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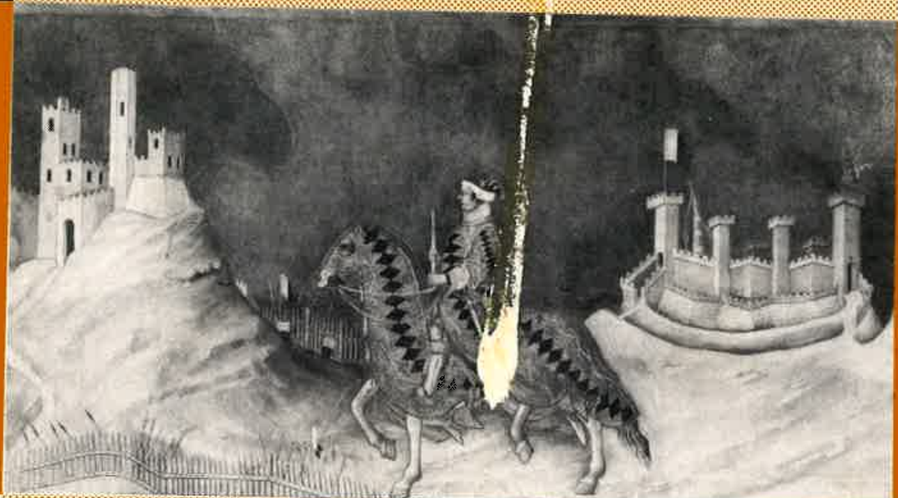
THE NATURAL RATE OF UNEMPLOYMENT AND RATIONAL EXPECTATION HYPOTHESES: SOME EMPIRICAL TESTS



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THE NATURAL RATE OF UNEMPLOYMENT AND RATIONAL EXPECTATION HYPOTHESES: SOME EMPIRICAL TESTS

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1. *Introduction**

This paper is the continuation of a previous research (G. Cifarelli (1983)) in which a macrorational model was developed and estimated using Italian data over the 1960-1979 time period. This very model is used in the tests set forth below.

The Natural Rate of Unemployment with Rational Expectations model -in the various versions- implies that:

- anticipated money supply changes (and anticipated changes in other policy instruments) are reflected in price changes only, having no effect on output and employment;
- unanticipated changes in economic policy instruments only are reflected on output changes.

This is the "economic policy ineffectiveness" proposition: it depends upon the association of the Natural Rate of Unemployment and of the Rational Expectations hypotheses, which are thus of paramount importance.

These hypoteses have been investigated in this paper comparing neutral and nonneutral versions of the model that include the (maintained) Rational Expectations hypothesis, and comparing Rational and non-Rational versions of the model that include the (maintained) Natural Rate of Unemployment (neutrality) hypothesis.

The "economic policy ineffectiveness" proposition has also been investi-

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* Paper submitted in October 1983.

gated directly by means of a Granger causality test between output and economic policy stimuli, and by means of an analysis of the reaction of the model estimates to changes in the lags with which data are assumed to enter the information set the public uses to derive expectations.

2. *An Outline of the Main Difficulties*

The estimation of models incorporating the hypotheses mentioned above brings about econometric problems that have been faced in different ways, giving rise to a variety of empirical specifications.

A first difficulty is associated with the quantification of anticipated stimuli, which play a relevant role in models of this kind, the actual value of these stimuli being unobservable.

A second problem arises because of the so-called "observational equivalence", mentioned by T.J. Sargent (1976a) between natural and non-natural rate of unemployment (ouput) relationships.

The expectations of the public about an economic stimulus have been quantified by moving averages, over a certain number of time periods, of the past value of this stimulus: such an approach has been used by A.H. Meltzer (1977), M. Fratianni (1978), P. Korteweg and A.H. Meltzer (1978) and others.

Sometimes anticipated stimuli have simply been set equal to the previous time period value of these very stimuli. Such an approach has been followed by A. Fourcans (1978) and P. Korteweg (1978).

Alternatively the anticipated stimulus is the fitted value of an autoregression of this very stimulus on its own past values, autoregression that can be estimated by means of OLS or by means of Box and Jenkins approaches. The latter technique has been used by M. Fratianni (1978), P. Korteweg (1978) and E.J. Bomhoff (1980)[1].

Unanticipated stimuli have been obtained by subtracting from the original series the chosen anticipated stimuli proxies.

Both the moving average and own autoregression approaches have been used in our empirical investigations below.

Anticipated prices (i.e. Rational Expectations about prices) have been obtained as fitted values of OLS regressions of prices on anticipated stimuli. Alternatively anticipated prices have been obtained as fitted values of OLS regressions of prices directly on the determinants of anticipated stimuli, i.e. on the elements assumed to enter the information set of the public. Such an approach has been followed by J. Rutledge (1974), B.T. McCallum (1976) and T.J. Sargent (1973, 1976).

"Observational equivalence" brings about severe restrictions on the neutrality proposition.

This problem can be dealt with in various ways: at an intuitive level it is required that factors that influence price expectations do not enter directly the output relationship (i.e. the Lucas supply curve). Otherwise the latter becomes liable to a nonneutral interpretation, being indistinguishable from a standard Keynesian reduced form between output and factors that influence prices[2].

This problem has been investigated by R. Barro (1977, 1978), B.T. McCallum (1979, 1979a) and M.H. Pesaran (1980).

3. *Macrorational Models Specification Tests*

3.1. *Lucas Supply Curve Tests.*

At an intuitive level Rational Expectations and neutrality tests can be developed in two ways:

a) - comparing (the quality of fit) of neutral and nonneutral versions of relationships incorporating the Rational Expectations hypothesis;

b) - comparing (the quality of fit) of Rational and non-Rational Expectations versions of relationships incorporating the neutrality hypothesis.

