Modeling deposit prices

G U S T A V W A L Å S

Master of Science Thesis
Stockholm, Sweden 2013

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Degree Project in Mathematical Statistics (30 ECTS credits)
Degree Programme in Engineering Physics (270 credits)
Royal Institute of Technology year 2013
Supervisor at KTH was Boualem Djehiche
Examiner was Boualem Djehiche

TRITA-MAT-E 2013:20
ISRN-KTH/MAT/E--13/20--SE

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May 17, 2013

Abstract

This report investigates whether there are sufficient differences between a bank's depositors to motivate price discrimination. This is done by looking at time series of individual depositors to try to find predictors by a regression analysis. To be able to conclude on the value of more stable deposits for the bank and hence deduce a price, one also needs to look at regulatory aspects of deposits and different depositors. Once these qualities of a deposit have been assigned by both the bank and regulator, they need to be transformed into a price. This is done by replication with market funding instruments.

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1 Introduction

Deposits are important to banks as funding but also to maintain relationships by having a complete and competitive offer. As such there are many different aspects when pricing deposits. The focus of this report will however be to develop a pricing model to be able to assess the value of deposits for the bank as a source of funding in complement to bonds, equity and other financial instruments and only briefly describe some of the factors that are likely to affect the interest rate paid to the depositor.

Deposits are in this context defined as money placed into a banking institution for safekeeping overnight or at term. The deposit can be made either on savings accounts, checking accounts or money market accounts. Withdrawal of deposits on accounts might be subject to conditions while money market deposits most often have a fixed tenor.

The value of a deposit is ultimately dependent on its stability or likelihood of not being withdrawn. The simple logic is that the longer time it will remain in the bank the longer time the bank can lend out that money and, as a long loan is worth more than a short one, charge a higher price for it. As all deposits have a contractual tenor this could be used for pricing but as behavior might be very different from what is allowed by the contractual terms the value is poorly represented by the contractual tenor.

Apart from the stability of the deposit, regulatory aspects of liquidity risk also have pricing implications. The Basel Committee on Banking Supervision has put forward recommendations on how liquidity risk can be regulated. This has not yet been implemented on European level but the Swedish Financial Supervisory Authority (SwFSA) has implemented a quantitative metric on liquidity risk which was put into place starting from January 1, 2013. It is expected that a different but very likely similar metric will be implemented in the European Union by January 1, 2015. In this proposition the stability of deposits has been assessed and hence this gives a view of the value of deposits in general.

2 Delimitations

This study will try to establish the value of deposits as a funding source for the bank. This means that the results presented in this model constitute a suggestion of what the bank's treasury function should be willing to pay for deposits given the current alternative. This rate does not necessarily compare to the interest rate received by a depositor as the deposit might be priced stand alone and then has to generate income through a margin or as part of an offering where margins might be negative on this specific product. Much of the research on the dynamics of deposit prices relates to the paid rates, which only to a certain degree represents the value of the deposit as a funding source.

3 Background

In this section we will go through a wide range of aspects that need to be considered when assessing the value of a deposit. Even though most articles on deposits focus on pricing on the dynamics of retail deposit rates this is interesting as there are no clear cuts in segmentation of deposits and depositors

3.1 A basic deposit pricing method

As previously said the contractual tenors of deposits do not fully reflect the value but one can derive a least favorable valuation since the contractual duration of the deposit tells us that it will remain at least that long in the bank. The value as a function of the contractual tenor can be found by looking at observable market rates as the different IBOR rates which reflects the banks funding costs for different tenors. For tenors longer than a year one can look at senior unsecured bond prices to deduct an appropriate interest rate. This way of looking at deposits underestimates the values of deposits where behavioral tenors are much longer than contractual ones but it reflects the value of deposits in the case where we does not allow any assumptions of prolongation and may serve as a reference point to any other derived value.

3.2 Funds transfer pricing and its impact on deposit pricing

The value of a deposit for a bank is dependent on what return the bank can get from lending the amount received. So to be able to know whether or not to accept a deposit we need some reference rate reflecting lending or investment opportunities. Banks typically have a funds transfer price (FTP) framework from which margins on deposits and lending can be calculated. A very simple way of calculating a fund transfer price is to calculate a weighted average cost of capital (WACC) which then can serve as a reference for calculating margins on lending or specific funding sources.

Dermine (2011) brings up several aspects of setting FTPs by creating a foundation and an advanced FTP framework. The foundation approach (named FTP1) uses three components, the price elasticity of loans and deposits with regards to the banks customers and an interbank rate (IBOR). Under the assumption that the interbank market is sufficiently deep to not react to any additional lending or deposits from one single bank the situation can be represented as in figure 1.

Here lending and borrowing decisions are independent of each other but only depend on the IBOR rate and hence the name separation theorem. Optimal lending and deposit volumes can be derived as L^{OPT} and D^{OPT} while the gap or surplus can be covered or deposited in the interbank market. Figure 1 represents a specific tenor e.g. a two year term loan. One would have to apply the same methodology for all tenors that are of interest to the bank.

For products where contractual and behavioral tenor is very different e.g. deposits on salary accounts or savings accounts without conditions Dermine (2011) suggests a multi period approach (FTP2). For this purpose the deposit volume is split into core

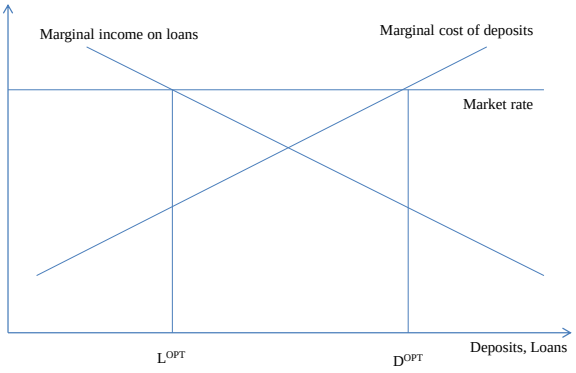

Figure 1: Separation Theorem

and volatile deposits each assigned a maturity, long and short respectively. Effective maturity is then the weighted average. Denoting the deposit rate d_t, the volume as a function of the rate and the volume the previous period as $D_t(d_t, D_{t-1})$ and b_t the market rate, one can calculate the present value of profits and marginal income of deposit increase.

$$PresentValueOfProfits = [(b_t - d_t) \cdot D_t(d_t)] + \frac{[(b_{t+1} - d_{t+1}) \cdot D_{t+1}(d_{t+1}, D_t)]}{1 + b_{t+1}} \quad (1)$$

$$MarginalIncome = (b_t - d_t) + \frac{(b_{t+1} - d_{t+1})}{1 + b_{t+1}} \cdot \frac{\partial D_{t+1}}{\partial D_t} \quad (2)$$

Multi period models are suitable for all product types known to have a market share stickiness as wells as a rigidity of interest rates. These two first approaches rely on a well-functioning interbank money market and where widely used until the financial turmoil started in 2007 but after that several new aspects of funds transfer pricing has been researched as the impact of mismanagement became evident.

On a rationed interbank market the previously described internal pricing models can not be used as funds are not available to cover an eventual gap i.e. the bank has to be self-funded (FTP3). Figure 2 shows the FTP in a situation when interbank funding is unavailable and hence the entire loan volume must be funded by deposits.

Dermine (2011) also writes about pricing implications of Basel III Liquidity Buffers

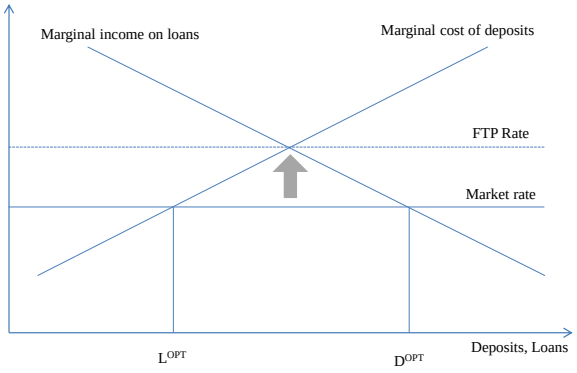

Figure 2: Separation Theorem on Rationed Interbank Market

which impact mainly the usage of demand deposits for funding loans. This approach is based on a five component balance sheet found in table 1.

Table 1: Simplified balance sheet

Assets	Liabilities
Loans L	Deposits D
	Interbank Deposits I (i)
Liquid Bonds B (b)	Long Term Debt F (f)

Under the condition that the entire buffer is funded by long term funding, α % of deposits has to be covered by reserve and β % of interbank funding has to be covered by the reserve. The result is that the marginal cost of loans and deposits has to be adjusted with the cost or revenue related to the liquidity reserve. This can be described by the following expressions called FTP4.

$$MarginalCostOfLoans = i + [\beta * (f - b)] \tag{3}$$

$$MarginalIncomeOfDeposits = i + [(\beta - \alpha) * (f - b)] \tag{4}$$

Asset quality should impact the bank's funding cost and hence the cost of liquidity mirrored by the FTP. Taking an example with an A rated bank with a funding cost

of 5,6% and a cost of equity of 10% buying a AAA rated asset expected to yield 5,5% while the market expects 5%. With a tax of 40% on profits the Economic profit can be calculated as follows.

$$\begin{aligned} StandardEconomicProfit &= Profit - CostOfAllocatedEquity \\ &= (1-0,4)*[5,5\%*100-5,6\%*98]-[10\%*2] = -0,1928 \end{aligned} \tag{5}$$

The *standard economic profit* is likely to be underestimated since the value created by the safe loan is charged a too high cost of interbank debt and equity. The very safe AAA asset reduces the overall risk of the debt of the bank and hence the marginal cost of interbank funding should be less than 5,6% and the same goes for cost of equity. A revised method to calculate the economic profit can be derived by looking at the two balance sheets in tables 2 and 3. Table 2 represents a typical leveraged bank balance sheet and while table 3 represents an unleveraged transaction for the bank but with a funding transaction on behalf of the shareholders.

Table 2: Traditional balance sheet

Assets	Liabilities
New Safe Loan 100 (5,5%)	Debt 98
	Equity 2

Table 3: Revised balance sheet

Assets	Liabilities
New Safe Loan 100 (5,5%)	Equity 100 (5%)
-Debt 98 (5%-ϵ)	-Equity 98 (5%-ϵ)

Calculating the economic profit with a demanded return on equity of 5% as expected by the markets and a funding cost ϵ smaller than 5% since there is an equity cushion protecting the lenders Dermine (2011) finds the following *advanced economic profit* of buying the asset.

$$\begin{aligned} AdvancedEconomicProfit &= (P/L - CostOfAllocatedEquity)_{bond} \\ &\quad + (P/L - CostOfAllocatedEquity)_{funding} \\ &= [(1-0,4)*5,5\%*100-5\%*100] \\ &\quad + [-(1-0,4)*(5\%-\epsilon)*98-(5\%-\epsilon)*98] \\ &\approx 0,26 \end{aligned} \tag{6}$$

This result indicates that the transaction should be done with regard to the economic profit of the shareholders. The ability to differentiate the funding costs with regard to

asset quality as presented in FTP5 changed the view of whether the deal would be profitable or not.

Dermine (2011) also discusses the implications of Basel III metrics such as the Net Stable Funding Ratio which compares asset and liability mismatch around the 1 Year point and concludes that the relevant funds transfer price in such an environment will be the market rate on the banks long term debt (FTP6).

Bank credit risk will have an impact on the banks' funding cost. Dermine (2011) present two ways, the conditional and unconditional approach, to incorporate this cost into the FTP. Considering a one year risky asset with a contractual return a, a probability p of being repaid and hence a probability (1-p) of default with a recovery REC. The loan is funded with corporate bonds C with return c and equity. The return on assets will not be paid when in default which gives the following balance sheet.

Table 4: Incorporating Bank credit risk unconditional approach

Assets	Liabilities
Asset A (a)	Corporate Bond C (c)
	Equity E (unconditional cost of Equity R_E)

Assuming that a default of the asset put the bank in default then the bondholder recovers the assets REC. The possible outcomes can be represented by table 5.

Table 5: Payout table

State	Probability	Asset	Bond	Equity
No default	p	aA+A	cC+C	$R_E\|_{\text{no default}}$+E
Default	1-p	REC	REC	0

Value creation is achieved when unconditional expected return on the asset is higher than the unconditional expected cost of funds.

$$p*(aA+A)+(1-p)*REC > p*(cC+C)+(1-p)*REC+ \\ +(1-p)*(R_E|_{nodefault}+E)+p*0 \quad (7)$$

This is to be compared with the conditional approach where Dermine (2011) only considers the case of no default and which yields the following condition:

$$(aA+A) > (cC+C)+(R_E|_{nodefault}+E) \quad (8)$$

Dermine (2011) proposes to use the conditional approach for allocation of the contractual cost of debt.

3.3 Academic research on deposit pricing

In the article "Using physical models to describe and vale core deposits" a model is developed that "link rate policy to rate modeling", "provide a basis for interpreting modeling parameters" and " propose a conceptual foundation for valuing retail deposits, including core deposits". The retail market is characterized by its size (US bank retail deposits totals more than $3.0 trillion) and its illiquidity (about 1 % turnover). Hence with a good pricing strategy one can build a large low-cost funding base. Building a model for pricing deposits is complex due to the large extent of optionality surrounding deposits compared to other financial derivatives. These options consists of a continuous bank option to increase maintain and decrease rates, continuous customer option to withdraw partial or entire balances and continuous customer option to increase balances. In its turn, rate setting might be affected by "customer perception of implicit product specific floors", "bank perception of product-specific caps", "increased availability of customer alternatives", which increase the probability of customers exercising their balance withdrawal option. The rate to be assumed driving change in bank deposit rates is supposed to be LIBOR and hence the model uses three-months LIBOR. Banks have in practice used their optionality to change rates as follows; moving deposit rates in same direction as market rates, changing deposit rates less (or more) than the change in market rates (for example, fractional sensitivity) and changing retail rates at a later date than the change in wholesale rates (for example, lagging behaviors). The authors state three fundamental postulates; for every market rate there is a unique equilibrium rate and vice versa, equilibrium response is achieved only after the passage of sufficient time and the market-administered rate relationship is linear. The postulates are identical to assumptions of relaxation processes in condensed-matter physics and hence implies that similar models might be used for setting interest rates. This gives the possibility of constructing a model not solely based on regressions but derived from a set of theoretically consistent relationships long established in literature. Market rate, deposit service cost competitive responses, yield curve slope measures and macroeconomic factors are stressors likely to affect the deposit rate. Fitting data to the models reveals that money market and time deposit rates exhibit similar behavior but deposit rates are quicker to follow market rates by a factor three. When reviewing bank and regulatory valuation of core deposits the article concludes that bank practitioners typically value bank deposits by explicit cash flow definitions.

3.4 Commercial deposit modeling

Firmac Solutions has a service/solution that they call "Deposit Analytics - a predictive solution for deposit pricing and management". In the article "Deposit pricing and management through price optimization and predictive behavioral modeling" they state that methods for deposit pricing are rather unsophisticated. The most commonly used technique seems to be checking the competition and pricing accordingly. This is said to be efficient only if all organizations operate with equal efficiencies and that the depositors of each institution possess the same price sensitivities. Other techniques judged

to be mundane by Firmac Solutions are ""walking rates", simple account segmentation or sectoring, establishing pricing "rules", pricing at the margin and monitoring to see if things are working...". Walking rates refer to raising prices until desired balance growth is reached. Firmac solutions believe that deposit pricing should have a methodology from a mathematical perspective, be able to predict balances and depositor behavior, measure net cost of a deposit at a given offered price level, determine net present value of a deposit gained and should address efficiency of deposit gathering. Firmac's method is based on "seeking an equilibrium rate that is in response to changes in market rate. With factors bearing such elasticities (both short and long term), future market rates, competitor pricing responses, account migration, cannibalization...".[1] Essential to get good results is to understand the behavior of all depositors but one must also see the "larger context of asset and liability management (ALM) with issues such as liquidity needs, slope of the curve, duration matching, alternative cost of funds, and others".[2] The model developed by Fimac is for price optimization and does not give any support to the more strategic ALM questions.

Novantas Solutions supplies a tool called Pricetek to be used for deposit pricing. The tool is said to be able to earn an additional 10 to 15 bps compared to a non price discriminating strategy. Parameters used for analyzing deposit market includes competitor characteristics, rate history, projection of future market rates based on past correlation to indexes and the yield curve.

Deposit prices are impacted by market structures and several studies have been carried out to find explanatory factor to interest rate levels. One of the most studied factors is market concentration. Typically a high degree of concentration leads to lower interest rates on deposits. Size and structure of the banks on the market may also impact the prices i.e. large banks might have a wider range of investment and funding opportunities than smaller banks. The direction of this impact remains somewhat unclear. Large banks should be able to pay up more for deposits as they should have a larger range of investment opportunities but on the other hand might be able to have a more opportunistic approach to a certain depositor segment as they have a wider range of funding sources. Another possible reason for small and large banks setting different interest rates is that large banks operating in several markets set a single deposit rate rather than optimizing in each market. Yet other reasons for offering different prices might be that depositors are reluctant to switch banks for small differences in interest rates which means that it is very likely that new entrant in a market will have to offer significantly higher interest rates to attract customers. All these reasons are affecting not only relative pricing but also have an effect on the average rates offered in the market since banks tend to price at least partially in repose to its competitors. This dynamic becomes very interesting when large multi-market players are present in the same market at the same time as local players. Rates have been found to correlate inversely to the local market share of multi-market banks. Economies of scale and funding advantages have been put forward as an explanation but these advantages are not necessarily limited to multi

[1]Deposit Pricing and management through price optimization and predictive behavioral modeling
[2]Deposit Pricing and management through price optimization and predictive behavioral modeling

market players but are more a function of bank size and product mix. Rosen defines an empirical model:

$$\begin{aligned} DepostInterestRate_{i,m,t} = f(&MarketConcentrationvariables_{m,t}, \\ &SizeStructureVariables_{m,t}, MultimarketShare_{m,t}, \\ &OtherMarketStructureControls_{m,t}, BankSpecificControls_{I,m,t}, \\ &MarketConditionControls_{m,t}) \end{aligned} \tag{9}$$

Measuring market concentration can be done by calculation of the Herfindahl-Hirshmann index (HHI) which sums up the squared market shares of the banks in the defined. Rosen finds a negative correlation between concentration and deposit rates. Market structure measured through number of banks (negatively correlated), share of multi market banks (positively correlated), size structure showing that many small or very large banks tend to decrease deposit rates, multi market share (positive correlation) while multi market bank rates are lower than other banks rates. Pricing in urban areas tends be higher and prices are also higher in larger markets. A bank also generally prices deposits higher if not being a full service bank and also raises rates if it is financially weaker than its competitors. Rosen also finds evidence that banks fight more aggressively over deposits in what they define as their home markets.

3.5 Legislation and regulations

Legislation and regulation might cause digital effects on deposit prices as well as imply boundary conditions if trying to find optimal prices since the usability of deposits might differ alot.

In the Basel III international framework for liquidity risk measurement, standards and monitoring one can find the definition of a Liquidity Coverage Ratio (LCR).In this metric deposits are split in two main categories. "Retail deposits are defined as deposits placed with a bank by a natural person. Deposits from legal entities, sole proprietorships or partnerships are captured in wholesale deposit categories. Retail deposits subject to the LCR include demand deposits and term deposits...".[3]Retail deposits are then split into stable and less stable portion of funds. Stable retail deposits have a run off rate of 5% and higher and contains deposits fully covered by an effective deposit insurance scheme or by a public guarantee and depositors have a relationship with the bank or the deposits are in a transactional account. The less stable deposits have run off rates 10% or higher and these would typically consist of deposits not covered by an effective insurance scheme or sovereign guarantee, high-value deposits, deposits from sophisticated or high net worth individuals, deposits that can be withdrawn quickly and foreign currency deposits. The Basel committee also specifies a category called "Retail fixed-term deposits". These deposits are to be excluded from the LCR if they have a "withdrawal notice period of more than 30 days or if the depositor has no legal right to withdraw

[3]p.12 Basel III: International framework for liquidity risk measurement, standards and monitoring

within 30 days or if early withdrawal results in a significant penalty that is materially greater that the loss of interest"[4]. "The unsecured wholesale funding is defined as liabilities and general obligations that are raised from non-natural persons and are not collateralized. Obligations related to derivative contracts are explicitly excluded from this definition. Wholesale funding included in the LCR is defined as all funding that is callable within the LCR's horizon of 30 days or that has its earliest contractual maturity date stated within this horizon. For funding with options exercisable at the banks discretion, supervisors should take into account reputational factors that may limit a bank's ability not to exercise the option".[5] Unsecured wholesale funding is split into five categories; "unsecured wholesale funding provided by small business customers", "unsecured funding with operational relationships", "deposits in institutional networks of cooperative banks", "unsecured wholesale funding provided by non-financial corporates and sovereigns, central banks and public sector entities" and unsecured wholesale funding provided by other legal entity customers". The funding provided by small business customers is in turn divided into a stable and less stable part with run off factors of 5 and 10 % respectively. Definitions of the two categories are to be supplied by local authorities. These categories consist of "non-financial small business customers that are managed as retail exposures and are generally considered as having similar liquidity risk characteristics to retail accounts, provided the total aggregated funding raised from one small business customer is less than €1 million".[6] The Basel committee regards operational relationships to have a stabilizing effect on deposits and the run off rate is set to 25 % to reflect this fact. An operational relationship in this context refers to "clearing, custody or cash management relationships in which the customer is reliant on the bank to perform these services as an independent third party intermediary in order to fulfill its normal banking activities over the next 30 days. These deposits have to be by-products of the underlying services". [7] For the deposits in a cooperative network the run-off rate is also set to 25 %. Conditions for this category is that the money is part of statutory minimum deposit requirements or in the context of common task sharing and legal statutory or contractual arrangements as long as all banks involved, depositor and receiver, are subject to the same liquidity risk. Unsecured wholesale funding provided by non-financial corporates and sovereigns central banks and public sector entities have a 75 % run-off rate while unsecured wholesale funding by other legal entity customers has a 100 % run-off factor.

The Basel III framework also suggests a more long term structural metric called Net Stable Funding Ratio (NSFR) which also asses the stability and hence usability of deposits.

These regulatory assessments of deposit stability could have significant impact of deposit pricing if the regulatory ratios becomes the binding constraints when it comes to liquidity risk taking. Judged from banks current outcome in these metrics it is very

[4]p.13 Basel III: International framework for liquidity risk measurement, standards and monitoring
[5]p.14 Basel III: International framework for liquidity risk measurement, standards and monitoring
[6]p.15 Basel III: International framework for liquidity risk measurement, standards and monitoring
[7]p.15 Basel III: International framework for liquidity risk measurement, standards and monitoring

Table 6: LCR Run-off rates

Main Cat	Sub. Cat.	Run-Off	Examples
Retail	Stable	5%	Deposit covered by insurance, relationship with bank and transactional accounts
	Less Stable	10%	Other retail deposits
	Fixed term >30 days	0%	Maturity contractually >30 days with significant breakage fee
Corporate	Fixed term >30 days	0%	Maturity contractually >30 days
	Operational & guaranteed	5%	Deposit covered by insurance for operational purpose
	Operational	25%	Deposit for operational purpose
	Fixed term short	40%	Maturity contractually <30 days
Financial	Fixed term >30 days	0%	Maturity contractually >30 days
	Operational & guaranteed	5%	Deposit covered by insurance for operational purpose
	Operational	25%	Deposit for operational purpose
	Fixed term short	100%	Maturity contractually <30 days

likely that if these metrics are implemented with current run off rates optimization under these constraints will become important to remain profitable.

A bank with empirical evidence of much lower run off rates on its deposits volumes than suggested by these metrics will have the incentive of turning towards market funding as the stability of its deposits is not fully recognized by the NSFR and LCR. From the LCR and NSFR we can derive implicit tenors and hence prices of the assessed volumes by comparing to unsecured debt instruments e.g. a 25 % run off under the LCR of a deposit corresponds to rolling commercial papers with 120 days tenor for the same amount. Rolling a volume with 120 days initial tenor corresponds to 25 % maturing within 30 days giving an LCR outflow. In both cases 75 % percent of the volume can be used for e.g. long term lending.

In tables 8 and 9 we can for each deposit and depositor find an alternative funding source by issuance of senior unsecured debt matching the maximum implicit tenor derived from the LCR and NSFR metrics to guarantee an at least as good treatment as the deposit under the Basel III metrics. One can observe that very seldom both constraints are active why more complex structures than senior unsecured instrument with bullet

Table 7: NSFR Run-off rates

Main Cat	Sub. Cat.	Run-Off	Examples
Retail	Stable	10%	Deposit covered by insurance, relationship with bank and transactional accounts
	Less Stable	20%	Other retail deposits
	Fixed term >1 Year	0%	Maturity contractually >1 year
Corporate	Fixed term >year	0%	Maturity contractually >1 year
	Other	50%	Maturity contractually <1 year
Financial	Fixed term >year	0%	Maturity contractually >1 year
	Other	100%	Maturity contractually <1 year

Table 8: LCR Implicit Tenors

Main Cat	Sub. Cat.	Run-Off	Implicit Tenor (days)
Retail	Fixed term >30 days	0%	Tenor/(30*RunOff$\|_{>30}$)
	Stable	5%	600
	Less Stable	10%	300
Corporate	Fixed term >30 days	0%	Tenor/(30*RunOff$\|_{>30}$)
	Operational & guaranteed	5%	600
	Operational	25%	120
	Fixed term short	40%	75
Financial	Fixed term >30 days	0%	Tenor/(30*RunOff$\|_{>30}$)
	Operational & guaranteed	5%	600
	Operational	25%	120
	Fixed term short	100%	0

repayment might be suitable if trying to optimize under the Basel III metrics.

4 Regression analysis of the depositor base

4.1 Data selection

For the regression analysis only certain types of deposits are selected, transaction accounts and money market deposits. This means that e.g. received margins of safety and deposits in structured leases are excluded as changes in these amounts are to a very high degree linked to the contractual terms of that business activity and the money is a necessity for conducting that business.

Table 9: NSFR Implicit Tenors

Main Cat	Sub. Cat.	Run-Off	Implicit Tenors (years)
Retail	Fixed term >1 Year	0%	Tenor/(1*RunOff$\|_{>1}$)
	Stable	10%	10
	Less Stable	20%	5
Corporate	Fixed term >1 Year	0%	Tenor/(1*50%)
	Other	50%	2
Financial	Fixed term >1 Year	0%	Tenor/(1*100%)
	Other	100%	0

4.2 Product characteristics

The transaction accounts are used for daily operations of the customers and most often the money is always accessible. One may however choose to lock up the money for a higher interest rate. Normal tenors are one or three months and prolongation can be automatically or not. The deposit sales desks accept money of any tenor and amounts are repaid at maturity hence renewal is an active choice of the customer.

4.3 Assessing deposit stability

As the deposit value can be identified by it's stability an easy to grasp and rather intuitive measure can be defined by the standard deviation and average volume received from each depositor. These two figures can then be combined into a ratio by splitting the standard deviation by the average volume hence giving a depositor score easily expressed in percent assessing the stability of the amount deposited.

$$StabilityScore = \frac{StDev(X)}{Average(X)} \tag{10}$$

4.4 Regression results

Running a regression analysis on the transaction account customers over variables such as average volume on the accounts, number of account held by the customer, number of sites where the customer holds accounts, number of currencies on these accounts and the size of the company estimated by the customers turnover as well as industry type of the customer one hopes to be able to identify stable deposit volumes.

Several parameters are significant and suggest that one can build a pricing formula based on the company's main activity as well as depth of relationship with the bank measured by numbers of accounts held by the customer with the bank and number of geographical points of interaction. Number of currencies as well as corporate size can not be said to have an impact on the stability of received deposits.

Table 10: Regression results

Parameter	Estimate	Std. error	T value	P
Intercept	a $_1$	0.0630	23.61	0.000000
Average volume	a $_2$	0.0000	-2.53	0.011460
No Of Accounts	a $_3$	0.0004	-4.35	0.000014
No Of Sites	a $_4$	0.0213	-7.29	0.000000
No Of Currencies	a $_5$	0.0088	-1.17	0.241440
Turn Over	a $_6$	0.0000	-0.01	0.990990
Industry A	a $_7$	0.1655	1.45	0.146530
Industry C	a $_8$	0.0793	2.67	0.007690
Industry D	a $_9$	0.1827	1.32	0.188300
Industry E	a $_{10}$	0.7641	0.74	0.462460
Industry F	a $_{11}$	0.1524	2.02	0.043660
Industry G	a $_{12}$	0.0772	1.64	0.100410
Industry H	a $_{13}$	0.1050	0.67	0.502630
Industry I	a $_{14}$	0.2544	1.24	0.216180
Industry J	a $_{15}$	0.1043	0.49	0.626750
Industry K	a $_{16}$	0.0719	2.62	0.008720
Industry L	a $_{17}$	0.0781	2.52	0.011840
Industry M	a $_{18}$	0.0735	5.69	0.000000
Industry N	a $_{19}$	0.0811	1.85	0.064930
Industry O	a $_{20}$	0.0991	0.22	0.830140
Industry P	a $_{21}$	0.1848	-1.20	0.229390
Industry Q	a $_{22}$	0.1515	0.70	0.486130
Industry R	a $_{23}$	0.1829	1.02	0.308190
Industry S	a $_{24}$	0.1095	0.12	0.907310
Industry T	a $_{25}$	0.6255	0.79	0.430090
Industry U	a $_{26}$	0.4438	0.75	0.452890

An attempt at finding industries that where negatively correlated to the development of the overall volume was made but no statistical evidence of such existence could be made.

$$\begin{aligned} EstScore &= f(Industry, NoOfAccounts, NoOfSites) \\ &= a_1 + a_3 \cdot NoOfAccounts + a_4 \cdot NoOfSites + \\ &+ \mathbb{1}_{[Industry=A]} \cdot a_7 + \mathbb{1}_{[Industry=B]} \cdot a_8 + ... + \mathbb{1}_{[Industry=U]} \cdot a_{26} \end{aligned} \tag{11}$$

Current deposit pricing methods is based on an assumption that deposits are equivalent to senior unsecured market funding of a specified tenor. Then a cost of holding a reserve based on regulatory treatment as well as internal stability assessment for the total deposit base is deducted from that price which gives the internal price of that deposit.

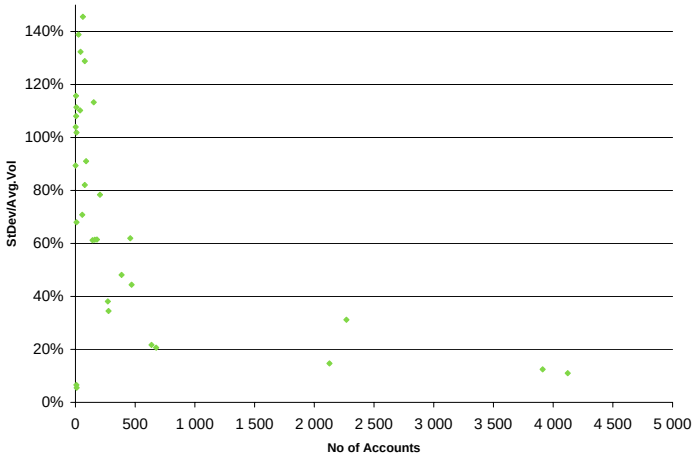

Figure 3: Standard Deviation of volumes per No of Accounts (enlargement)

Using the current framework for deposits with a fixed tenor and a reserve cost we can now calculate an adjustment to that price based on what we now about the depositor using the same components as in the current method. This way of differentiating the interest rate will be based on how the stable part of the depositor volume changes with depositor behavior.

Under the assumption that the behavior of each account depositor can be described by the normal distribution with a mean and a standard deviation one can easily aggregate these distributions. Reasoning in terms of quantiles trying to asses a floor level of the total deposit volume based on the stability of individual customers one finds the following expression.

$$\delta p_{account} = f(IFTP, EstScore, CurrAvgScore, CurrNoOfDepositors) \quad (12)$$

$$\delta p_{account} = IncreaseInStableVolume * ReserveCost \quad (13)$$

$$IncStableVol = \mathcal{N}^{-1}(P, 1, NewStDev) - \mathcal{N}^{-1}(P, 1, CurrentStDev) \quad (14)$$

$$CurrentStDev = \frac{CurrAvgStabilityScore}{\sqrt{CurrNoOfDepositors}} \quad (15)$$

$$NewStDev = \frac{EstDepositorStabilityScore}{\sqrt{CurrNoOfDepositors}} \quad (16)$$

$$(17)$$

Hence the price adjustment will be based on current prices of available funding

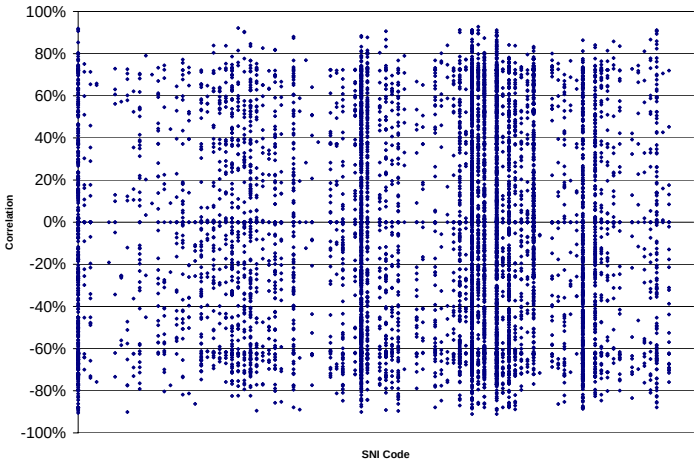

Figure 4: Correlation vs. total volume for different Industries

(IFTP), the assumed customer behavior (EstimatedStabilityScore) and how that relates to the existing customer base (CurrentAverageScore and CurrentNoOfDepositors). Approximate impact on deposit pricing can be derived from studying tables 11 which shows how the stable deposit volume changes with regards to stability score and confidence interval used and 12 which shows the relation to number of depositors and stability score. The increase in stable volume directly translates to a decreased need to hold reserve against deposit runs. The cost of such a reserve and hence the price adjustment varies with the funding of the reserve and what types of assets that are suitable for the purpose. If one would say that such reserve typically have had a price of 1% on average over the last couple of years the pricing implication on a deposit in a depositor base consisting of depositor base of 1000 customers with average stability score of 150% and a confidence interval of 0,001 where the estimated stability is 20%-age points better than average would merit paying up 2 basis points.

A price difference of two basis points is too small to be a competitive advantage when negotiating terms for account conditions why a broad implementation e.g. assessing every account with this model is judged unnecessary. We do however know from the gathered data that several depositor characteristics seem to have positive correlation with deposit stability why if one has the choice such deposit gathering should be prioritized.

Table 11: Sensitivity of confidence interval and Stability Grade

		P				
		0,1	0,01	0,001	0,0001	0,00001
Δ Grade	0%	0,00%	0,00%	0,00%	0,00%	0,00%
	-10%	0,44%	0,81%	1,07%	1,29%	1,48%
	-20%	0,89%	1,61%	2,14%	2,58%	2,96%
	-30%	1,33%	2,42%	3,21%	3,87%	4,43%
	-40%	1,78%	3,22%	4,28%	5,15%	5,91%
	-50%	2,22%	4,03%	5,35%	6,44%	7,39%
	-60%	2,66%	4,84%	6,42%	7,73%	8,87%
	-70%	3,11%	5,64%	7,49%	9,02%	10,34%

Table 12: Sensitivity of No of Customers and Stability Grade

		NoOfCustormers				
		1	10	100	1000	10000
Δ Grade	0%	0,00%	0,00%	0,00%	0,00%	0,00%
	-10%	34,32%	10,85%	3,43%	1,09%	0,34%
	-20%	68,63%	21,70%	6,86%	2,17%	0,69%
	-30%	102,95%	32,56%	10,29%	3,26%	1,03%
	-40%	137,26%	43,41%	13,73%	4,34%	1,37%
	-50%	171,58%	54,26%	17,16%	5,43%	1,72%
	-60%	205,90%	65,11%	20,59%	6,51%	2,06%
	-70%	240,21%	75,96%	24,02%	7,60%	2,40%

5 What is the tenor of a deposit?

The method presented previously is based on existing pricing methods and then suggests a way of adjusting deposit prices based on the regression analysis of the data. The deposit price, using this method is largely determined by one of the input parameters which is determined through an entirely qualitative process with little or no quantitavive support. To be able to justify the overall accuracy of the described approach a quantitative model for assessing the overall price would be of good use.

5.1 Relating deposits to other funding sources

The obvious alternative to deposits is market funding why it is important to make a comparison that one is not obviously cheaper than the other. Market funding characteristics are easy to describe as money is invested under a contract describing all cash flows from which exceptions are rare and prices are relatively easy to observe. Given a set of market instruments of different tenors implying different prices and regulatory treatment we may represent all or a selection of borrowing opportunities in the funding markets. Given the assessed stability of a depositor and the regulatory treatment of that

deposit it might be able to replicate the deposit characteristics through a combination of market instruments.

In this model the comparison is made over three parameters; internal stability measure, NSFR and LCR. Internal stability should always be one of the parameters as this represents the banks best estimate of the deposit characteristics and hence represents the true value/risk of the deposit according to the banks view. LCR and NSFR are taken into account as these two metrics are even though not fully implemented, very likely to become binding constraints in the coming years and will have a vast impact on banks funding strategy.

5.2 The set of Market Instruments

In the same manner as LCR and NSFR percentages were translated into tenors in tables 8 and 9 we may inversely use the tenor of market instruments to derive LCR and NSFR impact of rolling a large number of such instruments with an evenly distributed maturity profile. In the same way we can calculate the outflows from such contracts for the time horizon used in the internal stress testing models. This gives a set of market instruments presented in table 13 that one can use to replicate various deposits. All instruments represent the bank borrowing money but the first one which represents depositing money with the central bank.

Table 13: Funding market

Product	Tenor	LCR Run	Internal	NSFR ASF	Add on	Interest rate
CB	0	-100%	i_1	0%	-126	-0,9000%
1d	1	100%	i_2	0%	-20	0,9560%
1m	30	100%	i_3	0%	-10	1,0560%
2m	60	50%	i_4	0%	-5	1,1060%
3m	90	33%	i_5	0%	0	1,1560%
4m	120	25%	i_6	0%	7	1,2260%
6m	180	17%	i_7	0%	15	1,3060%
1Y	365	8,2%	i_8	0%	30	1,4560%
2Y	730	4,1%	i_9	50%	51	1,6660%
3Y	1095	2,7%	i_{10}	67%	70	1,8560%
4Y	1460	2,1%	i_{11}	75%	80	1,9560%
5Y	1825	1,6%	i_{12}	80%	89	2,0460%
6Y	2190	1,4%	i_{13}	83%	94	2,0960%
7Y	2555	1,2%	i_{14}	86%	99	2,1460%
8Y	2920	1,0%	i_{15}	88%	103	2,1860%
9Y	3285	0,9%	i_{16}	89%	105	2,2060%
10Y	3650	0,8%	i_{17}	90%	109	2,2460%
15Y	5475	0,5%	i_{18}	93%	120	2,3560%
20Y	7300	0,4%	i_{19}	95%	130	2,4560%

We introduce some notation describing the properties of these instruments in table 14 to be used for the remainder of this study.

Table 14: Notation: Market instruments

n	Number of instruments in funding market
i_i	Interest rate paid for instrument i
w_i	Amount borrowed with instrument i
$lcrrun_i$	LCR run of instrument i
$intrun_i$	Internal run of instrument i
asf_i	Available stable funding under NSFR from instrument i

5.3 Prizing through replication

With each deposit's characteristics known we can set up a linear optimization problem where we want to combine the instruments in table 13 into a "synthetic" deposit with the same properties as the real deposit. Index d refers to the deposit.

$$
\begin{aligned}
Min.\ Depositrate &= \sum_{i=1}^{n} w_i * i_i \qquad (18)\\
s.t.\ Lcrrun_d &= \sum_{i=1}^{n} w_i * Lcrrun_i\\
Intrun_d &= \sum_{i=1}^{n} w_i * Intrun_i\\
asf_d &= \sum_{i=1}^{n} w_i * asf_i\\
1 &= \sum_{i=1}^{n} w_i\\
0 &\leq w_i
\end{aligned}
$$

This problem does not always have a solution due to the boundary conditions imposing a restriction on going short in the funding market instruments. This condition represent current behavior but it should no be seen as an absolute condition. For some deposits solutions with equality conditions can be found but for others one needs to find alternative approaches.

A simple way of getting around this issue is to allow for the mix of markets instruments to be at least as good (ALAG) as the deposit by letting go of the equality conditions and replacing with inequality conditions. This will not exactly determine the value of the deposit as there will be some unused lending/borrowing opportunities but

this calculation can come in handy as a reference point when applying more complex approaches.

$$
\begin{aligned}
Min.\ Depositrate &= \sum_{i=1}^{n} w_i * i_i \\
s.t.\ Lcrrun_d &\leq \sum_{i=1}^{n} w_i * Lcrrun_i \\
Intrun_d &\leq \sum_{i=1}^{n} w_i * Intrun_i \\
asf_d &\geq \sum_{i=1}^{n} w_i * asf_i \\
1 &= \sum_{i=1}^{n} w_i \\
0 &\leq w_i
\end{aligned}
\tag{19}
$$

To be able to get a more precise calculation of the price three more approaches will be explored all based on allowing for short positions but with slightly different views of the implications of taking on short positions. The first approach would be to simply remove the condition of w_i being positive. This would allow for short positions in the market instrument which also could be interpreted as lending with zero margins. This does however poorly represent reality where balance sheet growth comes with a cost (e.g. capital, leverage ratios & stability fees). The usability of this method would hence depend on the size of the short positions of the solution to the problem.

$$
\begin{aligned}
Min.\ Depositrate &= \sum_{i=1}^{n} w_i * i_i \\
s.t.\ Lcrrun_d &\leq \sum_{i=1}^{n} w_i * Lcrrun_i \\
Intrun_d &\leq \sum_{i=1}^{n} w_i * Intrun_i \\
asf_d &\geq \sum_{i=1}^{n} w_i * asf_i \\
1 &= \sum_{i=1}^{n} w_i
\end{aligned}
\tag{20}
$$

As a second option we will optimize with equality conditions but not try to minimize the interest rate but instead minimize the transacted amount (MTA) as balance sheet

growth comes with a cost as previously mentioned. The result of this method is not suitable for direct implementation but has to be subject to an expert based judgment weather this long-short strategy is possible to execute and how it relates to the ALAG price.

$$
\begin{aligned}
Min. \sum_{i=1}^{n} abs(w_i) \\
s.t.\ Lcrrun_d = \sum_{i=1}^{n} w_i * Lcrrun_i \\
Intrun_d = \sum_{i=1}^{n} w_i * Intrun_i \\
asf_d = \sum_{i=1}^{n} w_i * asf_i \\
1 = \sum_{i=1}^{n} w_i
\end{aligned}
\tag{21}
$$

Yet another option is to only minimize the short positions (MSP) and not to penalize excess borrowing and central bank deposits. The results of this method also need an expert opinion weather the provided result represents a feasible strategy.

$$
\begin{aligned}
Max. \sum_{i=1}^{n} min(w_i, 0) \\
s.t.\ Lcrrun_d = \sum_{i=1}^{n} w_i * Lcrrun_i \\
Intrun_d = \sum_{i=1}^{n} w_i * Intrun_i \\
asf_d = \sum_{i=1}^{n} w_i * asf_i \\
1 = \sum_{i=1}^{n} w_i
\end{aligned}
\tag{22}
$$

A more sophisticated approach would be to expand the set of market instruments with a number of lending opportunities. This would allow us to more accurately calculate the surplus value of the ALAG-method. One would still have to make a much simplified approach of the possible value of lending. In this case you need to study the regulatory treatment of different lending options as well as the banks view of the liquidity in the same type of lending to get factors for the LCR, internal assessment and

the NSFR. Instead of interest rate paid one needs to know what profit that could be generated from each lending opportunity to then get the correct price of the deposit. This method demands many more parameters which might not be easily observable such as the demand for loans preferably all over the curve but might be still be the fairest approach for certain products that demands large short positions to be replicated in the MSP and MTA methods.

6 Discussion

The developed model offers some factors that can be used for predicting depositor behavior but largely behavior is dependent on factors other than the ones that have been investigated in this report. There seems to be some differences depending on industry belonging of depositors but the large impact of industry belonging when assessing deposit value comes from regulatory constraints. Differentiating the current depositor base only with regards to the banks own empirical experience does only motivate price differences of a few basis points.

The other maybe more interesting result trying to put the price paid for deposits in the context of other funding sources where the deposit is described by parameters derived from the internal empirical experience as well as considering regulatory aspect of deposit usability shows that there is reason to differentiate prices with regards to several parameters (i.e. industry, average volume etc.).

The model gives prices related to costs of raising funding in the markets but it has a weakness in not being sensitive to lending opportunities and hence an implementation without close monitoring of the effects might lead to paying more for the funding received than received from lending creating an "Ebberöds Bank". The obvious next step in developing this model should be to look at if an Ebberöds-factor should be applied to calculated deposit prices if balance sheet assets do not generate enough income to cover for cost of liabilities.

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