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PRICE LEVEL DETERMINACY WITH AN INTEREST RATE POLICY RULE AND RATIONAL EXPECTATIONS

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ABSTRACT

This paper reconsiders a result obtained by Sargent and Wallace, namely, that price level indeterminacy obtains in their well-known model if the monetary authorities adopt a policy feedback rule for the interest rate rather than the money stock. Since the Federal Reserve seems often to have used the federal funds rate as its operating instrument, with the money stock determined by the quantity demanded, this result suggests that the Sargent-Wallace model -- as well as others incorporating rational expectations -- is inconsistent with U.S. experience. It is here shown, however, that the indeterminacy result vanishes if the interest rate rule is chosen so as to have some desired effect on the expected quantity of money demanded. This revised conclusion holds even if considerable weight is given, in the choice of a rule, to the aim of smoothing interest rate fluctuations.

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I. Introduction

It would be unreasonable to argue that the Sargent-Wallace (1975) paper, "'Rational' Expectations, the Optimal Monetary Instrument, and the Optimal Money Supply Rule," has been neglected by the profession; in fact, it has been frequently cited by both admirers and critics. Virtually all of the attention, however, has been devoted to its policy-ineffectiveness or "neutrality" result: that, in the rather orthodox IS-LM-NRPC[1/] model considered, the "probability distribution of output ... is [with rational expectations] independent of the particular deterministic money supply rule in effect" (1975, p. 241). By contrast, practically no attention has been devoted to the paper's second major conclusion: that, in the same model and again with rational expectations, "under an interest rate rule the price level is indeterminate" (1975, p. 241). Indeed, the only discussions of this result that I have seen are in Sargent's own Macroeconomic Theory (1979, pp. 360-363) and in very recent papers by Taylor (1979) and Turnovsky (1980). The purpose of the present paper, accordingly, is to discuss and reconsider this second result of the Sargent-Wallace (S-W) analysis.

The empirical relevance of an interest rate rule is, it would seem, undeniable; knowledgeable observers of the U.S. monetary policy behavior agree that the federal funds rate, rather than some measure of aggregate reserves, has been used for substantial periods of time as the Fed's operating policy instrument.[2/] To accept this view, it might be added, is not to deny that the Fed has been serious in its professed desire to influence the (M1) money stock or some other aggregate, but simply to recognize that this influence has been effected by setting the interest rate period-by-period at levels that are expected to make the quantity demanded of money (or the relevant monetary aggregate) equal to the desired amount, perhaps modified to keep interest rates from moving too rapidly. Since observations on the money stock are obtained with substantial lags, the Fed must of necessity seek to control it by setting either an interest rate or a reserve variable; in fact it has used the former.[3/]

The relevance of the Sargent-Wallace model with the rationality assumption is perhaps more controversial. But the aggregate demand (IS and LM) portions of the model are highly orthodox,[4/] and the Phillips curve or aggregate supply function is quite representative of relationships found in "practical" macroeconometric models designed to describe the economy of the United States.[5/] Indeed, it is because the Sargent-Wallace structure was basically orthodox that their neutrality conclusion was viewed by the profession as so striking.

How, then, is one to interpret the Sargent-Wallace price-level indeterminacy result? While a few economists might be tempted to use it as an "explanation" of recent price level behavior, I believe that would be inappropriate: the result says that the price level is not defined, not that it is high or rapidly rising. What the result seems to suggest, empirically, is erratic movements in both upward and downward directions of the price level (and the money stock). Consequently, the appropriate conclusion might appear to be that the Sargent-Wallace model with expectational rationality provides a seriously misleading picture of the U.S. economy. Indeed, it might appear that the indeterminacy result provides the basis for an empirical refutation of a wide class of rational expectations models![6/]

But that conclusion, too, would be unwarranted. The reason is that, despite appearances, the S-W result is not entirely general; i.e., does not apply to all interest rate rules. In fact, it does not apply to rules in which the rate is set so as to influence the money stock, as is done by the Fed. Only if the ultimate effects on money are entirely disregarded in the design of the rule does the indeterminacy prevail. The purpose of the following sections is to establish the validity of this claim.

II. The Model

In the discussion that follows, the basic analytical context will be the slightly modified version of the S-W model used in Sargent's (1979) more recent exposition. Accordingly, let us begin with the following specifications of the IS, LM, and NRPC functions:[7/]

$$(1) \quad y_t = b_0' + b_1[r_t - (E_{t-1}p_{t+1} - p_t)] + v_t' \quad , \qquad b_1 < 0 \quad ,$$

$$(2) \quad m_t - p_t = c_0' + c_1 r_t + c_2 y_t + \eta_t \quad , \qquad c_1 < 0 < c_2 \quad ,$$

$$(3) \quad y_t = a_0 + a_1(p_t - E_{t-1}p_t) + a_2 y_{t-1} + u_t \quad , \qquad a_1 > 0 \ , \ 1 > a_2 > 0 \quad .$$

Here y_t, p_t and m_t are logarithms of output, the price level, and the money stock, while r_t is the nominal rate of interest. The operator E_{t-1} denotes the expectation of the indicated variable within the model at hand and conditional upon values of all variables in periods $t-1$ and earlier. The stochastic variables u_t, v_t and η_t are generated by white noise processes and are independent of past values of all variables.

It might be noted that the S-W paper expresses the real interest rate in the IS function as $r_t - E_{t-1}p_{t+1} + E_{t-1}p_t$, rather than $r_t - E_{t-1}p_{t+1} + p_t$. This leads one to ask which specification is appropriate. In a macroeconomic model of the S-W type, $E_{t-1}p_t$ represents an average across individual agents or markets of agents' perceptions of the current aggregate price level, while p_t represents an average over agents or markets of "local" prices. Consequently, if the expected inflation rate that agents use to convert nominal into real interest rates, for decision making purposes, is one that involves current and anticipated future local prices, then the formulation in (1) will be appropriate.[8/] Another specificational issue is whether wealth terms should also be included in (1). The presence of a real money-balance term, $m_t - p_t$, would not affect the results in any significant way and so can be omitted for simplicity. The presence of a term reflecting private holdings of government bonds, on the other hand, would eliminate the price level indeterminacy. To see that this is true in a static classical model is an extremely simple exercise and a useful extension to a dynamic setting more like that of Sargent-Wallace was recently provided by Turnovsky (1980). It is, however, debatable whether bonds should be modelled as constituting net wealth to the private sector; the contrary "Ricardian" view (that the capitalized value of implied future tax liabilities precisely offsets the value of current bond holdings) has been given important support by Barro (1974). In any event, one object of the present paper is to show that determinacy does not require validity of the non-Ricardian view. Consequently, wealth terms will be omitted in the subsequent analysis.

The object in what follows will be to derive equations representing the stochastic behavior of p_t under various specifications of policy, all of which presume that the monetary authority's behavior is representable as a linear feedback rule for r_t. In conducting the analysis, I shall use the "undetermined coefficients" procedure introduced into the macroeconomic literature by Lucas (1972). In this way it will be possible to express the S-W indeterminacy result in a different, and perhaps intuitively appealing, way and also to obtain--with some loss of generality--greater explicitness in our new result.

Before turning to the analysis, however, it will be useful to simplify the model even further. Since output is, in this model, independent of policy, its behavior is basically irrelevant to the issues at hand. Thus nothing of importance will be lost, and considerable computational simplicity will be gained, if we simply treat output as a constant. With this done, we can (by appropriate definitions of b_0, c_0, and v_t) express the model as

$$(1') \quad r_t = b_0 + E_{t-1}p_{t+1} - p_t + v_t$$

$$(2') \quad m_t = p_t + c_0 + c_1 r_t + \eta_t \quad ,$$

plus a policy rule for r_t.

As one more preliminary point, let us note that nothing would be gained by appending to the model a money supply function reflecting bank behavior, such as

$$(4) \quad m_t = h_t + \nu_0 + \nu_1 r_t + \zeta_t$$

where h_t is a reserve aggregate and ζ_t a disturbance. For with r_t determined by a policy rule, (4) would simply explain h_t with the variables of major macroeconomic interest determined by the system (1)-(3) or (1'),(2'). Furthermore, there would be no point in interpreting r_t as (e.g.) the treasury bill rate and introducing a separate variable f_t for the federal funds rate--which would then enter (4) as a distinct argument--if the model were then closed with an "efficient markets" relation such as

$$(5) \quad r_t = \psi_0 + \psi_1 f_t + \xi_t \quad ,$$

with ξ_t white noise, etc. The reason is that, clearly, this last equation makes any discrepancy between r_t and f_t random and uninteresting. Consequently, most analyses of the instrument problem have been conducted in models with only one interest rate.[9]

III. The Sargent-Wallace Result

Let us now develop our version of the S-W indeterminacy result. Given our use of the undetermined coefficients approach, it is necessary to specify the variables that appear in the authority's policy rule for r_t. To keep the analysis as simple as possible, let us consider the deterministic rule

$$(6) \quad r_t = \rho_0 + \rho_1 r_{t-1} \quad ,$$

where ρ_0 and ρ_1 would presumably be positive. As in McCallum (1978), the analysis proceeds by using the model's linearity and the white noise property of the disturbances to express p_t and m_t as reduced-form functions of the sole predetermined variable r_{t-1} and the current disturbances. Thus for appropriate values of the π_{ij} parameters we have

$$(7a) \quad p_t = \pi_{10} + \pi_{11} r_{t-1} + \pi_{12} v_t + \pi_{13} \eta_t \quad ,$$

$$(7b) \quad m_t = \pi_{20} + \pi_{21} r_{t-1} + \pi_{22} v_t + \pi_{23} \eta_t \quad .$$

And our immediate object, necessary for understanding the dynamic behavior of p_t and m_t, is to determine the values of the π_{ij} coefficients in terms of the basic parameters appearing in (1'), (2'), and (6).

As a preliminary step, note that

$$(8) \quad E_{t-1} p_{t+1} = \pi_{10} + \pi_{11} E_{t-1} r_t = \pi_{10} + \pi_{11}(\rho_0 + \rho_1 r_{t-1}) \quad .$$

Then putting (6), (7a), and (8) into (1') we obtain

(9) $\rho_0 + \rho_1 r_{t-1} = b_0 + \pi_{10} + \pi_{11}\rho_0 + \pi_{11}\rho_1 r_{t-1}$

$$-(\pi_{10} + \pi_{11} r_{t-1} + \pi_{12} v_t + \pi_{13}\eta_t) + v_t \quad .$$

But for this equation to hold for arbitrary values of the system's variables, the following relations must characterize the π_{ij}'s:

(10) $\rho_0 = b_0 + \pi_{10} + \pi_{11}\rho_0 - \pi_{10}$

$\rho_1 = \pi_{11}\rho_1 - \pi_{11}$

$0 = -\pi_{12} + 1$

$0 = \pi_{13} \quad .$

Similarly, putting (6), (7a), and (7b) into (2') yields

(11) $(\pi_{20} - \pi_{10}) + (\pi_{21} - \pi_{11}) r_{t-1} + (\pi_{22} - \pi_{12})\, v_t + (\pi_{23} - \pi_{13})\eta_t =$

$$= c_0 + c_1(\rho_0 + \rho_1 r_{t-1}) + \eta_t \quad ,$$

which implies the identities

(12) $\pi_{20} - \pi_{10} = c_0 + c_1\rho_0$

$\pi_{21} - \pi_{11} = c_1\rho_1$

$\pi_{22} - \pi_{12} = 0$

$\pi_{23} - \pi_{13} = 1 \quad .$

Now, in a well-behaved system the eight equations in (10) and (12) could be used to evaluate the eight coefficients, $\pi_{10}, \ldots, \pi_{23}$. In the case at hand, however, we can see by inspection that π_{20} and π_{10} appear only in the first of equations (12), and there as the difference $\pi_{20} - \pi_{10}$. Thus the model says nothing about the magnitudes of π_{10} or π_{20} separately. Consequently, there is nothing to pin down either p_t or m_t, so the indeterminacy result can be seen to prevail.

Furthermore, the second of equations (10) gives $\pi_{11} = \rho_1/(\rho_1 - 1)$ while the first implies $\pi_{11} = (\rho_0 - b_0)/\rho_0$. But ρ_0, ρ_1, and b_0 are independent behavioral parameters so this amounts to an inconsistency in the model. This result is reminiscent of Sargent's observations regarding the consequence of a pegged interest rate in a textbook-style classical model (1979, pp. 94-95).

IV. Analysis with Revised Policy Rule

Our object now is to respecify the interest rate rule in a way that will make it more "realistic," i.e., will make it more nearly representative of actual Fed behavior as described above. The crucial aspect to be emphasized is that the rule is chosen not arbitrarily, but so as to provide some desired effect on the quantity of money demanded. The purest case would be that in which the policy rule for r_t is designed to make the expected value of m_t equal to some target value such as

$$(13)\quad m_t^* = \mu_0 + \mu_1 r_{t-1} \quad ,$$

with μ_1 presumably positive. In this pure case the rule would be to set r_t equal to the value

$$(14)\quad r_t^* = (1/c_1)(\mu_0 + \mu_1 r_{t-1} - c_0 - E_{t-1}p_t) \quad ,$$

which makes the expected value of money demand equal to m_t^*. Of course this rule differs from the type considered by S-W because its coefficients depend (via $E_{t-1}p_t$) on behavioral parameters of the model, but it can still be expressed as a feedback rule.

More general than the foregoing is the case in which, instead of (14), the rule is

$$(15)\quad r_t = (\phi/c_1)(\mu_0 + \mu_1 r_{t-1} - c_0 - E_{t-1}p_t) + (1 - \phi)r_{t-1} \quad ,$$

with $0 < \phi \leqq 1$. Clearly this specification says that the monetary authority sets r_t with some weight given to the target value of m_t, but with weight also given to the objective of interest rate smoothing (i.e., the avoidance of fluctuations in r_t). Thus the smaller is the value of ϕ, the less weight is given to the attainment of the target value m_t^* and the more weight is given to smoothing. Since this formulation is perhaps more realistic than (14), and includes (14) as a special case, we shall now assume policy behavior as specified in (15).

Analysis of the model (1'), (2'), (15) begins with the computations

(16) $E_{t-1}p_t = \pi_{10} + \pi_{11}r_{t-1}$,

(17) $E_{t-1}p_{t+1} = \pi_{10} + \pi_{11}E_{t-1}r_t$

$$= \pi_{10} + (\pi_{11}\phi/c_1)(\mu_0 + \mu_1 r_{t-1} - c_0 - \pi_{10} - \pi_{11}r_{t-1}) + \pi_{11}(1 - \phi)r_{t-1} \quad .$$

Then we substitute (15), (16), (17), and (7a) into (1'), obtaining:

(18) $$(\phi/c_1)(\mu_0 + \mu_1 r_{t-1} - c_0 - \pi_{10} - \pi_{11}r_{t-1}) + (1 - \phi)\, r_{t-1} =$$

$$b_0 + \pi_{10} + (\pi_{11}\phi/c_1)(\mu_0 + \mu_1 r_{t-1} - c_0 - \pi_{10} - \pi_{11}r_{t-1})$$

$$+ \pi_{11}(1 - \phi)r_{t-1} - (\pi_{10} + \pi_{11}r_{t-1} + \pi_{12}v_t + \pi_{13}\eta_t) + v_t \quad .$$

The implied equalities are then:

(19) $$(\phi/c_1)(\mu_0 - c_0 - \pi_{10}) = b_0 + \pi_{10} + (\pi_{11}\phi/c_1)(\mu_0 - c_0 - \pi_{10}) - \pi_{10} \quad ,$$

$$(\phi/c_1)(\mu_1 - \pi_{11}) + (1 - \phi) = (\pi_{11}\phi/c_1)(\mu_1 - \pi_{11}) + \pi_{11}(1 - \phi) - \pi_{11} \quad ,$$

$$0 = -\pi_{12} + 1$$

$$0 = -\pi_{13} \quad .$$

From these last two we immediately obtain $\pi_{12} = 1$ and $\pi_{13} = 0$, while the second is a quadratic equation in π_{11}, viz.,

$$(20) \quad \phi(\mu_1 - \pi_{11}) + c_1(1 - \phi) = \phi\pi_{11}(\mu_1 - \pi_{11}) - c_1\phi\pi_{11} \quad .$$

From the latter we obtain

$$(21) \quad \pi_{11} = (1/2)[\ (1 + \mu_1 - c_1) \pm \sqrt{\ (1 + \mu_1 - c_1)^2 - 4(\mu_1 - c_1 + c_1/\phi)}\ \ ] \ .$$

In order to tell which root is relevant, consider the special case in which $\phi = 1$ and $\mu_1 = 0$. In this case r_{t-1} does not appear in the structural equations so we should have $\pi_{11} = 0$. And (21) reduces, in this case, to

$$(22) \quad \pi_{11} = (1/2)[(1 - c_1) \pm \sqrt{(1 - c_1)^2}\ ] \quad .$$

Since $1 - c_1$ is a positive number, (22) gives $\pi_{11} = 0$ for the negative square root. Therefore, we conclude that the smaller root is generally relevant in (21), which then determines π_{11}.[10/]

Given π_{11}, finally, we find π_{10} from (19) as

$$(23) \quad \pi_{10} = \mu_0 - c_0 - b_0 c_1/\phi(1 - \pi_{11}) \quad .$$

Thus we see that all of the coefficients in (7a) are well defined by the model. With the interest rate rule (15), the price level is determinate in the S-W model.

For completeness, we might note that substitution into (2') gives

$$(24)\quad (\pi_{20} - \pi_{10}) + (\pi_{21} - \pi_{11})r_{t-1} + (\pi_{22} - \pi_{12})v_t + (\pi_{23} - \pi_{13})\,\eta_t$$

$$= c_0 + \phi(\mu_0 + \mu_1 r_{t-1} - c_0 - \pi_{10} - \pi_{11} r_{t-1}) + c_1(1 - \phi)r_{t-1} + \eta_t \quad ,$$

which implies the equalities

$$(25)\quad \pi_{20} - \pi_{10} = c_0 + \phi(\mu_0 - c_0 - \pi_{10}) \quad ,$$

$$\pi_{21} - \pi_{11} = \phi(\mu_1 - \pi_{11}) + c_1(1 - \phi) \quad ,$$

$$\pi_{22} - \pi_{12} = 0 \quad ,$$

$$\pi_{23} - \pi_{13} = 1 \quad .$$

Inspection shows these to be sufficient to determine the coefficients in (7b) so m_t is also determinate.

It is perhaps worth emphasizing that the foregoing result implies a determinate price level even when values of ϕ are small; i.e., when the authority emphasizes interest rate smoothing and attends to its monetary target only slightly. Only for $\phi = 0$ does the indeterminacy result prevail. It is in that respect that indeterminacy obtains only if the rule's effects on money are "entirely disregarded," as claimed above.

In conclusion, it should perhaps be emphasized that the foregoing result does not formally contradict the Sargent-Wallace conclusion, for their analysis presumes that the parameters in the interest rate feedback rule are autonomous--i.e., unrelated to behavioral parameters. But rules of the general type described in (15) would seem to be of greater practical relevance. And the existence of interest rate rules of that type provide, as we have seen, no basis for concluding that the S-W model or other rational expectations models are inconsistent with data recently generated by the U.S. economy. Finally, it should be said that the foregoing discussion suggests that use of an interest rate instrument is feasible, not that it is desirable.

Appendix

The object here is to show that the determinacy result of Section 4 remains intact under the alternative versions of the IS function mentioned in footnote 8. First, if (1') is replaced with

$$(1'')\quad r_t = b_0 + E_t p_{t+1} - p_t + v_t \quad ,$$

the first two equalities in (19) become

$$(1-\pi_{11})(\phi/c_1)(\mu_0-c_0-\pi_{10}) + (1-\pi_{11}) = b$$

$$(1-\pi_{11})(\phi/c_1)(\mu_1-\pi_{11}) - \pi_{11}(1-\phi) = -\pi_{11} \quad .$$

The second of these yields π_{11} in a manner analogous to (20) in Section 4, which permits determination of π_{10} from the first.

Next, if the Sargent-Wallace IS function is used with the deterministic policy rule (15) and output is treated as a constant, the disturbance v_t must be removed from (1') and thus from (7). The solution is then as in Section 4 except that $\pi_{12} = \pi_{22} = 0$. (Use of the more complete supply function (3), even with $a_2 = 0$, would of course permit retention of v_t.)

Footnotes

[1/] Here NRPC is an abbreviation for "natural-rate Phillips curve."

[2/] See, for example, Friedman (1977), Kareken and Miller (1976), Lombra and Torto (1975), Poole (1975), and Volcker (1978).

[3/] Perhaps a reserve instrument has been used since October 6, 1979 -- that remains to be seen. In any event, the federal funds rate was used during much of the postwar period prior to that date.

[4/] This view, that aggregate demand specifications of the IS-LM type are used by most macroeconomists, is evidently shared by Friedman (1970) and Modigliani (1977).

[5/] See McCallum (1979).

[6/] I have not been able to delineate the class rigorously, but it appears that the indeterminacy result holds for most (perhaps all) models with rational expectations and sensible steady-state properties. One example of a model with the indeterminacy but without the "policy ineffectiveness" property is that of Phelps and Taylor (1977). Thus the price level indeterminacy feature might even be regarded as reason for rejecting expectational rationality.

[7/] I have used different symbols for parameters and have not constrained the income elasticity of money demand to be unity, as does Sargent (1979, p. 360).

8/ This conclusion can be obtained more rigorously in the context of an "island model" of the type used by Lucas (1973). If there exists a security traded in all localities, so that agents observe an economy-wide interest rate, the S-W neutrality result will not hold, for reasons described by Barro (1979). Conclusions relevant to the present discussion remain intact, however, and these also hold if the S-W formulation, with $r_t - E_{t-1}p_{t+1} + E_{t-1}p_t$, is used. The relevant anaylsis is sketched in the appendix.

9/ See, e.g., Friedman (1977), Pierce and Thomson (1972), and Poole (1970).

10/ If the larger root were chosen, then (22) would give $\pi_{11} = 1 - c_1$ and (23) below would yield $\pi_{10} = \mu_0 - c_0 - b_0$. With $\pi_{12} = 1$ and $\pi_{13} = 0$ from (19) we would then have $p_t = \mu_0 - c_0 - b_0 + (1 - c_1)r_{t-1} + v_t$ as the reduced form equation for p_t. Substitution into the policy rule (15) would yield, after simplification, $r_t = (b_0/c_1) - [(1 - c_1)/c_1]r_{t-1}$. Since $c_1 < 0$, the coefficient on r_{t-1} in the latter exceeds 1.0. Thus the implied behavior of r_t is explosive, even though the target money stock is constant and the price level is white noise. This result is analogous to ones in which the price level explodes with a constant money stock. (For a discussion, see Flood and Garber (1980).) Some authors have ruled out such solutions, using the explosive behavior as a justification. The rationale employed here -- that a variable which appears nowhere in the model should not appear in reduced-form equations -- seems preferable.

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