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OPTIMAL MACROECONOMIC CONTROL POLICIES*

BY ROGER CRAINE, ARTHUR HAVENNER AND PETER TINSLEY†

The paper contains a formal examination of optimal policy sequences that minimize a fourteen-quarter objective function subject to the constraint of a medium-sized nonlinear model of the U.S. economy in order to find whether the optimal policy of the period (1971-I–1974-II) differed importantly from the historical policy, demanded unusual fiscal-monetary coordination, required multiple instruments for effectiveness, depended on small timing nuances, and tended toward the steady-state optimum. We argue that in retrospect policy should have been initially more expansive, with straightforward monetary-fiscal coordination necessary only to lessen the load on each individual instrument, although timing became critical when only monetary policy was used. The solutions did not tend toward the steady-state optimum: short-run losses always heavily outweighed more distant gains.

I. INTRODUCTION

In this paper we present macroeconomic policy sequences that minimize a multiperiod loss function subject to the constraint of a medium-sized nonlinear econometric model of the U.S. economy. Three control solutions are examined in an attempt to answer the following questions: (1) Could policy have been much improved? (2) Are there significant gains from monetary and fiscal policy coordination? (3) Is money alone an effective instrument? (4) How important are timing nuances in the overall solution? and (5) Will optimal adjustment over a long planning horizon ($3\frac{1}{2}$ years) approach a steady-state policy?

There have been few attempts to use formal optimization techniques on large-scale nonlinear economic models to analyze multiperiod policy questions.[1] In fact, many economists view optimization as not feasible, as demonstrated by Shupp's statement regarding the FRB-MIT and Brookings-SSRC models:[2] "The size and complexity of these models preclude formal optimization . . . ." Recently, Fair and Holbrook have demonstrated the feasibility of using open loop techniques to solve these computationally difficult problems.[3] In this paper we use a variant of the algorithm described by Holbrook to obtain the optimal solutions.

II. SOLUTIONS

A. *Loss Function*

The welfare measure includes four targets as ultimate goals. The primary ones are the unemployment rate, ULU, and the inflation rate, $\dot{p}$[4]—two traditional

* The views expressed herein are solely those of the authors and do not necessarily represent the views of the Board of Governors of the Federal Reserve System.

† James Berry not only performed the overwhelming programming task, but also gave invaluable assistance in improving the method of the solution algorithm.

[1] Palash provides an exception.

[2] Shupp, p. 94.

[3] The Fair and Holbrook articles concentrated on the algorithms and not the explicit solutions they produced. For example, Holbrook [1975], p. 41, says "This exercise uses instruments, targets, and loss function coefficients of my own choosing, and is designed solely to illustrate the use of the optimization technique."

[4] The price index is for nonfarm business output. This is almost totally endogenously determined. It is closely related to the GNP deflator which includes agricultural prices not explained by the model we used.

macroeconomic goals in which full employment is weighed against excess demand and inflation. The two secondary goals are the rate of change of inflation, $\ddot{p}$, and the rate of change in the Treasury bill rate, $R\dot{T}B$. $\ddot{p}$ is motivated by the argument that contracts could be written in real terms if the inflation rate were known, but that a variable inflation rate creates uncertainty which retards adjustment and increases the social loss. Similarly, interest rate fluctuations are believed to create uncertainty in financial markets.

The actual loss function is a compromise between the accelerationist position of stabilizing the inflation rate and the announced goal of the period, reducing inflation. Unemployment is weighted twice as heavily as inflation. Fluctuations in the Treasury bill rate receive a relative weight of 0.1. Finally, a penalty is attached to the cross product $\dot{p}\ddot{p}$ to encourage reduction of inflation.

The quadratic form

$$L_1 = \sum_{t=1}^{14} [2.0\ ULU_t^2 + 1.0\ \dot{p}_t^2 + 0.1\ \dot{p}_t\ddot{p}_t + 0.1\ R\dot{T}B_t^2]. \tag{1}$$

gives the loss on the target variables.

The desired paths of all the targets are zero, a virtually unattainable goal for both inflation and unemployment. In the short run the nonlinear Phillips curve makes the desired zero paths impossible for both inflation and unemployment simultaneously, while in the long run the Phillips curve is vertical at the "natural" rate of unemployment (4.8 percent in the model we chose). Since the targets are unattainable the loss function is effectively asymmetric and avoids the problem of penalizing negative inflation or unemployment rates.

A monetary and a fiscal instrument—nominal M_1 and deflated government expenditures—were selected as controllable by the policymakers, and quadratic instrument costs based on deviations of the instruments from their desired levels were imposed:

$$L_2 = \sum_{t=1}^{14} \lambda_1(G-G^*)_t^2 + \lambda_2(M-M^*)_t^2. \tag{1.1}$$

The total loss is the sum of the two components

$$L = L_1 + L_2. \tag{1.2}$$

Three control solutions are examined, differing in the instruments available to the policymaker and the cost imposed on instrument paths deviating from their desired settings. The table below gives the instrument parameter values in the loss function for the three runs.

TABLE 1

INSTRUMENT LOSS FUNCTION PARAMETER VALUES IN ALTERNATIVE SOLUTIONS

Solution	λ_1	λ_2	G^*	M^*	Notes
I	—	0.001	Historical	$(1.056)^{[(t-1)/4]}M_0$	Only one instrument, M
II	0.005	0.005	$61.854B$	$(1.056)^{[(t-1)/4]}M_0$	G^* is the 1970-IV value
III	0	0	$61.854B$	$(1.056)^{[(t-1)/4]}M_0$	No instrument costs

Solution I uses only one instrument (M) with a very light cost, solution II tests a coordinated policy with light instrument costs, and solution III is based on completely unrestricted instrument movements. In every case the desired path M^* is 5.6 percent growth from the 1971-I money base (M_0) of 226.94B. A 5–6 percent money growth rate seems to be consistent with the announced policies of the period; however, the policies were not specified in terms of monetary aggregates until 1974. Desired real government spending was set at a constant, the 1970-IV value.

The planning horizon is the $3\frac{1}{2}$ year historical period beginning in the first quarter of 1971 and running through the second quarter of 1974. This is a volatile period starting at the trough of a recession. The historical recovery was hampered by large exogenous shocks including major increases in agricultural goods prices and the price of oil, and a rapidly increasing aggregate inflation rate.

MINNIE,[5] a condensed (21 stochastic equations, 40 identities) version of the SSRC-MIT-Penn quarterly econometric model, was used as a deterministic description of the economy. Simulations over the period were based on actual values of the exogenous variables; no residuals were used to improve the tracking performance of the model. The effect of the wage/price freeze also has been omitted since it is a seldom used policy tool. As a result, the simulated-historical endogenous variables do not duplicate the actual-historical values. The solutions presented are valid within the context of the model, and represent policy alternatives to wage/price controls.

B. *Solution I—Monetary Policy Alone*

In recent years policymakers have begun to rely more heavily on monetary policy as the stabilization tool. In solution I, monetary policy is the only control and government spending is set at its historical path which showed a slight decline over the period. The optimal policy is labeled $\tilde{M}$ in Figure 1 and Table 2.

Although the optimal policy is not especially volatile—there are no significant single quarter switchbacks—it does move decisively in the first three quarters to offset the recession inherent in the initial conditions. Using the minimum target loss as a base (L_1), the historical policy results in a 15 percent increase in L_1 from the control solution (from 972 to 1115).

Since unemployment lies systematically below the historical values (the average for the control solution is 4.37 percent versus 5.49 percent for history) and inflation systematically above (the control solution average is 5.21 percent versus 4.29 percent historical), it seems likely that the policymaker's loss function differed significantly from ours.[6] Nevertheless, the historical money stock is within 6 percent of the control solution money stock in every quarter except for the early recovery quarters 1971-I and II, and it is within 1 percent of the historical stock for all of 1972. Thus relatively small changes in the timing and magnitude of the control can have significant effects on the policy loss function.

[5] MINNIE collapses several sectors of the large model to aggregate measures (the number of endogenous variables drops from 187 to 61) but replicates the medium term (3 to 4 years) dynamic properties of the full model. See Battenberg, Enzler, and Havenner.

[6] In addition, wage/price controls obviously altered the historical policy.

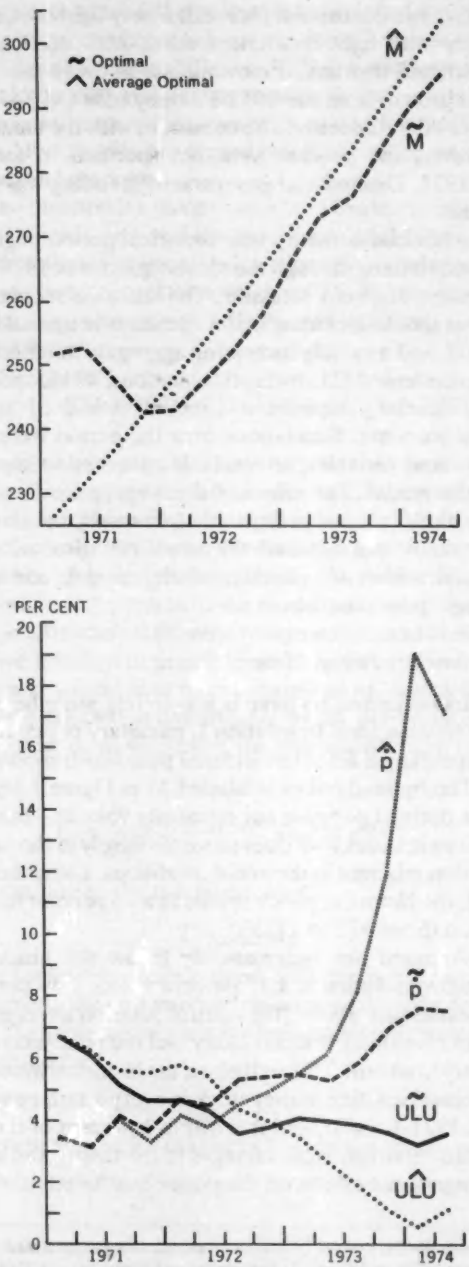

Figure 1 Solution 1. Optimal and Average Optimal Values

TABLE 2

SOLUTION I

HISTORICAL, OPTIMAL, AND AVERAGE OPTIMAL VALUES[1]

($\tilde{}$ optimal (minimum loss) path; * target path; $\hat{}$ average optimal path)

Quarter	Historical				Optimal					Average Optimal				
	M	p	ULU	$R\dot{T}B$	$\tilde{M}$	$\tilde{M}-M^*$	$\dot{p}$	ULU	$R\dot{T}B$	$\hat{M}$	$\tilde{M}-\hat{M}$	$\dot{p}$	ULU	$R\dot{T}B$
1971-I	226.94	3.421	6.739	−1.586	251.84	24.9	3.43	6.70	−4.96	226.56	25.28	3.420	6.741	−1.457
II	232.89	3.181	6.284	0.049	252.70	22.4	3.18	6.10	1.14	231.71	20.99	3.181	6.293	0.286
III	234.49	4.039	5.581	1.743	247.62	13.9	4.15	5.11	1.97	236.97	10.65	4.042	5.589	0.168
IV	235.33	3.315	5.560	0.566	242.49	5.4	3.62	4.67	2.36	242.35	0.14	3.317	5.512	−0.718
1972-I	241.28	4.143	5.988	−1.058	242.94	2.2	4.68	4.67	1.47	247.86	−4.92	4.166	5.788	0.036
III	245.38	3.671	5.902	1.185	247.46	3.4	4.48	4.29	0.34	253.49	−6.03	3.791	5.437	0.549
III	250.43	4.201	5.214	0.054	252.25	4.6	5.31	3.59	0.23	259.24	−6.99	4.526	4.386	0.334
IV	256.19	4.260	5.253	0.189	258.12	6.8	5.41	3.79	0.44	265.13	−7.01	4.911	3.953	0.692
1973-I	258.75	4.391	5.296	3.637	266.17	11.2	5.49	4.06	0.26	271.15	−4.98	5.520	3.434	1.898
II	265.98	4.144	5.045	−1.520	273.12	14.4	5.26	3.97	−0.27	277.31	−4.19	6.133	2.588	1.249
III	266.03	4.606	4.911	1.165	276.20	13.7	5.84	3.86	−0.81	283.61	−7.41	8.100	1.858	−1.322
IV	270.99	5.464	4.760	−0.502	283.73	17.4	6.93	3.58	−0.67	290.05	−6.31	12.012	1.110	2.235
1974-I	275.96	5.755	4.672	−0.659	290.30	20.0	7.58	3.21	−0.10	296.64	−6.30	19.052	0.556	3.548
II	279.80	5.433	5.461	−0.348	295.22	21.0	7.51	3.57	0.40	303.38	−8.16	17.050	1.145	2.574
Average	252.89	4.29	5.49	0.208	262.87	12.95	5.21	4.37	0.13	263.25	−0.37	7.09	3.89	0.719

Total Loss: Historical 1117; Optimal 975.2; Average Optimal 1636.
Instrument Loss: Historical 0.2; Optimal 3.2; Average Optimal 4.0.
Target Loss: Historical 1117; Optimal 972.0; Average Optimal 1632.

[1] The "historical" values of the targets are the model solution values given the historical path of the instrument.

In order to isolate the gains from the optimal timing of policy we have simulated a policy that has the same average money stock over the period as the true optimum but is generated by a constant money growth rate from the 1970-IV initial condition.[7] This solution is labeled "Average Optimal" in Figure 1 and Table 2. Even a cursory examination shows that this policy is inferior to the optimal policy, or even history, and it is further evident that it has left the economy in a poor final position (the last three quarters account for 15 percent of the loss of 1626). The gains from the correct timing of policy, in this case the rapid initial money increase, are very large. This is especially interesting since policies of gradual reentry are often proposed as a method of smoothing anomalous system dynamics even when it is recognized that past policies have resulted in a money base that is lower than the desired base. As the average optimal solution demonstrates, these cautious solutions may be extremely costly to the economy.[8]

C. *Solution II—Coordinated Monetary and Fiscal Policy*

Solution II is designed to determine whether a second active instrument significantly increases welfare, and whether close coordination of monetary and fiscal policy is important. This time the algorithm converged to a minimum target loss of 943. The instrument values given in Figure 2 and Table 3 show that government expenditures are used almost exclusively to offset the initial conditions (because the associated multipliers are larger in the beginning periods and better behaved than the money multipliers). Here monetary policy is used to set the level of economic activity and fiscal policy is the short term adjusting tool. After the first two quarters the policy is very smooth; although the additional instrument does not reduce the target loss appreciably (from 972 with M alone to 943 with M and G), it does reduce the burden on each instrument so that they can each follow regular patterns. Average government spending for the period is 12 percent above the historical level and the average money stock is within 2 percent of the average historical stock. Even the initially large government expenditures ($96B) are in the range of historical experience.

The smoothness of the instrument paths is even more apparent when the average optimal[9] solution, isolating the gain from optimal timing, is considered. This time, with two values to set to their means, the loss is only 7.6 percent higher than the minimum loss solution. If policymakers allow only small instrument movements, the gains from an additional instrument may be striking. Further, since there are no surprises in the direction the instruments should be changed—the dynamic multipliers are regular, with no spikes—coordination is not a difficult problem, implying that an independent agency charged with fiscal stabilization could have important benefits given that both monetary and fiscal policy are used cautiously. However, if policy is active there are no great improvements from two

[7] In this case the rate is 9.4 percent per year.

[8] We also searched for the constant growth rate which minimized the loss function. The "optimal" constant M_1 growth rate was 8.4 percent, much higher than any proponents of a constant rate suggested. Growth rates in the 3-5 percent range produced abysmal losses.

[9] Government expenditures are set to the mean of the true optimum, $66.61B; money grows at a constant 8.3 percent per year from its 1970-IV base to yield a mean again equal to that of the true optimum.

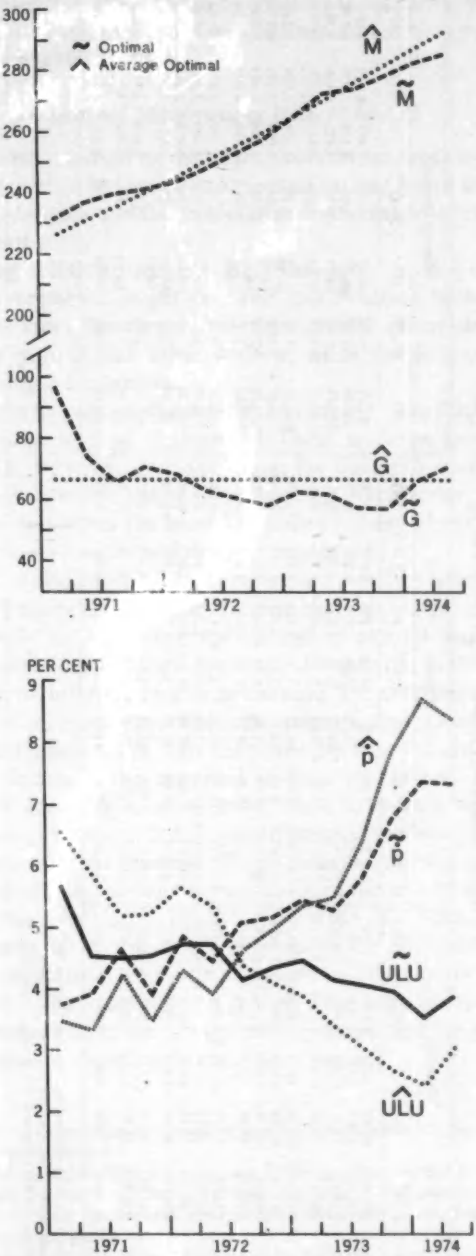

Figure 2 Solution 2. Optimal and Average Optimal Values

TABLE 3
Solution II
Historical, Optimal, and Average Optimal Values[1]

($\tilde{}$ optimal (minimum loss) path; * target path; $\hat{}$ average optimal path)

	Historical					Optimal								Average Optimal						
Quarter	M	G	$\dot{p}$	ULU	$R\dot{T}B$	$\tilde{M}$	$\tilde{M}-M^*$	$\tilde{G}$	$\tilde{G}-G^*$	$\dot{\tilde{p}}$	ULU	$R\dot{T}B$	$\hat{M}$	$\tilde{M}-\hat{M}$	$\hat{G}$	$\tilde{G}-\hat{G}$		ULU	$R\dot{T}B$
1971-I	226.94	60.22	3.421	6.739	−1.586	231.32	4.39	96.89	34.85	3.750	5.678	−1.784	225.99	5.33	66.61	30.28	3.467	6.572	−1.009
II	232.89	59.67	3.181	6.284	0.049	236.52	6.57	74.46	12.68	3.933	4.533	0.424	230.54	5.98	66.61	7.85	3.319	5.899	0.578
III	234.49	61.27	4.039	5.581	1.743	239.78	7.03	65.91	4.19	4.627	4.500	0.813	235.18	4.60	66.61	−0.70	4.225	5.198	0.364
IV	235.33	62.42	3.315	5.560	0.566	240.99	5.58	70.65	9.11	3.905	4.528	0.891	239.91	1.09	66.61	4.04	3.485	5.220	−0.764
1972-I	241.28	63.10	4.143	5.988	−1.058	243.31	5.01	68.35	7.12	4.849	4.736	0.889	244.74	−1.43	66.61	1.74	4.301	5.606	0.110
II	245.38	62.44	3.671	5.902	1.185	247.67	6.13	62.97	2.29	4.447	4.717	0.594	249.67	−2.00	66.61	−3.64	3.904	5.371	0.778
III	250.43	59.42	4.201	5.214	0.054	252.21	7.08	60.30	−0.13	5.085	4.161	0.510	254.70	−2.49	66.61	−6.31	4.636	4.383	0.603
IV	256.19	59.24	4.260	5.253	0.189	257.17	8.28	58.27	−2.23	5.157	4.348	0.478	259.83	−2.66	66.61	−8.34	4.959	4.086	0.914
1973-I	258.75	58.92	4.391	5.296	3.637	265.18	12.44	62.26	1.35	5.427	4.459	0.287	265.06	0.12		−4.35	5.357	3.877	2.322
II	265.98	57.72	4.144	5.045	−1.520	272.25	15.73	61.88	0.51	5.271	4.144	0.117	270.40	1.85	66.61	−4.73	5.469	3.393	1.220
III	266.03	56.15	4.606	4.911	1.165	273.85	13.65	57.23	−4.46	5.803	4.062	0.191	275.84	−1.99	66.61	−9.38	6.418	3.014	−2.192
IV	270.99	56.44	5.464	4.760	−0.502	278.26	14.44	56.56	−5.43	6.749	3.952	0.697	281.39	−3.19	66.61	−10.05	7.827	2.650	1.138
1974-I	275.96	56.29	5.755	4.672	−0.659	282.53	15.06	66.41	4.56	7.352	3.526	1.075	287.06	−4.53	66.61	−0.20	8.688	2.411	0.123
II	279.80	56.30	5.443	5.461	−0.348	285.86	14.65	70.41	8.72	7.313	3.879	0.968	292.84	−7.24	66.61	3.80	8.345	3.043	−0.427
Average	252.89	59.26	4.29	5.49	0.208	257.64	9.72	66.61	5.22	5.26	4.37	0.439	258.08	−0.46	66.61	1.192	5.31	4.34	0.268

Total Loss: Historical 1117; Optimal 960; Average Optimal 1027.
Instrument Loss: Historical 0.2; Optimal 17; Average Optimal 12.
Target Loss: Historical 1117; Optimal 943; Average Optimal 1015.

[1] The "historical" values of the targets are the model solution values given the historical path of the instrument.

coordinated instruments—they tend to be substitutes for each other (to the extent that either is effective) and the loss of one instrument can be compensated for by an aggressive policy with the other.

D. *Solution III—Unrestricted Movement of Both M and G*

Most of the costs imposed on the instruments do not represent real economic costs[10] but should instead be viewed as a mechanism that keeps the instruments in politically feasible bounds and the model close to the range where the functional forms were estimated.

The following solution turns the algorithm loose to find out how well an aggressive policy sequence might do. The loss function bottomed at 749, a significant decline from the targets only loss of 972 in solution I and 943 in solution II. As Figure 3 and Table 4 show, while the instrument means are plausible, the timing is imaginative.[11]

It is reasonable to question the validity of a solution like this; it clearly is not a strategy that could be seriously considered. There are some interesting things to be learned from it, however. For one thing, the unemployment average of 3.5 percent and the inflation average of 3.6 percent are much better than history. As a result, this policy dominates the historical policy for any quadratic loss function with the same primary targets and desired target paths.

Even given the unusual instrument paths, one wonders how the control did so well. MINNIE's Phillips curve includes a term that relates the percentage change in wages negatively to the percentage change in unemployment. As Figure 3 shows, one quarter of high inflation (each time) is suffered so that unemployment can be virtually zero, followed by a large increase. The resulting negative effect on wages and thus prices more than offsets the unemployment losses, and the policy ratchets back the Phillips curve.[12] In this particular case the initial position of the economy is so bad that the required instrument changes are prohibitively abrupt,[13] but the principle remains valid: even in models with long lags and smooth multipliers, decisive carefully timed policies can have high returns.

Another lesson from solution III is that the minimum loss cannot be approached by simply increasing the magnitude of the instrument settings from a cautious policy (like solution II). The direction of the 28 element control vector (G and M for 14 periods) is completely different in the two solutions. Taking the desired instrument paths as the origin, the angle (in 28 space) between the control vectors for solution II and solution III is 116°. Thus cautious policies do not even lie in the same general direction as aggressive policies, and the acceptable level of instrument movement significantly conditions the policy.

[10] Government purchase of goods cannot be rapidly altered; however, the timing of expenditures for goods might be easily altered.

[11] Since government expenditures are negative in two quarters, we have implicitly assumed that the tax multipliers are the negative of the expenditure multipliers. We believe that switching to the tax multipliers would not change the general conclusions of this purely illustrative exercise.

[12] The effect is model specific.

[13] Once the system has been allowed to move so far from the optimal path the burden of control must be spread to additional instruments, preferably those that accent the different responses of the targets.

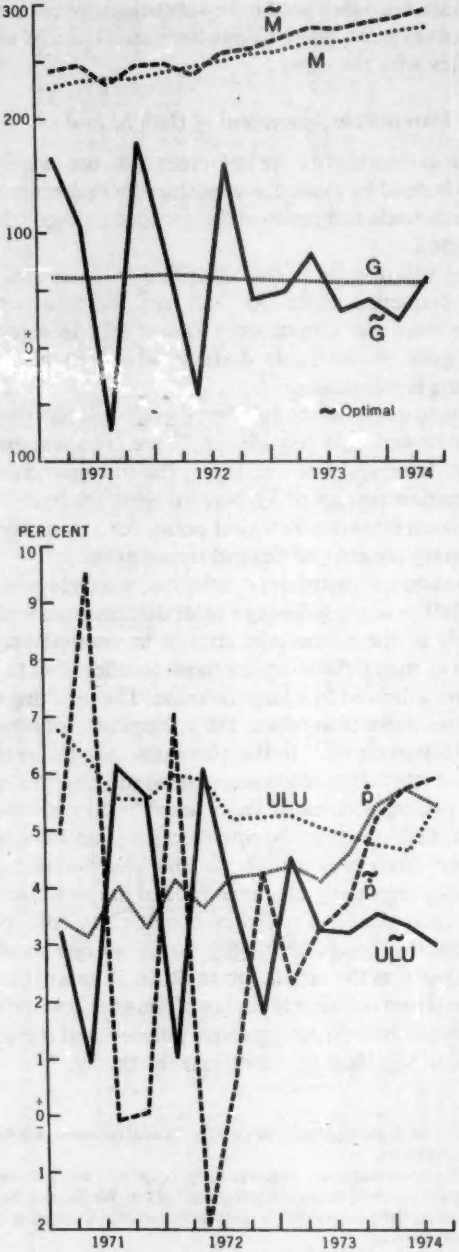

Figure 3 Solution 3. Historical and Optimal Values

TABLE 4

SOLUTION III

HISTORICAL AND OPTIMAL VALUES

($\tilde{}$ optimal (minimum loss) path; * target path)

Quarter	Historical					Optimal						
	M	G	$\dot{p}$	ULU	$R\dot{T}B$	$\tilde{M}$	$\tilde{M}-M^*$	$\tilde{G}$	$\tilde{G}-G^*$	$\dot{p}$	ULU	$R\dot{T}B$
1971-I	226.94	60.22	3.421	6.739	−1.586	241.60	14.68	165.91	104.06	4.928	3.248	−2.619
II	232.89	59.67	3.181	6.284	0.049	246.87	16.81	105.45	43.60	9.531	0.965	1.363
III	234.49	61.27	4.039	5.581	1.743	229.17	−4.05	−73.31	−135.16	−0.066	6.130	1.244
IV	235.33	62.42	3.315	5.560	0.566	246.22	9.79	178.73	116.88	0.082	5.608	0.419
1972-I	241.28	63.10	4.143	5.988	−1.058	248.24	248.24	77.54	15.69	7.065	1.056	0.429
II	245.38	62.44	3.671	5.902	1.185	237.93	−5.05	−40.90	−102.75	−1.917	6.090	1.166
III	250.43	59.42	4.201	5.214	0.054	257.54	11.23	159.82	97.96	0.594	3.766	−1.552
IV	256.19	59.24	4.260	5.253	0.189	262.32	12.62	42.26	−19.60	4.290	1.830	−1.484
1973-I	258.75	58.92	4.391	5.296	3.637	269.73	16.60	47.87	−13.99	2.335	4.519	−0.055
II	265.98	57.72	4.144	5.045	−1.520	279.05	22.44	80.48	18.62	3.299	3.263	0.139
III	266.03	56.15	4.606	4.911	1.165	277.89	17.75	32.38	−29.47	3.775	3.221	−0.123
IV	270.99	56.44	5.464	4.760	−0.502	283.91	20.18	40.52	21.33	5.241	3.542	−0.181
1974-I	275.96	56.29	5.755	4.672	−0.659	287.52	20.17	23.65	−38.20	5.762	3.340	0.000
II	279.80	56.30	5.443	5.461	−0.348	295.02	23.99	61.17	−0.68	5.925	2.999	0.169
Average	252.89	59.26	4.29	5.49	0.208	261.65	13.27	64.40	2.545	3.63	3.54	−0.077

Total Loss: Historical 1117; Optimal 749.
Instrument Loss: Historical 0; Optimal 0.
Target Loss: Historical 1117; Optimal 749.

[1] The "historical" values of the targets are the model solution values given the historical path of the instruments.

An interesting implication of this solution is that an active policy may do better than a constant policy even if the model is in the neighborhood of a steady-state equilibrium. MINNIE's long run Phillips curve is vertical at a natural rate of unemployment of 4.8 percent which implies in the steady state a constant inflation rate 2.6 percent less than the money growth rate.[14] Since government expenditures are neutral in the long run (determining only the public/private allocation of output and not the quantity produced), the optimal steady-state policy consists of setting G to its desired path and minimizing the portion of the steady-state loss function (L_{ss}) that varies with monetary policy:[15]

$$L_{ss} = (4.8)^2 + 1.0(m-2.6)^2 + 0.005(m-5.6)^2, \tag{5}$$

where m is the annual growth rate of the money stock. In this case the steady-state optimum is $\tilde{m} = 2.61$ percent.

Unfortunately or not, the actions of stabilizing authorities demonstrate that they are unwilling to incur large losses over anything like $3\frac{1}{2}$ years to approach the steady-state optimum. Since none of the solutions left the economy in the neighborhood of the long-term solution, we conclude that (if a constant policy is the goal) there will always be a conflict of short run adjustment considerations versus long run equilibrium paths. This tradeoff can be resolved by building it into the loss function—for example, by making the desired paths the long run equilibrium paths—but unless major inportance is attached to the constancy of policy this may not be the best strategy. That is, it is not necessarily true that the optimum long run policy is the one that minimizes the steady-state loss function. Solution III has significantly bettered the steady-state optimum, and appears capable of continuously doing so. It is an implausible solution—because it is working from difficult initial conditions using a very small lever—but the long term policymaker has the option of legislating certain nonlinearities to aid in the task.[16] Thus the optimal long term policy may dominate a steady-state policy by cycling between points on short term Phillips curves.

Conclusions

We conclude, conditional on MINNIE being an adequate representation of the economy, that between 1971-I and 1974-II economic policy could have been improved by being initially much more expansive to offset the 1970 recession. Either the monetary or fiscal instrument could have been used since over the $3\frac{1}{2}$ year period they appear to be broad substitutes, but if the policymakers favored minimal instrument changes a relatively straightforward combination of policies (no exceptional coordination necessary) would have met the needs. If monetary policy had been the sole stabilizer it could have performed almost as well as the joint policy but the timing becomes critical and the required changes become large enough to dismay those charged with the responsibility. Finally, even though $3\frac{1}{2}$ years represents a long planning horizon by current standards the control did not

[14] In the steady-state $\dot{p}$ and $R\dot{T}B$ are identically zero.

[15] Given that the exogenous variables are growing at the appropriate steady-state values.

[16] Though admittedly the formation of expectations would have to be treated very carefully.

tend to a steady-state optimum, and the costs of approaching the steady state are very high. However, in this model at least, the steady-state policy is unlikely to be the optimum long term policy.

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