3.2. *A Simple Macrorational Model.*

Consider the standard Lucas supply curve:

$$\text{(I)} \qquad y_t = \alpha + \beta y_{nt} + \gamma (P_t - P_t^o) + u_{1t} \quad ,$$

where

- P_t = rate of change of consumer prices;
- P_t^o = expected rate of change of consumer prices;
- y_t = rate of change of real output;
- y_{nt} = trend rate of change of output. In the empirical investigations below we assume that:

$$y_{nt} = c_1 y_{t-1} \quad \text{or that} \quad y_{nt} = c_1 y_{t-1} + c_2 y_{t-2} + c_3 y_{t-3}\ ^{(3)}.$$

We assume that the behaviour of prices can be explained by means

of the following reduced form:

$$\text{(II)} \qquad P_t = AM_t + BZ_t + C + u_{2t} \quad ,$$

where

- M_t = rate of change of the money supply;
- Z_t = vector of predetermined variables that influence inflation.

In the empirical investigations below, we assume that:

$$Z_t = (P_{mt}\ e_t\ y_{nt}\ P_{t-1})',$$

where

- P_{mt} = rate of change of import prices expressed in Italian lira;
- e_t = rate of change of the volume of Italian exports.

The aggregate supply relationship, equation (I), incorporates the Natural Rate of Unemployment hypothesis about the behaviour of economic agents: unexpected increases in the general price level raise supply because economic agents interpret such increases as increases in the relative price of the goods they are supplying, and they usually receive information about the price of their own goods faster than about the general price level. As a consequence unanticipated increases in the inflation rate have an expansionary effect on output, raising its rate of growth above the trend rate.

We assume economic agents believe price determination to be explained by equation (II).

Taking expectations of equation (II), we obtain the (Rational) price expectations formation relationship:

$$\text{(III)} \qquad E(P_t / \vartheta_{t-1}) = P^*_t = AM^*_t + BZ^*_t + C.$$

We assume that:

$$E\,(u_{2t}\,/\vartheta_{t-1}) = 0 \quad ,$$

where

- $x^\circ_t = E\,(x_t \,/\, \vartheta_{t-1})$ = value of x_t the public expects to prevail at time t;
- ϑ_{t-1} = set of observations on variables dated t-1 and earlier, at the disposal of the public and of the Government at time t. In the empirical investigations below $_{t-1}$ includes y_{nt}, P_{t-1} and lagged values of M_t, e_t and P_{mt} (with lags of up to four quarters).
- E (.) = mathematical expectations operator.

Equations (I), (II) and (III) constitute the model that shall be used as framework in the empirical investigations below.

Subtracting from the price determination relationship the corresponding price expectations relationship, we obtain an equation of the form:

$$\text{(IV)} \quad (P_t - P^\circ_t) = A\,(M_t - M^\circ_t) + B\,(Z_t - Z^\circ_t) + u_{4t} \quad .$$

It explains the behaviour of unanticipated price changes in terms of unanticipated stimuli.

It can be rewritten as:

$$\text{(IV')} \quad P_t = FP^\circ_t + A\,(M_t - M^\circ_t) + B\,(Z_t - Z^\circ_t) + u_{4't} \quad ,$$

where it is assumed that F = 1.

Substituting in equation (I), we obtain the Lucas supply curve "reduced":

$$\text{(V)} \quad y_t = \alpha + \beta\, y_{nt} + \gamma \left[A(M_t - M^\circ_t) + B\,(Z_t - Z^\circ_t) \right] + (u_{1t} + \gamma u_{4t}) \; .$$

It illustrates how unanticipated stimuli bring about output deviations from trend[4].

The empirical investigation deals with a relatively long time period, spanning from 1960, I° quarter, to 1979, IV° quarter, in which can be distinguished:

- the 1960, I° quarter - 1969, IV° quarter, subperiod, with relatively stable prices and rapidly growing output;
- the 1970, I° quarter - 1979, IV° quarter, subperiod, with rapidly growing prices and slow rate of growth of output.

On the whole the neoclassical elements of the model connected with the Lucas supply curve seem to be stronger in the 1970s than in the 1960s.

Expectations of the public about the behaviour of a given economic policy variable x_t are proxied in two ways:

- as a moving average of this very variable, spanning over four time periods;
- as the fitted value of a regression (by OLS) of this variable on its own past values.

MA (Moving Average):

$$E\,(x_t \,/\psi_{t-1}) = x^\circ_t = 1/4 \sum_{i=1}^{4} x_{t-i} \;^{(5)} .$$

OA (Own Autoregression):

$$E\,(x_t \,/\psi_{t-1}) = x^\circ_t = \eta\,(L)x_t \quad ,$$

where it is assumed that x_t can be represented by the corresponding time series:

$$x_t = \eta\,(L)\,x_t + \nu_t = \eta_0 + \eta_1\, x_{t-1} + \eta_2\, x_{t-2} + \ldots + \nu_t \quad .$$

- x°_t is the anticipated value of the stimulus x_t, conditional on information about it at time t-1. ψ_{t-1} is the information set of the public about x_t. The idea is that individuals derive expectations about the (unobservable) current value of x_t by looking at its own past values.

3.3. *Neutrality Tests Based on the Specification Analysis of the Lucas Supply Curve.*

Consider the following Lucas supply curve:

$$\text{(I)} \qquad y_t = \alpha + \beta y_{nt} + \gamma(P_t - P_t^\circ) + u_{1t} \quad .^{(6)}$$

As pointed out by T.J. Sargent (1973), macroeconomic theory implies that P_t and y_t be simultaneously determined and, as a consequence, that P_t and u_{1t} in equation (I) be correlated, making least squares estimation of this equation inappropriate[7]. (It is assumed that $E(u_{1t}\, u_{2t}) \neq 0$.)

T.J. Sargent suggests that the problem be solved by means of the standard instrumental variables approach, replacing P_t in equation (I) by $\hat{P}_t$, the predicted value of P_t from a first stage regression on auxiliary instruments[8]. As a consequence we have replaced it by the following equation:

$$\text{(I')} \qquad y_t = \alpha + \beta y_{nt} + \gamma(\hat{P}_t - P_t^\circ) + (u_{1t} + \gamma f_t),\ f_t = P_t - \hat{P}_t \quad .$$

The Lucas supply curve, in the specification above, implies that economic agents are not affected by money illusion: anticipated changes in the rate of inflation exert no effect on output.

This property can be assessed by checking whether in the relationship (VI) below, H = 1, satisfying the neutrality and absence of money illusion hypotheses.

$$\text{(VI)} \qquad y_t = \alpha + \beta y_{nt} + \gamma(\hat{P}_t - HP_t^\circ)' + (u_{1t} + \gamma f_t) \quad .$$

A test of this kind can be performed by estimating a relationship such as:

$$\text{(VII)} \qquad y_t = \alpha + \beta y_{nt} + \gamma_1 \hat{P}_t + \gamma_2 P_t^\circ + (u_{1t} + \gamma f_t)$$

and testing by means of F statistics the validity of the money illusion restriction

$$\gamma_1 = -\gamma_2 \quad .$$

Alternatively the following relationship, set forth by T.J. Sargent (1973), can be estimated:

$$\text{(VIII)} \qquad y_t = \alpha + \beta y_{nt} + \gamma(\hat{P}_t - P_t^\circ) + \Delta P_t^\circ + (u_{1t} + \gamma f_t) \quad .$$

The null hypothesis can then be investigated that

$$\Delta = 0 \quad .$$

In that case the neutrality hypothesis holds.

The estimates show that the anticipated (systematic) component of the rate of inflation does not affect output rate of growth (deviations from trend) over the 1970.I-1979.IV time period: the null hypothesis that $\Delta = 0$ is always accepted in equation (VIII) at the 5% significance level (with the exception of the case of MA anticipated stimuli and $y_{nt} = c_1\, y_{t-1}$).

Anticipated inflation affects output rate of growth if the estimates are performed over the 1960.I-1979.IV time period: with one exception the null hypothesis that $\Delta = 0$ is refused at the 5% significance level. (It is not refused, however, at the 1% significance level.)

Support for the neutrality hypothesis is weakened somewhat by the estimates of equations (VII) if we assume that $y_{nt} = c_1\, y_{t-1}$, since the hypothesis that

Table I

(VII) $y_t = \alpha + \beta y_{nt} + \gamma_1 \hat{P}_t + \gamma_2 P^*_t + (u_{1t} + \gamma f_t)$*

$y_{nt} = c_1 y_{t-1}$

Period		Ant. St. F** $\gamma_1 = -\gamma_2$	$\bar{R}^2$	D.W.		Ant. St. F** $\gamma_1 = -\gamma_2$	$\bar{R}^2$	D.W.
1960.I-1979.IV	MA	(1,60) 4.65***	0.58	2.05	OA	(1,60) 4.75***	0.57	2.03
1970.I-1979.IV	MA	(1,36) 4.35***	0.64	1.93	OA	(1,36) 3.66	0.58	1.91

$y_{nt} = c_1 y_{t-1} + c_2 y_{t-2} + c_3 y_{t-3}$

Period		Ant. St. F** $\gamma_1 = -\gamma_2$	$\bar{R}^2$	D.W.		Ant. St. F** $\gamma_1 = -\gamma_2$	$\bar{R}^2$	D.W.
1960.I-1979.IV	MA	(1,58) 4.49***	0.59	2.22	OA	(1,58) 5.66***	0.62	2.17
1970.I-1979.IV	MA	(1,34) 2.45	0.64	2.09	OA	(1,34) 2.56	0.64	2.18

* Analogous results have been obtained with relationships in which no corrections for simultaneity between P_t and y_t have been made.

** F tests of the null hypothesis that $\gamma_1 = -\gamma_2$.

*** Hypothesis accepted at the 1% significance level only.

(VIII) $y_t = \alpha + \beta y_{nt} + \gamma(\hat{P}_t - P^*_t) + \Lambda P^*_t + (u_{1t} + \gamma f_t)$†

$y_{nt} = c_1 y_{t-1}$

Period		An. St. F†† $\Lambda=0$	$\bar{R}^2$	D.W.		An. St. F†† $\Lambda=0$	$\bar{R}^2$	D.W.
1960.I-1979.IV	MA	(1,59) 3.87	0.58	1.97	OA	(1,59) 4.03	0.57	1.96
1970.I-1979.IV	MA	(1,35) 4.31	0.64	1.93	OA	(1,35) 3.64	0.58	1.91

$y_{nt} = c_1 y_{t-1} + c_2 y_{t-2} + c_3 y_{t-3}$

Period		An. St. F†† $\Lambda=0$	$\bar{R}^2$	D.W.		An. St. F†† $\Lambda=0$	$\bar{R}^2$	D.W.
1960.I-1979.IV	MA	(1,57) 5.43	0.63	2.08	OA	(1,57) 6.01	0.64	2.14
1970.I-1979.IV	MA	(1,33) 2.37	0.64	2.09	OA	(1,33) 2.42	0.64	2.18

† Analogous results have been obtained with relationships in which no corrections for simultaneity between P_t and y_t have been made.

†† F tests of the null hypothesis that $\Lambda = 0$.

$$\gamma_1 = -\gamma_2$$

is not rejected -with one exception for the 1970.I-1979.IV time period- at the 1% level of significance only. If we assume instead that $y_{nt} = c_1 y_{t-1} + c_2 y_{t-2} + c_3 y_{t-3}$, the neutrality hypothesis is always accepted at the 5% confidence level over the 1970.I-1979.IV time period.

It is more difficult to reject the neutrality hypothesis in the 1970.I-1979.IV time period than in the 1960.I-1979.IV time period.

3.4. *Rational and Non-Rational Quantifications of Inflationary Expectations.*

The Lucas supply curve has been associated in the previous section with Rational Expectations, and estimates have been obtained that are closely connected with the a priori hypotheses about parameter coefficients signs and absolute values provided by the theory.

We assess here the consequences, from this point of view, of the use of alternative non-Rational hypotheses about the formation of inflationary expectations.

We estimate the following relationship:

(IX) $y_t = \alpha + \beta y_{nt} + \gamma(\hat{P}_t - \bar{P}_{it}) + (u_t + \gamma f_t)$,

where $\bar{P}_{it}$ is the expected value of P_t and has been proxied as:

- naive expectations $\bar{P}_{1t} = P_{t-4}$;
- extrapolative expectations $\bar{P}_{2t} = 2/3P_{t-4} + 1/3P_{t-8}$;
- partly-Rational expectations $\bar{P}_{3t} = \tilde{P}_t$,

Table II

$$\text{(IX)} \quad y_t = \alpha + \beta y_{nt} + \gamma(\hat{P}_t - \bar{P}_{it}) + (u_t + \gamma f_t) \, .$$

$$y_{nt} = c_1 y_{t-1}{}^{*}$$

Naïve Expectations $= \bar{P}_{1t}$;

Extrapolative Expectations $= \bar{P}_{2t}$;

Partly-Rational Expectations $= \bar{P}_{3t}$.

Period	Equation (t-statistics in parentheses)	$\bar{R}^2$	S.E.	D.W.
1960.I-1979.IV	$y_t = 0.01 + 0.78\, y_{t-1} - 0.33\, (\hat{P}_t - \bar{P}_{1t})$ (1.55) (8.14) (-2.33)	0.51	0.049	2.07
	$y_t = 0.01 + 0.75\, y_{t-1} - 0.42\, (\hat{P}_t - \bar{P}_{2t})$ (2.01) (8.53) (-2.98)	0.53	0.048	2.12
	$y_t = 0.03 + 0.34\, y_{t-1} + 0.86\, (\hat{P}_t - \bar{P}_{3t})^{**}$ (2.35) (2.91) (1.63)	0.50	0.050	2.07
1970.I-1979.IV	$y_t = 0.01 + 0.77\, y_{t-1} - 0.29\, (\hat{P}_t - \bar{P}_{1t})$ (1.50) (5.69) (-1.57)	0.46	0.058	1.93
	$y_t = 0.02 + 0.76\, y_{t-1} - 0.40\, (\hat{P}_t - \bar{P}_{2t})$ (1.87) (6.23) (-2.13)	0.49	0.056	1.99
	$y_t = 0.02 + 0.38\, y_{t-1} + 0.73\, (\hat{P}_t - \bar{P}_{3t})^{**}$ (1.34) (2.54) (1.10)	0.49	0.057	2.00
1960.I-1969.IV	$y_t = -0.003 + 0.84\, y_{t-1} - 0.97\, (\hat{P}_t - \bar{P}_{1t})$ (-0.30) (5.90) (-2.70)	0.64	0.031	1.45
	$y_t = 0.001 + 0.71\, y_{t-1} - 1.54\, (\hat{P}_t - \bar{P}_{2t})$ (0.15) (6.06) (-4.79)	0.77	0.024	2.20
	$y_t = 0.001 + 0.89\, y_{t-1} - 2.51\, (\hat{P}_t - \bar{P}_{3t})$ (0.08) (5.72) (-1.76)	0.58	0.033	1.22

* The estimations have also been performed with $y_{nt} = c_1 y_{t-1} + c_2 y_{t-2} + c_3 y_{t-3}$, with no significant alteration of the results.

** First order serial correlation of residuals has been eliminated by means of the Cochrane Orcutt iterative approach.

where

$\tilde{P}_t$ is the fitted value of the following OLS regression:

$$P_t = a_0 + a_1 P_{t-1} + a_2 P_{t-2} + a_3 P_{t-3} + a_4 P_{t-4} + a_5 P_{t-5} + \varepsilon_t \; ;$$

$$\bar{P}_{3t} = P_t - \varepsilon_t = \tilde{P}_t \, .$$

The estimations above (Table II) show that with non-Rational inflationary expectations the quality of fit is rather poor over the three time periods taken into consideration. The γ coefficient, which quantifies the effect of forecast errors on output deviations fom trend, is either negative, contradicting the Natural Rate of Unemployment hypothesis, or not significantly different from zero.

4. *"Economic Policy Ineffectiveness" Proposition Tests*

4.1. Neutrality Tests.

T.J. Sargent (1973, 1976) has suggested an indirect test of the neutrality hypothesis (and indeed also of the Rational Expectations hypothesis) based on "Granger Causality" analysis of relationships between economic policy stimuli and output rate of growth, derived from the Lucas supply curve set forth above.

The following equations are estimated:

$$\text{(X)} \quad y_t = \sum_{i=1}^{q} c_i\, y_{t-i} + \sum_{j=1}^{f} \beta_j\, x_{t-j} + u_t$$

where x_t represents alternative specifications of components of the information set of the public, u_t is a serially uncorrelated, normally distributed, random variable, and the null hypothesis that $(\beta_1, \beta_2, ..., \beta_f) = 0$ is assessed by means of F tests(9).

We have performed this test for the following specifications of x_t, over the 1960.I-1979.IV time period:

$$x_t = M_t \ , e_t, P_{mt} \ , DG_t \ , DB_t \ .$$

- DB_t = quarterly rate of change of public debt issues in the hands of the public;
- DG_t = quarterly rate of change of Government expenditure.

We have assumed that:

$f = 4$, i.e. we have tested the hypothesis that

$$\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0 \quad \text{and that}$$

$f = 6$, i.e. we have tested the hypothesis that

$$\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0 \ .$$

In both cases, as in the Lucas supply curve estimation above, we have assumed alternatively that $q = 1$ and $q = 3$. Variables are expressed as rates of change.

The empirical findings do not reject the "economic policy ineffectiveness" proposition. If four lagged values of the stimuli are considered, $f = 4$, we obtain mixed results.

