EUROPEAN CENTRAL BANK
EUROSYSTEM

Modelling the duration of retail bank deposits

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We investigate the behaviour of depositors in response to changes in the interest rate environment through a simple model of banks' deposits, comparable to the ones used by banks in their Asset and Liability Management (ALM). In the low interest rate environment, when negative rates were largely not passed to retail customers, the duration of retail deposits was much higher than during 'normal times', when a shortening in the duration of liabilities may impact the overall interest rate risk taking. We further model how the deposit volatility experienced by banks' during an idiosyncratic shock reflects in a shortening of deposit duration, an input seldom considered by banks in their ALM. We also report on the model risk inherent in deposit modelling assumptions, which has several implications for banks' risk management.

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1 Introduction

This paper studies the behaviour of euro area retail bank deposits in response to changes in interest rates. Bank deposits are of special interest to economists and policy makers alike for several reasons. First, the ability to issue deposits is a privilege that comes with a banking license. Accordingly, deposits are particularly relevant for bank funding, with household deposits accounting for 23% of banks' total liabilities as of January 2023 according to BSI statistics. Second, most deposits are 'non-maturing': they do not have a pre-arranged maturity and can be withdrawn on demand at any time. From the perspective of banks, this gives rise to both liquidity risk, since the maturity of a large component of their liabilities is effectively random while the maturity of assets is mostly pre-defined, and to interest rate risk, as the repricing profile of deposits can vary over time, for example as a function of the competitive environment, whereas the repricing profile of most other assets and liabilities is fixed or indexed to market rates. To manage these risks and optimize their Asset Liability Management (ALM), banks typically employ statistical models that estimate the behaviour of their deposit base (**Hoffmann et al., 2019**). A general feature of these models is that deposit behaviour is not fully elastic with respect to interest rates changes (**Drechsler et al., 2019**).

Supervisory analyses conducted by the European Central Bank (ECB) highlighted how inadequate modelling can give rise to asset-liability mismatches and undue exposure to interest rate risk (**ECB, 2017**). European regulators require banks to consider the model risk associated to deposit models and to regularly assess the dependency of deposit models to interest rate levels (**EBA, 2022**). Risk management challenges related to the ALM profile of bank deposits have been highlighted by bank failures in the first half of 2023 (**Federal Reserve, 2023**).

Third, bank deposits are subject to significant frictions in a negative interest rate environment. In particular, banks have proven reluctant to passing on negative policy rates to the bulk of their retail depositors, reflecting banks' considerations over the commercial and regulatory value of those deposits, as well as legal constraints (**Demiralp et al., 2021**). Since bank deposits were thus effectively remunerated above market interest rates, their volume has grown significantly over the past decade. Other things equal, this development weighed on banks' profitability. There is evidence that they aim to counter this effect by increasingly investing into riskier assets (**Heider et al., 2019**). [A comment on the abrupt reversal of 2022/ 2023]

Against this background, we study a rich Eurosystem bank-level dataset on deposit rates and volumes. Our analysis is guided by a simple model in the spirit of **Jarrow and van Deventer (1998)**. More specifically, we develop a simple statistical model with four building blocks: market interest rates, deposit rates, deposit volumes, and bank risk (proxied by sovereign CDS premia).

Our model features market rates that follow a random walk and are subject to a lower bound of -60 bps, as well as a limited and bank-specific pass-through of deposit rates to market rates. Moreover, we allow deposit growth to depend on the opportunity cost of holding bank deposits, as well as bank risk. Using simulations, we derive estimates for the effective duration of retail deposits based on the sensitivity of the net present value of banks' deposit liabilities to changes in interest rates.

Our findings for sight deposits are as follows[1]. Consistent with the existing literature on imperfect competition in deposit markets (**Hannan and Berger, 1991, Neumark and Sharpe, 1992**), we find a limited pass-through from market to deposit rates. Using an error correction model, we estimate a short-run pass through of 9% and a long-run pass-through of 29% for sight deposits. As expected, the growth of deposit volumes depends positively on the difference between deposit and market rates, a proxy for the opportunity cost of holding deposits vis-à-vis investing them. A 100 bps increase in this interest rate differential is associated with an annual deposit growth of 5%. Similarly, an increase of the domestic sovereign CDS spread beyond 200 bps implies a decrease in deposit volumes of 5% per year. Both effects are economically and statistically significant.

Based on our model estimates, we then conduct simulations to obtain 1,000 sample paths for the future developments of all relevant quantities. We use these to compute the duration of retail sight deposits, which is given by the sensitivity of the deposit liability to an increase in market rates. Crucially, the duration estimates in our setup are a function of the time-horizon of the simulation. We obtain a duration of 8.7 years over a simulation time horizon of 10 years for the average bank and we illustrate the sensitivity of this estimate to changes in market interest rates.

Finally, we examine how our estimate for the expected duration behaves under two different scenarios: (i) a sudden increase in market rates by 200bps; and (ii) an increase in the pass-through from market to deposit rates by two standard deviations. Both scenarios imply a significant shortening of deposit durations.

Our results are relevant from a policy perspective for several reasons. First, they provide a yardstick for assessing the impact of low interest rates and non-standard policy measures on the profitability of banks' maturity transformation activities. Second, the fact that we adopt the same model for a wide range of banks provides benchmark estimates for interest rate pass-through and deposit durations. Cross-countries differences matter in explaining the Asset Liability Management choices by banks in the euro area. Third, our sensitivity analyses reveal potential vulnerabilities for banks asset and liability stemming from changes in customer behaviour and changes in market rates, that is deposit duration is likely to shorten significantly in an increasing interest rate environment. Fourth, we provide evidence that banks' creditworthiness affects its interest rate risk profile significantly, and not only its liquidity risk profile, a feature that is not always incorporated in banks' risk management toolkit.

Our work is closely related to the existing literature analysing the duration of non-maturity deposits. Broadly speaking, this literature relies on two different modelling approaches.

[1] We obtain qualitatively similar findings for redeemable-at-notice (RAN) deposits, which display a higher pass-through and a lower expected duration consistent with their nature as savings product.

One strand of the literature uses a “replicating portfolio” to approximate the behaviour of deposit liabilities according to a specific criterion (based on historical data), such as the standard deviation of the net interest margin (**Maes K., Timmermans T. (2005)**), or the maximisation of the Sharpe ratio of net interest income (**Konings W., Ducuroir F (2014)**). The duration of the deposit franchise can then be computed as the duration of the replicating portfolio.

By contrast, stochastic models of non-maturing deposits make assumptions concerning the evolution of market interest rates, deposit rates, and deposit volumes. Based on these, they are able to derive the net present value of the deposit value, and its sensitivity to changes in interest rates. The latter provide an estimate of the deposit duration. This approach was spearheaded by the seminal contribution of **Jarrow and van Deventer (1998).**

2 Modelling strategy

Our analysis builds on the seminal approach of **Jarrow and van Deventer (1998)**. The net present value of a non-maturity deposit liability, denoted by V_0, is equal to the expected sum of discounted margins earned on their face value. The margin is given by the difference between short-term market and deposits rates. Formally,

$$V_0 = E_0\left(\sum_{t=0}^{\tau-1}\frac{D_t(r_t - d_t)}{B_{t+1}}\right) \qquad (1)$$

where D_t is the deposit volume at time t, d_t is the deposit rate, r_t is the short-term risk-free rate and B_{t+1} is the price of a money market fund at time t (i.e. $B_0 = 1$ and $B_{t+1} = B_t(1 + r_t)$).

To estimate equation (1), one needs to make assumptions concerning the evolution of the risk-free rate, the deposit rate, and deposit volumes. We next describe our specifications for these three building blocks.

2.1 Risk-free interest rate

The short-term market rate r_t reflects the opportunity cost that investors face when allocating their portfolios on risky assets. We assume that changes in the market rate follow an AR(1) model in first differences. Furthermore, we introduce a lower bound at -0.6%.[2] Our model is

$$\Delta x_t = \mu \Delta x_{t-1} + \epsilon_t$$
$$r_t = \max(x_t, -0.6\%) \qquad (2)$$

This specification captures the autocorrelation generates by central bank policy rate cycles: increases in policy rates are likely to be followed by further increases in policy rates. While the model is very simplistic, it has a few advantages over standard interest rate models used in the literature. For example, a CIR model (**Castagna, Manenti, 2013**) does not allow for negative interest rates. Similarly, a Vasicek model (**Castagna and Scaravaggi, 2017**) is empirically indistinguishable from a random walk based on historical data from the last two decades due to the secular decline in interest rates.

2 Marginal changes to this lower bound do not materially affect our analysis provided it is below zero.

2.2 Deposit interest rate

In the existing literature, deposit interest rates are often modelled as linear function of market interest rates (see **Elkenbracht and Nauta, 2006**). While the simplicity of such a specification is appealing, it implies that deposit rates adjust instantaneously to changes in market rates. However, such adjustments are considerably more sluggish in practice because banks tend to exert considerable market power in deposit markets (**Hannan and Berger, 1991**, **Neumark and Sharpe, 1992**).

We therefore assume that individual bank deposit rates evolve according to an Error Correction Model. While there is a long-term linear relationship between market and deposit rates, the adjustment is only gradual. Our model is

$$\Delta d_{i,t} = \beta_i \Delta r_t - \kappa_i (d_{i,t-1} - \gamma_i r_{t-1} - \alpha_i) + \varepsilon_{i,t} \qquad (3)$$

where κ_i is the speed of adjustment of the deposit interest rate towards the long-term relationship $d_{i,t-1} = \gamma_i r_{t-1} + \alpha_i$, and β_i is the short run pass-through – the response of deposit rates to contemporaneous changes in market rates. The long run pass-through is γ_i. For the process to be stationary, we require $\alpha_i > 0$. We expect that the long-run pass-through is larger than the short-term one, i.e. $0 \leq \beta_i \leq \gamma_i \leq 1$.

2.3 Deposit volumes

We assume that depositors face a choice between holding bank deposits remunerated at rate $d_{i,t}$ or financial market instruments which yield the risk-free market rate r_t. In normal times, deposit rates are below market rates because consumers derive an additional utility from deposits with respect to risk free assets (e.g. transaction/payment services). The relative attractiveness of bank deposits vis-à-vis market rates is reflected in interest rate differential $d_{i,t} - r_t$ ("opportunity cost"). As the remuneration of financial market instruments increases (decreases) relative to deposits, deposits will flow out of (into) the banking system, which is known as the "deposit channel of monetary policy" (see **Drechsler et al., 2017**)

Deposit volumes can also be affected by risk considerations, especially in the absence of unlimited and fully credible deposit insurance (see **Bonfim and Santos, 2020**). Depositors may respond to increases in idiosyncratic bank risk by re-allocating their savings to other instruments or other banks. However, the relationship between deposit volumes and bank risk will typically non-linear, as depositors are only likely to become concerned once bank risk is at elevated levels.

Based on these considerations, our model for the growth of deposit volumes is combining the impact of the opportunity cost and of the CDS spreads. We assume the deposit volume growth is given by

$$\Delta \ln D_{i,t} = \phi_i + \lambda_i (d_{i,t} - r_t) + \theta_i \mathbf{1}_{CDS_{c,t} > 200bp} + \varepsilon_{i,t} \qquad (4)$$

Due to the limited coverage of bank-level data on individual risk profile, we proxy bank risk by sovereign risk, based on the economic relevance of the bank-sovereign nexus (**Dell'Ariccia et al. ,2018**). Therefore, $\mathbf{1}_{CDS_{c,t}>200bp}$ is a dummy variable equal to one if the CDS premium for country *c* (the domicile of bank *i*) exceeds 200 bps at time *t*, and zero otherwise.[3] Following our discussion, we expect $\lambda_i > 0$ and $\theta_i < 0$.[4]

In order to operationalize equation (4), we additionally need to model sovereign CDS premia. We assume that the natural logarithm of CDS premia follows an AR(1) process, that is

$$\ln CDS_{c,t} = \eta_c + (1-\rho_c)\ln CDS_{c,t-1} + \varepsilon_{c,t} \qquad (2)$$

This specification ensures that the modelled CDS premia cannot be negative, and that volatility increases with the price level.

[3] The threshold of 200bps was chosen based on a sensitivity analysis.

[4] In the estimation, we restrict θ_i to be non-positive.

3 Data

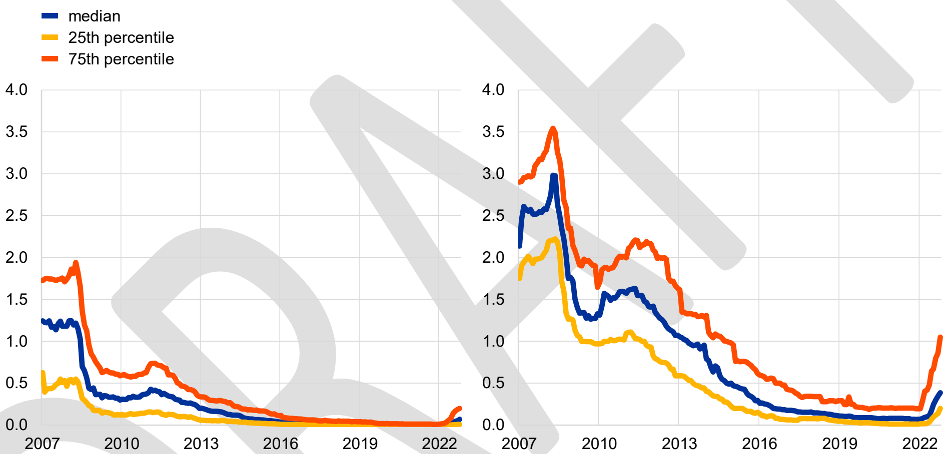
Our dataset contains monthly bank-level information on deposit volumes and interest rates for euro-denominated deposits from July 2007 to January 2023. The information is collected by the Eurosystem to monitor the transmission of monetary policy in the euro area[5]. We focus on household demand deposits[6] and saving deposits which are redeemable at notice (henceforth RAN deposits) with a notification period up to 3 months. Chart 3.1 depicts the time-series evolution of the underlying interest rates, separately for each category, while the chart 3.2 shows aggregated deposit volumes for the euro area

Chart 3.1

Deposit interest rates observed in the sample

for demand deposits and saving accounts

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: years; vertical axis: interest rate in percentages)



Sources: Authors' calculations based on IMIR data.

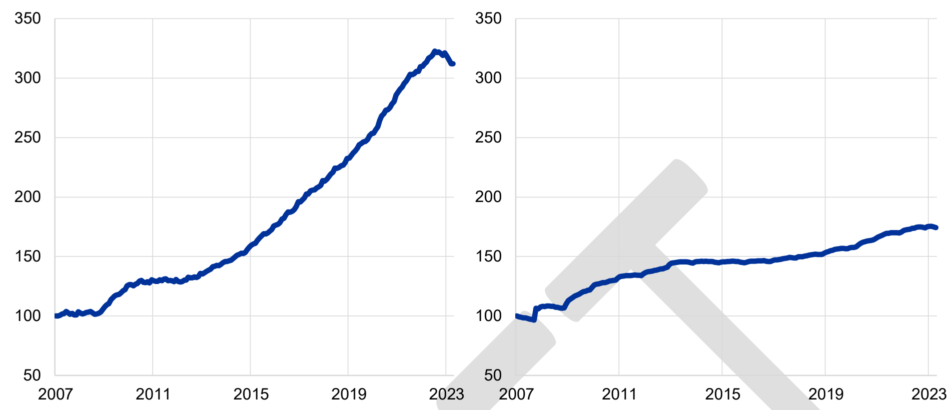
[5] The same data collection also produces aggregate country-level series for deposit rates and volumes. We provide an overview of these data in the Annex. is also Country level summary is available in the annex in Table 7.1 and Table 7.2 for sight deposits and deposits redeemable at notice respectively.

[6] This category includes sight deposits

Chart 3.2
Deposit volumes observed in the sample

for sight deposits and saving accounts

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: years; vertical axis: index Jan 2007 = 100)



Sources: Authors’ calculations based on BSI data.

The database contains information on 318 banks. We restrict the sample to series that are economically meaningful (bank-level deposit volumes that exceed 1 billion euro and constitute at least 5% of total liabilities) and have a time series of at least five years. These conditions are applied separately to the data on demand deposits and savings accounts. This implies that there are banks which we retain for only one deposit type, reflecting local market specificities. The final dataset consists of 132 institutions for overnight deposits and 67 for RAN deposits. Table 3.1 provides summary statistics. For overnight deposits (deposits redeemable at notice), our data represents 63% (69%) of the euro area total deposits, and 49% (47%) of euro area total banking assets.

Table 3.1
Summary statistics

(Numbers for total assets and deposits are in billion EUR)

	Sample Banks	Total assets Mean (St. Dev)	Deposits Mean (St. Dev)	Share of EA banking assets	Share of EA deposits
Overnight	132	142.7 (264.0)	25.4 (38.9)	48%	63%
Redeemable at notice	67	218.6 (338.1)	24.5 (47.8)	37%	69%

Our model specification relies on deposit growth rates. In order to eliminate jumps related to reclassifications, changes in reporting framework and reporting errors, we winsorize the deposit growth at 5% and 95%. We also seasonally adjust the data[7].

For measuring sovereign risk, we collected sovereign CDS spreads at the monthly frequency. We proxy data for Luxemburg using German CDS spreads.

[7] We employ TRAMO-SEATS in JDemetra+, as made available by the European Commission

4 Results

In this section, we describe the results. We first comment on the model output and illustrate the simulated paths for the key variables. We then discuss the resulting estimates of deposit durations.

4.1 Model estimation

Estimates of the model for the market rate in equation (2) suggest a substantial degree of persistence in short-term interest rate movements. The coefficient estimate for μ is equal to 0.71 with a t-statistic of 13.06.

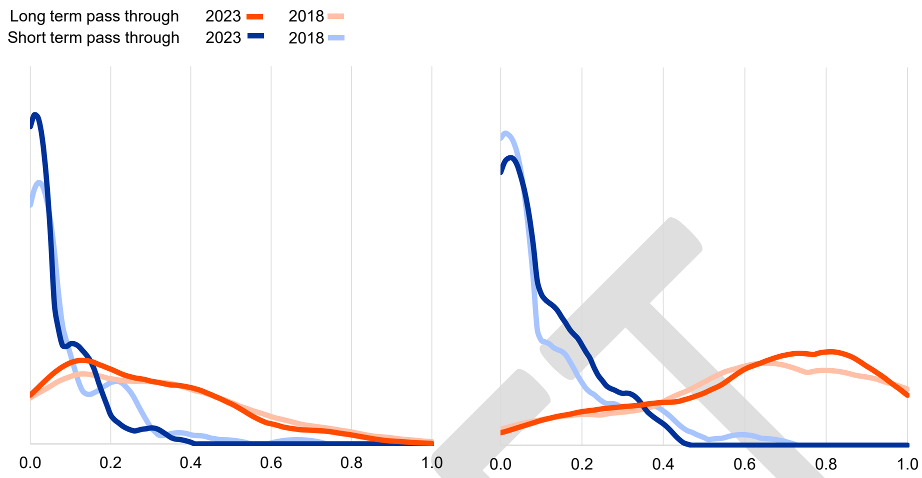
The model for CDS premia in equation (2) is estimated separately for each country, where we restrict the long-term mean to be equal to the value prevailing at the end of our sample period. The estimates of ρ vary relatively little across countries and are all very close to zero, suggesting that CDS premia approximate a geometric random walk.

Next, we turn to the estimation of the bank-level models of deposit rates and volumes in equations (3) and (4). We run separate estimations for sight and RAN deposits. Chart 4.1 depicts the cross-sectional distributions for the short-term (β) and long-run (γ) pass-through coefficients. Consistent with the existing literature, we observe that sight deposit rates move relatively little in response to changes in market rates (left panel). On average, the short-run pass-through equals 7%, while the long-run pass-through equals 28%. However, there is a considerable cross-sectional variation. While most banks cluster below 40%, a few banks display a relatively high pass-through. The pass-through is considerably higher for RAN deposits, especially in the long-run, in line with their nature as savings product (right panel in Chart 4.1).

Chart 4.1

Long- and short-term pass-through from market to deposit rates

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: estimated pass through; vertical axis: density)



Source: Own calculations

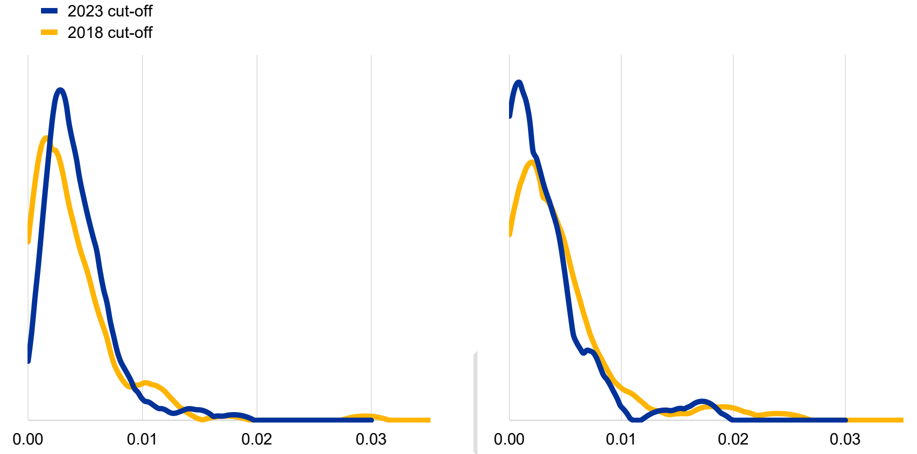
As expected, deposit volumes growth accelerate when deposit rates exceed market rates (Chart 4.2). On average, a 100 bps increase in the difference between deposit and market rates implies a monthly increase in sight deposits of 0.4% (or 5% per year) for sight deposits and 0.5% (or around 6% per year) for RAN deposits. The dispersion of deposit volume growth rates across banks (and across different deposit products) is lower than the dispersion across pass-through rates.

Chart 4.2

Sensitivity of deposit volumes to changes in the pricing of deposits

Density distribution of the monthly growth rate of deposit volumes in response to a 100 bps increase in the difference between deposit rates and market rates (‘opportunity cost’)

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: estimated ‘opportunity cost’ coefficient; vertical axis: density)



Sources: Own calculations.

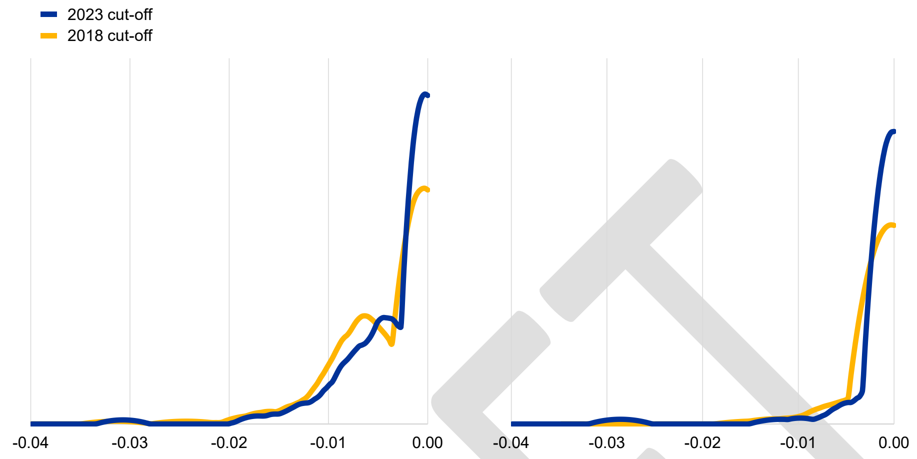
Finally, Chart 4.3 illustrates the effects of increases in the sovereign CDS spreads to values above the 200 bps threshold on deposit growth. Focusing on sight deposits, we see that the effect is economically modest for most banks, but a limited set of banks displays considerably larger effects. A sharp deterioration in a bank’s creditworthiness can alter considerably the Asset and Liability Management, as the deposit base shrinks significantly at times of stress, with liquidity issues to compounding to interest rate ones. The average sensitivity of deposit volumes to a jump in CDS spreads corresponds to a monthly deposit outflow of 0.3% (or 3.5% per year). The cutoff for the first quartile is 0.5% meaning that for a quarter of the sample the outflow of deposits is equivalent to 6% should the CDS spread exceed 200bps. These are predominantly banks from countries having experienced sovereign debt turbulences in the aftermath of the global financial crisis. For banks which have not experienced a credit shock in their recent past, these findings would suggest using a layer of prudence in calibrating deposit models for sight deposits. While the effects are qualitatively similar for RAN deposits, the economic magnitudes are significantly smaller with few exceptions: the lever of pricing and different contractual forms seem to relatively effective in securing more stable sources of funding for banks.

Chart 4.3

Sensitivity of deposit volumes to CDS premia

Density distribution of the CDS dummy coefficient

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: estimated CDS dummy coefficient; vertical axis: density)



Sources: Own calculations.

The model estimation reveals significant cross-country heterogeneity, both in terms of interest rate pass-through and the determinants of deposit growth (see Table 7.4 in the Appendix). For example, the long-run pass-through for sight deposits is close to zero in France, but averages 43% in Germany. The sensitivity to a credit risk shock – proxied by the impact on volumes of CDS staying above 200 bps – is concentrated in economies which suffered from the euro crisis in the early 2010s (e.g. a 1.7% monthly outflow rate for Greek banks), whereas it is negligible for most other countries. Further, a comparison with Table 7.6 results for RAN deposits highlights the rather local nature of deposit markets in Europe. While French sight deposits are pretty inelastic to interest rate changes, French RAN deposits are among the most price-sensitive (73% pass-through) due to the prevailing contractual form[8]. This difference is irrelevant in many other jurisdictions, e.g. in Italy.

Similar differences underscore the need for rather different Asset and Liability Management strategies in different local markets: in France, the overall low sensitivity of parts of the deposit base to interest rate changes is matched by the offer to retail clients of long-dated fixed rate residential mortgages, whereas such products exhibit a much shorter duration where depositors are way more reactive to interest rate changes, e.g. in Germany or Finland, ceteris paribus (see **Albertazzi et al., 2019** and **Hoffmann et al., 2019**).

[8] This is related to the presence of regulated saving products in France: deposit rates paid on the "Livret A" (and similar accounts) are set by the French Ministry of Finance and based on the combined evolution of short-term market rates and inflation. Whereas the frequency of the repricing and the intensity of the two factors have changed over time in recent years, short term rates tend to account for 50% of the changes in the remuneration of these deposits.

4.2 Simulations

We simulate 1,000 sample paths for market rates, sovereign CDS premia, as well as bank-level deposit rates and volumes 10 years ahead (120 months) based on equations **Error! Reference source not found.** to (4). We account for correlations in the error terms by using a Cholesky decomposition based on the empirical variance-covariance matrix. To account for a theoretical lower bound on market rates, we floor r_t at -60bps. Similarly, we impose a floor of zero on deposit rates, in line with the empirically observed reluctance of banks to enter negative territory (see **Heider et al., 2018**). For the simulations of sight deposit volumes, we exclude the constant term in order to avoid explosive behaviour that due to high past growth rates that are not explained by movements in CDS spreads or the deposit spread.

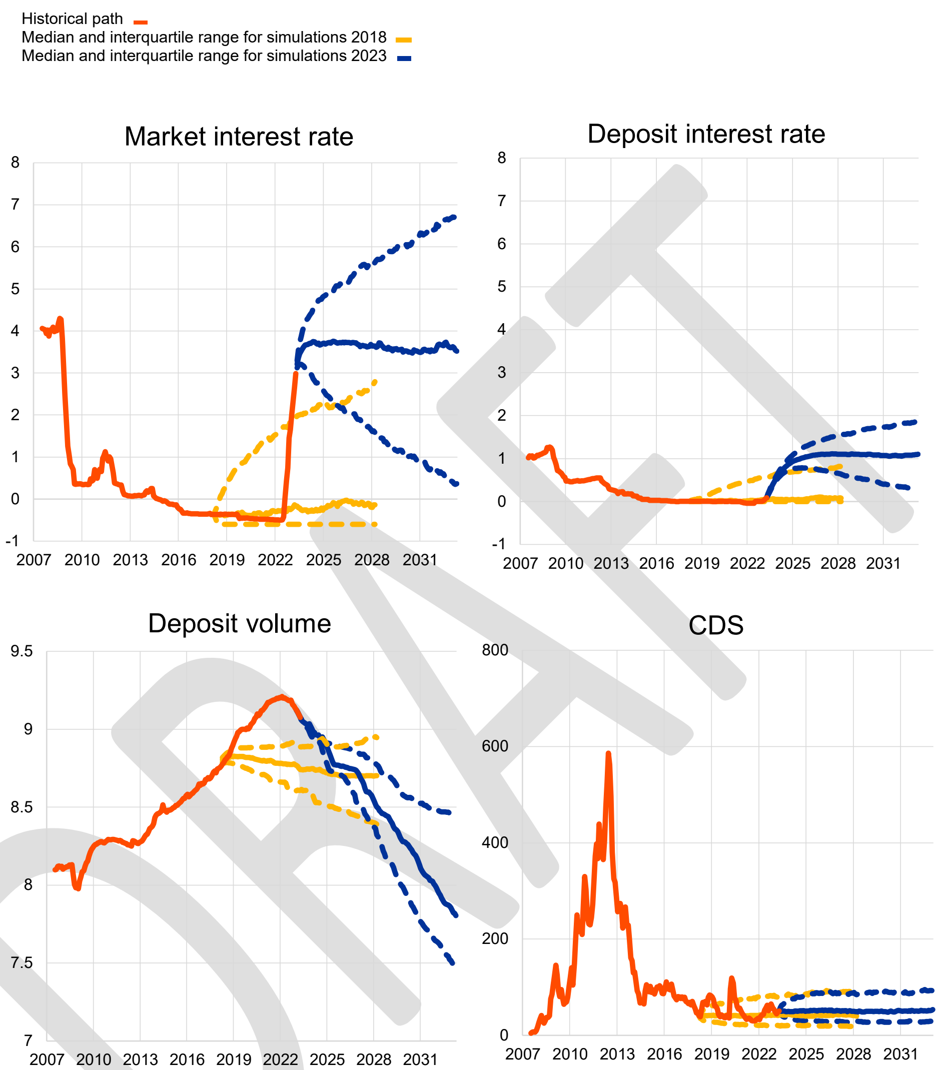
Chart 4.4 illustrates the distribution of simulated future paths for all model components for one representative bank. Note that only the simulations of the deposit rate and volume are bank specific. The median paths for market and deposit rates are constrained by the respective lower bounds imposed in the simulations.

Chart 4.4

Simulations of individual part of the model for a sample bank

Charts based on 1000 stimulations

horizontal axis: years; vertical axis: for interest rates: percentages, for CDS bps, for deposit volumes: bn EUR
Market interest rate



Sources: Own calculations.

4.3 Durations

For each sample path $\mathrm{k} = 1, \ldots, 1000$, we then compute the associated present value of the deposit liability as $PV_i^k = V_{i,0}^k - D_{i,0}$, where $V_{i,0}^k$ is the term inside the expectations operator in equation **Error! Reference source not found.**, evaluated using the *k*-th sample path. The associated (modified) duration of the deposit liability is given by its sensitivity to a marginal change in interest rates,

$$Duration_i^k = -\frac{1}{PV_i^k} * \frac{\partial PV_i^k}{\partial r} \qquad (3)$$

We compute the derivative in equation (3) using a one basis point increase in the sample path for market rates and use equations **Error! Reference source not found.** to (4) to infer the corresponding changes in deposit rates and volumes. The 1,000 simulations give rise to a bank-level distribution for the present value of the deposit liability as well as its duration. We record the margin and duration as the median from these distributions.

In normal times, the margin V_0 tends to be positive because retail deposits are remunerated at a rate below r_t. However, due to the zero lower bound on deposit rates, this is no longer the case when market rates are negative.

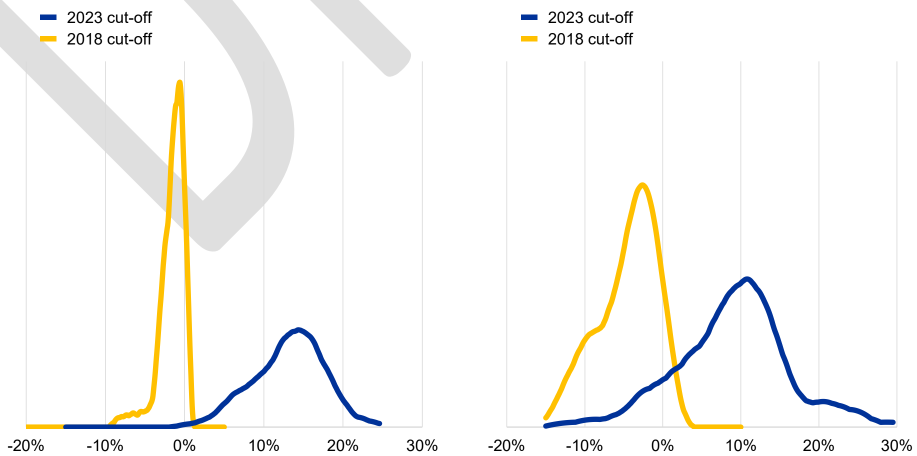
To illustrate this point, Chart 4.5 plots the cross-sectional distribution of the expected margin at two points in time, at the beginning of 2018 (in a period of negative market interest rates but non-negative deposit rates) and upon normalization of the interest rate environment in 2023. For comparability across institutions, we plot the ratio V_0/D_0, i.e. the expected margin normalized by the current amount of deposits. As can be seen, the expected margin is estimated to be negative for most banks in 2018. This means that 1 EUR of retail sight deposits constitutes a liability with a present value of more than 1 EUR from the bank's perspective, because the bank is expected to earn a negative margin over the following 10 years. By contrast, the expected margin turns positive for most banks in 2023, as banks extract a profit by paying deposit rates that are below market rates.

Chart 4.5

The expected margin earned on deposits

Subtitle if necessary

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: expected margin earned on deposits (expressed relative to the volume of deposits); vertical axis: density)



The fact that the expected margin V_0 is negative does not necessarily play a role for the duration of the deposit liability. Because of an imperfect pass-through from market to deposit rates, higher market rates typically increase the margin, and thus decrease the present value of the deposit liability. Therefore, the associated duration will be positive[9]. Chart 4.6 plots the cross-sectional distribution of banks' deposit durations. As can be seen, the average duration of sight deposits is 3.16 years. This is a consequence of a very low pass-through combined with roughly stable deposit volumes. Due to the zero lower bound on deposits, there is also relatively little cross-sectional variation, which is mostly driven by volume effects. The results for RAN deposits exhibit slightly lower expected durations (3.2 years on average), but more cross-sectional dispersion. The main reason for the additional variation is particularly driven by the fact that the prevailing deposit rates are above zero in some jurisdictions, which leads to a more prominent role for pass-through to affect deposit durations.

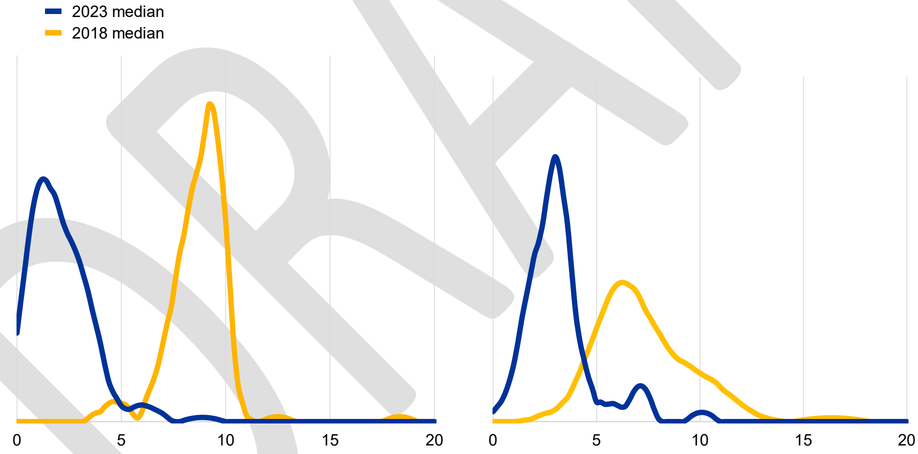
In addition, Chart 4.6 also deposits the distribution for the 5th percentile of deposit durations. This corresponds to a value-at-risk perspective, since it indicates the level of deposit durations corresponding to the tail of the bank-level distribution. For the average bank, these correspond to durations of 1.31 and 1.84 years for sight and RAN deposits, respectively.

Chart 4.6

Duration of the deposit liability (median)

Density of duration estimates

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: estimated duration in years; vertical axis: denstity)



Sources: Own calculations.

Cross-sectional differences in duration estimates across countries are reported in the Appendix (Table 7.7). We find that Estonian deposits exhibit the longest duration (4. 91years) followed closely by Italian (4.81 years) against shorter than average duration e.g. Austria (1.63 years). Greek deposits exhibit the shortest overall duration due to the high impact of the sovereign crisis, which is captured in our modelling by the heightened sensitivity of the deposit base to the evolution of CDS premia.

[9] Duration in simulations can turn negative in rare cases when the deposit growth is very sensitive to the opportunity cost and the pass through is low. In this situation, a marginal increase in market rates implies a higher margin. At the same time deposit volumes increase much slower/decrease much faster, resulting in a smaller base on which the margin is earned. If the depletion in deposit volumes is sufficiently large, the overall effect of an increase in the market rate on the margin will be negative. This implies a negative duration.

4.4 Lengthening deposit duration in response to decreasing interest rates

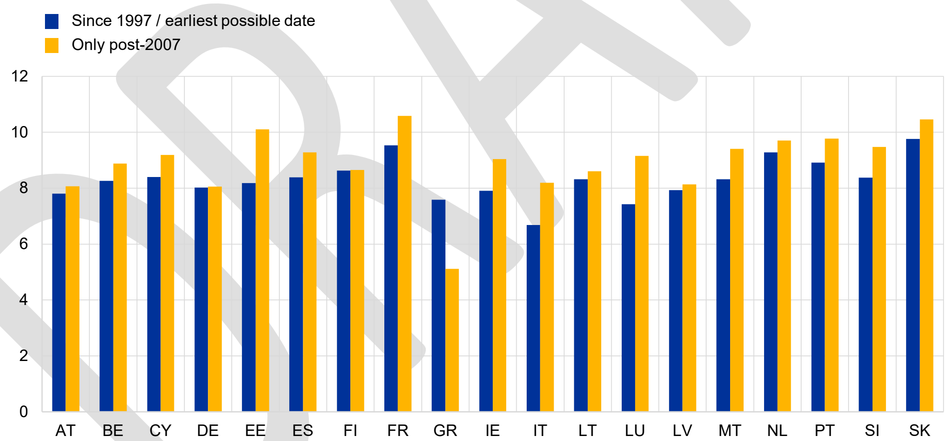
We performed the same analysis as presented above also on country level data which have a longer time series (running for most Euro Area countries from 1997 to 2018). We estimated our model on the full time horizon and compared results with those of a shorter time window following the global financial crisis which started in 2007, when global interest rates started a prolonged declining phase. Indeed deposit duration estimates computed over the whole sample are generally lower than the deposit duration post-2007: declining interest rates and an increase in central bank balance sheets have made deposits an attractive asset class for retail investors, thereby decreasing incentives for depositors to move their assets into alternative asset classes. The most notable exception is Greece, whose 2007-2017 time series reflects the severe crisis – coupled with significant deposit outflows – which hit the country in the first half of the 2010s. Estimates over an even shorter time window – (from 2013 to [2018]) not reported in Chart 4.6 – exhibit a further increase as the average market rate fluctuates only around zero.

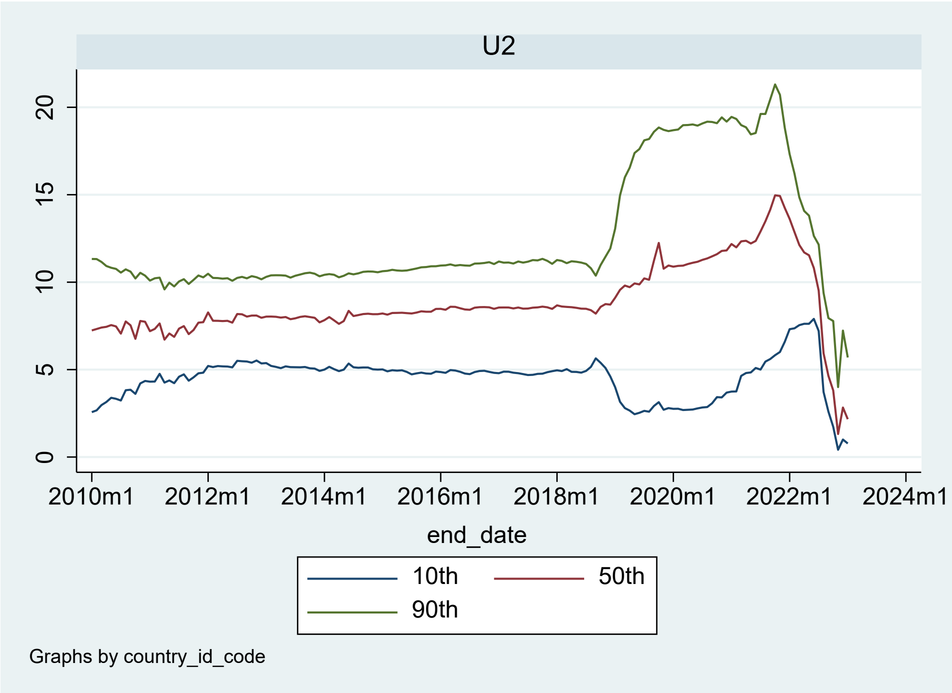
Chart 4.7

Duration of the deposit liability based on country aggregates

Duration per country in years

(horizontal axis: countries; vertical axis: years)





Sources: Own calculations.

Based on country aggregates we also confirmed that the increase in liabilities duration is mirrored in the duration of the loans to households and NFCs. The initial rate fixation period of new loans for households and non-financial corporations fluctuated between 1.2Y and 1.7Y until 2010 when it started increasing to reach 3.1Y in March 2018.

4.5 Why are duration estimates so long?

In this subsection, we aim to shed further light on why our estimated of deposit durations are so long (8.7 for sight deposits and 7.5 for RAN). To this end, we analyse their dependence on the development of market interest rates, which we summarize using the compound market interest rate (CMIR). For sample path *k*, it is computed as $r^k = \prod_{t=1}^{120}(1 + r_t^k) - 1$. A positive (negative) CMIR indicates that interest rates have been predominantly high (low) over the simulation horizon.

Chart 4.8 illustrates how deposit durations depend on the simulated path for market rates. While these results apply to sight deposits, similar results are obtained for RAN deposits.

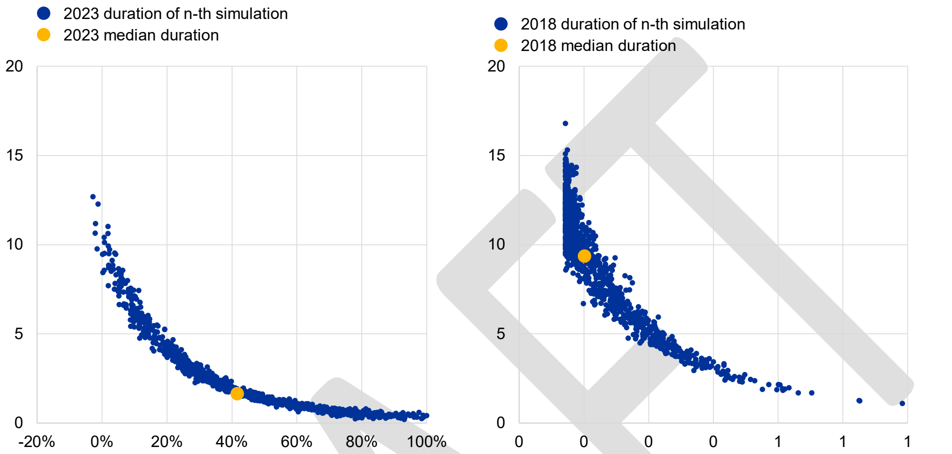
The left panel shows percentiles of cross-sectional durations for the simulated interest rates paths. We calculate the duration corresponding to each of the interest rate paths for all the banks in the sample and then depict the resulting 25th, 50th and 75th percentile. Additionally, we indicate the median duration for each bank (green dots), i.e. the number we focused on in Chart 4.6.

The right panel zooms in on an individual bank. It can be considered as representative because its pass-through and opportunity cost coefficients are close to the sample medians. The picture shows all 1,000 durations calculated for each set of sample paths as a function of the CMIR. The yellow dot is the median duration.

Chart 4.8

Durations as a function of compound interest rate - example for one bank

(left chart: cut-off 2023, right chart: cut-off 2018; horizontal axis: interest rate compounded through the simulation horizon; vertical axis: years; both charts for ON)



Sources: Own calculations.

Chart 4.8 gives rise to several insightful observations:

- Increasing interest rate paths result in shorter durations. For example, a CMIR of 20% (corresponding to an annual interest rate of 1.9%) yields durations below 5 years.
- Across simulations, the CMIR is concentrated between the lower bound and zero (the median CMIR equals 0.27%).
- The median bank durations (green points in the left panel) are centred around the median CMIR. This is intuitive, since longer (shorter) durations are associated with a lower (higher) CMIR.

The relatively long estimated durations are mainly rooted in the current low interest rate environment. Since market rates are assumed to follow a random walk, they are expected to stay close to zero over the simulation horizon. This also ensures that deposit volumes will be subject to little change because, based on opportunity costs, there are no incentives to withdraw deposits.

When the market rates increase on average (paths with positive CMIR), durations shorten due to decreasing deposit volumes. This effect is more pronounced for banks where customers are more sensitive to opportunity costs, and which exhibit a lower pass-through.

Worth noting that an apparently innocuous modelling choice such as the selection of the simulation horizon (10 years in our case) is perhaps the most relevant driver of the duration estimates (8.7 years on average), i.e. longer/shorter duration estimates would correspond to a longer/short simulation horizon. In fact, negative rates amplify the direct link between risk management modelling choices and a bank's risk appetite, see Formenti (2019).

5 Scenarios

In this section, we analyse the impact of three economic scenarios on banks' estimated deposit durations. These scenarios are:

- A parallel up shock by 200bps
- A decrease in the effective lower bound on interest rates from -60 bps to -100 bps
- An increase in the pass-through from market rates to deposit rates by 2 cross-sectional standard deviations (around 0.4)

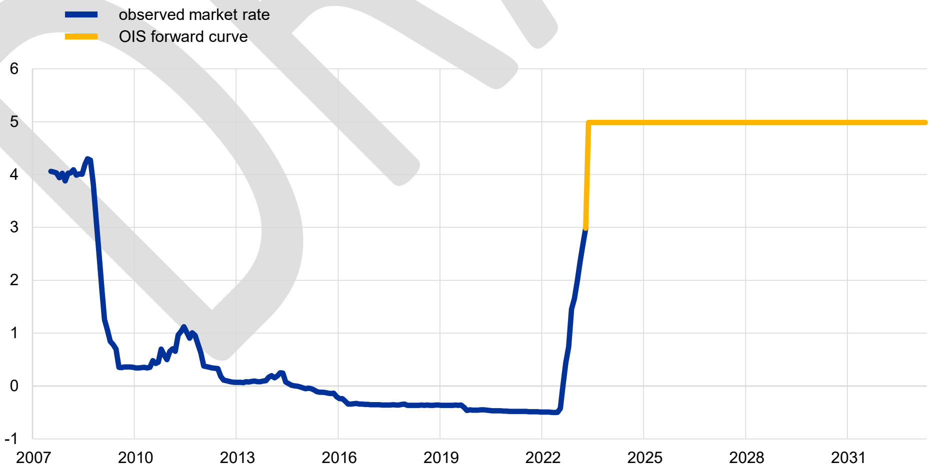
Country level averages with the results are presented in Table 7.6 and Table 7.7 for sigh deposits and deposits redeemable at notice respectively.

Chart 5.1 below illustrates the effects of the first scenario where the EONIA rate increases over time in line with the OIS forward curve from the cut off date. While the empirical evidence on the expectations hypothesis is mixed at best (see **Ranaldo and Rupprecht, 2017**), this exercise still provides a useful benchmark on how estimated durations are affected by a steady, but sustained increase in interest rate. Notice the difference to the median future interest rate paths in Chart 4.4, which is flat.

Chart 5.1

+200 bps parallel shock

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: date; vertical axis: interest rate (%))



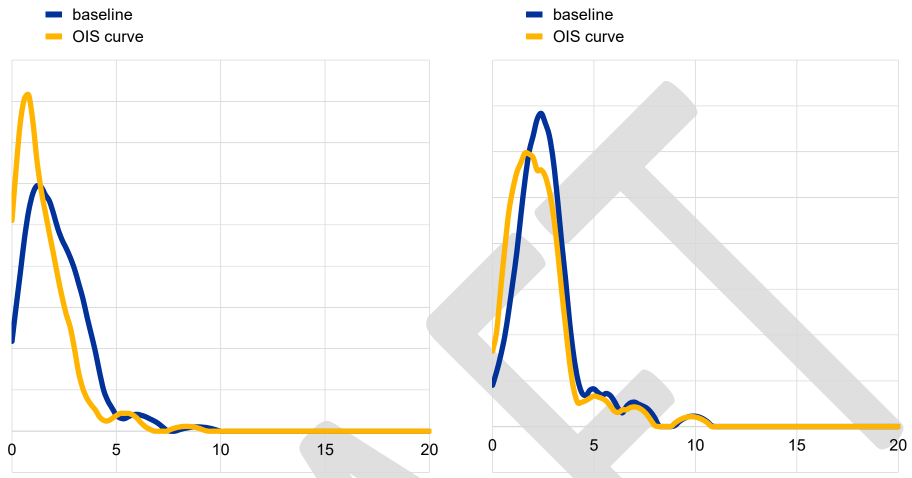
Sources: SDW

Chart 7.2 depicts the expected duration under the above scenario (yellow line) and contrasts them with the expected durations from our simulations (blue line). As can be seen, the scenario of increasing interest rates gives rise to a significant shortening of durations for both sight and RAN deposits by 2.05 and 2.55 years, respectively. These numbers emphasize the sensitivity of estimated durations to the underlying model governing the future evolution of interest rates.

Chart 5.2

Duration of the deposit liability when interest rates increase by 200 bps

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: duration in years; vertical axis: density)



Sources: Bloomberg and authors' calculations.
Notes: LHS: OIS forward curve as of XX/XX/20XX. RHS: Deposit durations basline case and when IR follow OIS forward curve

Next, we investigate how the magnitude of the effective lower bound affects deposit durations. To this end, we re-run our simulations after changing the lower bound on market rates from -60 bps to -100 bps. Chart 5.3 illustrates the effects by contrasting the baseline cross-sectional distribution of durations with the one obtained under the reduced effective lower bound. As can be seen, a decrease in the effective lower bound only has a marginal impact on deposit durations, which is driven by a potential increase in volumes due to further increases in market rates relative to deposit rates.

Chart 5.3

Duration of the deposit liability when the effective lower bound on market rates is reduced to -100 bps

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: duration in years; vertical axis: density)

Sources: Own calculations

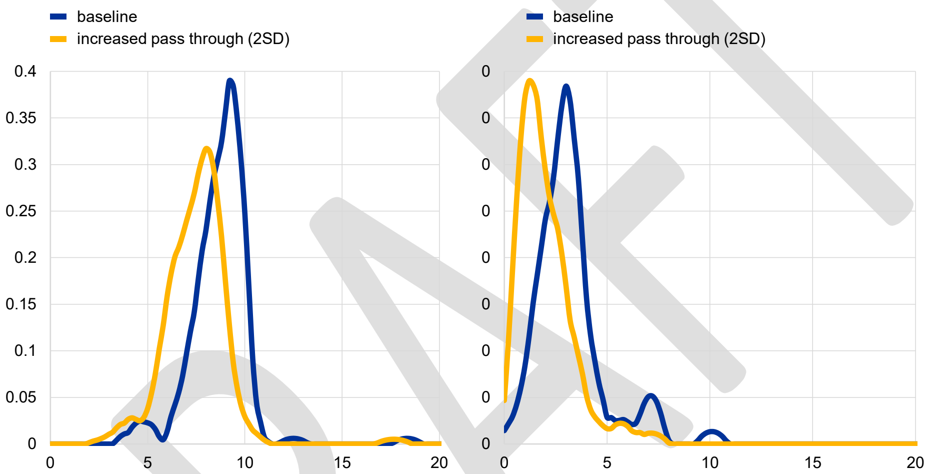
Finally, we examine the effects of an increase in the pass-through from market to deposit rates. The observed low level of pass-through is typically attributed to banks' market power in deposit markets and the inertia of retail investors. Clearly, disruptions to the market for retail deposit have the potential to change the behaviour of deposit rates in the medium and long term, leading deposit rates to respond more strongly to changes in market rates. In order to gauge the possible effects, we increase each bank's pass-through rate by two cross-sectional standard deviations, i.e. by 0.43 for sight deposits and 0.53 for deposits redeemable at notice. We cap the pass-through at 1. Chart 5.4 illustrates the resulting impact on deposit durations.

As could be expected, a higher pass-through implies shorter durations mainly because of the underlying volume effects. In our environment of negative interest rates, pass-through only matters when interest rates increase (as both market and deposit rates are constrained on the downside). When interest rates increase, a higher pass-through leads to lower deposit volumes in the future by affecting the opportunity cost. This shortens durations on average. Also, as one would expect, this effects is quantitatively more important for sight deposits, as RAN deposits often already have pass-through rates close to one.

Chart 5.4

Duration of the deposit liability when increasing pass-through by two cross-sectional standard deviation

(left chart: sight deposits, right chart: deposits redeemable at notice; horizontal axis: duration in years; vertical axis: density)



Sources: Own calculations

6 Summary & policy conclusion

We have studied a simple stochastic model to measure the duration of bank deposits, defined as the sensitivity of the deposit net present value to changes in interest rates. The decline of interest rates in the 2010 pushed yields into negative territory. In this environment, non-negatively remunerated deposits were an attractive asset class for savers, relative to other low-risk alternatives such as short-dated fixed-income assets. Demand deposits piled up on euro area banks balance sheets.

Our empirical analysis illustrates how these developments have shaped the interest rate sensitivity of bank deposits. The secular decline in interest rates and the resulting growth of deposit volumes gave rise to deposit durations of close to 10 years for most euro-area banks. This is substantially above XXX estimates.

Ceteris paribus, the non-negative remuneration of deposits in such an environment implies a drag on bank profits. However, an increase in deposit durations also incentivizes banks to increase the duration on the asset side of their balance sheet (**Drechsler et al., 2021**) in order to neutralize the overall effect on their interest rate risk exposure. This partially neutralizes the increase in interest expenses relative to market rates. While the flattening of the yield curve since the great financial crisis has often been associated by search-for-yield and increased risk-taking (**Dell'Ariccia et al., 2014; Martinez-Miera and Repullo, 2017**), our results show that part of this evolution could also arise from asset-liability management in an environment of more sticky deposits.

