Base rate pass-through: evidence from banks' and building societies' retail rates

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Abstract

Official interest rate changes are intended to influence short rates on money market instruments and retail products, such as deposit accounts and mortgages, and complete pass-through is often simply taken for granted. This paper provides a theoretical and econometric framework for assessing the evidence for this assumption using 14 years of monthly data for interest rates on deposit and mortgage products offered by UK banks and building societies. The method employed allows for asymmetries and non-linearities in adjustment and the results show that the speed of adjustment in retail rates depends on whether the perceived 'gap' between retail and base rates is widening or narrowing.

Summary

Nearly all central banks in the industrialised countries conduct monetary policy through market-orientated instruments designed to influence short-term interest rates. They reserve the right to supply the money market shortage at a price of their own choosing (the official rate), which then feeds through to short-term money market rates and the rates set by banks and building societies on retail products, such as deposit accounts and mortgages. For this reason, the official rate can be described as a lever that operates through short rates and longer rates to influence aggregate demand.

Ideally, official rate changes should be completely 'passed through' to market and retail rates over a reasonably short horizon. In practice, official rate changes may not be fully and instantaneously passed through to retail rates, but differentials may persist for a time. This paper explores some of the reasons why banks and building societies may face incentives to make discontinuous changes to rates. Our interest in this paper is the pass-through of official rates to bank and building society retail rates.

We consider the retail rate setting process as potentially asymmetric and non-linear. Our model allows for switching according to the size of and the change in, the difference between the current retail rate and its long-run equilibrium value. We make use of detailed monthly data on retail rates set by UK banks and building societies provided by the major clearing banks' annual publications and the Building Society Commission over the period 1985–99.

Examining the relationship between the level of each retail rate by product and by type of institution we reveal complete pass-through to be the norm in the long run for deposit rates, but not for the mortgage rate. We then consider the non-linearities that exist in the dynamics, and this requires that we specify what drives the process of adjustment. We split the drivers into endogenous and exogenous categories. Drivers that were significant included the actual or expected change in the base rate, the yield spread for three to six-month horizons, and a measure of interest rate uncertainty based on option prices. Adjustment was unaffected by indicators of market competition, such as differentials between rates on similar products of banks and building societies, differentials between mortgage and deposit interest rates as a measure of margins, or activity in the housing market.

We conclude that the main driver of base rate pass-through is the change, or the expected change, to the official instrument. This creates faster adjustment when the 'gap', between the base and retail rates, is growing in absolute size. Both banks and building societies move significantly faster to close 'grouping gaps'. Although the response is quantitatively different for each retail product and for banks versus building societies, the direction of change is the same.

1 Introduction

In recent years, virtually all central banks in the industrialised countries have conducted monetary policy through market-orientated instruments designed to influence short-term interest rates (Borio (1997)). By ensuring that the money markets are always short of cash on a daily basis, central banks reserve the right to supply the shortage at a price of their own choosing (the official rate). There is a presumption that these official rate changes will feed through to influence the array of short-term money market rates and the rates set by banks and building societies on retail products, such as deposit accounts and mortgages. If monetary control is to be effective, and official rate changes are to be influential over the future path of spending and inflation, it is desirable that – changes in the supply side of financial intermediaries aside – market and retail rates should follow official rates closely. Goodfriend (1991) has described the official rate as a lever that operates through short rates on longer rates, which have greater influence over aggregate demand. If monetary policy actions are to be influential, official rate changes should be completely 'passed through' to market and retail rates over a reasonably short horizon. In practice official rates changes may not be fully and instantaneously passed through to retail rates but differentials may persist for a time if banks and building societies adjust their margins, or if they face non-negligible costs of adjustment to rates. Both banks and building societies have incentives to make discontinuous changes to avoid menu costs, but they may find these costs do not impinge identically and their responses to rate changes may differ. Despite deregulation of the financial markets to encourage competition between banks and building societies, banks continue to have greater access to wholesale markets, and are therefore relatively less dependent on their deposit base for funds. The trend towards demutualisation has ensured that few large building societies remain, but those that do may have incentives to set rates differently from banks to reinforce their mutuality.

Our interest in this paper is the pass-through of official rates to bank and building society retail rates. Two papers by Paisley (1994) and Heffernan (1997) use conventional linear methods to investigate these relationships but these studies find mixed evidence for pass-through. Heffernan's study finds complete pass-through for repayment mortgages and incomplete pass-through for savings and chequing accounts in the long run for UK banks and building societies; Paisley does not find complete pass-through in mortgage rates for UK building societies. The evidence taken from cointegration analysis and *linear* error correction models assumes that the speed of adjustment is the same under all circumstances. We investigate the possibility that there are asymmetries and non-linearities in the adjustment process. Both Hannan and Berger (1991) and Mester and Saunders (1995) have allowed for asymmetries in their models, but they use US deposit and prime rate changes, rather than UK data; and assume that rate changes are discrete. Their models attempt to determine the probabilities associated with upward, downward or no rate changes using a multinomial logit model.

We consider the retail rate setting process as potentially asymmetric and non-linear and implement a non-linear switching model that has some similarities with the approach taken by Hannan and Berger (1991) and Neumark and Sharpe (1992) who use a switching model of partial adjustment for US deposit rates. Our model allows for switching according to an indicator function that can determine the influence and the sign of, but also the size and the change in, the difference between the current retail rate and its long-run equilibrium. Switching can be driven by this difference itself or by exogenous variables that provide information on its expected future path. The switching variable is then used to create a non-linear error correction model to capture asymmetries and non-linearities in the adjustment of deposit and mortgage rates, using methods introduced by Granger and Lee (1989) and further developed by Scholnick (1996) and Frost and Bowden (1999). These papers have used two-step estimators. We utilise both two-step and one-step estimators of linear and non-linear adjustment models of official rate pass-through to retail rates in order to allow for potential biases in the estimates.[1][2] We make use of detailed monthly data on retail rates set by UK banks and building societies provided by the major clearing banks' annual publications and the Building Society Commission over the period 1985–99.

The paper is organised as follows. The next section explains the background and the model, Section 3 sets out the econometric methodology we employ, Section 4 describes the data and Section 5 reports the results. Section 6 concludes.

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(1) Empirical assessments of the pass-through of base rates have also been conducted on market rates by Cook and Hahn (1989) and Thornton (1999) for the United States and Dale (1993) for the United Kingdom. These studies show that market rates respond significantly but incompletely to changes in the official rate in the days surrounding the change, with the size of the response decreasing in the maturity of the underlying product. Cointegration analysis by Dale (1993) suggests that pass-through is complete only for very short maturities.

(2) We note that Holly *et al* (1999) report potential biases in estimated long-run coefficients when two-step estimators are used. In practice we find little difference between the estimates using one and two-step procedures.

2 Background and model

Banks and building societies in the United Kingdom only became major competitors after the early 1980s when banks began to compete for mortgage business and building societies started to offer interest rates on chequing accounts. Prior to that banks had offered transaction and liquidity services and building societies had concentrated on the business of directing personal sector savings towards loans for house purchase. Once the two began to compete, building societies were regarded as disadvantaged relative to banks by the legislative restrictions imposed upon them. The Building Society Act (1986) opened up new areas of business to building societies, allowing them greater access to wholesale markets and life assurance. It also provided scope for them to hold a wider spectrum of liquid assets to ensure fair competition. Through the process of deregulation in a growing mortgage market, building societies were increasingly able to compete on similar terms with banks for the expansion in new retail business and in wholesale markets that had previously been the preserve of banks alone. Nevertheless, some societies still regarded banks as advantaged compared with building societies, and in 1989 the Abbey National began the process of demutualisation. From 1994 the Cheltenham and Gloucester, the Halifax, the Leeds, the Woolwich, Alliance and Leicester, National and Provincial, Northern Rock, Bristol and West, and Birmingham Midshires all converted by merger with banks or transfer to private limited company status. The largest societies – with the exception of the Nationwide – covering over two-thirds of building society business, have converted to banks.

The remaining building societies are relatively more dependent on their deposit base than banks and therefore may be more inclined to maintain deposit rates to keep market share. On this basis we might expect building society deposit rates to exceed those offered by banks on average. But the erosion of non-interest bearing deposit accounts as a proportion of total liabilities from 15% to 5% in the decade from 1985 may have raised average deposit rates offered by banks. Since the separation of the building societies into converters and non-converters there have been additional incentives for the remaining mutuals to reinforce their market position by behaving differently in retail rate setting. In the absence of windfall share issues, some prominent mutuals have sought to set higher interest rates on mortgage products and deposit accounts compared with non-mutuals. In practice, this has affected the margins between mortgage lending rates and wholesale funding rates more than margins with average retail deposit rates for banks as well as building societies, Gallagher and Milne (1997).

Given these institutional characteristics, how do we expect banks and building societies to adjust interest rates? It is typically assumed in theoretical models that banks and building societies have some degree of monopoly power in price setting, and they are normally represented in theoretical settings by monopolistic competitors facing linear demand functions and quadratic costs. But monopolistic competition is not sufficient to generate the discontinuous adjustment that we observe in retail rates, and costs of adjustment must imply that the profit function flattens off to discourage instantaneous adjustment in response to shocks. For a departure from continuous adjustment to retail rates (instantaneous and complete pass-through) we require costs to be associated with adjustment of rates. Costs may arise due to the search for information, Blanchard and Fischer (1989); menu costs of adjusting prices, Akerlof and Yellen (1985), Ball and Romer (1989), Mankiw (1985), Ball and Mankiw (1994); or non-pecuniary costs of lost custom after adjustment to rates, Rotemberg (1992).[3] Both banks and building societies face these same kinds of costs when adjusting retail rates but the incidence of the costs may not be the same; this may explain why the adjustment to retail rates differs by type of institution.

