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Long-term bank balance sheet management: Estimation and simulation of risk-factors

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ABSTRACT

We propose a dynamic framework which encompasses the main risks in balance sheets of banks in an integrated fashion. Our contributions are fourfold: (1) solving a simple one-period model that describes the optimal bank policy under credit risk; (2) estimating the long-term stochastic processes underlying the risk factors in the balance sheet, taking into account the credit and interest rate cycles; (3) simulating several scenarios for interest rates and charge-offs; and (4) describing the equations that govern the evolution of the balance sheet in the long run. The models that we use address momentum and the interaction between different rates. Our results enable simulation of bank balance sheets over time given a bank's lending strategy and provides a basis for an optimization model to determine bank asset–liability management strategy endogenously.

1. Introduction

The recent global financial crisis has highlighted the need for better risk management practices. Several banks faced liquidity and solvency problems. Since then, the banking community has been very active in finding ways to manage effectively all the risks in the balance sheet while maintaining profitability. Regulation has evolved a great deal with the so-called "Basel III" proposals, as seen in the consultative papers from the Basel Committee on Banking Supervision (2009a,b).

Today's bank manager is faced with the task of maximizing shareholder value, while keeping the risks in the balance sheet controlled – a balance sheet management problem. With this in mind, our objectives include:

1. Solving a simple one-period model that briefly describes the optimization decision faced by a bank. This simple model has an intuitive solution that will help us address the more complicated dynamic model in the future.
2. Estimating the stochastic processes underlying the risk scenarios faced by banking institutions.
3. Creating a tool that simulates the joint behavior of the risk factors related to banks, i.e., mortgage rates, deposit rates, non-core deposit rates, and charge-offs.
4. Describing the equations that govern the evolution of the balance sheet.

In subsequent research we will address the simulation and optimization of balance sheets and analyze the optimal policy throughout the credit cycle. Our research is closely linked to bank asset and liability management, but it also includes credit risk.

We briefly survey the related literature. Scenario generation for asset and liability models often uses vector autoregressive processes (VAR), which have been advocated by Sims (1980), or stochastic differential equations. The theory on modeling market interest rates is quite vast and has evolved a great deal since the short rate models of Vašíček (1977), Brennan and Schwartz (1982) or Cox et al. (1985), but these models are still very useful in the context of simulation. The links between market interest rates and retail banking rates have been studied in the past, as seen for instance in Hutchison and Pennacchi (1996), Jarrow and Van Deventer (1998), Janosi et al. (1999) and Diebold and Sharpe (1990).

Credit risk models have also been around for a considerable time now. We refer the reader to two surveys by Gordy (2000) and by Crouhy et al. (2000). Standard references include

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CreditMetrics (Gupton et al., 1997), CreditRisk+ (Credit Suisse, 1997), CreditPorfolioView (Wilson, 1997b,a); Gordy (2003), Vašíček (2002) and the KMV model (see Bohn and Crosbie, 2003) which builds upon the asset value framework of Merton (1974).

Asset and liability management has progressed significantly over the past half-century in the context of individuals, insurance, and pensions. Given the vast literature in this area, we will be unable to cite all the research but we will mention a few papers that can serve as an introduction to the field. Merton (1969) and Samuelson (1969), for example, have studied the portfolio problem for a single investor who has a lifelong consumption stream. Other important references include the book by Campbell and Viceira (2002), which is a compilation of some of the extensive work the authors have done in this field, and the research by Brennan et al. (1997).

Surveys for insurance and pension funds can be found in Birge (2007) and in the books by Ziemba and Mulvey (1998) and Zenios and Ziemba (2007). Among the many references in pensions and insurance are Cariño et al. (1994), Mulvey (1996), Mulvey and Thorlacius (1998), Consigli and Dempster (1998), Gondzio and Kouwenberg (2001), Kouwenberg (2001), Zenios (1995), Mulvey and Vladimirou (1989), Lucas and Zeldes (2009), Boender (1997). A thorough review of the state of the art in bank asset and liability management can be found in Kosmidou and Zopounidis (2008). We will not attempt to conduct a separate survey here; so, in the next few paragraphs, we use some of the findings and references contained in their paper.

Bank asset and liability models can be classified as deterministic or stochastic. Examples of deterministic models are Chambers and Charnes (1961), Eatman and Sealey (1979) and Giokas and Vassiloglou (1991). Stochastic bank ALM models have been developed since the 1970s. Pyle (1971) and Brodt (1978) created Markowitz-type models. Charnes and Thore (1966) used a chance-constrained programming model, with the chance constraints on meeting withdrawal claims. Sequencial decision theory has been applied to bond and securities portfolios in Wolf (1969), while Bradley and Crane (1972, 1973) used stochastic decision trees.

Another set of models uses stochastic linear programming with simple recourse (these programs are described in the book by Birge and Louveaux (2011)). Kallberg et al. (1982) analyzed a short-term cash planning problem where the cash requirements are stochastic. Kusy and Ziemba (1986) created a full bank asset and liability model with several features, including transaction costs and stochastic cost of funds and cashflows. Other references include Oğuzsoy and Güven (1997), and Korhonen (2001). Simulation methods have also been studied, particularly by Kosmidou and Zopoundis (2004), who in their research combine interest rate scenario generation over a one-year horizon with goal programming.

Recently, Hahm et al. (2011) have addressed the interaction between liquidity and credit risk in the balance sheet. In their innovative research, they have shown that lending booms typically are associated with growth of non-core liabilities, which in turn relate to the vulnerability of the financial system. Among other contributions, their research includes a simple static model that explains these linkages.

Even though all the models above have brought important insights to the study of balance sheet management, we believe that the distributional assumptions underlying the stochastic processes could be further developed. This is why we propose incorporating a vector autoregressive process (VAR) to generate the long-term scenarios incorporating all the basic risk factors in the balance sheet. We address the interactions among credit risk, interest rate risk, and liquidity risk, where, in our setting, liquidity risk is the risk associated with the inability to refinance liabilities at a reasonable cost. The data shows momentum, so we have included this feature in our model. Momentum is also relevant for bank management: for example, in the short run, an environment of increasing interest rates is usually worse than an environment of decreasing interest rates, since the bank has to refinance the liabilities while most of the mortgages are kept in the balance sheet.

Our stochastic interest rate process generates scenarios for mortgage rates, core deposit rates and non-core deposit rates. We specify that the variance of the residuals follows a square root rule, similar to Cox et al. (1985). Charge-off rates are specified by a modification of the Vašíček (2002) model, inspired by a recent paper by Kupiec (2009). Kupiec documents the autocorrelation in corporate default rates, so that he can create unbiased estimates of the Vašíček model. Our model is applied to real estate, introduces momentum, and we show that the residuals are normal and uncorrelated, which makes our simulations more effective. We have found the momentum term important, as it reduces the autocorrelations of the residuals.

We also propose that the simulation is carried over a long period horizon. We use a balance sheet similar to Hahm et al. (2011), but study the intertemporal setting. In subsequent research, we intend to solve the resulting stochastic program numerically with the abridged nested decomposition method proposed by Donohue and Birge (2006).

The layout of this report is as follows: we first address the one-period model in Section 2, and its numerical results in Section 3; the evolution of risk factors in the dynamic setting is developed in Section 4; in Section 5, we write the equations for the evolution of the balance sheet which we will address in the future; Section 6 reports data and estimation issues while the specification of the models is studied in Section 7; we compare our credit risk model with the Vašíček credit model and draw conclusions in Section 8; in Section 9, we briefly talk about the simulation of risk factors and make comparisons with previous models in the literature; Section 10 concludes this report.

2. A simple one-period model

In this section we analyze a one-period model which will serve as preparation for the multi-period model. Our setting is similar to that of Hahm et al. (2011); however, instead of maximizing return subject to a CreditVaR constraint, our bank maximizes expected utility, which captures risk aversion. This model has also a relation with Wong (1997), whose focus is on the optimal interest margin.

Suppose the bank has the following assets and liabilities:

1. E_0 in equity;
2. L_0 in loans that pay an income of I;
3. D_0 in deposits that pay zero rate;
4. N_0 in short term non-core funding.

Assets should be equal to the sum of liabilities and equity, so that $L_0 = E_0 + D_0 + N_0$. N_0 can be positive, in which case the bank has a deficit of funds and needs to borrow from the interbank market, or negative, in which case the bank invests the surplus in the interbank market.

Let us suppose that new mortgage rates are at r and that the funding rate for short term non-core liabilities is equal to f.

A bank is faced with the decision of issuing new loans, which we call L_{new}. We assume, as in Hahm et al. (2011), that core deposits are fixed and therefore new growth on loans is financed with non-core deposits. At the end-period, the default rate on loans will be equal to λ, which we assume to be a stochastic variable.

The bank would like to maximize the expected utility of equity for the shareholders. We suppose that the shareholders' preferences follow a power utility: