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THE INDICATOR SYSTEM

Note by the Secretaries

The attached article "The Indicator System and UK Monetary Policy" by Karakitsos, Rustem and Zarrop is circulated for information.

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The Indicator System and U.K Monetary Policy

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I. Introduction

The use of intermediate targets in the conduct of short run monetary policy is closely associated with indicator systems. Having adopted an intermediate target approach, the U.K. authorities are now considering the merits of supplementing this approach with an indicator system. This paper provides an optimization framework within which indicator systems can be analysed and evaluated. Numerical examples are provided, using the monetary sector of the nonlinear econometric model of the U.K. economy developed by the National Institute of Economic and Social Research, to support our main theoretical proposition.

II. The Indicator Issue.

It is beyond any doubt that the government's main economic policy objective is the fight against inflation through a progressive reduction in the rate of growth of money stock over a period of years. This reflects the government's belief in the long run quantity theory of money and is almost explicitly recognised in para. 3 of the recent consultative document (Green Paper) entitled "Monetary Control".

> "The relationship between the rate of growth of the money stock and the growth of prices and incomes is complex. They can diverge in the short run, but there are strong grounds for believing that they will not diverge significantly over a period of years."

The aim of the Green Paper is to consider various methods of bringing down the trend in the money supply as well as to eliminate fluctuations around this trend (para. 4). One of the methods considered for this purpose is an indicator system on either the monetary base or on sterling M3. The system is envisaged as operating in the following way. Any divergence of the base or sterling M3 from its desired path would automatically trigger changes in the instuments (e.g. the Minimum Lending Rate, MLR). "The desired path for the base is calculated to correspond to a smooth path seasonally adjusted for the growth of the target variable, sterling M3." However, an indicator system based on sterling M3 rather than the base is regarded as a more direct system and thus more appropriate for this purpose (para. 5.2).

Indicator systems of the kind considered in the Green Paper can be formulated as feedback laws, for example

$$MLR_t - MLR_{t-1} = b_1(B_{t-1} - B^d_{t-1}) \qquad (1a)$$

or

$$MLR_t - MLR_{t-1} = b_2(M3_{t-1} - M3^d_{t-1}) \qquad (1b)$$

where B is the monetary base, the d superfix indicates desired values and the b_i are constants. The main advantage of an indicator system is considered to be an added assurance that the authorities would react without delay to any divergence of sterling M3 from its desired path. This prompt adjustment, it is argued, would favourably affect expectations in effective monetary control and thus encourage stability in the financial system.[1]

Furthermore, it is argued, "it might be desirable to relate such an automatic system to weekly rather than monthly sterling M3 figures, in order to achieve a significant time advantage over the existing system (para. 37) ... in which discretionary decisions by the authorities are based on monthly data" (para. 5.3). There are a number of problems, however, with such a system. Leaving aside the problems of accuracy of measurement and of seasonal adjustment (which are, in fact, discussed in the Green Paper) three further problems seem to arise in the possible implementation of such a system. First and foremost, how would the desired path for sterling M3 on a weekly or even monthly basis be determined? Is there a short term desired path for sterling M3? If not, then the suggested indicator systems are meaningless. If such a desired path is assumed to exist, what is this path? It cannot be a fixed rate of growth, because it is clear that such an assumption would imply the validity of the short run quantity theory of money and this clearly does not hold.

Second, are such feedback laws ad hoc or are they related to a model being for example a reduced form? This is discussed in the

1. There are, of course, disadvantages with such a scheme which are explicitly stated in para. 5.8.

next section. Third, how is the b parameter in the feedback law determined? The first two problems are not even mentioned in the Green Paper whereas the discussion of the third seems to be unsatisfactory. It is argued that the parameter "would be varied as experience was gained. Initially at least the (parameter) would also have an upper limit in order to reduce uncertainty".

This paper provides a framework for analysing and evaluating the merits of indicator systems. This framework consists of the minimization of an objective function subject to the constraints imposed by the model equations. The minimization is carried out by choosing the parameters of a feedback law (the indicator equation) and thus resolving the third problem. This optimization framework may also be extended to determine the optimal paths of instruments not subject to such a feedback law. The main advantage of this approach is that the parameters of the indicator equation (b_i in equation (1)) are not ad hoc but are obtained as a product of optimization and depend among other things on how vigorously the authorities decide to pursue their objectives. The present approach is therefore consistent with the authorities' concern about the size of b_i. That is, instead of imposing an upper limit on b_i (for the purpose of reducing uncertainty) the authorities can still achieve this purpose by changing the objective function. If, for example, a quadratic objective function is being used that attaches penalty weights to deviations from specified desired paths of instruments and targets, reducing the weight on deviations of a target variable from its desired path has the required effect. This would allow the authorities to reduce uncertainty while securing that the parameter b_i would still be optimal.

