repeat this process (beginning again by drawing values for $u_t$, $v_t$, and $e_t$) 10,000 times, obtaining 10,000 sets of coefficients. The *p*-values and test results reported for tests of the hypothesis that $b_1 = 1$ in the first two columns of Table 3 are based on the distribution of coefficient values generated by this procedure.

*Case II. Regressions with Multiple Right-Hand-Side Variables*

We now consider the case of multiple right-hand-side variables; for illustrative purposes, we assume just two right-hand-side variables:

(A.7) $y_{0t} = b_0 + b_1 y_{1t} + b_2 y_{2t} + u_t$.

The right-hand-side variables, $y_{1t}$ and $y_{2t}$, are determined according to:

(A.8a) $y_{1t} = a_1 + y_t^* + e_{1t}$

(A.8b) $y_{2t} = a_2 + y_t^* + e_{2t}$

where $y_t^*$ follows a random walk:

(A.9) $y_t^* = y_{t-1}^* + e_t$.

The right-hand-side variables are driven by a common random walk embodied in $y_t^*$. Such an assumption is needed to account for the high correlations across right-hand-side variables in the original data. Although $y_t^*$ is not directly observed, we can generate pseudo-data for it given an initial value, $y_1^*$, and given a variance for $e_t$.

We are able to obtain values for the variances of $e_1$, $e_2$, and $e_t$ in the following way. First, note that we can write the processes for $y_{1t}$ and $y_{2t}$ as:

(A.10a) $y_{1t} = y_{1t-1} + w_{1t}$

(A.10b) $y_{2t} = y_{2t-1} + w_{2t}$

where $w_{1t} = e_t + e_{1t} - e_{1t-1}$ and $w_{2t} = e_t + e_{2t} - e_{2t-1}$. From residuals for equations (A.10), we can calculate estimates of Var($w_{1t}$),Var($w_{2t}$), and Cov($w_{1t}, w_{2t}$). However, we know that

$$\text{Var}(w_{1t}) = \text{Var}(e_t) + 2\text{Var}(e_{1t})$$

$$\text{Var}(w_{2t}) = \text{Var}(e_t) + 2\text{Var}(e_{2t})$$

$\text{Cov}(w_{1t}, w_{2t}) = \text{Var}(e_t)$.

Replacing Var($w_{1t}$),Var($w_{2t}$), and Cov($w_{1t}, w_{2t}$) with their observed sample estimates, the three equations above can be solved to obtain estimates of Var($e_1$), Var($e_2$), and Var($e_t$). In the case of three variables on the right-hand side of (A.7), our procedure is almost identical. For this case, our specification implies that $\text{Cov}(w_{it}, w_{jt}) = \text{Var}(e_t)$ for all *i,j* pairs. Our sample estimate of $\text{Cov}(w_{it}, w_{jt})$ for each *i,j* pair is therefore set equal to the average of the sample values of $\text{Cov}(w_{it}, w_{jt})$ observed over all *i,j* pairs. In several cases, a more restrictive specification was required. The model described above requires that $\text{Var}(w_{it}) > \text{Cov}(w_{it}, w_{jt})$ for any *i,j* pair, but for two variables included in our empirical models the sample variances and covariances did not satisfy the condition. For those cases, we made the additional assumption that $e_{it} = e_{jt}$ for all *i,j* pairs and estimated each $\text{Var}(w_{it})$ as the mean of the observed sample estimates over all *i*.

The bootstrapping procedure is then similar to that described in the previous case. Using the estimated error variances, we draw values for each of the random errors, $u_t$, $e_1$, $e_2$, and $e_t$. Using historical data to provide an estimated initial value for $y^*$ (we assume that $y_1^*$ is equal to $y_{11}$) we then use the process described by (A.7)-(A.9) to generate a 99-observation sample of pseudo-data for $y_{0t}$, $y_{1t}$, and $y_{2t}$. At this stage, we set $a_1 = 0$ (a normalization) and estimate $a_2$ as the sample mean of $y_{2t} - y_{1t}$. Next, using the 39- and 63-observation subsets of data described in the text, we estimate equation (A.7), saving values of the parameter estimates for $b_0$, $b_1$, and $b_2$. We then repeat this process (beginning again by drawing values for $u_t$, $e_1$, $e_2$, and $e_t$) 10,000 times, obtaining 10,000 sets of coefficients. The *p*-values and test results reported for tests of the hypothesis that $b_1 + b_2 = 1$ are based on the distribution of coefficient values generated by this procedure.

## References


Hamilton, J. *Time Series Analysis*. Princeton: Princeton University Press, 1994.

Sims, C.A., J.H. Stock, and M.W. Watson. "Inference in Linear Time Series Models with Some Unit Roots." *Econometrica* 58 (1990), 113-144.

West, K.D. "Asymptotic Normality, When Regressors Have a Unit Root." *Econometrica* 56 (1988), 1397-1417.

## Table A1. Unit Root Test Results

| | Test Statistic | P-Value | Number of Lagged Augmentation Terms |
|---|---|---|---|
| *TARGETR* | -2.3732 | 0.149 | 3 |
| *BURNS* | -2.3938 | 0.143 | 4 |
| *MEAN* | -2.4959 | 0.116 | 4 |
| *MEDIAN* | -2.5160 | 0.112 | 4 |
| *MEANGOV* | -2.4032 | 0.141 | 4 |
| *MEANBP* | -2.5705 | 0.099 | 4 |

## Table A2. Engle-Granger Cointegration Test Results

| Specification | Test Statistic | P-Value | Number of Lagged Augmentation Terms |
|---|---|---|---|
| Mean | -4.5616 | 0.000 | 4 |
| Median | -5.4620 | 0.000 | 4 |
| Mean with Burns | -4.9366 | 0.000 | 4 |
| Median with Burns | -5.4861 | 0.000 | 4 |
| Presidents and Governors | -4.4516 | 0.006 | 4 |
| Hybrid | -5.3598 | 0.000 | 4 |

**Figure A1. Burns Preference and Adopted Target**

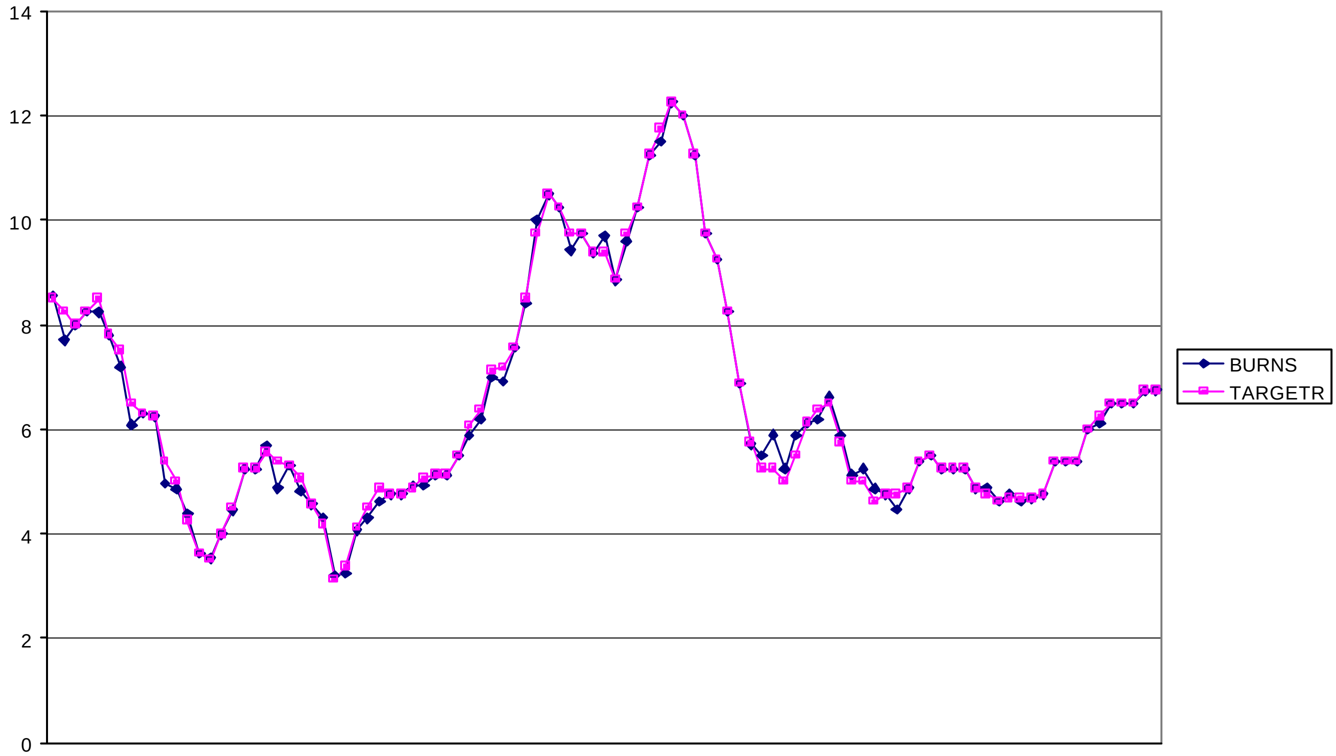

**Figure A2. Committee Mean and Committee Median**

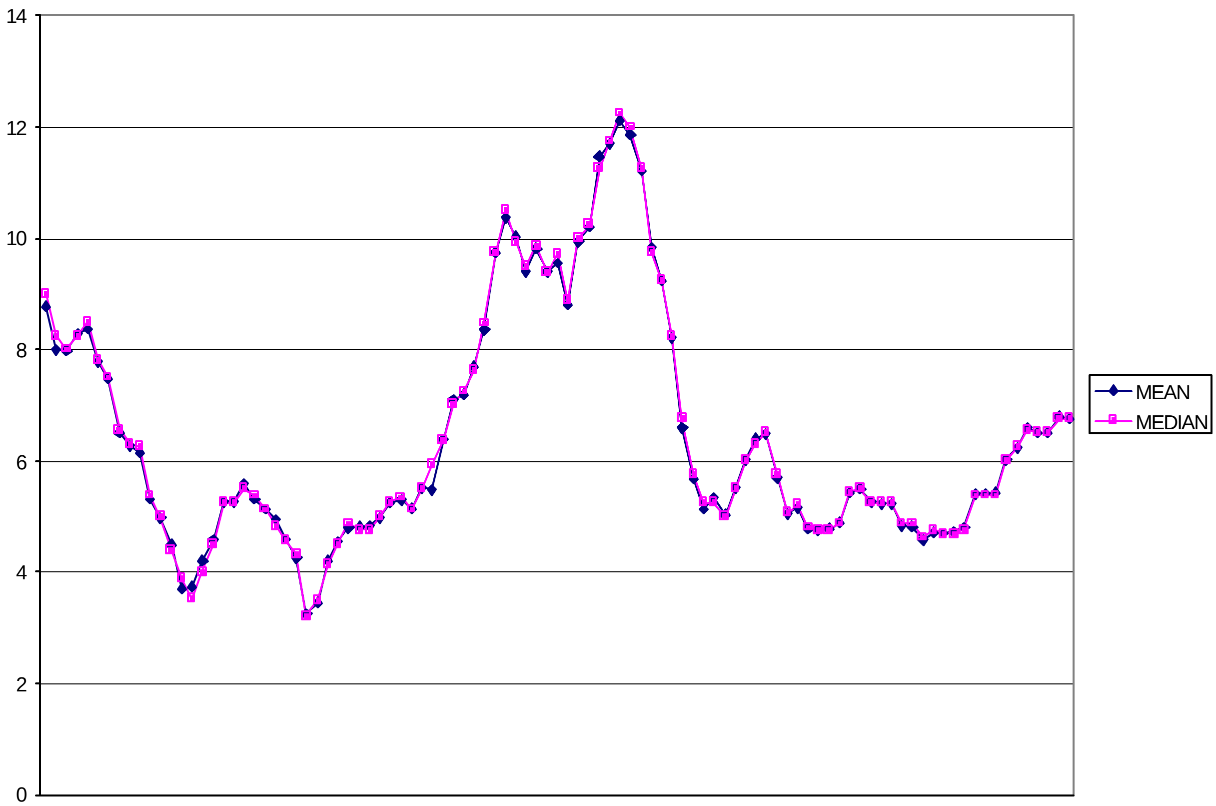

**Figure A3. Governors' Mean and Bank Presidents' Mean**