Bank of England

Discussion Paper No.13

The Bank of England small monetary model: recent developments and simulation properties

by

B.C.Hilliard

November 1980

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1

Introduction

1 The main aim of this paper is to analyse the simulation properties of the Bank of England's small monetary model of the UK economy.[1] First, though, it will be helpful to restate the basic equations used in the original form of the model. This is done in Section 2. Moreover, various factors have led to a change in the specification of several equations from those originally reported by Coghlan (1979). In addition, an equation explaining the rate of change of the exchange rate has been incorporated into the system; there are, however, problems with this so it is only used in some simulations. As a logical precursor to the simulations, the changes to the structural equations are discussed in Section 3. The simulations themselves are then given in Section 4 and the paper is completed by conclusions in Section 5.

[1] See Coghlan (1979).

The original structure of the model

2 The details of the structure are presented in Coghlan (1979), but a brief outline will be given here. The model is built around the money supply identity for sterling M3, net of public sector deposits, i.e.:

$$\Delta M \equiv PSBR - \Delta B + \Delta L + CA + \Delta N - \Delta NDL - \Delta Dg \quad (1)$$

where:

M	=	private sector sterling balances (= sterling M3 net of public sector deposits);
PSBR	=	public sector borrowing requirement;
B	=	private sector holdings of public sector debt;
L	=	sterling bank lending to the private sector;
CA	=	current account of the balance of payments;
N	=	net external sterling liabilities of the private sector;
NDL	=	non-deposit liabilities of the banking sector; and
Dg	=	public sector bank deposits in all currencies.

3 The aim is to model all the endogenous elements of the identity. This results in equations explaining B, L, N, the long rate of interest (RB), real exports (X), real imports (Z), real private sector expenditure at factor cost (EFC), and the domestic price level (P).[1]

4 Many of the equations employ a long-run constraint variable of the type popularised by Hendry and Mizon (1978) but for some of the equations it was not possible to identify a significant role for one. The particular applications in the model will be discussed as they arise. Let us consider the equations in turn.

Private sector holdings of public sector debt, B

5 Demand for debt is a function of relative rates of return on competing financial assets and of two disequilibrium terms which are

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[1] At the time the Coghlan paper was written, the exchange rate was treated as exogenous.

the ratio of money stock to nominal private sector expenditure, and the ratio of the stock of lending to money stock. Both of these terms reflect the fact that the demand for debt is considered in the context of a portfolio that includes bank loans, money, and real goods, as well as public sector debt. When stocks of these variables are not in the desired ratios, adjustment of the stock levels will then take place. The estimated equation form is:

$$\Delta B/EP = f[RB, RFB, \Delta RFB, \Delta RM, (M/EP)_{-1}, (L/M)_{-1}] \qquad (2)$$

where:

E = real private sector expenditure at market prices;

EP = nominal private sector expenditure at market prices (= E.P);

RFB = foreign long rate of interest; and

RM = UK short rate of interest.

Sterling bank lending to the private sector, L

6 As mentioned above, bank loan demand is considered in the context of a wide portfolio encompassing real and financial assets; the basic form of the equation explaining it will therefore be similar to that explaining B. However, great difficulty was encountered in obtaining sensible interest rate effects, and consequently there is only one interest rate in the equation; some of the problems associated with this are discussed in Section 3. A further difference is that the lending to money stock ratio is omitted because its effect was insignificant in the lending equation. In any case, it only need appear in one or other of the B or L equations to ensure determinate long run stock equilibria for B and L.

7 A novel feature of the equation is the inclusion of the rate of change of expenditure. The justification for this is that the accelerator mechanism usually applied to investment should also be applied to bank lending because there is a financing requirement that is prior to the actual delivery of the investment goods.

8 Because bank lending has, on occasions, been supply constrained, the equation also contains variables for the imposition of quantitative restrictions and calls for special deposits. The effects of the latter appear to be temporary but the former generate pent-up pressure of demand for bank lending which will increase the actual level when

the restrictions are removed. A pressure variable is therefore included. The estimated equation form, which also contains an exchange rate term on expectations grounds, is:

$$\Delta L/EP = f[\dot{E},\dot{E}_{-1},RB,QD,PR,PR_{-1},\Delta SD,\dot{e}_{-1},(M/EP)_{-1}] \qquad (3)$$

where:

QD = quantitative restrictions dummy;

PR = pressure of demand dummy;

SD = special deposits dummy;

e = \$/£ exchange rate; and

$\dot{x}$ = proportional rate of change of x.

<u>Net external sterling liabilities of the private sector, N</u>

9 The main determinants of N are domestic credit expansion (DCE) relative to nominal private sector expenditure, both here and abroad. The rationale for this is that the lower is DCE relative to nominal expenditure the less will be the ability to obtain additional finance. The ratio of DCE to nominal expenditure is not used as a variable; rather, the relationship between the two variables is freely estimated. The other determinants are trade credit, which will cause a temporary increase in N, and exchange rate expectations. The estimated equation form is:

$$\Delta N = f[e,DCE,DCE_{-1},\Delta EP,DCUS,\Delta EPUS,\Delta CA,\dot{e}] \qquad (4)$$

where:

DCUS = DCE in the United States;

EPUS = nominal US private sector expenditure; and

CA = current account of the balance of payments.

<u>The UK long rate of interest, RB</u>

10 The long-run constraint that the UK long rate will bear a stable relationship to the foreign long rate is incorporated in this equation. In the short run there will be other influences, the most obvious of which is the UK short rate of interest, assumed to be set as an instrument of government policy. Additionally, changes in the rate of inflation, exchange rate expectations and the change in reserves will have temporary effects. The estimated equation form is:

$$\Delta RB = f[k, \Delta RM, \Delta RM_{-1}, \Delta \dot{R}, \Delta \dot{P}_{-1}, e_{-1}, (RB-RFB)_{-1}] \qquad (5)$$

where:

k = constant; and

R = level of UK reserves, so $\Delta R = CA + \Delta N$.

Exports, X and imports, Z

11 These two equations are fairly conventional demand equations. They are functions of UK prices relative to prices of imports, both in sterling terms, and the various components of demand. In the case of exports these are an index of world demand (F), real government expenditure (G), and real private sector expenditure (E); and in the case of imports they are government expenditure, private sector expenditure, and the level of exports. The estimated equation forms are:

$$X = f(k, TIME, P_{-1}, PZS, PZS_{-2}, e, F, G, E) \qquad (6)$$

$$Z = f(k, TIME, P_{-1}, P_{-2}, PZS_{-1}, PZS_{-2}, E, X, X_{-1}, G) \qquad (7)$$

where:

PZS = sterling price of UK imports;

F = index of world demand;

G = real government expenditure; and

TIME = time trend.

The inclusion of e in equation 6 is to allow a partial response of export prices to exchange rate changes. It should be noted that because X appears as a determinant of Z, Z will be a function of F, inter alia. This becomes important when a simulation shocking F is carried out.

Private sector expenditure at factor cost, EFC

12 The underlying long-run constraint on EFC is taken to be the level of potential output, $\overline{Y}$, in the economy. It is assumed that out of any given $\overline{Y}$, government expenditure will always be met first, the residue remaining for private consumption. The constraint variable is therefore $EFC/(\overline{Y}-G)$.

