Bank of England

Discussion Paper No.14

A quarterly small monetary model of the UK economy: preliminary estimation and simulation results

by

J.M.Hoffman

December 1980

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The object of this series is to give a wider circulation to research work being undertaken in the Bank and to invite comment upon it; and any comments should be sent to the author at the address given below. The views expressed are his, and not necessarily those of the Bank of England.

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Contents

Introduction[1]

1 An attempt at the Bank of England to construct a small, highly aggregative, econometric model of the UK economy, in which money plays a prominent role, was reported by Coghlan (1979). The results then described were estimated employing annual data from 1950-52 to 1976, and real expenditure flows based on 1970 prices.

2 More recently, two lines of research have been pursued in the monetary model work - the detailed examination of the simulation properties of the annual model (SMMA) reported by Hilliard (1980), and the development of a model employing quarterly data and real expenditure flows based on 1975 data (SMMQ). Some estimation and simulation results for the SMMQ model are reported here.

3 These results do not by any means mark the termination of the SMMQ work. Specifically, the tabulated coefficients are from the single equation ordinary least squares estimates; no ex-ante simulations have yet been undertaken; and no rigorous examination of the response of the endogenous variables to shocks in the exogenous ones has yet been conducted. But it was thought that the estimation results, and, in particular, the base simulation results thus far obtained were sufficiently encouraging to warrant a wider circulation. This base simulation is dynamic - that is, endogenous variables (whether current or lagged) appearing as explanatory variables in equations of the model are those simulated by the model itself, rather than taking their observed historic values. The test of dynamic simulation, by a relatively small model, of forty-four quarters of macro-economic history, and then of dynamic forecasts of a further six, is clearly not an easy one: but the SMMQ appears to pass without any major, cumulative simulation or forecast errors.

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[1] The author would like to thank C.A.E.Goodhart, R.T.Coghlan (now with the International Bank Credit Analyst) and B.C.Hilliard (now with the Bank of New South Wales) for their helpful comments and encouragement. The simulations were carried out with the benefit of the patient assistance of J.F.Nugée and M.E.Clack, both of the Bank's Financial Statistics Division.

4 The purpose of undertaking work on a new model, where money - and in particular the process by which desired money balances and the supply of money move to equality - plays a leading role, was considered in detail in Coghlan (1979). In brief, the emergence of what has been termed 'practical monetarism' has been recognised in some of the major UK macro-models by the introduction of fully-specified monetary sectors, linking back into the original income expenditure determining process via, for example, the determination of the exchange rate, a liquid assets variable, and interest rates.[1] An alternative approach is to model income/expenditure flows and financial markets in a more integrated manner, as advocated, for example, by Archibald and Lipsey (1958). The Bank's small monetary model is in this latter vein.

[1] As, for example, in Spencer et al.(1978).

Theory of the model

5 Much of the relevant theoretical underpinning for the detailed specification of the model was considered in Coghlan (1979). To recap, money is seen to have two types of effect in the model. The first, or 'primary', effect is that which derives from demand for, and supply of, credit in the economy. The process of granting a request for credit will itself result in the creation of money to meet the additional expenditure engendered; this can be viewed as a relationship between credit and expenditure. The 'secondary' source of monetary influence in the theoretical model is that of money as a 'buffer asset' - the residual asset which individuals hold, not as part of a long-term desired portfolio, but as a widely-accepted medium of storage which they build up and run down in response to temporary changes in their circumstances, whether these are anticipated or not. Herein lies the distinction [cited in Archibald and Lipsey (1958)] between an equilibrium that is 'full' and one which is 'temporary'; what is termed the 'secondary' role of money can only be operative when the system is in less than complete equilibrium, whereas the existence of equilibrium is not relevant to the effects of changes in demand for, and supply of, credit in the economy.

6 This theoretical framework, with money viewed as possessing unique attributes, has important consequences for the way that the equations of the model have been specified. For example, it implies that, of the spectrum of financial assets which could all be regarded as, in some degree, substitutes for 'real' goods and services, money should be seen as having the most important effects, not only on income/expenditure flows, but also on holdings of financial assets. A number of researchers [for example, Jonson et al. (1977)] have found the difference between actual and desired money balances to be an important influence in goods and asset markets; and there is at least one study [Jonson (1976)] which has tested and rejected the hypothesis that other financial assets, apart from money, act as 'buffer' stocks in portfolios.

7 A further consequence of the theory for the specification is the many different places where, and forms in which, monetary variables appear in equations in the model. Money appears directly in the expenditure, prices, capital flows and public sector debt equations of the model; where there are theoretical reasons to believe the short-run and long-run influences of money on an endogenous variable to be dissimilar, then both changes and stocks of money (relative to nominal expenditure) have been employed in the specification of the equation.[1] The capital flows equation includes in addition a domestic credit expansion variable. In the imports, exports, long rate of interest, bank lending and exchange rate equations, money impinges through the inclusion of expenditure, prices and the current account.

8 Because the model is simultaneous, money, as well as being a determining variable, is itself determined, through an identity which is formed employing identities for the public sector borrowing requirement (PSBR),for the balance of official financing, and for the counterparts of the change in broad money, Δ£M3.[2] This identity represents the counterparts to the change in the UK private sector's holdings of sterling M3 balances:

$$\Delta M \equiv [(PSBR-\Delta Dg)-\Delta B+\Delta L]+CA+\Delta N-\Delta NDL$$

where:

ΔM = change in private sector holdings of sterling M3 balances;

PSBR = public sector borrowing requirement;

ΔDg = change in the bank deposits of the public sector;

ΔB = net private sector transactions in public sector debt;

ΔL = flow of sterling bank lending to the private sector;

CA = current account, at current prices;

ΔN = net private sector borrowing from abroad in sterling - specifically, net borrowing from abroad minus the net foreign currency deposit/liability position of the private sector with

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[1] The methodology of forming behavioural equations including long-run equilibrium variables was developed in, for example, Davidson <u>et al.</u> (1978).

[2] See Appendix 3 of Coghlan (1979) for the detailed derivation of this identity.

the banking sector; and

Δ NDL = change in the non-deposit liabilities of the banking sector.

Of the proximate determinants of money in the above identity, ΔB, ΔL, CA and ΔN are wholly determined by behavioural equations within the model. ΔDg and ΔNDL are wholly exogenous. PSBR, however, is rather a hybrid; it is made up by taking the difference between current price expenditure and current price revenue (plus an exogenous residual item). Although the volume of public sector expenditure, the income tax rate and the expenditure tax rate are taken as exogenous to the model, the price level, and income and expenditure (to which the tax rates are applied to give revenue) are endogenous.

Details of the model

9 In the transition from an annual model to a quarterly one, there are two issues which must be confronted prior to undertaking any estimation:

(i) whether to use seasonally-adjusted or unadjusted data; and

(ii) where, for example, a lag up to n years has been included on a right-hand-side variable in an equation in the annual model, whether to estimate up to 4n lags in quarterly estimation, or up to n lags, or whether to estimate the quarterly version from scratch, ignoring any knowledge of lag lengths gained from work with annual data.

10 Insofar as the purpose of seasonal adjustment is to allow for seasonal patterns (rather than for tax revenue timing effects, days of the week adjustments, and so on) the answer to the first issue above now seems to be quite well accepted.[1] If different seasonal adjustment filters are used for different series, this can create serial correlation and dynamic specification problems which lead to biased and inefficient coefficient estimates. Therefore, all estimation for the SMMQ has employed unadjusted data, testing, and incorporating where significant (in the expenditure equation), quarterly seasonal dummy variables.

11 The second issue above is not so clearly resolved. The answer seems to depend on whether the model is in continuous or discrete time. It is usual to employ discrete-time models in econometric work, probably because this is the form in which most economic time series are observed. But since time itself is a continuous variable, this procedure is really an approximation to the true continuous-time formulation. This implies that an equation such as:[2]

$$D\rho = \alpha(m^d - m)$$

where: ρ equals logr; and

m equals logM

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[1] See, for example, Hendry and Mizon (1978).

[2] This example is taken from Fisher (1976).

which states that the rate of interest adjusts continuously according to the discrepancy between the logarithms of desired and actual money balances, would be represented in discrete approximation by something like:

$$\rho_t - \rho_{t-1} = \lambda(m_t^d - m_{t-1}),$$

and the unit of time over which the lag on m operates could be weeks, months, or years; since we are dealing with an approximation to the true model, it is not clear what frequency of data observation is optimal. Hence, if we were passing from a discrete approximation to a continuous-time process using annual data to one using quarterly data, there would be no necessary reason to estimate up to 4n quarters where significant lags of n years have been found in annual estimation.

12 Appendix 1 lists the nine equations of the model. All estimation periods end in 1977 Q4, with subsequent quarters used as a base for outside sample forecasting. The start of the estimation period is 1963 Q2 because quarterly money statistics are available from that time; equations with long lags on determining variables have a correspondingly later start date.

13 All the results in Appendix 1 were obtained by ordinary least squares; although this is known to produce biased and inconsistent coefficient estimates when used for estimating structural parameters of simultaneous equation systems, there is reason to believe that in a highly-interdependent model, such as the SMMQ, the intended re-estimation using more appropriate estimators will not markedly alter the results.

14 All the nine equations in the model are overidentified, using the order condition that the number of predetermined variables in the model excluded from an equation must be not less than the number of included endogenous variables, less one.

<u>Private sector expenditure, ΔEFC</u>

15 In this equation and the next one (for prices), recognition is given to the quantity theory of money in its modern form,[1] which

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[1] See, for example, Anderson and Carlson (1970).

suggests that changes in the money stock can influence real magnitudes in the short run, but in the long run influence only the price level. Output, in the long run, is determined by growth in the productive potential of the economy, the calculation of which is described in the next paragraph; this is governed by growth of natural resources, capital stock, labour force, and technological change/productivity. (All of these are at this stage exogenous to the model.)

16 The chart opposite compares actual output (which equals national income at factor cost, not seasonally adjusted) with potential output in the SMMQ. Compared with the SMMA, the calculation of potential output was slightly complicated by the seasonality of the national income data. The method of calculation adopted was to take the logarithm of a four-quarter centred moving average of income at factor cost, and construct the equation for the line connecting two peaks of this series. This line represents the logarithm of the potential income series; its slope can be construed as giving the growth rate of productive potential, which works out as 2.88% per annum.

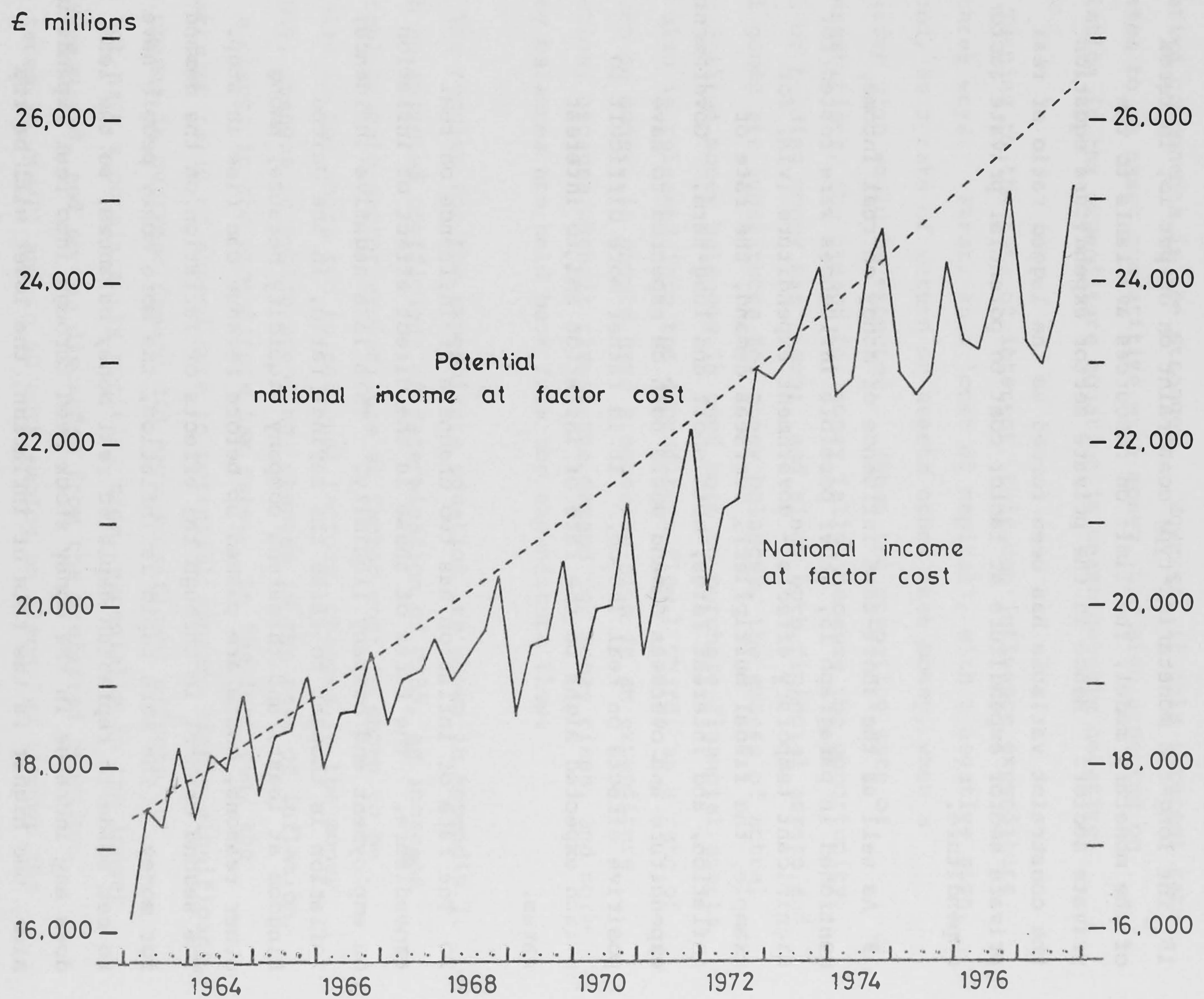
17 Many commentators have argued that the trend rate of growth of productive potential fell considerably following the oil price rises consequent on the Middle East war of October 1973. This may be so, but it was decided here not to build such a fall into the SMMQ, though this does not of course preclude later experimentation. There were two main reasons for this decision:

(i) the expansionary influence of the developing North Sea oil and gas industry in the United Kingdom must, at least to some extent, have offset the deflationary impact of the 1973 oil price rises; and

(ii) even if it is accepted that productive potential fell in 1973, its growth rate may not have altered; in other words, although the real resources available to the economy may well have declined, there does not seem to be any necessary reason for the growth rate of these resources to have been cut as well. This suggests that an appropriate modelling response to 1973 would have been for the intercept of the equation for the potential income series to be reduced,

Chart A

Relationships in the model between potential and actual national income



rather than the slope (i.e. a downward shift in the line for potential income at factor cost in the chart).

In the absence of any clear resolution of this issue it was decided to maintain the methodology described in paragraph 16, although this decision may well be reversed in future model development work.

18 The long-run monetarist-type constraint on output is, in terms of the monetary model, the limit on resources available to the private sector. Hence in the private sector expenditure equation the constraint variable has been formed as the lagged ratio of real private sector expenditure at factor cost to potential private sector expenditure.

19 As well as the short-term influence of money on real income, mentioned in paragraph 15, other possible influences were tested for significant temporary effects - government expenditure (via, for example, the fiscal multiplier), overseas demand, the rate of inflation, and interest rates, both short and long-term. Government expenditure and overseas demand would both be expected to have positive effects on real income. It is rather more difficult to attach expected signs to the rate of inflation and to interest rates.

20 The rate of inflation has two channels of influence on real expenditure. The first of these is the direct effect of inflation on employment and company liquidity. This is a negative influence; inflation is thought to raise the savings ratio, in the United Kingdom at least, and threatens company liquidity because, among other reasons, costs are pushed up before revenue can rise in step. The second channel is through the effects of inflation on the demand for money. The more rapid is inflation, the more money people have to set aside to replenish depleted real money balances, so the less does any increase in the money stock feed through into real expenditure. Also, the higher is the rate of inflation, the lower will be the real rates of interest which may appear in the money demand function; the competing rate has a negative effect on the demand for money, therefore a rise in inflation which cuts the real competing rate of interest will raise the demand for money and so inhibit the flow of money balances into spending; again, inflation has a negative effect

on expenditure. The own rate of interest has an a priori positive effect on the demand for money, and inflation in this case will have a positive effect on expenditure.

21 In summary, if the interest rate in an expenditure function is the own rate of interest on money, the sign expected on the rate of inflation is ambiguous; it depends on which of the positive or negative components is the stronger. However, if this interest rate relates to an asset competitive with money, the sign expected on inflation in the expenditure equation is unambiguously negative.

22 Turning to the rate of interest, this can influence expenditure in three ways. First, as a 'cost of capital', with a negative sign. Second, as a rate of return on assets other than money, when a positive sign would be expected. (When the competing rate of interest rises, the demand for money falls, because the opportunity cost of holding money has risen; and since both financial assets and real goods are substitutes for money balances, the excess of actual over desired money balances is used both to purchase financial assets and also is released into the expenditure flow.) Third, as a rate of return on money, it should have a negative sign in an expenditure equation, because when it rises, the demand for money rises, and more money balances are held back from the expenditure flow.

23 The results for the expenditure equation are shown in Appendix 1. With an adjusted coefficient of determination of 0.89, an increase in real private sector expenditure at factor cost is shown to be related in the short run to seasonal factors, changes in the money supply, changes in public spending, changes in the rate of inflation, and a change in the expenditure tax rate. In the long run, the constraint ratio of expenditure to potential appears highly significant. The change in overseas demand did have significant effects but did not have a consistently positive sign, especially in the longer lags examined, and so was discarded from the preferred equation. The terms in $\Delta(M/P)$ and in ΔG both employ an Almon lag (though the lags on $\dot{P}$ are freely estimated). The reason for this is that lags of these variables are highly collinear with each other, e.g. $\Delta(M/P)_{-1}$ with $\Delta(M/P)_{-5}$ and ΔG with ΔG_{-1}.

24 Changes in both the short money rate, r_m, and in the bond rate r_b, were tested, and the results analysed in the light of the theory of paragraph 22. As the theory would predict, there is no determinate or significant sign on $\Sigma\Delta r_{b-i}$. Although no term in r_m was included in the final equation, $\Sigma\Delta r_{m-i}$ was found to have a significant <u>positive</u> sign, and the theory of paragraph 22 says that this could only happen if r_m was a rate on assets competitive with money. However, it is always a problem that r_m may not be accurately reflecting the own rate on money, especially because of the difficulty of isolating a single representative own rate on money for the entire estimation period. This reasoning is supported to some extent by the freely-estimated signficant negative signs on $\Delta\dot{P}_{-i}$, since the implications of the theory were that only if r_m were acting as a competing asset rate could $\Delta\dot{P}$ have an <u>unambiguously</u> negative sign.

25 Perhaps the clearest result from the expenditure equation shown in Appendix 1 is the great influence that changes in money have, in the short term, on changes in expenditure. The total coefficient

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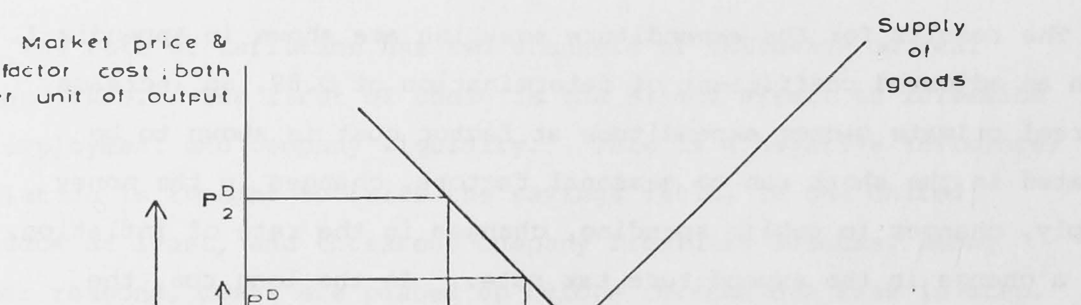

$$(OQ_2 \times OP_2^D) - (OQ_1 \times OP_1^D) = \tfrac{1}{2}\left[(OQ_2 \times P_2^S P_2^D) - (OQ_1 \times P_1^S P_1^D)\right]$$

implies that about 83% of changes in real money balances flow into real expenditure, and that this happens within two years. This result is remarkably similar to that of the annual monetary model [Coghlan (1979), page 34], where the total coefficient is 0.8664, and the lag is also two years.

26 Although a fiscal mechanism is present in the model through the appearance of G in the expenditure equation, the fiscal side of the model could not claim completeness in the absence of any taxation variables. Therefore average historical tax rates were constructed from national income data, and changes in these rates were tested for significant effects on expenditure. This resulted in the inclusion of ΔETR in the tabulated equation. An interpretation of the coefficient on ΔETR is offered below;[1] the conclusion is that the rise in expenditure tax revenue produced by a rise in the 'rate of' expenditure tax from s% to s+1% is only about a half reflected in a rise in expenditure at market prices. This result is presented graphically opposite.

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[1] The estimated equation (Appendix 1, equation A) in abbreviated form is:

$$\Delta EFC = \Delta(E - \frac{TE}{P}) = f(K;Q1;Q2;Q3;[\frac{EFC}{\bar{Y}-G}]_{-1};\ \Sigma\Delta(M/P)_{-i};\Sigma\Delta G_{-i};\ \Sigma\Delta\dot{P}_{-i}) - 63\Delta ETR.$$

$$\text{In 1975, } ETR = \frac{TE}{E.P-TE} = \frac{10422}{72562-10422} = 0.1677 = 16.77\%.$$

For this to rise by one percentage point (i.e. to 17.77%), TE would have risen by £131 million. But we know from the estimated equation that a one percentage point rise in ETR leads to a £63 million fall in EFC. Therefore we can work out the implied change in E as a result of a one percentage point change in ETR:

$$EFC \equiv E - \frac{TE}{P}$$

$$\therefore \Delta EFC + \Delta\frac{TE}{P} \equiv \Delta E$$

or, assigning values to this identity:

$$-63+131 = +68.$$

Thus, for 1975, the rise in market-price expenditure would only about one-half offset the rise in expenditure taxation. But this result generalises to all years, since, for example, doubling TE and EP doubles the rise in TE necessary to increase the tax rate by 1%, but leaves it unchanged in real terms.

The expenditure tax rate rises from s_1% to s_2% [=(s_1+1)%]; factor cost expenditure falls by £63 million for every one percentage point rise in the tax rate (this fall can be represented by the move from Q_1 to Q_2).

27 This result is clearly distinct from that of the annual monetary model, in which expenditure at market prices was found to increase by the full amount of any increase in expenditure taxes - i.e. expenditure at factor cost remains constant (equivalent in the diagram above, to a highly price-inelastic demand curve).

28 By assuming all the changes in the equation equal to zero, the long-run implications of the equation can be analysed:

$$\frac{EFC}{\bar{Y}-G} = 1.033-0.219Q1+0.007Q2-0.075Q3.$$

There does not appear to be any tendency for expenditure to be steadily above or below potential over the year - in the second and fourth quarters it tends to be above its potential, while in the first and third quarters it tends to be below potential.

29 The charts alongside the equations in Appendix 1 show their within-sample (single equation) fits. The expenditure equation has two charts alongside it. The reason for the second chart is that it was thought possible that the good fit portrayed in the first chart had been obtained purely because the equation models the seasonality of expenditure well; thus the second chart was drawn up, plotting actual and estimated values of changes in expenditure after the seasonal influences, as shown by Q1, Q2 and Q3 in the equation, had been deducted from both.[1]

The price level, P

30 From the basic identity $m \equiv kPy$, if:

(i) desired money balances bear a stable relationship to nominal income in the long run, and

(ii) potential output, rather than money, determines real income in the long run,

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[1] These values are not seasonally adjusted in its accepted sense; rather they 'normalise' every quarter on Q4.

then any change in the quantity of money which is not a desired change, resulting from interest rate changes or growth, must eventually be fully reflected in the price level.

31 In the short run, it is often observed that domestic prices are highly sensitive to import prices - as one would expect for a relatively small, open economy - and the second equation tabulated in Appendix 1 confirms this observation with an indicated lag of up to three years on import prices, estimated employing Almon lags. The standard error on the equation represents less than 0.75 percentage points of the mean rate of inflation over the estimation period.

32 Other temporary influences on inflation in the equation appear to be changes in real expenditure, changes in the money stock, and the rate of interest on bank deposits. (Changes in the money stock also enter in Almon form.) Changes in real expenditure have a negative influence on the price level, because with a given quantity of money, and assuming that the velocity of circulation is constant in the short run, real expenditure can only increase if prices fall. The rate of interest on money enters in both levels and difference form; if interest rates are expected to rise, then the link between growth in the money stock and rising prices may be partially broken, since a rise in interest rates implies a fall in the price of bonds, and the speculative motive will act to increase desired money balances. Hence, if expectations of interest rate changes are extrapolated from past changes in the short rate of interest (assumed to bear a close relationship to the authorities' policy rate), then such past changes will have a damping (i.e. negative) effect on the money-inflation link. The positive sign on the lagged level of r_m is consistent with the earlier argument (see paragraph 24 above) that r_m does not accurately represent the own rate for money throughout the period; as well as probably being partly a reflection of high rates of inflation over the estimation period of the equation, the positive sign may well be picking up the fact that a rise in the rate of return on non-monetary assets causes people to substitute bonds and goods for money.

33 The equation has the following longer-run properties (time subscripts are ignored):

$$1.1612 = 0.17082 \ln M - 0.17082 \ln P - 0.06804 \ln E + 0.04845 \ln r_m$$

$$\ln P = -6.8 + \ln M - 0.4 \ln E + 0.28 \ln r_m \qquad (1)$$

$$\text{or } \ln M = 6.8 + \ln P + 0.4 \ln E - 0.28 \ln r_m$$

$$\text{or } {}^{M}/P = 897.8\, E^{0.4}\, r_m^{-0.28} \qquad (2)$$

The term in $\ln E_{-4}$ was included in the equation so as not to constrain the expenditure elasticity in the implied money demand equation [(2) above] to unity. The unitary elasticity of money demand with respect to prices was tested by including a separate $\ln M_{-4}$ term in the equation, but its coefficient was not significantly non-zero.

34 The implied demand for money equation has an expenditure elasticity very similar to that found in the annual monetary model where it was argued (paragraph 45) that such a magnitude was not unreasonable. The implied interest rate elasticity is -0.28.

Exports, X

35 The context in which the exports and imports equations were estimated has been reflected in the specification of the reported equations; specifically, neither the point-of-sale price of foreign goods competing with UK exports, nor the price of UK exports in foreign currency terms, are variables included in the small monetary model, and so an element of approximation has had to be introduced by employing instead:

(i) the foreign currency price of UK imports; and

(ii) the domestic price level, and the exchange rate, entered separately.

36 The decision to estimate the equations in logarithmic form (thus imposing constant elasticities of trade flows with respect to their determinants) was not a clear-cut one in the estimation of the annual monetary model, because the assumption that these elasticities remained constant throughout the period 1952-76 seemed questionable. However, this assumption is more plausible in view of the much shorter estimation period of the quarterly model, and so this work has maintained the logarithmic form of the annual model.

37 The dependent variable in the reported exports equation (equation C in Appendix 1) has been adjusted for the influence of the UK

Continental Shelf oil and gas programme,[1] on the argument that this trade was determined by factors other than the normal influences on the pattern of international trade. The equation is specified along conventional lines - as a function of the price of domestic goods, P; of the price of foreign goods, represented by PZ$; of the exchange rate, e; of domestic expenditure, both private, E, and government, G; and of the volume of world demand, F. Money is not included directly in the equation, but appears 'once removed' through its effect on prices, expenditure, and the exchange rate.

38 Money, as well as influencing the current account in this way, is also influenced by the current account, even assuming the exchange rate does not change. This can be seen from two examples, showing how money acts in the model as an equilibrating variable.

(i) Suppose domestic prices rise faster than those abroad. The current account therefore deteriorates, which has a negative influence on the money stock, which itself (though the inflation equation) has a negative effect on prices. Therefore there will be a tendency for differential rates of inflation to be equalised.

(ii) Suppose foreign prices rise more rapidly than those at home. Observation, as well as the price equations of the monetary models, leads us to suspect that import prices are important determinants of the domestic price level. The long-run mechanism by which this occurs in the model is that the foreign price rise causes the current account to improve, which has a positive effect on the money stock, which (via the price equation) raises the domestic price level.

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[1] Data was obtained from the CSO for (i) North Sea related exports; (ii) North Sea related imports; and (iii) domestic consumption of North Sea oil and gas. OILX.P = item (i), and was subtracted from recorded exports to give 'North Sea oil adjusted' exports; OILZ.PZ = item (iii) minus item (ii), and was added to recorded imports to give 'North Sea oil adjusted' imports. Apart from 1977, 1978 and 1979, quarterly data for North Sea-related direct imports of goods are not available. Hence the distribution of the annual data over the quarters was estimated, using as a guideline the quarterly paths of the 1977 and 1978 data.

39 Equation C in Appendix 1 shows the preferred exports equation; this resulted from estimation with lags of up to four quarters on all the right-hand side variables. The price elasticities are clearly rather low, but the domestic price elasticity of -0.329, when taken with the domestic price elasticity of imports of 1.269, together ensure that the current account responds 'correctly' to a change in P. PZ$ is, as was pointed out in paragraph 35, a compromise variable, but its elasticity of 0.337 in the exports equation, when combined with an elasticity of -1.115 in the imports equation, sums to a total greater than unity.

The Marshall-Lerner conditions for a devaluation to be effective are clearly satisfied in the export and import equations.

Imports, Z

40 Equation D in Appendix 1 shows the preferred imports equation, again derived from initial estimation which included lags of up to four quarters on all the determining variables. Exports were included as a demand factor on imports, on the grounds that UK exports have a considerable re-export and imported raw material and component content. The total coefficient on exports in the equation is 0.472. The government expenditure variable did not prove significant, possibly because of the high service content of government spending. Price elasticities are much higher in magnitude than those in the exports equation; in view of the closer correspondence of the model's price variables to what the specification purported to include, this is not unexpected.

Private sector capital flows from abroad, ΔN

41 This conglomerate variable reflects all non-current account external private sector influences on the money supply, and could, in principle, be influenced by a wide range of factors, with variables affecting expectations likely to play a large role. The analytical approach followed here is similar to that of the annual monetary model; it has a good deal in common with that of Kouri and Porter (1974), who viewed capital flows basically as the mechanism by which a domestic excess demand for money is removed, including,

therefore, explanatory variables which all affect either the demand for, or supply of, money.

42 In this model the factors affecting credit flows, including monetary and fiscal policy decisions, were modelled individually. Such credit flows then may drive the actual money stock away from the underlying demand for money, which is largely determined by the level of prices and real incomes. This disequilibrium will then cause adjustments in all markets - goods markets, bond markets, and in the market for foreign assets - as the members of the economy seek to restore their equilibrium position. In this respect, the approach adopted is closely akin to that of the monetary theory of the balance of payments.

43 Accordingly, the relevant determining variables are the growth of domestic credit on the one hand, and nominal incomes on the other. The relationship between these variables can be regarded as measuring domestic pressure in the United Kingdom for outward and inward capital flows. In addition to this, however, it is necessary to estimate the pressure for such capital flows emanating from similar pressures in the rest of the world, proxied in this model by the United States.

44 This analytical basis gave results in the annual monetary model that were very good, perhaps surprisingly so in view of the single-equation approach and the very high level of aggregation of the dependent variable; the adjusted multiple correlation coefficient was as high as 0.89.

45 The equation finally estimated for the quarterly model is shown as equation E in Appendix 1. First results with the same equation, excluding the lagged money stock term, suggested that about 11% of any expansion of domestic credit flows overseas (compared with about 22% in the annual model). The tabulated equation includes money stock lagged two quarters. The negative coefficient on this variable suggests that a rise in money tends, *ceteris paribus*, to reduce net sterling capital inflows from abroad, as would be suggested by the approach adopted. However (perhaps not surprisingly in view of the relationship between DCE and money growth) there is a

considerable reduction in the total coefficient of the DCE_{UK} variable, although it does just still remain negative.

46 Domestic credit expansion 'abroad' (represented here by the United States) must also influence the domestic capital account, according to the international money arguments; this is represented in the equation by the appearance of DCE_{US}, which has a broadly similar effect to that in the annual monetary model.[1]

47 ΔCA (the change in the domestic current account) enters with negative sign, perhaps reflecting the fact that certain capital flows from abroad (e.g. trade credit) often partly represent financing of current account flows. In the monetary theory of the balance of payments, a current account surplus is just a substitute (for a capital inflow) means of obtaining the desired additional money balances from abroad, so a negative sign on that account would also be expected.

48 Nominal expenditure of the UK private sector, EP, enters the equation in current form and with three and four quarters of lags. This has a positive effect overall; one reason for this is, again, a monetary one; for a given rate of DCE, the higher is expenditure, the greater will be the demand for money inflows from overseas to supplement domestically-created money.

49 Δ lne, the proportional change in the $/£ exchange rate, enters with a positive sign - a rising exchange rate is a reflection both of past current account surpluses and of capital inflows from overseas, and, which is more relevant for this equation, could be a factor in views about the future course of the exchange rate.

50 Overall, the reported equation seemed reasonable. On a much more variable series, the standard error is only slightly higher than that of the annual monetary model (182 compared to 156); and over 75% of the movement in the series is 'explained' by the equation (after allowing for degrees of freedom taken up).

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[1] Coefficient in annual model = 0.016, units are $ millions; coefficient in quarterly model = 10.27, units are $ billions.

51 Considerable effort was devoted to looking for a significant interest rate effect on net capital inflows, with domestic and foreign interest rates being entered, both long term and short term, and in both level form and as a differential (between domestic and foreign rates). Nevertheless, the results were not significant; this failure is, however, at least consistent with the failure to find evidence of a significant interest rate effect on the underlying demand-for-money function in the annual model. Nor was it possible to find any significant effect for the US nominal expenditure term (which was found to be significant in the annual monetary model).

The long rate of interest, r_b

52 The relevant equation here is shown as equation F in Appendix 1; the dependent variable is the change in the yield to redemption on gilt-edged stock with five years to maturity. The theory underlying the equation is that, in the long run, the UK long rate has to maintain an equilibrium relationship with the long rate overseas; while, in the short run, the long rate bears a relationship to the short rate (as in the theory of the term structure of interest rates), as well as being determined by expectations of future exchange rate changes. There are many factors - apart from recently experienced exchange rate changes - which may influence such expectations; for example, the current equation includes the change in net foreign reserves, and the changes in the overseas long-term rate of interest.

53 The estimated equation has the long-run implication that a 1.1 percentage point differential has to be maintained by the domestic long rate over the foreign one (which, in this case, is for the United States). This seems to be quite a sensible result, which also accords with the annual version of the model. The equation indicates that the change in the domestic long rate is determined by changes in the domestic short rate and the foreign long rate, together with exchange rate expectations, working through the change in net foreign reserves, and the current change in the \$/£ exchange rate. ΔR_{-2} has a negative sign because the higher it is, the more buoyant will be expectations about the course of the exchange rate, and so the lower the long rate of interest needs to be to sell government debt.

The \$/£ exchange rate has a negative coefficient because when a surplus of willing buyers of sterling over willing sellers causes a rise in the exchange rate, this engenders exchange rate confidence, leading to buoyant conditions in government debt markets, with r_b falling.

54 Three additional variables were included in the reported equation to test statistical hypotheses about their influence on r_b.

(i) The difference between the domestic and foreign (=US) rates of inflation may affect expectations about the future course of the exchange rate. The results, however, showed that this influence was not statistically significant.

(ii) The higher the PSBR, the more debt the public sector needs to sell to meet a given monetary target, and the more pessimistic expectations about the exchange rate might be. Results, however, lent no support to this.

(iii) Since the sterling counterpart to inflows of foreign currency has to be financed the 'domestic financing requirement', (PSBR+CA+ΔN) seemed a sensible alternative to the PSBR on its own; however, the results were again negative.

Private sector (other than banks) purchases of public sector debt, ΔB

55 The dependent variable is the flow of purchases, rather than the stock, of public sector debt by the non-bank domestic private sector, deflated by nominal private sector expenditure, EP. The formulation of the equation as a flow does not mean that the stock of debt has no relevance; lagged money stock, deflated by EP, has been included in the estimated equation to represent disequilibrium between the actual and desired money stock/public sector debt ratio. Even though estimation did not produce statistically-significant t-values for this disequilibrium term, the variable was not discarded from the preferred equation, since the economic justification for including such a variable, which introduces some long-run desired relationship of money to incomes producing a 'spillover' into public sector debt when money and incomes are out of the desired proportion, is strong.

56 The estimated equation (equation G in Appendix 1) is a demand equation. As such, it includes interest rates, both own and competing, and 'confidence' variables, as well as the lagged money

stock term already mentioned. An alternative approach, which has not yet been explored, would be to estimate a 'reduced form' derived from demand and supply equations; a supply-side PSBR variable could then be included, although either r_b (the price of debt) or B/EP (the quantity of debt) would have to be eliminated, in order to have a reduced form.

57 The four interest rates in the model (short and long rates for the United Kingdom and the United States) were all tried in the public sector debt equation, with up to four quarters of lag on each one. The preferred equation has the domestic long rate entering in current form and with one lag, and the foreign long rate entering in four-quarter change form.

58 Several variables were tried in the original specification to represent 'market confidence', which is clearly a significant - though intractable - factor in public sector debt sales. These variables were: relative rates of inflation in the United Kingdom and United States; lagged rates of change of the exchange rate, to represent expectations; and the change in the reserves. Of these, the first and second appear in the preferred equation; the change in reserves was not significant and so was excluded.

59 In the tabulated equation, interest rates, the exchange rate, and the domestic rate of inflation relative to that abroad, all enter with direction of effect that accords with theory. The results (setting EP at its 1978 Q3 level) indicate that when the domestic long interest rate rises from r_b to r_b+1, about £320 million more public sector debt can be sold to the private sector (other than banks) per quarter; that when the foreign long interest rate rises from r_{fb} to $r_{fb}+1$ from time t-4 quarters to time t, sales of public sector debt in time t are cut by as much as £840 million; and that, if the domestic rate of inflation rises from being equal to the foreign rate to being twice the foreign rate, this cuts sales of public sector debt by £100 million for each quarter in which the doubled rate of inflation persists.

Bank lending, L

60 Equation H in Appendix 1 models bank lending in sterling to the UK private sector. Other recent work on bank lending - most notably at the Treasury [Spencer et al (1978)] - has, in part, used the classical market disequilibrium methodology [developed by Fair and Jaffee (1972)], handling supply factors and credit rationing in the market for personal advances by developing separate notional demand and supply schedules, and assuming that the observed quantity of advances is a weighted average of notional demand and supply.

61 The results presented here estimate a demand equation, including a dummy variable for those periods when there were quantitative restrictions on bank lending, and thus they follow the approach adopted by the annual model. The disequilibrium approach may also be tested as part of future work, although it is not clear how applicable it is to the highly-aggregative character of the model, where equality of notional supply and notional demand in the market for total bank lending could, for example, mask inequalities in the markets for bank lending to persons and bank lending to companies, when viewed separately.

62 Any statistical attempt to model bank lending must be capable of adequately explaining the extremely rapid growth during the years 1972-74 (the stock of loans doubled from 1963 Q1 to 1971 Q4, then redoubled again within the following two years).

63 Throughout almost all the period from May 1965 to September 1971, the banks were subject to quantitative limits on their creation of advances (the exception was April to November 1967). With the introduction of the new credit control arrangements in September 1971, which suggested that the authorities would be less concerned with the direct control of the quantity of bank credit to the private sector, the banks were able to meet some of the pent-up demand for credit which had accumulated over the previous six years of quantitative controls, as well as to regain some of the business which had been lost to other financial intermediaries and to the inter-company loans market.

64 The annual and quarterly monetary models try to represent this development by using a 'pressure dummy' in their bank lending equations. Counting 1 for each quarter when quantitative controls were in force [1] from 1965 Q2 to 1971 Q2 gives a total of 25 as the pressure dummy in 1971 Q3.

65 There is thus an important difference between the approach of this model, which seeks to explain the 1972-74 lending growth by the removal of constraints on banks' activities, and that of many other models, which employ a competition and credit control dummy, implying a behavioural change caused by the 1971 reforms. However, one of these latter models [by Spencer et al. (1978)] clearly hints at a pressure dummy, without explicitly including it:

> 'The reforms of 1971 appear to have had the effect of increasing lending to companies by about £2.3 billion in 1970 prices. This figure is large and suggests that the dummy is picking up the effect of other changes which occurred during the period.'

66 The dependent variable which has been used in this work is the flow of sterling bank lending to the UK private sector, deflated by nominal private sector expenditure; this is the same deflator as in the public sector debt equation.

67 A large number of possible determinants of bank lending were included in experimental specifications. The own rate on bank lending was entered as a first difference and as a 'real' rate (with the rate of inflation both directly subtracted and included in its own right), as well as on its own; unfortunately, none of these forms gave successful results, a conclusion which has emerged from several previous studies, and which could well in this case be attributable to the use of one interest rate to represent the multitude of rates charged to the many different categories of private sector borrowers from the banks. The competing rate, r_b,

[1] Including April to November 1967 when, although ceilings on the advances of the clearing banks were removed, for other banks and finance houses the existing ceilings remained in force; and lending in non-priority categories was still to be distinctly restrained.

was also tested, under the hypothesis that financing policy of firms may lead them to meet their borrowing needs by going outside the banks (e.g. by issuing industrial bonds). Although r_b was found to have a highly significant positive effect in the current period, its effect when entered with lags, although also significant, brought the total effect back to nearly zero, so r_b has not been included in the tabulated equation.

68 In addition to the dummies for quantitative controls and for the removal of quantitative controls (which both appear in the preferred equation), some additional dummies were tried; a special deposit dummy (equal to the average rate of call over the quarter), a qualitative instructions dummy (which is very much dominated by the quantitative controls dummy), and a supplementary special deposits dummy. None of these contributed to explanatory power. In addition, quarterly seasonal dummies were tried; Q2 was significant with negative sign, Q1 and Q3 were not significant.

69 Two other important possible determinants of the demand for bank lending that were tried are the PSBR, and inflows to the private sector from abroad. For the PSBR, a positive overall sign was found, which does not accord with the hypothesis of crowding out by the public sector of the private sector in the loans market (although taken alone the current value does have a negative sign). Inflows from abroad were entered under the hypothesis that earnings and capital from overseas are, to some extent, a substitute for finance from the banks. The results do not counter this hypothesis for the current period, but positive coefficients in the one-lag and two-lag periods dominate.

70 A variable which is notably absent from the tabulated equation is a 'disequilibrium stock variable' - that is, a term to reflect the fact that money balances held in the private sector but not desired as a permanent part of portfolios are used in part to repay bank lending. Several possible such variables [1] were included, but none proved to have the expected negative sign.

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[1] $(\frac{L}{EP})_{-1, -2, -3 \text{ and } -4}$; $(\frac{M}{EP})_{-1, -2, -3 \text{ and } -4}$; $(\frac{L}{M})_{-1, -2, -3 \text{ and } -4}$.

71 The tabulated equation suggests, first, that growth in real private sector expenditure leads, after a six month lag, to an expansion of $\Delta L/EP$; more precisely, the partial effect of a 1% change in real income is to raise real bank lending (L/P) by 1.4%. Second, the total effect of the pent-up demand for lending is estimated by the equation to be about 60% of the increase in bank lending that occurred from 1971 Q3 to 1973 Q1. The chart alongside equation H in Appendix 1 shows that in all but six quarters from 1963 Q2 to 1977 Q4 the equation correctly forecast the sign of $\Delta L/EP$.

72 One possible explanation for the absence of interest rate elasticity in any of the results may be that the bank lending figures include interest charges debited to outstanding advances. This effect would be greater, the higher the interest rate, in contrast to the straight behavioural direction of effect of interest rates; thus, the two effects may, partially or wholly, offset each other. To try to extract the debiting effect from the lending figures, figures were obtained from the Committee of London Clearing Bankers for total interest on advances, and 80% of these[1] were deducted from the total bank lending figures. This gives a new dependent variable, which was tested for negative interest rate elasticity, with r_m (the own rate) entered in three ways: (i) as a level; (ii) as a difference; and (iii) as a 'real' rate. Unfortunately this also met with little success.

<u>The exchange rate, e</u>

73 Specifying and estimating the way in which the authorities react to factors bearing upon an economy's external position has become a widely-used method of modelling exchange rates. For example, in the RBA76 model of the Australian economy, changes in the exchange rate relate to price competitiveness, an unemployment variable, the level of gold and foreign exchange reserves, and to the money supply and to its target value; a similar (more refined) method is the 'pressure approach', a two-stage approach which models pressure on the reserves and the exchange rate together, and then uses a policy

[1] This is the proportion assumed to be debited to outstanding advances.

reaction function to distribute the changes induced by the pressure between changes in the reserves and changes in the exchange rate [for an example of the pressure approach see Saville (1980)].

74 The first of these two variants has been employed in the quarterly monetary model, and equation J in Appendix 1 reports the results obtained, using as the dependent variable $\dot{e}$, the rate of change of the exchange rate.

75 The variables to which it was thought possible that the UK authorities might react, and which were tested in the equation, were:

(i) prices of UK goods relative to those produced abroad;

(ii) variations from an equilibrium differential maintained by UK interest rates over those in the United States;

(iii) an unemployment term, namely, private sector expenditure relative to potential private sector expenditure;

(iv) the current account of the balance of payments; and

(v) the stock of reserves.

76 If prices of UK goods rise out of line with those of foreign goods, then it is a reasonable working hypothesis that the authorities will want the exchange rate to fall, in order to try to maintain competitiveness, although they know that this will exacerbate domestic inflation. Similarly, if foreign prices rise out of line with those at home, this precipitates both pressure from abroad to appreciate the exchange rate, and an attempt to mitigate the extent of 'imported inflation' by allowing the exchange rate to appreciate.

77 The r_b equation revealed the equilibrium result (in paragraph 53 above) that a 1.1% differential has to be maintained by the domestic long rate over the foreign (=US) one. (The annual version of the model indicated a similar magnitude of 0.93%.) This information enabled a new variable, r_d, to be constructed for the exchange rate reaction function; r_d is defined as r_b-1.03-r_{fb}, and measures the amount by which the domestic long rate exceeds the necessary premium over the foreign long rate. The hypothesis is that one reason for r_d to rise is that foreigners sell sterling-denominated assets because they anticipate a fall in the exchange

rate, and that the authorities may allow such a fall so that r_b can return to its equilibrium level, desired on domestic employment criteria. We should therefore expect a negative relationship between $\dot{e}$ and r_d.[1]

78 Perhaps the most consistent policy aim of the authorities has been to achieve and sustain full employment. On theoretical grounds, there may well be a case for using the exchange rate as a tool to achieve internal balance; Mundell's principle of effective market classification, for example, states that authorities should 'tie' policy tools to those goals on which they have the most influence, relative to other tools. The test in the model of whether the authorities have in fact behaved in this way was to enter a term $EFC/\bar{Y}$-G, measuring the level of private sector expenditure relative to its potential level. There is, however, an identification problem here. The same negative coefficient on $EFC/\bar{Y}$-G that would be observed in the reaction function if it were indeed the case that the exchange rate had been used as a tool for internal balance, might also be present for very different reasons - namely, through the use of expenditure-switching or expenditure-reducing policies to achieve current account balance.

79 The role of the current account in the authorities' exchange rate policy is clear: the larger the deficit on current account, the more likely are the authorities to depreciate the exchange rate; and the larger the surplus, the more likely they are to appreciate it. Therefore one would expect a positive relationship between $\dot{e}$ and the current account (deflated by nominal expenditure, to adjust for the effects of inflation and growth).

80 Finally, the level of reserves was entered, on the arguments that:

(i) the lower the stock of reserves, the more must the 'pressure' (referred to in paragraph 78 above) be taken by the exchange rate; and

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[1] The estimated coefficient may well have been augmented by causation running in the reverse direction, from $\dot{e}$ to r_b; this was discussed in the context of the r_b equation, in paragraph 53 above.

(ii) expenditure 'switching' policies, such as exchange rate movement, will be used by the authorities to restore the desired stock of reserves.

81 The estimated equation indicates quite a strong reaction of the exchange rate to changes in competitiveness. The variable r_d was indicated by the estimation to enter as a first difference, and this is how it appears. The employment variable EFC/$\bar{Y}$-G was not generally found to have been a significant influence on exchange rate policy. The variable CA/EP tended to show an 'incorrect' negative total coefficient, implying, counter-intuitively, that the authorities responded to a worsening current account by improving the terms of trade (by appreciating the exchange rate). The reserves were entered both as a stock and as a change, but unfortunately neither was significant.

82 The lagged change in the exchange rate was entered and did prove to be significant, with a coefficient of 0.18, indicating smooth adjustment over time of the exchange rate to changes in domestic and foreign prices and to changes in the UK/foreign interest-rate premium. A dummy reflects the change in the exchange rate in 1967 Q4, as this took place during a period when the exchange rate was fixed.

83 The chart alongside the equation shows that in the period from 1972 Q3, when sterling was floating more or less freely, the equation only once (1974 Q1) wrongly predicts the direction of change of the exchange rate.

Simulation results

84 As mentioned in paragraph 3, the validation testing of the quarterly small monetary model is not yet complete. The principal omissions are multiplier analysis (showing the sensitivity of endogenous variables to changes in exogenous variables), and ex ante forecasting. What has been done, is first, ex post within-sample dynamic simulation of the model, for the period 1967 Q1-1977 Q4, and, second, ex post outside-sample dynamic simulation for the period 1978 Q1-1979 Q2. Even so, this is certainly a stringent test of a model [see, for example Klein (1979)]. The results, in graphical form, for the main endogenous variables in the model are shown in Appendix 3; each variable has its actual path plotted against its dynamically simulated path, both for within-sample and for outside-sample periods.

85 The results are encouraging. Summary statistics, such as root mean square errors (RMSEs), or Theil inequality coefficients, are not shown, since they were thought to overconsolidate information which can be gleaned from the charts.[1] The principal requirements of the simulated model were:

(i) to simulate the turning points of the series at the time when they occur;

(ii) to simulate the correct magnitude of changes in the series; and

(iii) where a simulated series has diverged from an actual series, to draw it back towards the actual path, rather than to lead it to further divergence.

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[1] The Theil inequality coefficient (which is the RMSE of forecast of the change in a variable, adjusted for the scale of the variable) performs only the very limited test of forecasts against a single alternative hypothesis (that of $x_t = x_{t-1}$). The RMSE is not independent of scale, and is not very meaningful when considered in isolation - although it is useful when comparing, for example, two forecasts of the same variable.

Within-sample simulations

86 Taking into consideration the 'noisiness' of many of the quarterly time series which were modelled, and the fact that some of the variables (e.g. bank lending and capital flows from abroad) are notoriously difficult to model even on the least stringent test of single equation within-sample results, the within-sample dynamic simulations depicted in Appendix 3 meet these requirements to a surprisingly high extent. There is no protracted divergence in any of the charts; indeed, it is encouraging that after divergence appears for several quarters (for example in the chart for r_b for 1974) there always seem to be forces bringing the simulated values back towards the actual ones. Clearly, this phenomenon owes much to the number of long-run equilibrium variables built into the model, giving it stabilising tendencies. The charts also show that the timing of the turning points in the actual series is reproduced reasonably faithfully by the simulations, and the magnitudes of the changes in the simulated series, although sometimes clearly incorrectly modelled, are generally not too discouraging.

87 Section 1 of Appendix 3 shows the expenditure and price variables. The close modelling of the highly-seasonal variable ΔEFC gives reasonable fits for the four real expenditure variables EFC/($\bar{Y}$-G); EFC; E; and GDP. The accurate fit of P means that this is maintained in the chart for E.P. The chart for $\Delta_4$lnP, which is the dependent variable in the price equation, shows some simulation error in the timing and magnitude of the 1975 Q1 peak, but otherwise the fit is quite close. The two average tax series fit well (as one would expect, given the accurate simulation of the real expenditure variables).

88 Section 2 of Appendix 3 shows all variables relating to the current account of the balance of payments. Because the variable CA is a difference between two large magnitudes, one might be entitled to think that simulations may not be particularly accurate. However, the only two major errors are for 1974 and 1976-77. Reference to the charts for Z.PZ and X.P shows that both these errors are attributable to underestimation of imports during these two periods. This underestimation can in turn be attributed to the exchange rate (which enters the import equation with a lag of one year) being

underforecast for most of the period 1972-75, hence leading to an underestimation of import competitiveness. Looking at the chart for exports, X, the effects of underforecasting the exchange rate can be seen to a lesser extent (because the exchange rate elasticity is estimated to be about half that in the imports equation, in a single equation context) in the undersimulation of 1972-73.

The chart for the exchange rate, e, has the historical policy implication that the magnitude of the 1967 devaluation was not as great as the pressures on the rate would have justified. However, during the period of floating since 1972, the course of the exchange rate has been quite faithfully simulated, apart from 1972-73, when the simulation suggests that, at least in comparison with the pressure on the currency, sterling was overvalued.

89 Section 3 of Appendix 3 shows the only interest rate, r_b, which is modelled. Δr_b, the dependent variable in the equation, generally has a good fit, although there is some deterioration with the increase in amplitude towards the end of the sample period; r_b itself, however, is perhaps not modelled as closely as the Δr_b results would lead one to hope, particularly in 1974-75.

90 Section 4 of Appendix 3 shows the money supply variables. The factors contributing to monetary growth which are endogenous in the model are ΔB, ΔL, ΔN, PSBR, and CA (which was described above in paragraph 88). ΔB has a good fit within the sample period; ΔL and ΔN have a surprisingly good fit in view of the intractability of the economic variables involved. The overestimation of ΔL in 1975-76 can probably be attributed to the overestimation of E in 1974-75. PSBR, which, as was pointed out in paragraph 8, is modelled as a rather hybrid, partially endogenous variable, has a good simulation fit, as one would expect.

The monetary aggregates in the model are DCE_{UK}, ΔM, M and NAFA. In addition the 'real' money supply, M/P, has been charted as a curiosum. All these have a respectable within-sample fit; the pattern of under and overestimation of M/P accords with the timing of the over and underestimation of P.

Outside-sample simulations

91 The post-sample accuracy of most of the simulations depicted in Appendix 3 is somewhat worse than the within-sample accuracy. However, this is only to be expected. To quote from Klein (1979):

> 'It is, perhaps, too little appreciated by other than experienced model builders how much error variance deteriorates between within and outside-sample simulations. Once a model is built, after careful fitting to data at the single equation, sub-system and full system levels, it is only a matter of a year or two, possibly even less, before errors begin to build up with variances about twice as large as in the sample period. This is a part of life and not something that can be changed by more careful (intensive or extensive) investigation of the sample period.'

92 Nevertheless, the post-sample simulations still appear to be good. In the variables of Section 1 of Appendix 3, the simulated values of ΔEFC show large errors in 1978 Q1 and Q4; but for the other two quarters of 1978 and the first two quarters of 1979, the fit is good. The implications for the four real expenditure variables is clearly shown in the chart for EFC; a large error appears in 1978 Q4, after the first three quarters of the year have been modelled quite accurately, but the error gets no worse in 1979, and the trough of 1979 Q1 is reproduced accurately. When the overforecasting of expenditure is combined with the slight over-forecasting of P in 1979, nominal expenditure (EP) can be seen to have significant simulation errors in 1979 H1, although it is tracked quite well in 1978.

93 The principal implication of the current account variables shown in Section 2 of Appendix 3 is that during 1978 and 1979 movements in the exchange rate became increasingly unrelated to the pressures on the rate, thus confirming the school of thought which holds that sterling was overvalued at that time. The implications can be seen in the current account for 1979 H1, where the simulation implies a surplus of about £400 million, as against an actual deficit of about £2,000 million.

94 Section 3 of Appendix 3 shows the post-sample fit of r_b. Δr_b is very closely fitted, and the chart for r_b appears to show that the only source of error in the interest rate during the post-sample period derives from the within-sample period (because the simulated r_b is virtually constantly below the actual r_b in the post-sample period).

95 The money supply variables of Section 4 have a somewhat mixed post-sample track record. ΔB has large, though not divergent, errors; ΔL is remarkably well simulated; and ΔN has very large errors in 1978 Q1 and Q4, and 1979 Q1, although again it is encouragingly not divergent. Mainly because of the underforecasting of ΔB in the post-sample period, the monetary aggregates are all consistently overforecast, though DCE_{UK} is almost correctly forecast in the final quarter of simulation; ΔM is exactly forecast for the same quarter.

Appendix 1

Estimation results

A Private sector expenditure

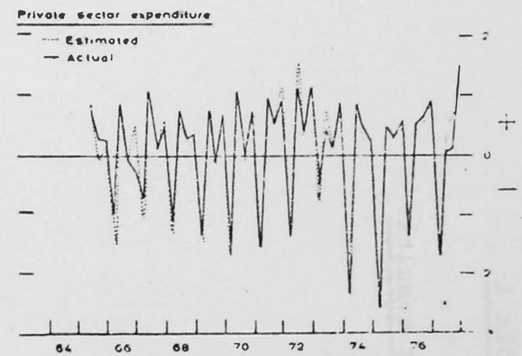
The dependent variable is the change in real private sector expenditure at factor cost, ΔEFC.

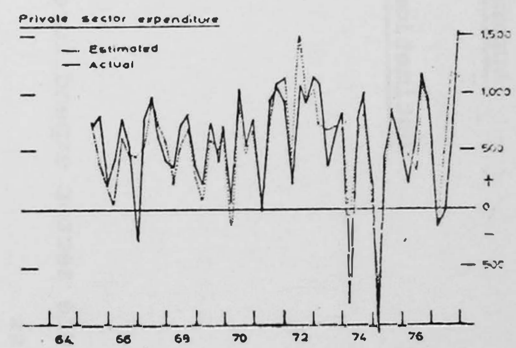
Estimation period: 1965 Q2 - 1977 Q4

K	Q1	Q2	Q3	$[\bar{EFC}/(\bar{Y}-G)]_{-1}$	$\sum_{0}^{8} A_i \Delta (M/P)_{-i}$	$\sum_{0}^{8} B_i \Delta G_{-i}$	$\sum_{0}^{6} C_i \Delta \dot{P}_{-i}$	ΔETR
7,070.7 (4.23)	-1,490.6 (6.43)	46.925 (0.23)	-515.70 (3.52)	-6,842.3. (3.99)	A_0 = 0.08705 (1.25)	B_0 = 0.14002 (0.54)	C_0 = - 33.090 (2.04)	-63.182 (1.25)
					A_1 = 0.07079 (2.42)	B_1 = 0.26937 (1.40)	C_1 = - 31.162 (1.41)	
					A_2 = 0.06203 (2.60)	B_2 = 0.36636 (2.15)	C_2 = - 40.708 (1.57)	
					A_3 = 0.06077 (1.51)	B_3 = 0.43098 (2.53)	C_3 = - 30.288 (1.18)	
					A_4 = 0.06702 (1.34)	B_4 = 0.46326 (2.70)	C_4 = - 42.303 (1.72)	
					A_5 = 0.08077 (1.58)	B_5 = 0.46317 (2.83)	C_5 = - 50.531 (2.45)	
					A_6 = 0.10202 (2.22)	B_6 = 0.43073 (2.84)	C_6 = - 54.391 (3.28)	
					A_7 = 0.13077 (2.81)	B_7 = 0.36594 (2.33)	Σ = -282.473	
					A_8 = 0.16703 (2.43)	B_8 = 0.26879 (1.30)		
					Σ = 0.82824	Σ = 3.19862		

$\bar{R}^2$ = 0.892 SE = 313.23 DW = 2.07

t statistics are shown in parentheses.





B Prices

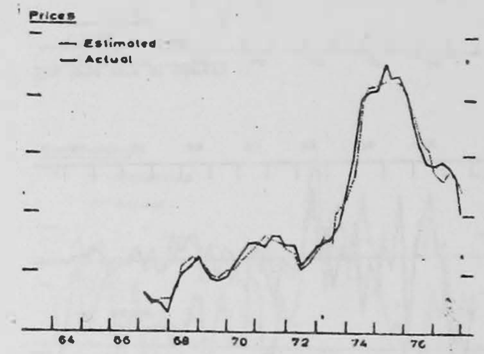
The dependent variable is the rate of change of P over four quarters, $\Delta_4 \ln P$.

Estimation period: 1967 Q1 - 1977 Q4

K	$\sum_0^{12} A_i \Delta_4 \ln PZ_{-i}$	$\ln(M/EP)_{-4}$	$\sum_0^{7} B_i \Delta_4 \ln M_{-i}$	$\Delta_4 \ln E$	$\Delta_4 \ln E_{-1}$	$\ln E_{-4}$	$\ln r_{m-2}$	$\Delta 4 \ln r_{m-2}$
-1.1612 (1.80)	A_0 = 0.040093 (2.75)	0.17082 (2.43)	B_0 = 0.15091 (4.78)	-0.09697 (1.61)	-0.15332 (2.95)	0.10278 (1.64)	0.04845 (2.85)	-0.02614 (1.78)
	A_1 = 0.046752 (3.62)		B_1 = 0.094548 (5.90)					
	A_2 = 0.051274 (4.14)		B_2 = 0.045590 (2.93)					
	A_3 = 0.053660 (4.29)		B_3 = 0.0040316 (0.20)					
	A_4 = 0.053909 (4.27)		B_4 = -0.0301271 (1.40)					
	A_5 = 0.052021 (4.21)		B_5 = -0.056806 (2.83)					
	A_6 = 0.047996 (4.16)		B_6 = -0.076245 (3.15)					
	A_7 = 0.041834 (4.16)		B_7 = -0.088205 (2.57)					
	A_8 = 0.033535 (4.20)		Σ = 0.043617					
	A_9 = 0.023100 (4.03)							
	A_{10} = 0.010527 (2.06)							
	A_{11} = -0.0041821 (0.51)							
	A_{12} = -0.021028 (1.56)							
	Σ = 0.42949							

$\bar{R}^2$ = 0.985 SE = 0.0074 DW = 1.68

t statistics are shown in parentheses.



C Exports, X

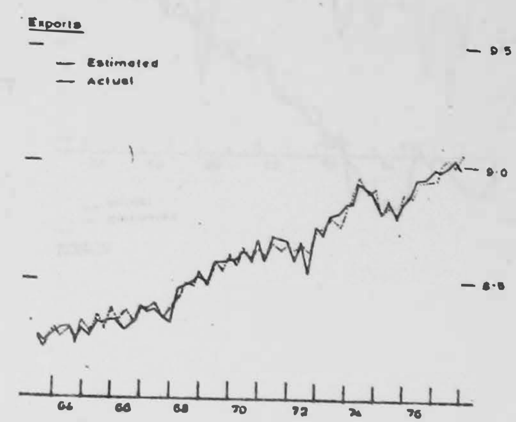
The dependent variable is the log of constant-price exports, adjusted for the influence of the UK Continental Shelf oil and gas programme, ln (X-OILX).

Estimation period: 1963 Q2 - 1977 Q4

K	ln P	ln PZ8	$\ln e_{-1}$	$\ln E_{-1}$	$\ln G_{-1}$	ln F
8.3019 (9.71)	-0.32948 (3.51)	0.33651 (5.06)	-0.45607 (5.04)	-0.21431 (2.64)	-0.10240 (1.38)	0.69642 (14.28)

$\bar{R}^2$ = 0.985 SE = 0.02973 DW = 2.56

t statistics are shown in parentheses.



D Imports, Z

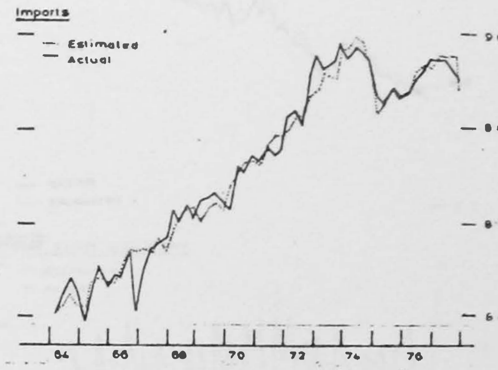
The dependent variable is the log of constant-price imports, adjusted for the influence of the UK Continental Shelf oil and gas programme, ln (Z-OILZ).

Estimation period: 1964 Q1 - 1977 Q4

K	$\ln P_{-1}$	$\ln PZ\$_{-4}$	$\ln e_{-4}$	$\ln E_{-3}$	ln(X-OILX)	$\ln(X\text{-}OILX)_{-1}$	$\ln(X\text{-}OILX)_{-3}$	$\ln(X\text{-}OILX)_{-4}$
2.8927 (2.73)	1.2691 (6.76)	-1.1146 (7.59)	1.0737 (8.38)	0.17668 (1.63)	0.18035 (1.81)	-0.11062 (0.95)	0.20231 (1.81)	0.19994 (2.26)

$\bar{R}^2 = 0.971$ SE = 0.03212 DW = 1.63

t statistics are shown in parentheses.



E Private sector capital flows from abroad, ΔN

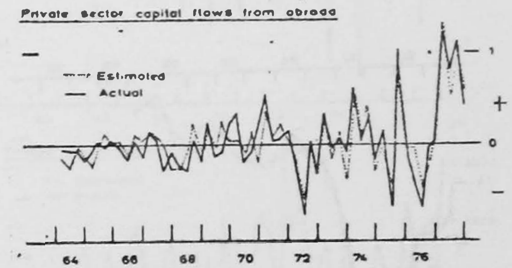
The dependent variable is the flow of net sterling lending from overseas to the private sector, ΔN

Estimation period: 1964 Q1 - 1977 Q4

K	DCE_{UK}	$DCE_{UK_{-2}}$	$DCE_{UK_{-3}}$	DCE_{US}	ΔCA	E.P	$(E.P)_{-3}$	$(E.P)_{-4}$	Δln e	M_{-2}
-534.35 (5.72)	-0.27870 (6.12)	-0.07842 (1.57)	0.34805 (6.21)	10.27164 (2.03)	-0.30441 (2.69)	-0.20912 (2.92)	-0.14116 (2.44)	0.49041 (4.53)	1478.6 (1.67)	-0.03288 (1.21)

$\bar{R}^2 = 0.772$ SE = 181.90 DW = 2.05

t statistics are shown in parentheses.



F The long rate of interest, r_b

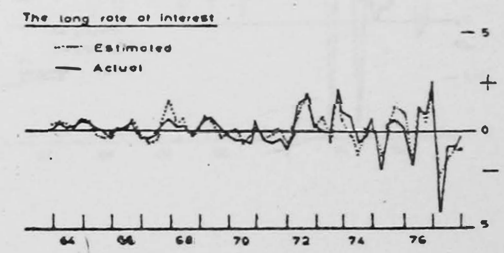
The dependent variable is the change in the yield to redemption on gilt-edged stocks with five years to maturity Δr_b.

Estimation period: 1963 Q4 - 1977 Q4

K	Δr_{fb}	$\Delta r_{fb_{-2}}$	Δr_m	$\Delta r_{m_{-1}}$	ΔR_{-2}	Δlne	$(r_{fb}-r_b)_{-1}$
0.22928 (2.35)	0.89301 (2.85)	-0.61076 (2.03)	0.46415 (7.08)	-0.09794 (1.56)	-0.00076 (3.20)	-4.51259 (1.73)	0.20984 (3.57)

$\bar{R}^2 = 0.710$ SE = 0.5067 DW = 2.18

t statistics are shown in parentheses.



G Private sector (other than banks) purchases of public sector debt, ΔB

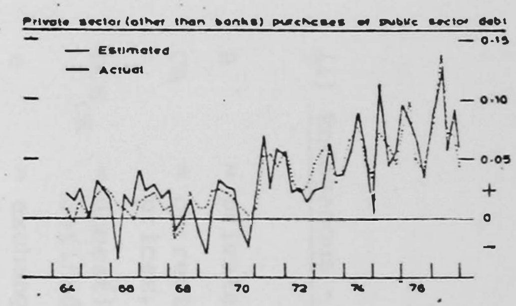
The dependent variable is net transactions in private sector holdings of public sector debt, excluding notes and coin, divided by nominal private sector expenditure, $\Delta B/EP$

Estimation period: 1964 Q2 - 1977 Q4

K	$(M/E.P)_{-3}$	r_b	$r_{b_{-1}}$	$\Delta_4 r_b$	Δlne_{-1}	Δlne_{-4}	$(\dot{P}/\dot{P}\,US)_{-1}$
-0.08653 (1.92)	0.02669 (0.92)	-0.00624 (2.14)	0.01683 (6.25)	-0.02799 (5.97)	0.23171 (2.54)	0.24400 (2.64)	-0.00363 (1.30)

$\bar{R}^2 = 0.702$ SE = 0.0186 DW = 1.98

t statistics are shown in parentheses.



H Bank lending, L

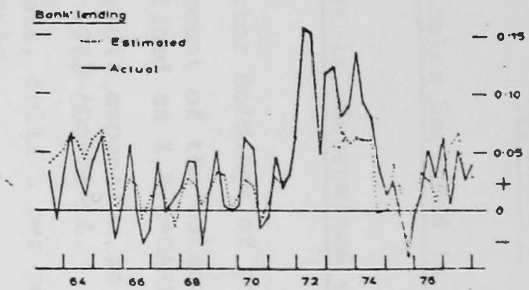
The dependent variable is the flow of bank lending in sterling to the UK private sector, deflated by nominal private sector expenditure, $\Delta L/E.P$

Estimation period: 1963 Q2 - 1977 Q4

K	QD	PR	PR_{-1}	PR_{-2}	PR_{-3}	PR_{-4}	PR_{-5}	PR_{-6}	$(\Delta E/E)_{-2}$	$(\Delta E/E)_{-3}$	$(\Delta E/E)_{-4}$	$(\Delta E/E)_{-5}$	$(\Delta E/E)_{-6}$
0.03793 (7.30)	-0.02823 (3.73)	0.00168 (1.48)	0.00102 (0.90)	0.00386 (3.39)	0.00379 (3.34)	0.00082 (0.73)	0.00272 (2.40)	0.00216 (1.89)	0.31921 (3.17)	0.43308 (4.55)	0.22924 (2.46)	0.25688 (2.70)	0.19762 (2.07)

$\bar{R}^2 = 0.618$ SE = 0.0268 DW = 1.33

t statistics are shown in parentheses.



J The exchange rate, e

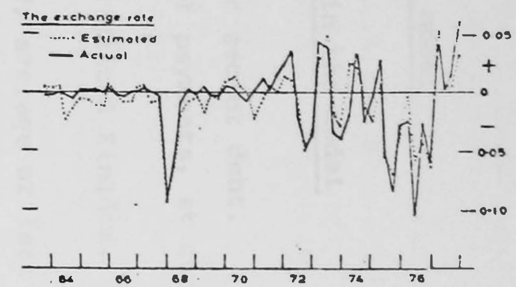
The dependent variable is the rate of change of the exchange rate (dollars per pound), Δlne

Estimation period: 1963 Q3 - 1977 Q4

$\Delta ln\, P\$$	ΔlnP	Δr_d	DEV	$\Delta ln\, e_{-1}$
0.[illegible]9963 (8.12)	-0.66610 (7.28)	-0.01304 (5.91)	-0.04135 (3.63)	0.18230 (2.52)

$\bar{R}^2 = 0.767$ SE = 0.0151

t statistics are shown in parentheses.



Appendix 2

Variables included in the model

(i) Endogenous - that is, determined within the model

B = private sector holdings of public sector debt.

CA = current account of the balance of payments, at current prices, defined as X.P-Z+CARE.

DCE_{UK} = domestic credit expansion in the United Kingdom, defined as PSBR-ΔDg-ΔB+ΔL.

e = exchange rate, dollars per pound, average of last working days of months.

E = total private sector expenditure at constant 1975 market prices.

EFC = total private sector expenditure at constant 1975 factor cost, defined as E-TE/P.

GDP = gross domestic product at constant 1975 market prices, defined as E+G+X-Z.

L = stock of bank lending in sterling to the private sector.

M = private sector £M3 money balances.

N = net external sterling liabilities of the private sector.

NAFA = net acquisition of financial assets by the private sector, defined as ΔB+ΔM+ΔNDL-ΔL-ΔN+NARE.

P = price deflator of total final expenditure.

$\dot{P}$ = ΔlnP annualised and expressed as a percentage rate of inflation.

PSBR = public sector borrowing requirement, defined as G.P-TY-TE+PBRE.

PZ = price deflator of the sterling value of imports, defined as PZ\$/e.

r_b = domestic long-term rate of interest, defined as the yield to redemption on five-year gilt-edged stock (average of last working days of months).

r_d = r_b-1.093-r_{fb}.

R = net foreign reserves, defined as Σ_o^t(CA+ΔN).

TE = expenditure tax receipts, minus subsidies, defined as 0.01(ETR.EFC.P).

TY = income tax receipts, minus transfer payments, defined as TR(E.P+NAFA)/(100-TR).

X = exports of goods and services measured at constant 1975 prices.

YFC = gross domestic product at constant 1975 factor cost.

Z = imports of goods and services measured at constant 1975 prices.

(ii) Exogenous - that is, determined outside the model

CARE = residual making up the current account identity.

DCE_{US} = domestic credit expansion in the United States, as defined in International Financial Statistics (published by the International Monetary Fund).

DEV = dummy to represent November 1967 devaluation.

Dg = bank deposits of the public sector.

ETR = average expenditure tax rate.

F = an index of world demand; the constant 1975 dollar value of world exports, as listed in International Financial Statistics, excluding the United Kingdom.

G = public expenditure on goods and services valued at 1975 expenditure prices.

K = the constant.

NARE = residual making up net acquisition of financial assets by the private sector.

NDL = non-deposit liabilities of the banking sector.

OILX = North Sea related exports, at constant 1975 expenditure prices.

OILZ = domestic consumption of North Sea oil and gas, minus North Sea related imports; measured at constant 1975 import prices.

PBRE = residual making up the PSBR, made up of grants and transfers not already included.

PR = a 'release of pressure' dummy to reflect the removal of quantitative controls in September 1971 (see paragraphs 63 and 64).

PUS = price deflator of US gross national product.

$\dot{PUS}$ = Δln PUS annualised and expressed as a percentage rate of inflation.

PZ\$ = foreign currency price of imports.

Q1, Q2
Q3 = quarterly seasonal dummies.

QD = a dummy to represent quantitative controls (ceilings) on bank lending to the private sector.

r_{fb} = overseas long-term rate of interest, defined as the US corporate bonds rate (average of months).

r_m = domestic short-term rate of interest, defined as the seven-day deposit rate +2% for 1963 to 1965 Q2; as a linear mix of seven-day and inter-bank rates, with a linearly declining addition to represent the difference between the seven-day and bank rates, for 1965 Q3 to 1971 Q2; and as the three-month inter-bank rate for 1971 Q3 to date.

TR = average income tax rate.

$\bar{Y}$ = potential GDP at constant 1975 factor cost.

(iii) Additional definitions

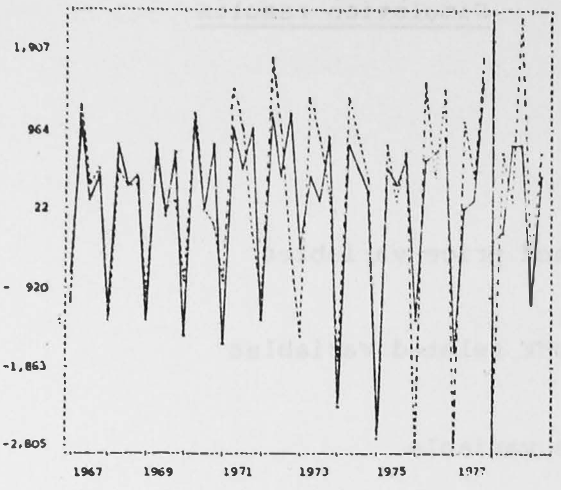
Δ_i	=	i quarter difference (i defaults to 1).
$-i$	=	subscript to represent i quarters of lags.
ln	=	natural logarithm of a variable.
$\sum_{i=1}^{j} x_i$	=	the sum of the x_i from i=1 to i=j.

Appendix 3

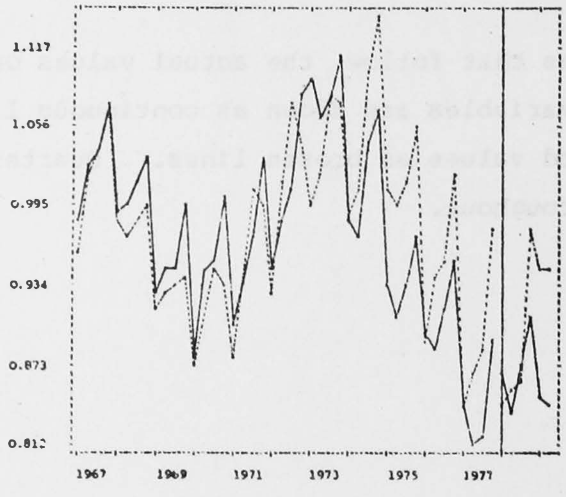
Simulation results

NB In the graphs that follow, the actual values of the endogenous variables are shown as continuous lines and the simulated values as broken lines. Quarterly plots are used throughout.

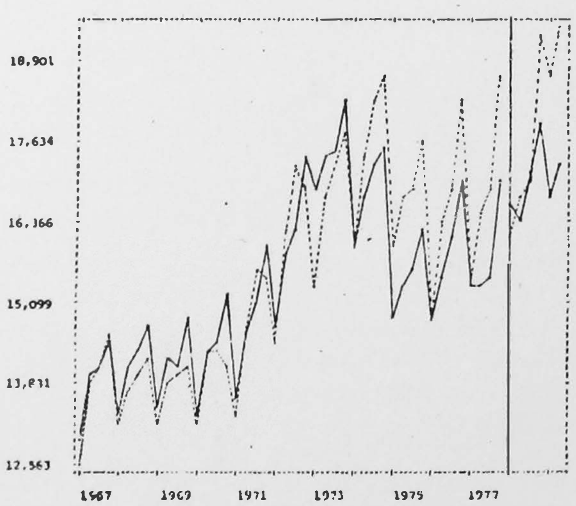
Endogenous variable: ΔEFC



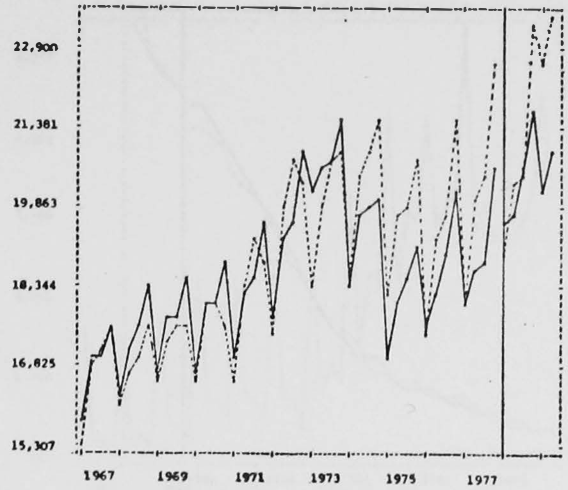
Endogenous variable: $EFC/\bar{Y}-G$



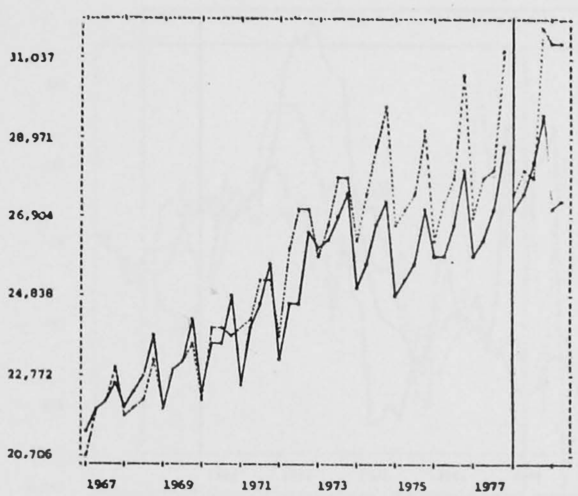
Endogenous variable:EFC



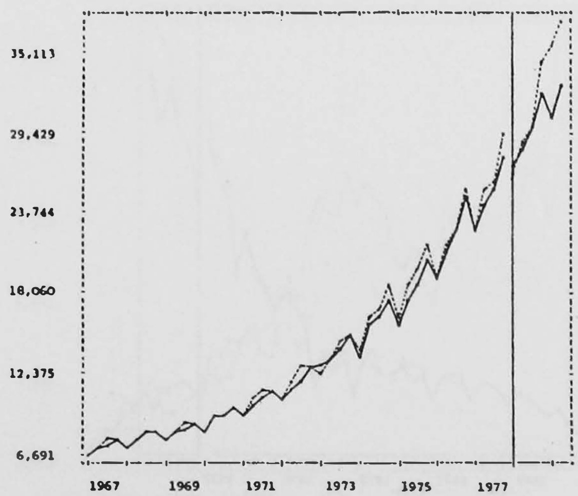
Endogenous variable: E



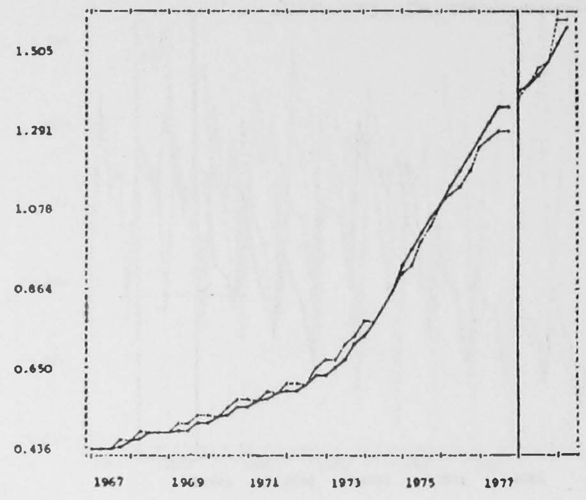
Endogenous variable: GDP



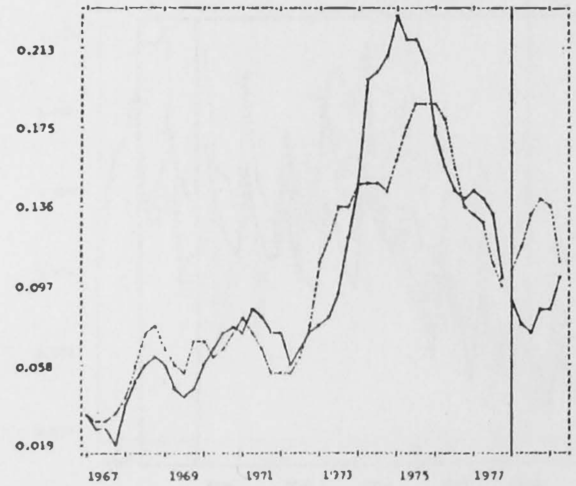
Endogenous variable: E.P.



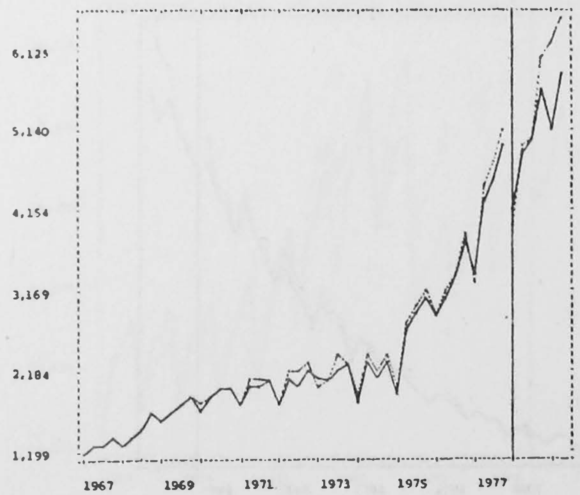
Endogenous variable: P



Endogenous variable: $\Delta_4 \ln P$

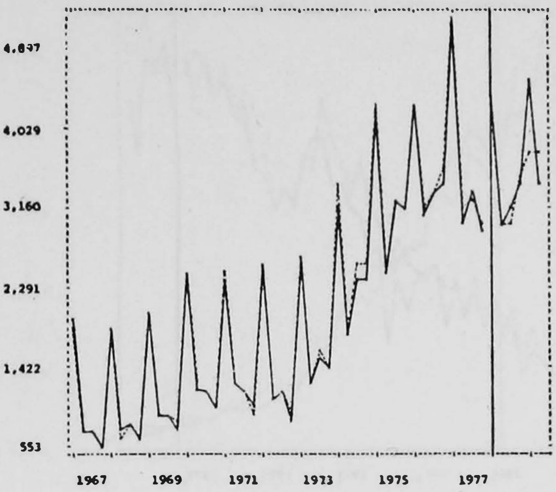


Endogenous variable: TE



Section 1 (cont.)

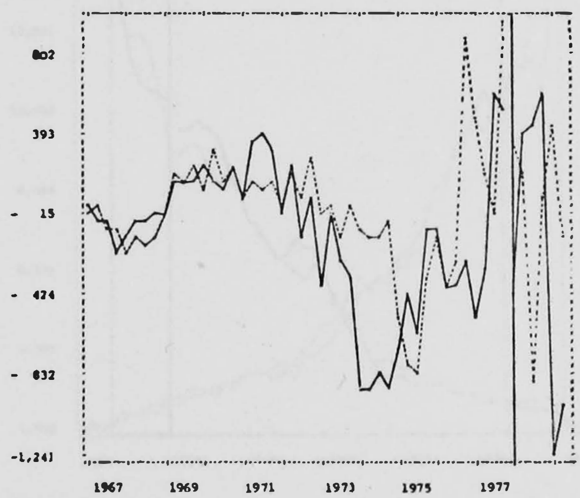
Endogenous variable: TY



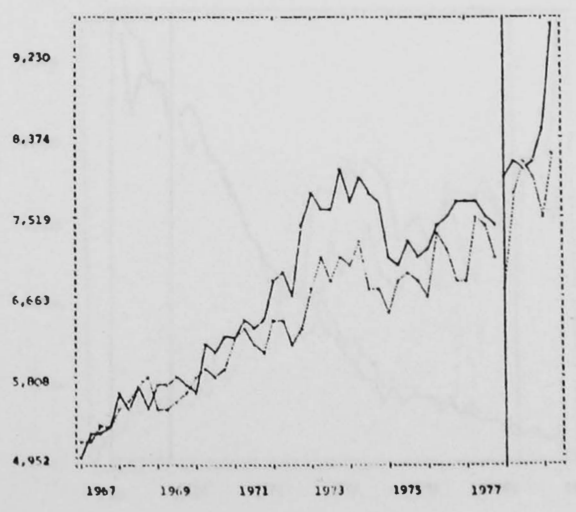
Section 2:

Current account related variables

Endogenous variable: CA



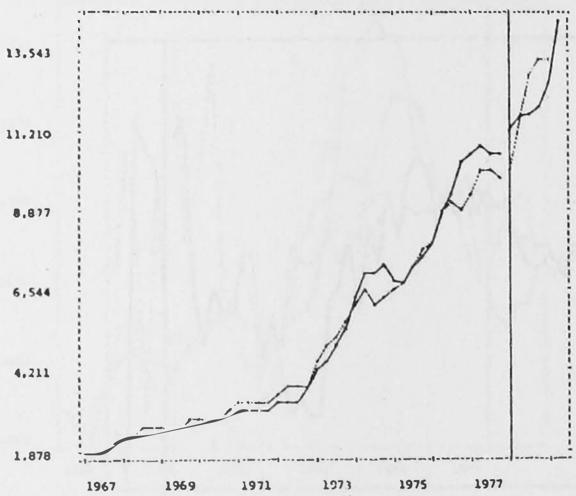
Endogenous variable: Z+OILZ



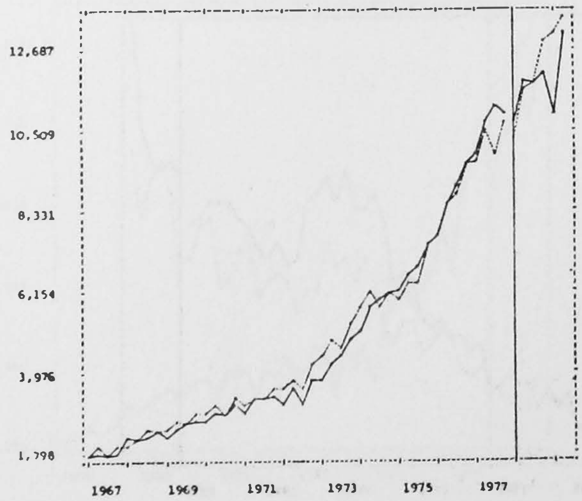
Section 2 (cont.)

Endogenous variable: X-OILX

Endogenous variable: Z.PZ+OILZ.PZ

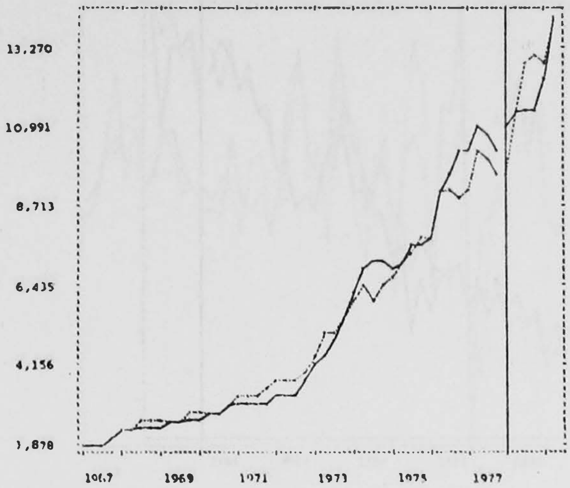


Endogenous variable: X,P-OILX.P

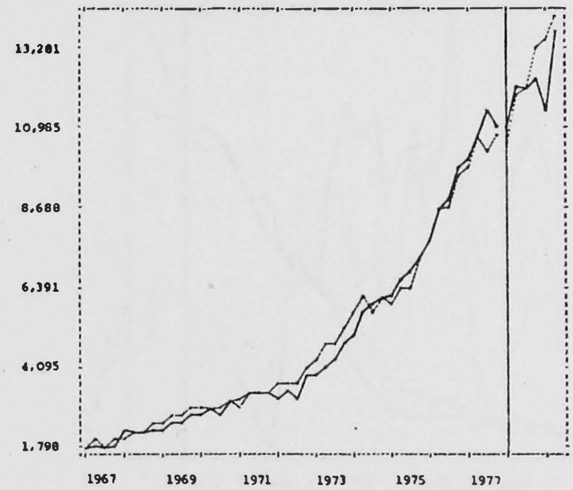


Section 2(cont.)

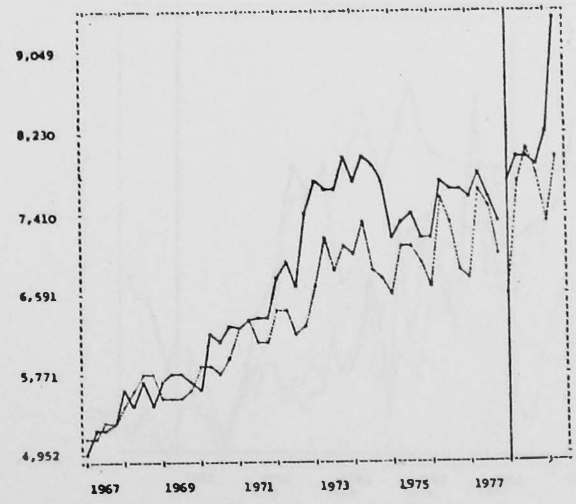
Endogenous variable: Z.PZ



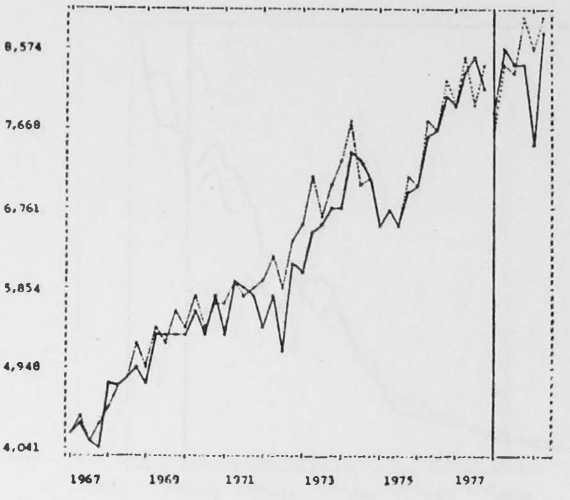
Endogenous variable: X.P



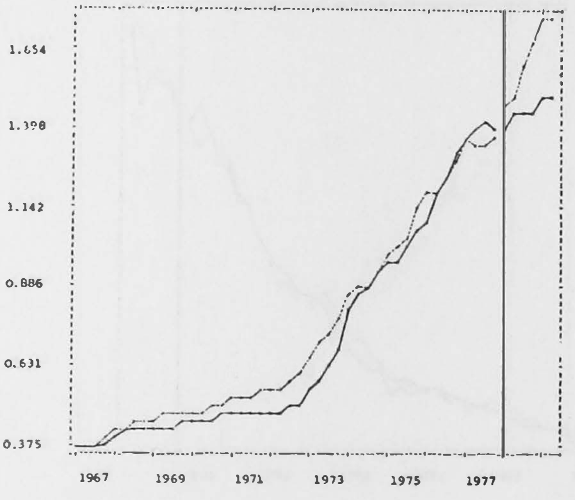
Endogenous variable: Z



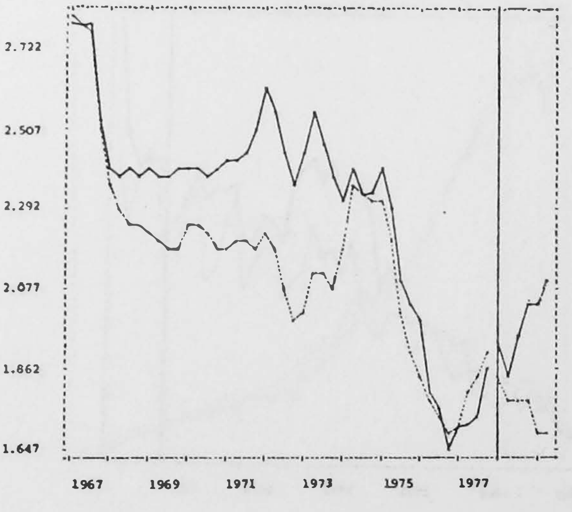
Endogenous variable: X



Endogenous variable: PZ

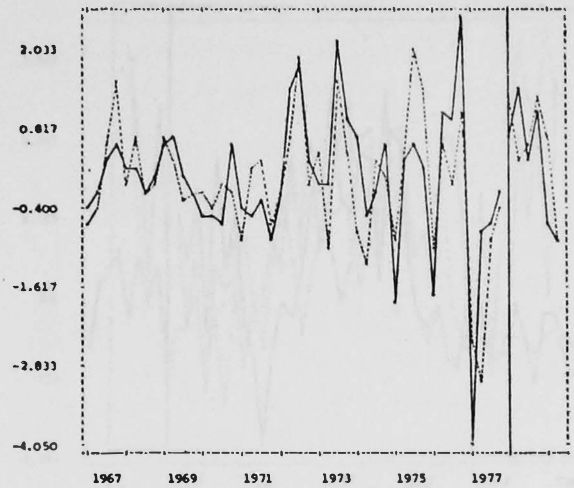


Endogenous variable: e

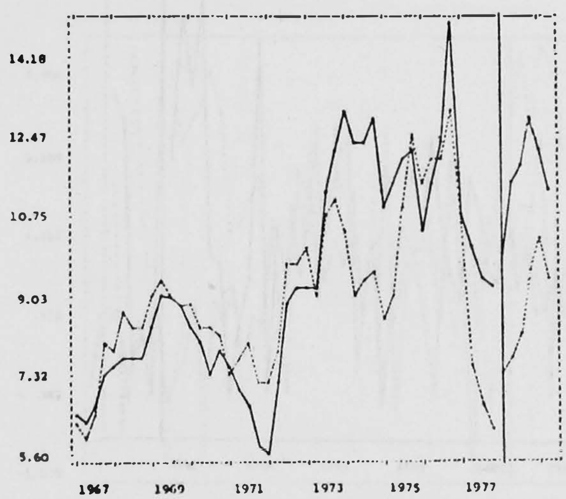


Section 3: Interest rate variable

Endogenous variable: Δr_b

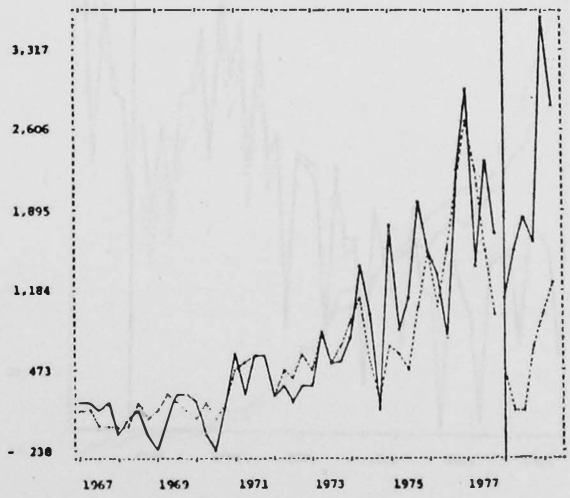


Endogenous variable: r_b

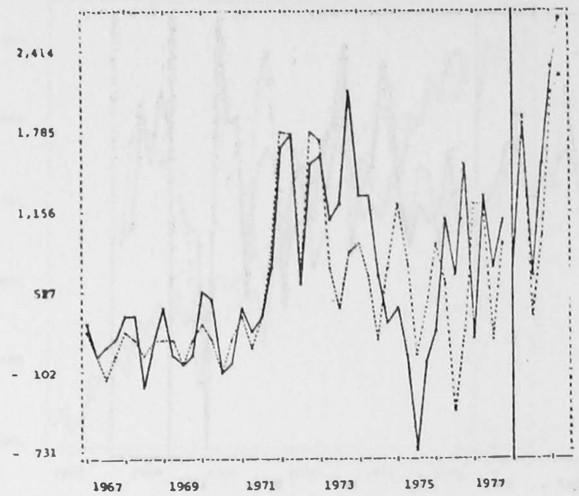


Section 4: Monetary variables

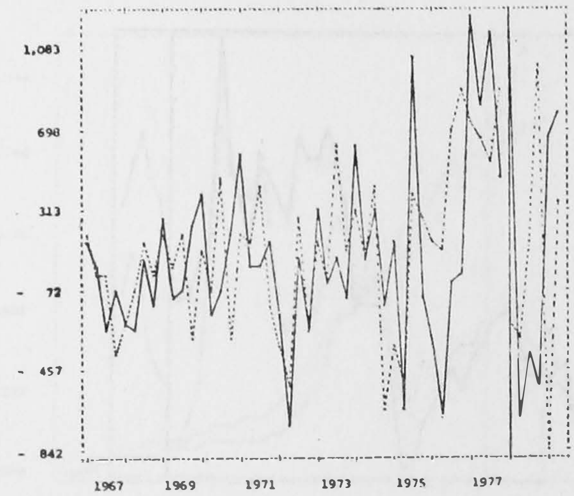
Endogenous variable: ΔB



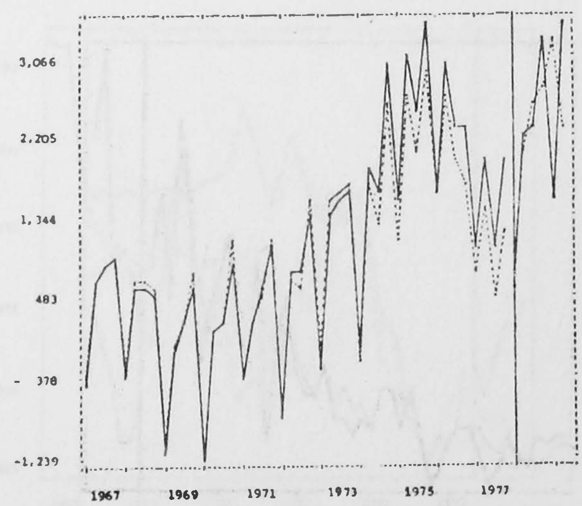
Endogenous variable: ΔL



Endogenous variable: ΔN

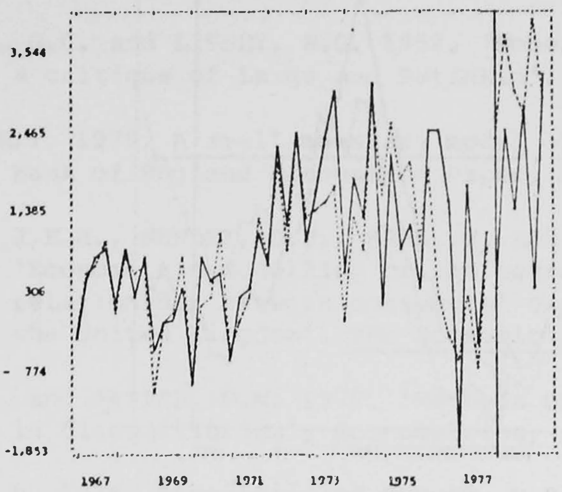


Endogenous variable: PSBR

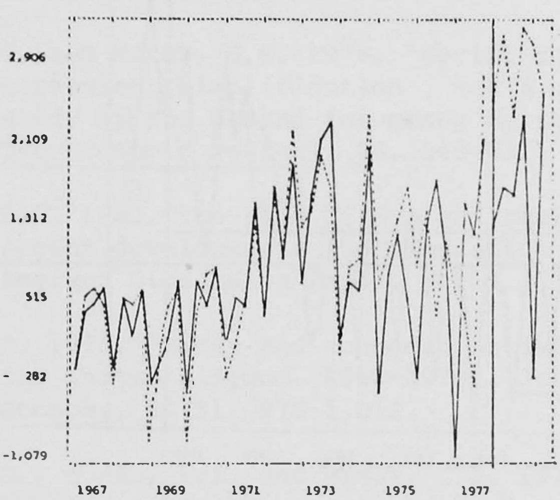


Section 4 (cont.)

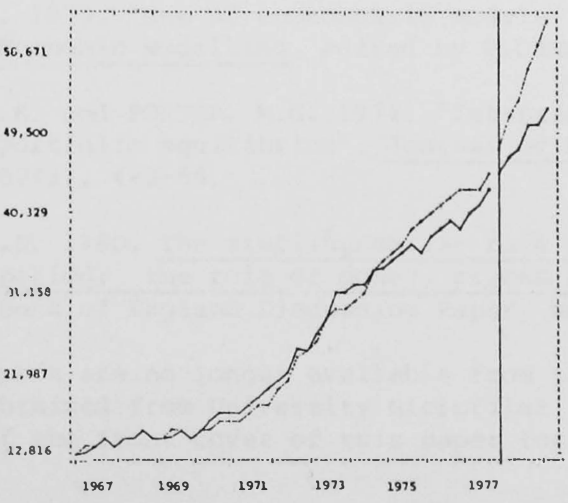
Endogenous variable: DCE_{UK}



Endogenous variable: ΔM

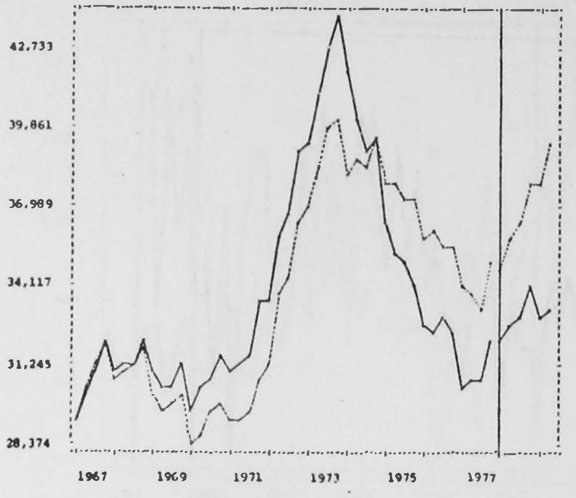


Endogenous variable: M

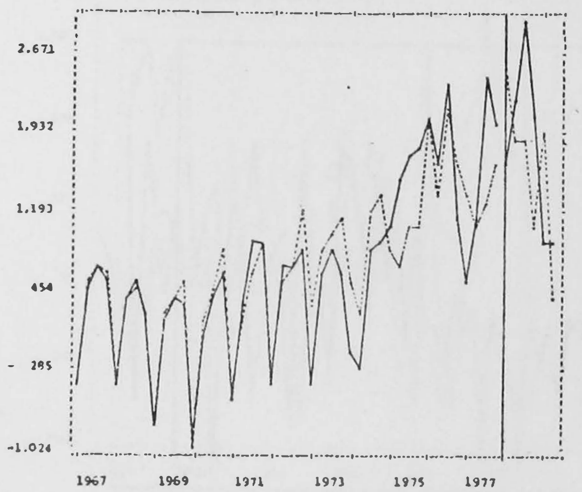


Section 4 (cont.)

Endogenous variable: M/P



Endogenous variable: NAFA



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