FUNDING LIQUIDITY RISK AND FUND TRANSFER PRICING IN BANKING
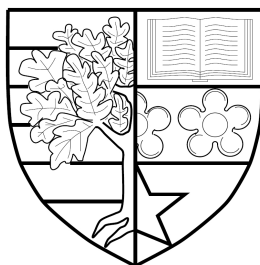
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Abstract

Funding liquidity risk was one of the main reasons for bank failure during the global financial crisis in 2007-2008. New legislation has been released in the form of Basel III, in particular the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR), to strengthen the liquidity requirements for banks; this makes funding liquidity a very important topic for banks. In this thesis, I will study the important factors that need to be taken into consideration when dealing with liquidity risk and how a bank can manage their funding liquidity risk.

A key concept used in banks is Fund Transfer Pricing (FTP). This approach helps the banks to manage their interest rate risk. I will investigate how funding liquidity risk can be incorporated into this framework. It is important that this approach will still maximise the bank's overall profits. In order to achieve this I will initially evaluate a one time period model. This shows whether the bank's overall profits can be optimised using FTP. My results show that it is possible to allow each business unit to work independently and that, by using FTP, individual business units can be optimised consistently with the bank's overall profits. However, for this to occur, it is important to decide whether a bank is deposit rich or deposit poor as an incorrect assumption will lead to sub-optimal profits for the bank.

Banks work in more than 1 time period; therefore, I will assess how the model can be extended and how FTP would work over multiple time periods. One major consideration is to account for the uncertainty regarding the timing of cashflows. This is because customers often have the option to prepay loans or withdraw their deposits. I will investigate an approach for calculating the cost of these options and how this can be included in the FTP framework. By applying a cost to the uncertainty, we can insure that the business units are incentivised in the correct way while still maximising the profits of the bank. Under my approach the treasury unit will be exposed to actual events in return for receiving a fair value for the cost of the option. The business units will be charged the cost of the option. There is potential for one party to act in their own interest by changing the value of the option. However, as both parties need to agree, this risk should be removed over time. I have shown how this can be done over 2 time periods but further research is needed to investigate over more time periods.

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Chapter 1

Introduction

One of the key risks a bank faces is liquidity risk. During the global financial crisis in 2007-2008, liquidity risk was what ultimately caused some banks to fail. In the UK, for example RBS, HBOS and Northern Rock had to be nationalised due to liquidity needs while other banks needed emergency funding from their central banks.

But what is liquidity risk? Liquidity risk can be split into market liquidity risk and funding liquidity risk. Market liquidity risk is the risk that the bank is unable to sell its assets at a fair price, in a timely fashion, and must sell at a significant discount if they wish to sell their assets.

Funding liquidity risk is the risk that the bank is unable to pay its debt when it is due. This is not the same as insolvency. Insolvency is when the assets of a bank are less than the liabilities. Funding liquidity risk can lead to insolvency and insolvency can lead to funding liquidity risk. However it is possible for a bank to be solvent and suffer from funding liquidity risk.

Brunnermeier and Pedersen (2009) state that market liquidity risk and funding liquidity risk are closely related. Market liquidity risk can lead to funding liquidity risk and vice versa. Brunnermeier and Pedersen (2009) say that this can easily lead to a negative spiral. If banks face market liquidity risk, they will not be able to sell their asset at a fair price and will have to reduce the price. This means that the bank will receive less money and there may be difficulty funding their liquidity needs. Therefore they may need to sell more assets to meet their funding liquidity needs. This would lead to greater market liquidity issues and hence increased

funding liquidity needs. Similarly if a bank had funding liquidity risk issues, it may need to sell assets which could lead to market liquidity risk issues. This could jeopardise funding and market liquidity further. Both market liquidity risk and funding liquidity risk are important issues for banks and both are worthy of further investigation. In this thesis, I will concentrate on funding liquidity risk and how it can be monitored in terms of a retail bank.

Basel III categorises the risks the bank faces into four areas:

Credit risk is the risk that the indebted may not be able to pay the money due to the bank;

Market risk is the risk of movements in the financial markets, in particular those which may lead to a loss;

Operational risk is the risk that systems and procedures are not adequate or abused and this could lead to financial loss; and

Liquidity risk is the risk that the bank is unable to pay its debts when they are due.

Previously, Basel II concentrated on the other risks rather than liquidity risk. This has now changed and there has been a lot more focus in recent years on liquidity risk. As a result, there have been a lot of changes in legislation regarding liquidity risk. I will look at the legislation and the changes that have impacted on liquidity risk.

One of the changes is the requirement for funding liquidity risk to be included in internal pricing. One method that can help to achieve this new requirement is the Fund Transfer Pricing (FTP) framework. The FTP framework is a method used by the bank to distribute profit and transfer risk between various business units. I will look into more detail at FTP and whether this is an appropriate method and how funding liquidity risk can be incorporated into it.

Overall, liquidity risk is a major risk for banks. I will look at funding liquidity risk in the context of a retail bank and how it can be monitored and assessed. I

will also look at the changes in legislation and how funding liquidity risk can be incorporated into a FTP framework.

Chapter 2

Liquidity risk management

2.1 A retail bank

Banks play an important role in society as they help bring borrowers and lenders of money together. Kratky (2012) notes that banks achieve this through:

- Maturity transformation;

- Lot size transformation; and

- Risk transformation.

Maturity transformation is where the bank transforms short term deposits into long term loans thus experiencing funding liquidity risk. Lot size transformation is where banks bundle deposits together so they are able to lend against these deposits. At an individual level, each deposit is relatively small and is difficult to model. However, by grouping deposits together it becomes possible to model and lend against these deposits. Risk transformation, Kratky (2012) notes that it aligns risk preferences of borrowers and lenders.

To get a better understanding of the importance of these factors, we need to consider how a bank works. In the first instances let us consider how a simple retail bank works. The customers of a retail bank are typically individuals and Small to Medium Enterprises (SME). These customers deposit their money in the bank. These deposits can generally be accessed immediately or after a short notice period

i.e. 30 or 90 days. Beau et al. (2014) define this as retail funding and it is often unsecured since depositors do not require the bank to post collateral. The bank pays interest to these customers for lending them money and the deposits are a liability of the bank.

Customers also borrow money in the form of loans and mortgages for the bank. Loans can often be made for up to 10 years, while mortgages are commonly for 25 years. As a result, it is a significant period of time before the bank receives the money back for these loans and mortgages. These loans and mortgages are assets for the bank.

Beau et al. (2014) state the bulk of funding comes through customer deposits and borrowing money from the wholesale money markets. Although each customer's deposits are usually very volatile, overall a significant proportion of the total deposits are stable i.e. a fixed amount remaining within the bank. This is how the bank creates lot transformation. Information on the percentage of deposits that remain within a bank are hard to come by and will vary by bank. BCBS (2013a) only requires the bank to assume withdrawals of 5% for stable deposits and 10% for less stable deposits indicating a higher proportion of deposits must remain within the bank. This means that the banks could lend the majority of customers' deposits as loans to other customers. This is how the bank achieves maturity transformation.

The banks can also use the wholesale money markets to make loans available to customers. Beau et al. (2014) define this as wholesale funding which can be either secured or unsecured. Section 2.1.3 discusses wholesale money markets in more detail. This is part of the process of how the bank assists with risk transformation. The bank borrows money from the wholesale money markets and lends this money out as loans to customers. Borrowing from the wholesale money markets and deposits are liabilities for the bank.

Since the retail bank's assets are generally long term in nature and the liabilities are short term in nature, this leads to funding liquidity risk. To manage funding liquidity risk, the bank needs to have money available that it can use to pay the liabilities as they fall due. Therefore the bank holds some of its assets in the form

of liquid assets. What constitutes liquid assets is discussed in Section 2.1.2.

A simplified version of the balance sheet of a retail bank is shown in Figure 2.1.1. This is similar to how Beau et al. (2014) assess high level funding issues. In the first chart, the bank is known as deposit rich. This is where the customer's deposits are more than sufficient to cover the loans and liquid assets. As such, the bank can lend out excess funds in the wholesale money markets. In the second chart, the bank does not have enough customer's deposits to cover the loans and liquid assets and needs to borrow money from the wholesale money markets. In this situation the bank is known as deposit poor. Beau et al. (2014) note that building societies are required to be at least 50% funded by deposits. Basel III restricts the size of the balance sheet by introducing a leverage ratio and requiring the bank to maintain a minimum 3% leverage ratio (BCBS, 2014a).
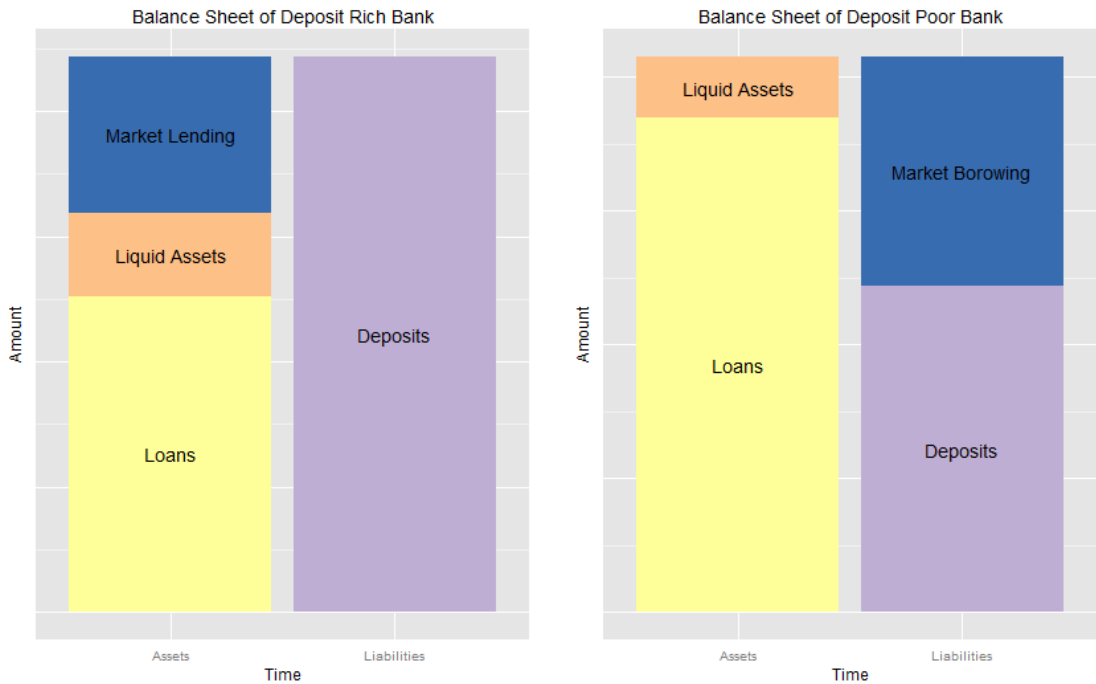
Figure 2.1.1: Simplified balance sheet of a bank

Two measures of the Bank's profitability are Net Interest Income (NII) or Net Interest Margin (NIM) (Crouhy et al., 2006). These measures are calculated as follows:

$$\text{NII} = \text{Interest Income} - \text{Interest Expense};$$

$$\text{NIM} = \frac{\text{NII}}{\text{Average Total Assets}}.$$

Choudhry (2012) notes that NII is a main driver of profitability for the bank and can contribute greater than 60% to operating income. Choudhry (2012) also points out that NII is sensitive to credit and market risk. It is often useful to compare the NII to the size of the assets of the bank, this is known as NIM. Buegler et al. (2013) note that the NIM at US commercial banks has shrunk from 4% in 2002 to 3.4% in 2014, a decrease of 14% in 10 years.

Intraday liquidity risk is also important for a bank to ensure it can meet its payments due throughout the day. The bank might assume it has adequate liquidity to cover the expected withdrawals based on assumed loans payment for that day. However, if money is withdrawn in the morning and loans are paid in the evening the bank will experience intraday liquidity risk. Therefore an appropriate assessment of intraday liquidity will need to be carried out. Information on intraday liquidity and how it can be monitored can be found in Ball et al. (2011), Limburg (2012) and BCBS (2013c). In this thesis, we will concentrate on strategic funding liquidity risk rather than intraday liquidity risk.

We now have an understanding of how banks are exposed to funding liquidity risk. We will now look at the different assets and liabilities of the bank in more detail.

2.1.1 Loans

The largest proportion of the retail bank's assets are invested in loans and mortgages. Loans are generally of a long term nature and can typically be for 3 to 10 years, while mortgages are often up to 25 years. Mortgages are a specific type of loan that is secured against a property.

Loans can be structured so they are either repaid by regular payment over the life of the loan or as a single bullet payment at the end of the loan. There is also the possibility that the customer could make prepayments and repay the loan early, as this is an option provided to customers. Loans can be provided unsecured or can be

secured against some property such as a house or car. A secured loan gives greater recourse in the event of a default.

For loans, there is prepayment risk and default risk. Prepayment risk is the risk that customers could pay back their mortgages earlier than expected. Pang (2012) notes that there are three reasons for prepayment:

- Selling the house;

- Refinancing; and

- Paying more than the scheduled payments.

Pang (2012) notes that prepayment is a call option sold to the mortgage borrowers and will result in higher borrowing costs. Default risk is the risk that a customer does not pay back the loan. Pang (2012) states that defaults generally occur when:

- The house value is less than the principal amount outstanding on the loan; or

- The loan holder has insufficient money to meet the monthly repayments.

Goodarzi et al. (1998) note that default risk is generally associated with credit risk. The bank manages credit risk by holding capital. Prepayment risk, Goodarzi et al. (1998) note is generally associated with interest rate risk.

Goodarzi et al. (1998) inform us that there are numerous factors that can cause prepayments such as interest rates, employment status, income, relocation and retirement. In regard to interest rates, Goodarzi et al. (1998) note that prepayments on loans generally increase when interest rates fall. Sherris (1993) notes the opposite is also true, if interest rates rise, loans are less likely to be prepaid. However, Sherris (1993) states that not all loan holders are economically rational. Therefore they may not exercise the prepayments when it is in their best interests to do so. This is supported by Deng et al. (2000) and Dunsky and Ho (2007) who both note there is significant heterogeneity among loan holders in exercising the prepayment option inefficiently. However, it should be noted that this discussion focuses on US mortgages where typical mortgage holders can fix interest rates for the entire life of the mortgage. The dynamics in the UK may be different as UK mortgages are

typically only fixed interest rates for up to 5 years before they are converted to a variable rate. Therefore, UK mortgage holders must refinance after the fixed period expires if they wish to have a fixed interest rate mortgage.

Credit scores have an impact on prepayments as well. Deng and Gabriel (2006) note that loan holders with higher credit scores are less likely to prepay. Cossin and Lu (2004) note that business customers are more rational than the irrational retail customers. As such they suggest they are modelled separately.

Prepayment risk and default risk need to be priced into the loan products for customers. There are many complications in valuing the options as discussed above. Goodarzi et al. (1998), Cossin and Lu (2004), Deng et al. (2000), Dunsky and Ho (2007), Sherris (1993), Ambrose and Buttimer (2000) and Ambrose et al. (1997) all discuss how these options can be priced by the bank.

Generally, loans are not very liquid. It is possible that the loans could be securitised and sold in the open market. Loutskina (2011) has shown that as banks increase their securitisation there has been a decrease in liquid assets held. The main reason for this is that securitisation adds liquidity to the banks by allowing them to sell their illiquid loans. Wagner (2007) says financial innovations such as securitisation and collateralised loan obligations have allowed the bank to subsequently reduce liquidity. However until the loans are securitised the bank still has liquidity risk by holding these illiquid loans.

One of the problems of securitisation is that some were set to be financed by asset-backed commercial papers, with an average maturity of 90 days and medium term maturity of just over 1 year (Brunnermeier, 2009). They are called asset-backed as the notes are collateralised by the loans. Investors generally prefer a short term horizon to the longer term options. However, there is a risk that investors may stop buying asset-backed commercial papers which are used to finance the securitisation. To ensure funding liquidity, banks provided credit lines to these vehicles. Brunnermeier (2009) points out that this still exposes the bank to liquidity risk from holding long term assets financed by short term borrowing.

Brunnermeier (2009) explains that one of the many reasons that the banks like

securitisation is that it lowers the amount of capital under Basel I that is required to be held. Banks were required to hold capital of at least 8% of the loans on their balance sheet. By securitisation they were not required to hold capital for these loans. Brunnermeier (2009) notes that Basel II did require some capital to be held for these products but this was still less than if they kept them on their balance sheet. This was a key motivator for the banks to produce these products.

Securitisation can help the bank with liquidity issues as they will get the immediate inflow of money when the product is sold in the market. However the bank is still responsible for providing credit lines to the product. Also during the time of the global financial crisis in 2007-2008, the securitisation market closed down and it was very difficult to sell these products. Securitisation did not provide the bank with liquidity when it needed it most. Wagner (2007) notes that due to the increased liquidity from financial innovations, this led to the bank increasing its risk to risky assets and hence higher probability of default.

2.1.2 Liquid assets

Another asset that banks hold is liquid assets. Although wholesale money markets usually have minimal market liquidity risk, Chiu and Hill (2015) note the global financial crisis in 2007-2008 showed that during the time of crisis the wholesale money markets can not be relied upon. Retail banks need to have liquid assets to hand to make sure they can pay their liabilities as they fall due. BCBS (2013a) sets out what the Basel Committee on Banking Supervision (BCBS) considers suitable liquid assets.

BCBS has developed the Liquidity Coverage Ratio (LCR) to help strength liquidity requirements and make them more transparent. The LCR is devised to ensure that banks can survive a significant stress scenario for a 30 day period. To achieve this the bank has to hold to High Quality Liquid Assets (HQLA). BCBS (2013a) define HQLA as assets that can easily be converted in cash at little or no loss in value. The main characteristics of HQLA identified by BCBS are:

- Low risk;

- Ease and certainty of valuation;

- Low correlation with risky assets;

- Listed on a developed and recognised exchange market;

- Active and sizeable market;

- Low volatility; and

- Flight to quality.

HQLA should ideally be eligible for central banks' liquidity facilities. However, being central bank eligible does not necessary mean it will constitute HQLA. HQLA can be split up into Level 1 and Level 2 assets. Level 2 assets can be divided further into Level 2A and 2B assets. Level 1 assets must be at least 60% of the total HQLA. While Level 2 assets (after allowing for any haircuts) can be up to 40% including 15% in Level 2B assets of the total HQLA. This is shown in Figure 2.1.2.
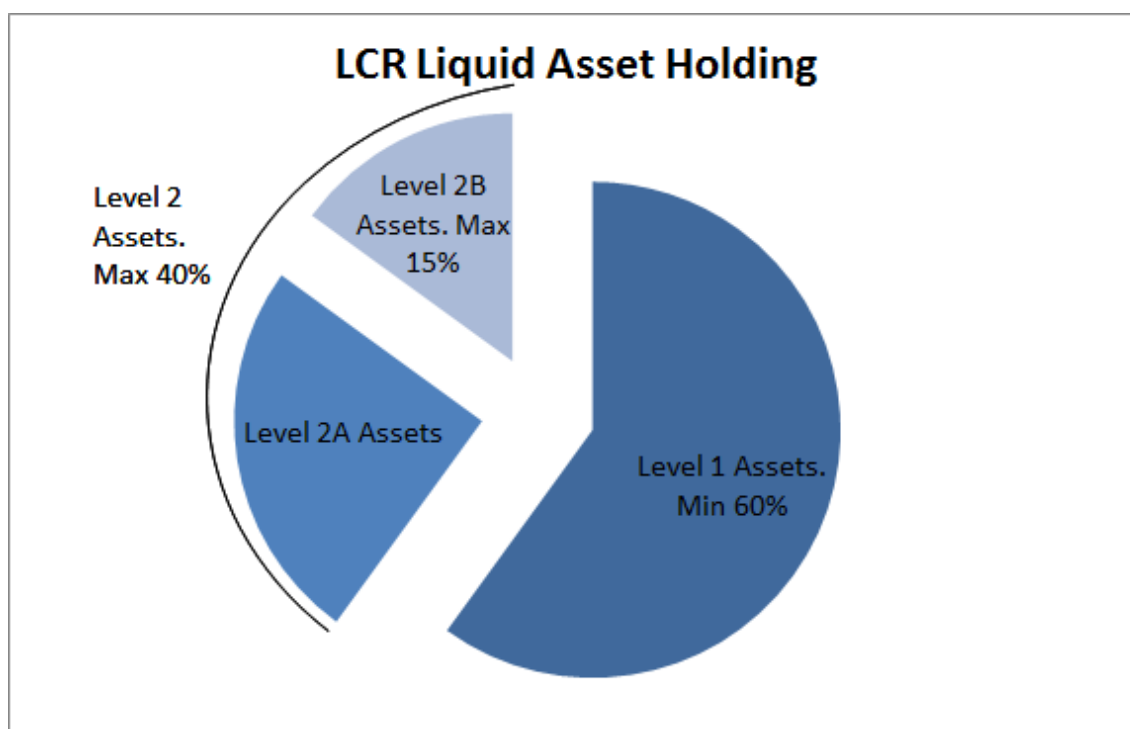
Figure 2.1.2: Breakdown of liquid asset holding under LCR

BCBS (2013a) describes Level 1 assets and below is a high level summary:

- Cash;

- Central bank reserves;

- Securities issued by sovereign nations, non-central government Public Sector Entities or multilateral development banks. They must have a 0% risk weighting under the Basel II Standardised Approach and be a reliable source of liquidity during stressed market conditions; and

- Sovereign nations which have not got a 0% risk weighting rating. Debt issued by them can be included if the debt issued is in the same currency as the liquidity risk.

At least 60% of HQLA are held in these Level 1 assets. The remaining amount are held in Level 2A and 2B assets.

For Level 2A assets a minimum haircut of 15% will be applied to the holding. The assets consist of:

- Securities issued by sovereign nations, non-central government Public Sector Entities or multilateral development banks that have a 20% risk weighting under the Basel II Standardised Approach. Also they must be a reliable source of liquidity during stressed market conditions. This has been defined as a maximum price decline of 10% over a 30 day period.

- Corporate Bonds and covered bonds that have a credit rating of at least AA- and not issued by a financial institution. Also they must be a reliable source of liquidity during stressed market conditions as defined above.

Up to 15% of the HQLA can be held in Level 2B assets. Level 2B assets will have a higher haircut than Level 2A assets. Level 2B assets are:

- Retail Mortgage Backed Securities (RMBS) with a 25% haircut applied provided they are at least AA rated and have a reliable source of liquidity during stressed market conditions. This time a reliable source of liquidity is defined as a maximum price decline of 20% over a 30 day period.

- Corporate securities with a 50% haircut applied provided they have a credit rating between A+ and BBB- and are not issued by a financial institution. Also they must be a reliable source of liquidity during stressed market conditions as defined above.

- Equity shares with a 50% haircut applied provided they are not issued by a financial institution and have a reliable source of liquidity during stressed market conditions. This time the maximum price decline is 40% over a 30 day period.

Zaffar (2013) produces a nice summary of eligible HQLA for the LCR as shown in Table 2.1.1.

Table 2.1.1: Summary of eligible HQLA for the LCR by Zaffar (2013)

HQLA	
Level 1 assets	Haircut
Cash	0%
Central bank reserves	0%
Government bonds with 0% risk weights	0%
Level 2A assets	
Government bonds with 20% risk weights	15%
Corporate bonds >AA- rating	15%
Level 2B assets	
Eligible RMBS	25%
Corporate debt securities rated A+ to BBB-	50%
Eligible Equity	50%

Initially, when the proposed framework was issued in 2010, the BCBS proposed only Level 1 and a slightly reduced version of Level 2A assets to be allowed as HQLA. However, it has now been extended to include further assets in particular Level 2B assets. Previously the proposed framework was quite narrow and generally consisted of debt with extremely low credit risk. Now assets with a bit more credit risk are included but higher haircuts are applied to them.

BCBS (2013a) sets out the minimum requirement of what a bank needs to hold as liquid assets. The bank should assess what it thinks is an appropriate amount of liquid assets that it should hold. Having a wide range of assets in the definition of liquid assets helps the bank to have a diversified source of funds in case there is

market liquidity risk in the future with one or more particular groups of assets. The bank needs to think carefully about the appropriate haircuts applied to different asset types. There have been many discussion regarding equity prices that are related to market liquidity. For more information see Acharya and Pedersen (2005), Holmström and Tirole (2001) and Lam and Tam (2011). Alphandary (2014) shows that there is a wide range of haircuts that the Bank of England applies to residential mortgage loan pools for accepting them as collateral. The most common haircut applied is within the range of 35-40% but this can be as low as 20% and higher than 55%. Gorton and Metrick (2012) found that the average haircut for some securitised products increased from about 0% to a peak of nearly 50% during the global financial crisis in 2007-2008.

Banks have relied on central banks to bail them out during a liquidity crisis. As Manning (2014) notes, one of the roles of the Bank of England is to be the lender of last resort. Ratnovski (2009) concludes that by central banks offering liquidity as a last resort this can lead to the bank's holding a sub-optimal liquid asset holding. Therefore appropriate policies and regulation is needed to help ensure that banks appropriately assess their liquidity needs so they don't need to rely on central bank support. However, Acharya et al. (2011) note that banks that do hold sufficient liquid assets can take advantage of fire sale asset prices during a crisis. This incentitives the bank to hold sufficient liquid assets and their analysis looks at the amount of liquid assets they need to hold so banks can profit from fire sale asset prices.

2.1.3 Wholesale money markets

Wholesale money markets are used by banks to borrow and lend money. They can either be an asset for the bank if the bank is lending in the market or a liability for the bank if the bank is borrowing from the market. Choudhry (2011) lists the main products in the wholesale money markets as follows:

- Time deposits;

- Certificate of deposits;

- Commercial papers;

- Banker's acceptance;

- Government bonds;

- Bills of exchange; and

- Repurchasing agreements.

Time deposits are money deposited in a bank for a short fixed period of time for up to a year. At expiry, interest and principal is paid. Time deposits are for a fixed period and can't be liquidated during this time. As a way around this liquidation problem, the banks introduced certificate of deposits. When the bank deposits money in another bank it receives a receipt for the money confirming the term and how much interest is going to be paid. This receipt for agreed upon interest and term can be traded in the market. This tradeable receipt is known as certificate of deposit and generally ranges from 1 month up to 5 years.

When a large corporation wants to raise funds for a short period of time it can issue a commercial paper. A commercial paper is a short term unsecured promissory note that promises to pay a certain amount at a fixed date and trades in the market at a discount to this value. Typically commercial papers are issued for between 30 and 90 days but can be up to 270 days. For small companies, they can get a bank to guarantee their payment and this debt is known as banker's acceptance and can be traded in the markets. A similar product is bills of exchange where one party agrees to pay another party a certain amount at a fixed time i.e. a bill due at a future time. The party due to receive payment for the bill, can sell the right in the market at a discount to receive payment now. The party paying the bill will then be paying this new third party.