13 As money is part of a portfolio of real and financial assets it should affect expenditure. Accordingly, the equation includes changes in the real money supply. An increase in the real money supply will first cause an increase in (real) expenditure but after

some time this will feed through to prices, thus reducing the real money supply - as in the standard monetarist proposition. The other monetary influences are the long and short rates of interest. The equation is completed by the inclusion of the income tax rate and the index of foreign demand. The estimated equation form is:

$$\Delta EFC = f\left[k, \Delta(M/P), \Delta(M/P)_{-1}, \Delta(M/P)_{-2}, RB_{-1}, \Delta RM_{-1}, \Delta RM_{-2}, \Delta ty_{-1}, \Delta F_{-1}, [EFC/(\bar{Y}-G)]_{-1}\right] \tag{8}$$

where ty is the average rate of income tax.

The domestic price level, P

14 The constraint variable in this equation is formulated on the assumption that, in the long run, velocity is stable. The price level is then a function of money supply and real expenditure. In the short run, additional factors are important, in particular sterling import prices and the short rate of interest. Of course, money supply and expenditure will also affect short-run as well as long-run behaviour so they too appear as short-run influences. The estimated equation form is:

$$\dot{P} = f[k, \dot{PZS}, \dot{PZS}_{-1}, \dot{PZS}_{-2}, \dot{M}, \dot{M}_{-2}, \dot{E}, \dot{E}_{-1}, \dot{E}_{-2}, \log E_{-1}, RM_{-1}, \log(M/EP)_{-1}]. \tag{9}$$

15 Since the original estimation of the model, various properties have required modification through the respecification of various equations. The following section explains the changes that have been made and the reasons for them.

Subsequent modifications

16 The most thorough method of examining the behaviour of the model is via simulation. However, as an exploratory exercise, an attempt was first made to forecast outside the sample period using the model as it stood and to see what the implications were.

17 Not surprisingly for a model at an early stage of development, the results were not particularly realistic, but they did bring to light some changes that needed to be made. In particular, the trade equations underpredicted and were unsatisfactory on three counts. First, the elasticities of imports and exports, with respect to changes in the exchange rate, were not very high; the current account of the balance of payments worsened when the exchange rate was lowered. It is possible to argue that there is nothing wrong with that, but in modelling this sector the strong prior belief was held that, at least for the trade sector run as an isolated sub-system, the current account should improve when the exchange rate falls. (The sub-system referred to comprises the two trade equations plus the current account identity and the identity expressing sterling import prices in terms of the exchange rate and the dollar import price.) There is a high degree of price responsiveness implied in the specification of the model, and low price elasticities in the trade equations would run counter to this approach. Second, because the import and export equations were specified in levels, the price elasticities increased sharply towards the end of the sample period. Third, the contribution of the North Sea oil and gas industry to the balance of payments distorted the estimated relationships.

18 One can overcome the problem of low elasticities by respecifying the linear form of the equations, but, to stop the elasticities rising at end of the period, it was necessary to respecify the equations in logarithmic terms, i.e. to impose constant elasticities throughout the sample period. The resulting equations then have reasonable properties, but one further improvement was made by removing

the North Sea influence from exports and imports. The variables explained are then referred to as LXN (log XN) and LZN (log ZN) respectively. A dummy variable, OILD, was also included to allow for the effect of the oil price shock in the early 1970s. Interestingly, the estimates were quite robust to these changes. These are given in the Appendix 2, where the full estimates of the current model are listed.

19 A second feature came to light in the process of forecasting under alternative policy regimes. When the short rate of interest is increased, the long rate of interest also increases, which has the effect of increasing bond demand and lowering the money supply, as one would expect. However, in the original version of the model, the long rate of interest also has a positive effect on bank lending, but the short rate has no effect. There is thus a large offset to the increased bond sales. It could be argued that this behaviour is not unrealistic in that the short-run effect of an increase in short rates is sometimes to make deposits more attractive, allowing more lending to take place. Eventually, however, lending demand would be choked off by the higher rates charged, and then money supply growth would fall. Hopefully, this would occur within a year, implying that a 'correct' response should be expected in the current period of an annual model.

20 On these grounds, the lending equation was respecified. Ideally, one would like to obtain a significant negative effect of the short rate of interest, but, even after exhaustive experimentation, this proved impossible to achieve. Purely as an expedient, the adopted equation includes only the foreign long rate with a positive sign. It is unfortunate that there is then no domestic interest rate effect, but this would seem to be better than having only a perverse effect. This new equation also incorporates a significant effect of the supplementary special deposits scheme (the 'corset'), by means of a dummy variable, SSD. Very recently, some encouraging results have been obtained using the domestic after-tax real rate of return as a determinant. This might be used in the model if further work with it is successful.

21 The exchange rate equation is specified as a reaction function explaining the authorities' behaviour.[1] The broad approach adopted was to include a comprehensive list of possible intermediate and final target variables of the authorities and to see whether these performed well in the equation. Only four influences were found to be significant. These were UK sterling prices relative to world dollar prices, the level of capacity utilisation, the current account of the balance of payments deflated by nominal expenditure, and the amount by which the domestic long rate of interest exceeds the world rate of interest. The rationale for the inclusion of these variables is quite standard and so will not be dwelt on here. The estimated equation form is:

$$\dot{e} = f[k, \dot{PZ\$}, \dot{PZ\$}_{-1}, \dot{P}_{-1}, E/(\bar{Y}-G), CA/EP, RDIF, DEV, \dot{e}_{-1}] \qquad (10)$$

where:

PZ$ = dollar import price;

RDIF = RB-0.93-RFB; and

DEV = devaluation dummy.

22 A surprising feature is that the level of reserves is not a significant influence. It is unreasonable to assume that the authorities control the exchange rate without some consideration of the current level or rate of change of the reserves and so, in that respect, the existing equation is deficient. It has therefore only been used in some simulations. Further work has been done by Coghlan to try to rectify this. The preliminary results are encouraging and may be incorporated in the model at a later date.

23 This concludes the discussion of changes made to the model. A caveat is appropriate at this point. All the specification changes discussed above were aimed at improving the performance of the model over the estimation sample period - 1955 to 1976. Since that time, there have been important structural changes, in particular the removal of exchange controls which presents the possibility of offshore intermediation. Additionally, the large changes in VAT and income tax rates, although strictly speaking manageable within the structure described, are likely to cause some changes in the

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[1] This work was done by Coghlan.

structure. Therefore, the model should only be viewed as a description of the economy up to and including 1976. The next section deals with the simulation properties of the current version of the model.

Simulations of the model

24 All simulations were carried out using ordinary least square (OLS) estimates of the equations. There seemed little point in preferring the instrumental variable estimates to the OLS estimates, because, with so few degrees of freedom, the appeal of instrumental variables estimation, which only has asymptotic properties, is somewhat limited. The two sets of estimates are generally similar and so no major differences should occur through using one set in preference to the other. All the results were obtained from dynamic simulations[1] of the model over the period 1955 to 1976. The exchange rate equation is only used in the simulations of the model run to assess the tracking performance. It is not used (i.e. the exchange rate is taken as exogenous) for the simulations where exogenous variables are shocked.

The tracking performance of the model

25 In Charts A to K (see Appendix 1), the actual and simulated values are shown for the endogenous variables explained by estimated equations and for the change in the money supply. In some cases, the variable explained by a particular equation is not very familiar (e.g. $\Delta L/EP$) so in such cases a more recognisable derivative is graphed. In the example given it would be ΔL.

26 Several criteria, such as the root mean square error and the u statistic, are usually employed in evaluating tracking performance, but not all are of use in the present context. In particular, every estimated equation except two (the export and import equations) has, as dependent variable, some form of rate of change which can be negative or positive. In such circumstances the u statistic has very little meaning and is therefore discarded. The main criteria used are more judgmental. They are whether:

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[1] That is, any lagged endogenous variables in the model take the values predicted from the simulation of the model in earlier periods rather than their actual values.

