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Rationality and the Gibson Paradox

Sargent's early work as a quest for consistency

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I. Introduction

From the 1970s onwards New Classical Economics attracted much attention in the economics profession. Both the 'realism' of its assumptions and the relevance of its conclusions have been severely criticized.' This criticism was particularly directed against Sargent and Wallace's (1976) policy-irrelevancy proposition, which holds that anticipated monetary policy does not have real effects. As Klamer's (1985) analysis of the 'rhetorics' of New Classical Economics (NCE) has shown, though, the controversy reflects considerable confusion about the central issues at stake in the 'rational-expectations revolution'. This becomes clear from the fact that New Classicals have been criticized on grounds which they themselves considered less important.[3] This constitutes the *raison-d'être* of studies that try to sort out what the 'revolution' was all about.

The studies of Maddock (1979, 1984) and Klamer (1981, 1985) have been the first to address this question. The former rationally reconstructs Lucas's contributions to the rise of the NCE along Lakatosian lines. He shows that Lucas (1972b) provided the initial formulation of the rational expectations research programme by combining Friedman's (1968) Natural Rate Hypothesis (NRH) with Muth's (1961) 'rational expectations hypothesis' (REH). In its most extreme version the resulting 'joint NR/RE hypothesis' holds (1) that deviations from the 'natural rate equilibrium' (NRE) are due to a lack of information on the part of the economic agents, and (2) that the resulting expectational errors are unsystematic. This was a novel prediction, so that Lucas's derivation of the joint hypothesis may be considered theoretically progressive. Maddock (1984, 295) further shows that Lucas's subsequent contributions aimed to develop (1) tests in order to provide empirical support for the programme's novel prediction, and (2) procedures which would protect the joint hypothesis from refutation. In other words, they were not geared towards novel predictions, but instead tried to protect the joint NR/RE hypothesis which formed the programme's hard core. The consequent danger of theoretical as well as empirical degeneration of the programme was averted by Sargent's (1973b) novel prediction that deviations of output from its natural rate in any period are independent from any information available in policy rules at the moment of prediction. Sargent and Wallace (1975, 1976) subsequently tested this prediction by evaluating the respective predictive powers of 'natural rate' and 'unnatural rate' models. Since it involved a novel fact, this shift in attention from the joint NR/RE hypothesis to the analysis of

the implications of rational expectations for the theory of economic policy constituted a progressive problem shift in the rational expectations programme. It led Maddock (1984, 291-292) to conclude that ". . . even though its roots are in monetarism, [the NCE] is more likely ultimately to find a place within the theory of policy."

As De Marchi (1990) pointed out, Maddock's reconstruction focuses on deduced test implications and novel facts, neglecting the underlying process of 'discovery'. In De Marchi's view, though, Lucas has never put much weight to empirical tests and the test results, and was more interested in apparent side issues, such as the Lucas critique. De Marchi therefore claimed that technical and conceptual considerations have played a more prominent role in Lucas's research agenda than the test implications. That is, the conclusions-generating process (the heuristic) itself has been more important in the development of Lucas's work than its outcomes.[4] This conclusion is supported by the fact that Lucas's (1973) test of the joint NR/RE hypothesis did not fully capture all knowledge available at the time, so that the epistemic value of his generative process was not fully reflected in its outcomes.' De Marchi (1990) subsequently analyzed this process, taking Lakatos's 'pluralistic model' as his starting point.

Lakatos (1970, 128-131) developed his pluralistic model in his attempt to explain why it can be rational (and intellectually honest) for scientists to adhere to theories that appear to be refuted by the facts. What he called 'naive falsificationism' holds that such a refutation should lead to a rejection of the theory in question. Agassi (1966, 18) had already argued that scientists may ". . . stick to the hypothesis [i.e. theory, RvZ] in the face of known facts in the hope that the facts will adjust themselves to theory rather than the other way round." However, he had not given an (normative) answer to the question under what conditions such an outcome should prevail. Lakatos's 'sophisticated falsificationism' tries to give such an answer. It starts from the insight that there are no such things as 'hard facts'. And since the 'hardness' of facts may thus be disputed, scientists may seek recourse to an appeal procedure in order to save their theories from rejection.

According to Lakatos's (1970, 129) pluralistic model, any explanation of an observed phenomenon contains two aspects (or 'theories'), one interpretative and one explanatory.[6] The former aspect contains all 'theories' that are necessary to yield the facts to be explained. These theories may concern such wide-ranging issues as the appropriate way to translate certain concepts into measurable variables, the best ways to measure these variables, or even the views about the (non-)rationality of the human actions which are reflected in the concepts and variables. The explanatory aspect, on the other hand, consists of the formal model actually developed in order to motivate the interpretative aspect. Both aspects may be closely related, although this does not mean that they cannot be inconsistent. In fact, Lakatos (1970, 129) argued that a refutation reflects such an inconsistency. To put it in his own words, "[i]n the pluralistic model the clash is not 'between theories and facts' but . . .

between an *interpretative theory* to provide the facts and an . . . *explanatory theory* to explain them" (italics in original). De Marchi's paper on Lucas's work in the late 1960s and early 1970s shows that such an inconsistency may constitute an important internal source for scientific dynamics.'

Both Maddock and De Marchi restricted their respective analyses to the role played by Lucas in the rise of the NCE.[8] This raises the question how other New Classical economists came to join this programme. In his conversation with Klamer (1985, 63), Thomas J. Sargent recalled that as a second- or third-year graduate student he became aware of the fact that there was no link between (neoclassical) theories and statistical tests. The latter treated the data probabilistically, thus assuming that agents act in an environment in which there is uncertainty, whereas neoclassical economics assumed this uncertainty away. In the early 1970s he considered this defect remedied, in the sense that "[t]he stochastic or random variables in new classical models provide the statistical properties that econometric testing requires; the rational expectations hypothesis introduces the necessary dynamic element" (in Klamer 1985, 244). Sent (1993) questioned this assessment. Her reconstruction of Sargent's early work shows that the link could only be established by assuming that random variables have finite variances. In her view, though, the adoption of this crucial assumption was hardly justified.

The above studies on Sargent's contributions to New Classical Economics stress his work in the field of econometrics. Consequently, they do not pay much attention to the economic-theoretical content of his work, presumably because of the complexity of social (scientific) reality. The present paper aims to supplement the above studies in this regard. Taking De Marchi's (1990) considerations about the generative process into account (see above), it aims to show how Sargent's conclusions-generating process involved a change of his explanation of the Gibson paradox. The paper is organized as follows. Section 2 discusses some early solutions to the Gibson paradox, and particularly those of Keynes (1930) and Fisher (1930). Section 3 outlines Sargent's interpretation and criticism of the latter's solution. It reflects the fact that Sargent considered this solution inconsistent with the rationality postulate. Section 4 describes how this forced him to choose between the postulate and the formal model (i.e. the explanatory theory). Favouring the former over the latter, he thus faced the problem of providing an alternative explanation of the paradox. Section 5 discusses how he solved this problem by changing both the interpretative and explanatory aspects of his explanation of the paradox. Section 6 subsequently addresses the empirical tests of this alternative explanation. The tests yielded rather unfavourable results. However, Sargent considered the derivation of the tests more important than their outcomes, and hence did not reject his explanation. Instead, he adopted three types of defenses. Section 7 contains a summary and the main conclusions.

II. Some early solutions to the Gibson paradox

Sargent's work in the late 1960s and early 1970s was concerned with the relationship between the general price level and the rate of interest. In his 'Commodity price expectations and the interest rate' (1969) he addressed what Keynes (1930) had called the 'Gibson paradox'. 'Classical' theory implies that a rise (fall) in the interest rate produces deflationary (inflationary) pressures because of the gap between desired savings and investment, and the ensuing fall (rise) in effective demand. It thus predicts that the price level moves in the opposite direction as the interest rate. However, Gibson (1923) found that in reality the interest rate and the price level tend to move together, thus confronting 'classical' economic theory with an anomaly. Presumably the best known solutions to this anomaly are those of Keynes (1930) and Fisher (1930).[9]

Following Wicksell (1898), Keynes (1930, 203-204) argued that the Gibson paradox is the result of the relative stickiness of the market rate of interest (r_m) ***as*** compared with the natural rate of interest (r_n). This means that the former cannot maintain equilibrium between ***ex-ante*** saving (S) and ***ex-ante*** investment (I). Since r_n is presumed to exhibit long-term movements, r_m will fail to equilibrate S and I. More particularly, if r_n is rising (falling), then $r_n > (<)\ r_m$ and hence $Z > (<)$ S. In turn, this means that the price level will fall (rise)." To summarize, a fall (rise) **in** r_n has two effects. Firstly, it induces a fall (rise) in r_m. Secondly, it ensures that $I < (>)$ S, bringing about a fall (rise) in the general price level. The interest rates and this price level thus move together.

Fisher (1930, 43) provided an alternative explanation of the paradox. He distinguished between the monetary and the real rate of interest. In equilibrium the former equals the latter ***plus*** the rate of inflation. In a situation of perfect foresight, economic agents will fully anticipate increases (decreases) in the rate of inflation, and will respond in such a way as to leave the real rate of interest unaffected. However, Fisher (1930, 44) opined that economic agents suffer from an "... almost universal lack of knowledge", so that their inflationary expectations are unlikely to come true. ***The unanticipated*** increases (decreases) in the rate of inflation will ***not*** be reflected immediately in what may be called the 'inflation premium' in the nominal interest rate. Hence the real rate of interest will be distorted. However, the expectational errors bring about an adjustment process, moving the real rate of interest towards its equilibrium value. This equilibrating process raises (lowers) the nominal rate of interest in response to some increase (decrease) in the rate of inflation. Fisher thus explained the Gibson paradox in terms of expectations adjustment. That is, he interpreted the positive correlation between the nominal rate of interest and the rate of inflation as the result of economic agents revising their expectations.

In his empirical work Fisher (1925, 184) and (1930, 419) used a formal model (an explanatory theory) that included what later came to known as the 'adaptive

expectations hypothesis' (AEH). This hypothesis holds that the expectations adjustment process can be described as a distributed lag function. Fisher found that the lag weights of this function declined slowly, and that the transition period was therefore rather long (Fisher 1930, 427). His estimates suggested that it could take no less than ten to thirty years before the effects of unanticipated changes in the inflation rate were incorporated in the nominal rate of interest, and even then the adjustment was still incomplete. In Fisher's (1930, 429) view, this length of the lag results from an intervening factor, namely ". . . business, as exemplified or measured by the volume of trade." His explanation runs in terms of what may be called ***Fisher's indirect effect***, which holds that unanticipated price increases and lagging factor remunerations lead entrepreneurs to earn larger profits. Consequently, they will increase ex-ante investments and hence their demand for credit. Given the propensity to save, banks will be forced to raise the nominal interest rate in order to avoid liquidity problems. This rate thus follows the upward movements in the rate of inflation, albeit with a lag."

To summarize Fisher's position, we can identify an interpretative and an explanatory aspect of his explanation of the Gibson paradox. The former holds that the positive correlation between the nominal rate of interest and the rate of inflation is due to expectational errors. The length of the adjustment lag was seen as the result of an intervening factor, namely 'business' (or aggregate demand). These interpretative theories were translated into a formal model, an explanatory theory. This model contained a distributed lag function that was intended to capture the length of the adjustment period. However, it did not fully express the interpretative aspects of Fisher's theory, because it did not specify the intervening factor 'business'. This may have wrong-footed Sargent in his early efforts to deal with the Gibson paradox.

III. A problematical interpretative theory: the implausible length of the transition period

Sargent (1969) also tried to explain the Gibson paradox in terms of expectations revision processes on the part of the economic agent. Both he and Fisher interpreted the positive correlation between the nominal rate of interest and the rate of inflation as the result of expectational errors. Nevertheless, Sargent's (1969) interpretative theory differed considerably from that of Fisher. The latter argued that the length of the lags between changes in the rate of inflation and in the nominal rate of interest reflects the influence of an intervening factor, called 'business'. In contrast, Sargent interpreted Fisher's distributed lag function as an expectations formation mechanism. His interpretative theory thus dispenses with the intervening factor, and instead explains the length of the lags as the result of sluggish expectations revision processes only. Given Fisher's estimates of these lengths, this means that it would take

ten to thirty years before economic agents would have learnt the new rate of inflation, and would act accordingly. Sargent concurred with Cagan (1965, 257) that such sluggish expectations revision is rather implausible. In his view, rational economic agents would revise their expectations more quickly. Sargent's (1969) interpretative theory thus turned out to be inconsistent with another of his interpretative theories, the rationality postulate. Initially, he tried to remove this inconsistency by distinguishing two effects. The *extrapolative effect* holds that an increase (decrease) in the general price level induces economic agents to expect prices to rise (fall) still further. It thus tends to shorten the transition period. In contrast, the *regressive effect* holds that rising prices generate short-term expectations of a fall in the general price level. According to Sargent (1969, 138), "[t]he presence of such a [regressive] component of expectations was rational, given the cyclical properties of price movements over the period we are considering." In his view, this latter effect was responsible for the sluggish adjustment of expectations and hence for the implausible length of the transition period. It should be noted, though, that the two effects fail to solve Sargent's problem. Firstly, they were not included in his formal model, so that his explanatory theory did not fully capture his interpretative theory. Secondly and more importantly, the effects allow for systematic expectational errors which may be easily detected and corrected. Consequently, Sargent's explanation of the Gibson paradox was in danger of being inconsistent with the rationality postulate. This possible inconsistency did not merely pose a theoretical problem for Sargent: it had an important econometric repurcussion as well.

In his 1971 paper 'A note on the "accelerationist" controversy', Sargent showed that the inconsistency between his interpretative theory and the rationality postulate invalidated a common test of the NRH.[12] His argument can be made clear with the help of the following equation:

$$(3.1) \qquad \frac{\Delta w_t}{w_{t-1}} = \alpha \sum_{i=0}^{m} v_i \frac{\Delta P_{t-i}}{P_{t-i-1}} + f(U_t, \ldots) + \epsilon_t$$

in which the present relative change in nominal wage rate ($\Delta w_t/w_{t-1}$) is expressed in terms of past inflation rates ($\Delta P_{t-i}/P_{t-i-1}$), and some other variables. The equation combines the 'natural rate hypothesis' (NRH) with the AEH. The NRH is supposed to be corroborated if the coefficient of the past inflation rates, α, and hence the public's inflation expectation, is close to unity, whereas it is rejected if it is closer to zero. Estimation of the parameters is possible only if some restriction is added. According to Sargent (1971, 34), "[a]lmost always, the constraint that has been imposed is that the distributed lags in [the AEH] sum to unity." This constraint is justified by the argument that in the long run rational economic agents will fully incorporate an unexpected change in the rate of inflation into their price-expectations. In other words, given the interpretation of distributed lag functions as expecta-

tions adjustment mechanisms, the unity-restriction is assumed to capture the rationality postulate. However, adaptively formed expectations fully reflect all changes in the rate of inflation only if the new inflation rate remains unaltered for quite some time (otherwise expectations are always lagging). Sargent (1971) observed that in reality this is never the case. Given the fact that agents are presumed to form their expectations according to the AEH, this implies that they will make systematic expectational errors. As shown above, this may be inconsistent with economic rationality. Instead, it may be argued that rational economic agents will try to minimize their errors. Such minimization occurs if their expectations formation mechanism is compatible with the observed (actual) behaviour of the rate of inflation. Sargent therefore suggested that the most reasonable restriction which can be imposed on the sum of the distributed lags is the one which is compatible with this observed behaviour. He subsequently showed that this appropriate restriction is that this sum is *less* than unity (Sargent 1971, 3536). Consequently, the unity-restriction leads to underestimation of α, in which case the estimates of the common test "… tell us virtually nothing about the validity of the accelerationist thesis" (Sargent 1971, 37). That is, the inconsistency between economic rationality (as reflected in the unity-restriction) and the interpretative theory (according to which the distributed lag function represents the AEH) distorts the test results of the common test, so that its usefulness as an empirical test of the NRH is severely diminished. The question then arises how this inconsistency can be eliminated, so that these estimation problems can be avoided. This question may be addressed with either of the following three strategies. Firstly, the inconsistency may be resolved by abandoning the rationality postulate. Expectations revision processes then need not be rational, and hence may take up to thirty years. Secondly, the interpretative theory may be changed while leaving the explanatory theory unaffected. This means that the length of the transition periods has to be explained in terms of some rational expectations revision process, whereas the model describes this process as a distributed lag function. Thirdly, the explanatory theory may be changed as well, so that the explanation runs in terms other than expectation revision.

*IV. **Muth-rationality** as the key to consistency*

Sargent's first step towards the removal of the inconsistency is to be found in his 'Anticipated inflation and the nominal rate of interest' (1972), in which he tried to improve the formal model (explanatory theory) which Fisher had used in his empirical work. This model can be formulated as follows:

$$(4.1) \qquad r_t = \rho_t + \pi_t$$

(4.2) $\rho_t = a + \epsilon_t$

where r_t is the nominal rate of interest, ρ_t is the real rate of interest, π_t is the anticipated rate of inflation, α is a constant, and ε_t is a stochastic term which is uncorrelated with the nominal rate of interest. Equation (4.2) holds that the anticipated rate of inflation does *not* affect the real rate of interest (see Sargent 1972, 212-213). However, in transition periods economic agents make expectational errors about the rate of inflation, so that the actual rate of inflation cannot be fully reflected in the nominal rate of interest. This implies that the real rate of interest must have changed. Consequently, equation (4.2) cannot hold in transition periods, and hence it must be replaced. The question then arises as to the correct way of modelling the relationship between the nominal rate of interest and the anticipated rate of inflation. This question was addressed Sargent's 'Interest rates and prices in the long run' (1973a).

Sargent (1973a) started his analysis by performing a test of the length of the transition period, based on the equations (4.1) and (4.2). He combined them with the AEH, which yielded equation (4.3):

$$(4.3) \qquad r_t = \alpha + \gamma \sum_{i=0}^{\infty} \lambda^i \frac{\Delta P_{t-i}}{P_{t-i-1}} + \epsilon_t$$

where r_t is the nominal rate of interest, α is a constant, the sum is the adaptively formed expected rate of inflation, and ε_t is a stochastic term which is uncorrelated with the nominal rate of interest. Sargent estimated this equation for the U.S. in the period 1870-1940. The resulting estimates of the 'decay parameter' λ were close to unity. He concluded that "[t]hese estimates corroborate the main outlines of Fisher's findings" (Sargent 1973a, 392).[13] Fisher's explanatory theory thus proved to be satisfactory, in the sense that it was consistent with the 'data' as provided by Sargent's interpretative theory. However, as Sargent (1973a, 392) noted, "[w]hile Fisher's explanation of that [i.e. the Gibson] paradox formally 'works', the implied lags in forming expectations do seem extraordinarily long." The inconsistency between the interpretative theory and the rationality postulate still posed a problem.

As the above analysis already suggests, Sargent was not prepared to abandon the rationality postulate. Consequently, he faced the problem of changing his interpretative theory. This means that he could either give a different (e.g. Keynesian) explanation of the positive correlation between the nominal rate of interest and the rate of inflation, or explain the length of the transition period differently. He chose the latter option, arguing that this length could not result from lagged expectations revision. This means that he replaced the AEH with some other expectations formation mechanism. In Sargent's view, Muth's (1961) 'rational expectations hypothesis' (REH) formed an appropriate alternative mechanism. This hypothesis

holds that.expectations are essentially the same as the predictions of the relevant economic theory. Or, as Muth (1961, 316) formulated more exactly, "... expectations of firms (or, more generally, the subjective probability distributions of outcomes) tend to be distributed, for the same information set, about the prediction of the theory (or the 'objective' probability distributions of outcomes)." This quotation makes clear that the agents' information sets play a crucial role in their expectations formation process. If a theorist wants to obtain definite outcomes of the assumed expectations formation mechanism (as Muth did), he must make assumptions with regard to the content of these sets. Therefore, Muth (1961, 3 17) used ("[f]or purposes of analysis . . .") a 'specific form' of the REH. He assumed that the random disturbances are normally distributed. Individuals are also assumed to know these distributions, which means that on average their expectations are correct. That is, the expectations of the 'representative individual' are based on all relevant information. The forecasts of economic agents will then be identical (in a probabilistic sense) to those of statistical and economic theory, and in this sense they can be considered 'rational'. The problem with this Muth-rationality was, though, that it could not explain the lag between changes in the rate of inflation and in the nominal rate of interest. This means that the substitution of the REH for the AEH did not suffice. Sargent (1973a) therefore tried to supplement his interpretative theory.

V. Sargent's alternative interpretative theory: the influence of omitted variables

Sargent (1973a) argued that in his empirical work Fisher had only taken into account a one-way causal relationship between the rate of inflation and the nominal rate of interest, with causality running from the former to the latter. In this sense the inflation rate is exogenous. Sargent opined that this is unduly restrictive, and that it would be more appropriate to transform the interest rate into an endogenous variable. He suggested to test Fisher's model for feedback from the nominal rate of interest to the rate of inflation, using the Granger-Sims notion of causality as an indication of causation. Such a test involves the estimation of the influence of past inflation rates on the current nominal rate of interest. The relevant test equation then becomes:

$$(5.1) \qquad r_t = \sum_{j=-m_1}^{m_2} h_j \; p_{t-j} + v_t$$

where m_1 and m_2 are positive parameters, the h_j's are the estimated distributed lag parameters, and v_t is a statistical residual. Given the Granger-Sims notion of causality, the existence of a feedback from the nominal interest rate to the rate of inflation

means that future values of the latter are correlated with current values of the former. Hence Sargent tested the hypothesis that $h_j = 0$ for all $j < 0$. The test results indicated that "... an explanation of the interest-inflation relationship that does not permit feedback from interest to inflation is probably unduly restrictive" (Sargent 1973a, p. 422). However, the inclusion of such a feedback mechanism yields an interpretational problem of the REH, because "... it will no longer be 'rational' to form expectations of inflation by looking at current and lagged rates of inflation alone, since current and past rates of interest are of some help in predicting subsequent rates of inflation" (Sargent 1973a, p. 427). The interpretative theory could thus become inconsistent with the rationality postulate, and hence Sargent's quest for consistency would remain unsuccessful. Therefore, Sargent tried to remove this inconsistency by changing his interpretative theory. He abandoned the view that the feedback from interest to inflation is due to lagged expectations adjustment on the part of the economic agents, and instead argued that what appears to be feedback is actually caused by some omitted variables which influence both r and p. In Sargent's view, aggregate demand would be the relevant variable.

Having thus returned to Fisher's interpretative theory, the problem of building a consistent formal model (explanatory theory) remained. Sargent (1973a) built such a model which describes a closed economy with one good that is produced according to a linear-homogeneous production function in both labour and capital. Both the nominal interest rate and the rate of inflation are endogenous, and dependent on the (exogenous) variable 'money supply' (representing aggregate demand). A once-and-for-all change in this variable shifts the LM curve to the right, raising aggregate demand and employment and hence nominal wages. Furthermore, the shift of the curve lowers the nominal rate of interest, so that the real costs of capital fall below its marginal productivity. Consequently, the rate of capital accumulation rises. However, since the rate of money growth has not changed, this new rate of capital accumulation cannot be sustained. Eventually, Sargent assumed, the economy will return to its steady-state equilibrium. He concluded that "[t]he final result of the once-and-for-all increase in the money supply is thus to drive the level of money wages and prices upward proportionally, and to leave the interest rate, the real wage, and the output-capital ratio unchanged. Employment will equal the labor supply when the steady-state is achieved" (Sargent 1973a, 435). In other words, the model is a 'natural-rate' model, in which the respective long-run equilibrium values of all real variables are independent from the path of the economy towards that equilibrium: there is no hysteresis.'* Sargent subsequently used this model to generate artificial data. Like the historical data, these artificial data also proved to be infested by the Gibson paradox. His new explanatory theory (model) thus 'worked', in the sense that it could explain the facts provided by his new interpretative theory.

Sargent's model simulations affirm that he had changed his interpretative theory. Throughout the simulations Sargent had assumed that anticipated inflation is zero.[15]

This means that expectations about the rate of inflation did not change over the simulations, so that "... the long mean lag that characterizes the relationship between interest and inflation has nothing to do with long lags in adjusting expectations of inflation in response to the occurrence of actual inflation" (Sargent 1973a, p. 441). The length of the transition period thus had to be explained in other terms than that of sluggish expectations revision. As was shown above, Sargent had accomplished this by changing his interpretative theory. The transition period was now seen to result from changes in the money supply, not from lagged expectation revision. However, this change in interpretative theory did not solve all inconsistencies. The assumption of zero anticipated inflation implies that there is no difference between Fisher's nominal and real rates of interest. As Sargent (1973a, p. 442) noted, this means that "... it does not seem necessary to stress differences between nominal and real rates of return in order to explain the Gibson paradox." Stated differently, Sargent's interpretative theory had to account for the fact that both nominal and real rates of interest are positively correlated with the actual rate of inflation. Since this positive correlation between nominal and real variables suggests that economic agents suffer from money illusion, it threatened to make Sargent's new interpretative theory inconsistent with the rationality postulate. This problem proved to be similar to the one Lucas had faced concerning the relationship between the rate of unemployment and the rate of inflation, the so-called Phillips curve. Lucas had reinterpreted this curve as an inverse cyclical relationship, due to incomplete information on the part of the economic agents. Sargent (1973a) chose to resolve the problem of revising his interpretative theory in a similar manner. He argued that the relation between the real rate of interest and the rate of inflation does not only reflect the influence of omitted variables, but also results from incomplete information about the nature of changes in aggregate demand and "... the [ensuing] failure of wages and prices to adjust sufficiently quickly to keep output always at its full-employment level" (Sargent 1973a, 442). Consequently, the Phillips curve and the Gibson paradox can be explained in similar terms. Both start from the same interpretative theory, according to which they are short-term cyclical phenomena caused by unanticipated changes in the money supply. As Sargent (1987, 117n1) noted, in the long run Friedman's NRH and Fisher's two-equations model are two sides of the same coin.

Lucas's solution to the problem of explaining the Phillips curve in terms of the actions of rational though ill-informed economic agents, as represented by the 'Lucas supply function', thus proved to solve Sargent's problem as well. It is not surprising that in his article 'Rational expectations, the real rate of interest, and the natural rate of unemployment' (1973b), Sargent incorporated this function, thus explicitly connecting his work to that of Lucas.

VI. Sargent's tests: the relative unimportance of test outcomes

Having derived a formal model, Sargent (1973b) wanted to test this explanatory theory. He outlined two test procedures which can be used to test the theories of both Fisher and Friedman. Both procedures build on the insight that rational economic agents will use all available information in forming expectations. That is, the test hypothesis holds that the forecasts of the current unemployment rate cannot be improved by using information available at a previous date *t-l*. Assuming that the normally distributed error term in the Lucas supply function (u_t) is lagged n periods, the test of this hypothesis involves the estimation of equation (6.1):

$$(6.1) \qquad E(Un_t \mid Un_{t-1}, Un_{t-2}, \ldots, Un_{t-n-q}, \theta_{lt-n-1}) = E(Un_t \mid Un_{t-1}, Un_{t-2}, \ldots, Un_{t-n-q})$$

This equation implies that the forecast of the unemployment rate (Un_t), based upon its own past observations, cannot be improved by including components of the lagged information subset θ_{lt-n-1}. Hence the coefficients of these components will not differ significantly from zero when added to a regression of Un_t upon lagged values of itself. The first test procedure now assumes that the error terms are serially correlated. According to Sargent (1973b, 176), "[t]he higher the order of serial correlation in the u's [i.e. the larger *n]*, the more periods components of θ_t must be lagged to warrant the implication that their coefficients are zero." However, he did not perform this test, but instead proposed a second procedure.

Sargent's (1973b) second test proposal concerns the case in which u_t is *not* serially correlated. This means that the economic agents cannot improve their forecasts by including more information. That is, the expected value of Un_t formed on any subset θ_{lt-1} of the full information set θ_{t-1} equals zero. This hypothesis can be tested by regressing the current rate of unemployment upon components of the information subset. Sargent performed this test twice. He first regressed the rate of unemployment against its own lagged values and a subset θ_{lt-1} which consisted of the lagged price level (p_{t-1}, p_{t-2}, p_{t-3} and p_{t-4}) and the lagged nominal wage rate (w_{t-1}, w_{t-2}, w_{t-3} and w_{t-4}). Testing the null hypothesis that the coefficients on these lagged variables do not differ significantly from zero, he found that the regression corroborated this hypothesis at the 95% confidence level. It thus appeared that his explanatory theory was consistent with his interpretative theory. However, his second regression which included a larger subset of θ_t led to a quite different conclusion.[16] Sargent again tested the null hypothesis that the coefficients of the components of the enlarged subset under consideration have zero coefficients, but this time he found that this hypothesis was rejected at the 99% confidence level. This indicated that there was an inconsistency between the interpretative and the explanatory theory.

The negative result of the second test does not mean, of course, that the null hypothesis should be rejected. In fact, Sargent (1973b, 177-178) adopted three types of defenses against such a rejection. Firstly, he implicitly subscribed to the Duhem-Quine thesis when arguing that the assumption about the absence of serial correlation in the disturbance terms u's may not hold.[17] Furthermore, these terms may also be correlated with components from the information set. In both cases the test result will be biased towards discorroboration of the null hypothesis. Secondly, Sargent adopted the methodological position of sophisticated falsificationism, which holds that a theory should not be rejected unless some better alternative is available. He argued that there is no way of knowing whether such a better alternative theory exists until a comparative test (a 'horse race') between a 'natural rate' and an 'unnatural rate' equation is performed. Sargent (1973b) formulated these respective equations as follows:

$$(6.2) \qquad Un_t = \sum_{i=1}^{q} \lambda_i Un_{t-i} + \beta(p_t - Ep_t|\theta_{t-1}) + u_t$$

$$(6.3) \qquad Un_t = \sum_{i=1}^{q} \lambda_i Un_{t-i} + \beta(p_t - Ep_t|\theta_{t-1}) + \beta(1-\alpha)(Ep_t|\theta_{t-1} - p_{t-1}) + u_t$$

Equation (6.2) explains deviations from the natural rate of unemployment (NRU) in terms of random expectational errors about changes in the general price level. Hence it is a Lucas supply function. The difference between this equation and the 'unnatural rate' equation (6.3) lies in the third term on the right-hand side of the latter. This term represents the influence of the difference between the price forecast Ep_t based on information available in the previous period, and the actual price at that time. Since the latter is included in θ_{t-1}, the third term holds that an ***anticipated*** change in the rate of inflation affects the actual unemployment rate. Obviously, this implication is inconsistent with the joint NR/RE hypothesis. Sargent tested both equations for the United States over the period 1952:1 - 1970:4, using quarterly data. The 'horse race' between (6.2) and (6.3) favoured the latter, thus suggesting the rejection of the former. Sargent defended his explanation of the Gibson paradox in a third manner, arguing that it had not been rejected at an 'unusually high confidence level'. This raises the question, why such a level would be required and why a usually high confidence level does not suffice. The answer to this question seems to lie in Sargent's quest after consistency between (both the interpretative and the explanatory aspects of) his explanation of the Gibson paradox, on the one hand, and, on the other, the rationality postulate. Having succeeded in establishing this consistency, he refused to abandon his new explanation. This indicates that he considered the

epistemic value of the derivation of the test hypotheses (i.e., of the conclusions-generating process) greater than that of the tests themselves.'* This conclusion is in line with that of De Marchi (1990) concerning the early work of Lucas. It thus seems that the epistemic value of New Classical Economics can only be captured in full if one takes account of its conclusions-generating processes.

VII. Summary and conclusions

Some twenty years after the rise of New Classical Economics, and the accompanying rational-expectations revolution, it appears that the debate between its proponents and opponents on the importance and empirical validity of its test hypotheses has been somewhat misguided. As De Marchi (1990) argued, Lucas never was much interested in empirical tests and their outcomes. Instead, he was concerned with technical and conceptual considerations, so that the generative process (heuristic) itself appears to have been more important than its outcomes. Klamer (1985) and Sent (1993) showed that Sargent's early work addressed similar issues, in the sense that he tried to establish 'conceptual integrity' between (probabilistic) econometrics and (deterministic) neoclassical economics. The present paper supplements these analyses by showing how Sargent's quest for consistency affected the economic-theoretical content of his successive explanations of the Gibson paradox. In doing so, it adopts the Lakatosian view that the heuristic is a quest for consistency among theories.

Sargent (in his pre-1973 work) interpreted Fisher's (1930) distributed lag function as a formalization of the adaptive expectations hypothesis (which does not seem to be what Fisher had meant by it). Given the length of the adjustment period, this means that it would take ten to thirty years before economic agents would have adjusted their expectations to a change in the rate of interest, and would act accordingly. This interpretative theory of the adjustment period was clearly inconsistent with the rationality postulate. Furthermore, Sargent (1972) showed that Fisher's formal model (explanatory theory) was inconsistent with (Sargent's) interpretative theory, because it cannot describe transition periods and hence does not allow economic agents to make expectational errors. He decided that both the interpretative and the explanatory theory should be altered. Sargent (1973a) changed the former, in the sense that he allowed for feedback from the nominal rate of interest to the rate of inflation. However, this change did not solve his problem: the feedback made it difficult to interpret the REH, because rational agents would not only base their expectations about the rate of inflation on current and lagged rates of inflation alone, but also on current and past rates of interest. Therefore, Sargent altered his interpretative theory in another way, arguing that what appears to be feedback from interest to inflation is caused by some omitted variables which influence both variables. The main variable in this regard was 'aggregate demand' (represented by 'changes in the

money supply'). He conjectured that the Gibson paradox resulted from wage and price stickiness which failed to keep output at its natural rate. Unfortunately, this new interpretative theory also appeared to be inconsistent with the rationality postulate, because it seems to imply that economic agents suffer from money illusion. Sargent showed, though, that this inconsistency is similar to the one Lucas had faced concerning the Phillips curve, thus linking his work on neoclassical economics and econometrics with the latter's microeconomic foundations of New Classical macroeconomics. In both cases transition periods are explained as the result of expectational errors on the part of the economic agents, due to imperfect information. Sargent's (1973b) subsequent test of the hypothesis that agents cannot improve their forecasts by including more information yielded discorroborative results. Nevertheless, he did not reject the hypothesis, but instead defended it on three grounds. Firstly, he noted that the assumption about the absence of serial correlation in the disturbance term may not hold. Secondly, he adopted the methodological position of sophisticated falsificationism, according to which a theory should not be rejected if no better alternative is available. However, the results of a comparative test ('horse race') failed to support the joint NR/RE hypothesis. Sargent then adopted his third reason and argued that the test had not rejected the joint hypothesis at an 'unusually high confidence level'. This reflects the fact that he was engaged in a quest for consistency, in which he aimed to solve technical and conceptual issues, not to make novel predictions.

Notes

1. This article builds on Van Zijp (1993, Chapter 8). I wish to thank Jack Birner, Willem Keizer, Rodney 'Maddock, Neil de Marchi, Esther-Mirjam Sent, Hans Visser, and an anonymous referee for their useful suggestions and stimulating comments. Of course, the usual disclaimer applies.

2. Following Barro (1981, 41), New Classical Economics can be characterized in terms of four assumptions, namely (1) the assumption of continuous market clearing; (2) the Lucas supply function (including some version of the 'natural rate hypothesis'); (3) the Rational Expectations Hypothesis (REH); and (4) some assumption about the information set of the individuals.

3. For instance, Sargent (in Klamer 1985, 70) claimed that others took the neutrality proposition more seriously than he and Wallace themselves did, and that most of his recent work would not have any reason for existing if he took the proposition seriously.

4. Lucas (1980, 272) already suggested that the 'growth' of economic knowledge is to a considerable part due to "... purely technical developments that enlarge our abilities to construct analogue economies." These "... include both improvements in mathematical methods and improvements in computational capacity."

5. De Marchi (1990, 28, italics in original) noted that "... the test . . . makes absolutely no use of the Lucas critique, except that awareness of the critique told Lucas what he had to do to avoid its implications."

6. Following Lakatos (1970), the term 'theory' is used in a rather loose sense. See also De Marchi (1990, 40n6).

7. As Lakatos (1970, 133) explained, the negative heuristic of a scientific research programme specifies the 'hard core' of hypotheses ('theories') that cannot be refuted. The positive heuristic, on the other hand, suggests ways in which the protective belt of auxiliary hypotheses around this core may be amended in response to an inconsistency between two or more 'theories'. Hypotheses in both the interpretative and the explanatory realms may be subject to such amendation.

8. According to Maddock (1984, 294), "... in 1970, a rational expectations research program had emerged. " In his reconstruction Sargent's work enters the New Classical scene only as late as 1973, when it is seen to have brought about a progressive problem shift. Since by this time the New Classical research programme was well under way, Maddock's analysis implies that Sargent did not contribute to its rise. The present paper claims instead that around 1973 two previously independent (though theoretically related) research agendas (that of Lucas and that of Sargent) proved to match.

9. For a more detailed discussion of Keynes's and other solutions of the paradox, see Visser (1974, 143-147).

10 This follows from Keynes's 'Fundamental Equations' (viii.) and (x.) (1930, Book III, Chapter 10, 138).

11. Fisher's indirect effect should not be confused with Wicksell's indirect mechanism. The latter traces the effects of changes in the money supply and the nominal (market) rate of interest. It assumes that causality runs from the nominal rate of interest to the price level, whereas in the case of Fisher's indirect effect this causality is reversed.

12. This conclusion had already been reached by Lucas (1972b, written in 1970), albeit along different lines. In fact, Lucas (1972b) and Sargent (1971) discovered this so-called ***Lucas critique*** simultaneously and independently.

13. The estimates were derived by a search procedure. As Sargent (1973a, 391n5) explained, "[o]ur procedure here was first to search over h's ranging from .l to .9 at steps of . 1. Having found the value of λ, say λ_0, that, among these nine values of λ, delivered the smallest residual variance, we then searched again over $[\lambda_0 - .09, \lambda_0 + .09]$ at steps of .01 for the λ_0 associated with the minimum residual variance. This value was taken as our estimate of λ."

14. As Sargent (1973a, 435) himself put it, "[a]ssuming that the system is dynamically stable, the final resting place for all variables will be the same as if [the anticipated rate of inflation] π had remained at its steady-state value throughout

the adjustment process; but the path to steady-state equilibrium may be much different. "

15. In explaining how his model works, Sargent (1973a, 435) allowed expectations to change. However, in his simulations and his formal model (explanatory theory) he assumed that such changes are absent,
16. This subset included '... values of the logarithm of the money supply (currency plus demand deposits), seasonally adjusted (*m*), the federal and state and local government deficit on the national income accounts basis (*Def*); and the logs of the GNP deflator, seasonally adjusted (*p*), of the implicit deflator for personal consumption expenditures (PC), of the average hourly wage rate in manufacturing, seasonally adjusted (*wr*), of government purchases of goods and services (g), of total federal and state and local government employment, seasonally adjusted (ng), and of GNP (*y*). Each of these arguments is included lagged one, two, and three periods' (p. 178).
17. The Duhem-Quine thesis holds that a hypothesis cannot be tested in isolation, so that negative test results may always be attributed to some of the supporting assumptions. For a more detailed analysis, see Harding (1976).
18. In a comment on an earlier version of the present article, Rodney Maddock argued that there appear to be at least two other alternative explanations for Sargent's methodological decision. The first and simplest holds that his statement about the confidence level is just 'a throwaway line' to cover up the weakness of his empirical results. Such a cover up is not without meaning, though. It implies that Sargent did not find it Worthwhile to improve these results before publishing them, presumably because in his view there were more important issues at stake. The present article argues that he was engaged in a quest for consistency among (interpretative and explanatory) 'theories'. Maddock's second explanation holds that scientists are conservative, and that they do not (and should not) abandon their theories too quickly. Again, such conservatism may reveal some (implicit) preferences about the conditions which scientific explanations should meet, although admittedly there may be other reasons.

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