

"MACROECONOMIC POLICY GAMES WITH INCOMPLETE  
INFORMATION - A SURVEY"

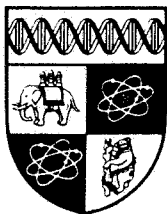
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MACROECONOMIC POLICY GAMES WITH INCOMPLETE  
INFORMATION -- A SURVEY

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I INTRODUCTION

The analysis of macroeconomic policy as a game of incomplete information has concerned itself largely with the problem of domestic monetary policy, inflation and unemployment, from among the areas discussed by Torsten Persson (1987) in his survey in this session. Papers by Backus and Driffill (1985a and b), Barro (1986), Vickers (1986), Driffill (1987), Rogoff (1987), and Cukierman and Meltzer (1986), focus on domestic monetary policy using roughly the same macroeconomic model and objective function as was used by Kydland and Prescott (1977) and Barro and Gordon (1983a and b). Horn and Persson (1985) have applied similar ideas to a small open economy using exchange rate policy and inflation as the key macro variables, as have Andersen and Risager (1987). Guido Tabellini (1987) has analyzed a situation where a government faces a single labour union rather than a decentralized competitive sector. Keith Blackburn (1987) has introduced incomplete information into a model of international policy coordination.

A broad thrust of this research is to provide a richer model of macro policy and in particular to formalize the notion of the "reputation" of the government which is widely used in media and popular discussions of policy but which has not been formally modelled. The aim has been partly to enrich the positive theory of policy, following the methodological line of

Barro and Gordon (1983a); partly it has been to develop normative results for policy. The models pursue further the question of the "consistency of optimal plans" identified by Kydland and Prescott, and whether or not this is a reason for wanting to impose constitutional restrictions on government freedom of action in the sphere of monetary policy.

Broadly speaking the results of the research to date appear to strengthen the arguments against such restraint. "Reputation" may in practice solve the problem. However, the extant literature has analyzed simple models only, and it may be that reputational discipline is weaker in models which incorporate features like imperfect monitoring of government actions in addition to uncertainty about government actions or behaviour (Driffill, 1987).

This paper reviews the structure of basic results in the area (Section II) and interpretations made criticisms made of them (Section III). Section IV comments on the few attempts which have been made to date at testing and estimating these models, and speculates on the possibilities for doing further empirical work in this area. Section V contains conclusions and speculations on further research in the area.

## II BASIC MODEL AND RESULTS

The macro policy problem with which this literature deals is the alleged inflationary bias of discretionary policy. It arises in the macro model used by Kydland and Prescott and used in most of the subsequent literature where deviations of output from the natural level are driven by the inflation surprise, viz., a standard expectations augmented Phillips curve or price surprise supply function, and where the government's objective is to maximize a function which depends on output and inflation: the cost

associated with inflation is increasing in the square of the inflation rate, but costs are decreasing with output so that the marginal benefit of more output is positive. The objective function in each period can be written as

$$(1) \quad u_t = -x_t^2/2 + c(x_t - x_t^e)$$

and the model of the economy is

$$(2) \quad y = y_n + (x_t - x_t^e)$$

where  $y_t$  is aggregate output, and  $y_n$  is the natural level of output.  $x_t$  is the inflation rate, and  $x_t^e$  is the expected rate of inflation. A model with the essential properties of this one is discussed in more detail in Persson's paper.

Kydland and Prescott argued that the discretionary outcome -- in which inflation is high ( $x_t = x_t^e = c$ ) and output equals the natural rate ( $y = y_n$ ) -- is the unique "consistent" outcome of the policy optimization problem, even when the one-shot game above is repeated infinitely and the government attempts to maximize an infinite discounted sum of per period utilities such as

$$(3) \quad \sum_{t=0}^{\infty} u_t \delta^t$$

where  $\delta$  is a discount factor, less than or equal to one in value. However, Barro and Gordon (1983b) showed that there were in fact many consistent policies. These may involve a lower equilibrium inflation rate than  $c$ , supported by a one-period punishment strategy imposed on the government by the private sector.

The equilibria discussed by Barro and Gordon (1983b) show that the problem of the inconsistency of optimal plans is less severe than Kydland and Prescott had believed, though private sector learning or "punishment" strategies are not a perfect substitute for constitutional restrictions or precommitment. Typically, the lowest inflation rate which can be sustained in this set-up will be greater than zero, though it tends towards zero as the

rate at which the government discounts future losses tends towards zero ( -- as  $\gamma$  tends towards one in equation (1)).<sup>1</sup>

The punishment strategy of the private sector is to be understood as an expectations formation mechanism, which is consistent with rational expectations and with individually rational behaviour. For each individual private sector agent, taking the behaviour of all other agents as given, and attempting to minimize expectational errors, rational behaviour involves in this set-up using the same forecasting rule as all other agents. No player has any incentive to deviate from the equilibrium, although there remains a problem of how the economy coordinates on this particular equilibrium. The equilibrium requires no concerted by agents in the private sector.

Barro and Gordon's modelling of macro policy indeed clarifies the issues, even though the private sector agents are assumed to be atomistic and simply pursue individually rational strategies. These may nevertheless be quite complicated, in the way they incorporate learning or punishment behaviour.

Their analysis is based on the analysis of an infinitely repeated game with complete information. It shows how and why an "inflationary" government

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<sup>1</sup>It may be noted in passing that the reason that the strategies described above which form the main focus of Barro and Gordon (1983b) do not achieve the optimal inflation rate is because they involve a one-period punishment period: a deviation from  $x_t = x^*$  in one period is punished by the private sector expecting inflation at the discretionary rate ( $c$ ) in the next period, and if the government responds with actual inflation at this rate, private sector expectations will revert to the equilibrium rate  $x^*$  in the following period ( $t+2$ ). If, by contrast, a longer punishment period is assumed, then a lower inflation can be sustained as a consistent solution. For example, with a infinite punishment period, and with a discount factor ( $\gamma$ ) greater than  $1/2$ , the optimal inflation rate (zero) is consistent on Kydland and Prescott's definition. Here the informal mechanism of punishment by private sector withdrawal of credibility from a deviant government is as good as a formal precommitment to zero inflation.

might credibly pursue a low or zero inflation policy without formal precommitment. The lowest credible inflation rate depends on how the private sector responds to a deviation from the equilibrium inflation rate and how much the government discounts the future.

The analysis leaves a number of issues unresolved, such as the question of how a particular length of punishment period is coordinated on by those atomistic private sector agents. It does not explain deviations from the equilibrium path, which never involves cheating by the government and the actual use of the punishment strategy. It does not predict any problem for a new government in acquiring credibility: a history of good behaviour is not required to make low inflation credible.

Introducing incomplete information, by having the private sector agents unsure about the form of government objectives or degree of commitment, attempts to formalize reputation, removes (at least on a superficial level) the indeterminacy of equilibrium, and rationalizes deviations from the low inflation outcome. Backus and Driffill (1985a) and Barro (1986) draw heavily on Kreps and Wilson's analysis of the chain-store paradox, and assume that the private sector enters the game not knowing whether the government has objective function (1) described above, or whether it is committed to zero inflation (when it could be represented as having the same loss function but with  $c=0$ , viz.,  $u_g = -x^2_t/2$ .) It is assumed common knowledge at the start of the game that the private sector attaches probabilities  $1-p_0$  and  $p_0$  to the two possibilities. The private sector forms expectations rationally. The game is repeated a finite number of times.

The equilibrium concept used is sequential equilibrium, following Kreps and Wilson (1982a), this being a generalization of subgame perfection to a

game with incomplete information. This solution is consistent in Kydland and Prescott's sense, and at each stage in the game players update their beliefs using optimally the information conveyed by their observations of moves made since the previous updating, using Bayes' rule. So, for example, if the uncommitted government is known to play the zero inflation strategy with probability  $q_t$  in stage  $t$  of the game, then conditional on having observed no inflation in stage  $t$ , the private sector revises the government's reputation to

$$p_{t+1} = p_t / (p_t + (1-p_t)q_t).$$

There are some minor differences between Backus and Driffill (1985a) and Barro (1986) -- Barro includes the possibility of discounting the future, and allows private sector agents to form expectations of inflation which lie anywhere on the real line, whereas Backus and Driffill restrict them to be either zero or the discretionary inflation rate ( $c$ ), a hangover from the industrial organization origins of these ideas -- but basically their results are the same.

The model has a unique sequential equilibrium. The government's reputation is identified with the probability ( $p_t$ ) with which the private sector believes that it is the type which is committed to zero inflation. Reputation disciplines the uncommitted government to play zero inflation in this set-up because the observation of zero inflation keeps alive in the mind of the private sector the idea that the government may indeed be a committed government, so holding down private sector expectations of inflation. If, by contrast, the government were to play positive inflation, that would at once give the game away, and identify it as being uncommitted. The consequence of this would be high inflation expectations to the end of the game ( $x^e = c$ ,



all  $s = t+1, \dots, T$ ) and the best the government could do would be to validate these expectations ( $x_s = c, s = t+1, \dots, T$ ). So the uncommitted government has an incentive not to inflate until the end of the game draws near, when the value of maintaining a good reputation diminishes, and the private sector, recognizing this factor at work, raises its expectations of inflation accordingly.

The key feature of the result is that at the start of the game the government plays zero inflation and the private sector rationally expects this, so we get the optimal outcome: full employment ( $y=y_n$ ) and zero inflation. Importantly, there is no initial credibility problem here: the new government with a long enough time horizon has no problem. It is the "lame duck" administration nearing its terminal date ( $T$ ) and with no interest in the economy after that date which tends to face a sceptical private sector whose inflation expectations are high even if the government has always played zero inflation and continues to do so. This leads to a recession of course.

#### IV. Comments

This model can formalize the idea of reputation and show how it evolves over time, and influences government and private sector behaviour. It meets some of the criticisms that may be levelled at the trigger strategy model used by Barro and Gordon. Here the equilibrium path does entail high inflation outcomes sometimes and the model ascribes to the private sector a theory about why such an event might have come about. It produces a unique sequential equilibrium to the game.

However, in other respects, the solution is a less than satisfactory representation of real-world credibility problems and raises further unanswered questions.

### Beliefs

The unique sequential equilibrium is obtained by assuming that the private sector agents have a particular set of beliefs at the start of the game. These might be a simple and convenient representation of uncertainty about government behaviour, but they are unexplained, and it is a notorious fact that the form they take has a major influence on the solution of the game. Fudenberg and Maskin (1986) show that almost any equilibrium can be obtained by appropriate choice of beliefs. In the macro policy context, Carraro (1986) argues that even better outcomes from the government's viewpoint can be obtained by suitable specification of beliefs and appropriate strategies. His "Stackelberg trigger strategy" equilibrium enables the government to achieve the global maximum (if it has one) of its objective function providing the private sector believes that the government may be of a type which will punish the private sector if private sector agents do not act in the way required to support the government's globally optimal outcome.

There are of course well known problems with the sequential equilibrium concept arising out of the fact that Bayes' rule cannot be used to update beliefs when events occur which are off the equilibrium path. It is possible for almost any beliefs to be invoked at such a point, and they may support "unreasonable" equilibria. Cho and Kreps (1986) derive criteria for imposing reasonableness on such beliefs, which are related to Kohlberg and Mertens' (1986) notion of stability of equilibria.

### Randomization as part of optimal policy

Another criticism is that the solution involves a period of time in which the government is indifferent between keeping its reputation and throwing it away by inflating, during which the government then randomizes between the two strategies. Randomization is widely thought not to be a feature of optimal policy choice in reality. In fact this feature of the solution is just a product of the simple structure of the game, and does not seriously affect the character of the results. Rogoff (1987) uses a slightly different formulation of the model -- he postulates a continuum of possible government types indexed by the amount they would have to pay to break their commitment to zero inflation, following Milgrom and Roberts (1982) -- which has an equilibrium in pure strategies and has broadly the same conclusions as above.

### The political business cycle

These models of credibility and reputation invite comparison with political business cycle models, since, as the horizon ( $T$ ) approaches, the government decides to throw away its reputation and there is a period with unexpectedly high inflation and low unemployment, followed (if this was not the last period) by periods with high inflation and full employment. It resembles the pre-election boom of the political business cycle. However the reputation models do not bear that interpretation. Policymakers here do not inflate to get back into power -- quite the opposite, they have no interest in events after  $T$ . There is no model of voters' preferences about alternative governmental types. The models are not well equipped to answer questions about what type of policymaker the public would prefer, and how

that would affect policymakers' behaviour. Rogoff and Sibert (1986) have devised a model of a rational political business cycle, based on a signalling model, which is very different from older generation political business cycle models, such as Nordhaus (1975), and from the above reputation models.

Rogoff and Sibert model the political business cycle as a signalling game, where the private sector is imperfectly informed about the government's efficiency in the production of a public good. The government's efficiency changes randomly over time, and the government signals its efficiency through the tax rate it sets to finance expenditure. However the government does not have to set taxes to cover expenditure exactly, and can make up a shortfall ex post by raising money with an inflation tax. The government faces competition from an opposition party, who would like to get into power, but have no way of signalling their efficiency to the private sector. The incumbent government in this situation has an incentive to overstate its efficiency to try to stay in power, but is restrained by the subsequent costs imposed by the inflation tax, and by the private sector's understanding of the significance of the observed tax rate for governmental efficiency. Rogoff and Sibert find a separating equilibrium, where the tax rate reveals to the private sector the government's efficiency, but this nevertheless involves an equilibrium amount of overstatement by the government, and consequently a cycle in tax rates related to elections.

#### Policymakers' Preferences

It has been objected that the assumption made above that government behaviour or preferences are unknown to the private sector is improbable, since they should represent voter preferences in some way. Cukierman and Drazen (1986) have argued that the preferences should in any case not be seen

as a social welfare function, only as a reflection of political pressures on the government, though this leaves the positive implications of the analysis unchanged and merely weakens any welfare significance. It has also been argued that the finite time period is inappropriate, and that any government -- whether in the form of individual officials or political parties -- puts some weight on events beyond the term of office, and in any case always attaches some probability to the party holding office on all future dates. This argument of course just strengthens the force exerted by reputational considerations to discipline governments.

Cukierman and Meltzer (1986) rationalize imperfectly understood government preferences by postulating that they fluctuate randomly over time. They use this idea to develop a completely different concept of reputation than that offered by Backus-Driffill and Barro. Their solution involves discretionary policymaking and in the absence of random shocks would correspond to Kydland and Prescott's consistent solution. The private sector uses a linear rule to infer government preferences from observed monetary expansion, and the government takes this learning rule into account when determining its monetary policy. The government has an incentive to lower the money stock on order to cause the private sector to reduce its estimation of the government's preference for inflation (it's "c" parameter). Private sector uncertainty about government objectives enables the government to save up monetary surprises for occasions when the benefits to higher output are particularly large. The government even has an incentive to use a noisy monetary policy instrument which masks its intended policy in order to slow down the private sector's learning about its preferences.

This setup embodies gradually evolving government objectives, and incomplete information about them, but the solution does not involve the same reputational ideas as used in Backus-Driffill or Barro. Indeed, the solution they develop reduces, in the absence of shocks, to Kydland and Prescott's consistent policy. Thus their paper addresses a different set of issues. It offers a rationale for "Fed-watching", and a justification for policymakers preferences which are imperfectly understood by the public.

### Teething troubles

A perhaps unappealing feature of the Backus-Driffill and Barro analyses is that credibility is not a problem for the new, untried and untested government as for the regime which is about to expire, and which leaves the private sector with no stick with which to punish it. In reality it often seems to be the case that credibility is a teething trouble which goes away once the agent's reputation is established.

Modelling a credibility problem at the start of the game has been done in two different ways. Backus and Driffill (1986b) took up another idea from Kreps and Wilson (1982a) and considered a model where incompleteness of information is two sided: the government is unsure about about private sector objectives, just as the private sector is uncertain about government objectives. The government believes that the private sector might be committed to high inflation expectations -- interpreted as being a commitment to large nominal wage increases. This makes sense if the private sector is a single large agent, since the action needed to maintain and increase its reputation would not conform to individual rationality. So this is a model of an economy with a single trade union encompassing the entire labour market, or a model of Thatcher versus Scargill, perhaps. In this

game, the interesting action takes place at the start of the game, when each player plays probabilistically his preferred action ( $x_t=0$ ,  $x_t=c$ ) and waits for the other to concede. There is a recession at the start of the game, while the government keeps inflation at zero, and the private sector persists with high "expected inflation" (high nominal wage settlements). If the union happens to concede first, the rest of the game has zero actual and expected inflation, and if the government happens to concede first, then the rest of the game has high actual and expected inflation. In the initial phase, each player is indifferent between fighting and conceding, and randomizes between the two strategies so as to make his opponent indifferent also. Conditional on neither side having conceded, each player's reputation grows so long as he does not concede.

John Vickers (1986) has taken an alternative approach, following Milgrom and Roberts' (1982) model of limit pricing under incomplete information. He considers a game similar to Backus and Driffill (1985a) and Barro (1986) but with two government types which differ in their inflationary tendencies, parameterized by the value of their parameter  $c$  in equation (1), with neither committed to zero inflation come what may. This relatively minor change to the Backus-Driffill structure gives some quite different results. Pooling equilibria, where the more inflationary government imitates the less inflationary at the start of the game can be ruled out, using Kreps and Cho's (1987) intuitive criterion. Separating equilibria survive, and here the less inflationary government sets an inflation rate in the first period of the game so low that the other would not want to imitate it even if it could be identified as being less inflationary as a result. So in this story, the presence of the more inflationary government actually disciplines the less

inflationary one at the start of the game; the more inflationary government is not disciplined by the presence of the less inflationary one. This is exactly the opposite of the Backus-Driffill/Barro story, where the possible presence of the committed government disciplines the uncommitted one. Driffill (1987) extends Vickers' analysis somewhat and shows that Vickers result depends paradoxically on there being sufficient similarity between the two possible government types, and that if one government is sufficiently less inflationary than the other, then a Backus-Driffill type equilibrium survives.

Vickers' analysis is carried out for a two-period game. It seems likely that the separating equilibrium is harder to sustain when the horizon is extended, since then the more inflationary government has a bigger incentive to mimic the other in the first period, and collect the benefits of being identified as less inflationary in later periods.

Tabellini (1987) discusses pooling and separating equilibria in a model of monetary policy with a centralized wage setter (the Nordic model) and with uncertainty only about government preferences. His union preferences are such that cycles in inflation and employment can emerge along the equilibrium path.

#### Imperfect Monitoring

An issue explicitly avoided in the simple models of reputation is the degree of monitoring of government policy actions, which in those models is assumed to be perfect. However imperfect monitoring may be an important feature of practical situations -- witness the way in which arguments for the government to adhere to sensible policy rules have been accompanied by arguments for these to be made simple so that the monitoring problem is



minimized -- and reduce the discipline which reputation can impose on discretionary policymakers. Canzoneri (1985) shows that, in a model in which government objectives are perfectly understood, a random element in the observed policy action in addition to the government's intended component will lead to periodic breakdowns of the cooperative mode of play, when the private sector responds to a large money supply increase (caused by a random shock to the money demand equation) by raising its inflation expectations for some time. However, the government is still disciplined in this setup to play the non-inflationary policy in each period. Soderstrom (1985) finds a similar result in a somewhat different model.

When both the monitoring problem (which is analysed by Canzoneri, Soderstrom, and also Cukierman and Meltzer) is combined with uncertainty about preferences, that result does not appear to hold. Driffill (1986) considers an extension of the Backus-Driffill (1985) model to include a random component so that observed inflation is not always equal to the government's intended inflation rate. The analysis is carried out only for a two period model, but the effect of reputation is much weakened, principally because the observation of inflation no longer identifies the government as being uncommitted. Consequently is more often in the (uncommitted) government's interest to intend inflation before the end of the game. In this model the analysis rapidly becomes untractable beyond two periods, and remains to be seen whether this result carries over to a game played over longer horizons.

#### IV. Empirical Work

There has to date been very little empirical testing of these models of reputation and credibility in a systematic way. If these models are to

provide a useful addition to existing explanations of the time-paths of macroeconomic variables, then they must be capable of explaining otherwise unexplained events, or provide a "better" explanation in some sense. Thus empirical implementation must be high on the agenda for future research in this area.

There are of course a number of problems. One is that these reputation models contain an additional unmeasured and unmeasurable, or at least hard to measure, variable, in addition to the usual problems created by expectational variables: that variable being reputation itself. A second problem is that the models so far worked out are much too schematic and simple for useful empirical testing, being largely static and deterministic, and dealing with only two or three macro variables. Clearly the development of models with a richer economic structure is needed. Perry (1983), Blanchard (1984), Baxter (1985), and Christensen (1986) are among those who have attempted some empirical testing of the importance of credibility models, using rather indirect tests. Typically they look for a breakdown of some reduced form model after the introduction of a new policy rule

Christensen (1986) uses Danish data. He considers interest rate determination in Denmark before and after the new government of October 1982 which announced that it would stabilize the kroner, reduce inflation, and reduce the government's budget deficit, previous experience having been of persistent exchange rate devaluation. His method is to estimate a reduced form equation for the interest rate based on data before October 1982, and then to forecast interest rates after the regime change using the equation. He finds that the reduced form equation overpredicts interest rates after the regime change, and he takes this as evidence for the credibility of the new

regime. This does not provide a sharp test among competing hypotheses, but it may indicate the difficulties of getting much out of the available data.

The reputation models of inflation and monetary policy predict periods of time, associated with changes of policy regime, when inflation expectations and actual inflation will diverge for a protracted period: there may appear intervals in which expectations appear to be systematically above actual inflation, and so serially correlated deviations of output from the natural level, not explained by wage/price stickiness or other sources of sluggishness. Effective tests of these models will have to attempt to use these predictions. Richer macro models would draw out predictions for other variables, particularly interest rates and exchange rates (see, e.g., Horn and Persson, 1985). For example, an incredible disinflationary policy may be associated with an apparent violation of the uncovered interest parity condition, or with a yield curve which appears out of line with policymakers stated plans for future money growth. Blanchard (1984) discusses the term structure of interest rates in this context.

Information about future policy plans is clearly essential to testing reputation and credibility models, and instances where governments have announced clear objectives, such as the UK's "medium term financial strategy" will provide important case studies.

#### V. Conclusions

Macroeconomic policy naturally invites discussion about credibility and the reputation of policymakers, and the application to it of formal analysis as a game of incomplete information has shed interesting light on it. Much of the analysis seems to reinforce the point made by Barro and Gordon, that the inconsistency problem in macro policy is less serious than first thought,

that formal constitutional restrictions on government action are unnecessary, and that the informal reputational mechanisms will do the work. However, such a conclusion may be premature (as Rogoff, 1987, remarks) because the game theoretic concepts used can in fact give almost any result. Existing work on monetary policy has relied on assumptions which enhance the force of reputational discipline. It is not clear that these are empirically the right assumptions to make about beliefs, and the multiplicity of solutions to the games raises the problem of how a decentralized economy coordinates on one particular solution.

There has been almost no systematic empirical work to measure or test the quantitative significance of reputational effects, and this must be high on the agenda for research in the area. Effective empirical work will require the development of economically richer models within which reputation etc. is embedded.

A criticism of the policy games discussed here is that they all take as given a rather ad hoc macro model and set of objectives. While these seem to represent widely agreed views of what a stripped down macro model might look like, it may be that research in this area would benefit from developing a firmer microeconomic foundation, specifying individual agents' objectives and budget sets more carefully, and developing more carefully the relationship between individual agents' preferences and those of the government.

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