(i) the predicted path follows the turning points of the actual series well;

(ii) there is any tendency for the actual and predicted path to diverge through time;

(iii) the larger changes in the actual series are accurately predicted.

27 Using these criteria, it is clear that the tracking ability of the model is generally good. A high proportion of the turning points in the actual series are predicted by the model and the very large changes that occur over time are followed quite well. It is worthy of mention that the overall structure of the model is highly interdependent so that disturbances that originate in one equation are fairly widely and rapidly fed through to the other equations in the model. Important errors of specification that were not rejected at the estimation stage might therefore show up in the simulations by resulting in a poor tracking performance throughout the model. On this criterion no large specification errors are apparent.

28 We now turn to a consideration of the individual charts, the first of these being of ΔEFC, the change in real expenditure at factor cost. Since this is such a large part of total demand it is of interest in its own right as well as being the equation through which the influence of potential supply enters the model. Most of the turning points are predicted and the size of the changes is quite accurate even near the end of the period. Also the tracking errors do not seem to build up.

29 The chart of $\dot{P}$ indicates a fit that is also good. It is noteworthy that the very large increase in the rate of inflation towards the end of the period is predicted very closely by the model, and there seems to be no systematic bias in the predictions.

30 The tracking of X depends on that of P and the tracking of Z will depend on that of X. It is therefore not surprising that the X and Z predictions are of similar quality, both following the actual series well. The general overprediction of the price level in the second half of the period will tend to make X underpredict. In many periods, however, this influence is offset by some small negative errors in e, thus leading to small prediction errors. Overall, the

X and Z predictions combine to give a reasonable performance for CA, the current account of the balance of payments.

31 The analysis of the external side of the economy concludes with an analysis of ΔN. The performance of this is surprisingly good considering the volatility of the series. It is a difficult equation to estimate and it is most encouraging that the resulting equation continues to predict so well as part of a model. (However, it will be seen in Table A, on page 19, that there is substantial deterioration in terms of the RMSEs). Some turning points are missed, but the amplitude of the oscillations in ΔN is tracked quite closely. This performance is a consequence of the good tracking of its major explanatory variables, DCE and EP.

32 The preceding discussion indicates that the two external private sector influences on the money supply, CA and ΔN, are modelled reasonably, with no systematic errors. An examination of the domestic components of the money supply increase will show if the same is true domestically. Besides the PSBR, which tracks well, these components are the bond transactions, ΔB, and the increase in bank lending, ΔL, of the private sector.

33 Of all the equations estimated, that explaining ΔB has nearly the lowest degree of fit with the $\bar{R}^2$ being 0.898 but despite this, the predicted path follows the actual path quite closely. Admittedly, when the mean level of ΔB was roughly constant during the period 1954 to 1970 the prediction does not follow all the turning points of the actual series, but from 1970 to 1976, when an extremely large increase in the actual series took place, the predicted path follows suit. One can therefore be reasonably happy with this equation, especially given the well-known difficulties in modelling it.

34 The remaining endogenous component of the money supply is ΔL. Generally, the tracking is good but it displays one or two large errors at the end of the period. This is probably due to underprediction of expenditure feeding through into this equation. Apart from this, it is clear that the equation picks up the sharp increase in bank lending after 1971 when competion and credit control was introduced and

experimentation with it has shown the pressure dummy to play a very important part in modelling that increase.

35 It would thus appear that most of the endogenous components of the increase in the money supply have a reasonable tracking record. The next logical step is to see how the increase itself tracks. This variable was not predicted very closely but in view of the volatility of the series and the fact that it is not directly modelled by an estimated equation its performance is acceptable. The tracking of the level of the money supply consequently turns out to be good.

36 The next chart shows ΔRB, the change in the long rate of interest. The actual series is followed very closely by the predicted series. Given the relatively small influence that ΔRB has within the model, it can be safely assumed that the tracking of this variable is sufficiently accurate to prevent it being the cause of any serious mis-tracking in the rest of the model. Lastly Chart K shows the simulation performance of $\dot{e}$, the rate of change of the exchange rate. The good tracking over the second half of the 1960s is due to the devaluation dummy in the equation, but beyond that point the behavioural elements of the equation account for the closeness of the actual and predicted paths.

37 An inspection of the charts has shown that the tracking performance of the model appears to be satisfactory. Additional evidence is provided by a comparison of the simulation prediction with the OLS prediction of each endogenous variable. Because the OLS prediction is simply the prediction from the equation simulated in isolation from the rest of the model, differences between the two predictions can only be caused by feedbacks from the rest of the model.

38 The root mean square prediction errors are presented in Table A. As one would expect, the simulation RMSE is greater than the OLS RMSE for most of the variables, but in several cases (LEP, ΔRB, BEP) the differences are only small, and in one case (LXN) the simulation RMSE is actually less than the OLS RMSE. On the other hand, the LZN and ΔN simulation predictions are significantly worse, although in the case of ΔN the prediction is still quite good, considering the volatility of the actual series.

Table A

Comparison of tracking errors of the behavioural relationships when simulated individually and when simulated in the full model

Simulation period: 1955-1976

Variable	A	B	C
Δ EFC	110.5	150.8	170.8
$\dot{P}$	0.00272	0.00446	0.00520
LXN	0.02700	0.01584	0.01704
LZN	0.00995	0.01860	0.02439
Δ L/EP	0.00664	0.00745	0.00810
Δ N	130.3	325.0	326.8
Δ RB	0.15241	0.20820	0.19579
Δ B/EP	0.01029	0.00145	0.01145
$\dot{e}$	0.00989	-	0.01031

A = RMSE when simulated individually, i.e. RMSE of OLS residuals from equations estimated from 1955 to 1976.

B = RMSE when simulated as part of the full model with exchange rate exogenous.

C = RMSE when simulated as part of the full model with exchange rate endogenous.

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39 The results also indicate that making the exchange rate endogenous seems to have little effect on the quality of the prediction, which is mildly surprising given that it makes a large difference when the system is shocked.

40 To recapitulate, the overall tracking performance seems reasonable. However, it is quite possible for this to be so but for the model still to have undesirable properties. The surest way of finding out is to conduct a multiplier analysis. To do this, the model is first simulated using the actual data, as for example in the tracking analysis described above. The model is then simulated again, but with the value of one of the exogenous variables altered or shocked. Any change in the path of an endogenous variable between the two simulations is then due to the change in the exogenous variable. If sensible changes in exogenous variables are specified then one expects the response of the endogenous variables to be stable. When a temporary change is made, only a temporary effect should be observed on most variables. If a constant permanent change is made, then it would generally be expected that the response of an endogenous variable would be to build up over time and then flatten out. Of course, deciding whether or not a response is sensible depends on one's prior beliefs about the true behaviour of the economy. To the extent that these beliefs are incorrect one will be attempting to build incorrect properties into the model and possibly to reject sensible properties.

41 The results of 'shocking' several of the exogenous variables in turn are given below. From the discussion of them it will be apparent that there are some properties of the model that still require attention.

The behaviour of the model in response to exogenous variable shocks

The response of the PSBR to price changes and the treatment of taxation

42 The structure of the model is such that monetary disturbances have a large effect and, in essence, the approach used has been to model the components of the money supply identity. Central to this is the PSBR; thus, any exogenous shocks to the system that either directly or indirectly affect the PSBR will also affect the money supply (subject to any offsetting influences in the other components of the money supply identity).

43 In several of the simulations it was found that the PSBR response was playing a large part in determining the overall response of the money supply and, through it, many of the other variables in the

model. It therefore seemed sensible to examine the PSBR response in some detail before considering the effect of changes in policy variables on target variables. The major part of the response was due to price changes altering the nominal value of the PSBR, which suggested that the main features would manifest themselves if a price shock was applied to the system. This was done by switching off the price inflation equation (thus making it exogenous) and then shocking the level of prices.

44 To obtain a measure of the elasticity of the PSBR with respect to price changes, the price level was subjected to a sustained 10% increase in each period's value. The percentage change in the PSBR is shown in Table B. After the beginning of the sample period, the response becomes fairly stable, being in the region of 12% or 13%.[1] The elasticity of the PSBR with respect to the price level is therefore approximately 1.3, which does not appear unreasonable.

Table B

A price shock (10% of current value)

Percentage change

	Effect on		
Year	PSBR	T_Y	T_E
1	14.80	8.85	9.03
2	25.97	8.16	7.39
3	24.39	8.20	8.38
4	25.26	8.15	7.83
5	18.94	8.58	9.06
10	15.15	9.31	9.72
15	-13.94	9.17	9.73
20	11.27	8.99	9.26

PSBR = public sector borrowing requirement;

T_Y = total income tax minus transfer payments;

T_E = total expenditure tax receipts less subsidies.

[1] There are negative values in 1969 and 1970 caused by the response being positive when the actual value is negative. They can therefore be disregarded.

For example, the value obtained from the Bank of England model of the UK economy (i.e. the disaggregated quarterly model) is slightly greater than one.

45 In the monetary model, the PSBR is determined by the following identity:

$$PSBR = G.P.-T_y-T_E+PBRES$$

where:

T_E = total expenditure tax receipts less subsidies;

T_y = total income tax minus transfer payments;

G = real government expenditure; and

PBRES = exogenous residual.

46 T_E and T_y are determined as the average rate of tax multiplied by nominal private sector expenditure at factor cost and nominal personal income respectively, i.e. by assumption, nominal taxes are constrained to have a unit elasticity with respect to the relevant taxable amounts. Average rates were used because, in such an aggregated model, it is extremely difficult to construct a sensible tax equation that yields a marginal rate tax different from the average rate. Specifically, there is no easy way of determining a realistic marginal rate to impose on the equation.

47 The simulation results show that the elasticity of both types of tax revenue with respect to price changes is also roughly one. This compares with values of 1.0 and 1.3 for expenditure tax and income tax respectively in the full Bank model. The fact that no progressivity is built into the identity explaining income tax therefore results in a slightly lower elasticity. However, this does not significantly alter the elasticity of the PSBR with respect to the price level, because the overwhelming effect of a price change on the PSBR is the increase in the nominal value of government expenditure which swamps the increase in the nominal value of tax revenues. Price increases therefore have an expansionary effect on the money supply through the PSBR. There are also price effects on other components of the money supply, but the overall conclusion is still that the money supply is increased.

An increase in the real value of government expenditure

48 The analysis of the previous section indicated that the level of real government expenditure, G, has a powerful effect on the money

supply. Even with G constant, an increase in the price level will cause a large change in nominal government expenditure and the PSBR. When G is itself increased, one would therefore expect even larger effects on the money supply and thus on the other variables in the model. This is indeed the case.

49 However, besides the effect through money supply, G also has a direct effect. The presence of a supply constraint in the expenditure equation (with an estimated elasticity of one) will cause an increase in G to lead to a decrease in real private sector expenditure, E, i.e. there is real crowding out. But in the short run (the first year), the increase in G does have the conventional effect of increasing E. Only from the second year onwards, when the long-run constraint starts to operate, does the crowding out occur. It is important to note that this is different from financial crowding out such as occurs when the financing of government expenditure causes interest rates to rise and thus private sector investment to fall. Rather, the increase in G diverts real resources (for example, people in employment) from the private sector to the public sector. As the model is specified at present, the degree of crowding out varies only slightly with the initial level of capacity utilisation; it would be more realistic if its strength increased as capacity utilisation rose. In future work it is intended to test such a specification.

50 To examine these properties, G was given a sustained shock of 10% of its value in 1955. The responses of some key variables are shown in Table C. As expected, the PSBR increases sharply in nominal terms throughout the period. In the base run of the model the price level was 0.59 in 1955 and 2.23 in 1976 (which is period twenty-two of the simulation). Even without the feedbacks of <u>increased</u> prices onto the PSBR, the evolution of the base-run price level through time would therefore cause the shock to G to result in a shock to the PSBR in 1955 equal to 59% of the G shock but a shock in 1976 equal to 223% of the G shock. This will reinforce the other expansionary influences on the PSBR and thus on the money supply.

51 On the other hand, an increase in G leads to an expansion of imports and a decline in exports. The net result is a large deterioration in

Table C

A government expenditure shock (10% of value in year 1)

Percentage change

Year	E	X	Z	M	PSBR (change in level)
	Effect on				
1	0.16	-4.04	- 0.10	1.32	411
2	-0.99	-3.90	- 0.57	3.94	482
3	-1.53	-3.83	0.06	6.44	527
4	-1.48	-4.11	0.85	8.31	543
5	-1.40	-4.47	1.67	9.94	559
10	-2.65	-6.24	6.17	15.59	893
15	-3.06	-8.17	10.54	19.98	1,171
20	-3.98	-8.28	11.52	15.98	3,056

E = real private sector expenditure at market prices;

X = exports;

Z = imports;

M = private sector sterling balances (= sterling M3 net of public sector deposits);

PSBR = public sector borrowing requirement.

the current account of the balance of payments and thus a reduction in the growth of the money supply. Because of the real crowding out, E has fallen by 3.8% by 1976. This seems unduly large and the reason for it is not yet clear. The net effect of all these individual influences is a large and sustained increase in the money supply. This feeds back into prices which, through the mechanism previously described, increases the PSBR. Money supply growth does, however, stabilise towards the end of the period as a result of a worsening of the balance of payments and a large increase in bond demand.

52 The other feature of note is the large fall in GDP (6.5%). This is the result of the real crowding out of E and the worsening of the trade position. Exports decrease by 8.2% and imports increase by 12.1%. The change in government expenditure therefore has a larger effect on the balance of trade than on private sector expenditure, the opposite of the result usually obtained from more orthodox models. These

effects seem too large and are undoubtedly the result of the unduly large change in E that occurs. The instability displayed is clearly unsatisfactory and further work will be required to rectify it.

53 The government expenditure shock just described can be thought of as having two main effects. It is an addition to aggregate demand and an expansionary influence on the money supply. Controlling G is therefore one way of controlling monetary expansion. In practice, however, whilst G is a powerful influence on the money supply it is not easily controllable in the short run. On the other hand, the short rate of interest can be more easily controlled in the short run, but it is necessary to determine how effective a check on money supply it is. The following paragraphs are addressed to this point.

An increase in the short rate of interest

54 The conventional description of the path through which this controls the money supply is that it pushes up the cost of borrowing, thus decreasing the demand for bank lending. Then, through some sort of term structure relationship, it increases the long rate of interest and thus the demand for bonds. The proximate effect is therefore to decrease the money supply, but this is only part of the story because it ignores all the feedbacks from the rest of the economy onto the money supply. The use of a full model enables us to take these into consideration; as will become evident, the result is not nearly as clear cut as might have been thought.[1]

55 A shock of 1% is applied to the short rate, and the initial effect is indeed to raise the long rate of interest (see Table D) by nearly 1/2% and so increase bond demand. But because in the long run the domestic long rate is tied to the world long rate the increase will be only temporary; after seven years, less than a tenth of the original effect remains. There is, however, not even a temporary domestic interest rate effect on bank lending. (As mentioned at the beginning of the paper, great efforts were made to find such an effect but were mostly unsuccessful. To the extent that one disbelieves that result, the conclusions will therefore be

---

[1] However, some effects are not in the model. In particular, higher interest rates would be likely to cause capital inflows, and to increase the debt interest component of the PSBR.

correspondingly weakened.) Although this is true, bank lending is still decreased but via another route. The change in the short rate reduces the change in real private sector expenditure, ΔE, by large amounts in the second and third years so that the change in the demand for bank lending is accordingly reduced via an accelerator-type relationship.[1]

Table D

A 1% shock to the short rate of interest

Change in level

Year	RB	L	B	CA	M (percentage change)
1	0.49	- 0.63	23.94	1.44	-0.16
2	0.46	-61.33	90.03	143.09	-0.06
3	0.28	-52.64	60.16	75.31	0.22
4	0.16	18.20	53.73	26.98	0.53
5	0.11	22.84	48.83	11.26	0.72
10	-0.01	- 1.03	17.27	9.21	0.43
15	-0.01	6.16	20.54	- 9.54	0.48
20	0.02	20.54	38.68	- 50.04	0.27

(Effect on: RB, L, B, CA, M)

RB = UK long rate of interest;
L = sterling bank lending to the private sector;
B = private sector holdings of public sector debt;
CA = current account of the balance of payments;
M = private sector sterling balances (= sterling M3 net of public sector deposits).

56 The level of E is reduced for most of the period because of the early falls in ΔE. As a result, exports are increased and imports decreased, the current account improving markedly in the second and third years. Private sector capital flows are also influenced but the response is, by comparison, small. Lower E will also reduce taxes and increase the PSBR.

[1] Since in both the bond and bank lending equations the dependent variable is deflated by nominal expenditure, E has a further influence on them but it is small in relation to those mentioned in the text.

57 A consideration of the effect of the interest rate change on the rest of the model has thus revealed several mechanisms which act contrary to the most obvious one. The net result is that the money supply is reduced only in the first and second years and then by only a tiny amount (0.16% and 0.06% respectively), and in subsequent years there is a small increase. The weakness of the interest rate effect is undoubtedly due to the problems with the bank lending equation. In reality it is likely to be much stronger.

An exchange rate revaluation

58 As already mentioned, the trade equations were revised to satisfy the condition, *inter alia*, that when the trade sector is considered in isolation from the rest of the model the current account improves in response to a devaluation. With the passage of time a current account deficit or surplus of a given nominal value becomes less important because the nominal value of trade is increasing, so that a more sensible measure of devaluation response needs to be found. In this paper the current account deflated by the nominal value of trade, CAT, say, is used.

59 From the estimated equations the elasticities of exports and imports with respect to a change in the exchange rate are -0.51 and +0.79 respectively. The sum of their absolute values is greater than one, and therefore taking the trade sector alone the current account will be improved permanently by a devaluation. When part of the full system, the exchange rate responses will, of course, be modified by feedbacks onto the trade sector.

60 To find the effect of an exchange rate change on the rest of the system and to examine the feedbacks from it, the exchange rate was shocked upwards by 10% of each period's value. This form of shock was chosen because it allows a direct comparison of the response of exports and imports with the estimated elasticities.

61 The results of the comparison are extremely interesting in that the feedbacks greatly modify the behaviour of the trade sector. From Table E it can be seen that the maximum elasticity of exports is 0.48 at the beginning of the period but this fairly rapidly declines to only 0.15 by the end of the period. Similarly for imports the

Table E

An exchange rate revaluation (10% of current value)

Percentage change

	Effect on			
Year	X	Z	CAT	P
			(change in level)	
1	-4.84	4.44	-0.001	-0.79
2	-4.84	6.53	-0.007	-2.41
3	-3.94	5.18	-0.005	-3.36
4	-4.47	6.64	-0.006	-2.43
5	-4.35	5.86	-0.002	-0.92
10	-3.37	6.08	-0.003	-2.01
15	-2.68	4.46	-0.002	-3.69
20	-1.89	3.22	-0.002	-5.59

X = exports;

Z = imports;

CAT = current account deflated by the nominal value of trade;

P = domestic price level.

maximum elasticity is 0.66 (in the fourth year) falling off to 0.26. The feedbacks are therefore reducing the size of the response by roughly two thirds over a period of twenty-two years.

62 The particular feedback causing this is the reduction in the price level which, because of large price elasticities, has a large effect on exports and imports, and thus the current account. The interesting point about this is that the change in the current account in the early years is the cause of the moderating influence on itself in the later years, i.e. the current account deterioration leads to a reduction in the money supply from the fifth year onwards which in turn causes the price level to fall. (The PSBR also falls because of the price fall but only in the last three years is this the major source of money supply reduction.) There is therefore a 'corrective' mechanism within the model that weakens the influence of exchange rate changes.

63 Devaluations are generally used in an attempt to improve the balance of payments but proponents of the monetary approach to the

balance of payments (MABP) would argue that such an improvement could only be temporary [see, for example, Whitman's (1975) analysis of Dornbusch (1973)]. In the present model, a devaluation of 10% will give rise to a permanent improvement in the balance of payments (the discussion concentrates on the current account but the capital account would also be improved) between £200 million and £300 million per year.

64 The size of the effect is fairly small so that, although the model is not built around the MABP (for example, DCE is endogenous rather than exogenous), the conclusion is fairly similar, i.e. devaluation does not have a powerful effect on the balance of payments in the long run.

An increase in foreign demand

65 F is increased by 10% of its 1955 value. The results are given in Table F. Such a large change in demand might be expected to have profound effects on the rest of the economy. For example, it is commonly assumed that an increase in foreign demand would lead to higher exports, a more healthy current account, and growth in GDP. Unfortunately, in this model only some of those results occur and an examination of the trade equations quickly reveals the reason: both

Table F

A foreign demand shock (10% of value in year 1)

Percentage change

Year	Effect on X	Z	CAT (change in level)
1	9.75	9.06	0.002
2	8.78	8.65	-0.002
3	8.16	7.80	0
4	8.39	8.11	0
5	7.71	7.50	0
10	5.18	5.19	0.001
15	3.32	3.61	0
20	2.17	2.52	0

X = exports;

Z = imports;

CAT = current account deflated by the nominal value of trade.

exports and imports have a high elasticity with respect to foreign demand, F, but crucially the elasticities are virtually identical (0.98 and 0.91 respectively). Any change in F therefore has approximately equal and offsetting effects on exports and imports. As a result, there is virtually no change in the current account; the biggest change being £78 million with the rest being less than £40 million.

66 Because F does not appear anywhere else in the model, except as a temporary influence on E, the change in the current account is the only means by which the influence of F is transmitted. But the current account effect is very small and therefore the impact of F on the rest of the system will be negligible, as will the feedbacks onto the trade sector.

67 Consequently it is necessary to look only at the trade sector of the model. With no feedbacks, the proportional effect of F will simply be the elasticity multiplied by the proportional change in F. The latter is 10% of the value in 1955, which represents 2.3% of the value in 1976. Accordingly the response of exports is 9.7% in 1955 and 2.1% in 1976. Similarly for imports the figures are 9.1% and 2.4% respectively. If F had been shocked by 10% of the current value instead of the 1955 value then the shock to exports would have been approximately 10% and to imports 9% in every year.

68 The conclusion from these results is that changes in the level of foreign demand have little net effect on the model. This is entirely due to exports and imports having similar elasticities with respect to foreign demand, F. In reality, the elasticity of imports with respect to F is much lower than the value implied by the equation used. If a realistic value could be estimated, then foreign demand changes would have a powerful effect.

Conclusions

69 Given the need to keep this paper to a manageable size, it has only been possible to present the results of a fairly small number of simulations, but it is hoped that many of the important ones have been included. The message that emerges is that, as always, more work still needs to be done. In particular, the following points require attention:

(i) the degree of crowding out displayed is too great;

(ii) the elasticity of imports with respect to changes in foreign demand is too high;

(iii) some of the responses are rather large, possibly indicating instability;

(iv) the exchange rate reaction function should include reserves in some way; and

(v) the determinants of bank lending need further clarification and estimation, the after-tax real rate of interest possibly being important.

No simulations have been reported for changes in tax rates. It is hoped to present these at a later date.

Appendix 1

Charts

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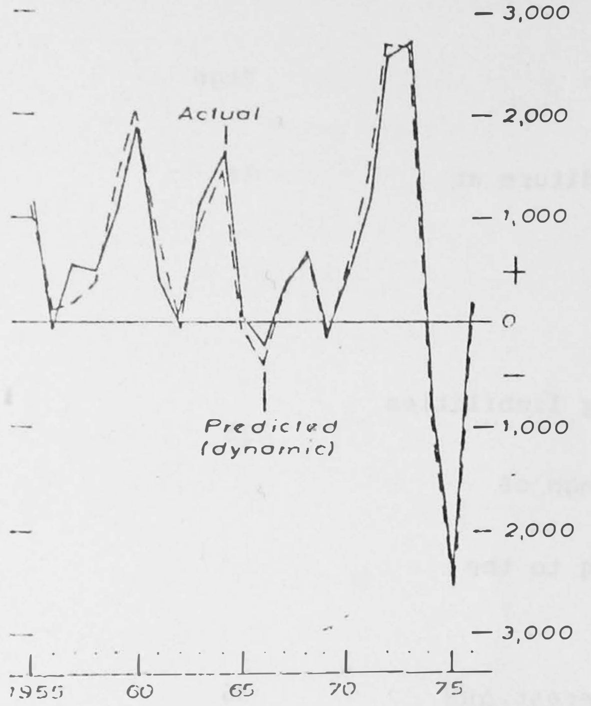
Chart A

Change in private sector expenditure at factor cost, ΔEFC

1970 £ millions



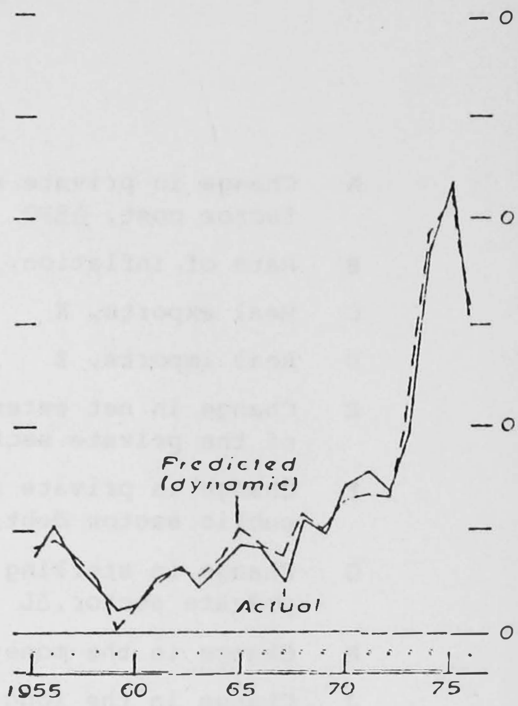
(a) Root mean square (actual-predicted) = 170.8

(b) Root mean square percentage (actual-predicted) = 113.8

Chart B

Rate of inflation, $\dot{P}$

Per cent per annum



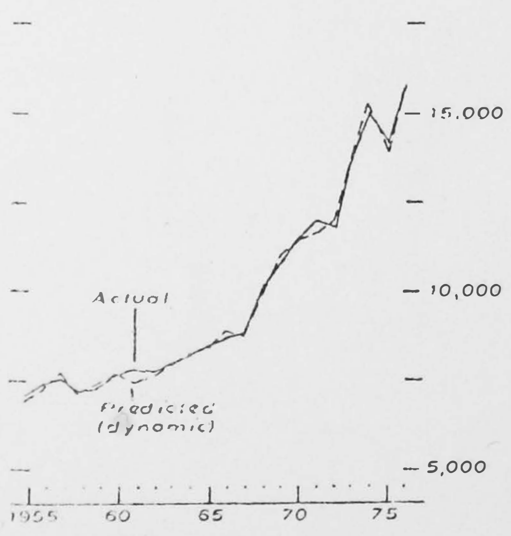
(a) 0.00520

(b) 21.59

Chart C

Real exports, X

1970 £ millions



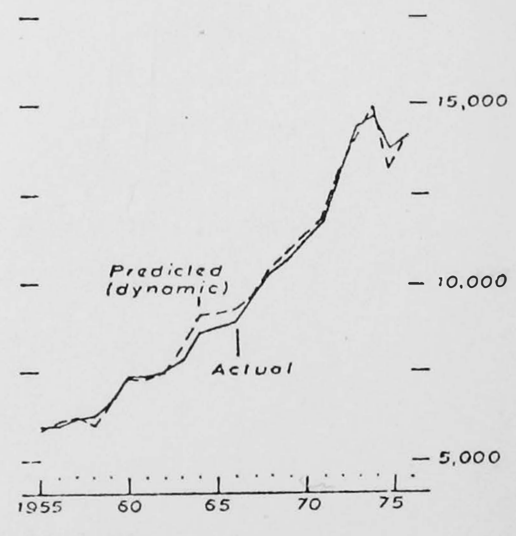
(b) 1.689

(c) Theil's U statistic=0.381

Chart D

Real imports, Z

1970 £ millions



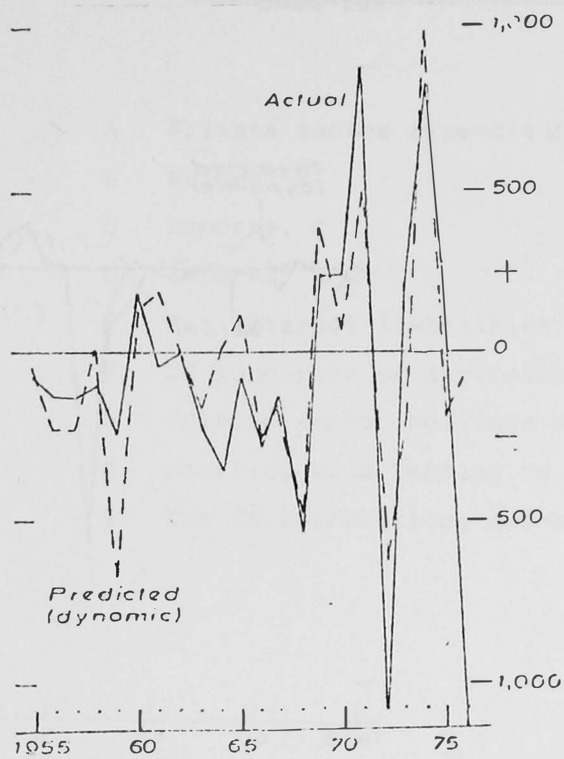
(b) 2.466

(c) 0.384

Chart E

Change in net external sterling liabilities of the private sector, ΔN

£ millions

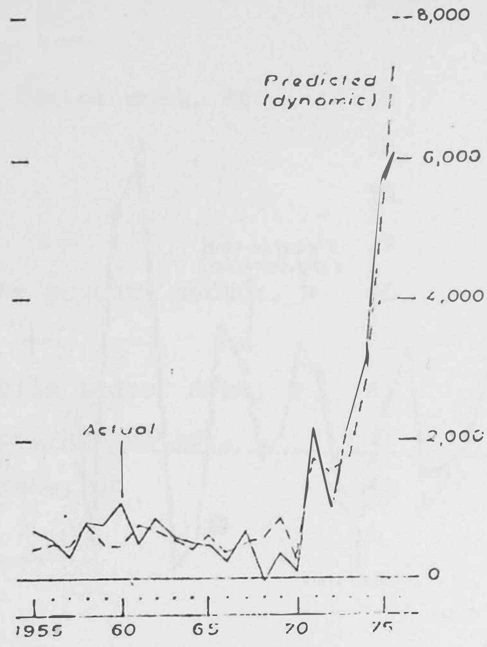


(b) 168.5

Chart F

Change in private sector holdings of public sector debt, ΔB

£ millions



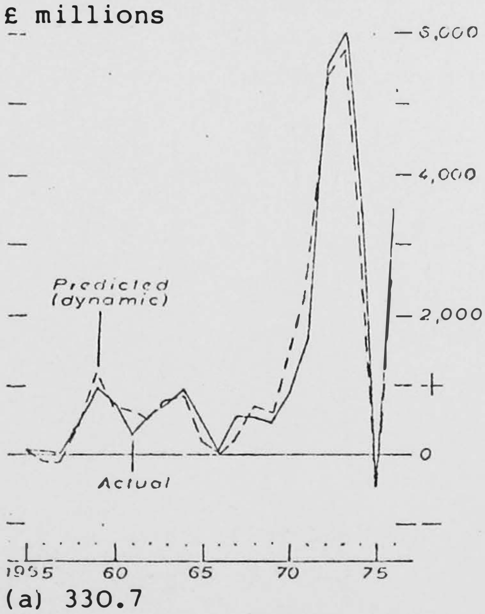
(a) 411.3

(b) 1,184.4

Chart G

Change in sterling bank lending to the private sector, ΔL

£ millions



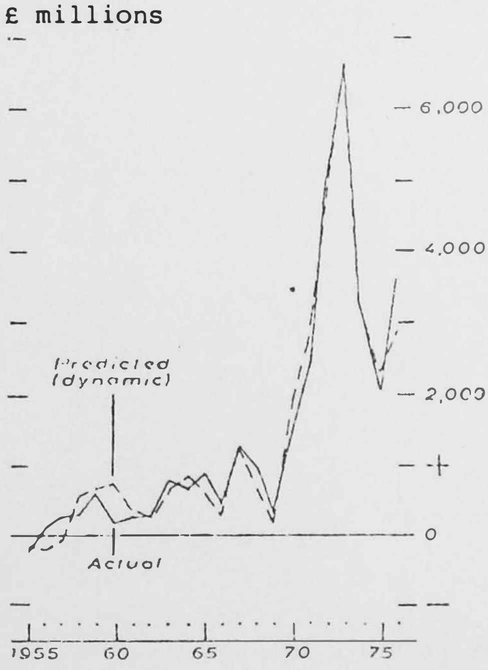
(a) 330.7

(b) 137.7

Chart H

Change in the money supply, ΔM

£ millions



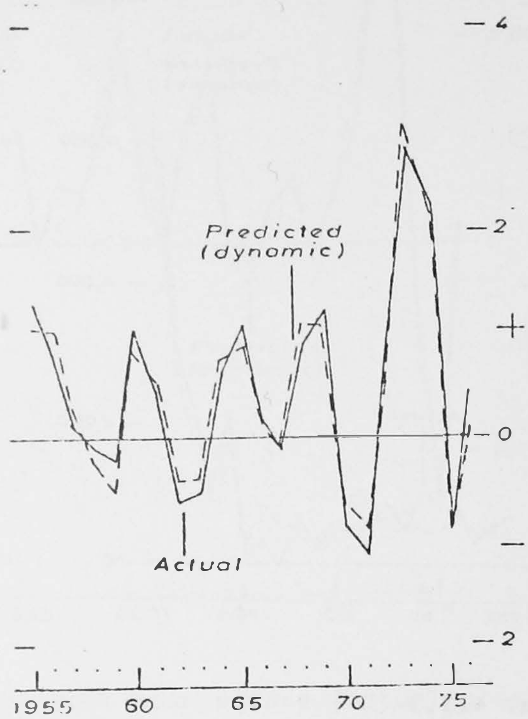
(a) 283.7

(b) 112.6

Chart J

Change in the long rate of interest, ΔRB

Per cent per annum

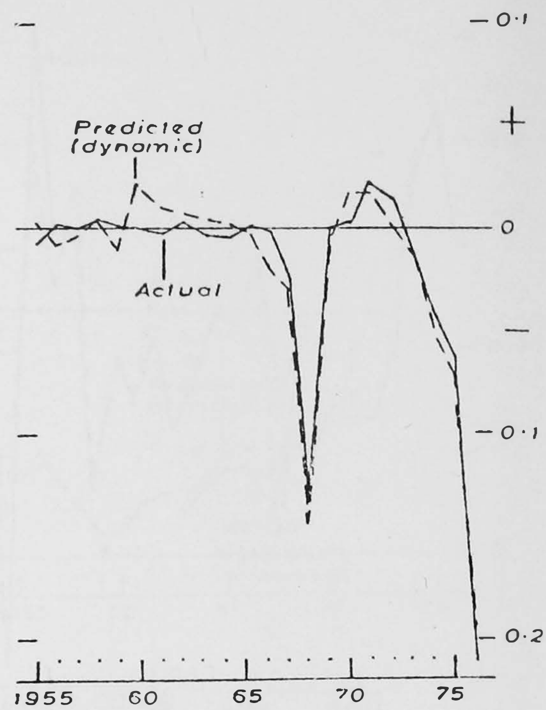


(a) 0.20
(b) 54.4

Chart K

Rate of change of the exchange rate, $\dot{e}$

Per cent



(a) 0.0103
(b) 1,401.7

Appendix 2

Ordinary least squares (OLS) and instrumental variables (IV) estimates

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A	Private sector expenditure at factor cost, EFC	38
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A Private sector expenditure at factor cost, EFC

Dependent variable is ΔEFC

	K	$\Delta(M/P)$	$\Delta(M/P)_{-1}$	$\Delta(M/P)_{-3}$	RB_{-1}	ΔRM_{-1}	ΔRM_{-2}	Δty_{-1}	ΔF_{-1}	$[EFC/(\bar{Y}-G)]_{-1}$
OLS	10568.1	0.1843	0.3894	0.3055	-112.69	-343.79	-90.32	-19625.5	0.01073	-9910.9
	(7.3)	(4.3)	(7.8)	(3.3)	(3.3)	(7.7)	(1.7)	(3.0)	(1.6)	(6.7)
					$\bar{R}^2$ = 0.982	SE = 149.6		DW = 2.01	DF = 12	
IV	10589.9	0.1726	0.3913	0.3001	-111.13	-350.20	-92.70	-19791.1	0.01115	-9942.3
	(7.3)	(3.6)	(7.8)	(3.2)	(3.2)	(7.6)	(1.8)	(3.0)	(1.7)	(6.7)
					$\bar{R}^2$ = 0.982	SE = 150.0		DF = 12		

B Prices, P

Dependent variable is $\Delta \log P = \dot{P}$

	K	$\dot{PZS}$	$\dot{PZS}_{-1}$	$\dot{PZS}_{-2}$	$\dot{M}$	$\dot{M}_{-2}$	$\dot{E}$	$\dot{E}_{-1}$	$\dot{E}_{-2}$	$\log E_{-1}$	$\dot{RM}_{-1}$	$\log(M/EP)_{-1}$
OLS	-1.009	0.0932	0.2424	0.2220	0.0952	-0.1778	-0.5495	0.3044	0.1046	0.1155	-0.0502	0.2094
	(4.1)	(3.9)	(7.5)	(9.1)	(3.5)	(3.8)	(5.3)	(4.4)	(2.7)	(4.5)	(4.6)	(7.6)
					$\bar{R}^2$ = 0.994		SE = 0.00428		DW = 2.70	DF = 11		
IV	-0.924	0.0995	0.2481	0.2238	0.1143	-0.1882	-0.6384	0.3386	0.1030	0.1061	-0.0607	0.1933
	(2.5)	(2.4)	(5.4)	(8.7)	(3.4)	(3.8)	(4.8)	(4.4)	(1.9)	(2.7)	(4.9)	(3.7)
					$\bar{R}^2$ = 0.994		SE = 0.00442		DF = 10			

C Exports, X

Dependent variable is log XN

	K	logF	logG	logE	log(P/PZS)
OLS	7.0220	0.9762	-0.4218	-0.5564	-0.5150
	(7.2)	(1.5)	(5.2)	(4.3)	(7.1)
IV	7.5607	0.9706	-0.3463	-0.6691	-0.5183
	(7.0)	(1.5)	(4.3)	(4.4)	(7.1)

OLS: $\bar{R}^2 = 0.995$ SE = 0.0184 DW = 1.94 DF = 20

IV: $\bar{R}^2 = 0.996$ SE = 0.0161 DF = 17

D Imports, Z

Dependent variable is logZN

	K	TIME	logE	$logE_{-1}$	logG	logXN	OILD	logP	logPZS	$logPZS_{-1}$	$logPZS_{-2}$
OLS	-12.21	-0.0451	1.630	-0.6690	0.3613	0.9316	0.2319	1.247	-0.9018	-0.2216	-0.1432
	(3.4)	(3.0)	(7.4)	(2.8)	(3.2)	(5.6)	(2.8)	(3.5)	(3.0)	(1.4)	(1.3)
IV	-9.69	-0.438	1.469	-0.7305	0.3586	0.9056	0.1874	1.482	-0.8271	-0.3903	-0.2400
	(1.9)	(2.2)	(5.0)	(2.7)	(2.3)	(3.9)	(1.6)	(2.8)	(2.0)	(1.7)	(1.4)

OLS: $\bar{R}^2 = 0.998$ SE = 0.0135 DW = 2.57 DF = 12

IV: $\bar{R}^2 = 0.998$ SE = 0.0153 DF = 11

E Net external liabilities of the private sector, N

Dependent variable is ΔN

	e	DCE	DCE_{-1}	ΔEP	DCUS	$\Delta EPUS$	ΔCA	$\dot{e}$
OLS	-92.75	-0.4038	0.2060	0.1555	0.0164	-0.0067	-0.1910	5491.6
	(4.0)	(8.9)	(7.2)	(4.0)	(5.1)	(2.2)	(2.9)	(5.6)

$\bar{R}^2 = 0.888$ SE = 157.9 DW = 2.02 DF = 15

	e	DCE	DCE_{-1}	ΔEP	DCUS	$\Delta EPUS$	ΔCA	$\dot{e}$
IV	-92.87	-0.4099	0.2040	0.1602	0.0161	-0.0068	-0.2116	5515.9
	(3.6)	(7.8)	(6.8)	(3.7)	(4.7)	(2.0)	(2.8)	(5.4)

$\bar{R}^2 = 0.885$ SE = 164.0 DF = 14

F UK long rate of interest, RB

Dependent variable is ΔRB

	K	ΔRM	ΔRM_{-1}	$CA+\Delta N$	$\Delta \dot{P}_{-1}$	$\dot{e}_{-1}$	$(RB-RFB)_{-1}$
OLS	0.2959	0.4929	0.1614	-0.0003	5.250	-4.16	-0.3271
	(4.7)	(1.3)	(4.4)	(4.7)	(2.3)	(2.4)	(4.4)

$\bar{R}^2 = 0.996$ SE = 0.206 DW = 1.49 DF = 16

	K	ΔRM	ΔRM_{-1}	$CA+\Delta N$	$\Delta \dot{P}_{-1}$	$\dot{e}_{-1}$	$(RB-RFB)_{-1}$
IV	0.3406	0.4699	0.1783	-0.0003	2.643	4.87	-0.3396
	(4.7)	(9.5)	(4.4)	(3.3)	(0.9)	(2.7)	(3.9)

$\bar{R}^2 = 0.963$ SE = 0.190 DF = 15

G Private sector holdings of public sector debt, B

Dependent variable is $\Delta B/(E\ P)$

	RB	RFB	Δ RFB	ΔRM	$(M/EP)_{-1}$	$(L/M)_{-1}$
OLS	0.0142	-0.00625	-0.0234	-0.00535	0.04918	-0.0932
	(4.7)	(1.7)	(4.2)	(2.8)	(4.2)	(2.9)
IV	0.0136	-0.00595	-0.0248	-0.00547	0.0633	-0.0995
	(4.4)	(1.6)	(4.4)	(2.8)	(4.0)	(3.0)

OLS: $\bar{R}^2 = 0.898$ SE = 0.0120 DW = 2.14 DF = 19

IV: $\bar{R}^2 = 0.906$ SE = 0.0121 DF = 16

H Sterling bank lending to the private sector, L

Dependent variable is $\Delta L/EP$

	$\dot{E}$	$\dot{E}_{-1}$	RFB	QD	PR	PR_{-1}	ΔSD	$\dot{e}_{-1}$	$(M/EP)_{-1}$	SSD_{-1}
OLS	0.2156	0.1808	0.00853	-0.0166	0.00338	0.0115	-0.00503	0.1032	-0.0532	-0.0308
	(3.7)	(3.3)	(8.8)	(4.1)	(1.7)	(5.8)	(2.2)	(1.4)	(5.4)	(2.6)
IV	0.1451	0.1378	0.00746	-0.0184	0.00372	0.0121	-0.00467	0.0937	-0.0329	-0.0390
	(1.7)	(1.7)	(5.9)	(4.1)	(1.8)	(5.6)	(2.0)	(1.3)	(1.8)	(2.8)

OLS: $\bar{R}^2 = 0.957$ SE = 0.0869 DW = 1.78 DF = 15

IV: $\bar{R}^2 = 0.918$ SE = 0.0898 DF = 12

J The dollar/sterling exchange rate, e

Dependent variable is $\dot{e}$

	K	$\dot{PZ\$}$	$\dot{PZ\$}_{-1}$	$\dot{P}_{-1}$	DEV	$E/(\bar{Y}-G)$	CA/EP	RDIF	$\dot{e}_{-1}$
OLS	-0.3315	0.1269	0.3572	-0.8159	0.8467	0.3642	1.2968	-0.0110	-0.2366
	(2.8)	(2.5)	(6.0)	(7.7)	(8.0)	(3.0)	(4.2)	(2.5)	(2.1)

$\bar{R}^2 = 0.943$ SE = 0.0124 DW = 1.80 DF = 14

IV	-0.2482	0.2194	0.4346	-0.9076	0.6791	0.2749	2.408	-0.0006	-0.1333
	(1.1)	(2.1)	(4.1)	(5.1)	(3.4)	(1.1)	(2.8)	(0.1)	(0.7)

$\bar{R}^2 = 0.890$ SE = 0.0188 DF = 13

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