

2 Analysing the Practical Problem

One of the major businesses and purposes of a bank is to act as an intermediary between savers and investors¹⁰. It collects deposits on the one side and issues loans on the other side. Thus, a main source of income is the interest rate difference between interest paid to savers on the one hand and received from borrowers on the other hand.

The bank earns money not only due to the intermediary service that it provides, but for taking on several risks. Thereof the most important are credit default risk, interest rate risk and liquidity risk. The latter two are, at least in part, arising from term transformation. Term transformation or “structural position” refers to the fact that liabilities tend to have much lower durations than assets in a bank’s balance sheet¹¹. This can be explained by the market demand for long term asset products like loans and short term liability products like transaction and savings accounts.

The major aim of asset and liability management (ALM) is to manage the interest rate risk and liquidity risk arising due to the mentioned differences and mismatches in the balance sheet structure¹².

However, creating a sound framework for ALM is not a trivial task, because certain products (NMAs) exhibit the special feature of having no contractual maturity, which means that cash flows can occur at any time, or only require a short time of notice. On the liability side sight deposits, money market deposits, and savings deposits are among others typical products of that type. On the asset side these products are less numerous, but exist in the form of credit card loans, overdrafts and in some cases loans with prepayment options.

In return for the client’s freedom of choice regarding timing and amount of the cash flows of these products, the bank reserves the right to adjust interest rates of existing contracts and also makes use of this possibility.

On the one hand, reasons for changes in those client rates may be strategic, such as raising rates relative to competitors in order to keep deposits longer and attract more volume. On the other hand, rate adjustments are due to changes in the

¹⁰ Llewellyn (1999), p. 9

¹¹ Bessis (2010), p. 274

¹² Bessis (2010), p. 268

current market situation, in other words the current interest rate level or yield curve.

Due to absence of direct hedging instruments for NMAs, they need to be modelled to be manageable. This can be done by fitting a replicating portfolio¹³ of fixed-income securities to either the expected present values and their interest rate sensitivity of NMAs or other optimization approaches with interest rates, client rates and volumes as major input factors. This portfolio may then be integrated in the ALM process and used to derive hedging and structural decisions as well as expected profit margins from it.

Moreover, as non-maturing accounts serve as funding for longer term asset products, their aggregate internal valuation or pricing becomes important. The term funds transfer pricing (FTP) stands for the rate that is paid internally to units of the bank that acquire the funds and that are charged for providing funds to asset side units, which e.g. give out loans. The bank's internal intermediary function is usually taken by the treasury department. The calculated FTP should give the profit-maximizing incentive for raising deposits¹⁴.

Furthermore, to follow an integrated risk management approach, this model should take liquidity risks into account, which arise from a possible decline of NMA volumes.

Finally, for accounting and taxation reasons, one may be interested in the economic value of NMAs. However, under the current legislation (IFRS) it is prohibited, to account for economic values of NMAs in financial statements, therefore the emphasis lies on the other purposes outlined above.

2.1 Expectations and Uses for the Model

The requirements for such a model are numerous. It has to reflect the complex real situation of the development in non-maturing accounts cash flows in an accurate way. This is difficult, as there is a wide range of possible influencing factors like market interest rates, macro-economic developments, political or environmental events, corporation specific events, and finally always human behaviour and reasoning.

¹³ This hedging approach is a widely used technique in most scientific papers on that topic and will be an integrated part in the model used in this thesis.

¹⁴ Sheehan (2004), p. 1

Apart from finding a causally correct model, the output of such a model must be sufficiently practical, so that users will be able to deduct business or hedging decisions from it.

In practise, the model has to be easy to use, easy to maintain, compatible with standard business IT-systems in banking environment, and implementation should require only a minimum necessary amount of resources. That implies a certain degree of simplicity and an efficient implementation into the IT-landscape of the bank.

Furthermore the model must be able to deal with available data, and data quality. This is a special topic in practise and in theory, as empirical studies are rather scarce in literature, and data samples usually comprise aggregate data published by central banks or specific product groups of individual banks. Therefore, a model that worked in such a case study doesn't have to be eligible for generalization.

Additionally, as risk management is mainly a forward-looking task, the model should rather simulate future scenarios than reflecting one past scenario only.

However, if a proper model for pricing of NMAs and timing of NMA cash flows can be found, hedging should be made possible with existing financial products.

2.2 Approaches in Literature and Banking Practise

Valuation and risk management of non-maturing accounts is a young topic in scientific literature. Generally speaking, all models currently suggested deal to some extent with the following three risk factors and their interrelations:

1. Market interest rates
2. Client rate paid on the NMA
3. Volume of the NMA

Although possibly crucial factors, macro variables are generally neglected¹⁵, due to the lack of frequent, timely and reliable data and even more sophisticated and still poorly performing forecasting models¹⁶ for macroeconomic figures.

This thesis concerns itself with dynamic replication models. The term "dynamic" indicates that the three risk factors mentioned above are simulated in numerous scenarios and do not rely on only one historical scenario. Furthermore, it alludes to

¹⁵ With exceptions: e.g. O'Brien (2000).

¹⁶ Kalkbrener, M., Willing (2004), p. 1566

the model's capability of considering future changes in the composition of the replicating portfolio, whereas a static model assumes the same composition at all time.

The following chart (Figure 1) gives an overview on the concepts of NMA valuation and risk management models that make use of market rates (r), client rates (cr), and NMA volumes (V).

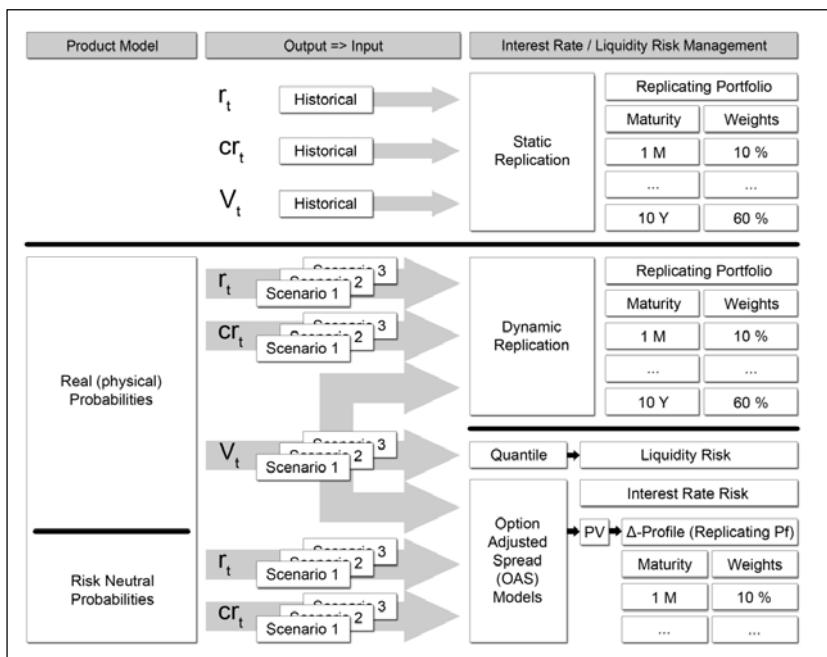


Figure 1: Overview of Static and Dynamic Models for NMA management¹⁷

A static replication model serves as a benchmark in a case study of this thesis. OAS models first implement a formula to calculate a NPV for the NMA, which is afterwards tested for interest rate sensitivity. From the resulting (interest rate) risk profile a replicating portfolio with the same risk profile can be generated. Liquidity risk then has to be treated separately. In this thesis no OAS model is implemented. Nevertheless, the important input and progress they brought for dynamic replication models are included in the following chronological literature overview.

¹⁷ Heidorn/Schmaltz (2008), p. 161

An early approach by the Office of Thrift Supervision¹⁸ (OTS) uses discounted expected cash flows to value NMAs and examine their interest rate sensitivity. The OTS calculates present values for different yield curve scenarios, without accounting for possible influences on client rates or NMA volumes. The major deficiency of this approach are deterministic functions for client rates paid, deposit volume evolution and market rates¹⁹, while the latter two are widely assumed to be at least partly stochastic in nature. Also the revised version of their framework²⁰ remains similarly simplistic.

O'Brien, Orphanides and Small²¹, introduce a stochastic valuation framework that values NMAs and durations of the NPV in a Monte Carlo simulation from a risk neutral view. However, this might be misleading, given that market agents are at least in some situations risk averse.

Selvaggio²² adds no-arbitrage arguments to his stochastic valuation framework.

Hutchison and Pennacchie²³ adopt an equilibrium-based valuation approach, accounting for market imperfections of bank liabilities²⁴ and incorporating a square-root, mean reverting interest rate process.

One major approach for the valuation of NMAs which has been used by many subsequent (OAS) models in literature has been brought forward by Jarrow and van Deventer²⁵ (1998). In their paper they introduce a framework for valuing NMAs based on imperfect markets and no arbitrage arguments. A net present value of future cash flows is derived using a risk-neutral valuation procedure²⁶. However, this implies the strong underlying assumption of a complete market. The authors therefore assume for simplicity that the variables for NMA volume and client rates

¹⁸ Office of Thrift Supervision (1994)

¹⁹ Jarrow/van Deventer (1998), pp. 251

²⁰ Office of Thrift Supervision (2001)

²¹ O'Brien et.al.(1994), pp. 400-435

²² Selvaggio (1996), pp. 363-373

²³ Hutchison/Pennacchi (1996), pp. 399-417

²⁴ This is the first model that claims to use a so-called general contingent claims framework. This alludes to the application of option-pricing theory (see Black/Scholes (1973), pp. 637-654) to any asset whose value depends on one or several "state variables" of possible relevant future states of the economy. For an elaboration on contingent claims, see Elliott/Kopp (1999), p. 2.

²⁵ Jarrow/van Deventer (1998), pp. 249-272

²⁶ No-Arbitrage Theory combined with a complete market assumption allows deriving a unique martingale measure that converts all discounted asset prices into martingales. The basis for this theory, assumptions and the mathematical derivation the risk neutral measure can be found in

for NMAs depend only on the term structure evolution deducted from treasury securities²⁷.

Furthermore, they show that the payoff using their formula resembles an exotic²⁸ interest rate swap with variable notional, which may be hedged by investing in bonds with different maturities (replicating portfolio).

Jarrow and van Deventer adopt previous approaches with regards to risk factors: A term structure model provides a scenario for the future (short-term) market rate, while client rate and deposit volumes are deterministic functions thereof.

A subsequent empirical analysis of by Janosi, Jarrow, and Zulli²⁹ shows a consistence with previous studies and promotes the validity of the model.

O'Brien³⁰ shows a way to account for deposit rate stickiness and asymmetric deposit rate adjustments³¹. This asymmetry leads to different interest rate sensitivities in case of positive or negative market rate shocks. He adds the level of income and a random error term as explanatory variables for deposit balances and another random error term to the client rate equation. Moreover, he expresses doubts that simple autoregressive models are valid for representing deposit premiums in a distant future.

De Jong and Wielhouwer examine particularly "the effects of the dynamic adjustment of the interest paid on the account and balance"³², while taking the market rate evolution as an exogenous variable. They use an error-correction model³³ for deviations from long term means of NMA volume and add the spread between a money market account (MMA) and the rate paid on the NMA as a variable to the their framework.

An intuitively reasonable specification of the methodology behind a term structure model for that kind of application has been first suggested by Kalkbrener and

²⁷ The assumption of a unique equivalent risk measure should only be made when using a term structure model with only one stochastic factor that follows the short rate. Using multi-factor models requires to derive an equivalent risk measure by other means (eg.: Schweizer 1995, pp. 1-32)

²⁸ "Exotic" refers in this case not only to the possibly increasing or decreasing notional, but also to the swap of two variable rates, client rate for market interest rate in particular.

²⁹ Janosi et al. (1999), pp. 8-31

³⁰ O'Brien (2000), pp. 1-44

³¹ Chapter 3.2 will elaborate on these concepts.

³² De Jong/Wielhouwer (2003), pp. 384

³³ For more information on error-correction models see Davidson et al. (1978), pp 661-692

Willing³⁴. They state that a calibration of the parameters should be done on a set of past data, rather than from current market values of plain vanilla instruments. This is due to the intention of forecasting realistic interest rates for a longer period of time (several years), whereas the usual goal is to price rather short-term derivatives.

