Non-Linear Base Rate Pass-Through in Banks' and Building Societies' Retail Rates

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ABSTRACT

In this paper we analyse the pass-through of the Bank of England base rate to banks' and building societies' deposit and mortgage rates. Cointegration analysis suggests that deposit and mortgage rates are cointegrated with the base rate. Long-run base rate pass through is complete for deposit rates and incomplete for banks' and building societies' mortgage rates. Based on linear error-correction models we analyse the speed of adjustment of banks' and building societies' retail rates to a permanent change in the base rate. We find that building societies retail rates adjust slower to a change in the base rate than banks' retail rates, a finding that may reflect institutional differences between banks and building societies. Because of the declining importance of building societies in the UK financial sector following the conversion of the largest building societies to banks since the late 1980s, this may imply that the transmission of monetary policy in the UK has become faster in recent years. Based on non-linear error-correction models we assess the significance of non-linearities in the adjustment process of UK retail rates. We find that expectations about the future path of base rates, proxied by the current change in the base rate or the spread of interest rates offered on the London interbank money market over the base rate, seem to have a highly significant effect on the adjustment process of banks' retail rates, but not on the adjustment of building societies' retail rates. This may imply that, because of the conversion of the largest building societies to banks, expectations about the future course of monetary policy have become more relevant for the adjustment of retail rates to changes in the base rate in recent years.

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 society 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. If monetary policy actions are to be influential, official rate changes should be '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 face non-negligible costs of adjustment. 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 less dependent on their deposit base for funds. Building societies also face legal restrictions imposed upon their lending activity which make them more dependent on their mortgage business. As a result, the adjustment of building societies' retail rates to base rate changes may differ from that of banks' rates.

In recent years, many large building societies, accounting for about two thirds of the total former building society business, have converted to banks. The potential existence of differences in the rate setting behaviour of banks and building societies together with the declining importance of

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building societies in the UK financial sector may have important implications for the transmission of monetary policy in the UK. If building societies' rates adjust slower to changes in the base rate than banks' rates, the declining market share of building societies in retail markets would imply a faster transmission of monetary policy via the direct interest rate channel. In this paper we want to assess whether differences in the pass-through of the base rate to bank and building society retail rates do exist and, if yes, what these differences imply for the transmission of monetary policy in the UK. Making 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 – 1999, we estimate linear error-correction models for banks' and building societies' time deposit and standard variable mortgage rates and simulate the adjustment to a permanent change in the base rate. We find that banks retail rates adjust faster than building societies' retail rates, implying that the transmission of monetary policy in the UK via the direct interest rate channel may have become faster in recent years.

We also consider the retail rate setting process as potentially asymmetric and non-linear and implement a non-linear error correction model that allows for asymmetry with respect to the direction of adjustment and with respect to expectations about the future path of base rates. The presence of non-linear adjustment in retail rates would have important implications for monetary policy. If there is a difference between the upward and downward responsiveness of retail rates, the transmission of monetary policy will be asymmetric over the interest rate cycle, and the central bank may want to take this into account in the conduct of monetary policy. If there is asymmetry with respect to expectations about the future path of base rates, the central bank will have to figure out rate setters' expectations about the future stance of monetary policy in order to obtain a proper assessment of the effects of its policy actions. In this paper we consider the retail rate setting process of banks and building societies as potentially asymmetric and non-linear with respect to both the direction of adjustment and expectations about the future path of base rates. The significance of these non-linearities is tested based on the generalised non-linear error correction framework proposed by Frost and Bowden (1999).

The paper is organised as follows. The next section reviews the conceptual issues on which the implementation and interpretation of the empirical analysis of base rate pass-through is based. Section 3 describes the data. In Section 4 we test for long-run relationships between banks' and building societies' deposit and mortgage rates and the base rate and simulate the speed of adjustment of retail rates to changes in the base rate. In Section 5 we test the significance of non-linearities in the adjustment of retail rates to base rate changes. Section 6 concludes.

2. Base Rate Pass-Through: Conceptual Issues

In the UK, the base lending rate set by the four major clearing banks adjusts fully and instantaneously to changes in the official rate set by the Bank of England[1]. The Bank of England therefore exerts perfect control over the base rate. The base rate is the reference rate for all short-term and adjustable long-term retail rates. But that does not necessarily imply that changes in official rates are also fully and instantaneously passed through to retail rates, since banks and building societies may face non-negligible costs of adjusting retail rates to the base rate. Based on Rotemberg and Saloner (1987), Hannan and Berger (1991) show that sluggishness in retail rates[2] may arise because of imperfect competition in retail markets and non-negligible costs associated with changing posted retail rates, such as the cost of advertising the new rates[3]. Given that financial institutions exercise some market power, because of product differentiation, chartering restrictions, or because they operate in a customer market, retail rates will only be

[1] In theory each individual bank may change its base rate any time, but in practice all major clearing banks set the same base rate and change it only in response to changes in the official rate. A more detailed description of the implementation of monetary policy in the UK can be found in Butler and Clews (1997).
[2] Hannan and Berger (1991) focus on the adjustment of deposit rates, but their model can also be applied to loan rate adjustment.
[3] The idea that fixed costs of changing prices gives rise to price rigidity was introduced by Barro (1972) and then further developed by Sheshinski and Weiss (1977, 1983), Rotemberg (1983), Mankiw (1985).

adjusted if the cost of not adjusting to a change in official rates is higher than the cost of adjusting.

Both banks and building societies have incentives to make discontinuous changes to avoid menu costs, but they may find that these costs do not impinge identically and their responses to base rate changes may differ. Banks and building societies in the UK 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[4]. 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.

But despite these measures to encourage competition between banks and building societies, there are still significant institutional differences between banks and building societies remaining. Building societies still face restrictions on their access to the wholesale money market and are therefore relatively more dependent on their deposit base for funds. Also, because of restrictions imposed upon their lending activity, building societies are more dependent on their mortgage business than banks. These institutional restrictions may cause building societies not to be able to follow base rates as closely as banks, giving rise to a more sluggish adjustment of retail rates set by building societies. There are only few studies analysing the pass-through of base rates to retail rates in the UK, and none of the existing studies investigates whether there are differences in rate setting behaviour between banks and building societies. Paisley (1994) analyses base rate

[4] For a documentation of institutional changes in the UK financial sector since 1970 see Bowen, Hoggarth and Pain (1999).

pass-through to building societies' deposit and mortgage rates and does not consider banks' retail rates at all. Heffernan (1997) analyses the pass-through of base rates to deposit rates offered for savings accounts and chequing accounts and to rates charged for repayment mortgages and personal loans based on a panel of individual banks and building societies. Her focus is on differences in the adjustment speed between retail products and not between types of institution.

However, the existence of differences in the rate setting behaviour between banks and building societies may have important implications for the transmission of monetary policy in the UK. Partly as a reaction to the institutional disadvantages they face, the largest building societies – with the exception of the Nationwide – covering over two thirds of building society business, have converted to banks since the late 1980s. The trend towards de-mutualisation started with the conversion of the Abbey National in 1989. 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 potential existence of differences in the rate setting behaviour of banks and building societies together with the declining importance of building societies in the UK financial sector may have important implications for the transmission of monetary policy in the UK. If building societies' rates adjust slower to changes in the base rate than banks' rates, the declining market share of building societies in retail markets would imply a faster transmission of monetary policy via the direct interest rate channel.

Recently there has been an increasing interest in the empirical literature in the possibility of asymmetric adjustment of retail rates to changes in policy-controlled rates. The focus in most studies is on the possibility of differences between upwards and downwards responsiveness of retail rates. Whether adjustment of retail rates would be expected to be faster upwards or downwards depends on the market environment. If competition in the market for deposits (loans) is very fierce, financial institutions may be more reluctant to adjust deposit (loan) rates downwards (upwards) in order to avoid loss of customers. On the other hand, if the intensity of competition is rather low and financial institutions operate in a customer market, i.e. if customers are not able or not willing to move quickly to another service provider offering better conditions, financial institutions may be slower to adjust deposit (loan) rates downward (upward) in order to increase average profits over the interest rate cycle (Scholnick, 1996). The empirical evidence seems to rather support the latter view. Hannan and Berger (1991) and Mester and Saunders (1995) model US deposit and prime rate changes respectively using a logit model. With this qualitative dependent variable approach they assess the effect of a change in the cost of funds on the probability of deposit/prime rate changes. Separating their samples into sub-samples, including only deposit/prime rate increases and decreases respectively, they investigate 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. Alternatively, non-linear adjustment in retail rates is modelled based on non-linear time series models. 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. Scholnick (1996) uses a non-linear error correction model to investigate the presence of non-linearities in the adjustment of deposit rates to money market rates in Malaysia and Singapore. Both studies find that deposit rates adjust significantly faster when they are above their long-run level than when they are below.

Thus, there is some international evidence that deposit (loan) rates are more rigid upward (downward) than downward (upward). More complicated non-linearities may arise if rate setters are forward looking. In the presence of costs associated with adjusting retail rates, rate setters have an incentive to avoid passing through transitory changes in official rates, since adjusting to a change in official rates that is reversed in the near future means incurring adjustment costs twice. Therefore, the decision of financial institutions whether to adjust their retail rates or not is likely to depend on their expectations about 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 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 lower bound is larger than the upper bound because trend inflation provides some of the adjustment necessary to counter the 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:

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

where b_0 is the current (even period) base rate and $E_0 b_1$ is the following period’s expected level of the base rate. 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):

$$(2) \qquad b_1 = Eb_1 + \varepsilon$$

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:

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

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:

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

This can be rearranged to yield:

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

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 iff:

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

This condition implies that the adjustment of retail rates to the base rate is asymmetric, depending on the expected future path of base rates. For a given positive disequilibrium, i.e. deviation of the retail from its desired level as a function of the base rate, 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. 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.

3. Data Issues

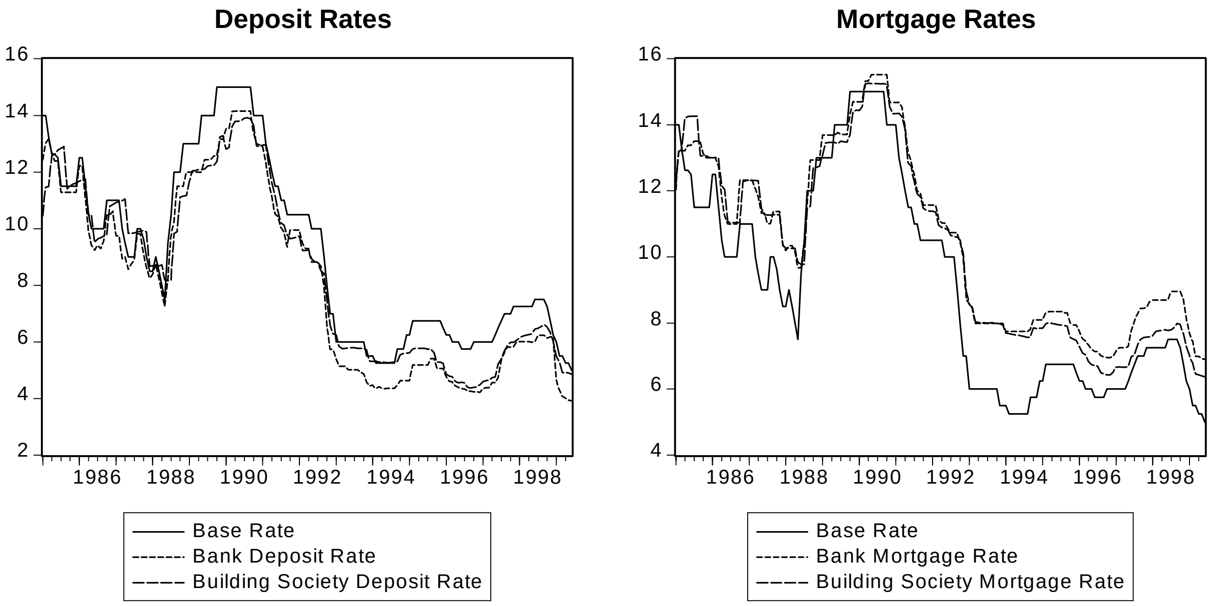
The data used in the following empirical analysis are all end-of-month and span the period 1985:1 – 1999:6. The base rate series is taken from official sources (ONS code AMIH) and is the average of the four major clearing banks' base rates. Very occasionally more than one rate change occurs within one 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[5]. 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[6]. 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. Nonlinear 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, i.e. the measured retail rate, responds to official rates, which

[5] 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, e.g. 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.

[6] 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 last few years. Their calculations suggested that 'cashbacks would have reduced spreads by between 9 and 13 basis points' (p.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 cashbacks, switch facilities, and telephone banking that augment the competitiveness of a retail product on non-price grounds.

can be informative about the extent to which providers may be concerned about ‘money illusion’ over the level of rates.

Figure 1: UK retail rates and the base rate



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 AJWV 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 – 1999:6 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[7].

Comparing bank and building society deposit rates in Figure 1 we find that the banks' and building societies' rates moved closely together until 1993, but that since then building societies' deposit rates are generally above bank deposit rates and building societies' mortgage rates are generally below banks' mortgage rates. One potential explanation for this observation is that the building societies were de-mutualising in the mid 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. It is therefore possible that the relationship between building societies' retail rates and the base rate has changed in the 1990s, so that we will have to pay special attention to the stability of the relationships estimated in the next section.

With the exception of banks' deposit rates, retail rates were generally less volatile than official rates, supporting the view that retail rates are smoothed in accordance with the principle of menu cost minimisation and forward looking behaviour[8]. The standard deviation for the sample is 3.15 for the base rate, 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.

[7] 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.

[8] 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. Gallagher and Milne (1997) attribute this as the principal cause of greater year on year variation in the margin of mortgage to deposit rates offered by banks.

Prior to the empirical analysis we assess the integratedness of the data, since standard distributional theory is not valid if the data follow a stochastic trend. The presence of stochastic trends in the data is tested based on standard augmented Dickey Fuller (Dickey and Fuller, 1981) and Phillips-Perron (Phillips and Perron, 1988) unit root tests. For the augmented Dickey-Fuller (ADF) test the order of the lagged dynamic terms was selected based on the Schwarz-Bayes information criterion. The truncation lag for the Phillips-Perron test was chosen based on the Newey-West (1987) automatic truncation lag selection criterion. A constant but no trend was included in the test regression equations, since the presence of a deterministic time trend in interest rates is economically implausible. Both tests, displayed in Table 1, suggest that the base rate as well as banks' and building societies' deposit and mortgage rates can be characterised as non-stationary over the chosen sample period.

Table 1: Unit-root test statistics

	Base Rate	Banks' Deposit Rate	Building Societies' Deposit Rate	Banks' Mortgage Rate	Building Societies' Mortgage Rate
ADF	-1.23	-1.15	-1.04	-1.25	-1.07
PP	-0.98	-1.05	-0.87	-0.88	-0.76

Note: The table displays the test statistics of the augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) unit root test. The 10% (5%) critical value from McKinnon (1991) is –2.57 (–2.87). The lag-order of the dynamic terms for the ADF test has been selected based on the Schwarz-Bayes information criterion, the lag truncation for the PP test was chosen based on the Newey-West (1987) automatic truncation lag selection criterion. Test regressions include a constant and no trend.

4. Long-Run Relationships and Linear Adjustment

Linear error-correction models are often used to analyse the pass-through of official rates to retail rates[9]. The advantage of this approach is that the systematic effect of a change in official rates on retail rates can be analysed. However, analysing base rate pass-through to retail rates in a single equation framework requires that there exists only a single long-run relationship[10] and that the base rate is at least weakly exogenous with respect to retail rates[11]. We analyse base rate pass-through separately for each deposit and mortgage rate, so that the former point does not represent an impediment to single equation analysis in our case. But weak exogeneity of the base rate cannot be simply taken for granted and must be established based on empirical tests. For this reason we first analyse the long-run relationship between deposit and mortgage rates and the base rate based on the multivariate Johansen approach and test for weak exogeneity of the base rate. Having established weak exogeneity of the base rate we analyse base rate pass-through employing single equation error-correction models.

The multivariate approach to cointegration analysis proposed by Johansen (1988, 1991, 1995) is based on the VAR model:

[9] For example, linear eror-correction models are employed by Heffernan (1997) to analyse the pass-through of base rates to deposit and loan rates in the UK, by Borio and Fritz (1995) to analyse the pass-through of official rates to short-term loan rates in industrialised countries and by Mojon (2000) to analyse the pass-through of overnight money market rates to deposit and loan rates in euro area countries.

[10] Estimating a single equation linear error-correction model in the presence of more than one long-run relationship between the variables in the model gives rise to inefficiency. A linear combination of all long-run relationships would be obtained.

[11] Johansen (1992) shows that if weak-exogeneity of regressors is not given, single equation estimates of long-run relationships will be inefficient.

(7) $$x_t = A_1 x_{t-1} + ... + A_n x_{t-n} + \mu + \Theta D_t + \varepsilon_t \; .$$

x is a vector comprising the endogenous variables, μ is a vector of constants and *D* is a matrix of centered impulse dummies[12] in order to control for large outliers caused by e.g. the 1992 EMS crisis. ε is a vector of error terms, which are assumed to be white-noise. The VAR can be reformulated in vector error correction form:

(8) $$\Delta x_t = B_1 \Delta x_{t-1} + ... + B_{n-1} \Delta x_{t-n+1} + C x_{t-1} + \mu + \Theta D_t + \varepsilon_t$$

The cointegration test is based on the rank of the matrix *C*, which gives the number of long-run relationships between the endogenous variables in the VAR. Johansen proposed two tests for the cointegration rank, the Trace-Test and the Maximum Eigenvalue Test[13]. The Maximum Eigenvalue test tests the null hypothesis that the rank of *C* is equal to *r* against the alternative that the rank is equal to *r*+1. The Trace test tests the null hypothesis that the cointegration rank is equal to *r* against the alternative hypothesis that the rank is equal to or larger than *r*+1. The cointegration test here is solely based on the Trace-Test, since the Maximum-Eigenvalue Test does not provide a coherent testing strategy (Johansen, 1994). Based on the number of long-run relationships indicated by the cointegration test, the matrix Π can be factorised as $\Pi = \alpha\beta'$. α is a (*nxr*) matrix of loading or adjustment coefficients and β is a (*nxr*) matrix of cointegrating vectors, with *n* equal to the number of endogenous variables and *r* equal to the number of long-run relationships in the system. β describes the relationships linking the endogenous variables in the long-run and α describes the dynamic adjustment of the endogenous variables to deviations from long-run equilibrium as given by $\beta' x$. Based on the significance of the loading coefficient we can assess whether a variable is weakly exogenous. A variable is weakly exogenous if there is no significant adjustment of this variable to deviations from long-run

[12] The use of centered as opposed to uncentered dummy variables ensures that the standard critical values for the cointegration test are still valid (Johansen, 1995).
[13] For a more detailed technical exposition of the Johansen approach see e.g. Johansen (1988, 1991, 1995), Lütkepohl (1993) and Hamilton (1994).

equilibrium, i.e. if the loading coefficient in the equation corresponding to this variable in the VECM is insignificant.

Table 2 reports the results of the Johansen cointegration test. In the underlying VARs we restrict the constant to lie in the cointegration space, assuming that there is no deterministic time 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. The test statistics imply that the null of no cointegration can be rejected at least at the 5 % level in all four cases. We tested in each case the hypothesis that long-run pass-through is complete, i.e. that the long-run coefficient of the base rate is equal to one. The hypothesis was only rejected for banks' mortgage rates and was thus imposed in all other cases.

A couple of centered impulse dummies had to be included in the VAR in order to eliminate heteroskedasticity. The dummies control for large outliers which can be explained by the EMS crisis 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 one percent 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, 1993). In order to assess stability of the estimated systems we carried out recursive Chow-breakpoints tests both for the individual equation of the VAR and for the system as a whole, considering every possible breakpoint over the full sample. With the exception of the system for the bank deposit rate, the results, shown in Appendix-Figure 1, do not indicate significant instability problems in the underlying VARs. In the system for bank deposit rates there is some evidence of a breakpoint at the end of the sample in late 1998. The test statistic is, however, only marginally above the 5% critical level and only for a single period.

The Johansen Trace test suggests that each retail rate is pairwise cointegrated with the base rate. The estimated vector-error correction models could also be used to simulate the adjustment of each retail rate to an innovation to the base rate by computing impulse responses. Since we estimate a separate system for each retail rate, the identified shocks to the base rate and the endogenous response of the base rate to its own shock would be different in each case, so that the results of the impulse response analysis would not be fully comparable. Moreover, within the multivariate framework of the Johansen procedure we may analyse the effect of shocks to the base rate, but not the effect of a systematic change in the base rate, which is of more interest in the context of pass-through. The natural framework to analyse the effect of systematic changes in the base rate on retail rates is a single equation error-correction model. In the beginning of this section we have pointed out that single equation estimation approaches are only applicable in the present context if the base rate is weakly exogenous with respect to retail rates. Weak exogeneity of the base rate can be assessed based on the significance of the loading coefficients in the base rate equations of the vector error-correction models. In Table 2 we also report the estimated loading coefficients with t-statistics in parentheses. For each system, α_1 represents the adjustment coefficient in the retail rate equation and α_2 the adjustment coefficient in the base rate equation of the vector error-correction model. We find that in each case α_1 is significantly smaller than zero at the 1% level, supporting the interpretation of the estimated long-run relationships as long-run interest rate setting relationships linking retail rates to the base rate. The adjustment coefficient in the base rate equation, α_2, is in each case not significantly different from zero, suggesting that the base rate is weakly exogenous with respect to each retail rate.