Neither public debt, DB_t, nor Government expenditure, DG_t, affect output, whilst import prices, P_{mt}, do exert a significant effect (the null hypothesis that the coefficients are zero is rejected at the 1% level of significance) and, depending upon the lags of output rate of growth used

Table III

Granger Causality Tests
1960.I-1979.IV

$$(X) \quad y_t = \sum_{i=1}^{q} c_i y_{t-i} + \sum_{j=1}^{f} \beta_j x_{t-j} + u_t$$

Specification of x_t	F tests that $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ (f=4): $y_{nt} = c_1 y_{t-1}$ (q=1)		$y_{nt} = \sum_{i=1}^{3} c_i y_{t-i}$ (q=3)		F tests that $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6$ =(f=6): $y_{nt} = c_1 y_{t-1}$ (q=1)		$y_{nt} = \sum_{i=1}^{3} c_i y_{t-i}$ (q=3)	
	1*	2*	1*	2*	1*	2*	1*	2*
M_t		(4,58) 4.122	(4,56) 2.255			(6,56)** 2.845	(6,54) 1.684	
e_t	(4,58) 0.053			(4,56) 4.172	(6,56) 1.353			(6,54) 3.795
P_{mt}		(4,58) 4.522		(4,56) 3.566		(6,56) 3.900	(6,54) 2.262	
DB_t	(4,58) 1.933		(4,56) 0.913			(6,56)** 3.110	(6,54) 2.282	
DG_t	(4,58) 0.159		(4,56) 0.637		(6,56) 0.348		(6,54) 0.578	
$(M_t e_t P_{mt})$***		(12,50) 2.940		(12,48)** 2.632	(18,44) 1.172		(18,42) 1.088	

1* Not Refused. At the 5% significance level.

2* Refused. At the 5% significance level.

** Accepted at the 1% significance level.

*** If the Granger causality test is performed with the following enlarged specification of x_t:

$$x_t = (M_t \, e_t \, P_{mt} \, DB_t \, DG_t) \ ,$$

the null hypothesis is always accepted.

to represent the systematic component of the output time series, the volume of exports, e_t, and money supply, M_t, may or may not have a significant effect on output. (Their coefficients may or may not be significantly different from zero at both the 5% and 1% levels.)

If the number of lags over which the test is performed is raised to six ($f = 6$), support for "economic policy ineffectiveness" sems to be stronger, the more so if the analysis is associated with output rate of growth lagged up to three time periods ($q = 3$). If the estimates are repeated over the 1970.I-1979.IV time period, we obtain the same result, even if overall support for "economic policy ineffectiveness" seems to be stronger.

T.J. Sargent (1973) suggests an additional test in which the simultaneous relevance of stimuli entering the information set of the public is assessed. The tests above have been repeated, over four and six lags of x_t, with the following specification of x_t:

$$x_t = (M_t \; e_t \; P_{mt}).$$

The null hypothesis (that the coefficients of the lagged stimuli x_t are zero) is always accepted if the test is performed over six lags ($f = 6$) at the 5% significance level, supporting the "economic policy ineffectiveness" proposition. The null hypothesis is rejected if the test is performed over four lags ($f = 4$); if $y_{nt} = c_1 \, y_{t-1} + c_2 \, y_{t-2} + c_3 \, y_{t-3}$ is used, it is not rejected however at the 1% level of significance.

Analogous results are obtained if the test is performed over the 1970.I-1979.IV time period.

4.2. Rationality Tests.

Rational Expectations imply that individual economic agents include in their information set past relevant data as soon as they become available to them. We have assumed above that data from the previous quarter onwards are perceived and enter the information set. Some events (data) may take longer to be perceived by the public and to influence the expectations formation process.

If we raise the length of the time lag with which data are assumed to enter the information set, i.e. give individual agents more time (and thus more data) to form their expectations, and if the Rational Expectations hypothesis holds, expectations should become more accurate.

The additional time needed to improve expectations may be sometimes very short: the shorter the time period needed to develop (optimal) Rational Expectations, the "stronger" the Rational Expectations hypothesis.

This assumption can be tested by means of the "economic policy ineffectiveness" proposition[10].

In order to investigate the nature of the Rational Expectations formation process and the corresponding timing of the reaction of the economy to unanticipated stimuli, various possible lags with which variables might be perceived and enter the information set of the public have been examined. Let

$$x^{o}_{t,j} = E\,(x_t \,/\, \psi_{t-1-j}) = 1/4 \sum_{i=1}^{4} x_{t-i-j} \quad , \quad j = 0, 1, 2, 3, 4.$$

be the MA anticipation proxy of the variable x_t, and

$$x^{\circ}_{t,j} = E(x_t / \psi_{t-1-j}) = \eta(L)\, x_{t-j} \qquad , j = 0, 1, 2, 3, 4.$$

be the OA anticipation proxy of x_t.

Unanticipated stimuli become:

$$x_t - x^{\circ}_{t,j} = x_t - 1/4 \sum_{i=1}^{4} x_{t-i-j} \quad \text{and}$$

$$x_t - x^{\circ}_{t,j} = x_t - \eta(L)\, x_{t-j} \qquad , j = 0, 1, 2, 3, 4.$$

A corollary of the Natural Rate of Unemployment with Rational Expectations model and of the ensuing "economic policy ineffectiveness" proposition, is that the longer the "black out" interval (between economic policy stimuli and their perception by economic agents), the larger the scope for active anticyclical economic policy of the authorities; the shorter the "black out" interval, the smaller the likelihood that systematic anticyclical economic policy measures will have real effects.

We can test these hypotheses with the help of the following relationships (the symbols are those of the previous section):

Price Expectations Formation Relationship

$$\text{(XI)} \quad P_t = AM^{\circ}_{t,j} + BZ^{\circ}_{t,j} + C + u_{11t} \quad , \quad P^{\circ}_{t,j} = P_t - u_{11t} \quad ,$$
$$j = 0, 1, 2, 3, 4.$$

Lucas Supply Curve[11]

$$\text{(XII)} \quad y_t = \alpha + \beta \cdot y_{nt} + \gamma(\hat{P}_t - P^{\circ}_{t,j}) + (u_{12t} + \gamma f_t)$$
$$j = 0, 1, 2, 3, 4.$$

Price Forecast Errors Equation

$$\text{(XIII)} \quad P_t = FP^{\circ}_{t,j} + a_3 (P_{mt} - P^{\circ}_{mt,j}) + u_{13t} \qquad (12)$$
$$j = 0, 1, 2, 3, 4.$$

Lucas Supply Curve Reduced

$$\text{(XIV)} \quad y_t = \alpha + \beta y_{nt} + \gamma_1 (M_t - M^{\circ}_{t,j}) + \gamma_2 (e_t - e^{\circ}_{t,j}) +$$
$$+ \gamma_3 (P_{mt} - P^{\circ}_{mt,j}) + u_{14t} \qquad j = 0, 1, 2, 3, 4.$$

If the Rational Expectations hypothesis holds, we expect the quality of fit of the Rational Price Expectations formation relationship, equation (XI), to improve as j is raised since individual agents are given more time to develop their expectations about the (unobservable) value of P_t. At the same time we expect coefficient γ of the Lucas supply curve, equation (XII), to become smaller in absolute value, or even not significantly different from zero as j is raised, since price expectations become more accurate and expectations errors correspondingly smaller.

If the Rational Expectations hypothesis holds, unanticipated stimuli coefficients, γ_1, γ_2, γ_3 of the Lucas supply curve reduced, equation (XIV), should become smaller or even not significantly different from zero as j is raised, since stimuli forecasts become more accurate.

Price expectations, $P^{\circ}_{t,j}$, should have a one to one effect on P_t in equation (XIII) as j is raised, whilst the coefficient of unanticipated import prices changes should become smaller.

Empirical investigations of equations (XI), (XII), (XIII), and (XIV), performed over the 1960.I-1979.IV time period, seem to support the Rational Expectations hypothesis.

Estimates of the Lucas supply curve (equation (XII), Table IV), however, do not always support this hypothesis: if MA stimuli are used, coeffi-

Table IV

$y_{nt} = c_1 y_{t-1}$ *

1960.I-1979.IV

Price Forecast Error Determination Relationship: (XIII) $P_t = FP^{\circ}_{t,j} + a_3(P_{mt} - P^{\circ}_{mt,j}) + u_{13t}$

Lucas Supply Curve: (XII) $y_t = \alpha + \beta y_{nt} + \gamma(\hat{P}_t - P^{\circ}_{t,j}) + (u_{12t} + \gamma f_t)$

Price Expectations Formation Relationship: (XI) $P_t = a_1 M^{\circ}_{t,j} + a_2 e^{\circ}_{t,j} + a_3 P^{\circ}_{mt,j} + EP_{t-1} + Fy_{nt} + C + u_{11t}$

Lags	Ant. St.	F	a_3	S.E.	D.W.	Ant St.	γ	$\bar{R}^2$	S.E.	D.W.	Ant St.	$\bar{R}^2$	S.E.	D.W.
0	MA	1.00	0.08	0.0130	1.69	MA	1.66	0.56	0.047	1.95	MA	0.94	0.0157	1.45
		(70.02)	(5.06)				(3.36)							
1	MA	1.00	0.05	0.0132	2.02	MA	1.50	0.55	0.047	1.96	MA	0.94	0.0157	1.47
		(58.06)	(3.69)				(2.99)							
2	MA	0.99	0.04	0.0130	2.02	MA	1.60	0.55	0.047	1.98	MA	0.95	0.0151	1.50
		(55.64)	(3.04)				(3.02)							
3	MA	0.99	0.03	0.0133	1.74	MA	1.86	0.58	0.046	1.96	MA	0.95	0.0146	1.67
		(66.43)	(2.76)				(3.68)							
4	MA	0.99	0.03	0.0127	2.02	MA	2.02	0.60	0.045	1.89	MA	0.96	0.0039	1.91
		(69.26)	(2.66)				(4.18)							
0	OA	0.99	0.13	0.0110	1.78	OA	1.45	0.54	0.048	1.98	OA	0.95	0.0146	1.80
		(77.40)	(5.65)				(2.90)							
1	OA	1.00	0.07	0.0121	1.97	OA	1.86	0.56	0.047	1.98	OA	0.95	0.0149	1.23
		(62.63)	(4.12)				(3.28)							
2	OA	0.99	0.06	0.0127	2.02	OA	1.27	0.52	0.048	1.97	OA	0.94	0.0155	1.44
		(57.15)	(4.04)				(2.40)							
3	OA	0.99	0.03	0.0129	2.00	OA	1.18	0.51	0.049	1.99	OA	0.95	0.0149	1.42
		(55.75)	(2.71)				(2.08)							
4	OA	0.99	0.03	0.0138	1.76	OA	1.31	0.59	0.046	1.96	OA	0.95	0.0142	1.61
		(63.40)	(2.86)				(3.99)							

* Estimates have been repeated with $y_{nt} = c_1 y_{t-1} + c_2 y_{t-2} + c_3 y_{t-3}$, with no significant alteration of the results in the case of equations (XIII) and (XI). Some relevant changes did occur however, in the estimation of the Lucas supply curve (equation (XII)).

Table V

$y_{nt} = c_1 y_{t-1}$ *

1960.I-1979.IV

Lucas Supply Curve Reduced

(XIV) $y_t = \alpha + \beta y_{nt} + \gamma_1(M_t - M^{\circ}_{t,j}) + \gamma_2(e_t - e^{\circ}_{t,j}) + \gamma_3(P_{mt} - P^{\circ}_{mt,j}) + u_{14t}$.**

Lags	Ant. St.	γ_1	γ_2	γ_3	$\bar{R}^2$	S.E.	D.W.	Ant. St.	γ_1	γ_2	γ_3	$\bar{R}^2$	S.E.	D.W.
0	MA	0.48	0.17	0.21	0.72	0.037	1.80	OA	0.57	0.25	0.25	0.70	0.038	1.95
		(4.59)	(3.25)	(3.39)					(9.17)	(3.65)	(2.97)			
1	MA	0.49	0.12	0.16	0.70	0.038	1.68	OA	0.50	0.19	0.10	0.34	0.041	2.34
		(5.33)	(2.49)	(3.00)					(3.89)	(2.78)	(1.87)			
2	MA	0.50	0.09	0.12	0.67	0.040	1.48	OA	0.43	0.14	0.07	0.31	0.042	2.17
		(5.78)	(1.98)	(2.33)					(4.13)	(2.22)	(1.57)			
3	MA	0.47	0.09	0.05	0.63	0.042	1.42	OA	0.37	0.13	-0.0003	0.30	0.042	2.05
		(4.94)	(1.70)	(1.00)					(4.34)	(2.25)	(-0.01)			
4	MA	0.38	0.07	-0.01	0.58	0.046	1.43	OA	0.35	0.11	-0.03	0.25	0.044	2.06
		(3.52)	(1.28)	(-0.18)					(4.11)	(1.73)	(-0.89)			

* The estimates have been repeated with $y_{nt} = c_1 y_{t-1} + c_2 y_{t-2} + c_3 y_{t-3}$, whith no significant alteration of the results.

** Non linear estimates have been performed: they provide similar results.

cient γ tends to become larger as j is raised from 0 to 4, contradicting the Rational Expectations test specified above, since the corresponding price expectations formation fit seems to improve, providing more accurate price forecasts. Only if 0A stimuli are used do the results confirm the Rational Expectations hypothesis test above, since the value of γ declines as j rises.

If these estimates are performed over the 1970.I-1979.IV time period, we obtain results that show a more rapid perception of data and a speedier convergence of Rational Expectations to their equilibrium value. The "black out" period seems to have become shorter and the Rational Expectations hypothesis stronger.

This can be seen from the estimates of the Lucas supply curve reduced (equation (XIV), Table VI), since the value of the coefficients of the unanticipated stimuli declines more rapidly than in the 1960.I-1979.IV time period estimation above. An analogous result is provided by the estimates of the price expectations formation relationship (equation (XI) , Table VI): the fit is already very good for $j = 0$ and does not seem to improve, as j is raised, showing that price expectations have, from the outset, converged to their optimal Rational Expectations value. Price equation (XIII), Table VI), provides results that support the Rational Expectations hypothesis, and are not very different from those obtained over the 1960.I-1979.IV time period.

Table VI

* $y_{nt} = c_1 y_{t-1}$ *

1970.I-1979.IV

Lucas Supply Curve Reduced**

(XIV) $y_t = \alpha + \beta y_{nt} + \gamma_1(M_t - M^{\circ}_{t,j}) + \gamma_2(e_t - e^{\circ}_{t,j}) + \gamma_3(P_{mt} - P^{\circ}_{mt,j}) + u_{14t}$

Price Forecast Error Relationship

(XIII) $P_t = FP^{\circ}_{t,j} + a_3(P_{mt} - P^{\circ}_{mt,j}) + u_{13t}$

Price Expectations Formation Relationship

(XI) $P_t = a_1 M^{\circ}_{t,j} + a_2 e^{\circ}_{t,j} + a_3 P^{\circ}_{mt,j} + EP_{t-1} + F_{ynt} + C + u_{11t}$

Lags	Ant. St.***	γ_1	γ_2	γ_3	$\bar{R}^2$	S.E.	D.W.	F	a_3	S.E.	D.W.	$\bar{R}^2$	S.E.	D.W.
0	MA	0.43 (3.43)	0.34 (3.02)	0.34 (5.03)	0.79	0.0360	1.74	1.00 (60.38)	0.06 (3.36)	0.0144	2.15	0.92	0.0170	1.93
1	MA	0.47 (3.49)	0.07 (0.91)	0.06 (1.11)	0.30	0.0486	2.01	1.00 (58.21)	0.04 (2.74)	0.0150	1.89	0.92	0.0173	1.73
2	MA	0.40 (3.28)	0.06 (0.76)	0.01 (0.22)	0.24	0.0590	1.86	0.99 (57.56)	0.03 (2.19)	0.0151	1.72	0.92	0.0169	1.68
3	MA	0.33 (2.82)	0.09 (0.98)	-0.04 (-0.77)	0.19	0.0524	1.74	0.99 (59.38)	0.02 (1.87)	0.0146	1.75	0.93	0.0161	1.71
4	MA	0.25 (2.17)	0.10 (1.01)	-0.06 (-1.29)	0.14	0.0542	1.71	0.99 (58.47)	0.03 (2.04)	0.0147	2.03	0.93	0.0164	1.92

* The estimates have been repeated with $y_{nt} = c_1 y_{t-1} + c_2 y_{t-2} + c_3 y_{t-3}$ with no relevant alteration of the results.

** Nonlinear estimates have been performed and have provided similar results.

*** The estimates have been repeated with OA anticipated stimuli, with no significant alteration of the results.

5. *Concluding Remarks*

The Natural Rate of Unemployment and the Rational Expectations hypotheses of classical macroeconomics have been subjected in this paper to some preliminary empirical tests using Italian quarterly data over the 1960-1979 time period.

These hypotheses do not seem to be contradicted by Italian data, especially in the 1970-1979 subperiod. The crudeness of the approaches used here, however, calls for further, more sophisticated, empirical investigations.

APPENDIX

Definition and Statistical Sources of the Relevant Time Series.

Definition	Source
P_t = rate of growth of consumer prices	ISTAT, "Annuario Statistico Italiano", various issues.
y_t = rate of growth of industrial output	ISTAT, "Annuario Statistico Italiano", various issues.
P_{mt} = rate of growth of import prices expressed in Italian lira	OECD, "Main Economic Indicators", various issues.
e_t = rate of growth of the volume of Italian exports	OECD, "Main Economic Indicators", various issues.
DG_t = rate of growth of Government expenditure	OECD, "Main Economic Indicators", various Issues.
M_t = rate of growth of money supply	IMF, "International Financial Statistics", various issues.
DB_t = rate of growth of the public debt in the hands of the public. This time series is assumed to include Treasury Bills and Public Sector Assets not purchased by the Bank of Italy. Public sector assets lump together Government Assets and bonds issued on behalf of the Treasury and of various local agencies (Enti Locali). To this aggregate are added Postal Savings.	Banca d'Italia, "Bollettino", various issues.

Rate of growth of the variable x_t (using quarterly data) =

$$(x_t - x_{t-4}) / x_{t-4} .$$

NOTES

(1) R. Barro, (1977, 1978) and others have used a rather different approach, and have developed a money supply growth relationship, which is supposed to quantify the authorities' money feedback rule as seen by the public.

E.J. Bomhoff (1980) interprets a Box and Jenkins ARIMA (0, 1, 1) money rate of growth relationship as a monetary reaction function too. The other anticipated stimuli quantification approaches have not been interpreted in that way.