III. Fundamental Principles of Policymaking

If policymaking is to be considered within a particular framework of analysis and therefore empiricism is to be avoided, we need to make some assumptions about the behaviour of the authorities. First, the authorities are assumed to base their policy decisions on, say, a quarterly model. This does not mean that any qualitative information and expertise on how the economy works, other than that from the model, is wasted. Quite the contrary, the point is simply that all this information ought to be used to shape or correct the policy that comes from the model and not as an alternative. The core of policymaking must come from the model if "consistent" policies are to be formulated. For suppose that the authorities make decisions using some rules of thumb and discard any policies based on the model. In this case it is most probable that one rule of thumb would indicate a different course of action from another. The problem is that each rule uses a subset of the total information set whereas a correct course of action ought to be based on an analysis of all the available information. The only way one can secure that the whole set is taken into account and is analysed correctly, is when the various rules of thumb that are used are related to each other in a consistent manner. However, accepting that the various rules of thumb should be related to each other means acceptance of the concept of a model, because a model is nothing other than a consistent way of relating various relationships that describe various aspects of one or more phenomena.

We thus believe that there is no other way to formulate policymaking but through a model. Use of arbitrary rules of thumb or even part of the model or finally of indicator systems provides no way of correcting errors on the basis of new information and provides no rational basis for analysing why past policy did not have the desired impact. In other words valuable information is wasted if simple rules or only part of the

model are used to analyse new information.

The second assumption underlying our framework for policymaking is that policy decisions are taken at the beginning of each quarter and there is no change of policy within quarters on the basis of monthly information. This assumption is required to avoid the perplexing problems of formulating policymaking on a month to month or even weekly basis using a quarterly model. In general, monthly or weekly policymaking should be based on monthly or weekly models. It is not optimal, to say the least, to use a quarterly model to formulate policies and then take corrective action on the basis of monthly information. Although this information is not useless it cannot be properly evaluated in the absence of a monthly model.

It has been suggested, however, that what the authorities should be doing is to use some quarterly feedback rules for fine tuning within quarters, that is, apart from actions taken at the beginning of each quarter they also use feedback laws to make corrections within the quarter. These feedback rules relate instruments to some variables, like money stock, for which there are monthly data. The indicator system is supposed to play this role. It seems, although it is not explicitly stated, that this is also the view taken in the Green Paper (given the short term basis, e.g. weekly, for which they want to use the indicator system).

It is not very clear, however, how such feedback laws should be estimated. One suggested method is to use monthly data to estimate such a relationship (Hamburger, 1970, Schadrack, 1974, Levin, 1974). Such direct estimation however would most probably lead to biased estimates because this relationship is essentially the reduced form of an implicit monthly model of the monetary sector. As the St. Louis reduced form equations, estimated from quarterly data, led to misleading results, it is likely that feedback laws, estimated from monthly data, will also be misleading. Alternatively, the feedback law can be derived using optimal control techniques. However, because of the disaggregation problem involved, there is no reason to suppose that these feedback laws would remain optimal or valid, for monthly decisions. Thus, the discussion of indicator systems is restricted in the rest of this paper to feedback laws with the same time partitioning as that of the model. Hence, given that the model we are using is quarterly, we can only evaluate the effectiveness of feedback laws between quarters but not within quarters.

IV. An Optimization Framework for Policymaking Under an Indicator System

The problem of policymaking under an indicator system can be formulated in terms of an objective function, a model and a feedback law. As mentioned in section 2, the objective function may be taken

to be quadratic that attaches penalty weights to deviations from specified paths of instruments and targets. In this case, it is assumed that the authorities want to see the economy tracking a desired trajectory in terms of the desired paths of some important variables - the target variables which can be ultimate targets like inflation or intermediate targets like the rate of growth of money stock. It does not necessarily follow that the economy can reach these desired paths whatever the authorities actions may happen to be. That is, the desired paths may be infeasible given the way the economy works. Thus the constraint in driving the economy to a desired trajectory is the model which supposedly portrays how the economy works and how it would respond to changes in policies and exogenous factors.

The authorities hope to alter the path of the economy by changing the paths of those variables which they actually control, the instruments or controls, like government expenditure, the minimum lending rate etc. In most circumstances where the desired trajectory is infeasible the authorities would like to trade-off their objectives so that at least some of them will be satisfied. That is, the authorities are asked, in case where all targets cannot be satisfied, to rank them according to which target they want to see most satisfied. This is equivalent to attaching penalty costs to deviations of the optimal from the desired paths. Similar preferences are also assumed to exist for the instruments. In almost all cases changing the paths of the instruments is not a costless procedure or one which the authorities need not be concerned with. For example, cutting (or even increasing) public expenditure might be politically undesirable. Similarly, frequent changes in the minimum lending rate may create fear and anxiety in the financial markets.

For these reasons the authorities are assumed to have desired paths for the instruments too and to attach penalty costs to deviations of the optimal paths from the desired ones. A relatively small weight on one instrument reflects the authorities' preference to pursue their overall objectives by allowing most of the burden of adjustment to be borne by this particular instrument.

Finally, the authorities are supposed to decide on the actual state of the economy and consequently on how to react by looking at the latest information on those variables that serve as indicators. The problem of policymaking is then seen as one in which the authorities choose the parameters of the feedback law (the indicator equation) and consequently the paths of the instruments so that the economy will move as closely as possible to a desired trajectory over a given time horizon.

Formally, the policymaking framework can be summarised as the minimization of an objective function $J(\underline{Y},\underline{U})$ subject to the restriction of the dynamic non-linear econometric model. The model can be written in the static form $\underline{F}(\underline{Y},\underline{U}) = \underline{0}$. Consider therefore the problem

$$\min \{ J(\underline{Y},\underline{U}) \mid (\underline{Y},\underline{U}) \in R \} \quad (2)$$

where

$$R \equiv \{(\underline{Y},\underline{U}) \mid \underline{F}(\underline{Y},\underline{U}) = \underline{0} \} \quad (3)$$

is the feasible region,

$$\underline{Y} \equiv \{ \underline{y}'(1), \ldots, \underline{y}'(t), \ldots, \underline{y}'(T) \}' \quad (4)$$

is the column vector of endogenous variables (outputs) throughout the period of optimization (1,T) with $\underline{y}(t)$ denoting the column vector of endogenous variables at time t, $1 \leq t \leq T$, and similarly

$$\underline{U} \equiv \{ \underline{u}'(1), \ldots, \underline{u}'(t), \ldots, \underline{u}'(T) \}' \quad (5)$$

is the column vector of policy instruments (controls). The solution to (2) is known as the optimal open loop solution. The values of all the exogenous variables are assumed to have been substituted in $\underline{F}(\underline{Y},\underline{U}) = \underline{0}$ before solving (2).

A feedback law is a relationship that determines $\underline{U}$ (or part of $\underline{U}$), given $\underline{Y}$ and hence is a restriction on $\underline{Y}$ and $\underline{U}$. Thus, $(\underline{Y},\underline{U})$ satisfying a feedback relationship are expected to be in the region

$$R_f \equiv \{ (\underline{Y},\underline{U}) \mid \underline{U} = \underline{f}(\underline{Y}) \} \quad (6)$$

where $\underline{f}$ denotes the feedback law that determines $\underline{U}$, given $\underline{Y}$. The optimization problem now becomes

$$\min \{ J(\underline{Y},\underline{U}) \mid (\underline{Y},\underline{U}) \in R \cap R_f \} \quad (7)$$

Note that if all instruments are determined by a given feedback law with fixed parameters, then $R \cap R_f$ may degenerate into a single point $(\underline{Y},\underline{U})$, i.e. (7) reduces to a trivial optimization problem yielding a unique trajectory.

If we parametrise the feedback law so that

$$R_f(\underline{\theta}) = \{ (\underline{Y},\underline{U}) \mid \underline{U} = \underline{f}(\underline{Y},\underline{\theta}) \} \quad (8)$$

then (7) becomes

$$\min \{ J(\underline{Y},\underline{U}) \mid (\underline{Y},\underline{U}) \in R \cap R_f(\underline{\theta}) \} \quad (9)$$

where the optimization is carried out with respect to $\underline{\theta}$ and those instruments not subject to feedback laws. This approach has been used to generate the results provided in the next section.

V. Alternative Indicator Systems.

In this section we provide particular applications of the indicator system within the above optimization framework. Although the Green Paper considered an indicator system based on sterling M3 or the monetary base (with a preference for the former) one should also consider alternatives. An obvious candidate is the short term interest rate.

We assume that the authorities have two targets: to force the rate of growth of M3 onto a smooth path of 8 per cent per annum and to impose stability on the short term rate of interest, RLA. We also assume that the authorities have at their disposal two monetary instruments (controls), the minimum lending rate (or treasury bill rate, RTB, since the two are linked together) and the Public Sector Borrowing Requirement, PSBR.