If a governments wants to raise funds they can issue government bonds. Government bonds are known as GILTS in the UK and bunds in Germany. These have been known to be issued with maturity up to 50 years in the future, though usually the maturity is a lot earlier. In the US, there are 3 different names for government bonds. T-Bills are issued with a maturity less than a year, T-Notes are issued with

a maturity between 1 and 10 years, and T-Bonds are issued with a maturity over 10 years. In the developed world, these are usually highly liquid and carry very little credit risk. Banks can hold government bonds to achieve a return on their money. Government bonds are often used as part of a Repurchasing Agreement (repo). A repo is an agreement where one party agree to sells an asset to another party and agrees to buy it back at a fixed price and time in the future. It can be thought of as a secured loan where the money borrowed is secured against the asset. The amount of the haircut that will need to be applied is dependent on how risky the underlying assets are. Government bonds usually have a very small haircut as they are generally low risk while shares generally have a much larger haircut.

The above gives a general description of how wholesale money markets work and the type of financial instruments that are traded. Generally, these have a short maturity, low credit risk and low market liquidity risk. However, during the global financial crisis in 2007-2008, there was a lot of uncertainty regarding the credit worthiness and associated funding liquidity risk of some large banks that operated in the wholesale money markets. As a result, this impacted significantly on the market liquidity and meant it was very difficult to trade. Further details of global financial crisis will be discussed in Section 2.4. For information on how exactly these product work and are traded, see Choudhry (2011).

2.1.4   Deposits

For a retail bank, one of the main sources of funding is customers' deposits. Buegler et al. (2013) note that the percentage of US bank deposits of total liabilities have increased from 37% in 2007 to 49% in 2012. Dewachter et al. (2006) state there are two main types of deposits, instant access accounts and term deposits. Instant access accounts, where customers can access their money immediately, are more formally known in the literature as demand deposits or non-maturity deposits. Term deposits have a set contractual time to maturity and Dewachter et al. (2006) note that term deposits are priced similarly to wholesale money market rates.

Bardenhewer (2006) notes there are two approaches for modelling non-maturity deposits. These are the replicating portfolio and Option Adjusted Spread (OAS) approach. The replicating portfolio approach assigns the deposits into time buckets and models these based on an underlying portfolio that replicates the cashflows. Bardenhewer (2006) looks at a deterministic approach to replicating the portfolio, while Frauendorfer and Schürle (2007) look at a stochastic optimisation approach to modelling the replicate portfolio.

The OAS approach is based on no-arbitrage methodology. Bardenhewer (2006) summarises the OAS approach as looking at the yields available on callable and non-callable bonds. For examples of this approach see Jarrow and Van Deventer (1998), Dewachter et al. (2006) and Hutchison and Pennacchi (1996). Bardenhewer (2006) notes the replicating portfolio approach is better for Fund Transfer Pricing (FTP) while the OAS approach is better for liquidity risk management.

There are different approaches for modelling the deposits into the different time buckets. Neu (2007) and Kalkbrener and Willing (2004) split the deposits into core (stable) and floating (volatile) parts. The floating part is assigned to the overnight bucket and the core part is split into longer time buckets. Musakwa (2013) looks at using survival models to project cashflows. Overall, there are different approaches to assigning cashflows to a future period and as Musakwa (2013) notes that there is no consensus yet.

We also need to consider the different aspects of behaviours of deposits. FSA (2012) discusses some of the different types of deposits that may potentially leave quickly such as deposits accepted through the internet, deposit amount exceeding deposit protection limits and interest rate sensitive depositors. Ideally, the bank wants stable deposits that remain within the bank for a long term and are unlikely to leave them at the first sign of liquidity issues. Chiu and Hill (2015) found that the elasticity of household deposits with respect to interest rates is typically 0.3. This means that in general households are not very sensitive to interest rates.

2.1.5 Shareholder's equity

The remaining part of the balance sheet is shareholder's equity. This is the capital of the bank. Beau et al. (2014) note that this usually consists of ordinary shares in the firm and bank's retained earnings. The BCBS prescribes the minimum amount of capital requirements and is used to cover the bank for unexpected losses and to protect the lenders to the bank. However there are no assets set aside as capital. Capital is the amount of loss on the assets the bank can handle before the liabilities of the bank are impacted. As such capital is no protection for liquidity risk. Only liquid asset and proper monitoring of liquidity can protect the bank from liquidity risk.

2.2 Monitoring liquidity risk

Neu (2007) explains why liquidity risk is different to other risks that the banks face: operational, credit and market risk. Capital or shareholder's equity can be used to cover any unexpected losses from operational, credit and market risk. Usually, the bank decides on a certain confidence interval (99% or 99.5%) of a distribution of unexpected loss and ensures it has enough capital to cover this loss. As Fiedler (2011) notes capital can not be used for liquidity risk. For liquidity, the risk is that cash outflows are needed to be met with cash readily available or cashflows coming in. As such, liquidity risk needs to be assessed in a different way.

It is important that all activities are included in the modelling, in particular off balance sheet activity. As Angbazo (1997) shows there is a significant relationship between interest rate risk and funding liquidity risk and off balance sheet activities.

As BCBS (2008b) notes not one single number can appropriately describe liquidity risk. Therefore we have to look at various approaches for measuring and monitoring funding liquidity risk. Banks need to take into account many factors:

- Cashflows - in and out;

- Liquid assets holding;

- Currency of cashflows; and

- Concentration of funding.

As well as monitoring the factors above on a regular basis, the bank also needs to consider adverse situations. To prepare the bank for adverse situations, it is important that the bank assesses:

- Its exposure to contingency liquidity risk;

- How it models its liquidity needs;

- Its use of liquidity indicators; and

- Its contingency plan.

2.2.1 Maturity ladder

BCBS (2008b) notes a maturity ladder is useful for investigating any shortfall in the cashflows. A maturity ladder shows the amount of expected money the bank expects to receive and pay out in different periods. The bank will model the expected cashflows over time and summarise these cashflows in a maturity ladder. Table 2.2.1 below is an example of a maturity ladder provided by Choudhry (2011).

Table 2.2.1: Example of a maturity ladder provided by Choudhry (2011)

Maturity Ladder										
	Sight	8 Day	1 month	3 months	6 months	1 year	3 years	5 years	5 years+	Total
Inflows	805	383	273	268	143	129	276	657	742	3,675
Outflows	980	813	838	1,563	277	52	11	0	0	4,533
Mismatch	(175)	(430)	(570)	(1,295)	(134)	77	265	657	742	(858)

The time buckets, shown in Table 2.2.1, are relatively short when close to the present and become much larger further away in time. This is because there is a lot more uncertainty with the cashflows further into the future. If the cash inflows are greater than the outgoings the bank is expected to have enough money readily available. If the outgoings are greater than the expected income, then the bank will need to take some action to fill the shortfall.

Although, the bank can see from the maturity ladder whether its cash outflows are greater than the inflows, it does not help the bank decide on the actions that

it needs to take. The bank may already have enough money available to cover any shortfall. Alternatively, the bank may need to sell or repo assets or use their credit facilities to finance any shortfall. The choice made will mainly depend on the timescales and costs associated with each action. Further information on maturity ladders can be found in BCBS (2008b).

The maturity ladder can be the first step in helping a bank decide if they need to take action. Using the results of the maturity ladder, the bank can then plan the appropriate action by looking at other measures.

2.2.2 Liquid asset holding

To fund any shortfall, the bank can use its liquid asset or borrow additional money from the wholesale money markets. Matz and Neu (2007) note it is important that the bank holds a diversified range of liquid assets. There might be a market issue on a particular day when they are trying to sell an asset and therefore they may not be able to get a fair price for this asset. By holding a diversified range, the bank then has options on which liquid assets to sell.

The types of assets held as liquid assets can be found in Section 2.1.2. BCBS (2008b) notes that it is important that the assets are unencumbered and that there are no legal, regulatory or operational reasons that stops them being used for funding. BCBS (2013b) requires the following metric to be monitored:

- Available unencumbered assets that are marketable as collateral in secondary markets; and

- Available unencumbered assets that are eligible for central banks' standing facilities.

Work done by Ringbom et al. (2004) look at the profit maximisation and the appropriate amount of liquid assets. Buegler et al. (2013) note that US financial institutions could increase their revenue by $1.5billion to $2.5billion by optimising their liquid asset holding. Matz and Neu (2007) note it is difficult to balance the right amount of liquid assets; holding enough liquid assets to meet unexpected funding

demands vs the advantages of minimising the liquid assets. This will often result in holding a smaller amount of liquid assets than required in a crisis. Therefore, liquid assets by themselves are not sufficient for appropriate management of funding liquidity risk. BCBS (2008b) states the appropriate size of liquid asset holding should be determined in line with the risk appetite of the bank.

2.2.3 Diversified access to wholesale money markets

If the bank decides to borrow money from the wholesale money markets instead of selling liquid assets it should have options available. The bank may have set up credit facilities with other banks or may be able to borrow from the wholesale money markets. The bank should not be too dependent on a particular section of the wholesale money markets. BCBS (2000) states that it is essential that the bank maintains a diversity funding base with regular market access to assess funding options. This will mean that if an area is particularly expensive or no funding is available, the bank will still have access to other areas of the wholesale money markets. However, Matz and Neu (2007) note that regular testing of the market may not be entirely useful. Matz and Neu (2007) say this is because it is done under normal conditions and the real issues with funding arise under adverse conditions where past experience has shown that even contractual commitments may not be honoured. Matz and Neu (2007) state that the only benefits of regularly accessing the wholesale money markets are to keep contact information up to date and to ensure counterparty communications and procedures are known. BCBS (2000) does note that the bank should consider funding from wholesale money markets under normal and adverse conditions.

BCBS (2008b) notes the following points when considering funding:

- Diversify across short, medium and long term;

- Take into account correlations between funding and market conditions;

- Consider counterparty limits, secured vs unsecured, currency; and

- Consider other sources such as deposit growth, asset securitisation and using committed facilities.

2.2.4 Funding concentration and currency

As well as diversifying its access to the wholesale money markets, the bank needs to make sure it is not relying too heavily on one section or an individual customer. As Choudhry (2011) notes any excessive concentration could be a potential problem in a future crisis. Therefore the bank needs to have a good mix of funding from different sources. Also the bank will need to investigate the composition of each source, to make sure it is not too concentrated on a single customer. For example, Choudhry (2011) demonstrates a concentration report which looks at the bank's largest depositors, or top few clients, to ensure they are not a significant proportion of the total deposits. This is because the bank could face funding liquidity risk issues if a larger depositor decides to leave them. Similarly, the bank will make sure it is not heavily exposed to just a few particular sectors such as manufacturing or financial companies, and try to have a broad range of clients. Therefore the bank will investigate its funding concentration and ensure it is well diversified. BCBS (2013b) requires the following metric to be monitored:

- Funding from each significant counterparty as a % of total liabilities;

- Funding from each significant product as a % of total liabilities; and

- List of assets and liabilities amounts by significant currency.

As can be seen from this list, the bank also needs to consider what currency the assets and liabilities are held in. BCBS (2000) notes there is a risk that there could be a sudden change in the foreign exchange rates or market liquidity which could lead the bank to funding liquidity issues. Therefore BCBS (2008b) states that banks should model the cashflows of each currency separately so the bank can understand its needs in each of the major currencies it operates in. BCBS (2013b) requires that the LCR is calculated for each major currency the bank operates in.

2.2.5   Example of liquidity report

Figure 2.2.1 (reproduced from (Choudhry, 2011)) shows an example of how the bank looks at liquidity risk . The figure shows:

Figure 2.2.1a: Maturity ladder and the banks funding needs;

Figure 2.2.1b: Exposure of assets and liabilities in different currencies;

Figure 2.2.1c: Ranking of assets by market liquidity risk and liabilities by likelihood of withdrawals; and

Figure 2.2.1d: Funding concentrate of liabilities.

(a) Maturity Ladder

(b) FX Mismatch

(c) Asset Liability Liquidity Ladder

(d) Funding Concentration
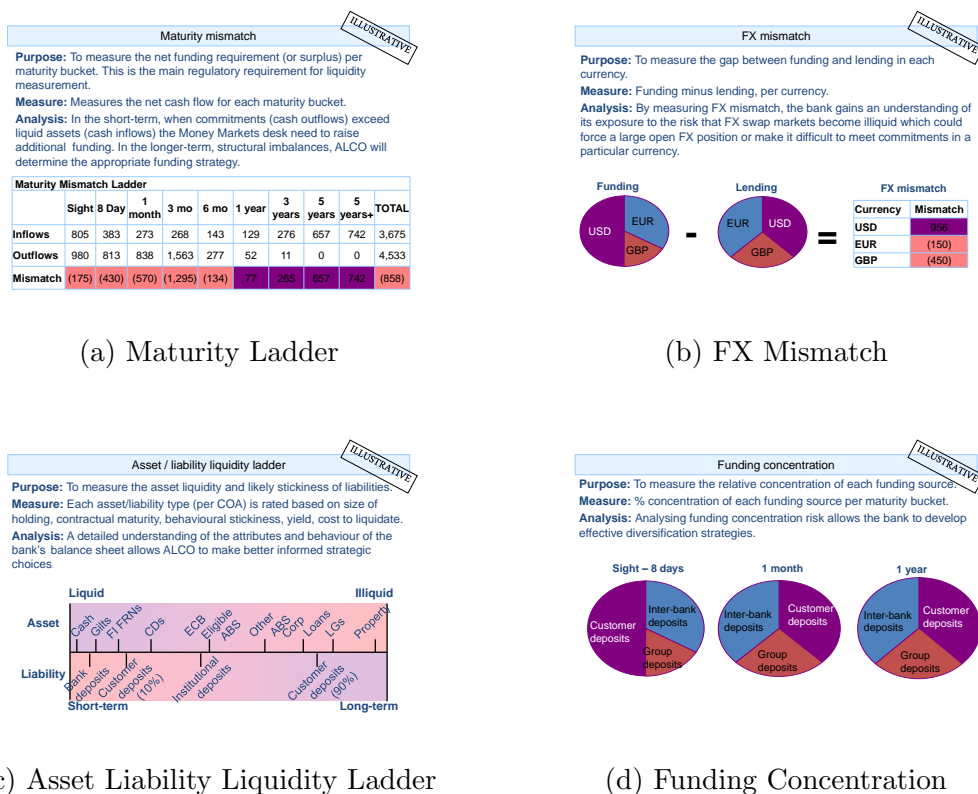
Figure 2.2.1: Illustration of a Liquidity Report reproduced from Choudhry (2011)

2.2.6   Contingency liquidity risk

This is not all a bank needs to consider as part of funding liquidity risk. The bank also needs to consider contingency liquidity risk. Matz and Neu (2006) define contingency liquidity risk as the risk that a significant amount of cash is unexpectedly

required. An example of how contingency liquidity risk may arise is from customers' use of credit cards and overdrafts. Banks often provide credit cards and overdrafts to their customers and the bank sets a credit limit. The credit limit is usually a lot higher than the usual amount the customers use. However, the bank is still committed to providing the full credit limit if the customers wishes to use it. Therefore the bank is exposed to contingency liquidity risk if customers decide to use more money from their credit cards and overdrafts than expected.

