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TESTING FOR REAL EFFECTS OF MONETARY POLICY REGIME SHIFTS

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ABSTRACT

Huizinga and Mishkin (1986) have recently proposed a simple method for testing whether monetary policy regime changes have affected the ex-ante real rate of interest. This paper shows that care must be taken in choosing the set of variables on which to project the ex-post real rate if inferences about the ex-ante real rate are to be drawn. It is shown that Huizinga and Mishkin's tests cannot distinguish between shifts in the real rate process and shifts in the inflation process.

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1. Introduction

One of the most important contributions of the rational expectations revolution in macroeconomics has been that it has forced economists to think about macro policy in terms of alternative policy rules or regimes. Realizations of policy instruments determined within a fixed regime and changes in the policy regime can have very different effects on both the evolution of macro variables and on the observed structure of the economy. Sargent (1976) has shown that it may be necessary to obtain data from more than one policy regime in order to test hypotheses such as the neutrality of money.

Sims (1982) has argued that the notion of a policy regime and of arbitrary regime shifts is subject to logical problems.[1/] Despite this, most economists seem willing to treat episodes like the Federal Reserve's change in its operating procedures in late 1979 as policy regime shifts. Following Sargent's suggestion, such episodes may provide evidence useful for testing important macroeconomic hypotheses.

Huizinga and Mishkin (1986), for example, have recently argued that monetary policy has important effects on the ex-ante real rate of interest. As evidence, they cite apparent changes in the stochastic properties of the real rate coinciding with major shifts in monetary policy regimes. More specifically, they claim the real rate process shifted in October 1979, the month the Fed changed operating procedures, in October 1982 when the Fed deemphasized monetary aggregates, and in June 1920 when the Fed shifted to a contractionary policy by raising the discount rate. Mishkin (1986) has argued that these results suggest monetary policy, not fiscal deficits, bears responsible for high real interest rates in the early 1980s.

Because an understanding of the impact of monetary policy shifts on real interest rates is important for many issues in macroeconomics, the method used by Huizinga and Mishkin (hereafter H-M) deserves careful scrutiny. It will be shown that their approach is theoretically unable to separate shifts in the real interest rate process from shifts in the inflation process. Hence, their procedure is likely to "find" a shift in the stochastic behavior of the ex-ante real rate when there is a monetary policy regime shift, even if the true ex-ante real rate process is completely invariant with respect to monetary policy. Evidence is presented to suggest this may explain their finding of a real rate shift in late 1982.

The flaw in the H-M methodology is shown formally by way of a simple example in section 2, but the intuition can be grasped most easily by considering the special case of an economy in which the real rate process is, by assumption, completely invariant with respect to perceived monetary policy shifts. In such an economy, the nominal interest rate will depend on monetary policy via the expected rate of inflation. Since shifts in monetary policy can influence the stochastic properties of inflation and the nominal interest rate, such shifts will also affect the coefficient obtained when the real rate is projected onto the nominal rate. Even though the behavior of the real rate is invarient with respect to monetary policy, the projection coefficient will shift in response to monetary policy regime shifts. Yet it is just such shifts in projection coefficients that H-M interpret as measuring shifts in the real rate process.

When a variable y is projected onto a variable x, the resulting projection coefficient depends on the stochastic properties of both x and

y. Evidence of a shift in the projection coefficient does not, by itself, allow one to infer that the y process has shifted.

There is, however, one case that would seem to be an exception to this general conclusion. If the variable y is defined as the projection on x, then it follows automatically that a change in the projection coefficient will represent a change in the y process. It will be argued in section 2 that even if the real rate is defined by a projection equation, neutral changes in the inflation process will appear to shift the real rate process, a conclusion that casts doubt on the usefulness of defining the real rate by a projection equation.

Section 3 provides some empirical evidence to suggest that the problem outlined in Section 2 is of quantitative significance. Conclusions are summarized in Section 4.

2. Shifts in the Real Rate Process

In order to discuss shifts in the real interest rate process, it is necessary to carefully specify what is meant by the real rate process. Two alternative approaches can be taken. One approach treats the real rate as a function of its fundamental determinants. The other approach defines the ex-ante real rate process as a projection equation.[2/] In this section, both approaches are discussed and it is shown that the H-M procedure will incorrectly identify changes in the inflation rate process as changes in the real rate process.

To first define the notation that will be used throughout, let r_t (r_t^e) equal the ex-post (ex-ante) real return from time t to t+1. The actual (expected) rate of inflation from t to t+1 will be denoted π_t (π_t^e). Finally, define i_t as the nominal return from t to t+1. These variables are linked by the Fisher relation in both an ex-ante and ex-post sense:

$$r_t^e = i_t - \pi_t^e; \tag{1}$$

$$r_t = i_t - \pi_t. \tag{2}$$

Subtracting equation (1) from equation (2),

$$r_t = r_t^e - \varepsilon_t \tag{3}$$

where $\varepsilon_t = \pi_t - \pi_t^e$ is the expectational error in the market's forecast of inflation.

Now suppose the ex-ante real rate of return is a function of a set of fundamental exogenous variables. Let these be divided into three classes. First, denote by a vector x_t exogenous and predetermined determinants of r_t^e that can be observed by the econometrician. Included in x_t might be factors such as the economy's capital stock, but the current nominal interest rate would not be contained in x since it is neither exogenous nor predetermined. Second, let v_t denote additional determinants of r_t^e that are observable to private agents but are not observed by the econometrician and that also potentially affect the expected rate of inflation. Finally, let e_t denote the net effect of unobserved real rate determinants that have no effect on inflation. For simplicity, I will assume that x, v, and e are mutually orthogonal; the basic results of this section are not sensitive to this assumption. Hypothesizing a linear structure, write

$$r_t^e = x_t\beta + v_t\delta + e_t = x_t\beta + u_t, \tag{4}$$

where $u = v\delta + e$. Substituting (4) into (3) yields

$$r_t = x_t\beta + u_t - \varepsilon_t. \tag{5}$$

If x_t is contained in the information set used to form expectations about π_t, the expectational error ε_t will be orthogonal to x_t under the assumption of rational expectations. Hence, consistent estimates of the parameter vector β can be obtained from the ordinary least squares regression of r on x since x_t and $u_t - \varepsilon_t$ are orthogonal. Thus, as Mishkin (1983) has emphasized, any hypothesis about the ex-ante real rate of interest that can be expressed in terms of restrictions on β can be tested, even though the ex-ante real rate is an unobservable variable.

In practice, of course, the correct elements of the x vector are unknown, and, as with the specification of any regression equation, the estimate of β will be influenced by any relevant variables that have been left out of (5) and that are correlated with those variables that are included in (5). In general, this might lead one to include in the ex-post real rate regression any variable known at time t. Adding extraneous variables will not affect the consistency of the least squares estimators.

Instead of testing a particular hypothesis about β under the maintained hypothesis that the coefficient vector has remained constant over the sample period, one might wish to investigate possible shifts in the real rate process. That is, a change in the real rate process might be defined as a shift in the coefficients in a regression of the real rate on a set of information variables. One might then attempt to discover whether major shifts in monetary policy affect the stochastic properties of the real rate by testing for coefficient shifts coincident with monetary policy changes. In contrast to the case in which a restriction on β is being tested, testing for shifts in the coefficient vector require a more careful consideration of the variables to include in the regression.

To see why, recall that the residual in (4) is equal to $v_t\delta + e_t$, and that v_t consists of factors that influence both the ex-ante real rate of return and the expected rate of inflation but that are unobserved by the econometrician. Suppose that the actual rate of inflation is given by

$$\pi_t = x_t\mu + z_t\gamma + v_t\alpha + \varepsilon_t. \tag{6}$$

In equation (6), z is a set of variables, known to private agents at time t, that affect inflation but not the ex-ante real rate. The vector v_t is likewise observed by private agents at time t, but is not observed by the econometrican. To simplify subsequent calculations, z is taken to be orthogonal to x, v, and e.

Equations (1), (4) and (6) imply that the nominal rate of interest is given by

$$i_t = x_t(\beta+\mu) + z_t\gamma + v_t(\delta+\alpha) + e_t. \tag{7}$$

Now suppose the econometrican regresses the ex-post rate r on x and, in order to capture the effects of some of the unobserved variables in v, the nominal rate of interest. This is the procedure employed by H-M. Intuitively, (4) shows that r^e depends on v, and, from (7), i is correlated with v. Therefore, including i should help to reduce the problem of omitted variables. In probability limit, the resulting coefficient on i_t

is equal to

$$\frac{\delta(\alpha+\delta)\sigma_v^2 + \sigma_e^2}{\gamma^2\sigma_z^2 + (\alpha+\delta)^2\sigma_v^2 + \sigma_e^2} \tag{8}$$

where σ_s^2 denotes the variance of the random variable s and, for simplicity, z and v have been taken to be scalars.

Now assume that there is a change in α in equation (6). This represents a pure change in the inflation process -- the process describing the real rate, equation (5), is completely unaffected. However, as (8) clearly shows, the change in α will affect the coefficient on the nominal interest rate in the ex-post real rate regression. Shifts in δ or σ_z^2 produce similar effects. It follows that evidence of shifts in the coefficients in the regression of the ex-post real rate on a set of variables which includes the nominal rate does not allow one to conclude that a shift in the real rate process has occurred.[3/]

This illustrates that great care must be taken in choosing the variables on which to project the ex-post real rate. Candidate variables must be orthogonal to all excluded factors which affect inflation.[4/] The nominal interest rate clearly fails this criterion.

If the exogenous and predetermined variables in x_t were known, a shift in the real rate process could be tested by estimating equation (5). The orthogonality between x_t and $u_t - \varepsilon_t$ insures that least squares will provide consistent estimates of β. The problem, of course, consists in correctly specifying the elements of x, and this leads to the second approach to specifying the real rate process. This approach <u>defines</u> the real rate process to be the projection of r_t^e on the set of available information. Since the nominal rate is clearly in this set, the real rate process would be <u>defined</u> by

$$r^e_t = \rho i_t + x_t\beta^* + u^*_t \,, \tag{9}$$

where $u^* = v\delta^* + e^*$. If changes in the real rate process are defined as changes in the projection coefficients ρ, β^* and δ^*, then it might appear that the H-M procedure, by providing consistent estimates of the projection coefficients, can provide a method for testing for shifts in the real rate process.

This argument, however, is incorrect. Because the unobservable (to the econometrician) variables in v_t also affect expected inflation, i will be correlated with the composite error term $u^*_t - \varepsilon_t = v_t\delta^* + e^*_t - \varepsilon_t$ obtained by substituting (9) into (3). In fact, making use of (6), it can be shown that in the special case of scalar and orthogonal v, z and x, the probability limit of the least squares projection coefficient on i in (9) is

$$\frac{(\delta + \alpha)(\delta + \rho\alpha)\sigma^2_v + \rho\gamma^2\sigma^2_z + \sigma^2_e}{(\delta + \alpha)^2\sigma^2_v + \gamma^2\sigma^2_z + \sigma^2_e}. \tag{10}$$

As equation (10) demonstrates, the estimate of ρ (and β^* also) will depend on α, γ, and σ^2_z — all parameters which appear only in the equation generating inflation. Hence, even if ρ, β^* and δ^* — the projection coefficients assumed to define the real rate — are unchanged, the estimated coefficients on i and x will shift with changes in the parameters describing the inflation process. Both alternative approaches to defining the real rate process — as a function of fundamentals or as a projection equation — imply that the H-M procedure runs the risk of misinterpreting pure inflation changes for changes in the real rate process.

When projecting one variable on another, the resulting projection coefficient will shift if the behavior of either of the two variables changes. Increased money growth volatility that affects the behavior of nominal interest rates would alter the coefficient obtained by projecting the ex-post real rate on the nominal rate. Such a coefficient shift, however, does not allow one to conclude that the real rate process has changed unless one tautologically defines such coefficient shifts to be real rate process shifts. Such a definition, however, does not seem to be a very useful one for understanding the real effects of monetary policy regime shifts.

Any time a variable y is projected onto another variable x, the projection coefficient will be a function of the stochastic processes generating both y and x. All one can legitimately infer from evidence of a projection coefficient shift is that either the x process, or the y process, or both, changed. Only if further evidence shows that the x process remained unchanged can one conclude that the y process changed.

3. Empirical Results

The previous section has shown that testing for shifts in the real interest rate process requires a careful consideration of the variables to include on the right-hand side of a regression for the ex-post real rate. Inclusion of a variable such as the nominal interest rate may cause the real rate process to appear to shift whenever the stochastic behavior of inflation changes, even if the underlying behavior of the real rate is completely unaffected.

While the theoretical argument implies that great care must be taken in attempting to identify real rate process shifts, theory obviously cannot determine whether or not real rate shifts were incorrectly identified in the particular empirical study carried out by H-M. This section attempts to partially address this issue.

H-M identify post-war shifts in the real rate process as having occurred in October 1979 and October 1982. Both of these dates are associated with changes in monetary policy and so, as seems reasonable, H-M attribute the real rate shifts to the change in monetary policy. Using one-month Treasury bill yields and one-month changes in the Consumer Price Index, these real rate shifts are found by testing for coefficient shifts in the following equation:

$$r_t = a_0 + a_1 i_t + a_2 \pi_{t-1} + a_3 \pi_{t-2} + a_4 \text{supply}_{t-1}, \tag{11}$$

where supply_t is the log of the relative price of fuel and related products in the producer price index.[5/] H-M calculate Quandt likelihood ratios[6/] for pairs of breakpoints around October 1979 and October 1982. These two months were chosen because they were associated with changes in monetary policy. The Fed shifted from a federal funds rate operating procedure to a nonborrowed reserves procedure in October 1979, and during the October 1982 FOMC meeting, a decision was made to deemphasize monetary targeting. H-M present -2 times the log of the Quandt likelihood ratio for all breakpoint pairs (s, t) where s runs from April 1979 to April 1980 and t runs from April 1982 to April 1983.[7/] The Quandt statistic suggests that October 1979 and October 1982 are in fact the most likely dates for shifts in equation (11).

The analysis of the previous section suggested that real rate regressions which include the nominal interest rate are particularly susceptible to apparent shifts when the inflation process changes. To test whether this problem may have affected H-M's results, the nominal rate was dropped from equation (11) and the Quandt likelihood ratios were again calculated for pairs of possible breakpoints around October 1979 and October 1982. Minus twice these ratios are presented in Table 1.

The maximum value now occurs at (1979:10, 1983:04). This first breakpoint at October 1979 coincides with the finding of H-M and serves to support their view that the change in monetary policy operating procedures on October 6, 1979 did have an impact on the behavior of the real rate of interest. However, the second breakpoint, April 1983, does not correspond to H-M's findings of an October 1982 break. The April date does agree, however, with the results of Antoncic (1986) who finds a trough in the real rate during April 1983.

The results in Table 1 do suggest that the problems with the H-M procedure discussed in the previous section may be empirically important. To further investigate this issue, an equation for the rate of inflation was estimated and used to test for breaks in the inflation process. To maintain similarity with (11), the inflation equation includes the same right hand variables as (11) with the exception that i_t is again excluded from the regression. Table 2 reports minus twice the log of the Quandt likelihood ratios for the inflation equation.

Quite significantly, the maximum value in Table 2 occurs at (1979:11, 1982:09). Both dates correspond closely to the real rate breakpoints identified by H-M. Since the results in Table 1 do not support H-M's finding of a real rate shift in October 1982, the Table 2 results are quite significant in that they suggest that the inflation process appears to have shifted in September 1982, just one month prior to the date H-M identify with a real rate shift. Recall that π_t is defined as the rate of inflation from period t to t+1; if the inflation rate at time t was defined more conventionally as the rate from t-1 to t, the breakpoint in the inflation rate process would be dated at exactly October 1982. Since no shift in late 1982 was indicated by the ex-post rate regression that excluded the nominal rate, this evidence seems to suggest that the shift in the real rate found by H-M in October 1982 may actually simply be a reflection of a shift in the inflation process.

Further evidence on the dates of shifts in the real rate process can be obtained by estimating equation (12), which includes only lagged values of the ex-post real rate and the supply variable as explanatory variables:

$$r_t = b_\circ + b_1 r_{t-1} + b_2 r_{t-2} + b_3 \, supply_{t-1}. \tag{12}$$

Table 3 reports minus twice the log of the Quandt likelihood ratio. The breakpoint pair with the maximal value is (1979:12, 1983:04).[8/] Significantly, the second break, in April 1983, agrees exactly with the results obtained by dropping the nominal rate from the H-M regression.

4. Conclusions

The empirical results of the previous section clearly indicate that procedures for identifying process shifts are sensitive to the choice of variables to include on the right-hand side of a projection equation. For example, H-M's conclusion that 1982:10, and not 1983:04, was the most likely date for a shift in the real rate process depended on the inclusion of the nominal rate of interest in their regression. This appears to have led them to identify the September 1982 shift in the inflation process as a real rate shift.

Many important hypothesis in macroeconomics take the form of an implied invariance across regime shifts. Hence, it is important to be able to empirically identify the timing of shifts in variables such as the real rate of interest. The analysis of this paper has shown that the problem of omitted variables can lead to incorrect inferences if "process shift" is interpreted to mean "projection coefficient shift."

While the focus has been on the problems created by including the nominal interest rate in a regression for the real rate of interest, the same problems are created by the inclusion of any variable that is correlated with omitted variables that affect the rate of inflation. Thus, while the focus here has been on the nominal rate of interest, lagged rates of inflation are also likely to give rise to similar problems. Thus, the empirical results reported in Section 3 should only be taken as illustrative of the care that must be exercised in testing for real rate shifts.

<u>Table 1</u>

Minus Twice the Quandt Likelihood Ratio

$$r_t = b_o + b_1\pi_{t-1} + b_2\pi_{t-2} + b_3 Supply_{t-1}$$

<u>First Breakpoint</u>

<u>Second Breakpoint</u>

	79:4	:5	:6	:7	:8	:9	:10	79:11	:12	80:1	:2	:3	:4
82:4	94.913	94.622	96.059	96.769	97.257	97.712	97.807	95.158	95.977	95.071	95.214	95.392	88.811
:5	93.885	93.581	95.015	95.690	96.185	96.657	96.807	94.413	95.333	94.385	94.491	94.629	87.881
:6	96.805	96.535	98.121	98.710	99.127	99.617	99.909	97.407	98.835	97.314	97.483	97.566	90.702
:7	95.947	95.657	97.227	97.818	98.251	98.736	99.031	96.720	97.605	96.652	96.782	96.924	89.919
:8	95.814	95.505	97.099	97.678	98.104	98.576	98.889	96.744	97.641	96.659	96.760	96.869	90.007
:9	97.618	97.384	98.686	99.299	99.818	100.39	100.59	98.090	99.478	98.611	98.797	98.985	90.405
:10	97.818	97.570	98.858	99.404	99.854	100.40	100.59	97.977	99.264	98.401	98.583	98.765	89.749
:11	96.629	96.361	97.656	98.199	98.648	99.178	99.374	96.907	98.207	97.317	97.470	97.622	88.769
:12	95.633	95.343	96.644	97.176	97.617	98.130	98.331	95.998	97.285	96.368	96.493	96.517	87.944
83:1	94.708	94.396	95.690	96.208	96.642	97.140	97.346	95.156	96.460	95.514	95.612	95.706	87.129
:2	97.820	97.503	98.783	99.339	99.778	100.25	100.39	98.045	99.168	98.226	98.342	98.456	90.261
:3	99.058	99.519	100.79	101.33	101.72	102.14	102.22	99.683	100.49	99.560	99.678	99.791	91.035
:4	100.56	100.26	101.60	102.16	102.65	103.17	$\boxed{103.40}$	101.21	102.29	101.34	101.45	101.56	93.417
:5	100.21	99.885	101.18	101.74	102.22	102.72	102.90	100.73	101.82	100.86	100.96	101.04	92.853
:6	97.843	99.496	100.78	101.38	101.77	102.23	102.37	100.12	101.02	100.06	100.16	100.23	91.730
:7	99.590	99.227	100.51	101.05	101.51	101.97	102.12	99.993	100.87	99.897	99.974	100.02	91.605
:8	98.154	97.772	99.037	99.568	100.01	100.44	100.55	98.393	99.182	98.216	98.293	93.328	89.940
:9	99.530	99.136	100.41	100.94	101.40	101.84	101.99	100.01	100.85	99.857	99.910	99.921	91.657
:10	97.557	97.153	98.370	98.913	99.359	99.768	99.855	97.743	98.486	97.533	97.616	97.634	89.349

Table 2

Minus Twice the Quandt Likelihood Ratio

$$\pi_t = c_o + c_1\pi_{t-1} + c_2\pi_{t-1} + c_3Supply_{t-1}$$

	79:4	:5	:6	:7	:8	:9	:10	79:11	:12	80:1	:2	:3	:4
82:4	39.677	37.390	37.745	37.080	38.194	37.931	38.992	41.905	41.408	37.109	35.179	35.407	33.910
:5	41.560	39.231	39.592	39.669	40.815	39.817	41.037	44.184	43.808	39.236	37.240	37.628	35.432
:6	47.367	44.991	45.417	45.435	45.732	45.521	46.839	50.057	49.652	44.960	42.848	43.155	40.958
:7	47.909	45.523	45.909	45.972	46.342	46.154	47.458	50.791	50.457	45.777	43.722	44.184	41.701
:8	44.583	42.174	42.741	42.821	43.220	43.103	44.510	47.609	47.320	42.610	40.547	41.068	38.257
:9	48.099	45.711	46.144	46.216	46.646	46.544	47.897	$\boxed{51.104}$	50.921	46.223	44.221	44.890	41.923
:10	47.090	44.707	45.160	45.353	45.887	45.808	47.180	50.564	50.423	45.744	43.752	44.315	41.528
:11	43.093	40.749	41.309	41.610	42.217	42.201	43.583	46.739	46.625	42.022	40.071	40.516	37.878
:12	41.419	39.875	39.734	40.077	40.682	40.661	42.067	45.123	44.936	40.354	38.370	38.655	36.291
83:1	40.779	38.425	39.106	39.475	40.084	40.042	41.452	44.567	44.337	39.760	37.751	37.955	35.775
:2	40.719	38.465	39.127	39.599	40.227	40.213	41.455	44.072	43.843	39.533	37.660	37.807	35.978
:3	43.524	41.295	41.947	42.385	42.928	42.873	44.002	46.251	45.960	41.833	39.997	40.132	38.453
:4	43.639	41.382	42.131	42.616	43.295	43.345	44.688	47.253	47.062	42.711	40.834	40.982	39.063
:5	40.864	38.668	39.255	39.765	40.453	40.494	41.625	43.929	43.764	39.686	38.003	38.313	36.202
:6	39.130	36.994	37.505	37.928	38.505	38.508	39.505	41.362	41.156	37.258	35.685	36.168	33.760
:7	39.128	36.938	37.481	37.892	38.490	38.430	39.409	41.252	41.020	37.151	35.574	36.068	33.652
:8	37.723	35.543	36.061	36.460	36.987	36.947	37.866	39.588	39.348	35.594	34.069	34.597	32.165
:9	39.152	36.953	37.460	37.870	38.403	38.348	39.279	41.078	40.817	37.046	35.501	36.017	33.603
:10	36.523	34.367	34.842	35.241	35.753	35.704	36.544	38.116	37.886	34.310	32.897	33.502	31.008

Table 3

Minus Twice the Quandt Likelihood Ratio

$$r_t = do + d_1r_{t-1} + d_2r_{t-2} + d_3Supply_{t-1}$$

	79:4	:5	:6	:7	:8	:9	:10	79:11	:12	80:1	:2	:3	:4
82:4	69.142	68.114	69.128	69.723	70.405	70.899	71.230	70.281	70.855	68.479	68.318	68.457	61.833
:5	67.122	66.068	67.148	67.785	68.576	69.145	69.599	69.087	69.877	67.387	67.209	67.322	60.626
:6	67.627	66.591	67.871	68.511	69.375	70.020	70.634	70.257	71.127	68.635	68.581	68.720	61.743
:7	66.177	65.132	66.396	67.073	67.990	68.659	69.288	69.124	70.145	67.634	67.527	67.636	60.577
:8	65.548	64.481	65.781	66.453	67.386	68.047	68.695	68.725	69.748	67.206	67.070	67.144	60.210
:9	68.356	67.358	68.517	69.173	70.022	70.680	71.218	70.523	71.587	69.147	69.068	69.253	61.844
:10	67.701	66.680	67.828	68.457	69.279	69.906	70.426	69.749	70.684	68.223	68.128	68.292	60.940
:11	66.515	65.475	66.658	67.294	68.147	68.779	69.327	68.844	69.810	67.323	67.205	67.339	60.035
:12	65.639	64.577	65.774	66.402	67.260	67.881	68.438	68.113	69.075	66.560	66.415	66.519	59.340
83:1	64.779	63.695	64.887	65.501	66.355	66.959	67.518	67.343	68.302	65.759	65.587	65.661	58.612
:2	66.990	65.913	67.094	67.719	68.564	69.158	69.679	69.330	70.209	67.686	67.513	67.603	60.435
:3	67.858	66.765	67.928	68.524	69.325	69.877	70.341	69.810	70.498	67.997	67.808	67.893	60.569
:4	70.630	69.555	70.816	71.475	72.395	73.038	73.648	73.486	$\boxed{74.372}$	71.840	71.671	71.753	64.570
:5	70.223	69.129	70.346	70.984	71.872	72.479	73.026	72.781	73.623	71.095	70.888	70.956	63.590
:6	68.913	67.802	69.001	69.609	70.461	71.031	71.525	71.150	71.889	69.368	69.149	69.218	61.428
:7	68.314	67.183	68.381	68.983	69.841	70.401	70.903	70.652	71.367	68.827	68.584	68.630	60.866
:8	67.002	65.856	67.035	67.617	68.447	68.978	69.439	69.118	69.762	67.236	66.987	67.032	59.147
:9	68.210	67.050	68.240	68.830	69.687	70.226	70.720	70.596	71.262	68.708	68.436	68.456	60.697
:10	66.525	65.366	66.512	67.086	67.903	68.412	68.832	68.462	69.068	66.576	66.332	66.382	58.364

Footnotes

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1. See also Sargent (1984).

2. That the real rate process might be <u>defined</u> by a projection equation was suggested to me by the referee.

3. Note that this conclusion holds even if $\delta = 0$; i.e. the factors represented by v do not need to directly effect the ex-ante real rate. Also, this result does not depend on the unobservability of r^e, as can be seen by noting that (8) is independent of σ_ε^2. The same point can be illustrated using the model of Litterman and Weiss (1985, p. 145). The H-M method would find apparant shifts in the real rate whenever a monetary policy shift occurred, even though the real rate in the Litterman and Weiss model is, by construction, exogenous with respect to monetary policy.

4. Huizinga and Mishkin explicitly recognize that the projection coefficients they estimate will incorporate the effects of any ommitted variables correlated with x_t (see pp. 235-236). This does not create a serious problem for the H-M procedures, since a change in the stochastic

behavior of the omitted variables will produce a shift in the projection coefficients H-M estimate. The case not considered by H-M occurs when the variables omitted from (4) also affect inflation.

5. For a complete description of the data, see Huizinga and Mishkin (1986, pp. 238-239). I would like to thank John Huizinga and Rick Mishkin for supplying me with their data.

6. If t_1 and t_2 are the breakpoints and T is the size of the entire sample, the log of the Quandt statistic is given by $t_1 \ln\sigma_1 + (t_2 - t_1)\ln\sigma_2 + (T-t_2)\ln\sigma_3 - T\ln\sigma$, where σ is the estimated standard error for the regression estimated over the entire sample, and σ_1, σ_2 and σ_3 are the estimated standard errors before the first break, between the two breaks, and after the second break, respectively.

7. See Huizinga and Mishkin (1986: Table 3, page 246).

8. These breaks were significant based on F-tests for equality of the coefficients:

Period	F-Statistic	Marginal Significance
(1953:01-1979:12, 1980:1-1983:04)	F(5,356)=12.13	$.72 \times 10^{-10}$
(1980:01-1983:04, 1983:05-1984:12)	F(553)=2.81	.025
(1953:01-1979:12, 1983:05-1984:12)	F(5,336)=6.03	$.23 \times 10^{-4}$

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