Interest Rates and the Channels of Monetary Transmission: Some Sectoral Estimates

by

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Abstract

We estimate a small sectoral VAR model of the UK macroeconomy. This model is then used to simulate the effects of an exogenous monetary policy shock upon asset prices, bank balance sheet variables and final target variables (real output and prices), for the personal and corporate sectors. Significant sectoral differences are found among the channels of monetary transmission. In addition, the use of sectoral data facilitates the identification of distinct money and credit channels in the transmission of monetary policy. These results contrast with the ambiguous findings on the roles of money and credit in the literature to date.

1. Introduction

"Though many macroeconomists would profess little uncertainty about it, the profession as a whole has no clear answer to the question of the size and nature of the effects of monetary policy upon aggregate activity." Sims (1992)

Sterling's membership of the ERM was suspended in September 1992. The abandonment of the exchange rate as the explicit intermediate target of monetary policy left a void in the framework within which economic policy was conducted in the UK. The authorities responded by introducing, for the first time, an explicit target range for the ultimate objective of monetary policy - price inflation. Moreover, instead of setting target ranges for one or more intermediate variables, the Chancellor introduced the concept of monitoring ranges for both broad and narrow money aggregates. These monitoring ranges specified growth rates for M4 and M0 outside which 'there would be increasing cause for concern' (HMT 1992).

This new monetary framework has re-focused attention upon the domestic transmission mechanism of monetary policy within the UK. And, in particular, upon the uncertainties which still surround its operation - as reflected in the opening quotation from Sims. With what speed and magnitude do changes in the monetary policy instrument feed into price inflation? What role do monetary aggregates play in the transmission of monetary policy? Is it sensible to set monitoring ranges for both (or either) broad and narrow monetary aggregates?

These uncertainties are clearly not distinct to the UK. Indeed, these types of question continue to underpin much of the current research in monetary economics. With these questions in mind, this paper seeks to address four aspects of the monetary transmission process:

(a) to define empirically some key features of the monetary transmission mechanism in the UK, using a small reduced-form system;

(b) to delineate, and quantify, some of the principal intermediate channels through which this transmission mechanism operates;

(c) to determine whether, and how, these channels of monetary transmission may differ sectorally; and

(d) on the basis of (a)-(b), to evaluate empirically contending theories of the monetary transmission mechanism.

The rest of the paper is planned as follows. The next section discusses in more detail the theoretical and empirical background to the four issues addressed by the paper. Section 3 considers the methodological approach adopted and contrasts this with contending approaches; while in Section 4 we discuss the construction and properties of the data used in estimation. Section 5 presents the results, and offers an interpretation of these in the context of (a)-(d) above. Section 6 briefly summarises and concludes.

2. Motivation

To take each of the four issues in turn:

(a) Defining the Monetary Transmission Mechanism. The monetary transmission mechanism can be thought of as a time-series mapping between the monetary policy instrument and the set of final target variables. Typically, this mapping will occur via a set of intermediate variables. More specifically, the monetary transmission mechanism is concerned with the *endogenous* behaviour of the intermediate and final variables in response to *exogenous* policy impulses. No transmission mechanism - monetary or other - can be defined unless the (weakly) exogenous driving force which sets this mechanism in motion is first

identified. But policy typically operates via a reaction function and is thus in part endogenous. And decoupling exogenous from endogenous policy impulses is inherently problematic; there is an identification problem to be solved. This identification problem lies at the heart of the uncertainties which persist regarding the nature of the monetary transmission mechanism [Sims (1992)].

What is meant by policy exogeneity? In defining the transmission mechanism, exogeneity of the monetary instrument is important in two senses. In an economic sense, the instrument must, at the margin, be perfectly controllable by the monetary authorities: the endogenous response of the instrument to developments in the economy must occur solely through the authorities' reaction function. In a statistical sense, sufficient restrictions need to be imposed to allow the identification of this reaction function and the (primitive) shocks pertaining to it. We are mindful of both exogeneity issues here.(1)

The instrument of monetary policy in the UK takes the form of the minimum rate at which the Bank of England is willing to supply marginal funds to the discount market. Prior to 1981 this rate was signalled by the Minimum Lending Rate (MLR), since when it has typically taken the form of the minimum rate (the 'stop' rate) at which the Bank is willing to discount eligible bills from the discount market. These rates satisfy the controllability criterion. In the market for the shortest-maturity (Band 1 and Band 2) eligible bills, the Bank is a known rate-setter: the supply of reserves is perfectly elastic at the authorities' desired rate. Moreover, movements in this minimum rate are widely recognised as providing the tool by which changes in monetary policy are signalled to the markets. Thus, the 'stop' rate in the UK appears to satisfy the economic exogeneity characteristics

(1) This exogeneity issue was considered, using very different techniques, most recently by Bernanke and Blinder (1992) and Romer and Romer (1990). Our approach follows that of Bernanke and Blinder (1992).

required of the monetary policy instrument in any analysis of the transmission mechanism.(2)

The issue of statistical exogeneity is largely methodological and is left to the next section. Suffice to say, however, that monetary impulses are identified by imposing the restriction that there is no *contemporaneous* feedback from non-policy variables onto the policy instrument. The combination of information and decision lags suggests that this restriction is likely to be satisfied when using monthly data, as here.

(b) Defining Channels of Monetary Transmission. Having defined the time-series mapping from the monetary instrument through to a set of final target variables, a further question is of obvious interest: what are the principal propagation mechanisms through which these monetary impulses are transmitted?

There are, of course, many such propagation mechanisms. Of particular interest is the role of commercial bank (and building society) money and credit in the monetary transmission process. The role of bank balance sheet variables, emphasised as early as Friedman and Schwartz (1963) and Sims (1972), remains a key feature of the monetary debate today. This role is highlighted, at a policy level, by the continuing widespread use of bank balance sheet variables as intermediate targets or indicators in the conduct of monetary policy. Theoretically, the emergence of a growing literature stressing the importance of endogenous bank behaviour in the monetary transmission process [see, for example, the survey in Gertler (1988)] has added substance to this debate. And - perhaps most importantly -

(2) Conveniently, these institutional characteristics of the 'stop' rate enable us to side-step many of the empirical tests conducted by Bernanke and Blinder (1992); they use the Fed funds rate - an endogenous interbank rate - as their policy instrument for the US. Neither do we pre-test to ensure that our policy instrument necessarily has explanatory power over final variables [as in Bernanke and Blinder (1992)]: in many ways, it is precisely this hypothesis which is being tested when simulating a monetary policy shock.

empirical differences of opinion have remained regarding the role of bank balance sheet variables in explaining nominal output, over and above, for example, financial prices [see the evidence surveyed in Bernanke and Blinder (1992)]. These debates have ensured that the role of bank balance sheet variables in the monetary transmission process has remained an active area of academic research.

One of the most topical aspects of this research is the long-pursued money versus credit debate. This debate, dating back at least as far as Brunner and Meltzer (1972), has been given a fresh impetus recently by a strand of literature stressing the importance of credit market imperfections in the monetary transmission mechanism [see, *inter alia*, Bernanke and Blinder (1988, 1992), Gertler and Gilchrist (1991, 1992), Kashyap, Stein and Wilcox (1993), Dale and Haldane (1993a, b)]. These papers, by incorporating the possibility of imperfect substitutability between bank and non-bank sources of credit, identify an independent *credit* multiplier which operates over and above the conventional monetary multiplier following a monetary shock [see Bernanke and Blinder (1988)]. This suggests a role for commercial bank credit in the transmission of monetary impulses, in addition to, or instead of, bank deposits.

But empirical evidence on the relative contributions of money and credit in the propagation of monetary policy impulses remains only tentative. Sometimes it is conflicting; contrast King (1986) and Romer and Romer (1990) with Gertler and Gilchrist (1992) and Kashyap, Stein and Wilcox (1993). More often it is ambiguous; consider Friedman (1983), Bernanke and Blinder (1988, 1992). These ambiguities derive, overridingly, from the high collinearity between aggregate money and credit, which in turn stems from the commercial banks' balance sheet constraint. This constraint means that, almost by definition, aggregate money and credit move together.(3) Thus identifying their potentially separate effects is hindered. This problem is particularly acute in the UK, where banks typically hold a much smaller proportion of their assets in non-bank securities, such as bills or bonds, than, for example, is the case with US banks.

(c) Sectoral Channels of Monetary Transmission. The estimation of distinct sectoral transmission mechanisms affords both econometric and economic benefits. From an econometric perspective, the use of sectoral data implies that the banks' balance sheet constraint need no longer apply. High collinearity between money and credit is no longer imposed; it is possible for sectoral money and credit data to display differing responses to monetary impulses even in the long run. Notably, the papers to date which have been most successful in distinguishing money and credit effects have also used disaggregated data. These studies have typically been concerned with a distinction based upon small versus large firms [Gertler and Gilchrist (1992)]. Here we use a sectoral distinction - persons and corporates - which is both an econometrically efficient and novel way of identifying distinct money and credit effects.

The advantages of sectoral data are not exclusively econometric. It is likely that the degree of substitutability between bank and non-bank sources of finance will vary across sectors. Due to various informational asymmetries, small firms and persons are typically less able to access non-bank sources of credit. Following Bernanke and Blinder (1988) and Dale and Haldane (1993a), these substitutability differences should be reflected in differences in the channels of monetary transmission. Gertler and Gilchrist (1991, 1992), using a small

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(3) For example, the correlation between aggregate M4 and M4 lending in the UK over our sample period was 0.99 for the level of the aggregates, and 0.92 for changes in the aggregates. Moreover, since this collinearity is generated artificially (by the balance sheet constraint), standard means of orthogonalisation cannot 'solve' the problem.

firm - large firm distinction, present evidence to support this assertion. They find: (i) a larger role for bank credit in explaining output fluctuations for small firms than for large; (ii) a larger and speedier role for monetary policy more generally for small firms than for large. Different sets of agents are found to exhibit behaviourally distinct monetary propagation mechanisms. Identification of these sectoral differences is not only central to understanding the transmission mechanism as a whole, but also provides an insight into how economically meaningful it may be to conduct monetary policy with reference to *aggregate* bank balance sheet variables.

(d) Distinguishing between contending theories of the monetary transmission mechanism. Sims (1992) dichotomises existing models of the monetary transmission process into: (i) IS/LM-Monetarist models, which ascribe a powerful role to monetary policy shocks in the generation of business cycle dynamics; and (ii) Real Business Cycle (RBC) models, where the role of nominal monetary shocks is weak, and output and price dynamics are driven principally by shocks to 'deep' parameters (productivities and preferences).

Provided monetary shocks are sufficiently well-defined, impulse response functions and variance decompositions of the variables comprising the transmission mechanism should offer a useful means of evaluating these contending theoretical approaches. It is only when policy endogeneity problems emerge that the time-series responses from the two models become blurred [see Sims (1986)]. Since these endogeneity issues have been formally addressed here, our estimates are particularly well-placed to distinguish between the two classes of model.

3. Methodology

As stated at the outset, our aim is to delimit, and quantify, the structural effects of a monetary policy change. Clearly, to do this we need first to define a structural model. Thus consider the following linear, dynamic system of equations, which we assume defines the 'true' structure of the economy:

$$B_0 y_t = B(L) y_t + u_t \tag{1}$$

where y_t is an $n \times 1$ vector of economic variables; B_0 is an $n \times n$ matrix of impact multipliers; $B(L)$ is a k^{th}-order matrix of structural polynomials in the lag operator L (such that $B(L) = B_1 L + B_2 L^2 + ... B_k L^k$; and u_t is an $n \times 1$ vector of structural disturbances, with covariance matrix Σ_u.

There are an infinite number of ways in which the structural parameter and disturbance terms in (1) may be identified. Bernanke and Blinder (1992) define two broad approaches to this identification problem.[4] The first approach is to estimate (1), the structural form, directly. This is the standard approach in the simultaneous equation literature. Identification comes from assuming elements of the y vector are strongly exogenous. This, in turn, places zero (exclusion) restrictions on blocs of the B matrix.

In principle, given a sufficiently well-articulated theoretical model, implementing such a structural approach would be straightforward. In practice, theory in general - and monetary theory in particular - is rarely so well-defined or unambiguous as to suggest such (strong exogeneity) restrictions. Using exclusion restrictions for identification is thus at best problematic and at worst 'incredible' [Sims (1980a)]. This problem is particularly acute when defining the monetary transmission mechanism, since competing (RBC and IS/LM) models would suggest strictly opposing exclusion restrictions.

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(4) The dichotomy is no more than illustrative. The two approaches differ only in that they impose different classes of identifying restriction on the underlying structure.

The second approach, followed here - and in recent papers by Bernanke and Blinder (1992) and Sims (1992) on the transmission mechanism - is to consider estimation of the reduced-form of (1):

$$y_t = B_0^{-1} B(L) y_t + B_0^{-1} u_t \qquad (2)$$

which can be given the more conventional Wold moving-average representation:

$$y_t = C(L) \epsilon_t \qquad (3)$$

where $C(L) \equiv (I - B_0^{-1} B(L))^{-1}$ is the reduced-form lag polynomial matrix; $\epsilon_t \equiv B_0^{-1} u_t$ is a vector of reduced-form disturbances; and I is the identity matrix.

Equation (3) defines the path of the endogenous variables as an (infinite-order) distributed lag of past structural disturbances. The literature on vector autoregressions (VARs) looks specifically to estimate and solve a system such as (3). Restrictions are then placed upon B and u_t, such as to allow identification of the structural parameter and disturbance terms (B_0, $B(L)$ and u_t), given empirical estimates of $C(L)$ and ϵ_t.

The original identifying restrictions employed in VAR models were those of Sims (1980a). These are worth rehearsing. Note that if B_0 - the matrix of impact multipliers - were known, the structural lag polynomial matrix and disturbances could be derived directly from (3) given estimates of $C(L)$. In practice, B_0 is not known. But we do have, from (3), an estimate of the covariance matrix of the reduced-form errors:

$$\Sigma_\epsilon = E(\epsilon \epsilon') = B_0^{-1} \Sigma_u B_0^{-1'} \qquad (4)$$

Sims proposed two identifying restrictions: that Σ_u was diagonal (the structural shocks are orthogonal) and that B_0 was lower triangular.

From (4), these restrictions are sufficient to identify exactly B_0 from Σ_ϵ, and thus $B(L)$ and u_t from (3) given an estimate of $C(L)$.(5)

The key restriction, from an economic perspective, is that upon B_0. It imposes a contemporaneous, recursive form on the system. This is consistent with a Wold causal ordering. As first outlined by Cooley and LeRoy (1985), this structure is restrictive as an economic matter. However, in so far as defining the transmission mechanism is concerned, these restrictions are not particularly onerous. Indeed, they offer some advantages.

To see this, note that our interest is fundamentally with the behaviour of the economy following a monetary policy shock. The contemporaneous, recursive structural form offers a simple means of isolating this policy shock; that is, of satisfying the statistical exogeneity requirements discussed in the previous section. Sims' triangularisation of B_0 means that each reduced-form disturbance, ϵ_t, is uniquely associated with a structural disturbance, u_t. Reduced-form shocks to the system are thus readily interpretable as policy shocks. With monetary policy shocks well-defined, simulations of these shocks are straightforward.

The disadvantage of Sims' identification procedure is that the 'true' structure of the economy may not follow a Wold causal chain. Moreover, reordering the variables within the recursive system may generate marked differences in the estimated structural model. These problems have led to alternative (structural) approaches to VAR identification. Recent examples here include Bernanke (1986), Blanchard and Quah (1989), Gali (1992), King, Plosser, Stock and Watson (1992), Shapiro and Watson (1988). These approaches look to

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(5) Formally, Σ_ϵ contains $n(n + 1)/2$ independent elements. This is the same number of elements contained in B_0 provided the matrix of impact multipliers is triangularised, and Σ_u is diagonalised (and normalised on unity). These restrictions allow a unique (Choleski) decomposition of the matrices on the right-hand side of (4) - thus identifying B_0.

impose alternative - typically long-run - identifying restrictions, which may have their source either strictly in economic theory [as in, for example, Blanchard and Quah (1989)], or result from prior estimation of cointegrating relationships between variables [as in, for example, King, Plosser, Stock and Watson (1992)].

The advantage of such a structural approach is that it is no longer necessary to impose that the economy conforms to some arbitrary recursive structure. But there is a cost. With restrictions placed upon the long-run, fewer restrictions are put upon the short-run (impact) multiplier B_0 for identification. As a result, structural - specifically monetary policy - shocks may no longer be uniquely identifiable from the reduced-form errors. Reduced-form shocks become a (potentially complex) linear combination of the structural shocks. Structural interpretation of the shocks is thus hindered, and the usefulness of such a system for defining channels of monetary transmission is thereby limited.

This problem is particularly acute when long-run restrictions are imposed on the basis of cointegration relationships. In such a system, shocks can, by definition, emanate either from the residuals from the r cointegrating vectors (in which case they have a temporary effect) or from the remaining n-r common stochastic trends in the system (in which case they have a permanent effect) - see King, Plosser, Stock and Watson (1992). In either case, it is extremely difficult to give these reduced-form innovations a structural interpretation. Having an agreed-upon structural model may help the interpretation of these linear combinations of shocks [as in King, Plosser, Stock and Watson (1992)]. But monetary economics does not typically offer such an 'off-the-shelf' structural model.

There appears, in a sense, to be a trade-off between the theoretical underpinnings of the restrictions used to identify the structural model and the usefulness of the resulting model for policy purposes. This trade-off becomes less distinct, however, if there is no contemporaneous feedback onto the reaction function from the non-policy variables. There is then a theoretical justification for placing the monetary policy instrument at the top of a recursively ordered system. As argued in Section 2, with the monthly data used here, institutional and informational factors mean that it is improbable that policy choices within the month would be affected by the realised values of non-policy variables for that month. Weak exogeneity of the policy instrument - the identifying restriction - is thus likely to be satisfied. And thus the recursive mapping between the policy and non-policy variables is a valid representation. Provided this mapping is valid, this is then sufficient to define accurately the monetary policy transmission mechanism.

Ordering the vector of non-policy variables is more subjective. Largely this is an empirical issue, since differing theories - say, IS/LM versus RBC models - would suggest competing orderings of these variables [Sims (1992)]. Thus our approach is to experiment with a variety of orderings, allowing the data to arbitrate between these and thus between competing theoretical explanations. That said, to the extent that we are concerned with the response of the non-policy variables to innovations in the policy instrument, the ordering of the non-policy variables is irrelevant. If the monetary policy instrument is ordered at the top of the system, the response of the non-policy variables to monetary policy shocks will be invariant to their ordering.

Although it may not be desirable to restrict the VAR to take account of cointegrating relationships, non-stationarity in the data cannot be ignored. Omission of significant levels terms from the estimated model would induce bias in the estimated coefficients and standard errors. The significance of levels terms can be investigated by pre-testing for the existence of cointegrating relationships among the variables contained within the VAR. If a long-run relationship does appear to exist, the whole system should be estimated in levels.[6] The 'superconsistency' theorem [Stock (1984)] then ensures unbiasedness of our coefficient estimates. And the Wold decomposition is still defined for non-stationary variables. Accordingly, impulse response functions and variance decompositions are unimpaired. Estimation in unrestricted levels terms is clearly econometrically less efficient than if the system were (correctly) restricted in its long-run response. But it accommodates - without imposing - an equilibrium, whilst simultaneously ensuring that the estimated reduced-form is in a form suitable for policy analysis.

4. Data

The monetary transmission process within our system is defined over: a monetary policy instrument (official interest rates); intermediate channels of monetary transmission (bank balance sheet variables together with various asset prices); and final policy objectives (real output and prices). Of these, sectoral data were collected on the bank balance sheet and final target variables, allowing separate VARs to be estimated for the personal and corporate sectors. A full description of the data and their sources is contained in the Appendix.

The analysis of bank balance sheet variables is hindered by the many breaks in the UK aggregates caused by changes in the sample of reporting banks. This problem was circumvented by collecting data from a consistent sample of nine major banks. The importance of building society lending and deposits, particularly for the personal sector, meant data on (total) building society assets and liabilities were also included. Due to various reporting conventions, it was not always possible to observe the sectoral composition of bank lending and

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(6) Such a system could, of course, always be reparameterised as an unrestricted vector error-correction mechanism, estimated in differences but with unrestricted lagged levels terms included. If no well-defined equilibrium is found between the variables, then the system can be estimated in differences.

deposits on a monthly basis. In this event, the sectoral splits were estimated using quarterly data. The choice of sectoral prices and real output data is discussed in the Appendix.

In addition to monetary and real-side developments, the authorities' reaction function may also depend upon the behaviour of asset prices. Certainly, asset prices would be expected to enter the reduced-form price and output equations. The possibility of significant asset prices effects within our system was allowed for by the inclusion of exchange rate and stock market variables. The fact that asset price data are available instantaneously implies that the ordering of the VAR, with official interest rates at the top of the system, now relies solely on decision-making lags, rather than on informational delays. The possibility that the authorities may respond to within-month movements in the exchange rate or the stock market can be investigated by re-ordering the variables such that asset price shocks lead official interest rate movements; re-ordering provides a second-check on our exogeneity assumptions.(7)

The VARs were estimated using monthly data from 1974:6 to 1992:10. Conscious of the critique made in Wallis (1974), the data were all collected in non-seasonally adjusted form. Following a multiplicative approach, the data were then logged before being individually seasonally adjusted using a model-based procedure (STAMP). All the variables appeared to be I(1), with the exception of the bank balance sheet and the price level variables, which were borderline I(1)/I(2) over the sample. Pre-testing the variables within the system using the Johansen (1988) procedure indicated the existence of long-run relationships between the variables for both the personal and corporate

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(7) Sims (1992) reports that including the exchange rate helps strip out a large amount of endogenous interest rate movement previously thought exogenous - thus facilitating the identification of *exogenous* monetary impulses.

sectors.[8] Hence all the variables were entered in (logged) levels,[9] giving our system the interpretation of an unrestricted vector error-correction mechanism.

The optimal lag length on the VARs were derived using a sequence of (likelihood ratio) exclusion tests. This restricted the VARs to include fourteen lags of each series. The estimated VAR coefficients are in themselves not very interesting and so are not reported here. Instead, the next section considers the impulse response functions and the variance decompositions embedded within the sectoral VARs' moving-average representations.

5. Interpretation

Figures 1 and 2 plot the impulse response functions of each of the seven variables (interest and exchange rates, stock prices, money, credit, output and prices) with respect to an innovation in the interest rate residual equivalent to a 1% point rise in official interest rates.[10] These are shown for the corporate and personal sectors and cover a five-year horizon. Standard error bands (of $\pm$ two standard deviations) are also included. All reduced-form errors have been orthogonalised using Sims' procedure, such that a shock to the reduced-form interest rate residual has the interpretation of a shock to the structural monetary policy reaction function. The ordering of the VARs is as shown in Figures 1 and 2: official interest rates, the exchange rate, stock prices,

(8) Unit root and cointegration test statistics are not reported, but are available on request.

(9) The interest rate variable was entered as $\log(1+r/100)$.

(10) That is, we are shocking the *unanticipated* part of monetary policy; the endogenous, anticipated component having been partialed out by the reaction function. This accords with the idea that non-neutralities are greater for policy 'surprises'.

credit, money, real output, prices.[11] Since the variables are in logs, the impulse responses have the interpretation of cumulative growth rates relative to base (except interest rates which can be interpreted as percentage point movements relative to base). The scales on each of the variables have been standardised across the two sectors, such that the (differential) responses between them can be considered. The resulting impulse response functions can be considered in terms of the four aspects of the monetary transmission mechanism discussed in Section 2.

(a) Defining the Monetary Transmission Mechanism. In general, the qualitative pattern exhibited by all of the variables following a monetary tightening accords with our priors. The effect of an interest rate rise is to: raise the exchange rate; depress share prices; reduce - at least eventually - money and credit growth; and depress output and inflation over the medium term. But the precise patterns and lags within these relationships are not always as expected, and as such are worth discussing.

The interest rate impulse response functions suggest that the monetary instrument follows a mean-reverting process. Positive innovations in official interest rates today are (partially) offset by falls in official rates after about two years: as the effects of the earlier tightening take effect upon output and prices, official interest rates *endogenously* fall via the policy reaction function. This mean-reverting tendency within official rates is consistent with the authorities adjusting monetary policy in response to (randomly distributed) temporary shocks. Recent evidence of mean-reversion in short-term interest rates is provided in Saunders and Unal (1988).

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(11) The VARs were re-ordered to allow for the possibility that the monetary authorities may react to within-month movements in asset prices. Although some of the quantitative patterns were sensitive to this re-ordering, the *qualitative* (particularly timing) patterns exhibited by the variables were not. This is further evidence favouring the proximate exogeneity of official interest rates.

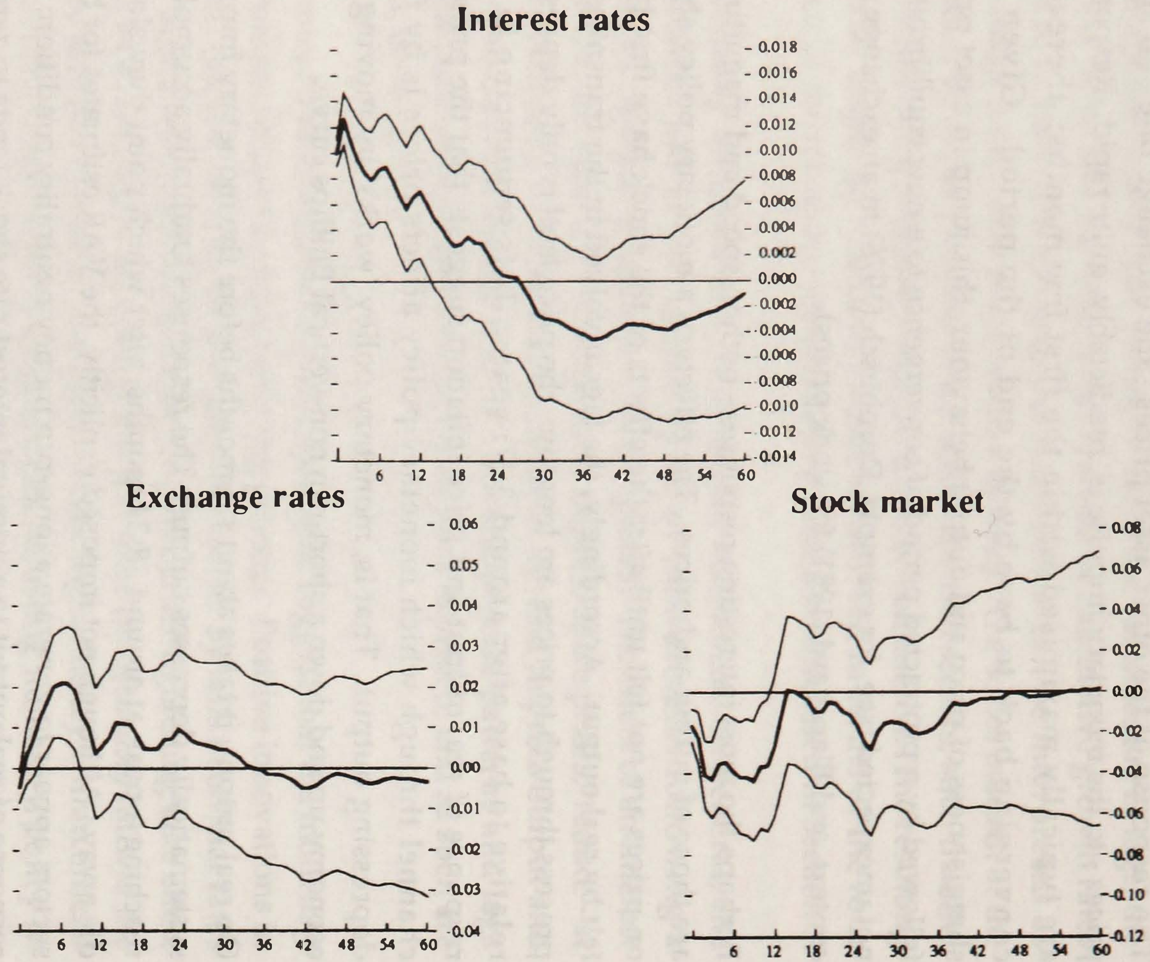
The response of the other asset prices - the exchange rate and stock prices - to the monetary impulse is, predictably, quite rapid. Responses are typically maximised within the first few months; thereafter converging back to base by the end of the period. Given the sluggishness of price and output behaviour, this jump in asset prices followed by a protracted period of convergence to a new equilibrium is not unexpected (see, for example, Dornbusch (1976) in an exchange rate context, and Blanchard (1981) for stock prices).

Perhaps the most interesting responses - both in speed and magnitude - are those of output and prices. The effects of a monetary policy shock on prices are not felt until *after* the effects of the shock have first been felt by real output. Accordingly, the lags involved in the transmission process through to prices are lengthy: the price *level* is only depressed relative to base after around 3 $^{1}/_{2}$ years. This sequencing in the response of real output and price inflation suggests that the primary channel through which monetary policy affects prices is by first depressing output. That is, monetary policy 'works' by moving the economy up and down a short-run non-vertical Phillips curve.

On real output, it takes about six months before the monetary impulse systematically depresses output. The responses gradually accumulate, reaching a peak at around 18-24 months, after which point they slowly die away. Although not imposed explicitly, the VAR estimates for both sectors appear to generate a long-run money neutrality condition: the response of real output to a nominal interest rate shock tends to zero by the end of the five-year horizon, for both the personal and corporate sectors. This response in real output is consistent with the implied temporal behaviour of (ex-post) *real* interest rates. The endogenous reductions in official interest rates, combined with the response in price inflation, suggest that monetary impulses only have significant effects on the real interest rate for about the first 2 $^{1}/_{2}$ - 3 years.

The dynamic response of prices following a monetary shock is, at first blush, difficult to reconcile with theory: the inflation response appears

Figure 1: Impulse Response Functions: Personal Sector



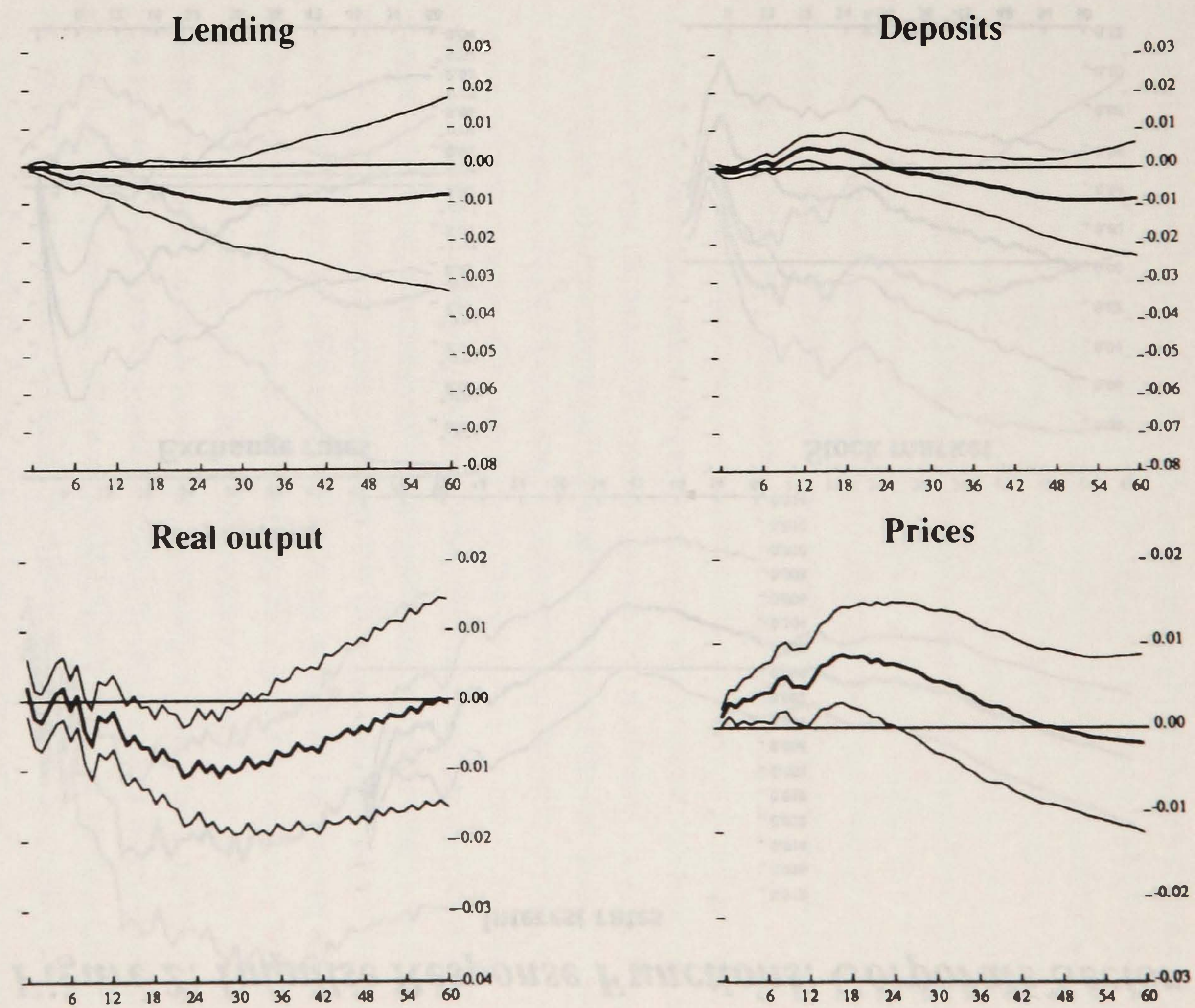
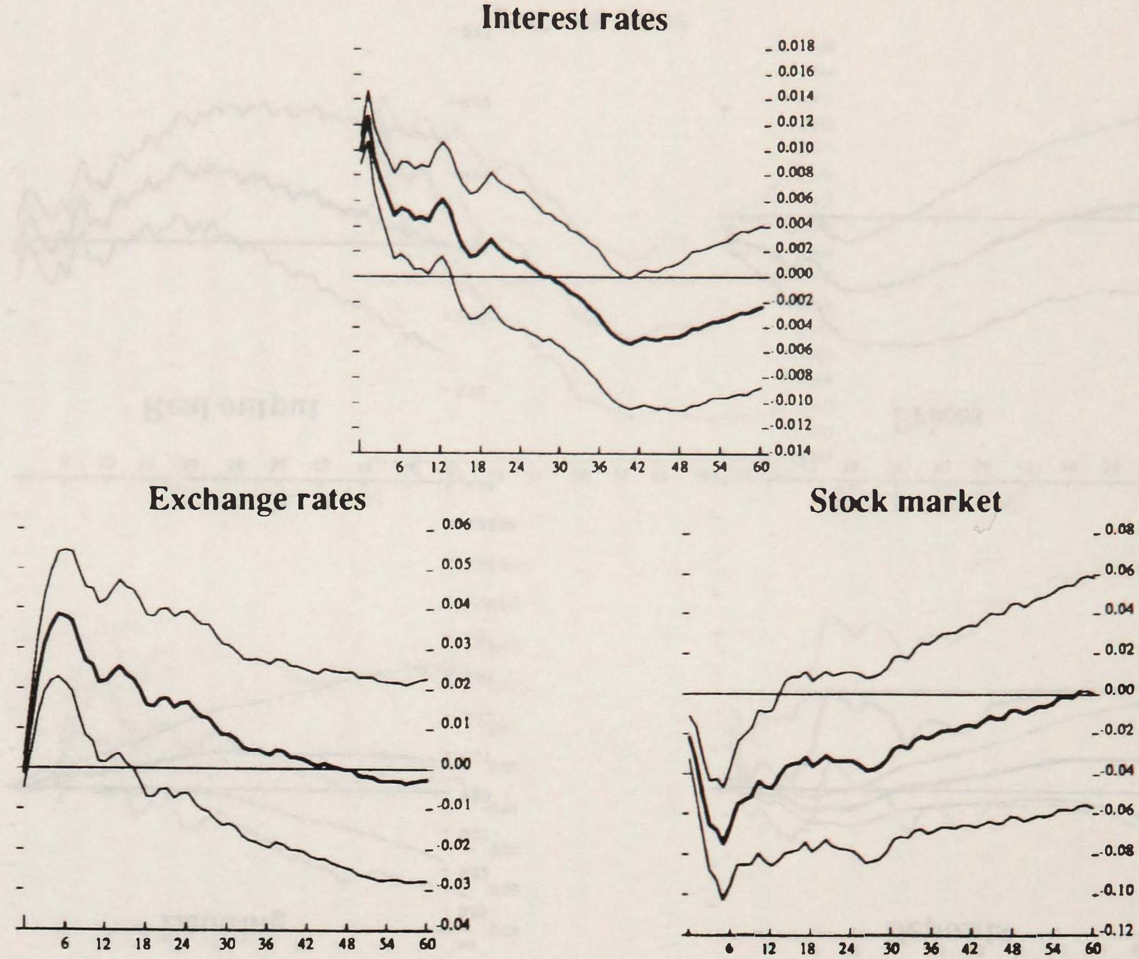
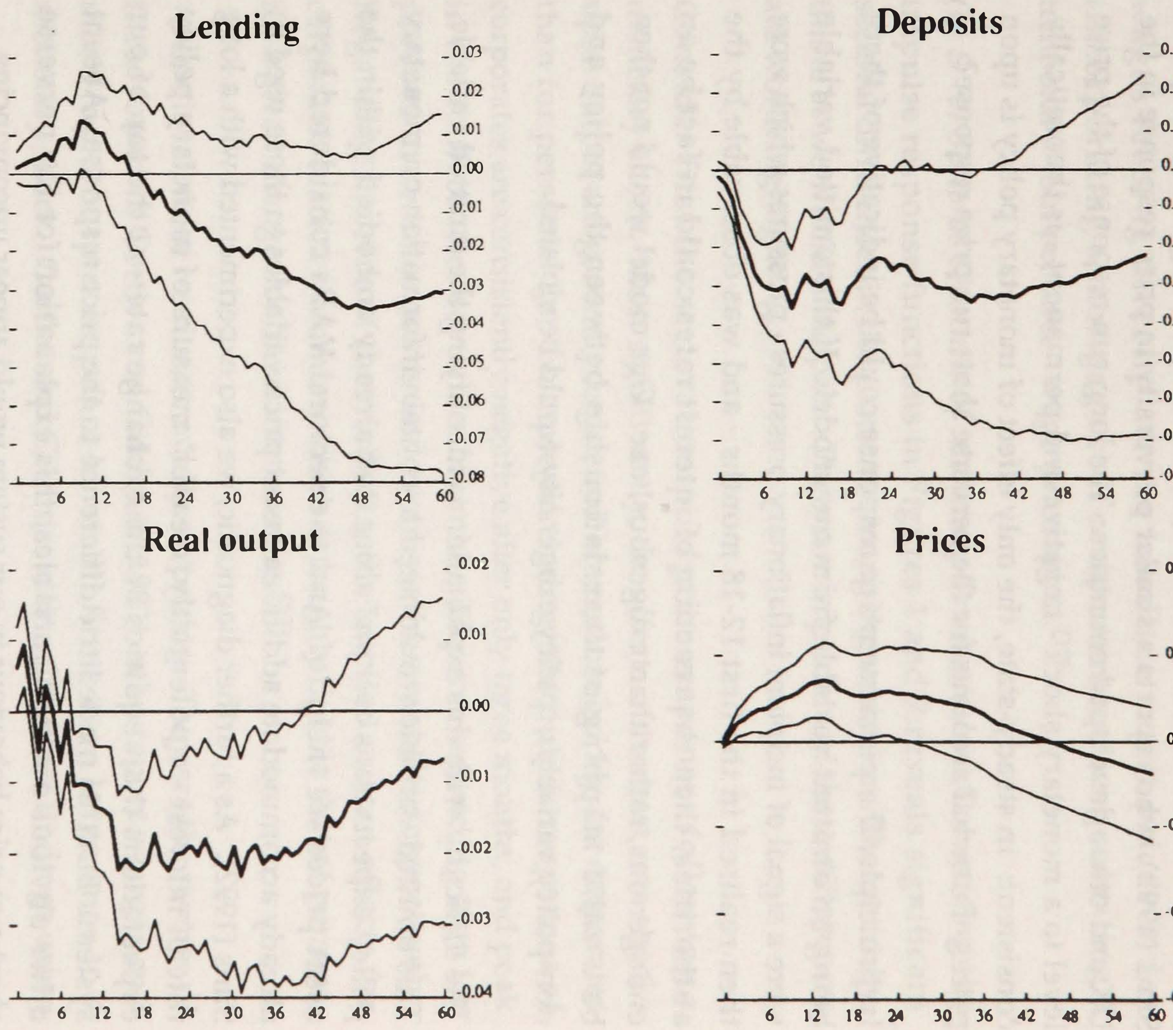

Lending
Deposits
Real output
Prices
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
6 12 18 24 30 36 42 48 54 60

Figure 2: Impulse Response Functions: Corporate Sector




Lending
Deposits
Real output
Prices
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
6 12 18 24 30 36 42 48 54 60

perverse for the first 12-18 months. This is the same finding as that in Sims (1992), who reports a similar perversity in price response in the UK and other developed countries. The long-run response of the price level to a monetary shock - negative and permanent - *is* theoretically consistent: in steady-state, the only effect of monetary policy is upon prices. But what accounts for the perverse short-run price response?

In principle, the perverse price response could be indicative of there being an omitted variable from our model. If this omitted variable were a signal of incipient inflationary pressures - pressures which were then realised in the first 12-18 months - and was observable by the authorities, then the reaction of interest rates could in fact be an endogenous, rather than exogenous, one. Our model would not then be a valid mapping of the relationship between the policy and non-policy variables; policy exogeneity would be violated.

The difficulty with this explanation is identifying the omitted variable. This omitted variable would need to contain information on monetary policy expectations *over and above* that already embodied within the asset prices we include. And the sectoral VARs considered here already accommodate additional asset price variables to those used in Sims (1992). As a further diagnostic, we also experimented with a long rate of interest - a potentially 'cleaner' measure of monetary policy expectations than equities or the exchange rate - at the top of our system. But this made little difference to the price response. Absent other obvious omitted variables, this explanation for the perverse short-run price behaviour in our system would appear unconvincing.

An alternative - preferred - explanation is simply that prices are set in accordance with some cost mark-up strategy. A rise in interest rates, by raising variable costs - indirectly via wages or directly via the cost of debt servicing - thereby raises prices in the short-run. This will occur until such time as demand is sufficiently depressed to provide an offsetting influence. A similar such mechanism is at work in many large-scale macroeconomic models of the UK economy. For example, in the Bank of England's model this perversity of prices is the result of wages feeding directly off the headline retail prices index (incorporating a mortgage cost component), thus generating a temporary - but perverse - wage-price spiral.[12]

(b) & (c) Sectoral Channels of Monetary Transmission. Comparing the impulse response functions in Figures 1 and 2 reveals significant sectoral differences in the patterns among the variables. Theoretically, this is as we would anticipate. The more important of these differences are worth highlighting.

Consider first the sectoral output/price responses following a monetary shock. Most significantly, the effects of interest rate shocks upon output are generally *larger*, and occur more *quickly*, for corporates than for persons. For example on timing, the output responses of corporates are consistently negative after only three months, and peak in their effect after seventeen months. The corresponding lags for persons are nine months and twenty-three months respectively. Regarding the size of these effects, the implied output effects for corporates reach a maximum which is roughly double that of persons, for a given change in official interest rates.[13]

At one level, these results are mildly surprising. They are the reverse of those found in Gertler and Gilchrist (1991), who report a larger and more rapid output response by small firms than large ones to a monetary shock. Gertler and Gilchrist rationalise their findings using

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(12) There is a third, purely statistical, explanation: if our measures of prices included mortgage costs, a raising of interest rates would increase prices simply as an accounting matter, even without the wage-price spiral. But this direct channel can be ruled out since the measures of prices included in the VARs - the retail sales deflator, and the producer price index - contain no mortgage cost component.

(13) In part, this larger and more rapid output response by corporates may reflect the fact that the responses of the asset prices are more pronounced for the corporate sector. However, these differential sectoral patterns were largely unaffected when the asset price effects were switched-off.

Bernanke and Blinder (1988) type reasoning. That is, small firms face greater credit market imperfections than large ones. This in turn inhibits these smaller firms' ability to access non-bank sources of finance, and thus amplifies the effects of a given policy shift.

This reasoning can just as easily be reversed, however. In two earlier papers [Dale and Haldane (1993a, b)], we observed how credit market imperfections may instead act to *weaken* the effects of monetary policy. Imperfect substitutability between different forms of credit may result in the marginal interest rates on loans becoming 'sticky' in response to official rate changes.(14) For sectors for whom asset/liability substitutability is low, official interest rate changes may be a less good guide to the overall change in monetary stance faced by agents. Hence the effects of a change in official interest rates are felt less strongly and/or more slowly by these agents. The results reported above appear consistent with this alternative view of the credit channel.

Variance decompositions of the sectoral VARs provide further support for this view. Looking at a decomposition of the forecast error variance of output (five-years-ahead) indicates that, for corporates, almost 50% of the error can be accounted for by shocks to official interest rates. By comparison, shocks to official interest rates account for only 20% of the output forecast error variance for persons. The above does not suggest that persons are necessarily less affected by changes in the underlying monetary stance. Rather, it suggests that official interest rates may be a less good guide to these underlying monetary conditions for persons than for corporates.

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(14) For recent empirical evidence of loan rate stickiness, see Berger and Udell (1992) for the US, and Dale and Haldane (1993b) for the UK.

The most striking differences in sectoral responses are those for money and credit.[15] This is suggestive of significant sectoral differences among the *channels* of monetary transmission - a possibility emphasised in Dale and Haldane (1993a) and Gertler and Gilchrist (1991, 1992). The sectoral patterns of money and credit are in many ways the mirror-image of one another.[16] For corporates, the effect of an interest rate rise is to *raise* their borrowings in the short term and to generate an immediate and pronounced contraction in deposits. The reverse is true for persons: it is lending which contracts immediately and most substantially, while deposits rise in the short term. Corporate lending and personal deposits do eventually become negative, but only after around one year and two years respectively.

These qualitative patterns for sectoral money and credit are consistent with those reported by Gertler and Gilchrist (1992). This consistency of response across the US and the UK is reassuring. The apparent perverse response of corporate lending, and strong contractionary response from corporate deposits, is given a buffer-stock interpretation by Gertler and Gilchrist. In the short term, corporates meet any cashflow shortfall resulting from a monetary tightening by either building up their liabilities (increasing credit), or liquidating their assets (reducing deposits). Thus corporate credit rises, and deposits fall, in the short run. It is reasonable to suppose a similar such buffer-stock explanation can be used in a UK context.

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(15) One apparent anomaly in the money and credit responses is that both exhibit a *permanent* shift following an interest rate shock. A number of factors may contribute to this: (i) the balance sheet variables are expressed in nominal terms and hence are not invariant to the price level response; (ii) the interest rate reaction function is only partially mean-reverting - a positive innovation in interest rates leads to a permanent increase in the *mean* level of interest rates. Bernanke and Blinder (1992) report a permanent effect upon *real* banks' balance sheets in the US.

(16) This may argue for joint estimation of the two sectoral sub-systems: if there is non-zero covariance between the sectoral equations' residuals, then joint estimation would improve efficiency. But this efficiency gain would likely be more than outweighed by the loss of degrees of freedom resulting from the need to estimate additional parameters.

These (distress) borrowing opportunities do not exist for smaller companies or persons, who typically face more acute credit market frictions. Accordingly, their lending profile falls monotonically following a rise in official interest rates. At the same time, personal deposits are inflated in the short run. This may reflect the fact that deposits are viewed by persons as less of a buffer-stock, and more as an interest-bearing component of wealth. A rise in interest rates may thus increase the attraction of interest-bearing, capital-certain deposits in the short run, relative to, say, capital-uncertain equities and gilts, whose prices will have fallen. Hence the apparently perverse short-term response of personal deposits.

These sectoral responses clearly offer information on the money versus credit debate. In Bernanke and Blinder (1992), the aggregate credit response is found to be *coincident* with the demand response. The authors interpret this as evidence in favour of bank loans being an important channel of monetary transmission. But this conclusion is necessarily tentative. Our sectoral estimates help firm up this conclusion.

For persons, the slowdown in lending clearly *precedes* that in output (and thus that in prices). Deposits, by contrast, only become negative after the effects of the monetary shock upon output have first peaked. These patterns are consistent with a credit channel operating for these less substitutable sectors: bank credit appears to be the primary bank balance sheet propagation mechanism for the transmission of monetary impulses. This is consistent with the 'specialness' of bank lending for those sectors unable to access alternative forms of finance [see, for example, Bernanke and Blinder (1988)]. Moreover, and in contrast with Bernanke and Blinder (1992), the relative timing patterns suggest a clear preference for credit over money as an intermediate indicator of the effects of monetary policy for persons.

These conclusions are reversed for the corporate sector. The impulse response functions here suggest that it is money which sends the more accurate and timely signals in the short term. Deposits appear to lead output movements and peak prior to the peak in output. Credit moves perversely over this initial period; its peak response clearly lags that in the final variables. These patterns in turn support a more conventional 'money view' of the transmission mechanism for companies.

These sectoral differences in money and credit responses, and the corresponding loss of information when working in aggregate bank balance sheet terms, can be illustrated formally by comparing the responses from Figures 1 and 2 with those from an aggregated, whole economy, system. These aggregate responses are shown in Figure 3.[17] The construction of an aggregate VAR is complicated by the absence of a suitable monthly aggregate output or price deflator series for the UK. Hence we were forced to estimate a quarterly model. The use of quarterly data means that the grounds for treating the monetary policy instrument as contemporaneously exogenous to the other variables in the system are no longer so compelling. It is quite possible that monetary policy may alter in response to *within-quarter* developments in the other variables. That said, for purposes of illustration and comparison with the sectoral VARs, the residuals were orthogonalised according to the same ordering restrictions. Reordering the VAR such that the interest rate was, for example, ordered last altered the scale of the impulse responses, but not their general timing patterns.[18]

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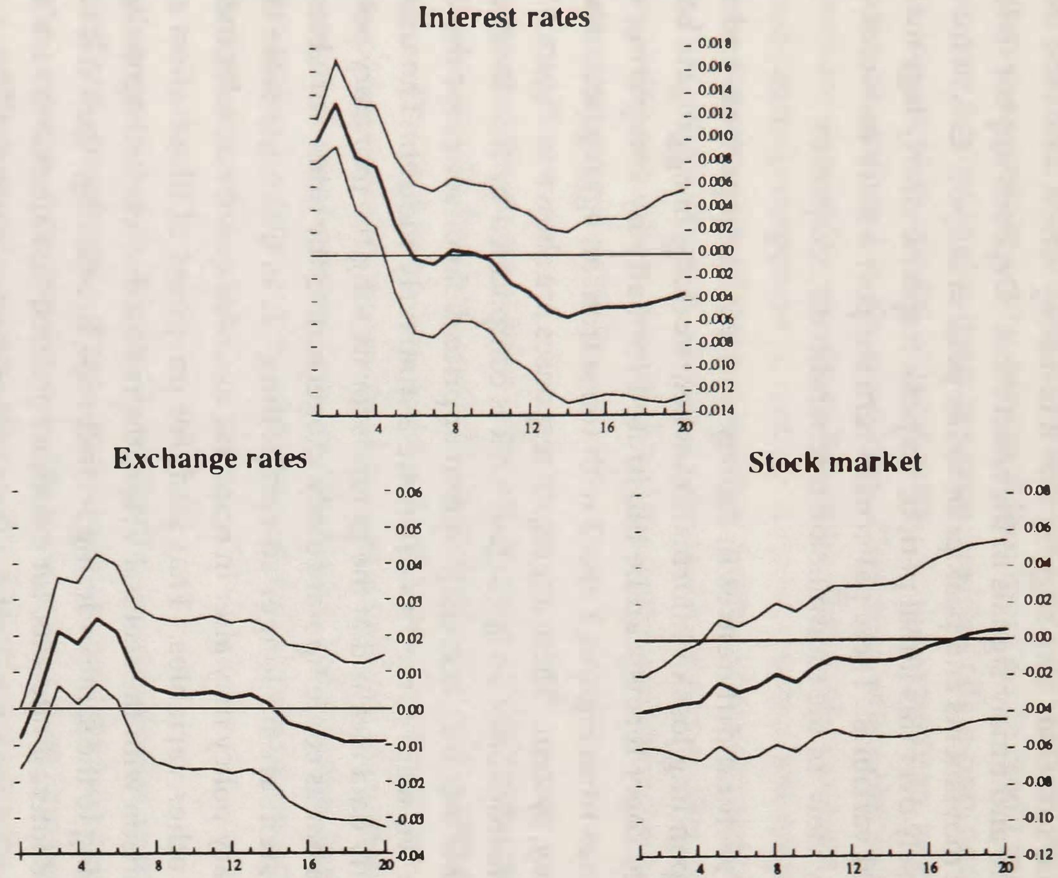
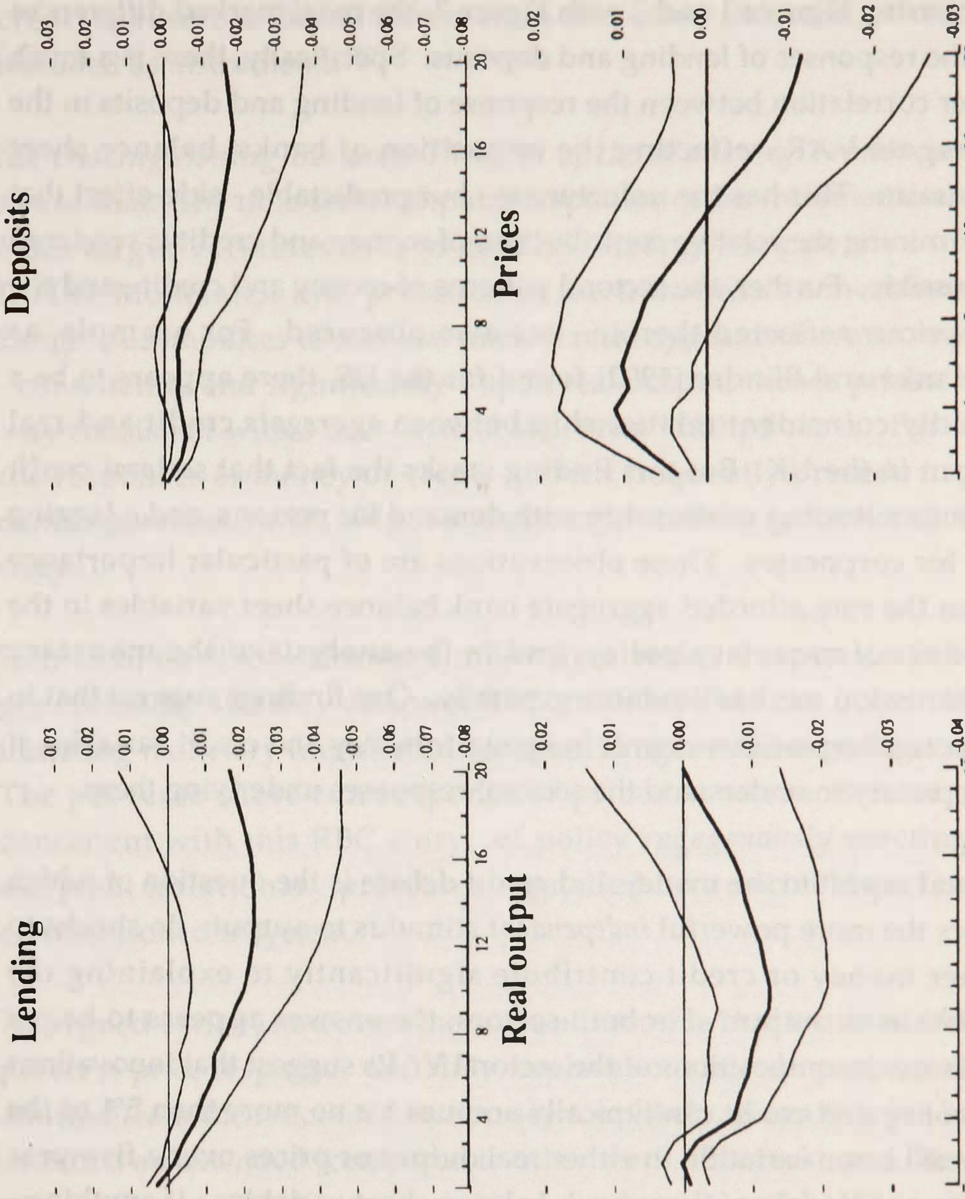
(17) The scales for each variable are the same as in the sectoral diagrams.

(18) The aggregate VAR was estimated over the same sample period as the sectoral VARs, with five lags on each variable - analogous to the fourteen lags included on the monthly variables.

Figure 3: Impulse Response Functions: Aggregate





Lending
Deposits
Real output
Prices
4 8 12 16 20
0.03 0.02 0.01 0.00 -0.01 -0.02 -0.03 -0.04 -0.05 -0.06 -0.07 -0.08
0.02 0.01 0.00 -0.01 -0.02 -0.03 -0.04
0.02 0.01 0.00 -0.01 -0.02 -0.03

Comparing Figures 1 and 2 with Figure 3, the most marked differences are the responses of lending and deposits. Specifically, there is a much closer correlation between the response of lending and deposits in the aggregate VAR, reflecting the imposition of banks' balance sheet constraint. This has the unfortunate - but predictable - side-effect that determining the relative contributions of money and credit is rendered impossible. Further, the sectoral patterns of money and credit - and the behaviour reflected therein - are also obscured. For example, as Bernanke and Blinder (1992) found for the US, there appears to be a broadly coincident relationship between *aggregate* credit and real output in the UK. But this finding masks the fact that *sectoral* credit exhibits a leading relationship with demand for persons, and a lagging one for corporates. These observations are of particular importance given the role afforded aggregate bank balance sheet variables in the conduct of monetary policy, and in the analysis of the monetary transmission mechanism more generally. Our findings suggest that in order to interpret movements in *aggregate* money and credit variables, it is necessary to understand the sectoral responses underlying them.

A final aspect to the money and credit debate is the question of which offers the more powerful *independent* stimulus to output: do shocks to either money or credit contribute significantly to explaining the variation in output? For both sectors, the answer appears to be no. Variance decompositions of the sectoral VARs suggest that innovations in money and credit can typically account for no more than 5% of the forecast error variation in either real output or prices over a five-year horizon. The role of these bank balance sheet variables - if anything - thus appears to be as a vehicle for transmitting monetary impulses, rather than as an independent source of such impulses. This is consistent with evidence from the US [Sims (1980b), Litterman and Weiss (1985)], who report that the predictive power of money and credit is absorbed once interest rates and other financial prices are included as instruments.[19]

(d) Distinguishing Between Theories of the Monetary Transmission Mechanism. The time-series impulse responses of the intermediate and final target variables are, in general, strongly supportive of an IS/LM-Monetarist interpretation of the transmission mechanism. Exogenous impulses to nominal interest rates appear to have an impact - consistently and significantly - upon real output, thence prices, in a way consistent with a non-vertical short-run Phillips curve. Further, the responses of money or credit - which frequently precede or are contemporaneous with output and price movements - corroborate this story.

But, as Sims (1986) shows, similar time-series responses can be generated by suitably-adapted RBC models. This can occur if the initiating monetary impulse is in fact not exogenous but endogenous. The perverse short-run response of prices in our model may be consistent with this RBC story: of policy *endogenously* reacting to incipient inflationary pressures, signalled by a variable currently omitted from our system.

As argued earlier, however, there are alternative explanations of this perverse price response. Certainly, explanations based upon variables omitted from the reaction function seem unlikely, given that we have included an extended [compared to other work - Bernanke and Blinder (1992), Sims (1992)] set of potential asset price and balance sheet variables. Having removed the endogenous influence of these factors, the time-series properties of the resulting system are far more easily explained from an IS/LM-Monetarist perspective, than from an RBC one.

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(19) Which argues against a strict Monetarist reading of the data, but in no way argues against money and/or credit as a (passive) intermediate indicator.

6. Conclusions

In this paper we have estimated a small, sectoral, vector autoregressive model of the UK macroeconomy. We then used this model to simulate the effects of an exogenous monetary policy shock and traced through its effects upon asset prices, bank balance sheet variables, and final target variables (real output and prices). On the basis of this, the conclusions we would draw are:

The transmission of monetary policy through to prices appears both sluggish and muted: the price *level* only falls relative to base around 3 1/2 years after the monetary tightening. Significantly, this price response occurs *after* the response in output. Thus, in our model, monetary policy 'works' by moving the economy up and down a non-vertical short-run aggregate supply curve; though our estimates also suggest that monetary policy is output-neutral (the long run Phillips curve is vertical) after around five years.

The model generates widely different responses from money and credit across sectors. In particular, there is a perverse short-term response from corporate sector lending and from personal sector deposits. Accordingly, insofar as their indicator properties are concerned, there appears a clear preference for monitoring corporate sector deposits, and personal sector lending. This is consistent with the well-documented 'specialness' of lending for those sectors less able to substitute into alternative (non-bank) sources of finance.

Further, both money and credit appear to be vehicles for transmitting monetary impulses, rather than separate sources of such fluctuations. This, of itself, does not of course argue against the use of money and credit aggregates as intermediate indicators - provided the impact of the differential sectoral responses within these aggregates is taken account of.

Finally, on distinguishing between contending theories of the monetary transmission mechanism, the time-series evidence presented here would appear to be more easily explained in an IS/LM-Monetarist world, than in one where only real shocks matter. This is not to say that real shocks are unimportant. Only that, when accounting for the dynamics of a monetary shock, the burden of proof seems to lie with RBC modellers.

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Appendix: Data Construction and Transformation

Balance Sheet Variables:[20] The balance sheet data include lending by, and deposits with, both banks and building societies in the UK. The banking data were based on a consistent sample of nine major banks: Abbey National PLC, Abbey National Treasury Services, Barclays, Standard Chartered, Lloyds, Midland, NatWest, TSB Scotland, and First Trust Bank (AIB Group Northern Ireland).[21] These lendings to and deposits from the private sector were separated into three sectors: personal (including unincorporated businesses), corporate and other financial institutions (OFIs).

Sectoral data for bank deposits are only collected on a quarterly basis in the UK. The monthly data used in the estimations were approximated by projecting the quarterly sectoral shares onto the aggregate monthly totals. These approximations were backward-looking - January's and February's totals were based on December's sectoral shares; April's and May's on March's sectoral shares *etc* - and hence avoid the possibility of violating the exogeneity restrictions. Sectoral data on bank lending are available on a monthly basis in the UK from November 1983 onwards. Prior to this, a similar approximation procedure was used to generate the monthly lending data from the quarterly observations.

Since persons account for between 98%-99% of total building society lending and a similar proportion of their deposits, building society lending to (and deposits from) the corporate sector were assumed to be negligibly small and hence were not included. Sectoral building society data are only available in the UK on a quarterly basis. However, from

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(20) The aggregate balance sheet data are available from the authors upon request.

(21) Abbey National only became a bank in June 1989. However, the fact that it simultaneously left the building society sector when becoming a bank ensures there is not a break in the aggregate (bank plus building society) balance sheet data.

June 1982 onwards, monthly data are available on building societies' total lending and deposits, with the deposit data separated into retail and wholesale components. Building society lending to the personal sector was proxied by their total lending, while personal sector deposits were set equal to retail deposits. Prior to 1982, these data were only available on a quarterly basis and hence the monthly data had to be interpolated from the quarterly series.

Asset Prices: Prior to December 1981, the official interest rate variable is given by the Minimum Lending Rate (MLR). After 1981, the official interest rate is set equal to the Band 1 'stop' rate. Until October 1991, the Bank of England's Band 1 *dealing* rates were quoted in the statistical annex of the *Bank of England Quarterly Bulletin.* More recent data are available in the monthly 'Money Market Statistics' press notice issued by the Bank. It is possible to calculate the 'stop' rates from the quoted dealing rates. The exchange rate variable is given by sterling's effective exchange rate index, and the stock market variable by the FTSE-100 index. All asset prices are quoted as monthly averages.

Real Output and Prices: Real personal sector output was proxied by the retail sales volume index. Personal sector prices were proxied by the corresponding retail price deflator. For the corporate sector, real output was proxied by the index of the output of manufacturing industries (SIC 2-4), and prices by the associated index of producer prices. The aggregate real output and price variables were proxied by the GDP index (expenditure based) at factor cost, and its associated price deflator. All the real output series were valued at 1985 prices. All these data are available from the CSO.

All the index variables were normalised to 1985=100; the balance sheet variables were entered as £ millions. The data were collected in non-seasonally adjusted form, and were logged before being adjusted using a model-based seasonal adjustment programme - Andrew Harvey's STAMP package.

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