Table 2: Johansen cointegration test results

	Banks' Deposit Rate	Building Societies' Deposit Rate	Banks' Mortgage Rate	Building Societies' Mortgage Rate
Trace-Test	$r = 0$ $r \leq 1$ 20.45 6.45	$r = 0$ $r \leq 1$ 20.93 5.79	$r = 0$ $r \leq 1$ 30.20 4.41	$r = 0$ $r \leq 1$ 20.85 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	$\alpha_1 = -0.154$, $\alpha_2 = -0.029$ (-2.84) (-0.47)	$\alpha_1 = -0.120$, $\alpha_2 = 0.000$ (-3.69) (0.00)	$\alpha_1 = -0.157$, $\alpha_2 = 0.043$ (-4.63) (0.69)	$\alpha_1 = -0.082$, $\alpha_2 = 0.026$ (-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)

Note: The variables DBK and MBK are the bank deposit and mortgage rate respectively; DBS and MBS are the building society deposit and mortgage rate respectively; BASE is the base rate. The 5% critical values for the λ_{trace} statistic (restricted intercepts) are 17.86 (r=0) and 8.07 (r<=1). α_1 is the loading coefficient in the VECM equation for the respective retail rate, α_2 is the loading coefficient in the VECM equation for the base rate. LM1 and LM12 are Lagrange-Multiplier tests for serial correlation of order one and up to order twelve respectively. H is White's (1982) test for heteroskedasticity and JB is a Jarque-Bera test for normality. All tests refer to the system as a whole. In parentheses we show respectively standard errors for the long-run parameters, t-statistics for the loading coefficients and probability values for the coefficient test and the diagnostic tests.

Having established weak exogeneity of the base rate, we can turn to the analysis of the speed of adjustment of retail rates to a systematic change in the base rate by estimating single equation linear error-correction models[14]. Moreover, based on the estimates of the error-correction models we can perform another test for cointegration and obtain estimates for the long-run coefficients and can thus check the robustness of the results we obtained from the Johansen procedure.

The estimated error-correction models are of the form

$$\text{(9)} \qquad \Delta r_t = \gamma\left(r_{t-1} - \beta_0 - \beta_1 b_{t-1}\right) + \sum_{i=1}^{n} a_i \Delta r_{t-i} + \sum_{j=0}^{m} b_j \Delta b_{t-j} + \varepsilon_t \text{,}$$

where r is a retail rate and b is the base rate. In order to obtain more efficient coefficient estimates and to be able to test cross-equation restrictions, we estimate equation 9 for banks and building societies jointly by non-linear SUR. The lag order of the dynamic terms was selected based on a general-to-specific strategy eliminating all insignificant lags. In this framework the null hypothesis of no cointegration is rejected if the adjustment coefficient γ is significantly smaller than zero. The distribution of the test statistic is non-standard, so that standard critical values for the t-test do not apply. Monte Carlo simulations by Banerjee, Dolado and Mestre (1994) suggest a 5% critical value for the cointegration test of –3.27.

The estimation results are reported in Table 3. A few impulse dummies had to be included in the error-correction models for the deposit rates in order to control for some large outliers associated with changes in the composite tax rate (1985/1986), unusually large changes in the base rate (1988) and the EMS crisis (1992). Including these dummy variables proved to be necessary to eliminate heteroskedasticity from the residuals. Diagnostic tests suggest that there is no evidence of autocorrelation and autoregressive conditional heteroskedasticity in the residuals of the estimated equations. But again normality of the residuals is rejected at the 1% level in each case. Sub-sample stability of the estimated error-correction models was again assessed based on recursive Chow-breakpoint tests, displayed in Appendix-Figure 2. The

[14] Monte Carlo simulations (Inder, 1993, Pesaran and Shin, 1999, and Pesaran, Shin and Smith, 2000) show that for the estimation of the long-run parameters the error-correction estimator performs better in small samples than

results suggest that there is no evidence of a significant structural break in the estimated relationships over the sample period.

Table 3: Linear error-correction models

Banks Deposit Rates	**Building Societies 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)	$\Delta DBS_t = \underset{(-4.18)}{-0.123}[DBS_{t-1} + \underset{(-5.33)}{0.883} - BASE_{t-1}]$ $+\underset{(3.24)}{0.165}\Delta BASE_t + \underset{(4.21)}{0.19}\Delta BASE_{t-1}$ 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 Mortgage Rates	**Building Societies Mortgage 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)	$\Delta MBS_t = \underset{(-5.74)}{-0.171}[MBS_{t-1} \underset{(3.96)}{-1.531} \underset{(23.66)}{-0.93}BASE_{t-1}]$ $+\underset{(2.68)}{0.133}\Delta BASE_t + \underset{(3.02)}{0.136}\Delta BASE_{t-1}$ 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 9. The variables DBK and MBK are the bank deposit and mortgage rate respectively; DBS and MBS are the building society deposit and mortgage rate respectively; 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. In brackets we show t-statistics for the estimated coefficients and probability values for the coefficient tests and the diagnostic tests.

other single equation estimators such as the Phillips-Hansen estimator (Phillips and Hansen, 1990).

Comparing the t-statistics of the adjustment coefficients with the critical value of –3.27 suggested by Banerjee et al. (1994), we find that the null of no cointgeration can be rejected at least at the 5% level in every case, confirming the finding of the Johansen test that each retail rate is pairwise cointegrated with the base rate. The long-run coefficients are also very similar to the ones obtained from the Johansen procedure. The long-run coefficient of the base rate is not significantly different from one for both banks' and building societies' deposit rates, implying that long-run pass-through to deposit rates is complete. The constant in the long-run relationship, which can be interpreted as the long-run mark up of deposit rates over the base rate, is somewhat larger in absolute value for banks, suggesting that banks offer on average lower deposit rates than building societies. This finding may reflect the higher dependence of building societies on their deposit base, as we have pointed out in Section 1. The long-run coefficient of base rates is significantly smaller than one for banks' mortgage rates at the 1% level. Building societies mortgage rates seem to be somewhat more closely tied to the base rate in the long-run, but long-run pass-through is still significantly smaller than one at the 5% level. The estimated adjustment coefficients imply about 14% (12%) adjustment to long-run equilibrium per month in deposit rates for building societies (banks) and 14% (17%) adjustment to long-run equilibrium per month in mortgage rates. Thus, the adjustment to long-run levels in banks' and building societies' retail rates is rather sluggish.

In Table 4 we present Wald-test statistics for cross-equation restrictions of equality of the long-run coefficients, the adjustment coefficients and the dynamic terms. The test statistics suggest that in the long-run there is no significant difference between banks' and building societies' deposit rates. The speed of adjustment to long-run equilibrium is also not significantly different. However, the dynamic effect of a change in the base rate on banks' deposit rates is significantly larger than on building societies' deposit rates. For mortgage rates we find that there is no significant difference in the speed of adjustment to long-run equilibrium, but that there are significant differences between both the long-run coefficients and the dynamic terms. Compared to building societies' mortgage rates, we find a significantly larger long-run constant and a significantly smaller long-run slope coefficient for banks' mortgage rates. The significant difference between the dynamic terms arises because banks' mortgage rates adjust significantly faster to changes in the base rate.

Table 4: Test of Cross-Equation Restrictions

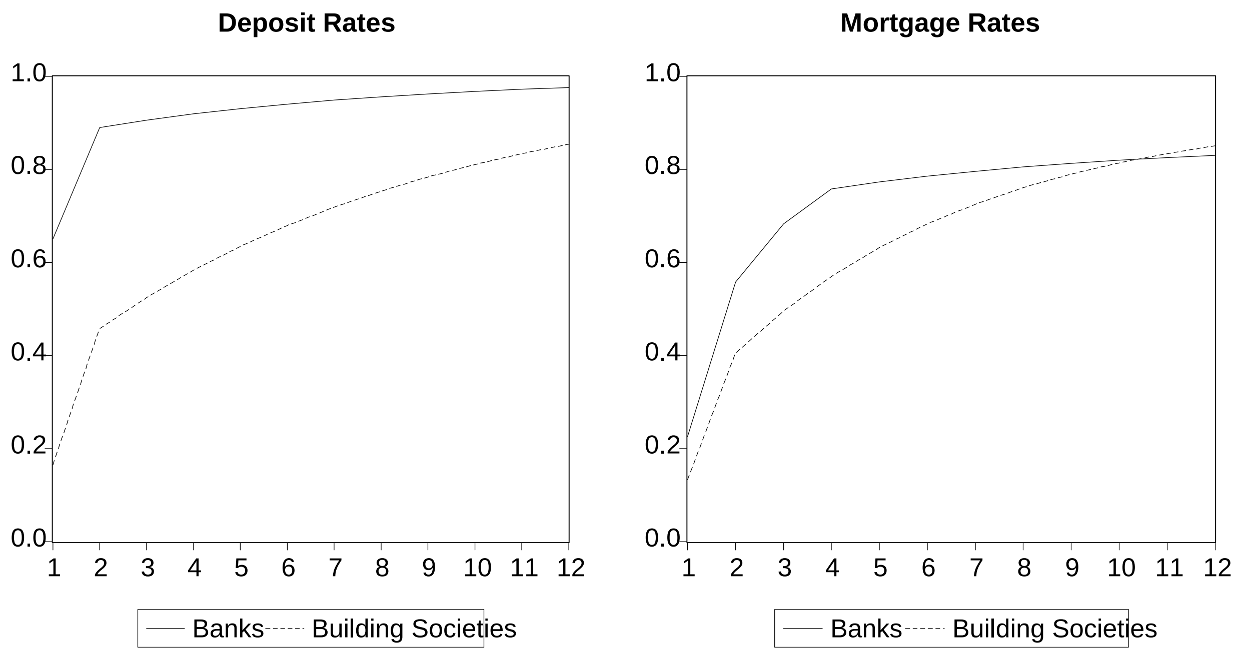
	Long-run coefficients	Adjustment coefficients	Dynamic terms
Deposit Rates	0.19 (0.66)	0.14 (0.71)	36.05 (0.00)
Mortgage Rates	15.20 (0.00)	0.28 (0.59)	11.61 (0.00)

Note: The Table displays Wald-test statistics with probability values in parentheses for tests of equality of banks' and building societies' coefficients

Based on the estimated error-correction equations we can simulate the dynamic response of UK retail rates to a systematic change in the base rate. The estimates of the short-run dynamic effects in Table 3 and the test statistics in Table 4 reveal that a change in the base rate has a significantly stronger dynamic effect on banks' retail rates than on building societies' rates. The sum of the coefficients of current and lagged changes in the base rate in the bank deposit rate error-correction model is 0.84, so that much of the total effect of a base rate change is already completed in the first month after the change. In the error-correction model for building societies' deposit rates the sum of the coefficients of the significant dynamic base rate terms is only 0.36. A similar picture emerges for mortgage rates. The coefficients of the significant dynamic base rate terms sum to 0.6 in the error-correction model for banks' mortgage rates and only to 0.27 in the error-correction model for building societies' mortgage rates.

These differences in the dynamic effects of a change in the base rate are reflected in the impulse responses to a 100 basis points permanent increase in the base rate, which are displayed in Figure 2. Building societies' retail rates respond slower than banks' rates to a change in the base rate. This finding suggests that the institutional differences between banks and building societies which we have pointed out in Section 1, the restricted access of building societies and their greater dependence on their mortgage business, give in fact rise to differences in rate setting behaviour. Given that the converted building societies are able to adjust quickly to the new institutional environment, an important implication of this result is that, because of the marked decline in the importance of building societies in the UK financial sector since the late 1980s, retail rates may now adjust faster to changes in the base rate, leading to a faster transmission of monetary policy.

Figure 2: Pass-through of a 100 basis points permanent increase in the base rate



5. Non-Linear Adjustment

The analysis of base rate pass-through in the previous section is based on the standard assumption that the adjustment of retail rates to the base rate is linear under all circumstances. Yet we have shown in Section 1 that adjustment might very well be nonlinear, either with respect to the direction of adjustment or with respect to expectations about the future path of base rates. In the following we will assess the significance of both kinds of asymmetry in the adjustment of UK retail rates to base rates. The framework for the analysis is the generalised non-linear error correction model proposed by Frost and Bowden (1999), which allows to generate and investigate a wide variety of asymmetry representations.

The generalised non-linear error-correction model proposed by Frost and Bowden (1999) takes the form:

$$\begin{aligned} \Delta r_t &= \gamma_0 u_{t-1} + \gamma_1 u_{t-1}^{+} d_t^{+} + \gamma_2 u_{t-1}^{-} d_t^{+} + \gamma_3 u_{t-1}^{-} d_t^{-} + \gamma_4 u_{t-1}^{+} d_t^{-} \\ &\quad + \sum_{i=1}^{n} a_i \Delta r_{t-i} + \sum_{j=0}^{m} b_j \Delta b_{t-j} + \varepsilon_t \end{aligned} \tag{10}$$

u_{t-1} is the deviation from long-run equilibrium in the previous period (i.e. $u_{t-1} = r_{t-1} - \beta_0 - \beta_1 b_{t-1}$). u_{t-1}^{+} and u_{t-1}^{-} indicate whether the retail rate was above or below its long-run equilibrium level. d_t is some ancillary process driving the asymmetry of the adjustment process. 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.

With this model it is possible to analyse a wide variety of non-linearities in the adjustment process. Here we focus on two possible causes of non-linear adjustment in UK retail rates: asymmetry with respect to the direction of adjustment and asymmetry with respect to expectations about the future path of base rates. Sign dependent error-correction can be generated from the general non-linear error-correction model by setting $d_t^+ = 1$ and $d_t^- = 0$. This yields an error correction model of the form:

$$(11) \quad \Delta r_t = \gamma_0 u_{t-1} + \gamma_1 u_{t-1}^+ + \gamma_2 u_{t-1}^- + \sum_{i=1}^{n} a_i \Delta r_{t-i} + \sum_{j=0}^{m} b_j \Delta b_{t-j} + \varepsilon_t \,.$$

γ_0, γ_1 and γ_2 cannot be identified separately, since $\{u_{t-1} = 0\}$ is in practice likely to be empty so that $u_{t-1}^+ + u_{t-1}^- = u_{t-1}$. Taking this into account and rearranging yields

$$(12) \quad \Delta r_t = (\gamma_0 + \gamma_2) u_{t-1} + (\gamma_1 - \gamma_2) u_{t-1}^+ + \sum_{i=1}^{n} a_i \Delta r_{t-i} + \sum_{j=0}^{m} b_j \Delta b_{t-j} + \varepsilon_t \,,$$

so that asymmetry can be tested as $\gamma_1 - \gamma_2 \neq 0$. In order to test this hypothesis we estimate equation (12) for each retail rate by non-linear least squares[15] and test whether $\gamma_1 - \gamma_2$ is significantly different from zero based on a standard t-test. The lag orders chosen for the dynamic terms are the same as those for the linear error-correction models estimated in the previous section. The estimates of $\gamma_1 - \gamma_2$ together with t-statistics in parentheses are reported in Table 5. $\gamma_1 - \gamma_2$ is in no case significantly different from zero, so that the results clearly suggest that there is no evidence of a significant difference between upward and downward responsiveness of UK retail rates.

[15] In the literature non-linear error-correction models are often estimated in two steps (Hofmann and Mizen, 2001, Scholnick, 1996, Ericsson, Hendry and Prestwich, 1998), estimating the long-run coefficients in the first step and the error-correction model in the second step. The advantage of this approach is that the analysis can be kept linear throughout. Following Frost and Bowden (1999) and Neumark and Sharp (1992) we estimate long-run parameters and short-run dynamics in one step by non-linear least squares, because the one step estimator is more efficient than the two step estimator.

Table 5: Sign dependent adjustment in UK retail rates

Deposit Rates		Mortgage Rates	
Banks	Building Societies	Banks	Building Societies
0.022 (0.157)	0.096 (0.993	-0.053 (-0.654)	0.137 (1.342)

Note: The table shows the estimated coefficient with t-statistic in parentheses for $\gamma_1 - \gamma_2$ *in equation 12*

The role of expectations in the error-correction process can be analysed in the framework proposed by Frost and Bowden (1999) by setting $d_t^+ = E_t^+ \Delta b$ and $d_t^- = E_t^- \Delta b$. $E_t^+ \Delta b$ indicates that base rates are expected to rise and $E_t^- \Delta b$ that base rates are expected to fall in the future. This yields an estimating equation of the form:

(13)
$$\Delta r_t = \gamma_0 u_{t-1} + \gamma_1 u_{t-1}^+ E_t^+ \Delta b + \gamma_2 u_{t-1}^- E_t^+ \Delta b + \gamma_3 u_{t-1}^- E_t^- \Delta b + \gamma_4 u_{t-1}^+ E_t^- \Delta b + \sum_{i=1}^{n} a_i \Delta r_{t-i} + \sum_{j=0}^{m} b_j \Delta b_{t-j} + \varepsilon_t$$

What are our priors for the signs of the adjustment coefficients? We would expect adjustment to slow down if retail rate are above their long-run equilibrium and base rates are expected to rise and if retail rates are below their long-run equilibrium and base rates are expected to fall, since in these cases banks and building societies expect base rates to close at least part of the equilibrium gap. If retail are above their long-run equilibrium levels and base rates are expected to fall and if retail rates are below long-run levels and base rates are expected to rise, then the equilibrium gap is expected to widen, what may motivate banks and building societies to adjust their rates faster. Thus, the expected sign is positive for γ_2 and γ_4 and negative for γ_1 and γ_3.

Direct measures of the expectations of banks and building societies about the future path of base rates are not available, so that we have to use proxies for these unobservable expectations. A guide for expectations might be the observation that central banks in industrialised countries tend to smooth policy rates by making many small steps going in the same direction in place of few large ones (Goodhart, 1996, Sack, 1997 and Yates and Clerc, 1999)[16]. As a result, official rates are highly autocorrelated, so that current period's change in the official rate may also be a good guide for the future path of official rates. In view of this, banks and building societies may form expectations about the future trend in base rates taking into account that official rates are likely to follow a sequence of steps. For this reason we will consider the current period's change in the base rate as a proxy for the expected future direction of base rate changes.

Market interest rate expectations about the path of official rates in the near future may also be inferred from money market instruments such as gilt repos, swap transaction and interbank loans[17]. A liquid market for gilt repos and swap transaction emerged just recently, so that we only consider the spread of rates offered on the London interbank money market over the base rate as a proxy for market expectations about the future path of base rates. The expected change of the base rate at the three month, six month and twelve month horizon is proxied with the spread of the three months, six months and twelve months London Interbank Offer Rate (LIBOR) over the base rate. The use of the LIBOR spreads to proxy expectations about future base rates is motivated by the Rational Expectations Hypothesis of the Term Structure (REHTS). According to the REHTS, the interest rate of a T-period money market paper is equal to the average expected base rate over the next T-periods plus a (stationary) risk premium[18].

Using the current change in the base rate and the LIBOR spreads respectively as proxies for expectations about the future path of base rates, equation (13) is fitted by non-linear least squares including the same set of dynamic terms and dummy variables that were included in the respective linear error-correction models. For deposit rates the hypothesis that the long-run coefficient of the base rate is equal to one was never rejected and thus imposed in the estimation. For building societies mortgage rates the long-run coefficient of base rates was

[16] An objective of the central bank to smooth short-term interest rates may be motivated by concerns about financial market stability (Goodfriend, 1989), uncertainty about the economic environment (Blinder, 1998) or the aim to influence long-term interest rates (Goodfriend, 1991).
[17] See Brooke, Cooper and Scholtes (2000) for a survey.

also not significantly different from one when the six months and the twelve months spread was used to proxy expectations.

The estimation results are shown in Table 6. We report the estimated long-run coefficients and the adjustment coefficients with t-statistics in parentheses. Error-correction coefficients which are significant at least at the 5 % level are in bold. The results again suggest that the rate setting behaviour of banks and building societies is different. While there is quite strong evidence of non-linear adjustment in banks' retail rates, there is only very little evidence of the presence of asymmetries in the adjustment process of building societies' retail rates. Expectations about the future path of base rates appear to have a very strong effect on the adjustment of banks' deposit rates. Banks' deposit rates are adjusted significantly slower when they are above their long-run level and base rates are expected to rise and when they are below their long-run level and base rates are expected to fall. Adjustment is also significantly faster if banks' deposit rates are above their long-run level and base rates are expected to fall. For building societies' deposit rates there is no evidence at all of non-linear adjustment. Banks' mortgage rates are adjusted significantly faster if they are above their long-run level and base rates are falling and if they are below their long-run level and base rates are rising. For building societies' mortgage rates there is only some evidence that adjustment is slower when mortgage rates are above equilibrium and base rates are expected to fall.

The evidence therefore suggests that expectations about future base rate changes only play a significant role in the adjustment process of banks' retail rates, but not of building societies' retail rates. Since the importance of building societies in the UK financial sector has declined and as a result of this the importance of banks has increased substantially in recent years, this finding implies that non-linearities in the adjustment of retail rates to base rates are likely to have become more relevant in the last years. Assessing the effect of base rate changes on retail rates may therefore have become more difficult and less successful if the predictions are based on linear models of pass-through.

[18]For a survey of the literature on the expectations hypothesis of the term structure see Shiller (1990). Cuthbertson (1996) provides evidence suggesting that the REHTS is a valid description of the relationship between short-term UK capital market rates.

Table 6: Non-linear error-correction in UK retail rates

$\Delta base$	β_0	β_1	γ_1	γ_2	γ_3	γ_4	γ_5	$\overline{R}^2$	DW
DBK	-0.995	1.0	**-0.134**	-0.07	**0.498**	-0.723	**0.62**	0.69	2.1
	(-8.295)		**(-3.05)**	(-0.16)	**(2.48)**	(-1.43)	**(2.33)**		
DBS	-0.776	1.0	**-0.124**	0.358	-0.018	-0.109	0.067	0.51	2.02
	(-4.312)		**(-3.60)**	(1.42)	(-0.18)	(-0.58)	(0.47)		
MBK	2.312	0.875	**-0.122**	**-0.362**	0.159	**-0.583**	0.206	0.64	1.92
	(7.256)	(28.97)	**(-3.25)**	**(-2.77)**	(1.21)	**(-2.52)**	(1.47)		
MBS	1.426	0.935	**-0.154**	0.104	0.099	0.101	0.093	0.43	1.94
	(3.561)	(22.98)	**(-4.88)**	(0.42)	(0.94)	(0.38)	(0.80)		
3 months spread	β_0	β_1	γ_1	γ_2	γ_3	γ_4	γ_5	$\overline{R}^2$	DW
DBK	-0.99	1.0	**-0.181**	0.018	**0.512**	**-1.211**	**0.707**	0.72	2.13
	(-12.33)		**(-3.48)**	(0.09)	**(4.15)**	**(-2.48)**	**(3.71)**		
DBS	-0.921	1.0	**-0.139**	0.016	0.06	-0.191	0.027	0.51	2.00
	(-4.90)		**(-3.59)**	(0.09)	(0.86)	(-0.91)	(0.22)		
MBK	2.279	0.876	**-0.127**	**-0.232**	0.143	**-0.625**	0.141	0.63	1.89
	(7.60)	(29.70)	**(-3.12)**	**(-2.20)**	(1.51)	**(-2.43)**	(1.10)		
MBS	1.376	0.929	**-0.166**	-0.079	0.137	0.012	0.056	0.44	1.9
	(3.74)	(24.79)	**(-4.72)**	(-0.41)	(1.91)	(0.04)	(0.55)		
6 months spread	β_0	β_1	γ_1	γ_2	γ_3	γ_4	γ_5	$\overline{R}^2$	DW
DBK	-0.995	1.0	**-0.166**	0.077	**0.388**	**-0.64**	**0.412**	0.71	2.09
	(-10.59)		**(-3.11)**	(0.51)	**(3.51)**	**(-2.17)**	**(3.04)**		
DBS	-0.966	1.0	**-0.139**	-0.021	0.074	-0.087	0.029	0.51	2.00
	(-4.92)		**(-3.45)**	(-0.10)	(1.28)	(-0.95)	(0.32)		
MBK	2.195	0.884	**-0.131**	**-0.169**	0.075	**-0.196**	0.023	0.63	1.92
	(6.75)	(27.45)	**(-3.03)**	**(-1.65)**	(1.06)	**(-2.27)**	(0.26)		
MBS	1.161	1.0	**-0.158**	-0.152	**0.137**	0.012	0.09	0.45	1.92
	(3.34)		**(-4.51)**	(-0.77)	**(2.53)**	(0.11)	(1.25)		
12 months spread	β_0	β_1	γ_1	γ_2	γ_3	γ_4	γ_5	$\overline{R}^2$	DW
DBK	-0.973	1.0	**-0.178**	0.099	**0.268**	-0.259	**0.249**	0.70	2.04
	(-7.97)		**(-2.93)**	(0.95)	**(2.76)**	(-1.28)	**(2.03)**		
DBS	-1.048	1.0	**-0.138**	-0.082	0.061	-0.027	0.013	0.51	2.01
	(-5.02)		**(-3.12)**	(-0.36)	(1.34)	(-0.37)	(0.16)		
MBK	2.036	0.897	**-0.142**	-0.176	0.066	**-0.139**	0.004	0.63	1.93
	(6.87)	(29.43)	**(-3.10)**	(-1.60)	(0.43)	**(-2.24)**	(0.05)		
MBS	0.982	1.0	**-0.162**	-0.292	**0.10**	0.054	0.052	0.46	1.95
	(3.47)		**(-4.47)**	(-1.03)	**(2.73)**	(0.65)	(0.87)		

Note: The table shows the estimated long-run coefficients and adjustment coefficients with t-statistics in parentheses obtained from estimating equation 13 using four different proxies for expected changes of the base rate as described in the text. Significant (10% level) error-correction coefficients are in bold.

6. Conclusions

Monetary authorities aim to exercise control over short interest rates by adjusting the official policy rate. For monetary policy to be effective, changes in the official rate must be passed-through to capital market and retail rates within a reasonably short period of time. In this paper we analyse the pass-through of the Bank of England base rate to banks' and building societies' deposit and mortgage rates. Cointegration analysis suggests that each deposit and mortgage rate is pairwise cointegrated with the base rate. Long-run pass through of base rates is complete for deposit rates and incomplete for banks' and building societies' mortgage rates. Based on linear error-correction models we analyse the speed of adjustment of banks' and building societies' retail rates to a permanent change in the base rate. We find that building societies retail rates adjust slower to a change in the base rate than banks' retail rates, a finding that may reflect institutional differences between banks and building societies. Building societies have only restricted access to wholesale money markets and are thus more dependent on their deposit base. Due to restrictions on their lending activities they are also more dependent on their mortgage business than banks. Because of these institutional restrictions, building societies may not be able to follow base rates as closely as banks. Following the conversion of the largest building societies to banks since the late 1980s, there has been a considerable shift in market share from building societies to banks in the UK financial sector. Given that the converted building societies are able to adjust their rate setting behaviour quickly to the new institutional environment, the trend towards de-mutualisation may have important implications for the transmission of monetary policy in the UK. Since banks' retail rates adjust faster to base rate changes, base rate pass-through may have become faster in recent years, implying a faster transmission of monetary policy.

The analysis of base rate pass-through based on linear error-correction models presumes that the adjustment of retail rates to the base rate is linear under all circumstances. But this must not be the case. Retail rates may be more rigid downwards than upwards or vice versa, and banks and building societies may try to economise on costs associated with changing retail rates by anticipating the future path of base rates. We assess the significance of non-linearities in the adjustment process of UK retail rates based on the generalised non-linear error-correction framework proposed by Frost and Bowden (1999). We do not find any evidence that the adjustment of retail rates depends on the direction of adjustment, i.e. on whether the deviation between retail rates and their long-run average level is positive or negative. Expectations about the future path of base rates, proxied by the current change in the base rate or the spread of interest rates offered on the London interbank money market over the base rate, seem to have a highly significant effect on the adjustment process of banks' retail rates, but not on the adjustment of building societies' retail rates. This implies that, because of the conversion of the largest building societies to banks, expectations about the future course of monetary policy are likely to have become more relevant for the adjustment of retail rates to changes in the base rate in recent years. Also, assessing the effect of base rate changes on retail rates may have become more difficult and less successful if the predictions are based on linear models of pass-through.

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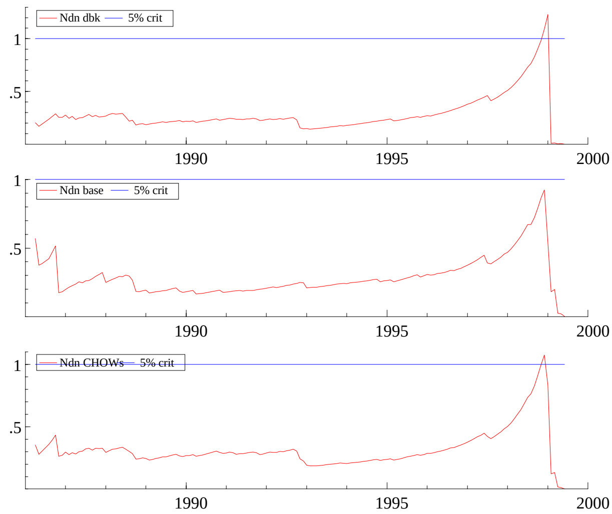
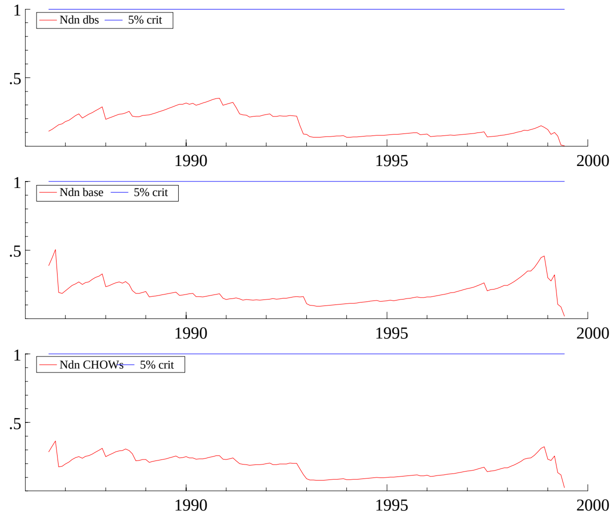
Appendix

Figure 1: Recursive Chow-breakpoint tests for the cointegrating VARs

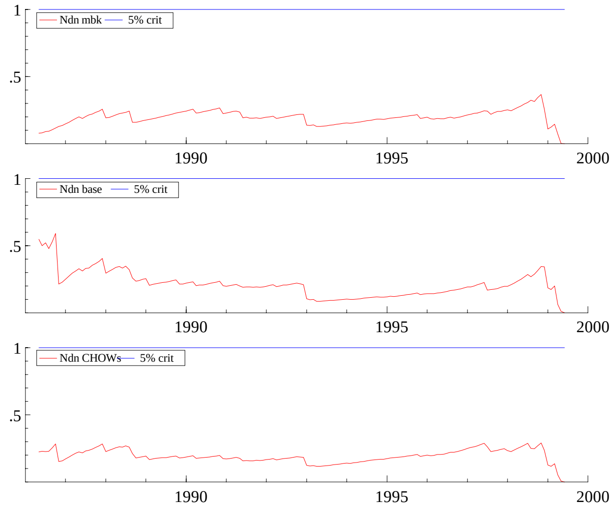
Bank Deposit Rate



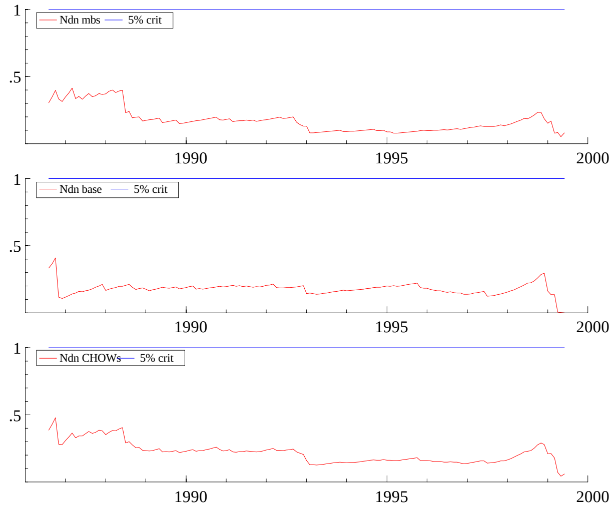
Building Society Deposit Rate



Bank Mortgage Rate



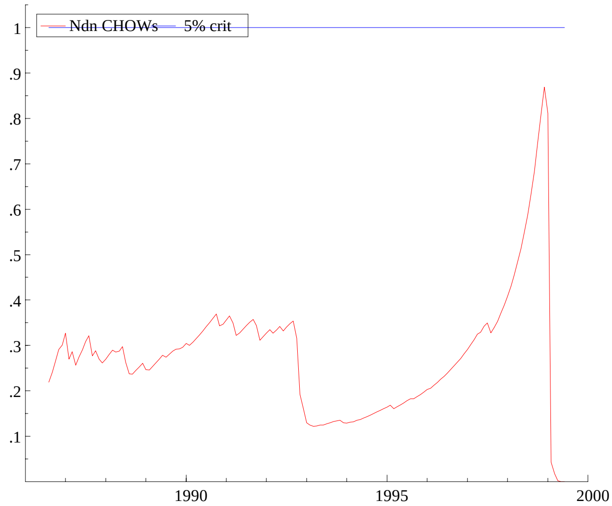
Building Society Mortgage Rate



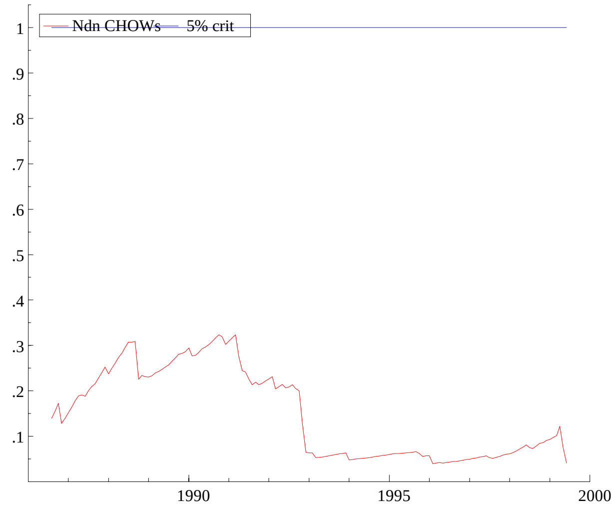
Note: For each VAR recursive Chow-breakpoint test statistics relative to the respective 5% critical value are displayed for each single equation and for the system as a whole.

Figure 2: Recursive Chow-breakpoint test for the linear ECMs

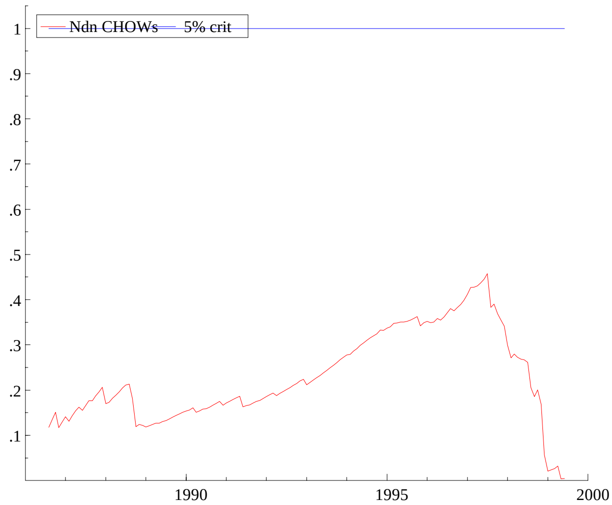
Bank Deposit Rate



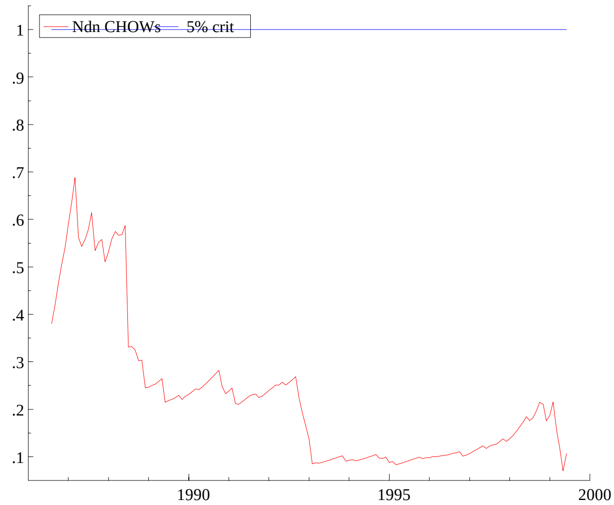
Building Society Deposit Rate



Bank Mortgage Rate



Building Society Mortgage Rate



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