Another example that could cause contingency liquidity risk as specified by BCBS (2000) is that banks provide credit facilities and financial guarantees to other banks. Banks that opt for the credit facility pay a fee for the option and pay interest when they borrow money. BCBS (2000) notes that generally the amount borrowed on a credit facility can be assessed in normal times however it can increase which could cause contingency liquidity risk.

In both these examples, it is likely that during a banking crisis customers will look to increase the amount they borrow from the bank and will be near their credit limit. BCBS (2000) notes that in market crisis there may be a significant increase in the use of these facilities regardless of the financial conditions of a bank. This is because others are trying to protect themselves from default and bankruptcies. This would be the worst time for the bank to experience contingency liquidity risk. During a banking crisis, the bank will likely be experiencing funding liquidity risk, so experiencing contingency liquidity risk at the same will add to the bank's problems. Therefore it is important that the bank models it liquidity risk and looks for global liquidity indicators to help it to assess how much liquid assets it needs to hold.

2.2.7 Liquidity indicators

At times, it will be difficult for the Bank to increase their holding of liquid assets. By watching global liquidity indicators, the bank can try and foresee if they have difficulty in raising in funding when they require them.

The Bank for International Settlements (BIS) regularly issues an update on their global liquidity indicators. BIS (2013) states that these indicators will look

at different factors that make up the the global liquidity picture. They note that
the usefulness of the global liquidity indicators does change over time so a flexible
approach much be adopted.

The global liquidity indicators that BIS (2013) looks at can be grouped into four
areas:

1. Credit;

2. Monetary Liquidity;

3. Funding Liquidity; and

4. Risk appetite.

BIS (2013) says that they look at these four areas for the following reasons:

- Liquidity relies on market participants willing to lend to each other in the
  market;

- Monetary polices impact on the amount of liquidity available; and

- Credit can lead to significant risk taking or unsustainable lending booms that
  can lead to liquidity issues.

Illing and Aaron (2005) have looked at various indices to assess market par-
ticipants' risk appetite. One of the key indices used to assess risk appetite is the
Chicago Board Options Exchange Index (VIX) which measures the implied market
volatility of the S&P 500. Figure 2.2.2 shows the VIX over a 10 year period. Caru-
ana (2013) notes that risk appetite and risk perception of market participants will
affect their willingness to lend to each other. This is particularly important as the
wholesale money markets rely on participants lending. IMF (2013) notes that banks
are relying more on the use of wholesale money markets to fund their assets rather
than solely using customer deposits.

As banks are using wholesale money markets, Chen et al. (2012) note it is im-
portant to look at 'core' and 'non-core' liabilities to assess liquidity. They define

Figure 2.2.2: VIX over 10 years reproduced from Chicago Board Options Exchange (2015)

'core' liabilities as funding the banks rely on in normal times such as retail deposits from households. While 'non-core' liabilities are the use of wholesale money markets to finance their assets. They therefore suggest looking at indicators that distinguish between 'core' and 'non-core' liabilities. IMF (2013) notes that it was a large decrease in 'non-core' liabilities that occurred during the global financial crisis in 2007-2008. For looking at 'core' and 'non-core' liquidity, Chen et al. (2012) suggest looking at price and quantity indicators. They note that quantity indicators can be slow to adjust and price indicators only spike once an event has happened. Therefore both measures are not very good forward looking indicators. However, Chen et al. (2012) note that analysing both price and quantity indicators together can help give a better understanding of liquidity.

We know from Brunnermeier (2009), that funding liquidity and market liquidity are closely related. Sarr and Lybek (2002) have looked at market liquidity indicators that can be used. They looked at bid-ask spreads, turnover ratios and price measures. Sarr and Lybek (2002) conclude that looking solely at these indicators will give mixed signals on liquidity. As such they believe it is very difficult to create one single measure to assess liquidity.

Similarly, Eickmeier et al. (2014) conclude that the liquidity can not be assessed by a single factor and believes there are three factors that must be measured: monetary policy, credit supply and credit demand. Caruana (2014) mentions that we need price and quantity measures; assessment of risk appetite and analysis of credit on a domestic and global basis.

It is important that a variety of global liquidity indicators are used to monitor global liquidity. Chen et al. (2012) and Caruana (2013) note that liquidity can quickly disappear.

2.2.8 Modelling

It is very important for banks to model their liquidity risk. Wylie (2012) says that one of the lessons that institutions learned from the global financial crisis in 2007-2008 is the need for better integration of liquidity risk management into the overall risk management process. By having a full picture of funding liquidity risk, this will help to ensure that the banks have a good understanding of how much liquid assets they may require. Global liquidity indicators may be useful to help the bank know when they might want to increase their liquid asset holding but the modelling will help them assess by how much.

Funding liquidity risk modelling is different to credit risk modelling. Adalsteinsson (2015) notes that credit risk is well identified, with good historic data and established correlation to macro-factors. While for funding liquidity risk, Adalsteinsson (2015) notes that data is limited, as each experience is different and difficult to assess. Therefore a variety of approaches will be needed to assess funding liquidity risk.

Fiedler (2011) highlights the basic components that need to be modelled. He suggests that banks model their forward liquidity exposure and assess this compared to their counter balance capacity. The counter balance capacity can be thought of as the bank's ability to raise liquidity. BCBS and Prudential Regulation Authority (PRA) have set out what they expect to see in the modelling. Generally they set out that all liquidity risk should be captured in the models. We will look at the different model approaches in this section rather than the details of how to model and what should be assessed.

In one approach Matz (2006b) says banks carry out stress testing to assess their liquidity needs. As part of this banks will perform scenario and sensitivity testing. For scenario testing, the bank will look at historical events and hypothetical cases.

For sensitivities, the bank will vary the key assumptions to quantity the impact.

Historical events are past experiences of liquidity events. Examples of historical liquidity events are the Asian crisis in 1997 and the Russian default in 1998. Matz (2006b) lists 12 different liquidity events during a 15 year period between 1987 and 2002. Matz (2006b) notes that each liquidity event is quite different to the previous event. Therefore, investigating just previous liquidity events might not prepare you for the next liquidity event.

Banks must look at hypothetical cases since each liquidity event is different. This allows the bank to create their own stress scenarios and help them identify key risks to their liquidity needs. They are not bound by previous events. Historical events can be used as a starting point and can be amended to allow for developments. Hypothetical cases are therefore very useful for stress testing. However, Matz (2006b) notes that the main disadvantage is that they are subjective so will require appropriate judgement and skill.

One method suggested by Matz (2006b) is to assess liquidity risk by looking at deterministic scenarios. This can be very useful as both historical and hypothetical cases can be applied. This will allow the bank to identify its key risks to their liquidity and assess the impact of different events. The downside of this approach is that it does not provide a probability of occurrence.

Another method, specified by Matz (2006b), that can be used is where Value at Risk (VAR) is considered. VAR looks at the loss at a selected confidence level, often 99% confidence level is used. This method can assign a probability to the likelihood of loss. However, this method is based on historical data so the results may be misleading if future events are different from past situations.

Matz (2006b) also suggests Monte Carlo simulation can be used to assess liquidity risk. This can be used to provide a probability of events. Matz (2006b) notes that it can be difficult to estimate parameters. If parameters are estimated from historical data, then this is implicitly assuming that liquidity crisis will be the same as before and will not allow for any structural changes.

Whatever method is used, Matz (2006b) notes the bank should also carry out

sensitivity testing. This will allow the bank to see how sensitive the results are to each of the assumptions and help the bank understand its key drives for its liquidity needs.

FSA (2009) requires banks to look at three scenarios for stress testing. One scenario is to look at a bank specific event that can last up to 14 days. Another scenario is a market wide stress event that can last up to 3 months. The final scenario is a combination of the first and second scenarios. Similarly, BCBS (2008b) states that banks should look at 'what-if' scenarios taking into account bank specific and market related factors. The PRA replaced the Financial Services Authority (FSA) legislation with Basel III so this is the only legislation requirement from 1 October 2015 (PRA, 2015).

BCBS (2000) notes these stress tests can be viewed in terms of maturity ladders and should be carried out for each major currency the bank operates in. BCBS (2013b) requires this to be done for contractual maturities of inflows and outflows. In addition, the bank can look at cashflow summary reports and sufficiency reports. Matz (2007) gives an example of a cashflow summary report and this is shown in Table 2.2.2. Table 2.2.2 shows the ratio of income to outflow of cash each month and is checked to see if it is above a certain level. If it is below the level, the bank will need to take action. Matz (2007) also gives an example of a sufficiency report and this is shown in Table 2.2.3. Banks want to know how long they can survive with their current liquid asset holding under different scenarios. They will monitor this expectation and check it is above their target survival period. If expected survival is less than the target survival period, the bank will take action to increase the survival period.

Table 2.2.2: Cashflow summary report from Matz (2007)

		March	April	May
Ordinary course of business scenario	actual	1.24:1	1.27:1	1.21:1
	limit	1.20:1	1.20:1	1.20:1
Bank-specific scenario, stress level 1	actual	1.16:1	1.11:1	1.12:1
	limit	1.10:1	1.10:1	1.10:1
Bank-specific scenario, stress level 2	actual	1.02:1	0.94:1	1.04:1
	guidance minimum	1.00:1	1.00:1	1.00:1
Numerals are ratios of total forecast cash inflows to forecast outflows				

Table 2.2.3: Sufficiency report from Matz (2007)

	Forecast number of months before negative cashflows consume the standby liquid assets	Required minimum number of time periods
Normal course of business scenario	24	12
Bank-specific funding scenario		
Stress level 1	18	12
Stress level 2	2	4
Systemic-funding scenario		
Stress level 1	15	12
Stress level 2	8	9

All these scenarios helps the bank understand its liquidity needs especially in times of crisis. As Brunnermeier and Pedersen (2009) note liquidity crisis can happen quickly and can impact across assets so it is important to have a plan in place so it can react quickly.

Liquidity risk modelling cannot be carried in isolation. Gea-Carrasco and Little (2013) note that considering liquidity risk without other risk leads to underestimating solvency risk. To effectively manage liquidity risk, Gea-Carrasco and Little (2013) say there is a need to address exposure in the following areas:

- Market liquidity risk;

- Funding liquidity risk;

- Liquidity stress testing; and

- Contingency planning.

As such liquidity risk modelling needs to be taken into consideration with Asset Liability Modelling (ALM). Wylie (2013) notes that the ALM team traditionally concentrates on interest rate risk. However, it has now become responsible for:

- Liquidity;

- FTP;

- Capital management; and

- Risk policy settings.

Kunghehian (2010) assesses the main tools used for ALM. These are:

- Gap analysis;

- Net interest income simulation;

- Market value sensitivity measures; and

- Earning at risk.

Information about these methods can be found in Wylie (2013) and Crouhy et al. (2006). Kunghehian (2010) lists the pros and cons of each method.

BCBS (2008b) notes a range of measurements and metrics are needed to be used as no single number can adequately quantify liquidity risk. The different approaches have their pros and cons but by carrying out multiple approaches this will assist the bank with their understanding of funding liquidity risk. BCBS (2008b) states that stress testing helps banks identify potential liquidity risk and the results can be used to develop their contingency plan.

2.2.9 Contingency funding plan

Brunnermeier and Pedersen (2009) found that market liquidity risk and funding liquidity risk can reinforce each other leading to 'liquidity spirals'. They find this is because liquidity can suddenly cease and can be impacted across many assets. In the event of this happening, De Haan and van den End (2013) note that the banks will take the following actions:

1. Reduce lending, in particular wholesale lending;

2. Increase liquid asset holding; and

3. Fire sale of assets.

As Bonfim and Kim (2014) found there is evidence of herding amongst the largest banks so potentially banks could be adopting the same approach. Acharya and Merrouche (2012) note that during the global financial crisis in 2007-2008 the banks

demand for liquidity jumped by about 30%. On 11 September 2007, the overnight liquidity demand increased by 24.7%. This occurred shortly before the run on Northern Rock (discussed in Section 2.4). Acharya and Merrouche (2012) look at the impact of other events on liquidity during the financial crisis and the impact this had. Acharya and Merrouche (2012) also note that liquidity demand by some banks can lead to higher borrowing costs for all banks. Huang and Ratnovski (2011) discuss the negative effects of the wholesale money markets and how funding can be quickly withdrawn based on a hint of negative news.

All this shows that liquidity risk can increase rapidly and can be severe when it does happen. Therefore it is important that a bank can act quickly and have a clear plan in place to deal with funding liquidity issues. This plan is known as Contingency Funding Plan (CFP).

The CFP, notes BCBS (2008b), should set out the policies, procedures and action plans for dealing with funding liquidity risk. Matz (2006a) notes that CFP is based on the following facts:

- Banks can not avoid liquidity risk;

- Banks can not hedge liquidity risk; and

- Banks can not hold enough liquid assets to cover severe or prolonged funding issues.

As Adalsteinsson (2015) has highlighted that each liquidity crisis has been different. BCBS (2008b) notes that banks need to respond quickly to a variety of situations so it is important that banks have a lot of flexibility in their CFP. Matz (2006a) suggests the CFP should include triggers and a menu of options. BCBS (2008b) states that it is important to set out clear responsibilities and details can be found in Matz (2006a) of how these responsibilities can be allocated.

Matz (2006a) mentions that a good CFP can increase the odds of surviving a crisis as well as instilling good liquidity risk management practices within a bank. BCBS (2008b) says that stress testing, analysis and CFP should be closely integrated. Further information on CFP can be found in BCBS (2008b) and Matz

(2006a). CFP plays an important role in liquid risk management and with regulation can help reduce the impact of a future liquidity crisis.

2.3   Regulation requirements

2.3.1   Financial Services Authority and Prudential Regulation Authority

At the time of the global financial crisis in 2007-2008, the FSA was responsible for regulating the banks. They found many failings within the banks and with the practices that the banks used. As such, they have subsequently come out with tight regulations in the hope of reducing the risk of any future crisis.

One of the failings was that banks were not holding enough liquid assets (FSA, 2009). Banks were set up to survive about 5 working days of liquidity stress under UK legislation (FSA Board Report, 2011). The FSA has now strengthened these requirements on a bank to ensure it can survive for a 14 days firm specific stress and a 3 months market wide stress (FSA, 2009). This will give the banks and regulators more time to respond during a crisis.

It also became apparent that some of the assets banks were holding for liquidity purposes were not actually liquid (FSA Board Report, 2011). Banks have been looking for liquid assets that produce higher expected investment returns to increase profits (FSA Board Report, 2011). They were also holding less highly liquid assets that produce lower expected investment returns such as GILTS. When the crisis hit, banks discovered they were unable to easily sell these so-called liquid assets and had to offer significant reductions to be able to sell them. The FSA has now tightened the requirements on what can be classified as liquid assets and expects banks to hold more GILTS going forward.

Other issues that became apparent during the crisis, was that liquidity risk was not a key focus for the banks. The banks were relying on the wholesale money markets to cover any short term liquidity issues. Previously, there hadn't been an extended problem for a long time with these markets and the banks never foresaw

there being one (FSA Board Report, 2011). As such, liquidity management was not a key risk management measurement and there was not enough oversight from the Board of Directors and senior management as to how this risk should be managed (FSA, 2009). This led to other problems such as banks not being fully aware of all their liquidity needs under certain scenarios. Some contracts that the banks entered into required additional margin calls, i.e. larger collateral, in the event of certain triggers (FSA, 2009). These could lead to a significant strain on the banks liquid resources. As a result, the FSA requires banks to have a clear liquidity policy approved by the Board of Directors and implemented by senior management. They have tried to ensure that this is a major focus that the banks must monitor regularly and that they have contingency plans in place to deal with a liquidity crisis. Banks were also made to improve their systems to incorporate all their needs of liquidity from various business streams and to be fullly aware of any potential demands. This has made liquidity risk a key risk that banks need to manage.

In 2009, the FSA released detailed new regulation in the UK in light of the global financial crisis in 2007-2008. Full details of the new policies can be found in FSA (2009). The policy specified what was expected under liquidity risk management and the different risks that the bank are supposed to take into consideration. A high level summary was created by FSA (2008) and is shown in Figure 2.3.1.

FSA (2008) states that the new liquidity standards in the UK hope to achieve:

- Improved liquidity risk management, in particular stress testing and CFP;

- Less use of short term borrowing from wholesale money markets;

- Increased incentives to bring in retail deposits; and

- A higher amount and quality of liquid assets.

On the use of stress testing, the FSA required large banks to carry out scenario testing and specifically three scenarios - two week idiosyncratic liquidity stress, three month market wide stress and a combination of the two (FSA, 2009). The regulator has provided some guidance, in particular 10 risk drivers shown in Figure 2.3.1, but has left it up to the banks to manage the finer details of their liquidity risk. The
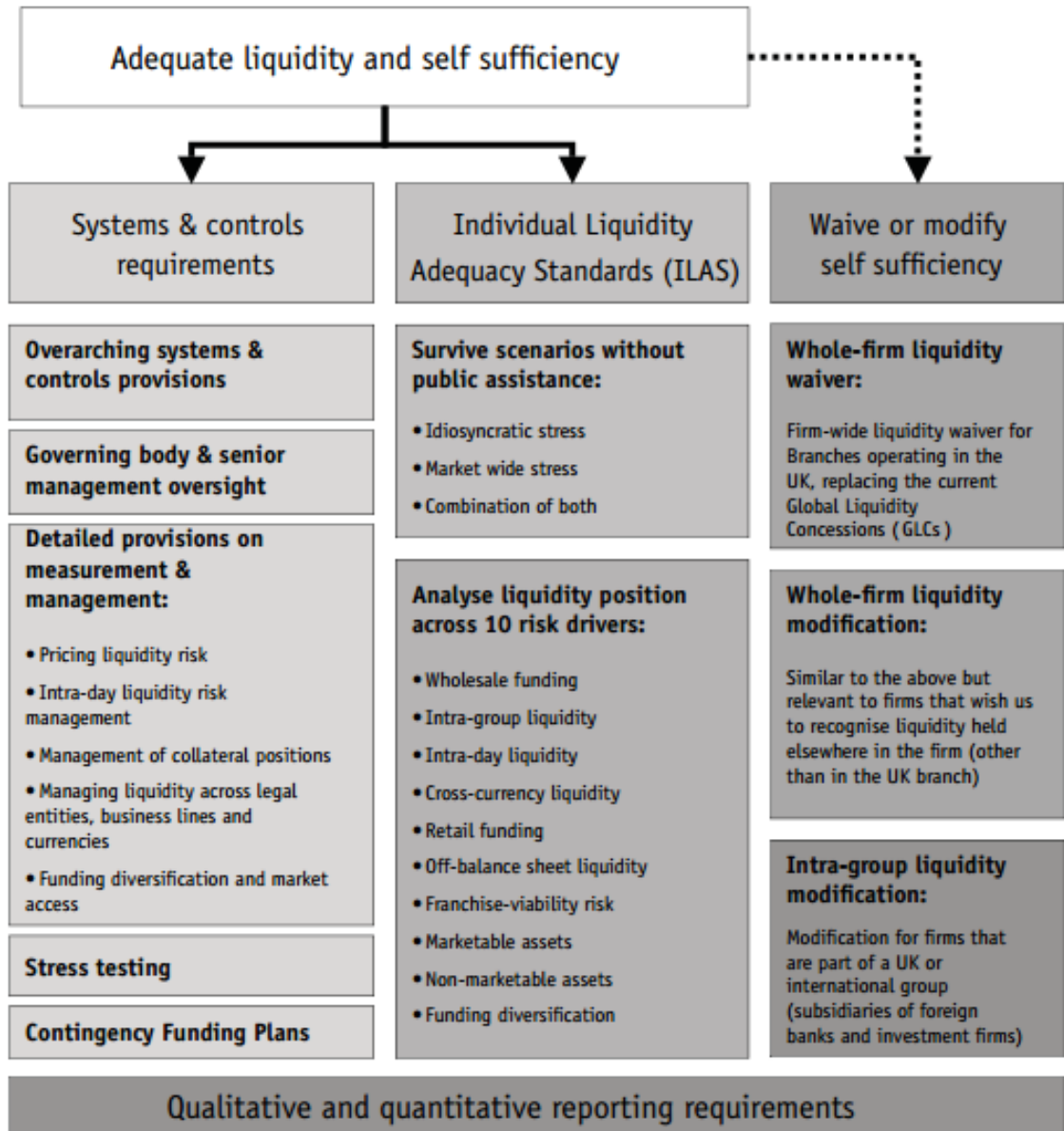
Figure 2.3.1: Summary of UK Liquidity Standards in 2009 by FSA (2008)

FSA will review their process and specify a multiplier to the bank to calculate the bank's minimum liquid asset holding. Therefore very rigorous and prudent banks should have a lower multiplier than other banks.

The costs to banks of complying with FSA standards will increase significantly. To make it easier for smaller banks that have less resources, and also a lower risk to society of causing an industry wide-risk, the FSA has specified a simplified approach that these banks can apply to adopt (FSA, 2012). Under the simplified approach (known as simplified ILAS), there are three components the banks need to measure to calculate the liquid asset buffer:

- Wholesale net cash outflow component;

- Retail and SME deposit component; and

- Credit pipeline component.

The wholesale net cash outflow component is a calculation based on the banks cumulative wholesale net cash outflows over the next three months. This component is calculated in the following way:

- For each day the expected net wholesale cashflows are calculated;

- Each day a cumulative total from the previous day is calculated; and

- The lowest cumulative total (i.e. the point where the cumulative wholesale funding net outflow is largest) is the wholesale component.

The retail and SME component is a rough approximation of how much money depositors may withdraw during a crisis. Retail deposits are split into two types: A and B. Type A depositors are customers who are more likely to withdraw their money in adverse conditions. For example, these would likely be internet based customers, high interest-rate chasers, and customers over the deposits protection limit (FSA, 2012). Type B customers are all other retail customers who are not deemed as type A. The retail and SME component is calculated as follows:

- 20% of Type A deposits;

- 10% of Type B deposits; and

- 20% of SME deposits

The third component is the credit pipeline component. This is calculated as 25% of outstanding credit granted to customers but not currently used. This includes overdraft limits, credit cards, and loans and mortgage applications approved but not yet paid.

The three components are added together and multiplied by a scalar to give the liquid asset buffer. The liquid asset buffer was the minimum amount of liquid assets that a small bank must hold. The scalar was initial 30% and was going to increase over time to 100%, however, in November 2012, the scalar was set as 50% (FSA, 2013). This approach still ensures that even small banks hold liquid assets but the tests are not as stringent as for the larger banks.

The FSA has now been dissolved and the PRA is now responsible for regulating the banks in the UK. The PRA adopted the same regulation for liquidity as the FSA. In 2013, new EU legislation was issued to implement Basel III and this is known as CRD IV (PRA, 2014). In particular CRD IV, required the implemention of the LCR. The PRA has replaced the legislation above and have implemented CRD IV: Liquidity requiring the banks to calculate the LCR instead of the scenarios mentioned above (PRA, 2015).

2.3.2 Basel

The BCBS is responsible for setting the global standards and regulations of banks. BCBS (1992) sets out what approaches are adopted by banks to manage liquidity risk. This is to be used as guidance for the banks so they can manage their liquidity risk.

BCBS (1992) notes that liquidity risk is an important issue as liquidity issues at a single bank can easily lead to systematic problems. As a result banks must assess their liquidity needs on an ongoing basis as well as under crisis scenarios. A bank must assess its needs using both quantitative and qualitative factors.

Banks are expected to have specific liquidity policy in place and a clear liquidity reporting structure. BCBS (1992) expects banks to assess its liquidity risk through

- Measuring and managing net funding requirements;

- Access to financial markets; and

- Contingency planning.

Through these approaches the bank is expected to assess its cashflows through a maturity ladder, as described in Section 2.2.1. In particular, BCBS (1992) specifies looking at the following three scenarios as a minimum:

- Ongoing concern;

- Bank specific crisis; and

- General market crisis.

Within these scenarios, BCBS (1992) prescribes that banks need to consider the following:

- Assess funding requirements in different currencies and how it plans to manage it;

- Liquidity of assets and how they will change under the scenarios, taking into account the ongoing nature of the bank;

- Assess impact on liabilities of the potential for withdrawals; and

- Off-balance sheet activities and the liquidity these may require.

For managing market access, BCBS (1992) expects the bank to ensure diversification of funding sources and to build relationships by using these different funding sources. Also, the bank should explore the possibility of how funding can be raised against liquid assets.

BCBS (1992) also specifies that the bank should have a contingency plan in place that clearly sets out the bank's strategy and to ensure that the bank has back up liquidity in place.

This clearly sets out good guidelines on how a bank should manage its liquidity risk. The one downside is that BCBS (1992) mentions that the timeframe for actively managing liquidity risk is only for a few weeks and certainly not much more than 4 or 5 weeks. For strategic decisions, a longer timeframe can be used. As was discovered during the global financial crisis in 2007-2008 these timeframes are quite short.

In 2000, the BCBS (2000) issued a new document building on the material in BCBS (1992). In particular it provides more detail regarding risks to liquidity and how a bank can manage these risks. In addition, it includes references to the role of public disclosure and the role of supervisors.

BCBS (2000) notes that banks need to ensure they have provided adequate levels of disclosure of information so that stakeholders can understand the soundness of the bank. The bank should provide this regularly and plan how to deal with the situation when the information is negative. This should help manage the outflow of funds and show that the bank is addressing any problems.

BCBS (2000) states that the role of supervisors for the bank should be to evaluate the following:

- Strategy;

- Policies;

- Procedures and practices; and

- Systems to measure and monitor liquidity.

This will help ensure the bank has good practices in place to deal with liquidity risk. The banks should provide sufficient information to supervisors so that they can evaluate these measures as well as the contingency plan in place.

These measures should have reduced the potential for liquidity risk if they are adopted properly and used in line with the full spirit of intention. However, the global financial crisis in 2007-2008 showed they were not adequate. The BCBS carried out a review and their findings can be found in BCBS (2008a). BCBS (2008a) notes that the initial guidance remains relevant but areas need updating.

They mention there has been many changes in banks over the last few years. In particular, BCBS (2008a) identifies the following developments:

- Heavier reliance on funding from wholesale money markets;

- Greater securitisation and the need for liquidity from these products;

- Advances in complex financial instruments such as CDS;

- Greater usage of collateral and the need for liquidity to fund margin calls with short notice;

- Quicker payment process and greater importance on intraday liquidity needs; and

- Increased cross-border activities and quicker speeds of settlement.

Therefore there is a need for liquidity management to keep up to date with these practices. However, BCBS (2008a) notes that banks failed in a few places:

- Stress testing wasn't enough. It failed to capture the duration of the shock as well as multiple events occurring simultaneously;

- Contingency plans were not sufficiently integrated with stress testing. Some banks were not in positions to be able to execute their contingency plans;

- Liquidity needs for off balance sheet activities were not fully realised;

- Regular reporting for monitoring liquidity were not suitable and sometimes could not be produced in timely fashion; and

- FTP did not allow for contingent liquidity risk. As a result, banks did not price this risk properly internally or externally.

This meant that some banks were unable to meet their funding liquidity needs during the global financial crisis in 2007-2008 and this implied that banks had not met some of the principles set out in BCBS (2008a). BCBS (2008b) published an updated approach. BCBS (2008b) sets out more comprehensive information on how

banks can manage their liquidity risk. Although, in spirit it was the same as BCBS (2000), it was much more explicit on what should be included. For instance, it specifies that liquidity risk should be priced in the internal pricing framework.

BCBS (2008b) states that banks should release information about their liquidity risk management and provides examples. It does not specify exactly what has to be disclosed and no need for consistency across banks. This came later when BCBS introduced Basel III. BCBS introduced the LCR and Net Stable Funding Ratio (NSFR). These were two ratios that banks have to publish to help investors understand the bank's liquidity position.

2.3.2.1 Liquidity coverage ratio

The LCR is defined as "an adequate level of unencumbered, high-quality liquid assets that can be converted into cash to meet its liquidity needs for a 30 day time horizon under a significantly severe liquidity stress scenario specified by supervisors" (BCBS, 2010). The LCR is calculated as follows:

$$\text{LCR} = \frac{\text{HQLA}}{\text{Total net cashflows over the next 30 calendar days}} \geq 100\%.$$

Details about HQLA can be found in Section 2.1.2. Here we will concentrate on total net cashflows. BCBS (2013b) shows the net cashflows are calculated as follows:

$$\begin{array}{ccccc} \text{Total net cashflows} & = & \text{Total expected} & - & \text{Min(total expected cash inflows;} \\ \text{over the next 30 calendar days} & & \text{cash outflows} & & 75\% \text{ of total expected cash outflows).} \end{array}$$

These cashflows are calculated on a deterministic basis under a specific scenario. BCBS (2013b) defines this scenario as a combination between a bank specific and a market wide shock. BCBS (2013b) says the bank should allow for the following:

- A proportion of retail depositors withdrawing;

- Detrimental impact on access to wholesale money markets;

- An assumed downgrade of bank's credit rating by three notches and assess the impact this will have on cashflows;

- Credit and liquidity facilities being used by customers; and

- A need to buy back debt or honour non-contractual obligations to limit reputational risk.

BCBS (2013b) specifies in more detail what is required in the scenario. The following is a summary of the main points:

- Retail deposits at least 3% or higher withdrawn:

  - Retail deposits split between stable and and less stable portions;

  - Stable deposits usually 5% or higher withdrawn;

  - Special cases of stable deposits with pre-fund insurance or government protection, 3% or higher withdrawn;

  - Less Stable deposit 10% or higher withdrawn; and

  - Same applies to small business customers,

- Operation deposits 25% withdrawn;

- Unsecured wholesale funding usually 40% or 100% withdrawn;

  - Usually 40% withdrawn for non-financial corporates and sovereigns;

  - Unless protected by insurance then 20% withdrawn; and

  - 100% for all funding in particular banks and insurance companies.

- Secured funding 100% withdrawn unless back by HQLA;

  - 0% if backed by Level 1 assets;

  - 15% if backed by Level 2A assets;

  - 25% if backed by eligible RMBS Level 2B asset; and

  - 50% if backed by other Level 2B assets.

- Committed credit and liquidity facilities between 5% and 100% drawdown;

  - 5% drawdown for retail and small business customers;

  - 10% for credit and 30% for liquidity facilities for non-financial corporates and sovereigns;

  - 40% drawdown for banks;

  - 40% for credit and 100% for liquidity facilities for insurance and securities firms; and

  - 100% drawdown for Special Purpose Vehicles (SPV).

- need to allow for cash inflows;

  - secured lending 100% unless backed by HQLA or used for Margin Lending;

  - 0% for secured lending against Level 1 assets;

  - 15% for secured lending against Level 2A assets;

  - 25% for secured lending against eligible RMBS Level 2B assets;

  - 50% for secured lending against other Level 2B assets;

  - no use of credit or liquidity facilities;

  - assume to continue to extend loans to retail, small business customers, non-corporates and sovereigns so allowing only for 50% inflow from loans; and

  - 100% inflow from loans to financial institutions.

BCBS (2013b) expects the LCR to be calculated for all major currency. To allow time for the banks to adjust to the new arrangements, they will only be required to meet 60% of the LCR from 2015 and will increase by 10% each year.

Fiedler (2011) notes a couple of issues with the LCR and discusses how the bank can improve their LCR. Two particular points are:

- The minimum balance of the cashflows may occur during the 30 days, however, the LCR requires the cashflow position at 30 days; and

- Even if the bank perfectly matches their liabilities with assets, they will still be required to hold liquid assets as the minimum holding is 25% of cash outflows.

2.3.2.2 Net stable funding ratio

The other ratio introduced under Basel III was the NSFR. BCBS (2014b) states the NSFR is to reduce reliance on short term wholesale funding. The NSFR is calculated by evaluating the Available amount of Stable Funding (ASF) and Required amount of Stable Funding (RSF) as follows:

$$\text{NSFR} = \frac{\text{ASF}}{\text{RSF}} \geq 100\%.$$

The ASF looks at the funding of the bank and applies a factor to it based on how stable it is. Table 2.3.1 shows the high level summary of the factors for the different types of funding and full details can be found in BCBS (2014b).

Table 2.3.1: High level summary of ASF factors

ASF	
Category	Factor
Capital (excluding Tier 2 with maturity $\leq$ 1 year)	100%
Liabilities with effective maturity $\geq$ 1 year	100%
Stable non-maturing/term deposits $\leq$ 1 year	95%
Less stable non-maturing/term deposits $\leq$ 1 year	90%
Funding less than 1 year from Sovereign nations	50%
Funding $\geq$ 6 months and $<$ 1 year	50%
All other funding	0%

The RSF looks at the assets of the bank and assesses their liquidity characteristic and maturities. Full details can be found in BCBS (2014b) and a high level summary is shown in Table 2.3.2.

Fiedler (2011) notes that a weakness of the NSFR is that it does not allow for new assets and therefore assumes that the bank stops creating assets which is quite unrealistic. The NSFR is due to be implemented by 1 January 2018.

Table 2.3.2: High level summary of RSF factors

RSF	
Category	Factor
Cash & central bank reserves	0%
Unencumbered Level 1 assets	5%
Unencumbered loans to banks with maturities $\leq$ 6 months secured against Level 1 asset	10%
All other unencumbered loans to banks with maturities $\leq$ 6 months Unencumbered Level 2A assets	15%
Unencumbered Level 2B assets Loans to banks with maturities > 6 months and $\leq$ 1 year All other asset with maturities $\leq$ 1 year	50%
Unencumbered residential mortgages with maturities > 1 year (risk weights $\leq$ 35%) Unencumbered (non-financial) loans with maturities > 1 year (risk weights $\leq$ 35%)	65%
Unencumbered (non-financial) loans with maturities > 1 year (risk weights > 35%)	85%
All assets that are encumbered for a period > 1 year	100%

2.4   Financial crisis

As we have seen, there has been significant changes in regulations due to the global financial crisis in 2007-2008. We will now look at the impact the global financial crisis in 2007-2008 had on three UK banks that experienced funding liquidity risk. The three banks are:

- Northern Rock;

- HBOS; and

- Royal Bank of Scotland (RBS).

2.4.1   Northern Rock

On 14 September 2007, Britain experienced its first run on a bank since Victorian times (Treasury Select Committee, 2008). Depositors lined up outside the Northern Rock bank demanding their money back. There were many factors that led us to this point, mainly liquidity issues. It was ultimately the worry about liquidity that caused customers to demand their money back and were willing to queue for hours for it. The Treasury Select Committee (2008) gives a very good account of the issues facing the bank and further information can be found in Shin (2008). We will look at some of the key factors.

Northern Rock's business model relied heavily on borrowing from wholesale money markets rather than deposits. In 2006, Northern Rock's assets were £101.0bn

with deposits accounting for only 22% of financing (Northern Rock, 2007). Northern Rock's business model was to sell loans under securitisation with credit risk and interest rate risk passed to investors. Northern Rock (2007) shows that this made up 40% of their funding. Northern Rock also issued covered bonds, these are bonds that are guaranteed against a book of loans which accounted for 6% of funding (Northern Rock, 2007).

Northern Rock's business model was called 'originate to distribute' (Treasury Select Committee, 2008). Under this model, the bank issued loans with the intention of selling these loans to investors. This is achieved through securitisation and covered bonds. In securitisation the loans are combined together and used to secure funding against these loans. The credit risk and interest rate risk is transferred to the investor. Covered bonds are similar to securitisation where funds are raised against a book of loans but the risks remain with the bank. It is only in the event of a default from the bank that the creditors will get the security of these loans. Mr Applegarth, Northern Rock's CEO highlights in the Treasury Select Committee (2008) that Northern Rock's funding has increased to:

- 50% Securitisation;

- 10% Covered bonds; and

- 25% Wholesale borrowing.

In August 2007, there were issues with banks being able to access wholesale money markets and Shin (2008) notes the markets effectively closed down with the announcement of BNP Paribas closing three SPV exposed to subprime mortgages. As Northern Rock was heavily reliant on wholesale money markets this caused great stress on their business model. The Treasury Select Committee (2008) concludes Northern Rock's business model was "high-risk, reckless" and too reliant on wholesale money markets. They had inadequate insurance and didn't have appropriate standby liquidity facilities in place to cover risks they were facing. In fact, the Treasury Select Committee (2008) notes that Northern Rock could have accessed the European Central Bank (ECB) funding but did not have the required documenta-

tion in place. Northern Rock needed emergency funding from the Bank of England on 14 September that triggered the run on the bank.

One reason for the run was inadequate insurance provided by the Financial Services Compensation Scheme (FSCS). The FSCS covered 100% of the first £2,000 and then 90% of the next £33,000. Also the payment of the insurance was not particularly quick. The Treasury Select Committee (2008) states it could actually take years before the payments could be made. According to the Treasury Select Committee (2008), Northern Rock's bank run on 18 September 2007 was only stopped once the UK Government guaranteed consumer deposits. However, Shin (2008) notes the damage was already done before the retail depositors started to queue to get their money.

The FSA as regulators were also criticised for their role. The FSA only carries out a full comprehensive assessment every 3 years and the last one was done in January 2006 (Treasury Select Committee, 2008). The regulators seemed to ignore the two clear warning signs according to the Treasury Select Committee (2008):

- Rapid growth in Northern Rock; and

- Decline in share price of 30% in the first 6 months of 2007.

The FSA had discussed with Northern Rock issues around their stressing test scenarios. However, the Treasury Select Committee (2008) notes that the FSA failed to appropriately communicate this to the board and seek remedial action from Northern Rock.

These are just some of the factors surrounding Northern Rock and its eventual failure. Clearly the main issue was not having adequate funding liquidity for its business model.

2.4.2 HBOS

Northern Rock was not the only bank to suffer during the global financial crisis in 2007-2008 in the UK. HBOS needed to be taken over by Lloyds TSB and in total required funding by the UK taxpayer of £20.5 billion (Parliamentary Commission on

Banking Standards, 2013). The Parliamentary Commission on Banking Standards (2013) has carried out a review of HBOS and the issues that occurred. The Parliamentary Commission on Banking Standards (2013) notes that although HBOS failed because of liquidity issues, it was mainly due to solvency. As the Parliamentary Commission on Banking Standards (2013) states if it was solely a funding and liquidity issue, the effect on the taxpayer would have been less. There is much to learn from HBOS regarding liquidity.

The Parliamentary Commission on Banking Standards (2013) notes that the funding gap (difference between loans and deposits) for corporate customers increased from £33 billion at the end of 2001 to £84.5 billion by end of 2008, while for retail customers the funding gap was £111 billion at the end of 2008 and the total funding gap was £213 billion. This translated into a loan/deposit ratio of 196%. This funding gap had to be funded by wholesale money markets.

The Parliamentary Commission on Banking Standards (2013) notes that HBOS had made efforts to increase its duration of wholesale funding. They note that HBOS wholesale funding with a duration of less than one year fell from 86% in 2001 to 50% in 2008. However, with total borrowing of £238 billion this still meant £119 billion was in short term funding. HBOS did diversify its wholesale funding using covered bond, securitisation and senior debt. The global financial crisis in 2007-2008 did cause the wholesale funding profile to change as maturing long term borrowing could only be replaced by short term borrowing.

The bank did have significant liquid assets due to its exposure to the wholesale money markets. The Parliamentary Commission on Banking Standards (2013) notes that the liquid asset holding initially consisted of government bonds and certificate of deposits. From 2004, HBOS changed their liquid assets to be more dependent on exotic products such as credit derivatives as they had a higher expected return. As a result, the £60 billion liquid asset holding was not adequate as the bank was unable to raise funds from these assets. In addition, the Parliamentary Commission on Banking Standards (2013) notes that HBOS suffered outflows of between £30 billion and £35 billion of customer deposits, which where mainly large corporations.

Ultimately, HBOS was not able to raise sufficient funds from the wholesale money markets to meet its outflow.

2.4.3 RBS

The other major UK bank to fail during the global financial crisis in 2007-2008 was RBS. At the end of 2008, RBS reported total assets of £2.4 trillion and a pre tax loss of £40.6 billion (RBS, 2009a). There were many reasons why RBS failed in 2008, these are discussed in the FSA Board Report (2011). The FSA Board Report (2011) notes that RBS failed because of liquidity issues but these were driven by solvency concerns. It should be noted that RBS's purchase of ABN AMRO in 2007 played a significant factor in RBS's failure (FSA Board Report, 2011). In particular, RBS's decision to fund the acquisition by short term debt, increased its reliance on wholesale money markets (FSA Board Report, 2011). The purchase of ABN AMRO is particularly well summarised by RBS chairman, in a statement in 2009: "the wrong price, the wrong way to pay, at the wrong time and the wrong deal" (RBS, 2009b). RBS needed taxpayer support in the form of liquidity and solvency to survive (FSA Board Report, 2011).

RBS relied very heavily on short term borrowing from the wholesale money markets. RBS was the second highest amongst its peer group for relying on short term borrowing of less than 30 days and the largest in absolute terms (FSA Board Report, 2011). The FSA Board Report (2011) notes that RBS borrowed at least 3 times more from non-sterling wholesale money markets than sterling wholesale money markets. The FSA Board Report (2011) reports that if the LCR regulations had been in place, RBS liquid asset holding would need to increase by between £125 billion to £166 billion. The RBS board had delegated responsibility for liquidity policies so the board may have not fully understood the bank's liquidity risk (FSA Board Report, 2011). From all this we can see that there was clearly warning signs for the bank regarding its liquidity risk.

However, the FSA Board Report (2011) also reports that there was failure by the FSA themselves, the regulators at the time. The regulator had a seriously flawed

liquidity framework. The FSA Board Report (2011) notes the following regarding the FSA:

- Did not monitor wholesale borrowing in other currencies other than sterling;

- Basic liquidity requirement was to cover only 5 business days of net outflow in sterling; and

- Liquidity regulation and supervision was a low priority.

From these cases we can clearly understand why there has been increased work into funding liquidity risk and improving liquidity risk management. This has lead to significantly more regulation on the topic and the focus by banks on funding liquidity risk.

Chapter 3

Fund transfer pricing

It is important for banks to assign revenue and costs to different parts of their business so senior management know what areas are profitable. This allows senior management to concentrate resources in the most profitable aspects of their business. For this to be meaningful, costs and revenue have to be assigned accurately. As mentioned previously a significant proportion of the bank's profitability is derived from the Net Interest Income (NII). Therefore we need to consider how this can be allocated between the different divisions within the bank. Seeliger (2012) notes that Fund Transfer Pricing (FTP) can be used to do this. In this chapter, we will consider the following:

- Different approaches to FTP;

- The importance of FTP; and

- What should be included in the FTP framework.

3.1 Different approaches to FTP

3.1.1 Single-pooled approach

FTP is an internal framework used for providing a cost to a business unit for using funds and a credit to the business unit providing funds. To demonstrate this, assume there are three departments in the bank: deposits, treasury and loans. The treasury

department is in charge of funds and lends out the funds at a fixed rate to business units. In the single-pooled approach, the treasury unit pays out the same fixed rate as a credit to business units for providing funds as it charges for user of funds. For example, the deposits department pays a deposit rate of 1% to customers, while the loan department charges 8% to customers for loans. The treasury department sets their rate at 4% for receiving and paying out funds. Figure 3.1.1, explains how this works.
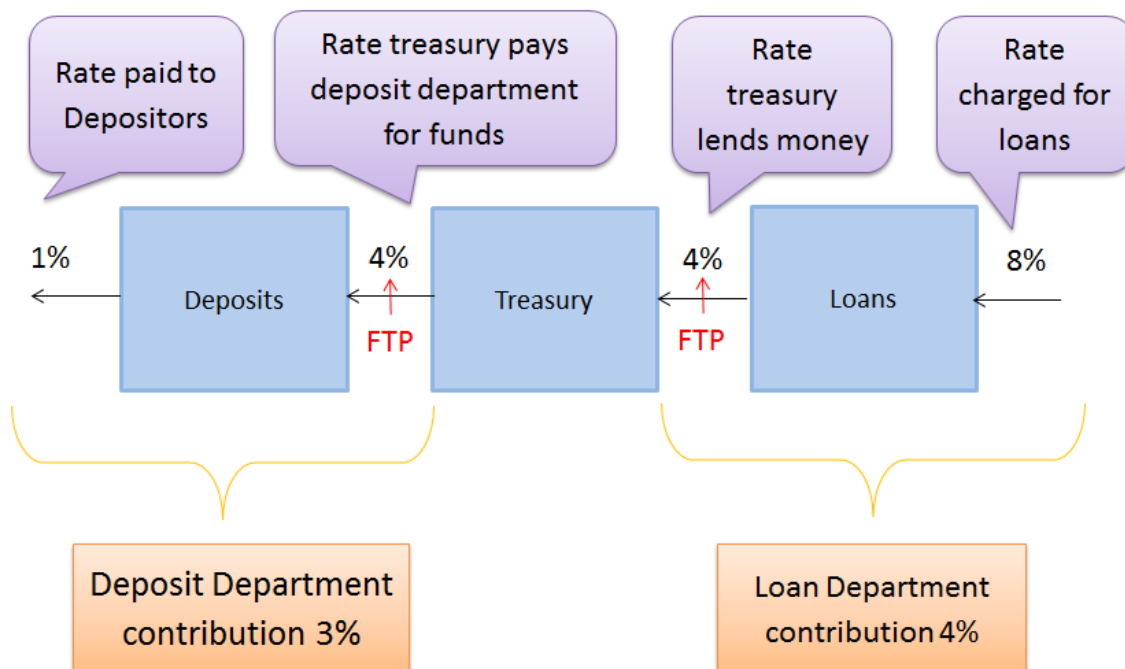
Figure 3.1.1: Single-pooled FTP

The deposit department transfers the funds they receive from customers to the treasury and receives a rate of 4%. Thus the deposit department makes a contribution of 3%, the difference between the rate offered to customers and the rate received from treasury. The loan department borrows funds from the treasury department at 4% and lends it to their customers at 8%. Therefore the loan department makes a contribution of 4%, the difference between the loan rate and the money received from treasury. Assuming that the amount of loans equals amount of deposits, the overall contribution is 7% (3% from the deposit department and 4% from the loan department). This is known as the single pooled approach. The overall contribution would just be the same if there was no FTP framework in place. The overall contribution is just the difference between the rate offered to deposits and the rate

paid by loan borrowers, similar to NII. So in this case 7% (8% - 1%). If there was no FTP framework, deposits would be a cost to the business unit since the deposit rate has to be paid to customers and all the profit comes from the loan department since it is lending out money and receiving income. Levey (2008) notes historically this was the practice within a bank. There is clearly a benefit to having deposits as they are quite stable (i.e. they remain constant within the bank) and usually pay a lower rate of interest than market rates from wholesale funding (borrowing money from the wholesale money markets). In other words, if the bank does not have a deposit unit, it might need to borrow from the wholesale money markets at 4% and then its profits would only be 4% in total. Woodward (2007) notes that FTP rate is similar to the opportunity cost; the bank generates risk adjust profit from lending to customers or lending in wholesale money markets. While for deposits, the consideration for the bank is whether it is better to generate money from deposits or borrow from the wholesale money markets. FTP helps allocate the profits between deposit and loan departments and helps evaluate the opportunities for the business unit.

The single pool rate for FTP has advantages identified by Kawano (2000), as simple and easy to understand and implement. However, he also identifies that there is no separation of credit risk and interest rate risk and that providing incentives to one department comes at a cost to another department. For example, if the bank wanted to increase deposits it could offer a higher FTP rate as this would incentivise the deposit department to raise more funds. However, this would come at a cost to the loan department who would have a higher rate to borrow money and would lend out less money. Tumasyan (2012) notes that under this approach, assets and liabilities are matched at the business unit before the difference is then transferred meaning that the treasury will not know the maturity and will work on an average rate basis. This will result in interest rate risk and funding liquidity risk. Wyle and Tsaig (2011), also highlight that this approach does not take into account maturity and several other attributes. Therefore, this may incentivise the departments in the wrong way such as encouraging the loan department to grant loans for a longer

period of time and creating a rate mismatch in the bank. Coffey and Palm (2001) highlight that this approach would result in the same FTP rate being offered on a 30 year mortgage as a 3 month customer deposit, although the mortgage is riskier to the bank. An FTP rate still seems better than not having one at all though Tumasyan (2012) notes that the single-pooled approach is increasingly becoming too simplified as the bank's business evolves.

3.1.2 Multi-pooled approach

An alternative FTP method is a multi-pooled approach. Kawano (2000) defines it as a method assuming at least two pools - one for the user of the funds and another for the provider of the funds. Different maturities can be taken into account. For example, the treasury might lend money out at 4.5% and pay 3.5% for funds. Figure 3.1.2 shows how this would work.
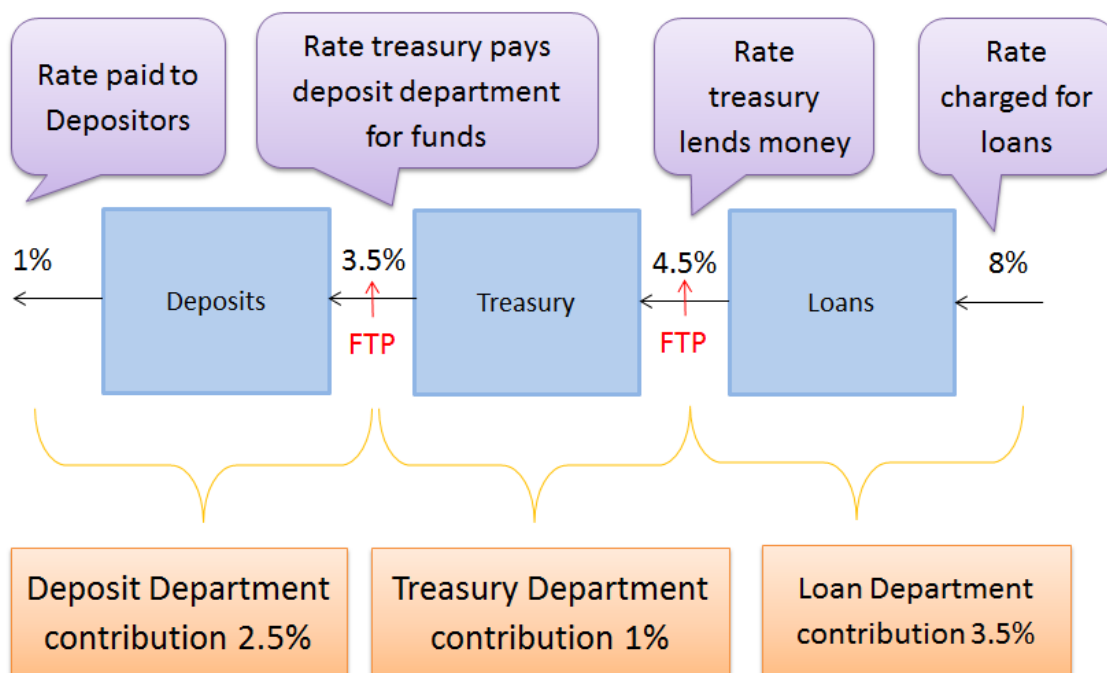
Figure 3.1.2: Multi-pooled FTP

Overall, the total contribution is still the same as before, 7%. The only difference is how it has been allocated between the departments. The treasury is awarded 1% contribution for managing the mismatch on maturity. This allows the bank to incentivise the deposit departments without penalising the loan departments and vice versa. Kawano (2000) notes the multi-pooled approach provides more flexibility

and is closer to the reality than the single-pooled approach. However, he notes it is more complicated than the single pool approach. Tumasyan (2012) states that it can still suffer from pooled averages and there can be issues with the appropriate number of pools.

3.1.3   Matched-maturity approach

An advanced form of the multi pool approach is the matched-maturity approach where the cash flows are matched for the FTP framework. Wyle and Tsaig (2011) provide a simple example of how this works in their paper. Here different rates may be used for deposits and loans and a yield curve approach based on maturity is adopted. To illustrate this, assume we have a 2 year deposit with the customer receiving 2.5% and a 5 year loan rate of 5%. The treasury department offers 3% for funds for 2 years and 4% for 5 years. Figure 3.1.3 shows the various contributions from each department.
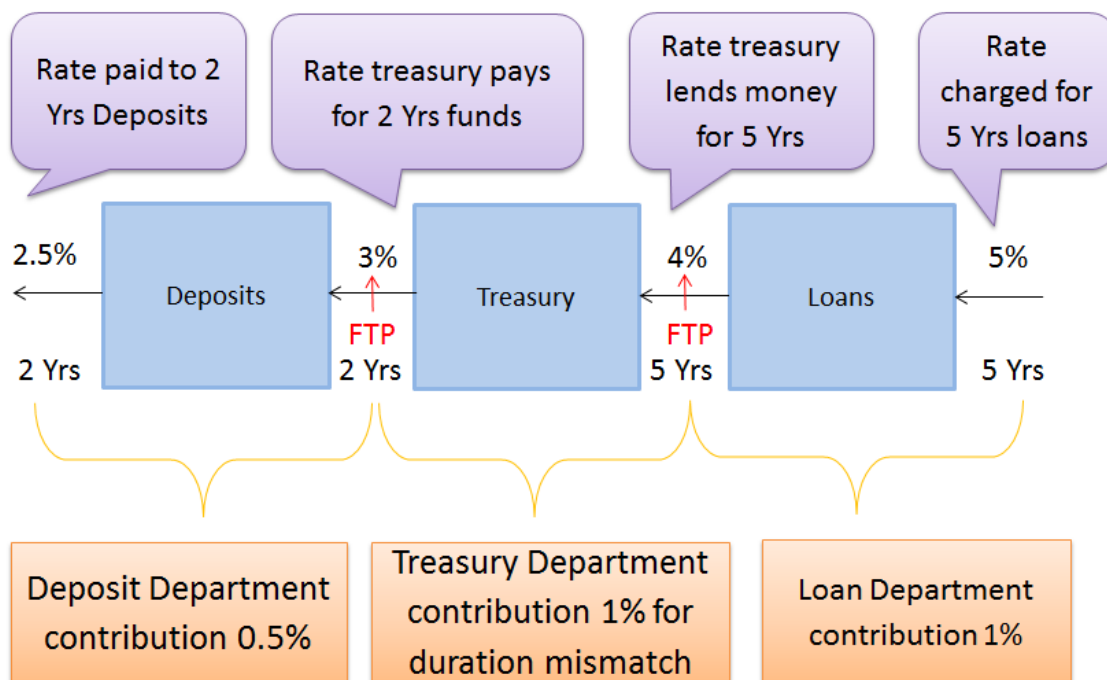
Figure 3.1.3: Matched-maturity FTP

The 1% contribution from the treasury department is for taking on interest rate risk and funding liquidity risk. Kawano (2000) highlights that this approach can separate credit and interest rate risk where the business unit is left with the credit

risk. The interest rate risk is then managed separately by a specialised department. This means that each business unit can be assessed based on what is within their control and the treasury is responsible for interest rate risk. Tumasyan (2012) notes the matched-maturity approach does not dictate what the treasury has to do and the treasury can attempt to increase profits by taking funding liquidity risk and interest rate risk. Tumasyan (2012) states the treasury can express its view and create exposure to:

- Funding liquidity risk by maturity mismatch;

- Interest rate risk by funding with fixed or variable rates; and

- Basis risk by mismatching the tenor.

The treasury will be rewarded with the profit or loss for the risks they decide to take under their control.

The FTP rates can be based on prevailing market rates or historical market rates. Wyle and Tsaig (2011) show the preferred method is to use the historic approach of using the prevailing rates at the time of origination. This is good as it allows management to assess past performance and to evaluate pricing decisions for transactions made. Tumasyan (2012) notes that this is the most adequate approach for achieving the goals of FTP framework. Choudhry (2012) notes that the downside of maturity matching is that it does not allow for maturity transformation that is performed by the bank. However, it could be argued that this is part of the risk that the treasury unit is taking so they should be rewarded with the return.

3.2 Importance of FTP

Thomas (2007) shows that an appropriate FTP is very important and states that issues with FTP are almost 8 times more significant than issues with the cost allocation data. Therefore, improving the FTP framework will likely result in better management decisions. Kawano (2000) identifies three main objectives for an FTP framework:

1. Motivate profitable decision in line with the bank's goals;

2. Allow for performance evaluation; and

3. Systems should be understandable.

Woodward (2007) notes that FTP is a useful tool for profitability and risk management. Plassmann (2015) points out that it integrates three core management activities: pricing, profit management and risk management. Wyle and Tsaig (2011) note that FTP should help measure business unit profitability, separately from interest rate risk. In addition, Dougherty (2013) notes an FTP framework should centralise the management of interest rate risk and funding liquidity risk. Cadamagnani et al. (2015) state that the treasury will take responsible for funding liquidity risk and interest rate risk and be a centralised risk management unit. Dougherty (2013) states that separating risk and business decisions allows the treasury to concentrate on interest rate risk and funding liquidity risk and the business units to concentrate on credit risk and managing the customer. Dougherty (2013) says centralisation has the following benefits:

- Reduce costs through optimised funding;

- One point of contact for the market;

- Netting assets and liabilities; and

- Improved risk and performance management through use of hedging of interest rate risk.

Levey (2008) highlights that FTP analysis:

- Makes better profitable decisions;

- Evaluates alternative funding decisions;

- Improves the strategic allocation of resources; and

- Identifies top products.

Overall, the matched-maturity approach seems to be the preferred method for meeting the objectives and goals of FTP.

3.3 What to include in FTP?

Hanselman (2009) notes there is no best practice yet for choosing a FTP curve for matched-maturity approach. Hanselman (2009) states that the following characteristics are important considerations:

- Curve(s) should represent the opportunity cost, i.e. the alternative rate the bank could lend at, or benefit from the funds, i.e. the alternative cost of borrowing funds for the bank;

- Curve(s) should represent the current wholesale money market rates that the bank can borrow or lend at;

- Curve(s) should be derived from reliable and readily available data; and

- Curve(s) should be credible and understood.

Shih et al. (2004) note banks which are deposit rich will select a marginal curve based on investment rates in the wholesale money market. While banks which are deposit poor will select a marginal curve based on borrowing in the wholesale money market. Shih et al. (2004) note that the same reference curve should be used for all business units. Using different reference curves for different business units will lead to misallocation and will hinder interest rate risk management.

It is clear that interest rates should be included in an FTP decision as this allows centralisation of interest rate risk and this can be managed by a specialised department. This allows each profit centre to be measured on a performance that they can control. Wyle and Tsaig (2011), state that there are six components that an FTP framework could be made of:

1. Commercial margin;

2. Option spread;

3. Credit spread;

4. Contingent liquidity spread;

5. Funding liquidity spread; and

6. Reference rate.

Payant (2004) states that any non-interest related items such as fixed assets should be assigned to the cost allocation basis and not to the FTP framework. In addition, he believes that capital should be considered outside the FTP framework but as part of the overall profitability measure. This seems very appropriate looking at profitability once all the costs are allocated. The appropriate departments will be left with the credit risk; the risk will be determined by senior management objectives. Thomas (2007) shows how return on capital can be calculated outside the FTP framework. Although Kipkalov (2004) argues that it can be included in the FTP framework, this seems to be adding extra complications with few additions of benefits. Therefore, commercial margin and customer credit risk faced by the bank do not need to be included in the FTP rate.

3.3.1 Cost of funds

Cadamagnani et al. (2015) note that the FTP curve reflects the bank's cost of funds. They note that the cost of funds is made up of the reference rates and additional funding premium consisting of the term liquidity premium and the bank's own specific credit risk. Wyle and Tsaig (2011) note that large banks may be able to construct their own specific cost of funds from their own observed market data. Fiedler (2011) notes that the secondary markets for the bank's debt may not be appropriate as they could be too small and hence have a different value attached to it. Fiedler (2011) also notes that only a new issue of debt would be appropriate for accurately valuing the bank's cost of debt which may not always be possible on every occasion that funds are demanded. Some banks do not raise funds from the market or do not raise funds across a wide range of durations. Therefore it might not be possible for banks to know what their specific costs of funds from the market are and an estimate needs to be made. The estimate can be split into three parts, reference rate, term liquidity premium and bank's own credit risk. The term

liquidity premium and the bank's own credit risk can be thought of as the funding spread.

3.3.1.1 Reference rate

Fiedler (2011) suggests that the reference rate should be the risk-free rate and this can be calculated from government bond yields and adjusted for credit risk by Credit Default Swaps (CDS). However, he argues that we should then add the initial cost of the seller of the first CDS to the reference rate so a risk-free rate does not really exist. Therefore Fiedler (2011) concludes that the best market rate to use is the London Interbank Offered Rate (LIBOR)/Swap curve as the LIBOR has almost no liquidity risk and the swaps almost have no credit risk. Grant (2011) notes that the LIBOR/Swap curve is constructed using the LIBOR rates up to 1 year and Swap rates beyond 1 year. Grant (2011) notes that some banks before the global financial crisis in 2007-2008 were solely using the Swap curve with no adjustment for their cost of funds implying a zero cost for funding liquidity spread. He notes that this resulted in significant maturity transformation and holding of long term illiquid assets with short term funding.

Intercontinental Exchange (2016) states that the LIBOR rate is set by the average rate that banks will lend to each other. There are sixteen banks in the UK that contribute to the creation of the LIBOR rate. It should be noted it is not the rate they are borrowing funds from the London interbank money market but the rate at which they expect to borrow funds. It is supposed to be based on a reasonable market size but Intercontinental Exchange (2016) does not define what a reasonable market size is. According to Intercontinental Exchange (2016), the company now responsible for creating the LIBOR rate, the definition of reasonable market size is left deliberately vague as it would constantly change and would require regular monitoring. They believe it could lead to confusion as this would vary between currency and maturity. Depending on how much a bank would like to borrow at a particular maturity would affect the rate at which it can borrow.

The banks provide the interbank offers for the following maturities: overnight, 1

week, 2 weeks, 1 month, 2 months, 3 months, 6 months and 12 months. These are all short term rates and therefore not appropriate to use at longer duration. The term liquidity premium would be quite low at these rates but would be expected to increase significantly at longer durations so making it difficult to simply extend these rates without explicitly allowing for the term liquidity premium.

As the banks themselves have credit risk, there is some credit risk included in the LIBOR rate. Moody's (2014) provides information on the credit rating of the banks and as at 22 May 2014 the common rating for the banks was low risk so there is potential that customers would have a better credit rating of minimal or very low risk. The implications of this are discussed in Section 3.3.1.2.

Banks are able to swap future variable rates for a fixed rate set now; this is known as a swap. Banks usually agree to swap the unknown 3 months future LIBOR at a certain term for a fixed rate set today. In a swap the parties agree a principal amount that will be used to calculate the interest payments. One side of the interest payment is made based on the unknown 3 month LIBOR rate and the other side is based on the fixed rate. Parties usually exchange the net amount i.e. the difference between the fixed rate and LIBOR rate. The initial principal amount is not exchanged.

Swaps are traded Over The Counter (OTC) so a set market rate is not available. However, banks usually quote rates from 1 year up to 30 years. The swap market is highly traded and as such is a very liquid market. There is credit risk associated with swaps as counterparties are relying on the bank to make good the resulting net payments. So swap rates reflect the credit risk of the banking sector. However, the credit risk is lower than if borrowing money from the market as it is only the net payment which is exchanged and this is a significantly smaller amount. If a margin account is required to be maintained to cover the cost of replacing the swap contract this will reduce credit risk further. Therefore swaps do not reflect the cost of funds for the bank. If the swap rate is used as a reference rate, this may include credit risk if a margin account is not required but does not allow for the term liquidity premium that should be included in the FTP rate.

Choudhry (2013) argues that banks are in the business of maturity transfor-

mation therefore the reference rate should reflect this. He suggests that the rate should be the LIBOR 1 month or 3 month rate depending on how the bank raises its funds. A term liquidity premium should be added to this but not to allow for interest rates at different maturities. This way the reference curve will reflect how the bank funds the various assets. Although theoretically the bank should apply a matched-maturity approach, Choudhry (2013) argues this is not practical. However, the bank is taking a risk by not matching its exposure perfectly. A bank is taking a decision not to match perfectly, maybe for practical reasons, and has to deal with the corresponding risk. Since the risk is with the bank, it should receive the reward. If the FTP rate is set in regard to funding, the division is receiving the benefits of the bank taking the risk which it could then pass on to the customer. Therefore, it makes more sense for the FTP to be based on maturity matching but the bank may decide to take the risk and not match.

The LIBOR/Swap seems to be an appropriate reference rate but needs adjustment to be a suitable cost of funds for the FTP framework.

3.3.1.2   Bank's own credit spread

Webber (2007) notes that corporate bonds have a higher yield than government bonds - the difference is known as the corporate bond spread. The corporate bond spread can be broken down as follows:

$$
\text{Corporate bond spread} \;=\; \underbrace{\text{Expected credit loss} + \text{Credit risk premium}}_{\text{Credit spread}} \\ + \text{Term liquidity premium.}
$$

The expected credit loss is the probability that the corporate may default and only repay a proportion of the borrowing. The credit risk premium is the premium that investors demand for having the uncertainty of whether the corporate may default. The expected credit loss and credit risk premium can be thought of as the credit spread. The term liquidity premium is the premium that investors demand

to compensate them for market liquidity risk.

It should be noted that there is different views on what exactly makes up the corporate bond spread. Amato and Remolona (2003) note that it is difficult to explain corporate bond spreads and the associated credit risk. They note the presence of the "credit spread puzzle" which is defined as the wide gap between corporate bond spreads and the expected default loss. Tsuji (2005) has looked at several economic factors to assess corporate bond spread including the business cycle. A good summary of the "credit spread puzzle" and a review of the literature can be found in Muir et al. (2007).

The corporate bond spread and the reference rate together would be an approximation to the bank's cost of borrowing from the wholesale money market. Wyle and Tsaig (2011) suggest comparing the swap curve to a published credit rating agency curve for financial institutions reflecting the target credit rating of the bank. This difference would be the corporate bond spread for financial instituions and include the term liquidity premium and an allowance for the bank's credit spread. This is basically saying that the credit rating agency curve for a financial institution should be used as the appropriate FTP rate. The credit risk included will depend on the target credit rating of the bank. It does depend on the maturity of bonds that have been issued by the financial institution; it is often difficult to find bonds above 15 years maturity which would limit its use.

However, there is some doubt as to whether the bank's own specific credit risk should be included in the FTP. