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How do banks' funding costs affect interest margins? *

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Abstract: We use a dynamic factor model and a detailed panel data set with quarterly accounts data on all Norwegian banks to study the effects of banks' funding costs on their retail rates. Banks' funds are categorized into two groups: customer deposits and long-term wholesale funding (market funding from private and institutional investors including other banks). The cost of market funding is represented in the model by the three-month Norwegian Inter Bank Offered Rate (NIBOR) and the spread of unsecured senior bonds issued by Norwegian banks. Our estimates show clear evidence of incomplete pass-through: a unit increase in NIBOR leads to an approximately 0.8 increase in bank rates. On the other hand, the difference between banks' loan and deposit rates is independent of NIBOR. Our findings are consistent with the view that banks face a downward-sloping demand curve for loans and an upward-sloping supply curve for customer deposits.

JEL classification: E43, E27, C33
Keywords: interest rates, NIBOR, pass-through, funding costs, bank panel data, dynamic factor model

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1 Introduction

In this paper we investigate the pass-through from banks' funding costs to their retail rates. We do so by estimating an econometric model using quarterly microdata on individual Norwegian banks from 2001Q2 to 2010Q3. Our focus is on the transmission mechanism from changes in the level and volatility of market interest rates to deposit and lending rates. Traditionally this issue has been examined either by employing time series econometrics on aggregate bank interest rate data (e.g., Chong, 2010; Hofman and Mizen, 2004) or panel data methods on individual banks' interest rates (e.g., Hannan and Berger, 1991; De Graeve et al., 2007). In contrast, we consider the retail rates of various banks (or bank groups) as jointly dependent within a large system of equations.

There is related empirical literature on interest rate margins using banks' net interest income relative to total assets as the main dependent variable, either at the aggregate level (for a representative bank) (e.g., Saunders and Schumacher, 2000; Andersen et al., 2008) or, more rarely, at the bank level (e.g., Maudos, 2004). These approaches suffer from the weakness that the dependent variable is a mixture of price (interest rate) and volume effects. Hence, it is not straightforward to infer anything from these studies concerning responses of banks' interest rates or interest margins to changes in exogenous variables, because different effects are entangled.

We employ a detailed panel data set with quarterly accounts data on all Norwegian banks from 2001Q2 until 2010Q3. In the data, volumes and interest rates over a quarter are specified for various types of deposits and loans, according to sector (such as households or nonfinancial firms) and type of loan (mortgage, other loans). Microdata allow us to study heterogeneity between banks, for example, whether the interest margins of different banks react differently to exogenous shocks. Moreover, we are able to analyze differences in interest margins between loans to businesses and households, and in the speed of adjustment of banks' interest rates to changes in exogenous variables. The bank-specific dynamics in *retail rates* (in this paper defined as all interest rates on deposits and loans set by the bank) implies that estimates of long-run coefficients will be biased, even if the primary interest is in the parameters of the long-run relation between retail rates and funding costs of an average or "representative" bank (cf. Pesaran and Smith, 1995). This paper addresses this problem by estimating a flexible model with heterogeneous, bank-specific parameters from microdata and aggregating these with equations specific to each individual bank (or bank groups; see Section 3) to obtain the corresponding empirical relation for a representative bank.

We focus on (i) loans to households, (ii) loans to corporations in the nonfinancial sector and (iii) households' bank deposits. The corresponding interest rates are collected from all banks (or bank groups), placed in a high-dimensional system of equations and analyzed within the framework of dynamic factor modeling. This framework allows us to consider interdependence between retail rates and banks within one system of equations, while avoiding the "curse of dimensionality" associated with high-dimensional vector autoregressive (VAR) models. In accordance with most empirical literature on interest margins (e.g., Saunders and Schumacher, 2000), our model includes an interbank market rate, i.e., the three-month Norwegian Inter Bank Offered Rate (NIBOR), as an explanatory variable.

More specifically, we formulate and test particular hypotheses about the effects of changes in market rates on banks' retail rates, both in the short run and in a steady state. In particular, we consider three types of interest margins at the bank level: the difference between (i) the household loan rate and the deposit rate,

(ii) the corporate loan rate and the deposit rate and (iii) the average net interest margin: the ratio of total funding costs to total loans. The latter is a measure of banks' earnings per unit in total outstanding loan. In a competitive bank market, a permanent change in the marginal cost of wholesale funding should be passed fully over to loan and deposit rates (see Hannan and Berger, 1991). However, if banks have market power, they are faced with a trade-off between conflicting goals: high (low) interest on loans (deposits) on the one hand and high volume on the other. The spread between the price of market funding and retail rates may therefore change as a result of a change in the former; that is, there may be incomplete pass-through in both the long and the short run. The completeness hypothesis is formally tested in our analysis.

A novelty of our approach is that we consider the retail rates of each individual bank (or bank group) as interdependent endogenous variables within a joint system of equations, rather than independent units analyzed by means of panel data methods. The comovements among various banks' retail rates are captured in our approach by common dynamic factors. As a result, we are able to separate the effect on retail rates of common observed variables (such as interbank market rates) from the effect of unobserved common variables (reflecting, for example, changes in bank regulations, competition and productivity). The 10-year period we analyze is particularly interesting because it is characterized by increased competition between banks, as well as productivity growth due to wider use of Internet-based payment services.

The remainder of the paper is organized as follows. Section 2 discusses the main concepts and describes the empirical model, Section 3 presents the data, Section 4 presents the results and Section 5 concludes.

2 The modeling framework

Funding costs Banks need to raise funds to provide loans. We organize these funds into two categories: customer deposits and wholesale funding (market funding from private and institutional investors, including other banks). According to lenders, the marginal funding source for loans to households and businesses is wholesale funding. Banks may need to raise a large amount of funding over a short period. This cannot be done through raising retail deposits by increasing the rates on deposits, because bank customers (households and firms) typically do not react quickly to changes in interest rates. Wholesale funding is typically bonds, which to varying degrees match the expected maturity of the loans provided. There may be considerable heterogeneity between banks with regard to the extent and composition of market funding (e.g., regarding the maturity of debt). In this paper we interpret the marginal funding cost as that of raising senior unsecured bonds. An unsecured bond may be issued with a fixed or variable interest rate. In the first case, a Norwegian bank typically enters into an interest rate swap to achieve a level of variable rate exposure that matches the variable rate loans. The banks' costs may be expressed by two components: the variable rate cash flows paid in the interest rate swap (normally three-month NIBOR) and the fixed cash flow due to the issuer-specific credit spread over the swap rate[1]. In this paper we include both the three-month NIBOR and the spread of unsecured senior bonds issued by Norwegian banks as measures of the cost of market funding. The spread of unsecured senior bonds is represented by the indicative spreads of three-year bonds as reported by DnB NOR Markets. We use an index consisting of indicative bid spreads based on average trading levels over

[1]See https://www2.sparebank1.no/portal/1001/3_privat?_nfpb=true&_pageLabel=page_privat_innhold&aId=1201861729341 for examples of bank bonds with varying maturity and where the interest payment is typically equal to the three-month NIBOR plus a fixed credit spread.

the swap rate (three-year fixed/three-month NIBOR) for senior bonds issued by a range of Norwegian banks since 2001. The series includes DnB NOR Bank, Nordea Bank Norge and a representative selection of banks of various sizes and ratings.

It is clear from Figure 1 that until 2008 the variation in funding cost was dominated by variations in NIBOR. However, from 2008Q1 to 2008Q4, the spread increased dramatically, and was still much higher than its pre-2008 level at the end of 2010. The (issuer-specific) spread may consist of compensation for types of risk other than credit risk. During the financial crisis, a substantial part of the spread was compensation for liquidity risk; that is, it occurred largely because of reduced liquidity in funding markets[2]. Data for issuance indicate that the banks reduced their ordinary funding activity dramatically in this period. At the same time, several authority measures to support banks' funding took effect. The combined effect on banks' funding costs caused by observed increases in spreads seems difficult to assess. Hence, we have decided to include the credit spread as a separate variable, rather than adding it to the NIBOR rate to obtain an estimate of total long-term funding costs.

The net interest margin is the difference between the interest that a lender receives on all loans and the interest it pays on all funding of those loans divided by total loans. In our analysis we distinguish between two categories of loans: those to businesses (in the nonfinancial sector) and those to households. If L_H, L_B and D denote loans to households, loans to businesses and bank deposits, respectively, with corresponding interest rates r^H, r^B and r^D, and r denotes the (average) market interest rate, the average net interest margin, π, can be expressed as

$$\pi = \frac{(r^H - r)L_H + (r^B - r)L_B + (r - r^D)D}{L_H + L_B}. \tag{1}$$

π thus involves three interest spreads relative to the NIBOR rate: $r^H - r$, $r^B - r$ and

[2]See Chapter 3 (especially Figure 3.16) in Bank of England's Financial Stability Report, Issue 27, June 2010: http://www.bankofengland.co.uk/publications/fsr/2010/fsrfull1006.pdf

$r - r^D$. It is obviously important for banks' profitability how the market rate (r) is passed through to the retail rates (r^H, r^B and r^D). Assuming that the residual outstanding loan $L_H + L_B - D$ is financed by variable rate market funding at the rate r, π will be a measure of the *average* profitability per NOK in outstanding loans. A complementary issue, deferred for later study, is how interest rate changes affect demand for loans and supply of deposits.

Econometric model As mentioned above, our analysis distinguishes between two categories of loans: loans to businesses and households (the personal market). The corresponding loan rates for bank i ($i = 1, ..., N$) at time t ($t = 1, ..., T$) are denoted by r_{it}^B and r_{it}^H, respectively, where t refers to the end of a particular quarter in the given year. The interest rate on bank deposits is denoted by r_{it}^D. At this level of aggregation, r_{it}^D, r_{it}^H and r_{it}^B can be calculated as weighted averages of more disaggregate interest rates, where the weights are available from the outgoing balance in the bank accounts data (see Section 3).