The rapid interest rate increases in 2022-2023 reversed such trend: with market rates well above deposit rates, deposit-taking returned to be a profitable business for euro area banks and deposit volume growth declined. As a result, duration estimates decreased rapidly to an average of approximately [2.5 years] Banks have started to react by shortening the duration of their asset portfolio: such pro-cyclical behaviour likely contributed to steepening the yield curve, other things equal.

As part of our analysis, we also show that deposit durations contract following a deterioration in banks' risk profile (measured through sovereign risk spreads). The impact is quantitatively important, consistent with the significant decline in deposit volumes of Greek banks following the 2010 crisis. Aside from systemic events, idiosyncratic credit shocks are another source of uncertainty which should be factored into banks' deposit modelling, even though it is not a standard risk management practice. Spring 2023 events, and the failure of a number of U.S. regional banks, were a stark reminder of the link between banks' exposure to interest rate risk and solvency and liquidity concerns.

Our simple model does not account for potential structural changes in market structure or in the competitive environment. However, we would argue that technological progress, such as the rise of Fintech non-bank competitors, aided by legislative changes, like the European Payment Service Directive 2, are likely to compound to the above effects. Banks are likely to face increased competition from non-banks in an increasing interest rate cycle. [It is]

While our model can be used to infer the direction in which deposit durations are likely to move with interest rates, our simple methodology bears on a few modelling choices whose relevance is amplified by the current low interest rate environment. For example, the longer the time horizon of the stochastic simulations used to estimate deposit duration, the longer the estimated duration itself. This is intuitive: when non-remunerated retail deposits offer a premium over market rates, depositors have little incentives to move their deposits at all. As duration estimates suffer from modelling limitations in the current interest rate environment, banks' risk management should factor in such uncertainty in their Asset and Liability Management. Such uncertainty, compounds to challenges for banks' risk management related to the documented relationship between deposit rates and market rates.

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7 Appendix

Table 7.1
Summary statistics of the sample - sight deposits

Subtitle (delete if not needed)

(units, further description)

	Banks in sample	Average total assets, banks in sample	Average deposits, banks in sample	Share of sample assets in country total	Share of sample deposits in country total
Total	134	140,937	25,088	48%	63%
		(262,453)	(38,928)		
AT	8	60,892	13,218	46%	49%
		(66,546)	(11,335)		
BE	7	128,690	13,851	68%	80%
		(101,485)	(10,543)		
CY	2	23,321	6,689	70%	80%
		(2,715)	(78)		
DE	32	119,999	23,521	36%	41%
		(252,252)	(37,326)		
EE	2	10,843	3,942	57%	84%
		(3,987)	(2,341)		
ES	15	163,998	57,061	83%	92%
		(214,083)	(66,680)		
FI	4	40,985	13,606	21%	52%
		(57,756)	(19,459)		
FR	16	358,076	29,781	49%	75%
		(466,827)	(35,873)		
GR	3	25,457	18,235	24%	98%
		(40,756)	(14,899)		
IE	4	73,639	28,832	19%	83%
		(55,882)	(24,072)		
IT	10	194,480	55,397	49%	59%

	Banks in sample	Average total assets, banks in sample	Average deposits, banks in sample	Share of sample assets in country total	Share of sample deposits in country total
		(252,163)	(62,486)		
LU	6	32,589	6,976	14%	77%
		(20,115)	(6,399)		
MT	4	6,495	3,323	62%	95%
		(5,939)	(3,437)		
NL	5	453,733	24,728	78%	94%
		(424,496)	(18,516)		
PT	5	60,216	13,897	70%	77%
		(20,133)	(8,038)		
SI	6	6,351	3,006	74%	78%
		(5,124)	(3,145)		
SK	5	18,208	5,714	79%	83%
		(7,313)	(3,415)		

Table 7.2
Summary statistics of the sample – deposits redeemable at notice

Subtitle (delete if not needed)

(units, further description)

	Banks in sample	Average total assets, banks in sample	Average deposits, banks in sample	Share of sample assets in country total	Share of sample deposits in country total
Total	67	218,563	24,519	37%	69%
		(338,082)	(47,819)		
BE	7	128,690	13,851	68%	80%
		(101,485)	(10,543)		
DE	28	126,579	4,461	33%	25%
		(269,381)	(9,641)		
FI	1	Not shown due to confidentiality (too few banks)			

	Banks in sample	Average total assets, banks in sample	Average deposits, banks in sample	Share of sample assets in country total	Share of sample deposits in country total
FR	15	369,613	31,281	47%	74%
		(480,844)	(36,609)		
IE	3	93,036	38,010	18%	82%
		(49,262)	(19,072)		
IT	5	387,037	100,577	49%	43%
		(285,234)	(80,582)		
MT	1	Not shown due to confidentiality (too few banks)			
NL	6	380,753	24,728	78%	94%
		(419,659)	(18,516)		
SK	1	Not shown due to confidentiality (too few banks)			

Table 7.3
Coefficients of CDS premia model

Average of the t-statistics provided in brackets
(units, further description)

Country	Assumed long term mean	Lagged CDS $(1-\rho_c)$	t-stat	Constant
AT	17.5	0.967	65.7	0.094
BE	24.6	0.969	76.1	0.101
CY	93.0	0.986	109.1	0.062
DE	16.6	0.937	48.8	0.177
EE	78.9	0.944	52.6	0.247
ES	48.4	0.973	81.6	0.106
FI	23.8	0.949	45.8	0.163
FR	24.5	0.954	62.0	0.147
GR	117.3	0.991	109.8	0.042
IE	24.4	0.988	120.0	0.038
IT	113.3	0.933	58.0	0.316
LU	16.6	0.937	48.8	0.177

Country	Assumed long term mean	Lagged CDS $(1-\rho_c)$	t-stat	Constant
MT	87.6	0.936	35.4	0.288
NL	17.0	0.959	65.2	0.116
PT	48.3	0.985	105.9	0.056
SI	48.6	0.985	97.6	0.058
SK	28.8	0.958	58.6	0.141

Table 7.4

Coefficients of deposit volumes model – sight deposits

Average t-statistics reported in bracket

(units, further description)

	Deposit rate model (eq. Error! Reference source not found.**)** $\Delta d_{i,t} = \beta_{1,i}\Delta r_t - \alpha_i(d_{i,t-1} - \gamma_{2,i} r_{t-1} - \gamma_{0,i})$				**Deposit volume model (eq. (4))** $\Delta \ln V_{i,t} = \beta_{0,i} + \beta_{1,i}(d_{i,t} - r_t) + \beta_{2,i}\mathbf{1}_{CDS_{c,t}>200bp}$		
	Short term pass-through $\beta_{1,i}$	**Adjustment coefficient α_i**	**Long term pass-through $\gamma_{2,i}$**	**Constant (in pp) $\gamma_{0,i}$**	**Constant $\beta_{0,i}$**	**Opportunity cost $\beta_{1,i}$**	**CDS dummy $\beta_{2,i}$**
Full sample	0.068	0.142	0.277	0.129	0.007	0.004	-0.003
	(7.8)	(10.3)	(15.2)	(11.6)	(21.3)	(13.8)	-(7.3)
AT	0.003	0.123	0.427	0.212	0.006	0.009	0.000
	(1.4)	(5.6)	(18.4)	(12.7)	(7.3)	(5.2)	
BE	0.049	0.092	0.133	0.025	0.007	0.002	-0.002
	(2.2)	(2.1)	(4.6)	(2.3)	(9.6)	(7.3)	-(2.1)
CY	0.041	0.027	0.216	0.067	0.012	0.006	-0.005
	(3.6)	(7.8)	(8.3)	(2.7)	(19.8)	(6.1)	-(1.0)
DE	0.066	0.105	0.431	0.169	0.006	0.003	0.000
	(4.2)	(9.1)	(13.7)	(7.3)	(9.7)	(3.9)	
EE	0.000	0.086	0.046	0.021	0.010	0.002	0.000
		(11.9)	(8.9)	(10.1)	(92.1)	(2.2)	
ES	0.059	0.136	0.220	0.107	0.009	0.004	-0.005

	Short term pass-through $\beta_{1,i}$	Adjustment coefficient α_i	Long term pass-through $\gamma_{2,i}$	Constant (in pp) $\gamma_{0,i}$	Constant $\beta_{0,i}$	Opportunity cost $\beta_{1,i}$	CDS dummy $\beta_{2,i}$
	(3.0)	(4.6)	(4.0)	(3.6)	(20.3)	(6.6)	-(5.1)
FI	0.247	0.110	0.423	0.218	0.006	0.002	0.000
	(5.2)	(3.0)	(3.1)	(10.3)	(3.9)	(2.9)	
FR	0.004	0.349	0.079	0.097	0.005	0.005	-0.001
	(2.0)	(4.5)	(3.0)	(2.2)	(5.8)	(8.4)	-(2.8)
GR	0.038	0.133	0.352	0.237	0.014	0.006	-0.017
	(2.2)	(4.2)	(7.2)	(5.7)	(4.2)	(4.5)	-(4.9)
IE	0.134	0.026	0.246	0.162	0.007	0.005	-0.007
	(5.6)	(2.7)	(3.6)	(8.8)	(2.7)	(24.3)	-(2.9)
IT	0.117	0.149	0.302	0.084	0.006	0.001	-0.004
	(4.6)	(4.2)	(7.2)	(3.9)	(9.9)	(5.2)	-(6.9)
LU	0.351	0.174	0.475	0.260	0.004	0.005	0.000
	(7.3)	(2.4)	(8.3)	(12.1)	(3.5)	(3.2)	
MT	0.125	0.100	0.185	0.158	0.012	0.003	-0.005
	(2.8)	(1.0)	(7.5)		(6.7)	(5.1)	-(2.4)
NL	0.022	0.081	0.331	0.180	0.005	0.003	0.000
	(2.9)	(2.6)	(1.8)	(1.9)	(3.2)	(19.3)	
PT	0.014	0.166	0.062	0.020	0.010	0.004	-0.007
	(1.9)	(1.5)	(2.6)	(1.0)	(13.2)	(7.4)	-(14.9)
SI	0.006	0.115	0.178	0.012	0.010	0.003	-0.005
	(2.0)	(2.1)	(1.8)	(0.4)	(12.0)	(8.3)	-(3.0)
SK	0.001	0.078	0.070	0.048	0.009	0.008	-0.006
	(1.0)	(3.7)	(3.0)	(4.8)	(25.8)	(15.3)	-(7.7)

Table 7.5
Coefficients of deposit volumes model – deposits redeemable at notice

Average t-statistics reported in bracket

(units, further description)

	Deposit rate model (eq. Error! Reference source not found.)	Deposit volume model (eq. (4))

	$\Delta d_{i,t} = \beta_{1,i}\Delta r_t - \alpha_i(d_{i,t-1} - \gamma_{2,i}r_{t-1} - \gamma_{0,i})$				$\Delta \ln V_{i,t} = \beta_{0,i} + \beta_{1,i}(d_{i,t} - r_t) + \beta_{2,i}1_{CDS_{c,t}>200bp}$		
	Short term pass-through $\beta_{1,i}$	**Adjustment coefficient α_i**	**Long term pass-through $\gamma_{2,i}$**	**Constant (in pp) $\gamma_{0,i}$**	**Constant $\beta_{0,i}$**	**Opportunity cost $\beta_{1,i}$**	**CDS dummy $\beta_{2,i}$**
Full sample	0.086	0.068	0.650	0.423	-0.001	0.003	-0.001
	(7.1)	(9.6)	(20.6)	(8.7)	-(0.8)	(6.0)	-(2.0)
BE	0.126	0.076	0.559	0.303	0.004	0.002	-0.001
	(2.6)	(3.5)	(12.3)	(5.8)	(11.0)	(3.5)	-(1.5)
DE	0.064	0.056	0.662	0.200	-0.004	0.004	0.000
	(3.8)	(5.6)	(16.1)	(4.7)	-(2.4)	(5.6)	
FR	0.113	0.092	0.734	1.015	0.002	0.002	0.000
	(5.2)	(9.5)	(14.8)	(31.9)	(1.8)	(2.0)	-(1.0)
IE	0.177	0.020	0.757	0.181	0.000	0.009	-0.019
	(1.9)	(1.9)	(3.4)	(3.8)	(0.1)	(1.0)	-(2.1)
IT	0.081	0.132	0.231	0.519	-0.004	0.001	-0.002
	(2.0)	(2.6)	(6.0)	(2.0)	-(1.8)	(1.7)	-(2.2)
NL	0.004	0.033	0.943	0.367	-0.001	0.004	0.000
	(1.0)	(5.8)	(23.7)	(8.3)	-(0.5)	(2.9)	

Table 7.6
Average durations per country in various specifications – sight deposits

Standard deviation reported in bracket

(units, further description)

	lower bound at -60bps	**lower bound at -100bps**	**Increased pass through**	**OIS curve/+200**
Full sample	3.16	3.34	2.17	2.05
AT	1.49	1.63	1.31	0.67
BE	4.13	4.41	3.15	2.55
CY	1.39	1.53	1.59	0.48
DE	3.95	4.09	2.11	3.05
EE	4.91	5.17	3.48	3.26
ES	3.34	3.60	2.39	2.03
FI	3.62	3.76	2.15	2.52
FR	2.33	2.58	2.09	1.13
GR	1.85	1.92	1.31	1.14

	lower bound at -60bps	lower bound at -100bps	Increased pass through	OIS curve/+200
IE	1.69	1.91	1.69	0.61
IT	4.81	4.96	2.53	3.78
LU	2.91	3.07	1.31	2.08
MT	3.21	3.41	2.99	1.72
NL	3.37	3.53	2.70	2.05
PT	2.78	3.04	2.47	1.35
SI	3.33	3.61	2.87	1.75
SK	0.76	0.86	1.20	0.14

Table 7.7

Average durations per country in various specifications – deposits redeemable at notice

Standard deviation reported in bracket

(units, further description)

	lower bound at -60bps	lower bound at -100bps	Increased pass through	OIS curve
Full sample	3.20	3.30	2.00	2.55
BE	3.44	3.57	1.39	2.72
DE	2.65	2.78	1.84	1.93
FR	3.15	3.22	1.68	2.64
IE	3.55	3.62	3.56	3.11
IT	5.87	5.99	2.86	4.99
NL	2.32	2.41	2.05	1.84

8 Appendix - Economic interpretation of deposit duration

The modified duration informs the bank how sensitive the present value of the deposit portfolio is to changes in the risk-free interest rate. The higher the duration the bigger the impact of the interest rate movements. Following an increase in a risk-free interest rate, the present value of deposits decreases. For a bank, deposits represent a liability, therefore the decrease in the value of deposits means that the bank owes less, in other words it makes a profit. However, if the interest rate had fallen, the bank would have made a loss. To reduce this volatility a bank could invest in an asset which changes in value match the ones of the deposit portfolio. This can be achieved by investing in an asset with duration equal to the duration of the deposit portfolio. The numerical example below summarizes the considerations presented in this section.

Assumptions for baseline scenario:

- constant risk-free interest rate of 1%,
- constant deposit interest rate of 0.8%,
- constant annual deposit withdrawal rate of 7% of the existing balance.

Assumptions for a scenario after marginal change in the risk-free interest rate:

- risk-free interest rate of 1.01% throughout the whole simulation horizon (i.e. increase by 1bp at the beginning of period 1),
- an immediate 6.18% pass-through of the risk-free interest rate change to the deposit interest rate (i.e. deposit interest rate equal to 0.800618%),
- due to increased opportunity cost (risk-free interest rate increases more than deposit interest rate) depositors withdraw their funds slightly faster, now at an annual rate of 7.1%.

Table 8.1 presents the cash flows associated with this deposit portfolio in both baseline scenario and the scenario following the marginal increase in the risk-free interest rate. The cash flow in each period is calculated as $CF_t = D_t - D_{t-1} * (1 + d_t)$, where D_t is the volume at the end of period t, and d_t is the deposit interest rate in period t. The withdrawals are assumed to happen instantly before the end of the period. The present value of the cash flow in each period is calculated by using an appropriate discount factor. Thanks to assuming a constant risk-free interest rate, the equation for the present value simplifies to $PV_t = \frac{CF_t}{(1+r)^t}$. For baseline r equals 1% and for the scenario after interest rate increase it is equal to 1.01%. After summing up present values of cash flows from all periods, we obtain the present value of the deposit portfolio, both in baseline case and after a marginal change in the interest rate. This is all the input we need for the calculation of modified duration.

Table 8.1
Cash flows for the calculation of a deposit portfolio duration

	Baseline			After an increase in interest rate		
T	**Volume at the end of period**	**CF_t**	**PV of CF**	**Volume at the end of period**	**CF_t**	**PV of CF**
0	1000			1000		
1	930	-78.00	-77.23	929	-79.01	-78.22
2	865	-72.54	-71.11	863	-73.40	-71.94
3	804	-67.46	-65.48	802	-68.19	-66.16
4	748	-62.74	-60.29	745	-63.34	-60.85
5	696	-58.35	-55.52	692	-58.85	-55.96
6	647	-54.26	-51.12	643	-54.67	-51.47
7	602	-50.47	-47.07	597	-50.79	-47.34
8	560	-46.93	-43.34	555	-47.18	-43.54
9	520	-43.65	-39.91	515	-43.83	-40.04
10	0	-524.57	-474.89	0	-519.52	-469.85
		Sum	**-986.0**			**-985.4**

$$Duration = -\frac{1}{986} * \frac{(-985.4 - (-986.0))}{0.0001} = 6$$

The duration of 6 informs us that following a 1pp increase in the interest rate the present value of the deposit portfolio decreases by 6%. We already noticed that for the bank the deposit represents a liability (hence the minus sign in front of the present value), and therefore the bank gains in this situation (it owes less). To counteract the volatility in the present value, the bank invests the equivalent of the deposits' present value (986.0) in an asset with a duration matching the duration of deposits, i.e. with a duration of 6 years. Let assume the bank invests in a zero coupon risk-free bond maturing in 6 years[10]. The bond's face value should be equal to $986.0 * (1 + 1\%)^6 = 1046.7$. If the interest rate increases to 1.01%, the present value of this bond would decrease to $\frac{1046.7}{(1+1.01\%)^6} = 985.4$. The bank would lose on this investment the same amount it gained in the deposit portfolio. Should the interest rate decrease leading to the bank gaining on deposit portfolio, it would at the same time lose on the investment in the zero coupon bond. By calculating the duration of the deposit portfolio and then investing in an asset with matching duration the bank hedged the present value of its deposits and eliminated volatility of its EV(E) coming from risk-free interest rate changes.

[10] Technically speaking the duration of such bond is slightly shorter than 6 years, but the approximation is good enough for the sake of this example.

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