(2) This proposition has been set forth by T.J. Sargent (1976a). Consider the following Lucas supply relationship:

(I) $\lambda(L)\, y_t = \gamma(P_t - E_{t-1}\, P_t) + u_t$

(II) $P_t = d\,(L)\, \mu_t$,

where

$$d(L) = \sum_{i=0}^{\infty} d_i\, L^i \quad ; \lambda(L) = \sum_{i=0}^{\infty} \lambda_i L^i ,$$

y_t = rate of change of output;

P_t = rate of change of prices;

$E_{t-1}\, P_t$ = mathematical expectations of P_t, conditional on past P_t.

$\lambda(L)$ and $d(L)$ are assumed to have both one-sided inverses under convolution and u_t and μ_t are mutually and serially independent random variables, with mean zero and finite variance. Unanticipated changes in prices bring about changes in y_t.

The system above can be rewritten as:

(III) $y_t = \lambda^{-1}(L)\,\gamma\, d_0\, \mu_t + \lambda^{-1}(L)\, u_t$

(IV) $P_t = d\,(L)\, \mu_t$.

Inverting (IV) and substituting into equation (III), we obtain:

(V) $y_t = \lambda^{-1}(L)\,\gamma\, d_0\, d^{-1}\,(L)\, P_t + \lambda^{-1}(L)\, u_t$.

Inverting (V) we obtain:

(VI) $\lambda(L)\, y_t = \gamma d_0\, d^{-1}\,(L)\, P_t + u_t$.

Equation (VI) is a standard reduced form used by Keynesian econometricians to quantify Phillips curve like relationships, and is "observationally equivalent" to the Lucas supply curve (equation (I)). Such an equivalence would disappear if P_t were to depend on factors that do not appear in equation (I).

(3) These assumptions have been made on the basis of the autoregressive structure of the y_t time series, which can be represented either by a first order or by a third order autoregression. Over the 1960.I-1979.IV time period,

we obtain the following estimates:

$y_t = 0.79\, y_{t-1}$; S.E. = 0.052 ; D.W. = 1.81 ; D.h. = -0.97 ;

(10.15)

$y_t = 0.85\, y_{t-1} + 0.13\, y_{t-2} - 0.28\, y_{t-3}$; S.E. = 0.050 ; D.W. = 2.13 ;

(6.89) (0.79) (-2.27) D.h. = 2.69.

(4) Reduced form (V) has been used to measure the relevance of the "economic policy ineffectiveness" proposition once equation (I) has been used to assess its validity, since relationships of this kind are compatible with nonneutral interpretations. (This is the case because we assume that M°_t and Z°_t depend only on own past values.)

(5) In the case of moving average expectations (MA),

$$\psi_{t-1} = (x_{t-1}\ x_{t-2}\ x_{t-3}\ x_{t-4})\ ;$$

in the case of own autoregressive expectations (OA):

$$\psi_{t-1} = (x_{t-1}\ x_{t-2}\ \ldots)$$

depending upon the autoregressive structure of the time series under examination. Since ϑ_{t-1} is composed of M_t, e_t, P_{mt}, y_{nt} and P_{t-1}, with lags of various length, ψ_{t-1} is a subset of ϑ_{t-1}.

The quarterly rate of growth (quarterly rate of change) of the variable x_t is given by

$$(x_t - x_{t-4}) / x_{t-4}\ .$$

(6) This relationship is important for the neutrality issue. We assume that M°_t, e°_t and P°_{mt}, variables that influence price expectations, do not have an independent influence on output rate of growth. We avoid in this way the problem of observational equivalence between neutral and nonneutral relationships mentioned by T.J. Sargent (1976a). The statistical independence of y_t from lagged values of M_t, e_t and P_{mt} has been checked by means of Granger tests in section 4.1 below.

(7) This "so-called simultaneous equations bias" affects coefficient γ only. Since it is assumed that

$$E\,(u_{1t} / \vartheta_{t-1}) = 0\ ,$$

it follows that u_{1t} is uncorrelated with P°_t, since the latter is a linear combination of elements of ϑ_{t-1}. Moreover, by construction of P°_t in equation (III), $(P_t - P^{\circ}_t)$ is orthogonal to y_{nt}, P_{t-1} and to M°_t, e°_t and P°_{mt} by the orthogonality of least squares residuals to regressors. However P_t, and thus $(P_t - P^{\circ}_t)$, are correlated with u_{1t}, the error term of equation (I).

(8) $\hat{P}_t$ is the fitted value of P_t from a first stage OLS regression of P_t on a constant, y_{nt}, P_{t-1} and current and lagged values (with lags of up to four quarters) of the exogenous variables of the model, i.e. of M_t,

e_t and P_{mt} .

(9) According to T.J. Sargent (1973), the rationale for this test is the following: assume output rate of growth has the following ARMA representation:

$$y_t = \sum_{i=1}^{q} c_i y_{t-i} + \sum_{j=0}^{f} \beta_j \varrho_{t-j} ,$$

ϱ_{t-j} is a serially uncorrelated, normally distributed, random variable. The Natural Rate of Unemployment (neutrality) hypothesis implies that the random part of output rate of growth cannot be correlated with past endogenous and exogenous variables:

$$E (\varrho_t / \vartheta_{t-1}) = 0 ,$$

or, if we want,

$$E (y_t / y_{t-1} , ... , y_{t-q} , \vartheta_{t-1}) = E (y_t/y_{t-1} , ... , y_{t-q}) =$$

$$= \sum_{i=1}^{q} c_i y_{t-i} .$$

F tests above, based on the standard C.W.J. Granger (1969) causality analysis, are meant to test this hypothesis.

(10) S. Fischer (1980) had analysed a similar problem in the context of R. Barro's standard model of 1978.

(11) We assume here that the Lucas supply curve is not affected by

money illusion, i.e. that it satisfies the neutrality principle. This assumption has to be made in order to isolate the effects of different rationality hypotheses on the "economic policy ineffectiveness" proposition.

(12) Unanticipated changes in money supply and in the volume of exports have no effects on P_t and have thus been dropped from the estimation of the price forecast errors equation.

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