In this framework an interest rate indicator is one in which the feedback law (4) is some function of interest rates alone. On the other hand, a money supply indicator is one where the feedback law is some function of money stock alone. The problem is to choose that feedback law (by determining its parameters) which will allow both objectives of controlling M3 and maintaining money market stability to be achieved most successfully.

Table 1 presents the various feedback laws that we have considered along with the resulting cost function value from each optimization.[2]

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2. The absolute size of the cost is of no importance because the optimal trajectory depends only on the relative weights. Proportional reduction of all weights would reduce the size of the total cost but not the relative importance of the targets and controls. In the comparison of the various indicator systems what is of importance is the cost of one optimization run relative to another.

This cost serves as the criterion for ranking the performance of the various feedback laws. Thus, one can see that experiments A and B represent a money supply indicator system (both instruments are made functions of the money stock alone). Experiments C and D, on the other hand, represent an interest rate indicator system. Finally, experiments E, F and G represent mixed indicator systems.

One can immediately see that including more lagged values of the information variable improves the performance of that indicator system. Thus, including RLA_{t-2} in both feedback laws (PSBR and RTB), experiment D, decreases the cost from 0.69×10^9 to 0.64×10^9. The same is also true of $M3_{t-2}$ in experiment B.

A direct comparison of an interest rate indicator system with a money supply indicator system (experiments A and B with C and D) indicates the superiority of the latter. Even with one lag in M3 the cost is only 0.46×10^9 whereas the cost of an interest rate indicator based even on 2 lags is 0.64×10^9. We must note however, that this result should be interpreted with caution. It does not imply that from the whole class of interest rate feedback laws there is no interest rate feedback law that might perform better than the feedback rule of experiment B. The point is simply that within the class of feedback laws assumed here and with a maximum of two lags, the authorities should prefer the money stock indicator system.

Rather than increasing the lags, however, it might be more interesting to see whether, within the class of feedback laws with two lags, a mixed indicator system should be preferred to the exclusive use of any pure indicator system. Experiments E, F and G provide examples of such a mixed system. Intuitively, one may expect that the level of PSBR should be decided in accordance with information on M3. In addition, intuition again, may indicate that RTB should be determined using information from RLA. This situation is presented in experiment E. One can immediately see that such a policy is superior only to an exclusive interest rate indicator (experiments C and D), whereas it is far inferior to an exclusive money stock indicator. This provides further support to the argument that money stock is a better indicator of the state of the economy than interest rates.

Experiment F examines the converse combination of attaching interest rates to PSBR and M3 to RTB. One can see that this mixed indicator system is far better than any indicator based on interest rates alone or on money stock alone. A mixed indicator, however, based on two lags of both variables (experiment G) only marginally decreases the cost from 0.23×10^9 to 0.21×10^9.

From the class of indicator systems considered above three conclusions seem to follow. First, between an interest rate and a money stock indicator the authorities should prefer the latter. Second, a mixed strategy is almost certain to yield improvements. Third, simple feedback laws can be constructed which can provide almost as good information as some more complicated feedback laws. This seems to suggest that simple mixed feedback rules may be preferred to complicated ones, i.e. including the extra variables is worth more than including the extra lags.

VI. The Inadequacy of Indicator Systems.

A quantitative way of evaluating an indicator system is to compare the cost value obtained with that generated by the optimal open loop solution for the same problem. We note that in table 1 experiment H the open loop cost is around 100 times smaller than the cost generated via the feedback laws. This suggests that the indicator system performs poorly if the feedback laws are chosen on an ad hoc basis as in (1). This confirms the theoretical view that feedback laws as in (1) or (8) can be seen as a further restriction on the open loop policy optimization problem (2). Hence the solution of (9) is, in general, inferior to that of (2).

In spite of the above argument, if feedback laws have to be used then two problems arise: (i) Which variables should be included in the indicator system? (ii) What is the form of the feedback law?

For nonlinear models the second question is in general unanswerable in an exact way. However, for linear models, the optimal feedback law (which will give the same cost as the optimal open loop solution) will be linear and in general will include all the lagged values of all the variables. If we linearise the nonlinear model such a law is approximately valid. It follows that the only rational approach to formulating simple laws for such a model is to systematically select the key variables and lags which enter into the optimal law.

Nevertheless, given the need to incorporate updated exogenous information into policy decisions, we would argue that a sequential open loop approach is preferable to any indicator system. By this we mean that optimal open loop policies are calculated for the period (1,T) on the basis of the information available at t=1. Policy is applied for the first quarter and then the calculations are repeated for the period (2,T+1) after integrating the updated information which has become available.

This process is repeated.

It is argued in the Green Paper that an important advantage of the indicator system is its favourable effect on expectations from the fulfilment of short term objectives. We can also argue that the announcement of the desired values for M3 used in the objective function will have the same effect.

VII. Conclusions.

This paper has discussed the question of monetary indicators and makes three basic points: First, there is a basic conflict between adherence to the long run quantity theory of money and the need to fix short run objectives on which indicator systems are based. Second, a prerequisite for operating indicator systems on a rational basis is to use them in conjuction with a compatible model. Third, in general, the performance of any simple ad hoc indicator system is far worse than the performance possible using open loop methods.

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Table 1

Feedback Laws

Run	PSBR =	MLR =	Cost	Ranking
A	$a_{10}+a_{11}M3_{t-1}$	$b_{10}+b_{11}M3_{t-1}$	$.46\times10^{9}$	5
B	$a_{20}+a_{21}M3_{t-1}+a_{22}M3_{t-2}$	$b_{20}+b_{21}M3_{t-1}+b_{22}M3_{t-2}$	$.32\times10^{9}$	4
C	$a_{30}+a_{31}RLA_{t-1}$	$b_{30}+b_{31}RLA_{t-1}$	$.69\times10^{9}$	8
D	$a_{40}+a_{41}RLA_{t-1}+a_{42}RLA_{t-2}$	$b_{40}+b_{41}RLA_{t-1}+b_{42}RLA_{t-2}$	$.64\times10^{9}$	7
E	$a_{50}+a_{51}M3_{t-1}+a_{52}M3_{t-2}$	$b_{50}+b_{51}RLA_{t-1}+b_{52}RLA_{t-2}$	$.60\times10^{9}$	6
F	$a_{60}+a_{61}RLA_{t-1}+a_{62}RLA_{t-2}$	$b_{60}+b_{61}M3_{t-1}+b_{62}M3_{t-2}$	$.23\times10^{9}$	3
G	$a_{70}+a_{71}M3_{t-1}+a_{72}M3_{t-2}+$	$b_{70}+b_{71}M3_{t-1}+b_{72}M3_{t-2}+$		
	$a_{73}RLA_{t-1}+a_{74}RLA_{t-2}$	$b_{73}+RLA_{t-1}+b_{74}RLA_{t-2}$	$.21\times10^{9}$	2
H	Open Loop Optimal Policy		$.88\times10^{7}$	1

Table 2

Parameters of Feedback Laws

Run	PSBR			MLR		
A	$a_{10}=-1034.8$	$a_{11}=.07$		$b_{10}=6.706$	$b_{11}=.92\times10^{-4}$	
B	$a_{20}=-1563.8$	$a_{21}=-.48$	$a_{22}=.585$	$b_{20}=6.015$	$b_{21}=-.11\times10^{-3}$	$b_{22}=.24\times10^{-3}$
C	$a_{30}=-623.5$	$a_{31}=158.1$		$b_{30}=12.79$	$b_{31}=-.24$	
D	$a_{40}=-2008.8$	$a_{41}=53.4$	$a_{42}=241.3$	$b_{40}=11.83$	$b_{41}=-.30$	$b_{42}=.153$
E	$a_{50}=-1797.2$	$a_{51}=-.294$	$a_{52}=.395$	$b_{50}=11.94$	$b_{51}=-.296$	$b_{52}=.136$
F	$a_{60}=-4860.8$	$a_{61}=308.9$	$a_{62}=283.3$	$b_{60}=7.39$	$b_{61}=-.299$	$b_{62}=.38\times10^{-3}$
G	$a_{70}=-4986.5$	$a_{71}=-.2531$	$a_{72}=.29$	$b_{70}=7.72$	$b_{71}=-.164$	$b_{72}=-.18$
	$a_{73}=68.09$	$a_{74}=442.3$		$b_{73}=.196\times10^{-3}$	$b_{74}=.329\times10^{-3}$	

References

Hamburger, M.J. (1970): "Indicators of Monetary Policy: The Arguments and the Evidence" American Economic Review.

Levin, F. (1974): "The Selection of the Monetary Indicator: Some Further Empirical Evidence" in Monetary Aggregates and Monetary Policy, Fed. Reserve Bank of New York.

Monetary Control, HMSO, Cmnd. 7858

Schadrack, F. (1974) "An Empirical Approach to the definition of Money" in Monetary Aggregates and Monetary Policy, Fed. Res. Bank of New York.