DIPARTIMENTO
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Quaderni di Ricerca

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Dynamic specification in U.K. Demand for Money Studies

UNIVERSITÀ DEGLI STUDI DI ANCONA

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* This paper has benefited from the comments received on an earlier draft by A. Muscatelli: the usual disclaimer applies.

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C O N T E N T S

INTRODUCTION

For a long time the demand for money has been one of the least controversial topics in macroeconomics both in its underlying theory and in its empirical performance.

However from the early 70's onwards the confidence surrounding the demand for money has been shattered. Forecasts for demand for money for U.K. started to overpredict real money balances and when equations were estimated including post 73 data, implausible and unstable coefficients were revealed (Artis Lewis 1976).

In an attempt to save the traditional theory of demand for money two lines of inquiry emerged. One response to the temporal instability has considered the institutional changes occured in the 70's mainly due to deregulation in financial markets. The latter has caused an increase in competition and a surge of financial innovations which, at least theoretically, might determine shifts in the demand for money. The second response has tried to reconsider the appropriateness of the explanatory variables. New definitions of money, new scale variables and different measures of opportunity costs were included in the short run demand for money, in various combinations. However both these approaches have produced slight improvements in the stability of the function and left many points that need to be resolved

(Judd-Scadding 1982).

The puzzle of demand for money has been tackled in a second wave of studies, appeared mainly in the late 70's and in the 80's, which has introduced developments in both theory and econometric techniques. These two developments are strictly related to each other since the new econometric approach leads to more complex regression equations which necessitate of different theories to be explained and at the same time the latter have to satisfy more demanding and more careful empirical investigations.

The interest in the role of dynamic specification is related to this second wave of studies on the instability of demand for money function. The aim of this work is to analyse the different ways in which dynamics have been introduced in demand for money, how instability might be attributable to misspecification of the dynamic structure and how error correction and buffer stock models with rational expectations can improve the dynamic specification of demand for money.

These topics are here treated mainly from a theoretical point of view and no attempt is made to review the empirical evidence with, in some cases, is still at its infancy.

The remainder of this work is divided into four parts. Chapter 1 deals with the way in which the lagged dependent variable enters the conventional demand for money. Usually partial adjustment and adaptive expectations are invoked as rationalizations for a simple dynamic structure. Chapter 2 illustrates the general to specific approach which, broadly speaking, represents the econometric response to the breakdown in the demand for money. This approach criticises the way in which dynamics have been introduced and more generally the "traditional" way of modelling economic relationships. Chapter 3 provides some theoretical interpretations, based mainly on error correction models, for the regression equations obtained by the general to specific approach, and indicates some possible improvement in the formulation of the demand for money following the forward-looking buffer stock model. Finally, some conclusion and some direction for further research are pointed out in Chapter 4.

CHAPTER 1

THE STANDARD APPROACH TO MODELLING DEMAND FOR MONEY

1.1 Introduction

The long-run demand for money function indicates how much money individuals would hold in hypothetical alternative circumstances in which the determinants of money balances (usually opportunity costs and proxies for transactions) take on different values. The long-run function is usually considered as a demand for real balances and can be generally written as

$$M^*_t - P_t = f(X_t) \tag{1}$$

where upper case letters stand for log levels, M* for money, P for a price index and X_t is a vector of determinants of demand. Equation (1) assumes that tastes remain constant and individuals can adjust their holdings instantly and costlessly to any change in the independent variables. The latter assumption is of course not plausible. Decision making is in itself costly and there are difficulties in interpreting signals about changing economic conditions. Thus, given the presence of adjustment costs, individuals may rationally decide to respond to the continuing stream of information gradually. This accords also with considerable evidence as in general if the usual long-run demand for money is fitted to quarterly time series data it does not perform well statistically.

Researchers might theoretically consider a demand for money in which all costs of adjustment are included in the optimisation problem facing the individual. However, this kind of theories quickly become analitcally very complicated(1). As a result the conventional approach assumes that individuals undertake a two-stage decision process. Firstly, they decide on the optimal amount of money they want to hold in accordance with the long-run demand for money function, and secondly they undertake a separate optimisation problem concerning the speed at which they wish to adjust toward the optimal money balances.

As we will see in the following section this adjustment process can result in the lagged money value appearing as independent variable in the demand function. Therefore we can distinguish between the short-run and long-run concepts of the demand for money by seeing whether adjustment lags are present. Because of adjustment costs actual and desired real money balance are not always equal; only a part of the gap between actual and desired money is closed in a single discrete time period implying that the current level of real balances is a weighted average of desidered and lagged values of money namely:

$$M_t - P_t = \gamma (M^*_t - P_t) + (1 - \gamma)(M_{t-1} - P_{t-1}) \quad (2)$$

Assuming that an increase in the demand for money is always met by an increase in money supply, so that the short-run demand for money equals actual money balances, and combining equation (1) and (2) yields the short-run real demand for money:

$$M_t - P_t = \gamma f(X_t) + (1 - \gamma)(M_{t-1} - P_{t-1}) \qquad (3)$$

When specific determinants of money demand, as some measure of income and interest rate, substitute the vector X we obtain the standard specification of the demand for money that has raised many problems of statistical and economic interpretation during the 70's.

Section 1.2 expounds the theoretical explanation based on the partial adjustment process, the standard approach provides for equation (2). Section 1.3 underlines the role of adaptive expectations in the determination of the short-run dynamics for demand for money. More complete models might be used for introducing dynamics in the demand function but they are not examined here because the analysis is confined to single equations.

Finally Section 1.4 resumes very briefly the standard approach to econometric modelling.

1.2 Short-run dynamics: partial adjustment models

A less general and more satisfactory explanation for

Equation (2) can be obtained by considering the individual's portfolio adjustment costs.

This approach views an individual as facing a trade off between the cost of being out of his desidered equilibrium (K_1), and the cost of changing the stock of money (K_2). Both costs can be written in a quadratic form:

$$K_1 = k_1 \left[(M_{it} - P_t) - (M^*_{it} - P_t) \right]^2 \tag{4}$$

$$K_2 = k_2 \left\{ (M_{it} - P_t) - (M_{it-1} - P_{t-1}) \right\}^2 \tag{4a}$$

where k_1 is the cost per unit of disequilibrium, k_2 is the unitary cost of changing the stock of money and the subscript i denotes individual variables. This formulation assumes that these costs (and thus the adjustment coefficient) remain constant over time[(2)]. Moreover the quadratic form implies symmetric costs so that, for instance, costs of being above and below equilibrium are equal.

Given $(M^*_{it} - P_t)$ and $(M_{it-1} - P_{t-1})$ the individual chooses $(M_{it} - P_t)$ to minimise the total cost

$$C = K_1 + K_2 \tag{5}$$

$$\frac{\partial C}{\partial (M_{it} - P_t)} = 2k_1[(M_{it}-P_t)-(M^*_{it}-P_t)] + 2k_2[(M_{it}-P_t) - (M_{it} - P_t)] = 0 \tag{6}$$

$$M_{it} - P_t = \gamma (M^*_{it} - P_t) + (1-\gamma)(M_{it-1} - P_{t-1}) \tag{7}$$

where $\gamma = \frac{k_1}{k_1 + k_2}$. Equation (7) represents the first order partial adjustment mechanism[3]. If costs of being out of equilibrium are zero ($K_1 = 0$) then $\gamma = 0$ and $M_{it} - P_t = M_{it-1} - P_{t-1}$, and if costs of changing stock of money are zero ($K_2 = 0$) then $\gamma = 1$ and $M_{it} - P_t = M^*_{it} - P_t$. As we have already mentioned equation like (7) may be used for obtaining an aggregate estimation for the short-run demand for money. To do that the standard approach assumes that we can aggregate over individuals retaining the adjustment mechanism, which allows us to drop the i subscript. To make explicit the long-run demand for money function we can write Equation (1) as follows:

$$M^*_t - P_t = m_y Y_t - m_r R_t + u \tag{8}$$

where Y is current real income, R is a yield on alternative assets and u is an additive stochastic error. Substituting (8) into (7) we get:

$$M_t - P_t = \gamma (m_y \ Y_t - m_r \ R_t) - (1 - \gamma)(M_{t-1} - P_{t-1}) + \gamma u \tag{9}$$

or

$$M_t - P_t = b_1 \ Y_t + b_2 \ R_t + b_3 (M_{t-1} - P_{t-1}) + v \qquad 10)$$

where b_1, b_2, b_3 are the estimated coefficients which allow to determine exactly the structural parameter ($\gamma \ m_y \ m_t$). To put this another way, Equation (9) is exactly identified.

1.2.1 Criticisms of partial adjustment models

There are some aspects of the partial adjustment models that are open to criticism. These are directed either at the performance of the model or principally at the assumptions on which the model is built.

The four main criticisms relate to the functional form, the optimisation period, the equal adjustment speed for different variables and, last but not least, the use of the model to analyse aggregate data.

First, the functional form adopted is a quadratic cost function, but no rationalisation for it is usually provided, except for the simple results it allows to obtain. The use of a quadratic form implies also symmetric costs, but it seems likely that costs of being below the equilibrium are greater than being above equilibrium mainly because of different lending and borrowing rates.

Second, Equations like (6) consider a single optimisation period. This implies that individuals do not take into account that the minimisation of cost in the current period will influence next period's money stock and therefore next period's cost of adjustment too. To put this another way economic agents are completely backward-looking in assessing costs of adjustment. Conversely, as we shall see later, when the optimisation is extended to a multi-period framework future values and therefore expectations of independent variables appear in the demand for money function.

Third, the assumption of <u>equal adjustment speed</u> for each argument of the demand for real balances is apparent by looking at Equation (9), where money holdings adjust with the same coefficient $(1 - \gamma)$ to changes in either output or interest rate. However, considering the individual portfolio behaviour, the costs of adjustment to income and the interest rate should be quite different. For instance, since income is in most cases paid in the form of money there is no portfolio adjustment cost in raising money holdings but only in reducing them as part of the porfolio reallocation. Therefore at the individual level, adjustment costs make more sense for the interest rate. Moreover, no adjustment lag on transaction costs occurs in response to a price surprise since the change in real balances and in real income vary simultaneously. Thus, provided that it is costly to adjust nominal rather than real balances we should prefer a nominal adjustment to a real one. In addition real adjustment assumes an instantaneous adjustment to price (no money illusion) but slow adjustment to other variables.

By and large it seems more plausible to consider a nominal adjustment that is:

$$M_t = \gamma M_t^* + (1 - \gamma)M_{t-1} \tag{11}$$

implying

$$M_t = \gamma f(X_t) + (1 - \gamma)M_{t-1} \tag{12}$$

Note that adding and subtracting P_t and $(1- \gamma)\ P_{t-1}$ Equation (12) becomes:

$$M_t-P_t = \gamma f(X_t)+(1-\gamma)(M_{t-1}-P_{t-1})-(1-\gamma)(P_t-P_{t-1}) \tag{13}$$

which is equal to the real adjustment formulation of Equation (3) with the addition of the rate of inflation[4].

The nominal adjustment is however only a partial revision of the short-run dynamics since it still constrains the adjustment of all the components of vector X to be identical.

The last assumption, regarding the use of individual adjustment equation to analyse aggregate data, entails two different consequences.

Firstly it implies the identical behaviour of individual economic agents. However, in practice, the costs of being away from equilibrium and of changing asset stocks may vary considerably between different individuals and firms.

Secondly, and more importantly, if it is correct to assume that prices income and interest rate are exogeneous at the individual level it is not always right to make the same assumption at aggregate level. If it were right it would imply that the nominal money supply is totally passive in the face of changes in each independent variable in the demand for money function. This, of course, is not something that can be taken for granted. There are different situations in which the money supply moves independently of demand. The most common case is when money is exogeneous because controlled by the authorities, but independent movements of money supply can occur also in consequence of changes in commercial bank's behaviour and in the government's borrowing requirement (see Brunner-Meltzer 1976)[(5)]. In these situations it can be shown that the partial adjustment model has strange implications: it becomes an overshooting model. Consider for instance a long-run desired demand for money in real terms of the form:

$$M_t^* - P_t = m_y Y_t - m_r R_t \tag{14}$$

and a nominal partial adjustment

$$M_t - M_{t-1} = \gamma(M^* - M_{t-1}) \tag{14a}$$

so that we obtain

$$M_t = \gamma[m_y Y_t - m_r R_t + P_t] + (1-\gamma)M_{t-1} \tag{14b}$$

Putting $M^s = M_t$ for market clearing in the partial adjustment of equation (14a) and differentiating yields $\frac{\partial M^*}{\partial M^s} = \frac{1}{\gamma} > 1$, since $0 < \gamma < 1$, whereas in the long-run the response is unity. Equivalently from equation (14b) $\frac{\partial R}{\partial M_s} = -\frac{1}{\gamma M_r}$

whereas in the long run the response is $-\frac{1}{m_r}$ and $\frac{\partial P}{\partial M_s} = \frac{1}{\gamma} > 1$ versus 1 in the long run(6).

The first order partial adjustment may also be criticised where M* rises over time. In this case short run money balances continually differ from M*. More generally, the performance of the adjustment process, as measured by a steady-state error, depends on the dynamic properties of the equilibrium target (Salmon, 1982). In particular, the first-order partial adjustment ensures a complete adjustment to the long-run equilibrium if the latter is constant (M* = k), whereas if M* is constantly growing (M*=kt). The partial adjustment model never allows M to reach the long-run target level, and M remains constantly below it, and for higher-order equilibrium path ($M^*=kt^2$) the first-order adjustment model will cause M to change from equilibrium (Figure 1).

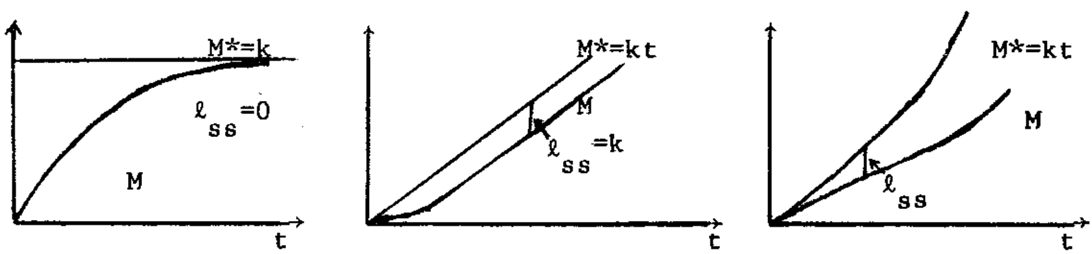

FIGURE 1

The poor performance of the partial adjustment model in these circumstances is a consequence of the order of the adjustment model. A higher-order partial adjustment process can provide better results when the equilibrium follows a dynamic growth path[(7)]. A simple, but roughly equivalent procedure is to assume that γ increases when the growth of long-run demand increases[(8)].

1.3 Short-run dynamics: adaptive expectations

Another way for introducing dynamics in the demand for money function regards the role of adaptive expectations.

Here we only consider adaptive expectations given that regressive and extrapolative expectations have not been widely used in the literature, and that rational expectations do not explicitly introduce any lagged dependent variable into the right hand side of the demand for money function. The use of rational expectations in this field is recent, and it presents some advantages which we will deal with when we discuss the issue of buffer stock in the final part.

A first-order adaptive expectations scheme assumes that the revision of expected income (Y^e) is a fraction Φ of the difference between current and expected income in the previous period:

$$Y^e_t - Y^e_{t-1} = \phi(Y_t - Y^e_{t-1}) \qquad (15)$$

or

$$Y_t^e = \frac{\phi Y_t}{1-(1-\phi)L} \tag{16}$$

where L is the lag operator, defined by the transformation $L^s Y_t = Y_{t-s}$. If we consider a long run demand for money of the form

$$M_t^* - P_t = m_y Y_t^e - m_r R + u \tag{17}$$

substitute for (16) and assume for the moment that adjustment is instantaneous, that is $M^*_t = M_t$, we obtain

$$M_t - P_t = m_y \left(\frac{\phi Y_t}{1-(1-\phi)L} \right) - m_r R_t + u \tag{18}$$

or

$$M_t - P_t = m_y \phi Y_t - m_r R_t + m_r (1-\phi) R_{t-1} + (1+\phi)(M_{t-1} - P_{t-1}) + u - (1-\phi) u_{t-1} \tag{19}$$

or

$$M_t - P_t = b_1 Y_t + b_2 R_t + b_3 R_{t-1} + b_4 (M_{t-1} - P_{t-1}) + u - (1-\phi) u_{t-1} \tag{20}$$

As partial adjustment also adaptive expectations introduce lagged dependent variable into demand for money. However in this case the equation, ignoring the error term, is overidentified and contains an additional term in R_{t-1} and the residuals are represented by a moving average process MA (1). As far as its dynamic performance is concerned, the adaptive expectations hypothesis suffers similar problems to those of partial adjustment. In particular, id does not provide a rational forecast method except for the special case where variables follow an integrated moving average (IMA 1,1) process. On the other hand, if we introduce adaptive expectations, the overshooting phenomenon is still present but theoretically consistent (bearing in mind the concept of permanent income).

Let us now drop instantaneous adjustment and consider partial adjustment and adaptive expectations together. For simplicity now M indicates real money balances. Using the lag operator, Equation (7) can be written as

$$[1 -(1-\gamma)L\ ]M = \gamma M^{*} \tag{21}$$

Combining Equation (17) with (21) and (16) we get:

$$[1-(1-\gamma)L]\ M = \ M^{*} = \gamma \frac{m_y \phi Y_t}{1-(1-\phi)L} - \gamma m_r R_t + \ u \tag{22}$$

multiplying through by $1 - (1-\Phi)L$ and rearranging we get:

$$\begin{aligned} M = {} & \gamma m_y \phi Y - \gamma m_r R + \gamma m_r (1-\phi) R_{t-1} + (2-\gamma-\phi) M_{t-1} \\ & -(1-\phi)(1-\gamma) M_{t-2} + \gamma[u-(1-\phi)u_{t-1}] \end{aligned} \tag{23}$$

or

$$M = b_1 Y + b_2 R + b_3 R_{t-1} + b_4 M_{t-1} + b_5 M_{t-r} + Z \tag{24}$$

where $Z = \gamma[u-(1-\phi)u_{t-1}]$

As in the previous case, ignoring the error term, this equation is overidentified. Notice that this model is more general than partial adjustment and adaptive expectations taken in isolation since each of the above models can be obtained by imposing the restrictions $\gamma = 1$ and $\Phi = 1$ on (23) respectively.

1.4 Econometric Modelling

The standard approach to demand for money thus transforms equilibrium relations into dynamic ones by adding to the explanatory variables a lagged value of the dependent variable. As we have shown this introduction has been mainly explained by the hypothesis of partial adjustment or adaptive expectations separately or in combination. However, as we will see below, the final regression equation is obtained not only from the above hypotheses but also from some other additional assumptions based on economic and statistical considerations.

Here we summarise very briefly the usual steps adopted in the basic modelling approach using Hacche's (1974) article as a standard example. Five consecutive steps may be identified. The first step has already been widely analysed in the previous pages and it recalled here for sake of completeness. A small number of variables is selected from those suggested by economic theory and put together through a simple relationship (usually a stochastic log linear function). The dynamics are also introduced at this first stage. In Hacche's article the outcome of this first step is the following equation:

$$M_t = b_o + b_1 Y_t + b_2 P_t + b_3 (1+r_t) + \gamma M_{t-1}$$

where all variables are in natural logarithms.

Secondly, a variety of economic and statistical assumptions are introduced. For instance a long-run price elasticity of unity is assumed and first differences of the variables are imposed. The former assumption is justified mainly by economic considerations, whilst the latter mainly by statistical reasons. In particular the use of first differences of the variables should avoid spurious regression between trended time series and induce stationarity in the data series (9). At this stage in Hacche the following equation appears:

$$\Delta(M_t/P_t) = b_1 \Delta Y_t + b_3 \Delta(1+r_t) + \gamma\Delta(M_{t-1}/P_t) + r_t$$

Thirdly, the equation is estimated from the available data using techniques that are optimal only in the case that the initial restricted model is correctly specified. The method of estimation is usually OLS. Fourthly, the estimates are compared in sign and size with the prediction of the original theory and tests for some assumptions underlying the method of estimation are carried out. Hacche's article, as most of the literature considers a Durbin-Watson test for serial correlation. The latter can be the consequence of two completely different causes: on one hand the model might be misspecified or on the other hand the true model might have been chosen, but it exhibits autocorrelation. Hacche adopts the latter assumption without providing reasons for it.

The presence of autocorrelation makes the estimates inefficient and therefore it is necessary to use an appropriate procedure to eliminate the residual correlation. This represents the last step in which the equation is revised and re-estimated accordingly. In Hacche's article the elimination of autocorrelation is carried out using a Cochrane-Orcutt transformation, the final equation estimated in Hacche was thus of the form:

$$\Delta(M_t/P_t)-P\Delta(M_{t-1}/P_{t-1}) = b_1(\Delta Y_t-p\Delta Y_{t-1})+b_3[\Delta(1+r_t)$$
$$-p\Delta(1+r_{t-1})]+\gamma[\Delta(M_{t-1}/P_t)-p\Delta(M_{t-2}/P_{t-1})] + r_t-pr_{t-1}$$

In the next chapter we will present some criticisms of the standard modelling approach and we introduce the "general to specific" econometric modelling procedure.

(1) For an attempt that explicitly incorporates the adjustment process in the demand for money see Milbourne et al. (1983).

(2) Milbourne et al. (1983) provide a different approach to the process of adjustment, in which the partial adjustment coefficient varies with the interest rate, the variance of receipts and brokerage fees.

(3) In this simple partial adjustment the speed of adjustment of money does not take into account the other disequilibrium(s) present in other asset(s) (at least one other asset must be in disequilibrium given that individuals face a wealth constraint). We do not consider here these implications which are the bases of the interdependent asset adjustment models. See Brainard-Tobin (1968) and B. Friedman (1977) for models of this kind.

(4) Since with a nominal adjustment the rate of inflation enters automatically in the equation, the finding of some studies that inflation is significant using a real adjustment might be evidence of misspecification. However we can test for misspecification using the restriction present in (13) (i.e. the coefficients on the real lagged values of money and the rate of inflation are equal and opposite in sign) with a likelihood test of (13) plus restriction, against the unrestricted form of (13). (see Milbourne 1983).

(5) The exogeneity of money causes trouble for the interpretation of demand for money. The most pessimistic view believes that we are unable to devise a statistical technique allows us to identify a demand relation (Wooley-Le Roy 1981).

(6) The overshooting can be avoided in different ways. For

example, as we shall see in Chapter 4, the buffer stock approach allows money shocks to be absorbed without any changes in the independent variables. Another approach is based on the inversion of the money demand with the interest rate taken as the dependent variable (Artis-Lewis 1976).

(7) For a more in-depth analysis see Salmon (1982).

(8) This point was suggested by Fleming in the context of modelling inflationary expectations (Fleming 1976).

(9) Stationarity is important because the properties of OLS estimates and normal statistical tests rely on the assumption that the error term is stationary.

CHAPTER 2

THE GENERAL TO SPECIFIC APPROACH

2.1 Introduction

Both the findings during the 70's that structural equations may be not constant, adjusting to changes in policy rules and to rational expectations about future events, and that many important real change occurred (move from fixed to floating eschange rates, inflation, deregulation of financial markets, etc), provide a rationale to the explanation of instability in demand for money in the U.K. based on "structural breaks" (instability is here regarded as predictive failure). However this is not very convincing if extrapolative naive time series models continue to forecast with reasonable accuracy and if demand for money equations estimed for other countries that sperimented the same real changes show a relative good stability.

Actually while a real structural break may be sufficient to cause predictive failure it is not always necessary. To clarify this statement consider a situation in which the structural equation remains unaltered but the behaviour of some exogeneous variables changes. Then all the misspecified econometric approximations to that equation might manifest shifts interpretable as apparent structural breaks. Put another way the interaction of misspecified equations and changes in some variables might cause predictive failure. Of course misspecification is not sufficient to determine predictive failure since in a stationary system incorrect equations will continue to forecast with the same accuracy. In sum instability as predictive failure implies either the experience of a real struxtural break or the adoption of misspecified equation in a changeable context, whereas the predictive accuracy is compatible with misspecified equation.

This consideration represents the framework for interpreting the general to specific approach (GSA) to the demand for money and to its apparent breakdown during the 70's.

Section (2.2) puts forward some criticisms and suggests some revision of the standard approach of the previous chapter. The objections on the standard specification represent the fundamentals for developing the GSA. The latter will be extensively treated in Section 2.3.

2.2 Criticism and Revision of the Standard Approach

Two main problems of misspecification with the standard approach may derive from (i) the introduction of dynamics and (ii) econometric methodology and additional assumptions.

We have previously noted that the theoretical justifications for imposing a restrictive dynamics of the partial adjustment and adaptive expectations type are weak but the resulting dynamic formulation is quite rigid. That specification therefore imposes several restrictions including the omission of longer lags for the right hand side variables and, in the case of partial adjustment, the imposition of the same lag distribution on income and interest rate. The consequence of these restrictions might be some form of dynamic misspecification.

In the absence of valid justifications for these strong a priori assumptions it seems more sensible to consider the issue of the existence and form of any lags as an empirical one. The performance of the demand for money equation might improve if the data itself were allowed to determine the structure of the relationship. Thus, instead of trying to justify a very specific equation, it would be better to start from a general form and only accept the former if the restrictions that it implies are found to be satisfied. In this way we leave the determination of the short-run dynamics to the data. The upshot might be a more complicated and different structure of lags for each of the explanatory variables but at least the dynamic structure does not derive from unrealistic assumptions(1).

The second type of objections regards the modelling procedure and the assumptions explicitly or implicitly introduced during its different stages and not tested.

The standard modelling approach tries to justify an initial very specific and narrowly defined equation as provided by economic theory. The initial equation is estimated, tested and then modified on the basis of every previous negative outcome. The major problem in this methodology is that "every test is conditional on arbitrary assumptions which are to be tested later and if they are rejected all earlier inferences are invalidated" [(2)].

An example of this approach is provided by Hacche (1974). In particular here we refer again to Hacche's study for discussing the problems related to additional assumptions.

Broadly speaking a non-negligible fraction of the traditional econometrics can be characterised by an inadequate examination of the economic and statistical hypotheses in conjunction with insufficient diagnostic testing.

In Hacche's article, three important assumptions are introduced without a careful examination of their repercussions and data admissibility. In particular Hacche postulates that (i) the long-run price elasticity is unity, (ii) the structural equation is better formulated in first differences and (iii) the equation comprises the true model but this model exhibits autocorrelation [(3)].

The first assumption is mainly justified with reference to economic considerations and it represents a fixed point in monetary theory. However econometric methodology provides both tests for existence of any long-run or equilibrium relationship between variables and for assessing the specific value of parameters. And although there may no theoretical reasons for supporting a specific hypothesis it is almost always worthwhile to test it to avoid the role of misspecification.

The second assumption involves the use of differenced data of the variables. Hacche postulates that the structural equation is more appropriately formulated in first differences rather than in levels. Some objections apply on this procedure. Firstly if we use only differenced data we cannot get a long-run solution for the levels even though if the latter on which economic theory usually provides testable a priori restrictions. Secondly, this approach imposes restrictions on the dynamics of the function without any previous check of their validity, and the lack of an inadequate check might lend to a wrong use of differencing. So while there might exist situations in which differencing provides some advantages (it avoids spurious regression and approximates stationarity) there might exist situations in which it causes some troubles as well. For instance consider the two interpretations of a difference transformation provided in Hendry (1977): operator form and restriction form.

The operator form ($\Delta = 1-L$) transforms an equation as follows:

$$Y_t = \gamma_1 + \gamma_2 X_t + \gamma_3 X_{t-1} + \gamma_4 Y_{t-1} + w_t \qquad (25)$$

to

$$\Delta Y_t = \gamma_2 \Delta X_t + \gamma_3 \Delta X_{t-1} + \gamma_4 \Delta Y_{t-1} + \Delta w_t \qquad (26)$$

An equation in first differences can be also obtained from (25) by imposing parameter restrictions $\gamma_1 = 1$ and $\gamma_2 = -\gamma_3$ which yields:

$$\Delta Y_t = \gamma_1 + \gamma_2 \Delta X_t + w_t \qquad (27)$$

As it is apparent the consequences of the two transformation are quite different. In the first case the properties of the error term are completely altered since Δw_t is white noise if and only if w_t is a random walk this does not occur in the second case that is a neutral transformation of (25) if the restriction holds.

As far as the last assumption is concerned Hacche states that the appropriate model has been specified but the true model exhibits autocorrelation. This therefore requires a correction, the Cochrane Orcutt transformation is applied and the final result is the presence of additional lagged variables in the equation. However especially for policy analysis it is important to determine whether estimates lags are due to "true" lag adjustments or merely to statistical properties of the disturbances. The first case implies that all the relevant variables have been included and there is some adjustment or some expectations formation mechanism in the independent variables. The second case tells us that the observed equation is a combination of a static equation and a first order autoregressive process.

The econometric methodology of common factor analysis allows us to distinguish between these two types of lags because of the non-linear restrictions implicit in the autoregressive process of disturbances. To demonstrate this consider a simplified demand for money with instantaneous adjustment where the error term is AR(1):

$$M_t = m_y Y_t + u_t \tag{28}$$

$$u_t = pu_{t-1} + \varepsilon_t \quad \text{or } u_t = (1-pL)^{-1} \varepsilon_t \tag{29}$$

with $-1 < p < 1$ and ε_t white noise. Substituting (29) in (28) and rearranging yields:

$$(1-pL)M_t = m_y(1-pL)Y_t + \varepsilon_t \tag{30}$$

or

$$M_t = c_o M_{t-1} + c_1 Y_t + c_2 Y_{t-1} + \varepsilon_t \tag{31}$$

where $c_o = p$, $c_1 = m_y$ and $c_2 = - p\, m_y$. Thus if (28) and

(29) represent the true model then there is an implicit non-linear relationship of the type

$$c_2/c_1 = -c_o \tag{32}$$

Put another way autocorrelation implies a common factor (1-pL) in the lag polynomials on M and Y. If (32) holds then we have separated out the error dynamics (that is the value of p in (29)) from the systematic dynamics (m_y in (28)) that are of zero order in this simple example (4). Thus if (28) is found to exhibit serial correlation, the first task of the researcher should be to test the implicit non-linear restriction using a likelihood ratio test[(5)].

However Hacche's study of the demand for money assumes that the equation is correctly specified, thus imposing the above-mentioned common-factor restriction without any test to back it up.

Furthermore common factor analysis is also useful from a purely statistical point of view, since it allows the reduction of the number of parameters to be estimated. In this sense, as we will see in the next section, it also plays an important role in the "general to specific" modelling strategy.

2.3 The General to Specific Procedure

In an attempt to avoid the problems of the standard approach and to improve the modelling of dynamic economic relationships four main suggestions can be extracted from the previous analysis.

Firstly, given that economic theory has little to say about short-run dynamics it would be better if the specification of the model started from a general unrestricted dynamic one and arrived at obtaining a restricted and specific model rather than in the other way round.

Secondly, the formulation should provide a model with a long-run solution that conforms to economic theory.

Thirdly a proper account of the serial correlation properties of the errors is necessary to avoid confusion between systematic and error dynamics.

Finally diagnostic checks of model specification should be carefully carried out both on the different stages of the formulation and on the final equation.

These four points represent as many pillars in the general to specific approach (GSA) pioneered by Sargan (1964) and developed largely at the London School of Economics mainly over the last decade. The essence of this methodology is to allow the data to play an important part in determining the short-run structure of the model. It represents a sort of bridge between static econometrics with some and hoc treatment of dynamics and residuals and the time series analysis. On the other hand it allows a role for economic hypothesis in choosing specifications and ensuring that the final equation has a long-run solution which is consistent with economic theory. Thus theory and data continually interplay during the determination of the regressive equation[6].

The general strategy for dynamic model selection implicit in the GSA therefore comprises essentially three stages:

(1) Formulate a general model including all the possible explanatory variables postulated by economic theory and allowing for a relatively high order of dynamics. Estimate and examine the coefficients in order to have some idea of which lags are likely to be important. Retain the value of residual sum of squares as a useful measure of goodness of fit against which more restricted models may be assessed.

(2) Reparameterise the model to obtain variables that are near orthogonal, and which provide a plausible interpretation of the long-run equilibrium. Simplify the model as much as possible (compatibly with the data), using statistical and economic theory. Check that the model so specified is consistent with the previously estimated model.

(3) Evaluate the final model by an extensive set of diagnostic tests.

It is to a more detailed description of these three stages we now turn.

2.3.1 First Stage

The first stage of the GSA starts with the determination of a set of k explanatory variables $Z = (z_1, z_2, \ldots z_k)$ suggested by the theory for the equilibrium relationship between Z and the dependent variable Y. Given the reluctance of economic theory and the probability that the z_i variable will influence Y with a certain structure of lags, it seems sensible to consider a general unrestricted form

$$d_o(L)Y_t = \sum_{T=1}^{k} d_T(L)Z_{Tt} + \varepsilon_{1t} \qquad (33)$$

where $d_i(L)$ is a polynomial in L of degree m_i. Equation (33) represents an Autoregressive Distribute Lag equation ADL $(m_o \ldots m_i \ldots m_y)$ with ε_{1t} white noise by definition. In the case of the demand for money the ADL model allows the money stock to be regressed on a large number of lagged values of itself and of the independent variables. Practically the maximal lags (m_i) with which each variable z_T influences Y_t will be determined by consideration such as the available degrees of freedom and the nature of data (e.g. with quarterly data usually five lags are considered).

Having determined the lags, the estimation of the general model will provide both a yardstick for goodness of fit and unrestricted parameter estimates against which the features of the more restricted models may be assessed. Despite its generality the formulation may be inadequate. Therefore diagnostic tests of the original equation remain worthwhile in order to find out a bad specification at the outset. Tests of misspecification can be conducted in order to check the adequacy of the chosen model.

It is apparent that an equation like (33) is sufficiently general to include many possible nested specifications that usually theory and previous experience have suggested as possible candidate for the final regression equation. An example of the typology derived from the simplest form of (33) is provided by Hendry and Richard (1981). Consider an ADL (1,1) namely

$$Y_t = \beta_1 Z_t + \beta_2 Z_{t-1} + \beta_3 Y_{t-1} + \varepsilon_{1t} \tag{34}$$

although (34) is a very restrictive equation it encompasses nine distinct types of dynamic models as special restrictions are imposed. Table (1) summarises the various possibilities, reporting the restrictions and the corresponding equations for each model. The nine models describe different lag shapes and long-run responses of Y to z_1. Here we are interested in some of these formulations. For instance standard partial adjustment form is obtained by imposing $\beta_2 = 0$, whereas a differenced data model requires $\beta_3 = 1$, and $\beta_2 = -\beta_1$ and the use of a filter $\Delta = 1-L$. A common factor representation involves the restriction $\beta_2 = -\beta_1 \beta_3$ which entails an autoregressive error[7]. Finally, in error-correction models the restriction required is $\Sigma\beta_i - 1 = 0$ and consequently (34) can be rewritten as

$$\Delta Y_t = \beta_1 \Delta Z_t + (1-\beta_3)(Z-Y)_{t-1} + \varepsilon_t \qquad (35)$$

when $\Sigma\beta_1 - 1 = 0$, an important property of (35) is that the remainder of the models of Table 1 become special case of (35). However common-factor and error-correction representations will be analysed in greater detail in the next section since they play an important role in the second stage of GSA.

Table 1

Type of model	Equation	Restrictions on (34)
(a) Static regression	$y_1 = \beta_1 z_t + e_1$	$\beta_2 = \beta_3 = 0$
(b) Univariate time series	$y_1 = \beta_3 y_{t-1} + e_1$	$\beta_1 = \beta_2 = 0$
(c) Differenced data/ growth rate	$\Delta y_1 = \beta_1 \Delta z_1 + e_1$	$\beta_3 = 1. \beta_2 = -\beta_1$
(d) Leading indicator	$y_1 = \beta_2 z_{t-1} + e_1$	$\beta_1 = \beta_3 = 0$
(e) Distributed lag	$y_1 = \beta_1 z_t + \beta_2 y_{t-1} + e_1$	$\beta_3 = 0$
(f) Partial adjustment	$y_1 = \beta_1 z_1 + \beta_3 y_{t-1} + e_1$	$\beta_2 = 0$
(g) Common factor (autoregressive error)	$\begin{cases} y_1 = \beta_1 z_1 + u_1 \\ u_1 = \beta_3 u_{t-1} + e_1 \end{cases}$	$\beta_2 = -\beta_1 \beta_3$
(h) Error correction	$\Delta y_1 = \beta_1 \Delta z_t + (1-\beta_3)(2-y)_{t-1} e_1$	$\Sigma \beta_1 = 1$
(i) Reduced form/ dead start	$y_1 = \beta_2 z_{t-1} + \beta_3 y_{t-1} + e_1$	$\beta_1 = 0$

(Source: Hendry Pagan-Sargan (1984))

2.3.2 Second Stage

The second stage of GSA represents the core of this methodology. It is very important but also rather difficult to implement since it is the result of statistical and economic inspections that continuously overlap. In an attempt to explain this search process clearly we can think of the second stage as formed by three different steps.

Firstly reparameterization and economically meaningful restrictions provide an equation which is economically interpretable and compatible with a long-run solution. Secondly a simplification procedure to go from the large model to a more parsimonious one is implemented until no more statistically significant restrictions remain. Thirdly checks of imposed restrictions and of the final resulting model for consistency with the general model are carried out.

Naturally the reparameterization of the first step can produce different outcomes. However the reparameterized equation is usually arranged so that any hypotheses of interest may be more easily tested. In the case of demand for money we are interested in searching for a long-run solution and imposing a long-run unit price elasticity. For this reason the GSA approach advocates the rewriting of the dynamics of the general model as an error correction mechanism. Consider a simple ADL equation as in (34)

$$Y_t = \beta_1 z_t + \beta_2 z_{t-1} + \beta_3 Y_{t-1} + \varepsilon_{1t} \tag{34}$$

and reparameterize it as follows:

$$\Delta Y_t = \beta_1 \Delta z_t + (1-\beta_3)(z-Y)_{t-1} + (\beta_1+\beta_2+\beta_3-1)z_{t-1} + \varepsilon \tag{36}$$

Equation (36) acts as an error correction mechanism since agents adjust Y_t from Y_{t-1} in response to changes in z_t, to the previous disequilibrium $(z-Y)_{t-1}$ ($(1-\beta_3)$ being the feedback coefficient) and to the previous level of z_{t-1}. The long run static equilibrium solution of (34) is:

$$Y_t = \frac{\beta_1 + \beta_2}{1 - \beta_3} z_t \tag{37}$$

and the steady state equilibrium solution for $\Delta Y = g$ and $\Delta z = g$, is:

$$Y_t = \frac{(\beta_3-1)-(\beta_1+\beta_2+\beta_3-1)}{\beta_3 - 1} z_t + \frac{(\beta_3-1)(1-\beta_1)-(\beta_1+\beta_2+\beta_3-1)}{(\beta_3-1)^2} g_1 \tag{38}$$

where the relationship between Y_t and z_t depends on the rate of growth of z [(8) (9)].

However economic theory usually gives an indication about the relationship between levels but does not provide any indication between the level of the variable of interest and the rate of growth of the independent variable. Actually in demand for money one of the main hypotheses to be tested is a long-run unit price elasticity. As we noted in (37) this hypothesis implies $\beta_1 + \beta_2 + \beta_3 - 1 = 0$ so that the error correction formulation of (36) provides a simple manner to test it, using a t test on the coefficient of z_{t-1}. To put this another way, under long-run proportionality the previous level of z_t becomes irrelevant. Furthermore, the error correction formulation ensures that the dynamic equation reproduces in an equilibrium context the associated equilibrium theory and it makes explicit the relationship between the parameters of the model and the implied long-run elasticity.

The second step of the second stage of GSA has to move from a general to a simplified model. Normally this transition involves the deletion of variables from the model but it might also involve grouping of parameters with similar values of coefficients (i.e. zero + unit restrictions). The simplification rarely requires a single restriction. Unfortunately the empirical studies usually report the final equation without providing a description of the path followed to the simplified version. In this sense this step remains perhaps the vaguest of the GSA. Our discussion will centre on the deletion of variables and mainly through the use of common factor analysis (COMFAC). Having dropped higher order lags until statistical tests indicate we can go no further, we can then test for common factors to reduce the number of estimated parameters.

We have already used COMFAC to separate out systematic and error dynamics and in that occasion to show how to apply COMFAC we used an example that starting from a static model in which residuals were AR(1) process, moved us to a dynamic model with white noise errors. Since we now use COMFAC to simplify the model we have to reverse that procedure namely we start with a dynamic model and move to a static one. As previously using a simple example consider the following model:

$$M_t = c_o M_{t-1} + c_1 Y_t + c_2 Y_{t-1} + \varepsilon_t \qquad (40)$$

or

$$(1-c_o L)M_t = (c_1 + c_2 L)Y_t + \varepsilon_t$$

or

$$(1-c_o L)M_t = c_1(1 + \frac{c_2}{c_1} L)Y_t + \varepsilon_t \qquad (41)$$

where $|c_o| < 1, \varepsilon_t$ is WN, and a common factor will be present if

$$c_2/c_1 = - c_o \qquad (42)$$

If the restriction (42) is imposed the model can be rearranged as

$$M_t = c_1 Y_t + u_t \tag{43}$$

where $u_t = \frac{\varepsilon}{1-c_o L}$ or $u_t = c_o u_{t-1} + \varepsilon_t$

Thus if there is a common factor the initial dynamic model with ε_t white noise and three parameters (c_o, c_1, c_2) has been transformed in a static model when residuals are AR(1) but with only two parameters (c_1, c_o). This is an example of simplification search. Thus serial correlation may be helpful in the context of dynamic specification and in this sense it can be regarded as a "convenient simplification rather than a nuisance".

Naturally this simple example restricted to the case of a one period lag and one regressor only can be generalised to higher order lags and more than one regressor. Thus recall the ADL of equation (33):

$$d_o(L)Y_t = \sum_{J=1}^{k} d_J(L)\ z_{Jt} + \varepsilon_t \tag{33}$$

where the order of the polynomials $d_o(L)$, $d_1(L), \ldots d_k(L)$ are $r, s_1, s_2 \ldots s_k$ respectively. These polynomials can therefore have almost ℓ common roots where $\ell = \min(r, s_1, s_2 \ldots s_k)$. Suppose there are $p < \ell$ common roots, this means that it will be a polynomial (L) of order p which is common to $d_o(L)$ $d_1(L)\ldots d_k(L)$. the polynomials can therefore be factorised as:

$$\begin{aligned} d_o(L) &= \phi(L)\, d_o^*(L) \\ d_1(L) &= \phi(L)\, d_1^*(L) \\ &\vdots \\ d_k(L) &= \phi(L)\, d_k^*(L) \end{aligned} \tag{43a}$$

where $d^*_o(L)$, $d^*_1(L)$, $d^*_k(L)$ are polynomials of order (r-p), (s_1-p) (s_k-p) respectively. Consequently, using (43a), then (33) becomes:

$$d_o^*(L)Y_t = \sum_{J=1}^{k} d_J^*(L)\; z_{Jt} + u_t \tag{44}$$

where $\phi(L)u_t = \varepsilon_t$

The final result is that the number of parameters is reduced by kp and the disturbances become an AR(p) process. The test procedure starts from one common factor and, if this hypothesis is not rejected, a test for two common factors is carried out, and so forth until an hypothesis is rejected and the process stops[10].

As a final step a continuous control of the process of simplification is necessary. In particular, the restricted forms have to be consistent with the general model. Large differences between the values of estimated parameters and a substantial increase in $\hat{\sigma}$ might require some change in specification and indicate misspecification. At the same time diagnostic tests based on the LM approach and some other tests of misspecification may be carried out.

2.3.3 Third Stage

The final stage concerns the role of evaluation in model building. It represents a very important part of the GSA and its relevance has shifted the emphasis of econometric techniques from estimation towards a more careful consideration of modelling. In this stage GSA provides a good deal of general research tools to assess if a particular specification may be regarded as acceptable. Here were do not look at how to derive and use these tools since it requires a lot of space and many sources of information are available in the literature(11). What we are going to do is just to recall the appropriate criteria that GSA suggests for assessing model adequacy. Before mentioning these criteria it is convenient to remember the various kinds of information on which these are based. Usually the existing information is partitioned as follows: observed data and within this relative to a fixed point of time we may distinguish three groups of information, namely past, present and future observations: theoretical and institutional framework; the measurement system including changes of data definition and methods of data collection and the like: earlier empirical analysis.

All this information is utilised to carry out tests that generally are based on $X^2_\ell(\xi_i(\ell))$ and $F_{J\ell}(\eta_i(J\ell))$ distributions. Having partitioned in six groups the available information we can link each source of information to a correspondent evaluating criterion. So we can relate the criterion of <u>data coherency</u> to the past sample observation. The former implies a goodness of fit and absence of residual correlation and residual heteroscedasticity [12]. The <u>valid condition</u> criterion is based instead on the present information. To allow appropriate use of contemporaneous variables as explanatory ones, requires the validity of the so-called exogeneity assertion. Information on future data are useful to assess of the model present accuracy of predictions and <u>parameter constancy</u>, as otherwise predictive failure occurs. The criterion of <u>data admissibility</u> is instead related to the measurement information. A model is data admissible if its fitted and predicted values automatically satisfy the definitional and/or data constraints. <u>Theory consistency</u> is naturally based on the validity of the theoretical hypotheses. One may consider sign, magnitude and interpretation of estimated parameters and the admissibility of a priori restriction in its context. Finally, the information of rival models is utilised to implement the criterion of <u>encompassing</u>. This is the notion of being able to account for the results of alternative explanations of the same set of endogeneous variables.

In sum a model is adequate if it describes the data without producing a systematic misfit, contains valid exogeneous variables, fits well to the data period and predicts well, is consistent with economic theory and measurement system and encompasses rival models.

(1) A first attempt to consider different adjustment lags for each variable, has been made by Price (1972), but his results were inconclusive mainly because of shortage of data. A successive and more successful result, using a similar approach has been obtained by Coghland (1978) who found a stable M1 demand for U.K.

(2) Hendry (1980) p. 226.

(3) The manner in which Hacche deals with the seasonal adjustment of the data has been also criticised (Hendry-Mizon, 1978). However here we discuss only the three above issues which are particularly useful for introducing the general to specific methodology.

(4) We can generalise the above example taking the dynamic version of (28) namely:

$$\beta(L)M_t = \delta(L)Y_t + \gamma(L)u_t \tag{28a}$$

$$\rho(L)u_t = \varepsilon_t \tag{28b}$$

where

$$\beta(L) = \sum_{i=o}^{T} \beta_i L^i, \quad \delta(L) = \sum_{i=o}^{D} \delta_i L^i,$$

$$\gamma(L) = \sum_{i=o}^{g} \gamma_i L^i \quad \text{and} \quad \rho(L) = \sum_{i=o}^{p} \rho_i L^i$$

Here $\gamma(L)$ and $\rho(L)$ are respectively the MA and the AR processes representing the error dynamics and $\beta(L)$ and $\delta(L)$ the systematic dynamics. Of course we do not observe these various dynamics neatly separated out but a fusion of (28a) and (28b). Their restricted transformed equation is

$$\rho(L)\ \beta(L)\ M_t = \rho(L)\ \delta(L)\ Y_t + \gamma(L)\varepsilon_t$$

and the unrestricted transformed equation is

$$\psi(L)M_t = \phi(L)Y_t + \gamma(L)\varepsilon_t$$

the task of the researcher is to factor out the observed dynamics into the systematic and error ones. For instance once the order of $\psi(L)$ is determined to be, say, T there it has to be allocated T = P+I by determining the orders of P and I of the lags, and the common factor analysis provides a methodology for implementing it.

(5) If the restriction is rejected different solutions can be implemented depending on the researcher's view of the "true" model. For example one could try a more complex error structure (for instance an ARMA model), or try a new structural form adding new independent variables, or re-estimate over shorter periods to see if several correlation is caused by structural breaks. However, a fourth option has been more often chosen namely to include additional lags in the dependent and independent variables assuming that residual serial correlation is the result of mis-specified dynamics. The case with this choice is that it does not require a new long-run equilibrium solution.

(6) The discussion of the GSA is here confined to a single equation analysis, but it can be generalised to a system of equations as well. An example of the latter application is provided in Hendry and Anderson (1984).

(7) This implies that despite ADL equation has white noise error by definition, it does not exclude autoregressive error processes.

(8) Equation (38) can be rewritten as:

$$Y_t = K + v\, z_t \text{ or in levels } Y = K\, z_t^{\,v}$$

where K is equal to the second term in (38) and v is the long-run elasticity namely the parameter of z_t in (38). Another useful reparameterization of (34) shows how a misspecified equation can work quite well in certain conditions and to show the role of the error correction mechanism is as follows:

$$\Delta Y = \beta_1 \Delta z_t + (\beta_3 - 1)\left[Y_{t-1} - \frac{\beta_1+\beta_2}{1-\beta_3} z_{t-1}\right]. \qquad (39)$$

The second term of the right hand side in (39) reflects the steady state linear relationship between Y and z, where $\beta_1 + \beta_2/1-\beta_3 = v$.
(Notice that both the formulation of (36) and (39) show that where the long-run elasticity is imposed to be unity the number of parameters is reduced by one).
From (39) it is evident that when Y and z stay close to the steady state growth path a model cast in first differences may be regarded as a reasonable approximation to a more general dynamic model. But if the observation start to deviate from the steady state growth path, the term in square brackets starts to play a fundamental role. Actually if Y_{t-1} begins to grow at a faster rate than is consistent with the steady-state solution, then the term in square brackets becomes positive and since its coefficient is negative ($|\beta_3| < 1$) the net effect is to reduce growth rate of Y and drive it back toward its long run growth path.

(9) Notice that if $g_1=0$, (38) yields the static equilibrium of (37).

(10) Notice that COMFAC is useful also to detect if the model may be formulated in first differences by testing firstly if there is a common factor in the alternative model and if this hypothesis is not rejected testing while the common root is unity.

(11) Harvey's book (1981) is a good starting point to analyse the subject.

(12) Notably a necessary condition for non systematic

residuals is that it be white noise (remember a WN process is that which cannot be predicted linearly from its own past alone). We have previously seen that autocorrelation can be removed also if an invalid common factor has been imposed through adding lagged variables. This entails that WN residuals constitute a weak criterion for model adequacy whereas a stronger condition is to require the residual to be an innovation unpredictable from its own past and also from the part of other variables.

CHAPTER 3

ERROR CORRECTION MECHANISM AND BUFFER STOCK APPROACH

3.1 An Assessment of the GSA

The GSA has doubtless improved our understanding of many problems in the empirical modelling of the demand for money and many of its suggestions have been taken up by researchers. The main contribution regards stage III, namely the battery of criteria to assess the validity of a model. Other advantages, but also questionable points, appear in the other two stages. Certainly the use at the outset of an ADL equation allows one to start with a model which is consistent with economic theory and using all the information contained in the data. This implies one should maintain all the relevant lags, drop the insignificant ones (1) and minimise the possibilities of statistical distortions. This is because including irrelevant variables increases the standard errors for the variables so that there is a limit to the initial generality of the model. Data limitation can also occur and the size of the sample may constrain the number of the possible lagged variables. Another statistical problem regards the individual tests. The latter might often have large type II errors if the overall sequence of simplification is not to have high type I errors.

We have also noted that GSA allows to establish a different lag structure for each variable and the particular structure corresponding to partial adjustment and adaptive expectations may be obtained as special case. However using the GSA it becomes impossible to identify the expectations and adjustment parameters and therefore in presence of instability it becomes difficult to diagnose the source of the latter. By the same token an explicit and separate equation for modelling expectations might be more useful.

Another questionable issue involves the sequence of simplification since there is no unique best sequence to move from the general to specific model. Furthermore, few insights are provided by researchers who have implemented the GSA on how to simplify their models.

We have also noted that another advantage is that the GSA yields a dynamic model which is both consonant with the time series of the data and provides a long-run solution which appears to be fully theory consistent. This feature of the GSA needs to be examined further. Actually it has been argued that the static long-run properties of these models are usually sensible and well determined by that the dynamic long-run properties are often not (Currie 1981). We have already seen a simple example of long-run dynamics when we considered the steady-state error correction formulation. In that case using an ADL (1.1) for Y and x we noted that the level of the dependent variable depends on the rate of growth of x. This conclusion is of course still valid in a more general model where the long-run dynamic relationship between Y and k explanatory variables x_i (i=1.....k) comprises all the terms of the static long-run relationship and also the rates of growth of each independent variable x_i. This result entails two types of problems: first, a problem of interpretations of the relationships between levels and rates of growth of variables: second, as Currie has shown, the coefficients of the rates of growth are not reliable since their values are very sensitive to the sample period and to the number of lags considered. However, despite these disadvantages, the GSA has been successful as far as its statistical performance is concerned. According to the large battery of tests for assessing modelling adequacy, the demand for money equations obtained by implementing the GSA have overcome the equations obtained with the standard approach.

One further feature of GSA equations is that, despite the important role played by the data in providing the dynamic specification, the final result is often an error correction model which is readly interpretable in economic terms. We now turn to examine the way in which error correction mechanism (ECM) may be interpreted in the light of dynamic optimisation.

3.2 <u>An Interpretation of the Error Correction Mechanism</u>

Since the publication of Davidson et al. (1978), the error correction mechanism (ECM) has become a very common feature of dynamic specifications in empirical economics. However it does not represent something completely new. As Hendry and von Vugeru Sternberg (1983) have pointed out, we can use the Phillips servomechanism control to interpret the ECM. In particular in equation (35) the parameters of z_t and $(z-Y)_{t-1}$ represent respectively a proportional and derivative control(2).

As we noted earlier, despite the fact that error correction formulations are the result of a simple reparametarisation, they provide some advantages in terms of the statistical properties of the model, and in terms of the sensible interpretation of economic agents' behaviour. Furthermore, it is possible to strengthen the reason for adopting an ECM if we consider a dynamic optimisation approach to economic behaviour.

As we shall see below, this is an important point since in this way ECMs become not only compatible with a servomechanism and thus backward-looking behaviour but also with forward-looking behaviour. To see this point, let us assume that agents minimize a quadrative loss function as suggested by Hendry and von Ungern Sternberg (1983), but in a dynamic framework rather than in a single period, that is

$$C = \sum_{s=o}^{\infty} D^{s} \, [\lambda_1 (x_{t+s} - x^{*}_{t+s})^2 + (x_{t+s} - x_{t+s-1})^2$$

$$- 2\lambda_2 \, (x_{t+s} - x_{t+s-1})(x^{*}_{t+s} - x^{*}_{t+s-1}) \tag{45}$$

where λ_1 and $\lambda_2 > 0$ and D is a discount factor. Compared to Equation (5) we have added a third term to indicate that costs of adjustment decrease when the actual change $(x_{t+s} - x_{t+s-1})$ is in the same direction of the desidered change $(x^{*}_{t+s} - x^{*}_{t+s-1})$. The minimsation of (45) is an exercise in the discrete time calculus of variation[3]. We first differentiate to obtain the first order necessary condition which yields a set of second order difference equations (Euler equations) which may be solved to obtain:

$$\Delta x_t = \lambda_2 \Delta x_t + (1-\mu_1)\{[\lambda_2 \, x_{t-1} + (1-\lambda_2)(1-D\mu_1) \Sigma (D\mu_1)^s x^{*}_{t+s}] - x_{t-1}\} \tag{46}$$

where μ_1 is the stable root[4]. Notice that if λ_2 is equal to zero, Equation (46) becomes a simple partial adjustment representation

$$\Delta x_t = (1-\mu_1) \, [(1-D\mu_1) \Sigma (D\mu_1)^s \, x^{*}_{t+s} - x_{t-1}] \tag{47}$$

In order to use Equations (46) and (47) we have to specify some forecasting methods for the expected variables x^*. Nickell (1985) shows that if the actual target value of $\tilde{x}$ follows a random walk with drift defined by

$$\tilde{x}_{t+s} = g + \tilde{x}_{t+s-1} + \varepsilon_{t+s} \tag{48}$$

where ε_{t+s} is white noise, then optimal expectations of (48) will be

$$x^*_{t+s} = E\,\tilde{x}_{t+s} = gs + x^*_t \tag{49}$$

given that for $s \leqslant 0$ $x^*_{t+s} = \tilde{x}_{t+s}$. Substituting into (46) we obtain a standard ECM, that is:

$$\Delta x_t = \frac{(1-\mu_1)(1-\lambda_2)D\mu_1 g}{1 - D\mu_1} + [(1-\mu_1)(1-\lambda_2)]\,\Delta x^*_t + 1-\mu_1(x^*_{t-1} - x_{t-1}) \tag{50}$$

Notice that in this case an ECM will arise only if $\lambda_2 \neq 0$. Another possibility very common in economics is that $\tilde{x}_t$ follows an AR(2) process with unit root and drift defined by

$$\tilde{x}_{t+s} = g + \beta\tilde{x}_{t+s-1} + (1-\beta)\,\tilde{x}_{t+s-2} + \varepsilon_{t+s} \tag{51}$$

where ε_{t+s} is white noise. This is a more interesting case because we can then obtain an ECM both substituting in equations (46) ($\lambda_2 \neq 0$) and (47) ($\lambda_2 = 0$). From equation (46) we get

$$\Delta x_t = \frac{(1-\mu_1)(1-\lambda_2)D\mu_1 g}{(1-D\mu_1)(2-\beta)} + [\lambda_2 + \frac{(1-\mu_1)(1-\lambda_2)}{(1+D\mu_1)(1-\beta)}]\Delta x_t^*$$

$$+ (1+\mu_1)(x_{t-1}^* - x_{t-1}) \tag{52}$$

and from equation (47)

$$\Delta x_t = \frac{(1-\mu_1)D\mu_1 g}{(1-D\mu_1)(2-\beta)} + \frac{1-\mu_1}{(1+D\mu_1(1-\beta)} \Delta x_t + (1-\mu_1)(x_{t-1}^* - x_{t-1}) \tag{53}$$

Thus we have shown so far that an ECM may be consistent with economic behaviour when agents optimise with respect to a quadratic loss function, in a dynamic framework. An ECM may therefore coexist both with some form of backward-looking adjustment as well as with forward-looking behaviour. In the next section we will provide an example of this dynamic optimisation applied in the demand for money using a forward-looking model of buffer stock money.

3.3 **Multiperiod Optimisation and Buffer Stock Approach**

The idea of modelling money as buffer stock has recently attracted much interest and some recent empirical studies are based on this concept. Here we focus on one of the possible ways of formulating the buffer stock approach (BSA), that is the so-called forward-looking buffer stock model[5].

As we noted in section 2.2.3 one of the criticism of partial adjustment models was related to the fact that they were derived from a single-period optimisation exercise. Consequently, in such models economic agents fail to realise that choises made in the current period influence the costs of adjustment in the next period. To avoid such extreme myopia we extend the optimisation to a multiperiod framework so that equation (5) becomes:

$$C = \sum_{t=1}^{\infty} k_1(M_t - M_t^*)^2 + k_2(M_t - M_{t-1})^2 \tag{54}$$

Equation (54) differs from equation (45) of the previous section because we have assumed that the discount factor is equal to unity (D=1) and $\lambda_2 = 0$. However the solution requires the same procedure of the previous section. Therefore differentiating we get:

$$M_{t+s} = \frac{k_1}{k_1+2k_2} M^*_{t+s} + \frac{k_2}{k_1+2k_2} M_{t+s-1} + \frac{k_1}{k_1+2k_2} M_{t+s+1} \tag{55}$$

$s = 0,1,2,\ldots.$

where (55) represents a set of second order difference equations. The latter can be solved by imposing the transversality condition and using the factorisation suggested in Sargent (1979). The optimal choise turns out to be the following

$$M_t = g_1 M_{t-1} + \frac{k_1}{k_2} g_1 \sum_{i=0}^{\infty} g_1^i M^*_{t+i} \tag{56}$$

where g_1 is one of the two characteristic roots of (55) (the stable root). In (56) M_t depends on its lagged value, M_{t-1}, and also on the expected values of the determinants of the desired stock of money. Notice that Equation (56) implies a testable restriction between the forward and backward-looking variables. In particular, the coefficient of the expected explanatory variables should decline geometrically with weights related to the coefficient of M_{t-1} (these are the so-called backward-forward restrictions).

To estimate Equation (56) we have to substitute M* with the expected values of its determinants. Proxies for future values can be obtained in different ways. Adaptive expectations, weakly rational expectations, Muth-rational expectations, or the Kalman filter are some methods available in the literature to form expectations, although in empirical studies the most utilised procedure has been to use autoregressive models, then adopting the chain rule of forecasting (McCallum 1976). Having obtained the expected values, we include them in the demand for money equation[6].

We noticed in the previous section that if the future values of the determinants of the demand for money are generated by an AR(2) with unit root, equation (56) assumes an error correction form. In this case the error correction form is the result of forward-looking behaviour and it may provide an explanation for the good performance of demand for money equations obtained with a GSA approach and containing an ECM.

Furthermore, and more importantly, the use of a particular expectations generation scheme represents a big advantage compared to the approach of the previous chapter in which the parameters of the regression equation were a convolution of expectations and adjustment lags. In fact if the forward-looking model is the true one, a change in variables forecasting equations will cause apparent instability in the parameters of the demand for money, whereas by explicity modelling the expectations process we might diagnose any such change. To put this matter another way this specification may provide a way to circumvent the Lucas critique.

Nevertheless the model presented here may still be subject to criticism on other grounds because it treats the money stock as entirely demand-determined. The buffer stock approach may now be incorporated in this multiperiod model providing also another set of omitted variables namely current and expected future shocks. Consequently we can assume that actual money holdings comprise a planned component M_t^p and an unplanned component M_t^u which will depend on any innovation in the explanatory variables of demand for money and shocks on the money supply, conditional on information at time t-1:

$$M_t = M_t^p + M_t^u \tag{57}$$

Therefore using (56) to represent M_t^p and introducing innovations in the explanatory variables and shock on money supply we obtain:

$$M_t = g_1 M_{t-1} + \frac{k_1}{k_2} g_1 \Sigma g_1^i M_{t+i}^* + \gamma(p-p^e)+\xi(y-y^e)+\delta(r-r^e)+v_t+u_t \tag{58}$$

where u_t is white noise and v_t is the unanticipated changes in money supply[(7)]. In this model shocks occuring at period t influence the unplanned component of money balances since agents make decisions concerning M_t based on information at period t-1. This model also allows us to distinguish between agents' expectations of the determinants of the demand for money and unexpected shocks in these variables. This has an important implication since it is apparent from Equation (58) that the obershooting result of Section 2.2.3 is now strongly mitigated. However in this model agents do not consider any possible future shocks. For instance there is not any variable which takes account of possible future increases in the money supply. To consider this we might include an additional term in our cost function. And since future expected changes in money holdings, X, due to an increase in money supply does not imply costs of adjustment we might rewrite Equation (57) as follows:

$$C = \Sigma\, k_1(M_t - M_t^*)^2 + k_2(M_t - M_{t-1} - X_t)^2 \qquad (59)$$

Naturally to minimise Equation (59) requires the same procedure utilised for Equation (57) and finally it will yield the same result with the only difference that now the solution will depend also on all future expected shocks because of the presence of X_t in (59).

Nevertheless the BSA outlined so far has still some criticisable theoretical features. By definition the asset utilised as buffer stock should be the less costly asset to adjust. Therefore it might seem inappropriate to consider a cost function which includes only the cost of adjusting the buffer asset. In fact if we assume a simplified world with only two assets this is an insignificant point given that any change in an asset has a counterpart in the other one.

However in practice agents are likely to hold a wide spectrum of alternative assets and furthermore, because of the existence of saving, the amount of wealth cannot be considered as fixed in time. In a more realistic context equations like (5), (45) or (54) seem paradoxical since they imply that agents are penalised if they hold new wealth in the form of money, that is in the form of the buffer asset. This type of objecton to the forward-looking BSA has been suggested in Muscatelli (1987) where an alternative model of buffer stock is prescribed to allow for costs of adjustment in non buffer assets. Therefore the cost function is modified as follows:

$$C = \sum_{t=1}^{\infty} k_1(M_t - M_t^*)^2 + k_2(A_t - A_{t-1})^2 + 2k_3(A_t - A_{t-1})(A_t^* - A_{t-1}^*) \qquad (60)$$

Equation (60) is a function cost similar to (45) but with alternative assets grouped in a single category (A) also considered.

Following the same procedure of the previous section we might solve (60) and obtain a regression equation. Unfortunately data on stocks of alternative assets are not available. To overcome this problem simple identities to express A in terms of saving and current and lagged values of the money stock are utilised and these estimations for the resulting model are presented. However, despite the use a more sensible model the data does not provide too much support for this alternative formulation in comparison with the previous results of the forward-looking BSA (Cuthbertson 1984 - Artis and Cuthbertson 1985). This may be due to some statistical problems which arise from using the slightly different cost function. In particular, the regression equation derived from the optimisation of (60) contains some additional terms as M^*_{t-1} and saving variables. These terms cause problems of exogeneity and multicollinearity. To avoid them one is forced to exclude some lagged values of the explanatory variables without any help from the theory in imposing the correct restrictions (see Muscatelli 1987). Overall, one of the reasons of the poor performance of this kind of model might be that they force the researcher to impose an inappropriate dynamic structure.

This is an important conclusion, since on the one hand this more sensible model casts some doubts on the interpretation of the previous favourable evidence on the forward-looking BSA, but on the other hand it does not offer, at least so far, a powerful data-supported alternative. What Muscatelli (1987) points out is that empirical evidence seems too sensitive to the cost function adopted, and also too sensitive to the forecasting methods used to generate future values (see Cuthbertson Taylor 1985). This is not a very encouraging result, and therefore whilst by and large BSA has improved the formulation of the demand for money, especially in solving some theoretical uncertainties of previous work, its superiority on the ground of empirical evidence is still not clear cut.

(1) We noted in the previous chapter that an important role in the simplification of the model is played by COMFAC which introduces a not white noise error term. This outcome may be criticised from a theoretical point of view because usually economic theory suggests that white noise errors are appropriate and for this reason COMFAC has been sometimes eschewed in applied economics.

(2) Actually in the original approach Phillips (1954 and 1957) considered three types of controls, namely: proportional derivative and integral. The latter is absent in the usual ECM used in the demand for money. Hendry and von Ungern Sternberg (1983) incorporated an integral control using a stock variable but in a consumption function.

(3) See Sargent (1979) p. 195.

(4) This example is taken from Nickell (1985) who provides details on how to get equations (46) and (47) from (45).

(5) See Laidler (1983), Goodhart (1984) and Bain-McGregory (1985) for a review of the buffer stock approach. Cuthbertson and Taylor (1987), Stevenson, Muscatelli and Gregory (1987) and Milbourne (1987) provide a brief account of the main empirical methods of implementing the buffer stock concept.

(6) The use of a two-stage estimation procedure gives rise to some econometric problems. For a discussion of this issues see Pagan (1984), Kennan (1979), Hausen & Sargent (1982).

(7) This model of buffer stock is a sort of mixture between the forward-looking approach and the shock absorber as presented in Carry and Derby (1981). The latter obtains the unanticipated changes in money supply from the

residuals v_t of the following equation: $m_c = \gamma Z_{t-1} + v_t$ where Z_{t-1} is a vector of variables known to agents at period t-1 which are considered to have a systematic influence on money supply.

CHAPTER 4

CONCLUDING REMARKS

Since the 70's most of research on demand for money has been directed to explain its breakdown. This study has focused on the possibility that instability might be the result of an inadequate dynamic structure. The simple dynamics of the traditional approach based on adaptive expectations and above all the partial adjustment mechanism has been criticised from different angles. In particular adaptive expectations are optimal only in special circumstances whilst partial adjustment constrains the lag structure unduly at the outset of the empirical investigation. The GSA has been the natural response to these shortcomings and seemed to explain some of the instability in terms of the previous inadequate dynamic specification. Starting from a general model (in which all the other usual and simple specifications of the demand for money are nested) and letting the data play a crucial role in the dynamic specification, the GSA leads to parsimonious short-run demand for money equations. More importantly these estimed functions exhibit parameter stability, and pass a wide battery of statistical criteria which the proponents of the GSA suggest for econometric modelling. Moreover the GSA usually ends up with an error correction formulation which provides a steady-state solution compatible with economic theory. We have shown how error correction can have a theoretical interpretation and in this respect it provides GSA with a solid response to the general critique that econometric models lack a justification based on intertemporal optimisation.

Two main points should be noted about the GSA. Firstly it involves a certain amount of data mining and sometimes the "purity" of the "testing down" is not strictly followed. For example in practical applications the addition of new variables can occur as more degrees of freedom are available namely when some simplification has been already implemented. Moreover despite the lack of any foolproof sequence for simplifying the model and the fact that different simplification paths lead to different results, the works that applied this methodology present often only the final equation (for example Taylor 1986). An exact description of the path followed moving from the general to the simplified model is therefore desiderable. Secondly the parameters obtained by GSA are a convolution of expectations and adjustment lags and therefore if instability appears it is difficult to diagnose its source. Consequently an explicit and separate equation for modelling expectations might be useful. This consideration is strengthened if we consider the recent warnings that long-run solutions of ADL equations may yield incorrect inference with respect to the values of the long-run parameters if no explicit consideration is given to the expectations formation mechanism (Kelly 1985; Taylor 1987). Equations estimated by the GSA cannot therefore be used to simulate policy changes that could be expected to alter the expectations generation mechanism. In this respect the forward-looking version of the buffer stock model presented in chapter 3 provides a solution. Extending the single period optimisation of partial adjustment, this approach allows expected future values of explanatory variables to influence current money holdings. The omission of such variables might be one reason why previous demand for money equations exhibited instability. At the same time this framework requires that the expectations formation mechanism enters in the function. Consequently studies of demand for money which so far have represented an exception in macroeconomic modelling as far as the use of forward-looking variables is concerned have started to adopt rational expectations in the formulation of demand for money. This application is in its infancy and the most utilised method of obtaining expectations has been to use autoreggressive models and then adopt the chain rule of forecasting. Further works could drop the assumption that expectations are "fully rational" and consider the practical methods of generating data on the variability of expectations about the explanatory variables of demand for money using the Kalman filter, or the autoregressive conditional heteroscedasticity. Empirical evidence for different countries and for different financial aggregates might be welcome as well. Particularly since the few empirical works about buffer stock money have been applied mainly to M1 in the U.K., broader definitions of money seem more appropriate given that one might expect buffer stock holding to be more sensible if related to larger aggregates than M1. A closer application of the idea of buffer stock money can be obtained if other variables regarding shocks and expected future shocks in the money supply are incorporated in the demand for money function. Implicit in this approach is the exogeneity of money stock and as usual this is a very controversial point (see Milbourne 1987). Exogeneity apart, we have seen that if on the one hand buffer stock models provide useful insights for the formulation of demand for money regarding forward-looking variables, anticipated and unanticipated shocks, overshooting etc., on the other hand simple changes in the cost function to allow a more consonant role of money as buffer stock lead to drastic changes in the final result.

In conclusion the buffer stock approach to the demand for money seems still searching for a definite theoretical framework. We have only offered a cursory glance at the empirical evidence on buffer stock money in this study, but we can offer an idea of the problems in interpretating the results achieved so far by the following two quotations:

"We believe that we have demonstrated considerable empirical support for certain versions of buffer stock approach"

(Cuthbertson, Taylor 1987) and

"when viewed apropriately current empirical results far from lending support, actually refute the buffer stock model and its assumptions"

(Milbourne 1987).

August 1987

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