Our explanatory variables represent the exogenous funding costs of banks and the associated risk. The main variable is the three-month NIBOR rate, r_t, which is a key determinant of external funding costs, as explained above. For the individual banks, it is reasonable to assume that r_t is exogenous; that is, the individual bank cannot influence NIBOR through its supply and demand for credit in the interbank market. The rationale behind this assumption is that (major) banks can borrow and lend NOK through the foreign exchange rate markets such as the NOK–USD exchange swap market. Covered interest rate parity implies that the NIBOR rate is determined by international lending and swap exchange rates, which are exogenous to individual Norwegian banks[3].

[3]For an example, see equation (1) in Akram and Christophersen (2011): http://www.norges-bank.no/upload/publikasjoner/staff%20memo/2011/staff_memo_0111.pdf

We also include the volatility of r_t, σ_t, as an explanatory variable. This variable is a proxy for interest rate risk, as described by Ho and Saunders (1981). In the Ho and Saunders model, banks finance the difference between the demand for loans and the supply of deposits by wholesale funding. If banks are risk averse, the interest margin between the loan rate and the deposit rate will be increasing in the volatility of the market rate[4].

In our empirical implementation, r_t and *squared* volatility, σ_t^2, are calculated quarterly, as weighted averages of daily interest rates and daily squared interest rate deviations from the mean, with geometrically decaying weights. Formally, let $r_{t,j}$, $j = 1, ..., M_t$ denote the NIBOR rate of day j in quarter t, where M_t is the number of trading days in quarter t. Then

$$r_t = \frac{1}{k_t} \sum_{j=0}^{M_t - 1} \lambda^j r_{t, M_t - , j},$$

with $k_t = \sum_{j=0}^{M_t-1} \lambda^j$. To measure σ_t^2, we calculate the weighted mean of the *squared deviations* $(r_{t,j} - r_t)^2$:

$$\sigma_t^2 = \frac{1}{\widetilde{k}_t} \sum_{j=0}^{M_t - 1} \xi^j (r_{t, M_t - j} - r_t)^2,$$

where $\widetilde{k}_t = \sum_{j=0}^{M_t-1} \xi^j$. In our application we use $\lambda = 0.9$ and $\xi = 0.5$, which means that the weight attached to the first observation in the quarter relative to the latest observation is about 10 percent for r_t, whereas only the latest 4–5 observations have nonnegligible weight when σ_t^2 is calculated. These parameter values approximately maximize the in-sample fit of the model when a grid search is conducted over possible λ- and ξ- values. We also include the spread of senior unsecured bonds, denoted by s_t, to examine the effect of changes in the credit spread on the banks' retail rates.

Our econometric model specifies a stochastic relation between the retail rates (r_{it}^D,

[4]This model has been developed further, for example by Allen (1988), to incorporate different types of deposits and loans, and by Angbanzo (1997), to allow both credit and interest rate risk. Empirical models of interest rate volatility and implications for interest rate risk are examined by Chan et al. (1992).

$r^H_{it}, r^B_{it},$) and the exogenous variables (r_t, σ_t, s_t) for each bank. It accommodates the following important features:

- asymmetries in the relation between the retail rates and r_t, depending on the sign of $\Delta r_t = r_t - r_{t-1}$;
- flexible short-term dynamics, where different r^X_{it}, $X = D, H, B$, are allowed to react differently to exogenous shocks;
- bank-specific parameters; stochastic shocks that are common across different banks (i) and type of interest rate (X);
- stochastic shocks specific to a particular bank and interest rate.

Conditional on the common explanatory variables, we model the individual retail rates as univariate autoregressive processes, augmented with common dynamic factors to account for joint dependencies. The use of common dynamic factors is a parsimonious way of capturing the comovements among variables. In contrast, the number of parameters in VAR models increases exponentially with the number of equations. Examples of dynamic factors are the so-called diffusion index models (see Forni et al., 2000, and Stock and Watson, 2002) and the factor-augmented VAR model, FAVAR (see Bernanke et al., 2005). However, our approach has more in common with the tradition of multivariate structural time series models than with the approximate dynamic factor models most commonly favored in the literature[5].

In our most general specification we assume that, for $X = D, H, B$; $i = 1, .., N$; and $t = 1, ..., T$:

$$\begin{aligned} r^X_{it} &= \mu^X_i + \alpha^X_{i,0} r_t + \alpha^X_{i,1} r_{t-1} + \alpha^X_0 \max(\Delta r_t, 0) + \alpha^X_1 \max(\Delta r_{t-1}, 0) + \\ &\quad \beta^X_{i,0}\sigma_t + \beta^X_{i,1}\sigma_{t-1} + \gamma^X_0 s_t + \sum_{j=1}^{p_i} \phi^X_{ij} r^X_{i,t-j} + \sum_{k=1}^{r} \theta^X_{ik} f_{kt} + e^X_{it}, \end{aligned} \tag{2}$$

[5]See Harvey (1989) for a general exposition of structural time series models.

where μ_i^X is a bank- and interest rate-specific fixed effect, the α-parameters capture the effects of the NIBOR rate by allowing both the current NIBOR rate, r_t (through $\alpha_{i,0}^X$), and the lagged NIBOR rate, r_{t-1} (through $\alpha_{i,1}^X$), to affect the current interest rate on loans ($X = H, B$) and deposits ($X = D$). One lag is allowed in order to capture the effect of notification rules that restrict the speed at which banks are allowed to increase their loan rates. Moreover, asymmetries in the effects of positive and negative changes are captured by the term $\alpha_0^X \max(\Delta r_t, 0)$ and the lagged term, $\alpha_1^X \max(\Delta r_{t-1}, 0)$. For example, if α_0^D is negative, the bank deposit rate r_{it}^D is changed more slowly as a result of a given positive change ($\Delta r_t > 0$) than for the corresponding negative change ($\max(\Delta r_t, 0) = 0$). The β parameters have an analogous interpretation as the corresponding α parameters with regard to the volatility of the NIBOR rate. The credit spread measure s_t is assumed to affect each bank through common parameters γ_0^X ($X = D, H, B$). The latter restriction is imposed in view of the very limited variation in s_t before 2008, as is evident from Figure 1.

How the effects of a shock in the explanatory variables evolve over time depends on the autoregressive parameters ϕ_{ij}^X, $j = 1, ..., p_i$. The number of lags, p_i, is allowed to differ from bank to bank. In practice, we find that $p_i = 2$ is adequate in most of the equations using the Akaike information criterion (see below). Finally, the unobserved stochastic terms consist of m dynamic factors, f_{kt}, $k = 1, ..., m$, which pick up the dependence across banks due to common, unobserved variables (e.g., effects of the business cycle, credit market regulations and competition) and the idiosyncratic error term e_{it}^X, that is, independent across banks (i) and over time (t). The vector $(e_{it}^D, e_{it}^H, e_{it}^B)$ is assumed to have a trivariate normal distribution, with covariance matrix Σ, whereas the dynamic factors, f_{kt}, are assumed to be independent, Gaussian AR(1) processes:

$$f_{kt} = \psi_k f_{k,t-1} + \eta_{kt},\ \eta_{kt} \sim \mathcal{IN}(0,1); k = 1, ..., m. \tag{3}$$

Thus, $(f_{1t}, .., f_{mt})$ are latent stochastic processes that capture the comovements between the interest rates of different banks not accounted for by the observed explanatory variables. The impact of the dynamic factors on the individual banks is determined by bank-specific impact coefficients, θ_{ik}^X. In our model the factors play a similar role to that of the "risk factor contributions" in Rosen and Saunders (2010), in the context of portfolio risk analysis. Our model is estimated by employing a version of the maximum likelihood algorithm described in Raknerud et al. (2010).

Partial effects Our econometric framework allows us to disentangle partial effects of changes in exogenous variables. In particular, we are interested in the effects of changes in market rates. Let $\Delta r_{i,t+j}^X(\delta)$ denote the causal effect $\Delta r_{i,t+j}^X = r_{i,t+j}^X - r_{i,t+j-1}^X$ due to a permanent change in r_t from $r_{t-1} = r^*$ to $r_{t+j} = r^* + \delta$ for $j \geq 0$ (all other variables are assumed to be constant when differencing). Then

$$\begin{aligned}
\Delta r_{it}^X(\delta) &= \alpha_{i,0}^X \delta + \alpha_0^X \max(\delta, 0) \\
\Delta r_{i,t+1}^X(\delta) &= \alpha_{i,1}^X \delta + \alpha_1^X \max(\delta, 0) - \alpha_0^X \max(\delta, 0) + \phi_{i1}^X \Delta r_{it}^X(\delta) \\
\Delta r_{i,t+2}^X(\delta) &= \phi_{i1}^X \Delta r_{i,t+1}^X(\delta) + \phi_{i2}^X \Delta r_{it}^X(\delta) - \alpha_1^X \max(\delta, 0) \\
&\vdots \\
\Delta r_{i,t+k}^X(\delta) &= \phi_{i1}^X \Delta r_{i,t+k-1}^X(\delta) + ... + \phi_{ip_i}^X \Delta r_{i,t+k-p_i}^X(\delta)\ (k \geq p_i).
\end{aligned}$$

The effect of a permanent change, initiated at time t, on $r_{i,t+h}^X$ is then given by the cumulative sum $\sum_{j=0}^h \Delta r_{i,t+j}^X(\delta)$. Moreover, in a steady state where all observed exogenous variables are assumed to be constant over time, $r_t = r$, $\sigma_t = \sigma$, $s_t = s$, we have

$$r_{it}^X = \frac{\mu_i^X}{1-\sum_{j=1}^{p_i}\phi_{ij}^X} + \left(\frac{\alpha_{i,0}^X+\alpha_{i,1}^X}{1-\sum_{j=1}^{p_i}\phi_{ij}^X}\right) r + \left(\frac{\beta_{i,0}^X+\beta_{i,1}^X}{1-\sum_{j=1}^{p_i}\phi_{ij}^X}\right) \sigma + \left(\frac{\gamma_{i,0}^X}{1-\sum_{j=1}^{p_i}\phi_{ij}^X}\right) s + d_t + \varepsilon_{it}^X, \tag{4}$$

where d_t captures the effects of the present and lagged dynamic factors, f_{js}, $s \leq t$, and ε_{it}^X is a moving average of the error terms e_{is}^X, $s \leq t$. Note that the parameters of the weighted average $\sum_{i=1}^N w_i r_{it}^X$, where w_i is the share of total assets (see Table 1), generally differ from parameters obtained by aggregating the variables first and then estimating the (aggregate) equation. This fact motivates a disaggregate analysis of microdata even if the main interest should be on aggregate results for the whole banking sector or a representative bank.

3 Data

The sample consists of quarterly accounts data on all Norwegian banks from 2001Q2 until 2010Q3 and is based on the accounts statistics for financial corporations assembled by Statistics Norway[6]. Bank-level data are aggregated into seven bank groups, as listed in Table 1. The grouping is done so that all banks in each group have a common covered bond mortgage (OMF) company. Covered bonds (OMFs) were introduced in Norway in June 2007 and have already become an important source of funding for Norwegian financial services groups and banking alliances[7]. Key statistics for the seven bank groups are given in Table 1.

Since 2001Q2, Norwegian banks have been obliged to report interest rates at the end of each quarter. We calculate the average interest rate of the banks in a group as a value-weighted average of the reported interest rates. From the bank statistics we have interest rates and volumes of various loans in each bank. The interest rates

[6] See http://www.ssb.no/skjema/finmark/rapport/orbof/ (in Norwegian).

[7] See the following article by Rakkestad and Dahl in Penger og Kredit 1/2010 (in Norwegian): http://www.norges-bank.no/Upload/80111/OMF_marked_i_vekst_PK_1_10_nov.pdf

Table 1: **Descriptive statistics for seven bank groups.**

	Percentage of market				Percentage of bank loans	
	Total assets	Loans to households	Loans to businesses	Deposits	Households	Firms
DnB NOR	42	33	32	35	64	35
Subsidiaries of foreign banks	14	13	17	12	60	40
Branches of foreign banks	13	11	17	10	54	46
SpareBank1-alliansen	15	20	17	19	68	32
Terra Gruppen	4	7	4	6	77	23
Other savings banks	10	14	11	13	70	30
Other commercial banks	3	3	3	4	69	31

are weighted by the corresponding nominal book values to obtain a value-weighted average interest rate. The three-month effective Norwegian Inter Bank Offered Rate (NIBOR) reported by Norges Bank is a proxy for the cost of long- and medium-term market financing. Illustrations of these interest rates are provided in Figure 2. The graph labeled "NIBOR +/- sigma" shows the range of *daily* NIBOR rates that lie within one standard deviation of the mean within the corresponding quarter.

There is considerable heterogeneity in the funding sources of banks. Small national banks tend to have more deposits than foreign or large national banks, while the latter banks rely more on market funding. For example, at the end of our sample period, Terra Gruppen, which is a group of small banks, has the highest ratio of household deposits over total loans over our sample period: 42 percent. The two foreign bank groups have the lowest ratio—18 percent—while Norway's largest bank, DnB NOR, has a ratio of household deposits over total loans equal to 29 percent. Figure 3 shows the difference in average deposit interest rates between a group of small banks and one of large banks. While the figure reveals considerable short-term fluctuations, there appears to be no systematic long-term difference between the deposit rates of these two bank groups.

Examining the stationarity of r_t To perform statistical tests and assess estimation uncertainty, it is important to assess whether the NIBOR rate is a unit root process or not, because this affects the asymptotic distribution of the maximum likelihood estimator. Taking as a starting point the assumption that r_t is *not* a unit root process, we can test this hypothesis using the test proposed by Choi (1994) in combination with Andrews' (1991) automatic lag truncation procedure, as recommended by Choi and Ahn (1999). We conducted the test both on daily data (yielding 2724 observations) and quarterly data. In neither case did we reject the null hypothesis of stationarity. For example, based on daily data the test statistic became 0.21, which is far from significant (P-value=0.45). This result is consistent with Choi and Ahn (1999), who do *not* reject that the real interest rate is stationary, using monthly data for several countries for 1980–1991 (Norway not included). Supporting evidence is provided by Anundsen and Jansen (2011), who reject the null hypothesis that the real interest rate is integrated of order one against the alternative of stationarity, analyzing quarterly NOK interest rate data for 1986–2008. Although we use nominal interest rates in our analysis, our data come from a period with inflation targeting and a low and stable inflation rate. Note that stationarity of r_t does not imply stationarity of the retail rates, r_{it}^X, because the common dynamic factors, f_{kt}, are allowed to be nonstationary. Thus there may be a (nonlinear) trend in the spread between retail rates and the NIBOR rate and/or in the loan and deposit interest margins, for example due to changes in competition or regulatory measures. This flexibility of our model is empirically important, because Figure 4 reveals a distinct decreasing trend for the interest margins between loans and deposits over the sample period.

4 Results

The results presented below are based on a final model specification where $\alpha_0^X = \alpha_1^X = 0$ for $X = H, B$. These zero restrictions were imposed because the estimates of α_0^X and α_1^X were clearly insignificant for both types of loans. On the other hand, we obtain a significant negative estimate of α_0^D equal to -0.22 (St. error= 0.06) and a negative, but insignificant, estimate of α_1^D equal to -0.08 (St. error= 0.06). Thus the deposit rate falls more quickly than it rises, but the loan rates do not.

In equation (5) estimates of steady-state equations for the weighted interest rates—that is, weighted by banks' market shares, w_i—are shown. These estimates are obtained by aggregating the individual equations shown in Table 2. Standard errors in parentheses are obtained by the delta method. We see that for the value-weighted average ("representative") bank, the coefficient of r in the steady state is close to 0.8, and is significantly below one for all three retail rates. Thus the hypothesis of complete pass-through in the long run is clearly rejected. If we examine the bank-specific estimates in Table 2, they are remarkably close to 0.8 across banks and interest rates. A formal test of whether all the steady-state coefficients of r are equal across banks is provided by the Wald tests reported in the last row of Table 2. We cannot reject the hypothesis of homogeneous long-run parameters. The corresponding equations for the two interest rate margins between loans and deposits are shown in (6), that is, the differences between the household loan rate and the deposit rates, and between the business loan rate and the deposit rates, respectively. We see that in the steady state, these two interest margins do not depend on r, because both estimates are almost zero.

With regard to the intercept of the steady-state equation, Table 2 shows that the bank-specific parameters vary considerably across banks, but also that the estimation uncertainty is considerably larger than for the steady- state coefficients of

r. The results from the Wald test show that we cannot reject the hypothesis that banks have the same steady-state intercept with regard to deposits, although we do reject it with regard to both types of loans.

Turning to the credit spread measure, the results in (5) show that there is no significant effect in the steady state of changes in s_t on the deposit rates. On the other hand, an increase in the credit spread induces a significant positive pressure on loan rates, especially loans to businesses. Recall that the underlying (short-run) parameters γ_0^X are common across banks, so we only report common long-run effects. The estimated effects on the interest rate margins between loans and deposits in (6) indicate that a permanent unit increase in credit spread leads to a long-term increase in these interest rate margins from roughly 0.3 to 0.4. It should be noted, however, that the estimated effects are identified mainly by events immediately before and after the onset of the financial crisis in 2008Q3 and must be interpreted with care, as discussed in Section 2. Specifically, as seen in Figure 1, from 2008Q2 we observe a marked fall in deposit margins and an increase in the margins of loans to households (relative to NIBOR). This pattern can be attributed to the sharp fall in the NIBOR rate during this period, which, according to our model estimates, causes an increase (decrease) in the loan (deposit) margins. The NIBOR rate fell, mainly due to a marked reduction in the policy rate. When the policy rate becomes very low, banks' opportunity to lower their deposit rates is limited, and the deposit margin falls. To compensate for the reduced margins on deposits, the banks may increase their margins on loans. Moreover, banks have a limited ability to quickly adjust the rates on loans because of notification rules, which may contribute to temporary high margins on loans during periods of falling policy rates.

$$
\begin{aligned}
\sum_{i=1}^{N} w_i r_{it}^{D} &= \mathrm{d}_t + \underset{(0.05)}{0.77} r + \underset{(0.24)}{0.58} \sigma - \underset{(0.08)}{0.08} s + \text{residual} \\
\sum_{i=1}^{N} w_i r_{it}^{H} &= \mathrm{d}_t + \underset{(0.05)}{0.80} r + \underset{(0.27)}{0.74} \sigma + \underset{(0.12)}{0.22} s + \text{residual} \\
\sum_{i=1}^{N} w_i r_{it}^{B} &= \mathrm{d}_t + \underset{(0.07)}{0.84} r + \underset{(0.33)}{0.70} \sigma + \underset{(0.14)}{0.32} s + \text{residual}
\end{aligned}
\tag{5}
$$

$$
\begin{aligned}
\sum_{i=1}^{N} w_i (r_{it}^{H} - r_{it}^{D}) &= \mathrm{d}_t + \underset{(0.03)}{0.03} r + \underset{(0.15)}{0.16} \sigma + \underset{(0.07)}{0.30} s + \text{residual} \\
\sum_{i=1}^{N} w_i (r_{it}^{B} - r_{it}^{D}) &= \mathrm{d}_t + \underset{(0.4)}{0.07} r + \underset{(0.24)}{0.12} \sigma + \underset{(0.09)}{0.40} s + \text{residual}
\end{aligned}
\tag{6}
$$

Let us now examine the impact of interest rate volatility, σ. The bank-specific parameter estimates shown in Table 2 reveal a high degree of statistical uncertainty regarding the impact of σ. Nevertheless, as predicted by economic theory (e.g., Ho and Saunders, 1981), the aggregate equations (5) show a significant positive relation between σ_t and the endogenous interest rates.

Figures 5 and 6 display the partial predictive power of r and σ, respectively, when all the other variables in the model (observed and unobserved) are kept constant over time. When the graphs are constructed, all variables except that on the horizontal axis are kept constant at the sample average, whereas the data points are ordered according to the variable on the horizontal axis. Comparing the actual data and the fitted interest curves in Figure 5, we see that the partial predictive power of r is quite good. On the other hand, using σ as (the only) explanatory variable results in large prediction errors, as evident in Figure 6.

Table 2: **Estimates of key parameters in the steady-state equation for six of the bank groups.** Standard errors in parentheses.

	Intercept			Coefficients of					
				r			σ		
Equation (X):	D	H	B	D	H	B	D	H	B
Bank A*	–.14 (.24)	2.82 (.23)	2.38 (.06)	.72 (.06)	.76 (.05)	.84 (.06)	1.04 (.39)	.87 (.26)	.46 (.30)
Bank B	–.26 (.16)	2.32 (.22)	2.05 (.06)	.79 (.03)	.82 (.05)	.86 (.06)	.52 (.19)	.75 (.26)	.40 (.27)
Bank C	–.27 (.34)	1.78 (.17)	1.33 (.35)	.91 (.04)	.85 (.04)	.93 (.07)	–.34 (.21)	.31 (.22)	–.17 (.55)
Bank D	–.30 (.21)	2.52 (.22)	2.45 (.39)	.79 (.04)	.82 (.05)	.82 (.10)	.70 (.22)	.80 (.25)	1.48 (.51)
Bank E	–.17 (19)	2.59 (.22)	3.55 (.29)	.78 (.04)	.80 (.05)	.73 (.05)	.69 (.21)	.63 (.26)	.79 (.26)
Bank F	–.22 (.23)	2.52 (.22)	2.83 (.49)	.76 (.04)	.81 (.05)	.77 (.07)	.58 (.19)	.71 (.25)	1.08 (.37)
Common estimate**	–.33 (.18)	2.34 (.20)	2.60 (.28)	.81 (.04)	.82 (.05)	.83 (.06)	.57 (.19)	.72 (.25)	.71 (.31)
P-value of Wald-test***	.15	.001	.000	.15	.53	.14	.004	.73	.20

* The bank groups reported here are not identified by name for confidentiality reasons.
**Average of bank-specific coefficients weighted by inverse variance.
***Wald test of the restriction that all parameters are equal (6 d.f.).

The estimated autoregressive parameters, ϕ_{ij}^X, corresponding to the bank-specific retail rates, and the AR(1) coefficients ψ_k, corresponding to the three common dynamic factors f_{kt}, are displayed in Table 3. The number of lags is equal to two in most cases, whereas the number of common factors is equal to three. These choices were made by applying the Akaike information criterion (see Raknerud et al., 2010, for details regarding model selection in a similar model). All the lag polynomials $1 - \phi_{i1}^X L - \phi_{i2}^X L^2$ (where L is the lag operator) have roots well outside the unit circle, so the individual retail rates clearly evolve as stationary processes after subtracting the effects of the dynamic factors f_{kt}. However, two of the dynamic factors are estimated to be unit root processes, so the retail series themselves are not stationary but evolve around a common stochastic trend. These common trends detect, among other things, the decrease in average loan-deposit interest margins over time that is evident from Figure 4. The downward trend in both household and business interest margins over time may occur because of increased competition and increased productivity in the banking sector.

The Wald tests reported in Table 3 reveal that there is significant bank-specific heterogeneity in the interest rate dynamics with regard to the first-lag parameter, ϕ_{i1}^X. On the other hand, the hypothesis that ϕ_{i2}^X has a common value across banks could not be rejected for any retail rate. The estimated autoregressive parameters are typically less than 0.2 in absolute value, with $\phi_{i1}^X > 0$ and $\phi_{i2}^X < 0$. These estimates suggest that retail rates adjust quickly to exogenous shocks.

Figures 7–8 depict the estimated response curves for the representative bank, that is, the *increase (decrease)* in retail rates as a function of time, given a permanent positive (negative) unit change in NIBOR ($\Delta r = \pm 1$). We see that all three curves are quite close, and stabilize at around 0.8, that is, $|\Delta r^X| \simeq 0.8|\Delta r|$. Moreover, the loan–deposit interest margins displayed in Figures 9–10 are not significantly changed at any point in time following the increase in NIBOR. The confidence intervals in the figures reflect the statistical uncertainty in the estimates of the interest rate response functions of the "representative" bank. As noted above, there exists significant asymmetry between the short-run effects of a unit increase and a unit decrease in the NIBOR rate. The speed of adjustments following a permanent unit increase ($\delta = 1$) and a decrease ($\delta = -1$) are further displayed in Table 4. Almost all of the adjustment is completed by the end of the first quarter after the change in NIBOR (quarter 1), and approximately one-third to a half of the full adjustment is conducted in the same quarter (quarter 0). The exception is the deposit rate when NIBOR increases; then, the adjustment in the same quarter is estimated to only approximately one-fifth on average, reflecting some rigidity in deposit rates in the case of a positive shock in the market rate. Table 4 reveals little, if any, systematic differences across bank groups.

Viewed in conjunction with the expression for banks' average net interest margin π in (1), our estimates reveal that π decreases with the level of the market rate, r, when r increases: the margins $r^H - r^D$ and $r^B - r^D$ remain unchanged, but the spread of loans relative to NIBOR, $r^H - r$ and $r^B - r$, decreases (because the coefficients of r are significantly less than one in the steady state). On the other hand, $r - r^D$ increases. In a perfectly competitive market, any increase in marginal funding costs, r, should be passed through to all retail rates. However, faced with a downward-sloping demand curve for loans, banks balance the positive price effect and the negative effect on the demand for loans when increasing their loan rates. Similarly, when faced with an upward-sloping supply curve for deposits, banks will take into consideration that deposits will decrease when the deposit rate is lowered. The presence of such effects is confirmed by our finding that the coefficients of r in (5) are clearly below one for all retail rates. This is in line with De Graeve et al.

(2007), who also analyze microdata, but contrary to most evidence from aggregate bank data (see De Bondt, 2002, for an overview).

The development in the average net interest margin of a representative bank when the NIBOR rate increases is illustrated in Figure 11. Here it is assumed that the average price of market funding in the quarter is equal to the three-month NIBOR. This assumption is not entirely realistic. First, the credit spread is ignored. Second, the *average* cost of market funding will not follow the NIBOR rate (the *marginal* cost) in the short run. The upper chart examines a scenario where the NIBOR rate is (*cet. par.*) gradually doubled from 2.6 at the beginning of quarter 0 to 5.2 percent at the end of quarter 0, and then remains permanently at this level. A tripling of the NIBOR rate to 7.8 during quarter 0 is illustrated in the lower chart of Figure 11. The immediate negative impact on the net interest margin is clearly visible. In the short run the banks can only partially adjust their retail rates, while (floating rate) market funding immediately becomes more costly. After 4–5 quarters, π stabilizes at a new but significantly lower level than the initial level because of incomplete pass-through. The peculiar nonmonotonic pattern in π in Figure 11 occurs because of the catch-up effect on the interest margins that follow the immediate decrease in π displayed in Figures 9–10. There is considerable heterogeneity between banks with regard to the effects of an increase the NIBOR rate. Banks with a large share of market financing (such as DnB NOR) are more vulnerable when NIBOR increases rapidly than are banks with a smaller share of market financing (such as Terra Gruppen). Banks' access to deposit financing makes them less vulnerable to short-run fluctuations in the NIBOR rate. On the other hand, to increase its market share a bank needs to rely more on market funding, which makes it more vulnerable to shocks in the market rate.

Table 3: **Estimates of autoregressive parameters for six of the bank groups.** Standard errors in parentheses.

	ϕ_{i1}^X			ϕ_{i2}^X			Common dynamic factors		
Equation: (X)	D	H	B	D	H	B	ψ_1	ψ_2	ψ_3
Bank A*	.56 (.08)	.24 (.06)	.35 (.08)	–.25 (.05)	–.18 (.04)	–.13 (.05)			
Bank B	.10 (.05)	.19 (.06)	.42 (.06)	–.18 (.03)	–.14 (.04)	–.14 (.04)			
Bank C	–.09 (.09)	.11 (.06)	.22 (.14)	–.10 (.05)	–.13 (.03)	–			
Bank D	.19 (.06)	.13 (.05)	.61 (.08)	–.15 (.04)	–.13 (.04)	–.10 (.04)			
Bank E	.14 (.05)	.11 (.05)	.24 (.05)	–.16 (.03)	–.13 (.04)	–.08 (.04)			
Bank F	.08 (.05)	.12 (.05)	.41 (.08)	–.14 (.04)	–.12 (.04)	–			
Common estimate**	.18 (.05)	.20 (.05)	.44 (.07)	–.13 (.04)	–.13 (.03)	–.09 (.04)	.59 (.04)	.99 (.01)	1.00 (.02)
P-value Wald-test***	.000	.005	.005	.40	.70	.22			

* The bank groups reported here are not identified by name for confidentiality reasons.

** The results for ϕ_{ij}^X are averages of bank-specific coefficients weighted by their inverse variance.

***Wald test of the restriction that all banks have equal parameters (6 d.f.).

Table 4: **Adjustment speed after a permanent change equal to delta in the NIBOR rate.** Standard errors in parentheses.

	Share of total adjustment in same quarter*				Share of total adjustment after one quarter			
	$\delta = 1$ $_{(increase)}$			$\delta = -1$ $_{(decrease)}$	$\delta = 1$			$\delta = -1$
Equation (X):	D	H	B	D	D	H	B	D
Bank A**	.34 (.08)	.42 (.06)	.41 (.06)	.59 (.08)	.71 (.07)	.99 (.06)	.89 (.04)	.97 (.05)
Bank B	.16 (.05)	.35 (.07)	.49 (.05)	.39 (.05)	.92 (.08)	.95 (.06)	.89 (.04)	1.06 (.03)
Bank C	.20 (.06)	.29 (.06)	.40 (.09)	.41 (.06)	1.05 (.08)	.99 (.06)	.77 (.05)	1.13 (.05)
Bank D	.20 (.05)	.32 (.07)	.72 (.08)	.43 (.05)	.82 (.08)	.98 (.05)	.88 (.06)	.98 (.04)
Bank E	.16 (.06)	.33 (.07)	.38 (.06)	.39 (.06)	.87 (.08)	.98 (.05)	.87 (.03)	1.01 (.03)
Bank F	.14 (.06)	.33 (.06)	.57 (.06)	.37 (.06)	.89 (.08)	.97 (.05)	.83 (.04)	1.03 (.04)
Common estimate***	.18 (.05)	.33 (.06)	.48 (.07)	.41 (.06)	.88 (.07)	.97 (.05)	.85 (.03)	1.02 (.03)
P-value Wald-test****	.72	.73	.006	.34	.28	.13	.55	.29

* That is, $\Delta r^X_{i,t}(\delta) \Big/ \sum_{j=0}^{\infty} \Delta r^X_{i,t+j}(\delta)$, $X = D, H, F$

**The bank groups reported here are not identified by name for confidentiality reasons.

*** Average of bank-specific coefficients weighted by inverse variance.

****Wald test of the restriction that all banks have equal parameters (6 d.f.).

5 Conclusion

We have used a dynamic factor model and a detailed panel data set with quarterly accounts data on all Norwegian banks to study how banks' funding costs affect their interest rates. Our estimates reveal that for a representative bank the net interest margin decreases with the level of the market rate, because we find clear evidence of incomplete pass-through from the market rate to retail rates. The cost of market funding is estimated by the three-month Norwegian Inter Bank Offered Rate (NIBOR).

Our estimates show that a unit increase in NIBOR leads to an approximately 0.8 increase in banks' retail rates (both loan rates and deposit rates) in the long run. Our findings are consistent with banks facing a downward- sloping demand curve for loans and an upward-sloping supply curve for customer deposits. While the margin between loan and deposit rates remains unchanged when the NIBOR rate increases, the spread between the loan rate and the NIBOR rate decreases. Our results indicate that banks balance a positive price effect and a negative effect on the demand for loans when deciding on an increase in lending rates. There is also a significant positive relation between the indicative credit spread of uncovered bonds issued by banks and loan rates, especially regarding loans to businesses. The estimated effects on the interest rate margin between loan and deposit rates indicate that a permanent unit increase in credit spread leads to a long-term increase in the interest rate margins of roughly 0.3 to 0.4.

The econometric relations established in this paper should be useful in a stress test framework, where the interest is typically in how shocks in market rates or policy rates affect banks' lending rates and net interest margins. Another topic, which is currently of great policy importance, is how the effect of tighter capital and liquidity requirements, for example as proposed in the Basel III reform, will affect bank rates (see Angelini et al., 2011). For example, the reform is expected to increase the average maturity of banks' wholesale funding, which will increase the credit spread relative to NIBOR if the yield curve is increasing. To the extent that the direct impact of these regulatory measures on the (indicative) credit spread can be assessed, our econometric framework can be used directly to estimate the impact of such changes on lending rates and interest margins.

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Figures

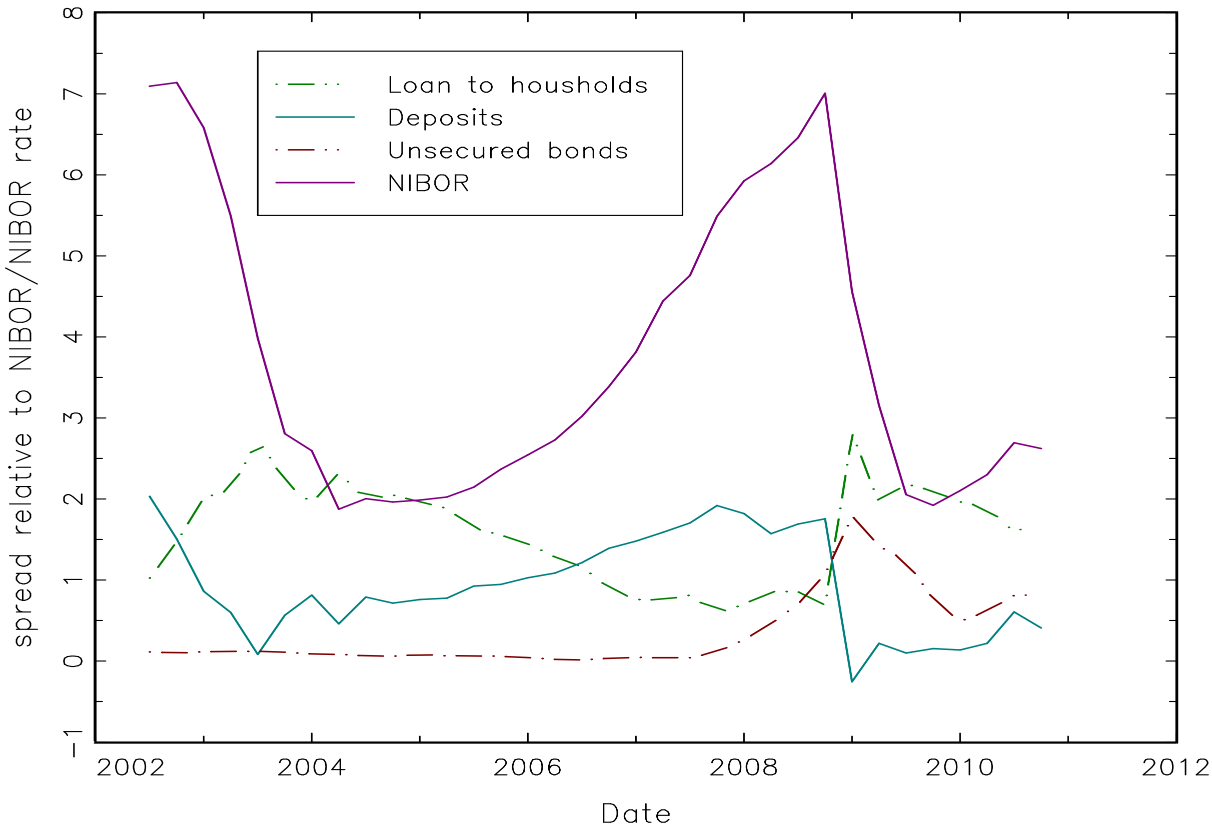


Figure 1: The NIBOR rate and interest rate spreads relative to NIBOR on i) loan to housholds ($r^H - r$), ii) bank deposits ($r - r^D$) and iii) unsecured bank bonds (s)

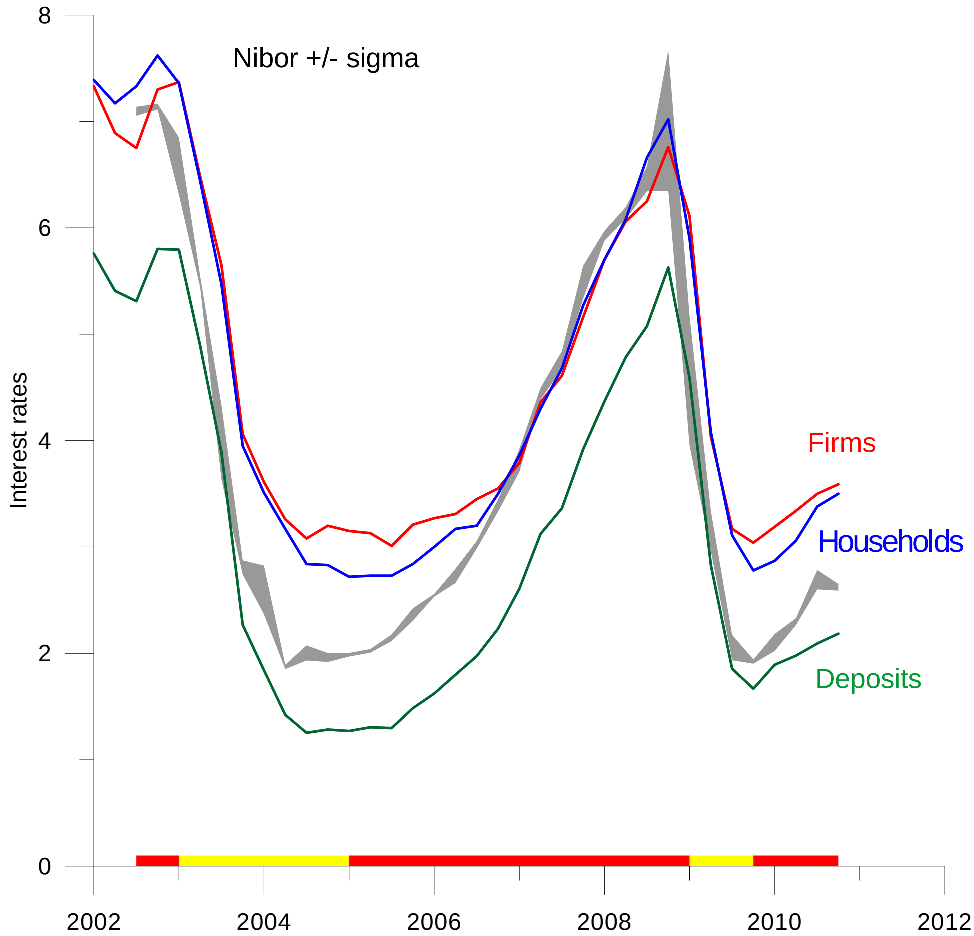


Figure 2: Three month NIBOR rates and average bank interest rates on deposits and loans to firms and housholds

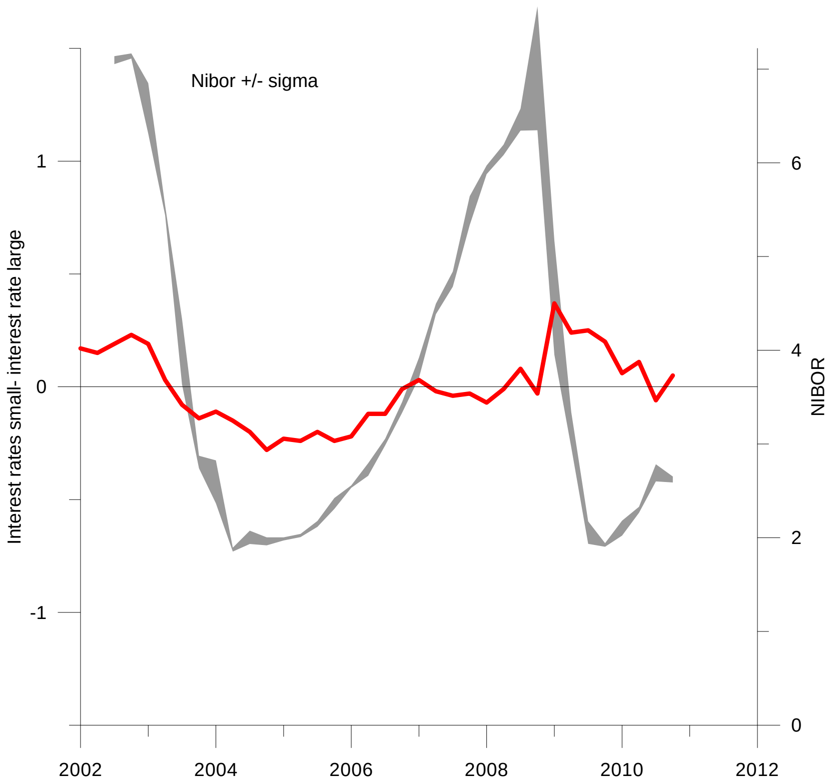


Figure 3: The deposit interest rate difference between a group of small banks and a group of large banks

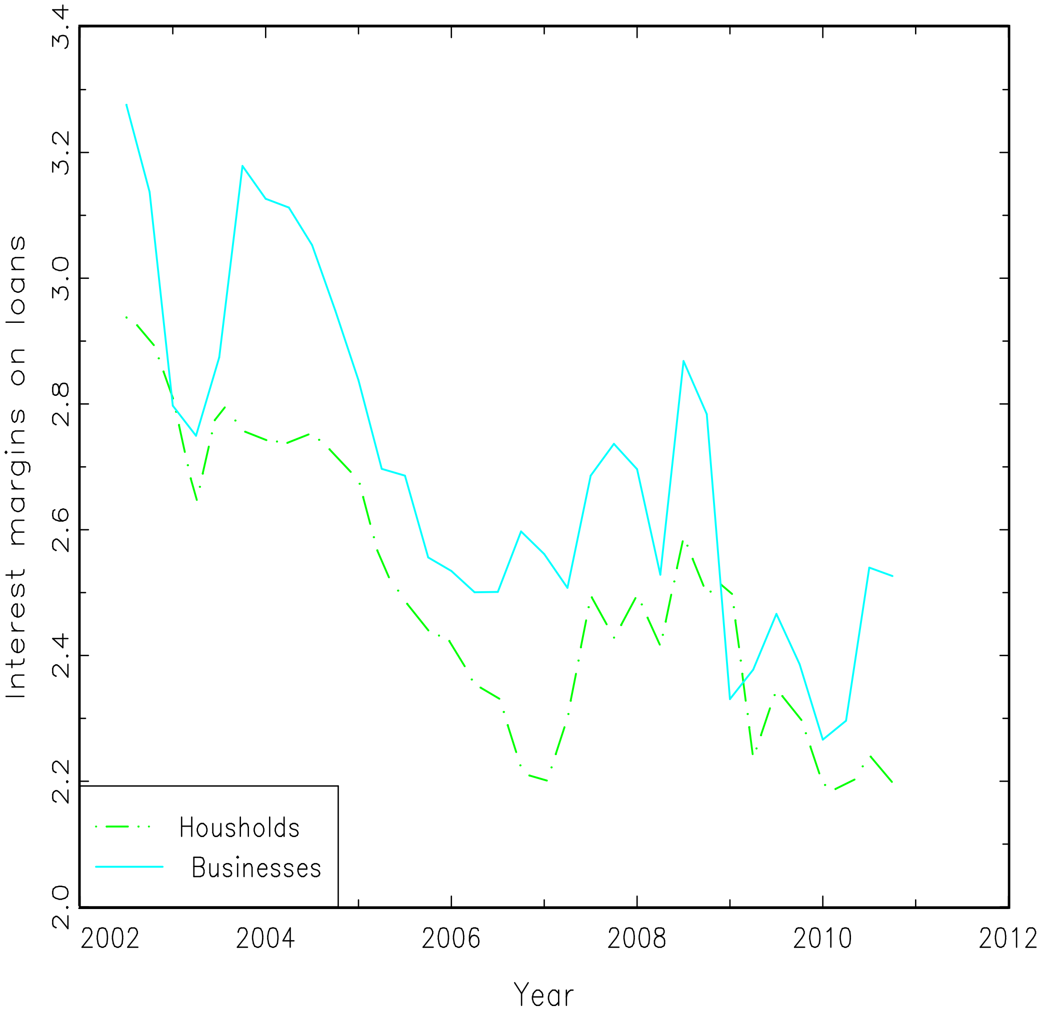


Figure 4: Interest margins between loans and deposits 2002-2010. Weighted average across banks

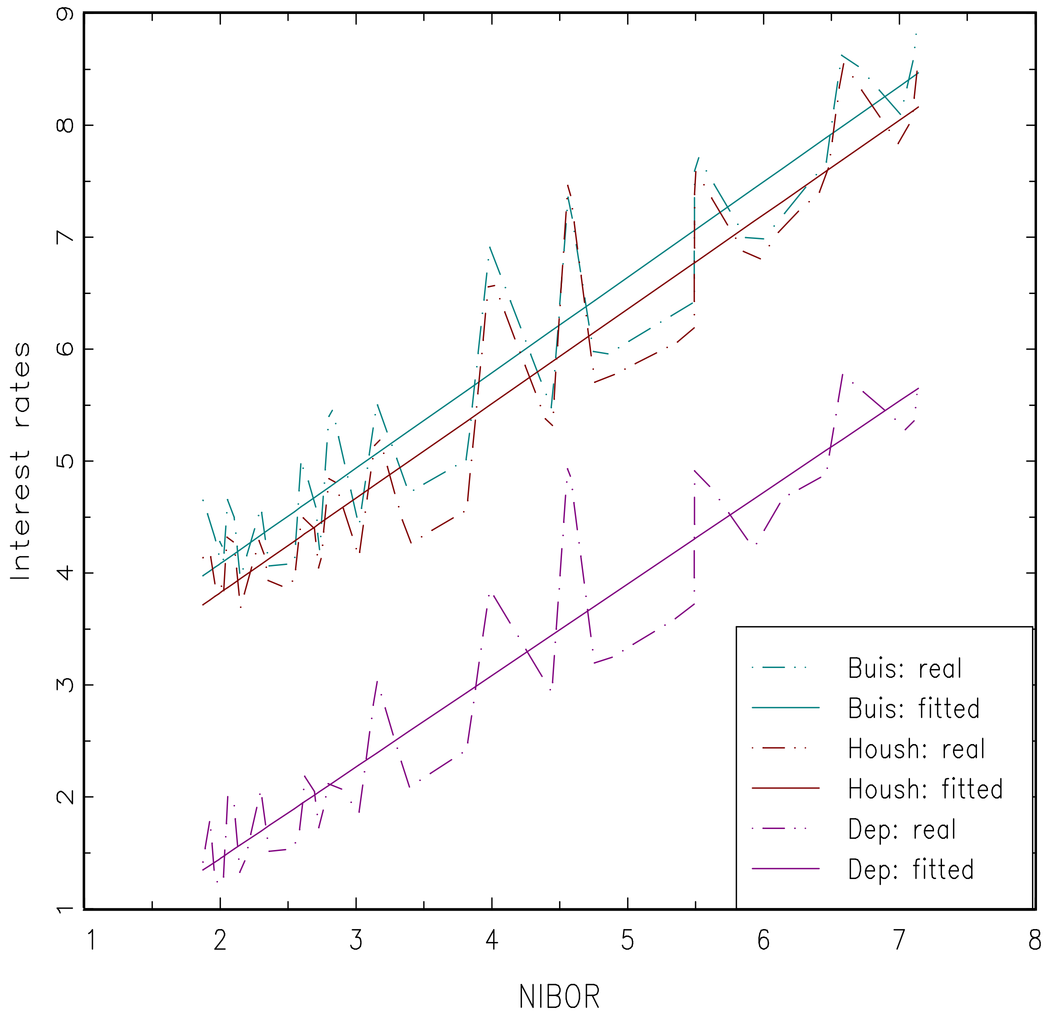


Figure 5: Actual data and fitted interest rate curves from estimated steady state equation using NIBOR as sole predictor

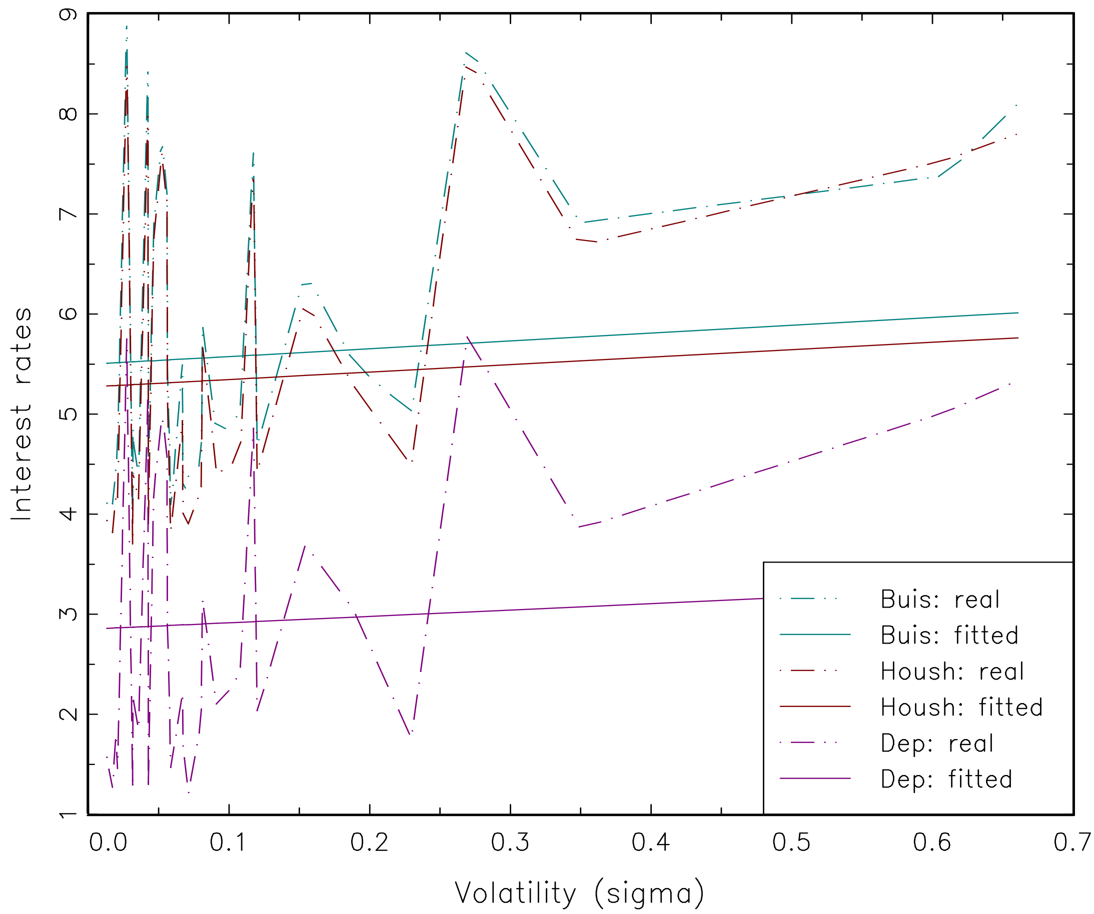


Figure 6: Actual data and fitted interest rate curves from estimated steady state equation using volatility as sole predictor

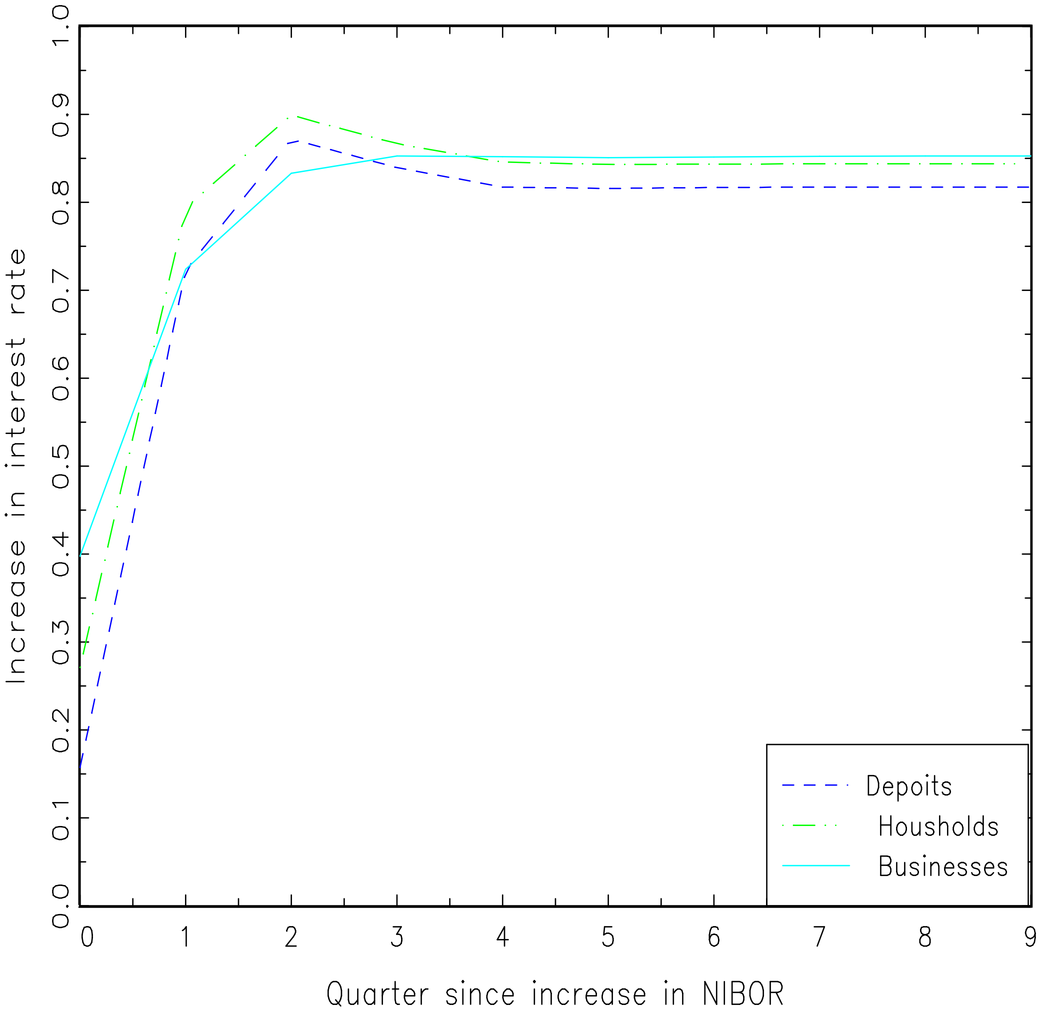


Figure 7: Estimated interest rates response functions: effects of a unit increase in NIBOR. Average across banks

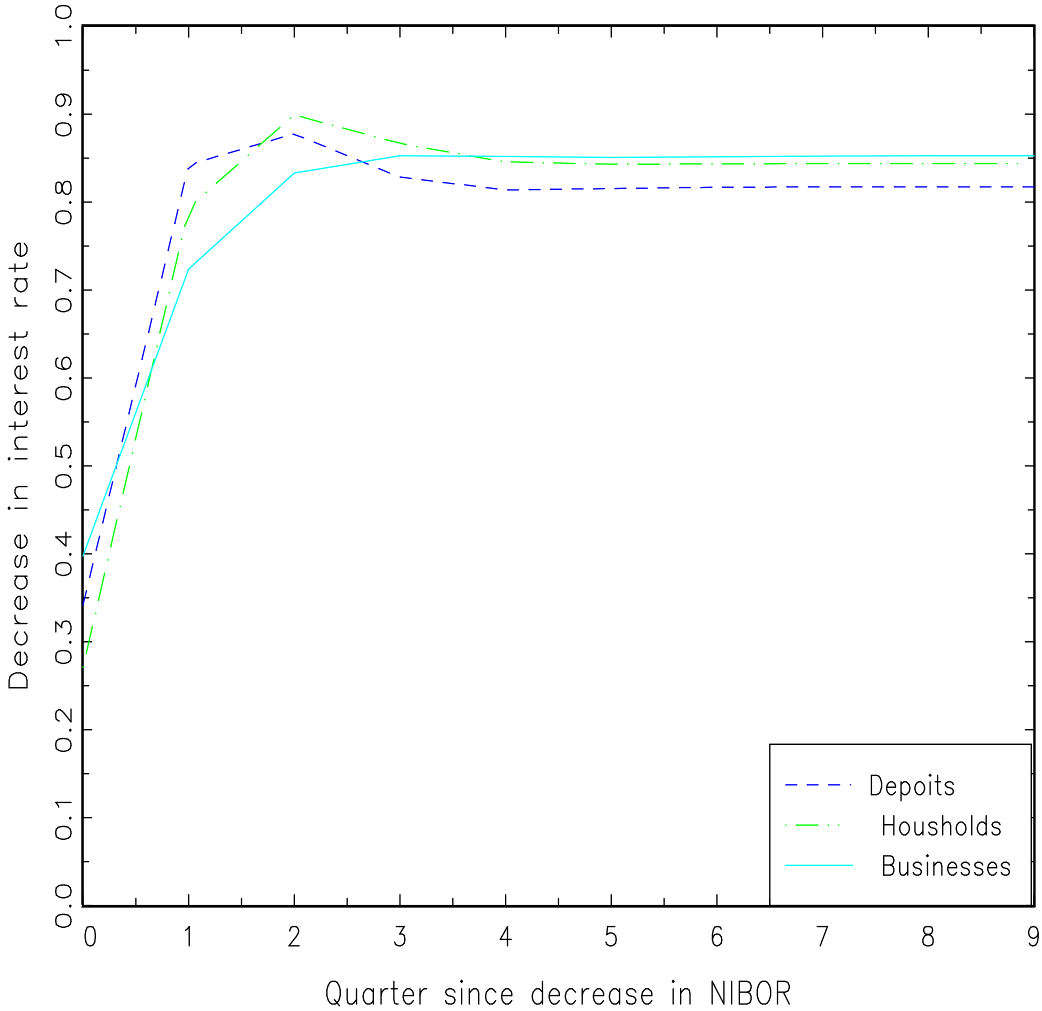


Figure 8: Interest rates response functions: effects of a unit decrease in NIBOR

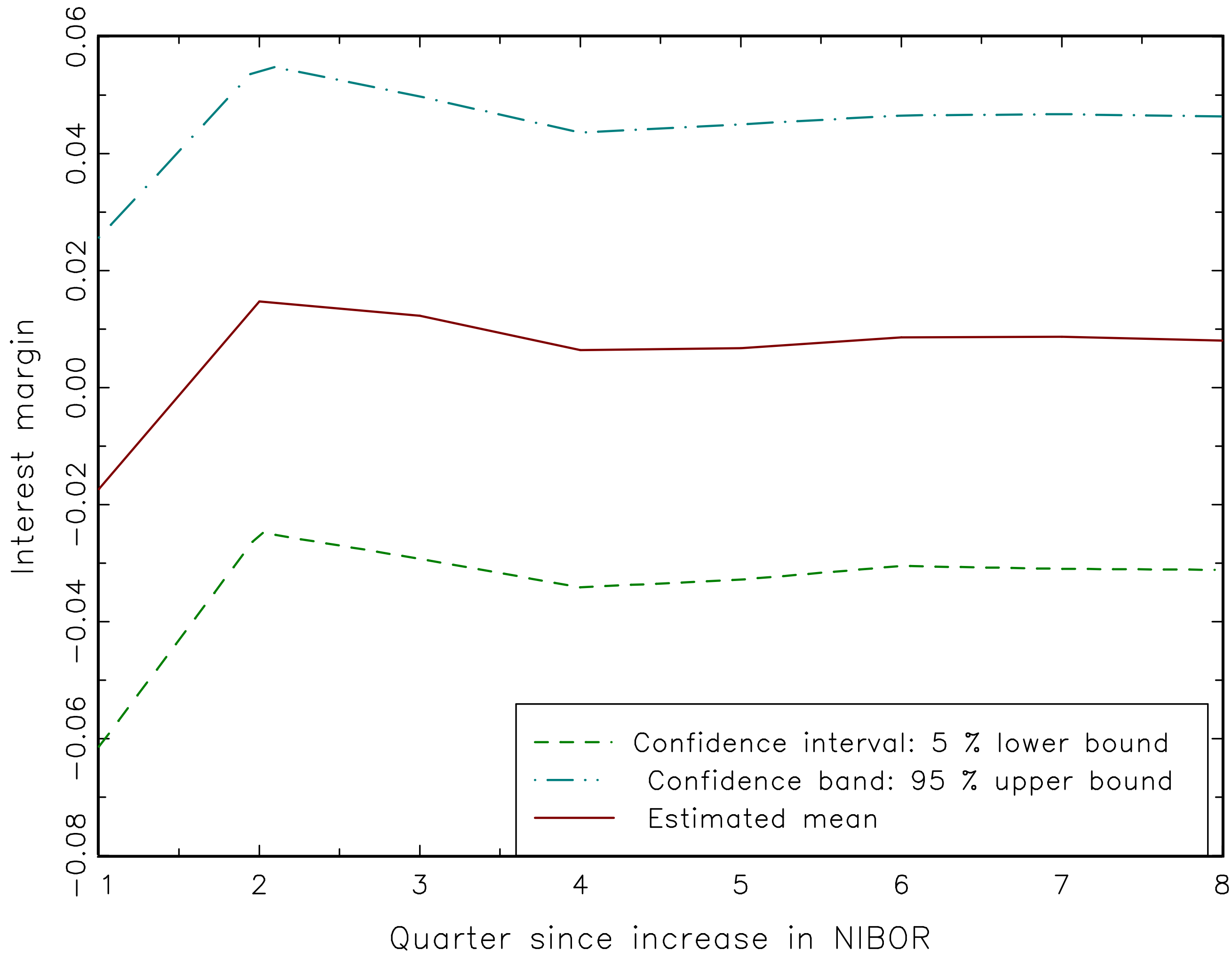


Figure 9: The difference between the houshold loan rate and deposit rate after of a unit increase in NIBOR for a representative bank

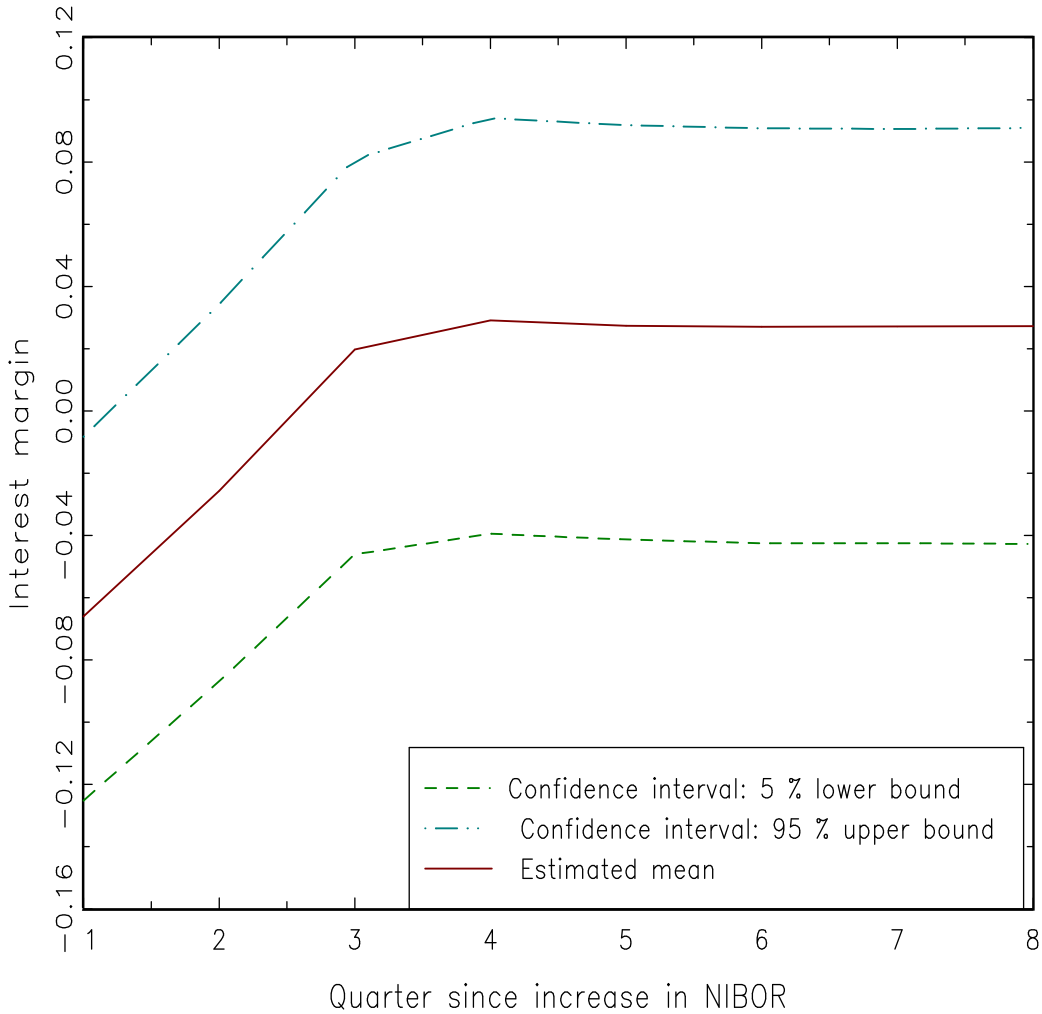
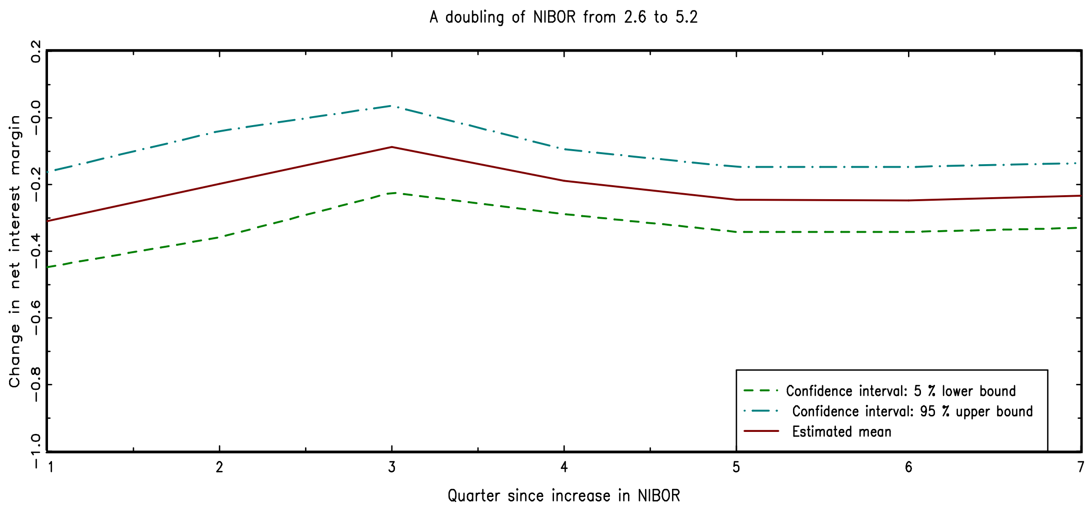


Figure 10: The difference between business loan rate and deposit rate after of a unit increase in NIBOR for a representative bank



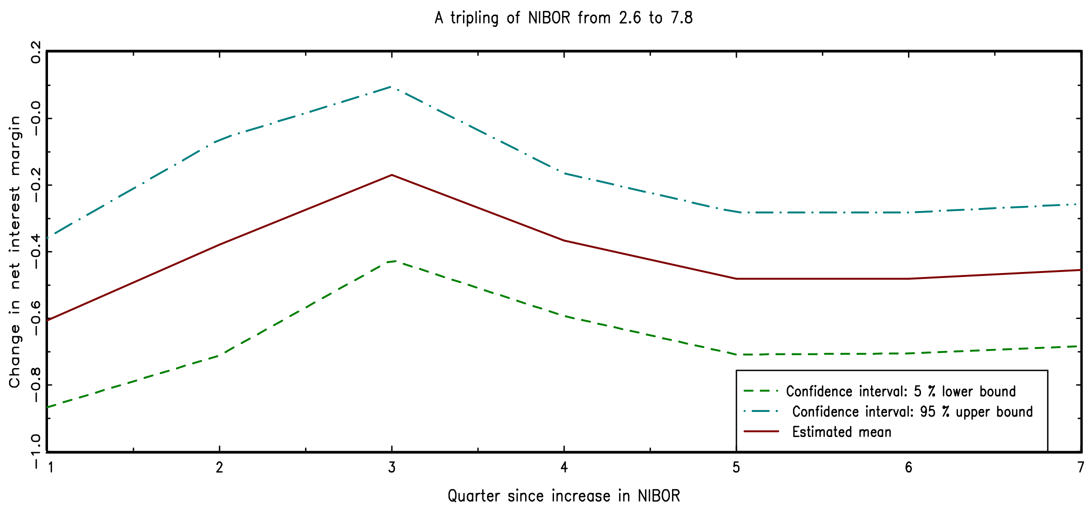


Figure 11: The estimated change in net interest rate margin when increasing NIBOR from 2.6 to 5.2 and 7.8 per cent. Weighted average across bank groups