They propose a deterministic client rate function, with dependency on market rates of different maturities. Furthermore, they use a stochastic term in their volume function, as they didn't find much correlation between market rates and NMA³⁵ volumes in their case study that would explain the volume evolution with sufficient accuracy. To account for liquidity risk, they introduce a quantile measure of the outcomes from a Monte Carlo simulation using their volume model.

A multistage stochastic programming methodology for the valuation of NMAs was published by Frauendorfer and Schürle³⁶ in 2003 (after previous publications on that topic³⁷). This refers to an optimization technique, which takes into account that decisions can be made in several points in time throughout the valuation or calibration period. In particular the weights of a replicating portfolio may be changed at each stage. This makes the model dynamic as compared to a static one, where the weights of the replicating portfolio are the same for the whole period. Their quite intuitive reasoning for the necessity of changing weights is the development of the environment (changing market rates, client behaviour, etc.) and its effects on the cash flow pattern of the NMA.

Their empirical case study showed an "improvement"³⁸ in model performance measured by either standard deviation or return (profit margin) figures. This was consistent with practical experience by a major Swiss bank, which had applied the model in practise for several years.

Sheehan³⁹ puts the focus on analysing the development of current volumes without new business (retained balances) of NMAs, stating that early works that

³⁴ Kalkbrener/Willing (2004), pp. 1547-1568

³⁵ In their paper they focus on deposit accounts such as demand deposits, saving accounts, and short time deposits.

³⁶ Frauendorfer/Schürle (2003), pp. 602-616

³⁷ Schürle (1998), pp. 1; Frauendorfer/Schürle (2000), pp. 67-101; Frauendorfer/Schürle (2000), pp. 189-209

³⁸ Improvement in this case, stands for a higher average margin, while causing less model violations in the form of refinancing activities.

³⁹ Sheehan (2004), pp. 1-34

use total balances do not capture the real interest rate sensitivity. Furthermore he questions the complete market assumption for the lending market and incorporates a lending market equation in his valuation model. He proves that the treasury rate (as a reference for the short rate) serves as a lower bound for the client rate.

Fidelity premiums⁴⁰, as they are common in the Benelux states, have been incorporated in the valuation model by Laurent⁴¹. Her findings include that a fidelity premium that raises the total interest paid to the client above the short-term discount rate might still result in a positive NPV of the NMA. Her work is particularly interesting in the current environment, where stable deposits are an integrated part in the Basel III liquidity coverage ratio⁴². With her specifications the model might be able to provide sufficient reason for regulatory reporting on that matter.

In the course of designing more profound regulations in the banking sector, the Basel Committee introduced “Principles for the Management and Supervision of Interest Rate Risk”⁴³. This rather rough framework explicitly mentions simulation approaches that may “involve assumptions about a bank’s strategy for changing administered interest rates⁴⁴ [...], about the behaviour of the bank’s customers [...], and/or about the future stream of business”⁴⁵. That recommendation aims for capturing option-like payoff structures in a bank’s balance sheet, but it also clearly indicates, that the Basel Committee is aware of already implemented and functioning models in practise. However, the state of scientific literature might not entirely reflect the progressiveness of models that may had existed by the time of the release of this principles and have been developed by now in banking practise, primarily by large sophisticated international banking groups.

Dewachter, Lyrio, and Maes⁴⁶ incorporate no-arbitrage multifactor flexible-affine term structure models⁴⁷ into their framework, which generate a better fit to

⁴⁰ This term refers to an extra remuneration on top of the base client rate for deposits that remain in the clients account for an extended period of time, e.g. longer than a year.

⁴¹ Laurent (2004), pp. 1-27

⁴² Basel Committee on Banking Supervision (2010), pp. 12-13

⁴³ Basel Committee on Banking Supervision (2004), pp. 1-40

⁴⁴ Administered rate products are a synonym for NMAs in the scope of this thesis.

⁴⁵ Basel Committee on Banking Supervision (2004), p. 30

⁴⁶ Dewachter et al. (2006), pp. 1-39

historical data as well as more realistic future yield curve dynamics. They suggest including future expected deposits only if “they can be identified in a verifiable way”⁴⁸. However, due to lack of data, they run their model several times assuming different decay rates of existing balances and one constant balance case.

Bardenhewer⁴⁹ provides a theoretical overview of NMA models with a special focus on the risk management purpose. He describes a methodology for constructing a replicating portfolio, based on moving averages of market rates⁵⁰. Additionally, he answers important questions that might confuse the risk management practitioner regarding assumptions and specifications of the model.

In 2007 Frauendorfer and Schürle⁵¹ published a comprehensive framework for NMA valuation, by extending their multistage stochastic programming model from 2003 with detailed descriptions of risk factor models and a more tangible explanation of their methodology. They use a two-factor extended Vasicek model for the term structure evolution, a threshold model for client rates with stepwise changes, and a third stochastic factor for their deposit balance equation.

An extensive empirical study of NMAs among German banks, including a wide range of different model specifications with respect to the term structure model (TSM) and the client rate model has been carried out by Entrop et al.⁵². Holding the NMA balances constant in their simulations, they conclude that:

- For assessing the NPV of the NMA, the choice of either TSM or pass-through model is of minor importance. Hence, less sophisticated model specifications can be used for simplicity and easy implementation.
- For assessing interest rate risk of the NMA it is important to use an elaborate TSM and an appropriate bank-specific pass-through model.

As this thesis is focused on the latter, it indicates the necessity of a sophisticated model approach.

⁴⁷ “Multifactor” refers to more than 1 stochastic factor. “Flexible-affine” alludes to possible changes in the market prices of risk. An example and evidence of superiority of such a model has been shown by Dai and Singleton (2000), pp. 1943-1978.

⁴⁸ Dewachter et al. (2006), p. 8. They give an example of a required deposit account for the salary of a customer that takes out a long-term mortgage from the bank.

⁴⁹ Bardenhewer (2007), pp. 220-256.

⁵⁰ The idea of this approach was provided by Wilson (1994).

⁵¹ Frauendorfer/Schürle (2007), pp. 327-359

⁵² Entrop et al. (2009), pp. 1-38

Paraschiv and Schürle introduce an elaborate model for client rate and NMA volumes in 2010⁵³. They incorporate a threshold error-correction model by deriving an equilibrium client rate from the co-integration⁵⁴ of market and client rates. Additionally, they take a long term market rate into account, whereas previous models used only one short term rate as explanatory variable. Their volume model uses amongst others a lagged spread between client rate and a weighted rate of a short and a long term market rate, which is also a new approach.

Recent literature attempts to enrich current models by adding behavioural aspects. Nyström⁵⁵ describes a modelling approach that incorporates a customer's option to shift money between a low rate transaction account and higher rate savings accounts. To take into account individual and possibly irrational behaviour he defines the concept of customer specific strike prices for exercising their options, which he models on an aggregate basis via a certain strike price distribution. The option is exercised, when it is exceeded by "certain stochastic processes, which depend on the market rate, the deposit rates on the accounts as well as the amounts already deposited."⁵⁶

Moreover, his deposit rate process is a function of the market rate and deposit balances, which reflects a bank's strategy to reward higher balances of single customers.

Blöchlinger⁵⁷ suggests an approach that integrates the banks marketing strategy into the hedging model. Instead of deriving the client rate by a regression model from market rates, he proposes a direct modelling of a banks pricing strategy in the form of a jump process. He therefore promotes a close cooperation between ALM and sales departments as an update of the rate function is required whenever the pricing strategy changes. When it comes to hedging, he claims that only cash flows after subtracting a profit margin should be replicated, since a portfolio of arbitrage-free instruments cannot possibly replicate cash flows that include excess returns.

⁵³ Paraschiv/Schürle (2010), pp. 1-24

⁵⁴ For further Information see Engle/Granger (1987), pp.251-276

⁵⁵ Nyström (2008), pp.709-756

⁵⁶ Nyström (2008), pp. 754

⁵⁷ Blöchlinger (2011), pp. 1-47.

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