When these costs exist, rate setters have an incentive to avoid passing through minor changes to official rates, to anticipate the direction of a sequence of small changes to official rates accumulating them in a single retail rate change, and to anticipate turning points. When the profit function is flat, there is little incentive to adjust rates to small changes in official rates. Only when it is anticipated that there will be a succession of rate changes in the same direction will banks and building societies have an incentive to adjust rates. These could then be introduced in a cost minimising way by pre-empting the full increase or by catching-up with official rates after the event. By foreseeing a turning point, the costs of reversals could be avoided by not following the curve all the way to the top and the bottom of the cycle, but rather catching the rates on the way back up or down. Banks and building societies can reduce costs by smoothing official rates: this involves forward-looking dynamic behaviour to anticipate the future path of official rates.

Our thinking on this point leads us to build a simple model as a variant of the asymmetric adjustment framework of Ball and Mankiw (1994). In their model, firms have a desired price made up of the

[3] There are a number of other causes of adjustment to retail rates. These include a decision to change the 'equilibrium' spread; the so-called phenomenon of 'gapping', ie moving mortgage rates more slowly than deposit rates when the base rate is falling, for example; adjusting the spread around the base rate (it is typically the case that retail spreads narrow when the base is falling); the endowment effect as spreads between deposit and mortgage rates will have to be wider for any given margin as rates fall.

sum of the general price level and the desired relative price. Assuming a steady inflation rate, firms set prices for two periods with the option to reset in the intervening period at a cost (the menu cost). Trend inflation is known, but relative prices are subject to shocks and these may trigger adjustment. Ball and Mankiw show that the range of shocks for which adjustment *does not occur* is asymmetric and the absolute value of the lower bound is larger than the absolute value of the upper bound. Trend inflation provides some of the adjustment necessary to counter a negative shock.

We consider a similar conceptual model in which the banking firm may adjust its retail rates every even-dated period, and can choose to make an additional change in an odd-dated period at a fixed cost, *C*. At the beginning of each even period the MPC decides on base rates. *After* observing this decision the banking firm sets retail rates for the current and the following period. If we assume that the loss of the banking firm is quadratic in the difference of retail rates from their desired levels (the 'gap'), the retail rate set at the beginning of every even period for the next two periods (0 and 1) is given by:

$$r_0^* = \frac{b_0 + Eb_1}{2} \qquad \textbf{(1)}$$

where b_0 is the current (even period) base rate and $E_0 b_1$ is the following expected base rate.[4] This determines the *ex ante* optimal retail rate.

After setting retail rates a shock, say an unexpected innovation to the base rate, can cause the desired retail rate for the next period to change (note that retail rates would be equal to the base rate if they could be adjusted continuously and without any cost):

$$b_1 = Eb_1 + \varepsilon \qquad \textbf{(2)}$$

where ε is a shock which is normally distributed with zero mean and constant variance. The bank can now decide to adjust rates, re-setting them to the optimal level for the next two periods:

$$r_1^* = \frac{b_1 + Eb_2}{2} \qquad \textbf{(3)}$$

There is only an incentive for the bank to adjust its retail rate if the loss of not adjusting is higher than the menu cost:

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[4] Although the adjustment process is quadratic and therefore puts equal weight on deviations of retail rates above and below the base rate, the presence of a positive trend in inflation generates an asymmetric response from the banking firm.

$$E_1 \sum_{i=0}^{1} \left[\left(r_0^* - b_{1+i} \right)^2 - \left(r_1^* - b_{1+i} \right)^2 \right] = 2\left(r_0^* - r_1^* \right)^2 > C \qquad \textbf{(4)}$$

This can be rearranged to yield:

$$\left[\left(r_0^* - b_1 \right) - \frac{E_1 b_2 - b_1}{2} \right]^2 > \frac{C}{2} \qquad \textbf{(5)}$$

The first term is the deviation from long-run equilibrium, the second term represents the expected change in the base rate. The firm will not adjust if:

$$\left(r_0^* - b_1 \right) \in \left[-\sqrt{\frac{C}{2}} + \frac{E_1 b_2 - b_1}{2}, \sqrt{\frac{C}{2}} + \frac{E_1 b_2 - b_1}{2} \right] \qquad \textbf{(6)}$$

This condition generates two hypotheses. First, adjustment is predicted to be asymmetric. We expect to find that the response to a shock of a given magnitude will depend on whether the shock is positive or negative. This hypothesis indicates that, for a given positive disequilibrium, adjustment is more likely if base rates are expected to fall, and for a given negative disequilibrium, adjustment is more likely if base rates are expected to rise. Second, adjustment is predicted to be non-linear and related to forward-looking variables that identify the future direction of rates. Adjustment will therefore be faster if the *expected* differential between the current base rate and its future value widens, and slower if the *expected* differential narrows. The role of forward-looking variables introduces expectations, the appropriate horizon over which the differential might be calculated, and other indicators of the future path of rates.

As central banks have tended to make many small steps in place of few large ones in recent years (Goodhart (1996) and Sack (1998)) base rates have been smoothed and therefore autocorrelated. In view of this, banks and building societies – for whom the menu costs of changing rates are considerably higher in pecuniary and non-pecuniary terms than for the central bank – have formed expectations about the future trend in base rates when official rates are expected to follow a sequence of steps. If the base rates are autocorrelated and the differential is expected to widen further, firms may pass through the total anticipated base rate change into retail rates in full. Whether this would tend to cause retail rates to anticipate official rates changes (so that retail rates lie ahead of the curve) or to follow them (so that retail rates lie behind the curve) will be a feature associated with the type of institution and the product in question.

Alternatively, if base rate changes are expected to be reversed in the future as a turning point is reached – so that the gap between retail and official rates is eliminated and the desired margin is restored without adjustment to the retail rate – pass-through may slow down or cease. The occurrence of plateaux, which often signal a 'pause for thought' might be taken as a signal of an imminent turning point. Goodhart (1999) notes that not all pauses lead to reversals, however, since many continuations (inflexions) are observed after a sequence of zero changes to rates, but long pauses tend to result in a change in direction. If continuations are anticipated we might expect retail rates to be ahead of the curve on the way up and on the way down. Where changes in direction do occur, and are anticipated, it is unlikely that rates will follow the curve all the way down (or up); thus, we do not expect retail rates to be as volatile as base rates.

As far as pass-through is concerned, banks or building societies have two options in the face of a shock: (i) they can take a lower margin in a specific period; or (ii) they can incur a one-off menu cost to increase retail rates, thereby narrowing the expected differential in a specific period. Under option one, pass-through of base rate changes to retail rates is 0%; under option two it is 100%. The possibility of intermediate levels of pass-through occurs, because the decision to wait/respond is re-assessed every period in the light of expectations about the future path of the base rate. A sequence of decisions to wait, followed by 100% pass-through in the kth period, would yield a rate of $(100/k)$% pass-through.

Our model has both state-dependent and time-dependent features that can take into account endogenous and exogenous factors influencing the expected path of future base rates.(5) Models of this kind should map a dynamic response to shocks in the face of these adjustment costs and the

(5) TD rules offer explanations for co-ordinated, synchronised changes to rates as well as staggered changes, where a proportion of institutions change all their rates or all institutions change a proportion of their rates. SD rules create incentives to revert to a target value only when a pre-determined threshold, above or below the target, is reached, ie (S,s) models of Sheshinski and Weiss (1983), Caplin and Spulber (1987), Caplin and Leahy (1991). (S,s) models give reasons to believe that certain states of the economy or market competition might determine the costs of adjustment to retail rates and thus the incentive to pass rates through. Evidence from other types of price setters – such as supermarkets and mail order catalogues – suggests that neither TD nor SD tells the whole story, (Carlton (1986), Cecchetti (1985, 1986), Kashyap (1995)) but elements of both are pertinent. Menu costs and externalities on customers create SD because the objective is to avoid incurring the costs except when necessary, ie when a threshold value above or below the target is crossed. But when the state is uncertain, or needs to be learnt, and changes to prices have been frequent in the recent past, TD dominates. Here the price setter may be inclined to pause to avoid a move in the wrong direction (that must be subsequently reversed) or may avoid imposing externalities on the customer through frequent changes to prices that may in turn create costs for its own business, ie lost custom to competitors.

econometric specification that we use is a switching model, (Frost and Bowden (1999)) as the next section explains.

3 Econometric implementation

At the outset we take advantage of the fact that we aim to understand the long-run relationship between only two variables, a retail rate (y_t) and the (official) base rate (x_t), both of which were found to be non-stationary using standard tests.[6] There can be at most one cointegrating relationship between these two variables, which can be estimated in a single-equation autoregressive distributed lag (ARDL) framework.[7] The ARDL-model takes the general form:

$$\begin{aligned} &\phi(L)y_t = \mu + \theta(L)x_t + \varepsilon_t \\ &x_t = x_{t-1} + \eta_t \\ &\phi(L) = 1 - \sum_{i=1}^{\infty}\phi_i L^i,\ \theta(L) = 1 - \sum_{i=1}^{\infty}\theta_i L^i \end{aligned} \tag{7}$$

Here $\phi(L)$ and $\theta(L)$ are lag polynomials, y_t is the dependent variable (the retail rate series), and x_t is the base rate, which is a random walk; μ is an intercept term. The variables ε_t and η_t are random errors. This model can be written as:

$$y_t = \alpha + \beta' x_t + \left[\frac{\phi(1)-\phi(L)}{\phi(1)(1-L)}\right]\Delta x_t + \left[\frac{\theta(1)-\theta(L)}{\theta(1)(1-L)}\right]\Delta y_t + \frac{\varepsilon_t}{\phi(1)} \tag{8}$$

where $\alpha = \mu / \phi(1)$ and $\beta = \theta(1)/\phi(1)$. Estimating **(8)** by instrumental variables, using lagged level terms as instruments for contemporaneous dynamic terms, we can get estimates for the long-run parameters and their asymptotic standard-errors (Bewley (1979)). Equation **(8)** can be reformulated in error correction model (ECM) form as:

$$\Phi(L)\Delta y_t = \mu + \Theta(\mathrm{L})\Delta x_t - \gamma[y_{t-k} - \beta x_{t-k}] + \varepsilon_t \tag{9}$$

where $\gamma = \phi(1), \Phi(L) = \left[\frac{\phi(L)-\phi(1)L^k}{(1-L)}\right]$ and $\Theta(\mathrm{L}) = \left[\frac{\theta(L)-\theta(1)L^k}{(1-L)}\right]$

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(6) Bounded variables should be stationary by definition, but within a sample can appear non-stationary due to weak mean reversion or the low power of conventional unit-root tests.

(7) Monte Carlo simulations (Inder (1993), Pesaran and Shin (1999), and Pesaran, Shin and Smith (2000)) show that the ARDL-estimator performs better in small samples than the alternative Phillips-Hansen estimator (Phillips and Hansen (1990)).

From this model we could estimate the average margin over base, α, the rate of pass-through in response to a base rate change, β, and the speed of adjustment to equilibrium, γ, ie the loading coefficient.

Given that the adjustment process in equation **(9)** is linear, it cannot take into account the possibility that adjustment is variable. Yet we have already shown that adjustment might very well be non-linear due to the menu-cost argument offered by Ball and Mankiw (1994). Then the adjustment might be increased in response to some endogenous driver (such as the sign, size or change in the deviation from base) or an exogenous driver creating a non-linear adjustment process.

The empirical literature has recently shown an increasing interest in non-linear time series models to explain the adjustment of retail rates to policy controlled rates.[(8)] Scholnick (1996) allows the error correction model to reflect the asymmetry of adjustment based on the sign of the differential between official rates and deposit (lending) rates in Malaysia and Singapore. Enders and Granger (1998) use a heaviside indicator to allow for sign-based asymmetries in a threshold autoregressive (TAR) model and a momentum-TAR model to allow for asymmetric responses to changes in the differential.[(9)] Frost and Bowden (1999) summarise these alternatives as sign, size and path based non-linearities, but extend the analysis by considering *endogenous* drivers, ie the differential between the base rate and the retail rate or the error correction, and *exogenous* drivers, such as the lagged change in the base rate.

[(8)] There is also a literature that uses a qualitative dependent variable approach to rate setting. Hannan and Berger (1991) and Mester and Saunders (1995) model US deposit and prime rate changes respectively using a logit model. With this approach they could assess the effect of a change in the cost of funds and other variables on the probability of deposit/prime rate changes. Separating their samples into sub-samples, including only deposit/prime rate increases and decreases respectively, they investigated the presence of asymmetries in rate setting. Mester and Saunders (1995) find that changes in the Federal Funds rate generally triggered a larger probability of an upward response than a downward response in prime rates. Hannan and Berger (1991) find that deposit rates are significantly more rigid when the direction of the stimulus is upward. Neumark and Sharpe (1992) use a switching model of partial adjustment for US deposit rates. The model switches according to an indicator function indicating whether the bank is below or above its long-run equilibrium mark-up, assuming long-run equilibrium deposit rates to be proportional to Treasury Bill rates (we note that this runs counter to the observed behaviour of margins which preserves the mark-up in percentage points, see footnote 20 below).

[(9)] The heaviside indicator creates a switching variable from continuous data by defining a variable with a value equal to one when the continuous variable is less than some threshold value, and zero otherwise. That is $I = 1$ if $x_t < X$, where X is the threshold, and 0 otherwise.

We can address some of the non-linearities in the adjustment process by allowing the adjustment to be dependent on endogenous drivers such as the sign, size or path of the disequilibrium between the retail rate and the base rate. If we define this disequilibrium, u_{t-1} to be the deviation from long-run equilibrium in the previous period, y_t - βx_t then we can consider the response of the adjustment process to the 'gap' as measured by the cointegration residual. In particular, suppose we distinguish between positive and negative gaps so that u_{t-1}^{+} and u_{t-1}^{-} indicate whether the deviation was above or below zero, defined by the product of $u_{t-1}.1^{+}(u_t)$ and $u_{t-1}.1^{-}(u_t)$, respectively. The indicator function implies $1^{+}(u_t)=1 \Leftrightarrow u_t>0$ zero otherwise and $1^{-}(u_t)=1 \Leftrightarrow u_t<0$ zero otherwise. With this model it is possible to analyse non-linearities in the adjustment process and its possible causes. Non-linear adjustment could be the result of different adjustment speeds for residuals above and below zero. Taking $u_{t-1}^{+}=u_{t-1}$ if retail rates were above long-run equilibrium in period t-1 (ie $u_{t-1}>0$), and 0 otherwise, and $u_{t-1}^{-}=u_{t-1}$ if they were below (ie $u_{t-1}<0$), and 0 otherwise. The model then takes the form: $\Phi(L)\Delta y_t=\gamma_1 u_{t-1}+\gamma_2 u_{t-1}^{+}+\gamma_3 u_{t-1}^{-}+\Theta(L)\Delta x_t+\varepsilon_t$, which can be written in an identifiable form (using $u_{t-1}=u_{t-1}^{+}+u_{t-1}^{-}$):

$$\Phi(L)\Delta y_t=(\gamma_1+\gamma_2)u_{t-1}^{+}+(\gamma_1+\gamma_3)u_{t-1}^{-}+\Theta(L)\Delta x_t+\varepsilon_t \qquad \textbf{(10)}$$

we can test asymmetry by attempting to reject the null that $\gamma_1+\gamma_2=\gamma_1+\gamma_3$.

If we take d_t as the driver of the non-linearity then d_t^{+} and d_t^{-} represent qualitative differences in the realisation of the driver and these are derived using an indicator function based on the sign of d_t. The driving process above assumes the values $d_t^{+}=1$ and $d_t^{-}=0$, but we need not treat d_t as a simple sign-based indicator. It could be a function of the disequilibrium terms u_{t-1}^{+} and u_{t-1}^{-} or changes in these terms Δu_{t-1}^{+} and Δu_{t-1}^{-} so as to offer more complex endogenous driving processes in the model:

$$\Phi(L)\Delta y_t=\gamma_1 u_{t-1}+\gamma_2 u_{t-1}^{+}d_t^{+}+\gamma_3 u_{t-1}^{-}d_t^{+}+\gamma_4 u_{t-1}^{+}d_t^{-}+\gamma_5 u_{t-1}^{-}d_t^{-}+\Theta(L)\Delta x_t+\varepsilon_t \qquad \textbf{(11)}$$

Alternatively, we may wish to explain asymmetry with *exogenous* drivers, that is states of the world that are not summarised by the deviation from equilibrium u_{t-1}. There can be many different types of process but these could include the size of the base rate change, for example, so that the driver d_t is then defined as the change in the base rate. Now $d_t^{+}=d_t$ if $d_t>0$, and 0 otherwise, and $d_t^{-}=d_t$ if

$d_t < 0$, and 0 otherwise. So $\gamma_1 + \gamma_2$ would give the speed of adjustment if deviation from equilibrium was positive and base rates were rising, and $\gamma_1 + \gamma_3$ would measure the speed of adjustment if deviation from equilibrium was negative and base rates were rising, and so on. The basic model remains **(11)** but the driving process changes from an endogenous to an exogenous process.

The issue in this paper is to determine the extent to which changes to the retail rates follow changes in base rates and to determine how fast the adjustment process occurs. The next section reports the results from each of the estimated models **(10)** and **(11)** for four different series. These indicate the relationship between base rates and the building societies' deposit and mortgage rates (DBS, MBS) and banks' deposit and mortgage rates (DBK, MBK). We take each retail rate as our dependent variable and consider how much of the adjustment in the base rate is 'passed through' to the retail rate. The interpretation of the parameters is straightforward. The intercept determines the percentage point difference between the retail rate in question and the base rate, while the slope parameter denotes the responsiveness of the retail rates to official rate changes. An estimated value of the slope parameter equal to one would indicate complete base rate pass-through in the long run; values below unity would indicate less than full base rate pass-through. An estimated parameter value greater than one is a statistical possibility but it is difficult to interpret economically because it suggests that the retail rate more than passes through the official rate change, ie it responds by more than the official rate change *in the long run*. Overshooting in the short term is a possibility that has a sensible economic interpretation, however, since rate setters may believe that more official rate changes are 'in-the-pipeline', especially if they believe central bankers smooth rate changes.

Of particular interest is the possibility of a non-linear response to disequilibria between retail and base rates. The error-correction approach outlined above enables us to test a wide variety of hypotheses discussed in the previous section that might reasonably cause asymmetries in base rate pass-through. We use a two-step estimation procedure, where the first step estimates the long-run equilibrium, and the second step involves estimation of the non-linear error correction model, using the residuals from the first step.[10] Theory can tell us so much about the likely adjustment processes, but empirical evidence will tell us which types of drivers introduce non-linearities. We select from a

[10] The non-linear ECM can be estimated in one step using maximum likelihood, Frost and Bowden (1999) and Neumark and Sharp (1992), but non-linearities introduce highly complex likelihood functions. The two-step model has been used previously for different problems by Scholnick (1996) and Ericsson, Hendry and Prestwich (1998). The advantages of this approach are that statistical inference on the cointegrating relationship is possible in the first step and the estimation in the second step is linear throughout (it is non-linear in variables, not parameters) so that it can be estimated by OLS.

set of endogenous drivers proposed by Frost and Bowden (1999) and a set of exogenous drivers that proxy the future (expected) change in the base rate.

4 Data

In this paper all data are end-of-month and span the period 1986(1)–1999(7). The base rate series is taken from official sources (ONS code AMIH) and is the average of the four major clearing banks' base rates, which moves closely with the official rate. Very occasionally more than one rate change occurs within one month and the monthly figure then records the total increase within the month. Retail rates are unweighted averages of 90-day deposit rates on medium balances (below £10,000) and of standard variable rate mortgages for banks and building societies separately.(11) They are quoted rates from a single tier product and do not represent the whole book. They do not reflect all the information on each product since there can be substantial competition in an array of non-price inducements built into retail products offered by banks and building societies that may alter more frequently than the retail rate itself.(12) Official rate changes may be met by alterations to these non-price dimensions to the product as well as changes to retail rates and we may find that a switch from one to the other introduces non-linearities in base rate pass-through as a result. This warns us to be cautious about our interpretation of non-linearities, since the 'true' price involves both pecuniary and non-pecuniary aspects. Non-linear adjustment may imply that adjustment has occurred in the unmeasured non-price dimension to the product rather than the measured retail rate. Non-linearities detected in this paper refer simply to the extent that the pecuniary dimension to the price, ie the measured retail rate, responds to official rates, which can be informative about the extent to which providers may be concerned about 'money illusion' over the level of rates.

(11) The standard variable rate (SVR) is a term adopted by the retail banks which typically refers to the reference rate against which they describe their other mortgage products, eg a mortgage rate is offered at a discounted rate of 0.5% below SVR, returning to SVR after a given period. Across the market less than 40% of mortgage stock is at this rate, down from 50% in early 1999. Until the 1990s almost all mortgages were charged at SVR, but following the increase in mortgage rates to 15 percentage points in 1989 and the experience of Black Wednesday, an increasing proportion of mortgage products have fixed rates.

(12) These are discussed by Gallagher and Milne (1997) in relation to UK mortgage margins and include cashbacks (cash payments to eligible new borrowers), interest rate discounts, free home and contents insurance. They are thought to have had an active role in the re-mortgage market in the past few years. Their calculations suggested that 'cashbacks would have reduced spreads by between 9 and 13 basis points' (page 39), but these would not have substantially altered the modest reduction in retail rates offered by building societies. Deposit rates have also been influenced by the provision of new services such as cashback, switch facilities, and telephone banking that augment the competitiveness of a retail product on non-price grounds.

Bank data are quoted rates for the clearing banks taken from published sources by the Monetary and Financial Statistics Division of the Bank of England (series codes CBTA and CBMG) and the building society rates are Building Society Commission data reported by the ONS (series codes AJNV and AJNL). Weighted series are composed of the reporters' own weighted averages of rates on their overall residential loan book (constructed using annual institutional reports, monthly flows data on market share or end-of-month mortgage business outstanding as weights). These were little different from the unweighted series over the period of the sample for which they exist. These data only exist for the period 1995(1)–1999(7) so if we had decided to use weighted rates we would have needed to splice the unweighted series to the weighted series to extend the sample backwards beyond 1995(1).[13]

Comparing bank and building society deposit rates in Chart 1 we find building society rates are generally above bank deposit rates when the rate is falling and *vice versa*. This is picked up later in the difference between the intercepts on these products in the long run (ie average spreads over base). After 1992 a noticeable divergence in rates emerged with building society deposit rates always above bank rates. One potential explanation for this observation is that the building societies were demutualising in the mid-to-late 1990s, Ryan (1997). The effect on the unweighted deposit and mortgage rate series as the larger societies became banks was to increase the representation of the smaller building societies. These smaller societies may have had a greater incentive to offer more favourable deposit and mortgage rates in order to attract business because they were less able, with fewer branches and products, to offer non-price inducements to attract customers. There is some evidence to suggest that, at low nominal rates of interest in a low-inflation environment, building societies were less inclined to pass on lower rates to depositors than banks, Ryan (1997).[14] This may reflect in part the greater dependence of building societies on deposits relative to banks, which are subject to less regulation over their access to wholesale money markets, and the greater sensitivity of deposit holders to rate reductions when nominal rates are low, due to 'money illusion'.

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(13) We also considered using individual bank and building society data on single tier products, but our investigations revealed that changes to product characteristics meant that consistent series in reasonable runs without breaks were not available. Time series methods could only be employed on unweighted averaged data.

(14) During the period of base rate cuts in late 1998, banks did not cut their mortgage rates because they argued they had a duty to protect rates offered on deposit accounts. The argument implied that spreads were maintained to allow cross subsidy of savings rates.

The data on bank and building society mortgage rates show the reverse. Again building societies on average were less inclined to pass on rate rises to their borrowers and almost always had *lower* rates than banks. That difference is more noticeable when rates were rising, since building societies tended to lag behind the banks in passing rate changes through, but when rates were falling the two rates were almost identical. There was a divergence between the rates after mid-1993, when the first plateau and base rate rise occurred under the inflation-targeting framework, and thereafter the rates remained apart by at least half a percentage point, although there remains a very strong positive association between the rates. The correlation between bank and building society mortgage rates is 0.99 for the full sample but it falls to 0.88 for the period 1992–99. We do not think that demutualisation is the factor entirely responsible for the deterioration in this relationship as the bulk of conversions were announced from 1994 and took place between a year to 18 months later. Further examination of the data shows that the reduction in base rate pass-through by building societies in the inflation-targeting period may be partly responsible for the deterioration between correlation of mortgage rates and base rates (as the correlation between building society mortgage rates and official rates falls from 0.96 for the full sample to 0.45). Mortgage rates for banks and building societies are highly correlated: the coefficient is 0.99 (whole sample) and 0.96 (1992-99).(15)

Retail rates were generally less volatile than official rates, confirming that the rates are smoothed in accordance with the principle of menu cost minimisation and the anticipation of turning points. For all but the bank deposit rates (for which there is a considerable outlier in the early sample) the standard deviation for the sample is 3.15 for base rates, 3.25 and 3.03 for bank and building society deposit rates, and 2.64 and 2.80 for bank and building society mortgage rates.(16)

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(15) The reduced correlation for building societies could be due to a number of other factors including a) the fact that the weighted average is dominated by the larger building societies and during the period 1994-97 many of these were converting; b) at much the same time it was recognised that building societies were less competitive than banks; c) the weighted rates include a growing proportion of fixed-rate lending, the weighted fixed rate of which would tend to be indifferent to changes in variable rates, only changing as a result of the mix of loans maturing at old rates and taken on at new rates combined to give a change in weighted fixed rates; and d) the fact that discounted loans took off during the mid to late 1990s, and would tend to have reduced the weighted rate at a time when SVRs were not themselves changing. Also it may not contrast with the pre-inflation targeting period but may just reflect the relative stability of interest rates over the later period and the discrete change in building society pricing policy as they narrowed their spreads.

(16) One reason for the greater volatility in the bank deposit rate may be the dependence of banks on the wholesale market for funds – they are less reliant than building societies on their deposit base – since the wholesale market accounts for more than 50% of bank liabilities as opposed to less than 20% for building societies. Gallager and Milne attribute this as the principal cause of greater year-on-year variation in the margin of mortgage to deposit rates offered by banks.

5 Empirical results

5.1 Cointegration and weak exogeneity

Table A reports the results of preliminary unit root tests, indicating non-stationarity cannot be rejected using augmented Dickey-Fuller and Phillips-Perron tests. Table B reports the results of the Johansen cointegration test. In the underlying VARs the constant was restricted to lie in the cointegration space, thus assuming that there is no deterministic trend in interest rates. The lag order was determined based on the Schwarz-Bayes information criterion, which suggests a lag order of two for banks' deposit and mortgage rates and a lag order of three for the building societies' retail rates. Centred impulse dummies had to be included in the VAR in order to eliminate heteroskedasticity.[(17)] Recursive Chow-breakpoints tests, Chart 2, do not reveal significant instability problems in the underlying VARs, with the possible exception of the bank deposit series at the end of the sample. The test statistics in Table B imply that the null of no cointegration can be rejected in all four cases. We tested in each case the hypothesis that the long-run pass-through is complete, ie that the long-run coefficient on base rates is equal to one. This hypothesis was only rejected for banks' mortgage rates and was thus imposed in all other cases.

Calculations based on the t-statistics of the loading coefficients establish that the base rate is weakly exogenous in all cases, since the adjustment coefficient of the base rate to the long-run equilibrium relationship, α_2, reported in Table B, is always insignificant. As previous authors have shown (see Johansen (1995) and Boswijk (1995)), if a variable is weakly exogenous, then the marginal process excludes the long-run relationship and any conditional model of the remaining endogenous variables is sufficient to recover information about the parameters of interest. Johansen's test of the weak-exogeneity proposition is used to confirm the validity of this partition, so that neglect of the marginal model for the base rate does not result a loss of information. Previous work has often taken it for granted that the base rate is exogenous and that retail rates are endogenous variables: we have shown that this is the case using empirical tests.

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(17) Centred impulse dummies do not affect the asymptotic distribution of the test statistics, so that the standard critical values are valid. The dummies included control for large outliers which can be explained by the ERM crisis in 1992/93 and a change in the composite tax rate in 1986. The outlier in 1988(8) was caused by a large jump in the base rate. Despite the inclusion of these dummies the null of normality is still rejected at the 1% level in each case. But that does not invalidate our test results, since the Johansen procedure does not strictly depend on the normality assumption (Lütkepohl (1991)).

We also estimate the long-run coefficients based on the more robust ARDL-model and re-assess cointegration by looking at the unit root test statistic of the long-run residuals (using a standard Phillips-Perron unit root test) and the t-statistics of the error-correction coefficient. The lag order of the ARDL-model was selected based on the Schwarz-Bayes information criterion, allowing lag lengths to differ between the variables; the maximum lag length considered was 12. The estimates obtained from the Johansen procedure are very close to the ARDL-estimates, and the hypothesis that the intercepts and slopes are identical cannot be rejected by the data.[18] The final row shows the Phillips-Perron test statistic (including a constant and with a lag truncation of four) of a unit root test on the long-run residual, ie the difference between the retail rate and its long-run equilibrium level as estimated by the ARDL-model. All test statistics are well above the MacKinnon (1991) 5% critical value (-3.37), so that we can reject the null of no cointegration in all four cases.

Cointegration can also be tested by examining the t-statistic of the error correction coefficient. Kremers, Ericsson and Dolado (1992) show that the distribution of this t-statistic lies somewhere between standard normal and Dickey-Fuller. In the first row of Table C we can see that the (heteroskedasticity robust) t-statistics of the error correction coefficients are all above the MacKinnon 5% critical value (-3.37), so that we can again reject the null of no cointegration in all four cases.

5.2 Linear error correction models

Having established cointegration we can turn to the analysis of the error correction models. The linear model can be estimated in a single step using non-linear least squares (NLLS) or in two steps using the ARDL approach. We report the NLLS-estimates of the long-run coefficients in Table C but the estimates are identical with those obtained under ARDL. In all error correction models estimated we included dynamic terms in accordance with the lag-length chosen in the ARDL-model. In order to get heteroskedasticity robust t-statistics we used Newey-West standard errors throughout. The consistency of the estimates of the margins compared to the previous estimates of the long-run

[18] The Phillips-Hansen estimator (Phillips and Hansen (1990)) and the two-step estimator proposed by Inder (1993) also gave results very close to the ones obtained from the ARDL-model, therefore, we can conclude that our estimates of the long-run parameters are robust with respect to the estimation method.

elasticities is encouraging and supportive of the theoretical model, which implies that banks and building societies attempt to preserve their margins subject to menu costs.[19]

The adjustment speeds in the unrestricted error correction models, reported in Table C, imply about 14% (12%) adjustment to disequilibria per month in deposit rates for building societies (banks) and 14% (16%) adjustment to disequilibria per month in mortgage rates.[20] These adjustment speeds are quite slow, but the speeds of adjustment increase somewhat in response to certain triggers of non-linear adjustment, as predicted by the theory. Recursive Chow-breakpoint tests reported in Chart 3 show that the linear ECMs are stable over the sample period.

We can now simulate the response of UK retail rates to a permanent 100 basis points increase in the base rate using the estimated linear model.[21] The impulse responses are displayed in Chart 4. For both deposit and mortgage rates the response of the building societies' rates is clearly slower than the response of the banks' rates. Thus, despite the institutional changes in the early 1980s, it seems that banks and building societies respond to deviations of their retail rates from the desired mark-up over base in different ways.

The limitations of the linear models are revealed by these impulse responses. The adjustment speeds are relatively slow compared to what we might expect from institutional evidence and suggest that rate changes are passed through rather sluggishly. This is because the linear approach ignores an important issue raised in Section 2. If there are costs of adjustment then the banking firm will not respond linearly, rather it will take steps to make adjustment at different rates according to the signals

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(19) Interestingly, the margins on deposits and mortgages *as a percentage of the base rate* are countercyclical with the base rate itself. This suggests that it is the percentage point margin that banks and building societies preserve not the percentage relative to the base rate; this policy generates the rise in the percentage margin as base rates fall and *vice versa*. As banks and building societies care about the real margin, it seems logical that the margin is additive rather than multiplicative.

(20) At all points in the following discussion the term 'disequilibrium' is shorthand for the phrase 'deviation of the actual retail rate from that which is consistent with average spread over the level of the base rate in the full sample'. It does not refer to an equilibrium retail rate implied by a model in which the base rate is at its 'neutral or equilibrium level', so there is no sense of having to buy the model before accepting the concept of disequilibrium. We are simply using this phrase to refer to the relation between the current retail rate and the average spread over the level of base rates observed over the full sample.

(21) It has been correctly pointed out by Peter Andrews that a permanent change in the base rate of this kind is liable to raise questions about whether the model itself had changed and raise the issue of the Lucas critique. Our interest in a large permanent shock is to examine the effects of bank and building society behaviour without the response being curtailed by a) the temporary nature, or b) the small size, of the shock.

it receives about the future expected direction of base rates. This may entail non-adjustment for a number of periods followed by rapid closure of disequilibrium. As we have already shown, the linear approximation to this adjustment pattern tends to give an implausibly slow adjustment speed because it averages the response under non-adjustment and adjustment.[22] The next section estimates the econometric model that takes non-linearity into account to avoid this problem.

5.3 Non-linear error correction models with endogenous drivers

We now consider the responsiveness of retail rates when there are asymmetries and non-linearities due to endogenous and exogenous driving processes. All of our results refer to non-linearities in the adjustment process, γ.[23] Taking the endogenous drivers first, we considered three models: (a) equation **(10)** where $d_t^+ = 1, d_t^- = 0$, ie for which the adjustment is *sign* dependent; (b) *state* dependence where $d_t^+ = u_{t-1}^+, d_t^- = u_{t-1}^-$; and (c) equation **(11)** where $d_t^+ = \Delta u_{t-1}^+, d_t^- = \Delta u_{t-1}^-$ so that the model adjustment is *path* dependent. The results are reported in Table D using an ARDL estimator.[24]

The first column of model (a) reports the estimated coefficient for the net combination of the symmetric and positive residual coefficients and the second column reports the equivalent for negative values. The absolute size of the coefficient indicates the responsiveness to positive (negative) disequilibrium. If the size is identical the model is symmetric. The point estimates of the coefficients imply that coefficients are different in size but a likelihood ratio test in column three cannot reject the null that the coefficients are equal on each of the positive and negative disequilibrium terms. This implies that sign is not a significant cause of non-linearity. We note that

(22) We note that there is also a theoretical inconsistency between linear ECMs and the menu cost model that we have used to motivate our study. A linear model with its assumption of convex costs of adjustment is unable to capture the occasional step changes in rates, but a non-linear model has no such difficulty.
(23) We introduced non-linearities into the short-run dynamics both before and after allowing for non-linearities in γ, but the results were not influential.
(24) We recognise that asymmetry may bias the estimates of the long-run intercept when two-step estimators are employed (Holly *et al* (1999)), we therefore re-estimated our non-linear models using NLLS. Our results showed no evidence of a bias, but in some cases we failed to find convergence so we have reported the ARDL estimates in Table D.

if the positive and negative values occur with equal frequency then we recover the average adjustment rate estimated under the linear model.

Our second model (b) implies that the speed of adjustment depends on *both* the size *and* the sign of the disequilibrium term, because the bigger the disequilibrium, the more costly it becomes to fail to adjust rates. The symmetric adjustment term is never significant in the model, but we do find significant coefficients on the squared positive and negative disequilibria. When the disequilibrium term is positive, the coefficient is reported in column two and implies faster adjustment to equilibrium. When the disequilibrium is negative the coefficient is reported in column five, and here faster adjustment is also indicated in this case by a positive sign. Our results show that all the coefficients imply faster adjustment, but there is still no systematic evidence for asymmetry in response to positive and negative disequilibria. The null of symmetry is not rejected by a likelihood ratio test (distributed $\chi^2(1)$) in three out of four cases, but the test does reject in one case. The mortgage rate for banks rejects the notion that adjustment to positive disequilibria is equal to the adjustment for negative equilibria. This implies banks were prepared to adjust rates more quickly when the mortgage rate was above the base rate than when the rate was below the base rate. This is consistent with the fact that the banks were actively entering the mortgage market in the early part of our sample and at the time may have priced their products more competitively in order to gain business.

Model (c) is derived from equation **(11)**, the columns show how retail rates are adjusted (in relation to the symmetric case given in column one) when the disequilibrium is positive and increasing, negative but decreasing, positive but decreasing, and finally negative and increasing. The first and fourth cases indicate that there is a widening gap between retail and base rates, the second and third cases show a disequilibrium that is moving in the ‘right direction’, ie narrowing. We would expect that when the gap is growing (ie moving in the ‘wrong direction’), there would be a move to ensure stabilising (ie gap narrowing) adjustment to the retail rates following our model above.

Our results are negative in this case. For two products offered by building societies, there is no evidence of path dependence since all the coefficients are insignificant. For banks the results are not much better. While in one case for bank deposits, the rate is reduced at a faster rate when the gap between the retail rate and its desired value is negative and widening, in another (bank mortgages) they do the reverse. The model implies that there is not much evidence in favour of a path dependent non-linearity in either bank or building society rates.

5.4 Non-linear error correction models with exogenous drivers

The remaining results reported in Table E are for exogenous drivers. These imply that the process generating the non-linearity are exogenous factors to the model that help explain the future evolution of base rates. Our theoretical model implies that expected future changes to the base rate should be important determinants of the speed of equilibrium adjustment. We consider several measures including the current change in base rates, the moving average expectation of future changes to base rates and expected inflation measured by the yield spreads. The results we report are consistent with faster adjustment to widening gaps and slower adjustment to narrowing gaps as predicted by the theory.

A. Actual changes to base rates

Model (d) takes the driver to be the actual change in the base rate, which we then split into increases and decreases and multiply each by the positive and negative disequilibrium term lagged one period, using equation **(11)**. The first term is interpreted as the underlying adjustment to a disequilibrium if the model is symmetric. The second (third) term indicates the non-linearity when the disequilibrium is positive but the base rate is rising (falling) and therefore narrowing (widening) the gap. The fourth (fifth) term indicates the case for negative disequilibria with a base rate that is rising (falling) and therefore widening (narrowing) the gap. We would expect non-linearities to induce faster adjustment when there is a gap that is widening and this is what we find. When interpreting our results we have to take care to ensure that we have the correct sign before we sum the coefficients.

In three cases when the gap is narrowing (columns 2 and 5) we find that the hypothesis that the banks and building societies will tend to respond (if at all) to convergence by slowing adjustment down is confirmed. There is a reduction in the adjustment speed indicated by a positive sign in column 2 and a negative sign in column 5, both of which reduce the prevailing speed of adjustment (which is negative in the first case and positive in the second). There are no cases where the adjustment speed increases when the gap narrows.

Equally, there are three cases where the widening gap leads to faster adjustment (in columns 3 and 4). The faster adjustment speed is shown by the negative sign in column 3 on both bank and building society mortgage rates, and by a positive sign in column 4. These coefficients augment the prevailing adjustment making it faster to converge on the equilibrium. There is one marginally significant case where the sign is positive when it is predicted to be negative in the case of building society mortgage rates. The results imply that both the banks and building society mortgage rates tend to adjust more quickly when the rates are below their desired levels and base rates are changing to widen the gap.

Given that the argument in our theoretical model depends on the future direction of base rates it is important to consider the expected change rather than actual current change in the base rate.

B. Measures of future expected changes to base rates

It might be a realistic assumption that expectations are partly backward and partly forward looking. Therefore we constructed a measure of expected base rate changes by calculating a centred moving average including three leads and three lags of the change in the base rate. This includes the past history and the future evolution of the base rate, and may capture the effects of smoothing if base rate changes are introduced with a sequence of small rate changes.[25]

The results in Table E (e) show all rates are adjusted more quickly when the retail rates are below their normal margin over base and the expected base rate change is positive; likewise, when rates are above the base and base rates are expected to fall, adjustment is more rapid. As the gap narrows, adjustment slows in the case of building societies' mortgage rates but otherwise it remains the same as the symmetric case. Just as with the actual change in the base rate we find support for our theoretical prediction that rates will respond to widening gaps by increasing the speed of adjustment, because all the signs are consistent with more rapid adjustment.

[25] Although this involves assumptions about the lag length, and symmetry of response to future and past rates, we use it as a convenient measure to summarise forward and backward-looking behaviour in expectations formation. The alternatives based on the forward rates from gilt contracts are only available on a reliable basis from 1997 since the gilt repo market started in 1996. Although there was a Treasury bill market before that it has never been considered sensible to try to splice Treasury bill rates on to gilt yields because the market was thin and distorted by institutional factors (the special role of Treasury bills in the Bank's open market operations). None of these alternatives seem to offer superior proxies for our expected base rate series for the sample we use in this paper.

According to the expectations theory of the term structure, the yield spread (ie the spread of the n-period nominal interest rate over the base rate) provides a measure of expected changes in the inflation rate. Given that central banks care about inflation, expected changes in the inflation rate could be an indicator for expected changes in the base rate. A market measure of expected inflation from surveys of market expectations or the yield spread could indicate that inflation is expected in the future (Mishkin (1990a, 1990b, 1991)). If so, the yields on longer-maturity assets will reflect this in their rates and yield spreads will widen.[26] This will be an indication that markets expect higher base rates in the future.[27] Thus measures of expected inflation can herald expected changes to base rates and could indicate that the gap between retail and base rates are likely to widen (narrow), which would then determine whether retail rates should adjust more quickly (slowly).[28]

We tried several yield spreads, from very short (three months) to very long (ten years) but report the results for the horizon that gave the best fit and lowest equation standard error (the horizon is reported in months by the lead, k). Results reported in Table E (f), are consistent with our previous result indicating that – when the gap is narrowing, retail rates adjust marginally more slowly, and when the gap is widening, adjustment is more rapid. In one case (building society deposit rates) there was no evidence for any non-linearity driven by the yield spread at any horizon, but for the other three cases the results were consistent with the theoretical predictions. When the retail rate is above the desired level so that the gap is positive and the base rate is falling, the rate of adjustment increases in two cases to close the gap. Banks adjust their deposit rates more quickly in these circumstances while building societies do not adjust any faster. When the building society mortgage rate exceeds its desired value and rates are falling, they respond by reducing rates more quickly.

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(26) Although with credible inflation (forecast) targeting the market may take the view that inflation and interest rates will return to normal in the long run.

(27) We recognise that our statements in this paragraph imply a narrow view of the expectations theory of the term-structure of interest rates since we assume forecasts of short-term rates are stationary, and do not contain risk premia. We also assume that the movements in the yield spread reflect expectations of future inflation rather than the business cycle and expectations of policy changes.

(28) While we use the spread between the three-month LIBOR and base rate, there are many other available measures of expected inflation. Two measures of expected inflation up to one year ahead indicate market expectation of future changes to official rates in the next twelve months. These can be derived from i) the Gallup survey on expected inflation; and ii) expected inflation measured over one year by the difference between real and nominal gilt yield curves. Each has its drawbacks as a measure of expected inflation. The first series is too smooth and lags behind the actual rate. The latter is difficult to implement in practice because the Svensson yield curves, Svensson (1994, 1995), constructed as an extrapolated curve over the whole maturity spectrum, rely on data for real and nominal gilt curves that are often patchy. At the short end of the spectrum this can be a particular problem due to the small number of gilts traded and the curvature of the yield curve. The spline-based method of Waggoner (1997) might be a solution – but again this can only be calculated for regions where the data exist – and thus it suffers from the same basic problem as the Svensson curves.

It appears that the actual or expected path of future base rates is the most important determinant of the speed of base rate pass-through. Retail rate setters appear to observe the likely future direction of change in base rates over the next twelve months before implementing changes to their own rates. The values of individual coefficients are of some interest, but the more important finding is that the pattern of responses is consistently supportive of the theory. Banks and building societies respond more aggressively to widening gaps but more passively to narrowing gaps.

Other potential exogenous drivers appeared less successful. Three different measures of market competition yielded little non-linearity in adjustment speeds. First, the existence of a differential between banks and building societies on rates for an equivalent product, for example, had negligible effect on adjustment speeds.[29] Second, the spread between the mortgage and the deposit rate, used as a proxy for the margins that banks and building societies might earn on their retail products, was not a significant driver of non-linearity either. Finally, the state of demand in the housing market measured by the deviation of the house price from trend, did not influence the speed of base rate pass-through for mortgage rates set by banks and building societies.[30] The fact that we were unable to find an impact from market conditions on retail rate adjustment may reflect the fact that the retail rates are average quoted rates for each group and do not fully reflect the competitive discounts and non-price inducements attached to deposit and mortgage products.

One exception to this rule was the level of uncertainty measured by the standard deviation of the constant horizon interest rate distribution at a three-month horizon, Table E (g). In all cases the results show that the behaviour of banks and building societies slows adjustment down relative to the symmetric case as the standard deviations increase. The implication is that increased uncertainty leaves retail rate setters without a signal to follow, which slows adjustment down.

6 Conclusions

It is a well-known feature of monetary policy operations that authorities aim to exercise control over short interest rates by adjusting the official rate, and that it is commonly assumed that there is

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(29) Comparing the monthly flows and amounts outstanding for building societies month by month does not suggest that differentials have an impact on quantities either. The data are reported in Table B2.1 of *Monetary and Financial Statistics* (see web site http://www.bankofengland.co.uk/mfsd/ms/010301/index.htm).
(30) The trend was extracted by fitting a Hodrick-Prescott filter, leaving the cyclical component.

complete transmission to short rates within a short period of time. With complete pass-through, monetary policy can be more efficient in its ability to control inflation, although incomplete pass-through can still be effective if it is predictable.(31) Empirical models of base rate pass-through have previously tested pass-through using linear or asymmetric adjustment processes. This paper has attempted to get to grips with a wider range of potential non-linearities in adjustment of retail rates to base rates arising from menu cost models.

The initial estimates of the relationship between the level of each retail rate by type of institution reveals complete pass-through to be the norm in the long run for deposit rates, but not for the mortgage rate. The non-linear forms of adjustment around these equilibria are consistent with menu cost models and may be of greater significance at low rates of interest and inflation. Endogenous and exogenous non-linearities increase the adjustment speeds of retail rates to base rates quite dramatically when the 'gap' between the retail rate and the base rate is widening but slow down the adjustment when base rates are moving in a direction that will 'automatically' close the gap. Drivers that were significant included the actual or expected change in the base rate, the yield spread for three to six-month horizons, and the standard deviation from constant interest rate pdfs (uncertainty about the future direction of base rates). Adjustment was unaffected by indicators of market competition, such as differentials between rates on similar products between banks and building societies, differentials between mortgage and deposit interest rates as a measure of margins, or activity in the housing market.

We conclude that the main driver of base rate pass-through is the change, or expected change, to the official instrument when the gap between the base and retail rates is growing in absolute size. Both banks and building societies move significantly faster to close 'growing gaps' and although the response is quantitatively different for each retail product and for banks versus building societies, the direction of change is the same.

(31) The effectiveness of monetary policy will depend on the real effects of real short rates, not just the degree of pass-through. It will also operate through many channels. The pass-through from the repo rate to retail rates is not the only channel by which monetary policy can operate, and therefore the point being made here is that the degree of effectiveness of monetary policy is influenced through the retail rate channel.

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Table A: Unit root test statistics

	Base rate	Banks' deposit rate (DBK)	Building societies' deposit rate (DBS)	Banks' mortgage rate (MBK)	Building societies' mortgage rate (MBS)
ADF	-1.23	-1.15	-1.04	-1.25	-1.07
PP	-0.98	-1.05	-0.87	-0.88	-0.76

Note: ADF is an augmented Dickey-Fuller test statistic based on a test regression including a constant and six lagged dynamic terms. PP is a Phillips-Perron test statistic based on a test regression including a constant and with a lag truncation of six. The 10%, 5% and 1% critical values are -2.58, -2.89, -3.47 respectively.

Table B: Cointegration tests

	Banks' deposit rates	Building societies' deposit rate	Banks' mortgage rate	Building societies' mortgage rate
Rank r = 0 r ≤ 1	λ_{MAX} λ_{TRACE} 14.00 20.45 6.45 6.45	λ_{MAX} λ_{TRACE} 15.14 20.93 5.79 5.79	λ_{MAX} λ_{TRACE} 25.79 30.20 4.41 4.41	λ_{MAX} λ_{TRACE} 14.92 20.85 5.92 5.92
Long-run relation	DBK = -1.141 + BASE (0.13) Coefficient test $\beta_1 = 1$: $\chi^2(1)$ = 0.524 (0.50)	DBS = -0.865 + BASE (0.17) Coefficient test $\beta_1 = 1$: $\chi^2(1)$ = 1.016 (0.31)	MBK = 2.515 + 0.863BASE (0.28) (0.03) Coefficient test $\beta_1 = 1$: $\chi^2(1)$ = 10.288 (0.00)	MBS = 0.901 + BASE (0.20) Coefficient test $\beta_1 = 1$: $\chi^2(1)$ = 2.245 (0.13)
Loading coefficients	α_1, α_2 = -0.154, -0.029 (-2.84) (-0.47)	α_1, α_2 = -0.120, 0.000 (-3.69) (0.00)	α_1, α_2 = -0.157, 0.043 (-4.63) (0.69)	α_1, α_2 = -0.082, 0.026 (-3.32) (0.63)
Diagnostics	LM 1 = 9.373 (0.05) LM 12 = 6.420 (0.17) H = 39.355 (0.45) JB = 298.102 (0.00)	LM 1 = 6.51 (0.16) LM 12 = 1.46 (0.83) H = 63.21 (0.18) JB = 300.69 (0.00)	LM 1 = 2.50 (0.65) LM 12 = 1.24 (0.87) H = 38.07 (0.51) JB = 282.61 (0.00)	LM 1 = 6.51 (0.16) LM 12 = 1.46 (0.83) H = 63.21 (0.18) JB = 300.69 (0.00)
ARDL results	DBK = -1.280 + 1.016BASE (-0.34) (0.04)	DBS = -0.630 + 0.974BASE (0.54) (0.05)	MBK = 2.536 + 0.854BASE (0.33) (0.03)	MBS = 1.507 1 + 0.922BASE (0.68) (0.07)
Phillips-Perron unit root tests	-4.600	-5.180	-4.400	-4.770

Notes: The variables *DBK* and *MBK* are the bank deposit and mortgage rate respectively; *DBS* and *MBS* are the building society deposit and mortgage rates; BASE is the base rate. The 5% and 10% critical values are 14.88 and 12.98 (r=0) and 8.07 and 6.50 (r<=1) for the λ_{max} statistic, and 17.86 and 15.75 (r=0) and 8.07 and 6.50 (r<=1) for the λ_{trace} statistic, restricted intercepts. LM1 and LM12 are Lagrange-Multiplier tests for serial correlation of order one and up to order twelve respectively. H is White's test for heteroskedasticity and JB is a Jarque-Bera test for normality. All tests refer to the system as a whole. In brackets we show standard errors for the long-run parameters, *t*-statistics for the loading coefficients and probability values for the coefficient test and the diagnostic tests.

Table C: Linear error-correction models

Results from a one-step estimator (NLLS)

Banks’ deposit rates $\Delta DBK_t = \underset{(-3.65)}{-0.141}[DBK_{t-1} + \underset{(-8.28)}{1.076} - BASE_{t-1}]$ $+\underset{(13.79)}{0.651}\Delta BASE_t + \underset{(5.18)}{0.190}\Delta BASE_{t-1}$ Coefficient test $\beta_1 = 1: \chi^2(1) = 1.626$ (0.204) Dummies: 88:8 88:11 92:10 $\bar{R}^2 = 0.65$ JB=174.1 (0.00) DW=2.09 LM12=9.27 (0.68) ARCH1=0.18 (0.67) ARCH12=3.91 (0.98)	Building societies’ deposit rates $\Delta DBS_t = \underset{(-4.18)}{-0.123}[DBS_{t-1} + \underset{(-5.33)}{0.883} - BASE_{t-1}]$ $+\underset{(3.24)}{0.165}\Delta BASE_t + \underset{(4.21)}{0.19}\Delta BASE_{t-1}$ Coefficient test $\beta_1 = 1: \chi^2(1) = 0.043$ (0.84) Dummies: 85:4 86:4 86:6 88:8 $\bar{R}^2 = 0.51$ JB=173.11 (0.00) DW=2.04 LM12=16.95 (0.15) ARCH1=2.11 ARCH12=9.33 (0.67)
Banks’ deposit rates $\Delta MBK_t = \underset{(-3.67)}{-0.143}[MBK_{t-1} \underset{(7.01)}{-2.527} \underset{(23.23)}{-0.86}BASE_{t-1}]$ $+\underset{(5.69)}{0.226}\Delta BASE_t + \underset{(6.07)}{0.241}\Delta BASE_{t-1}$ $+\underset{(2.47)}{0.082}\Delta BASE_{t-2} + \underset{(1.60)}{0.05}\Delta BASE_{t-3}$ Coefficient test $\beta_1 = 1: \chi^2(1) = 14.408$ (0.00) $\bar{R}^2 = 0.58$ JB=179.89 (0.00) DW=1.90 LM12=4.90 (0.96) ARCH1=0.11 (0.74) ARCH12=6.30 (0.90)	Building societies’ deposit rates $\Delta MBS_t = \underset{(-5.74)}{-0.171}[MBS_{t-1} \underset{(3.96)}{-1.531} \underset{(23.66)}{-0.93}BASE_{t-1}]$ $+\underset{(2.68)}{0.133}\Delta BASE_t + \underset{(3.02)}{0.136}\Delta BASE_{t-1}$ Coefficient test $\beta_1 = 1: \chi^2(1) = 2.99$ (0.08) $\bar{R}^2 = 0.37$ JB=177.27 (0.00) DW=2.09 LM12=20.37 (0.06) ARCH1=0.51 (0.48) ARCH12=17.28 (0.14)

Note: The table shows the results obtained from estimating equation **(7)**. The variables *DBK* and *MBK* are the bank deposit and mortgage rate respectively; *DBS* and *MBS* are the building society deposit and mortgage rates; BASE is the base rate. DW is the Durbin-Watson statistic, LM12 is a Lagrange-Multiplier test for serial correlation up to order 12, ARCH1 and ARCH12 are tests for autoregressive conditional heteroskedasticity of order one and up to order twelve respectively. JB is a Jarque-Bera test for normality.

Table D: Non-linear ECMs: endogenous drivers

Endogenous drivers								
(a)Sign dependence	$\hat{\gamma}_1+\hat{\gamma}_2$	$\hat{\gamma}_1+\hat{\gamma}_3$	LR test~$\chi(1)$ H_0: $\gamma_2=\gamma_3$		σ	R^2	SC ~$\chi^2(12)$	ARCH ~$\chi^2(12)$
DBK	-0.133	-0.150	0.027		0.241	0.65	9.21	2.88
	(-2.595)	(-2.679)					[0.69]	[0.99]
DBS	-0.142	-0.095	0.915		0.283	0.43	17.29	9.69
	(-3.822)	(-2.337)					[0.14]	[0.65]
MBK	-0.171	-0.114	1.080		0.197	0.63	4.91	6.75
	(-3.529)	(-2.433)					[0.96]	[0.87]
MBS	-0.178	-0.161	0.120		0.236	0.51	20.37	17.16
	(-4.805)	(-4.142)					[0.06]	[0.14]
(b)State dependence	$\hat{\gamma}_1$	$\hat{\gamma}_2$	LR test~$\chi(1)$ H_0: $\gamma_2=\gamma_5$	$\hat{\gamma}_5$	σ	R^2	SC ~$\chi^2(12)$	ARCH ~$\chi^2(12)$
DBK	n.s.	-0.183	0.282	0.233	0.241	0.648	8.32	3.08
		(-2.800)		(3.110)			[0.76]	[0.99]
DBS	n.s.	-0.124	1.620	0.082	0.280	0.440	14.54	7.50
		(-5.085)		(2.814)			[0.27]	[0.82]
MBK	n.s.	-0.216	7.272	0.071	0.192	0.649	6.70	7.90
		(-3.797)		(1.839)			[0.88]	[0.79]
MBS	n.s.	-0.176	0.104	0.160	0.232	0.527	19.86	15.62
		(-6.240)		(5.214)			[0.07]	[0.21]

(c)Path dependence	$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$	$\hat{\gamma}_4$	$\hat{\gamma}_5$	σ	R^2	SC ~$\chi^2(12)$	ARCH ~$\chi^2(12)$
Gap	-	W	N	N	W				
DBK	-0.108	n.s.	n.s.	n.s.	0.323	0.231	0.680	7.39	2.44
	(-2.727)				(2.588)			[0.83]	[0.99]
MBK	-0.163	n.s.	0.300	n.s.	-0.202	0.205	0.584	8.21	7.80
	(-4.258)		(1.937)		(-1.805)			[0.77]	[0.80]

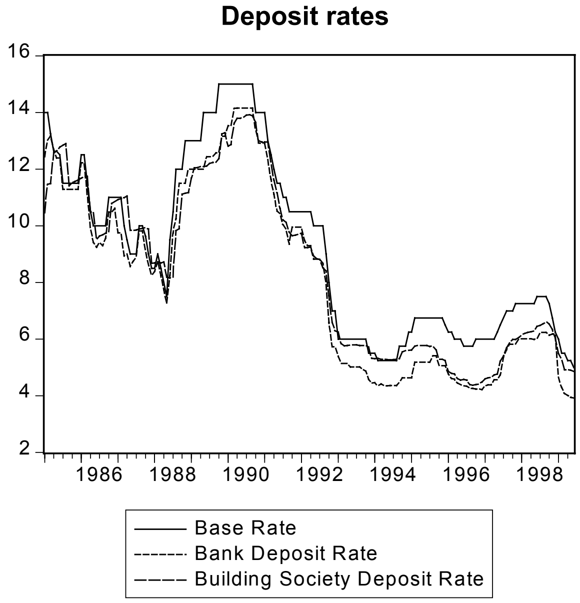
Notes: The variables *DBK* and *MBK* are the bank deposit and mortgage rate respectively; *DBS* and *MBS* are the building society deposit and mortgage rates; BASE is the base rate. n.s. indicates variable has been dropped due to insignificance. t-statistics in parentheses based on Newey-West standard errors. SC is a chi-squared test for serial correlation up to order twelve, ARCH is a chi-squared test for up to twelfth order autoregressive conditional heteroskedasticity [p values in brackets].

Table E: Non-linear ECMs: exogenous drivers

Gap	-	N	W	W	N				
(d) Change in base rate	$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$	$\hat{\gamma}_4$	$\hat{\gamma}_5$	σ	R^2	SC $\sim\chi^2(12)$	ARCH $\sim\chi^2(12)$
DBK	-0.139	0.547	n.s.	0.644	-0.917	0.225	0.701	10.00	4.17
	(-3.272)	(3.464)		(3.663)	(-2.135)			[0.62]	[0.98]
DBS	-0.128	n.s.	0.397	n.s.	n.s.	0.257	0.539	14.54	8.50
	(-4.360)		(1.856)					[0.27]	[0.74]
MBK	-0.142	n.s.	-0.218	-0.369	n.s.	0.206	0.613	4.91	9.09
	(-3.649)		(-2.194)	(-1.889)				[0.96]	[0.69]
MBS	-0.155	n.s.	-0.345	n.s.	n.s.	0.257	0.413	17.70	8.24
	(-5.462)		(-3.054)					[0.13]	[0.77]
(e) Expected change in base (centered MA)	$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$	$\hat{\gamma}_4$	$\hat{\gamma}_5$	σ	R^2	SC $\sim\chi^2(12)$	ARCH $\sim\chi^2(12)$
DBK	n.s.	n.s.	-1.623	0.945	n.s.	0.224	0.699	11.59	7.80
			(-4.886)	(3.587)				[0.48]	[0.80]
DBS	-0.093	n.s.	n.s.	0.457	n.s.	0.257	0.538	15.731	9.17
	(-2.800)			(1.805)				[0.20]	[0.69
MBK	n.s.	-0.811	-0.802	1.021	n.s.	0.201	0.627	9.060	6.95
		(-2.003)	(-5.801	(6.266)				[0.70	[0.86]
MBS	-0.088	n.s.	-0.684	0.779	-0.909	0.245	0.468	14.10	14.18
	(-2.591)		(-4.879)	(4.690)	(-1.651)			[0.29]	[0.29]
(f) yield spread (k months) over base	$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$	$\hat{\gamma}_4$	$\hat{\gamma}_5$	σ	R^2	SC $\sim\chi^2(12)$	ARCH $\sim\chi^2(12)$
DBK (k =3)	-0.151	0.650	n.s.	2.045	n.s.	0.215	0. 725	11.00	7.44
	(-3.393)	(2.967)		(4.544)				[0.53]	[0.83]
MBK (k = 6)	-0.417	n.s.	n.s.	n.s.	-0.206	0.207	0.603	4.57	6.88
	(-3.847)				(-1.948)			[0.97]	[0.87]
MBS (k = 6)	-0.151	n.s.	n.s.	0.329	n.s.	0.260	0.395	19.87	17.88
	(-5.021)			(1.916)				[0.07]	[0.12]
(g) uncertainty (constant horizon interest rate volatilities)	$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$	$\hat{\gamma}_4$	$\hat{\gamma}_5$	σ	R^2	SC $\sim\chi^2(12)$	ARCH $\sim\chi^2(12)$
DBS	-0.122	n.s.	0.822	n.s.	n.s.	0.209	0.541	13.68	25.80
	(-3.860)		(3.026)					[0.32]	[0.01]
MBK	-0.143	1.138	0.846	n.s.	n.s.	0.168	0.691	21.61	18.29
	(-3.695)	(1.659)	(3.006)					[0.04]	[0.11]
MBS	-0.148	n.s.	0.807	n.s.	n.s.	0.218	0.415	19.05	8.38
	(-5.172)		(2.868)					[0.09]	[0.75]

Notes: The variables *DBK* and *MBK* are the bank deposit and mortgage rate respectively; *DBS* and *MBS* are the building society deposit and mortgage rates; BASE is the base rate. n.s. indicates variable has been dropped due to insignificance. t-statistics in parentheses based on Newey-West standard errors. SC is a chi-squared test for serial correlation, H is a chi-squared test for heteroskedasticity [*p* values in brackets].

Chart 1: UK retail rates and the base rate



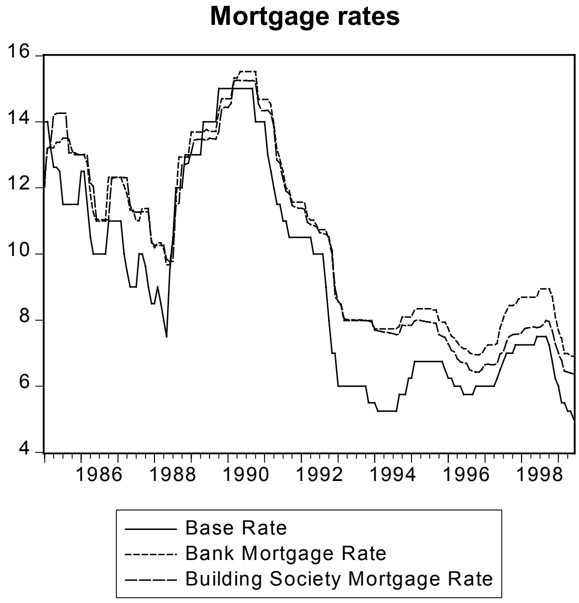
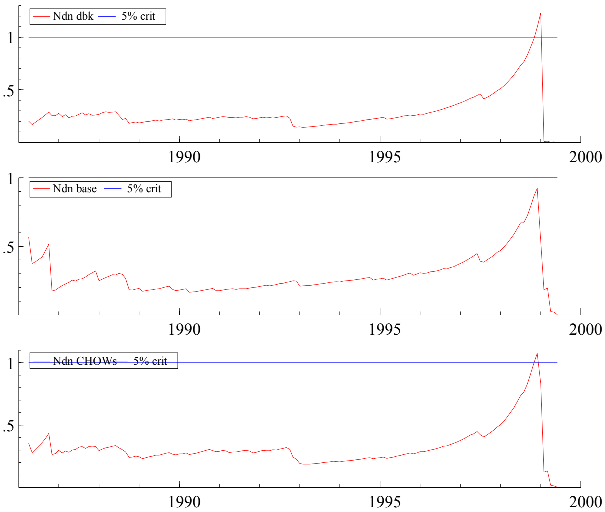
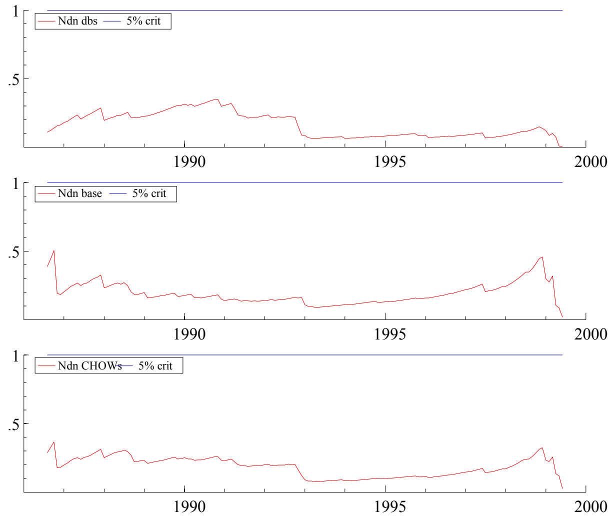


Chart 2: Recursive Chow-breakpoint test for cointegrating VARs

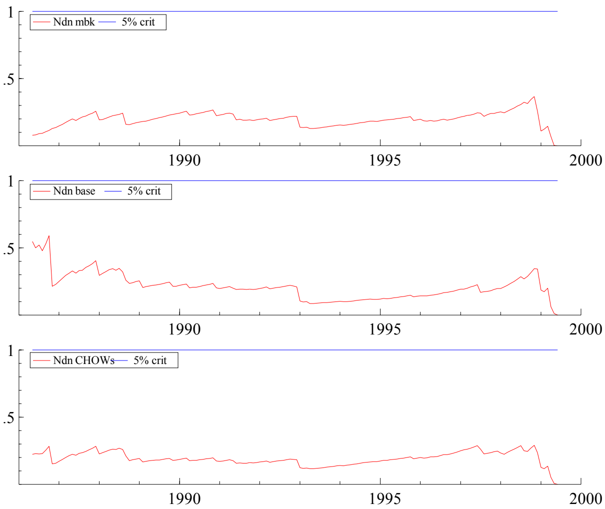
Bank deposit rate



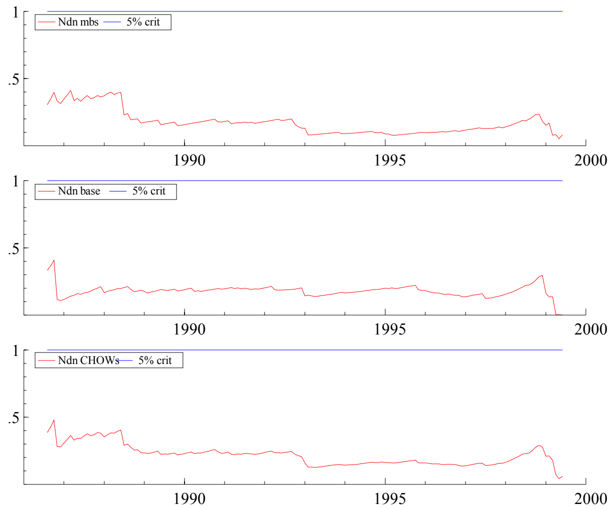
Building society deposit rate



Bank mortgage rate



Building society mortgage rate



Note: For each VAR recursive Chow-breakpoint statistics relative to the respective 5% critical value are displayed for each single equation and for the system as a whole.

Chart 3: Recursive Chow-breakpoint test for linear ECMs

Note: The charts show ECM recursive Chow-breakpoint statistics relative to the respective 5% critical value.

Chart 4: Pass-through of a 100 basis point permanent increase in the base rate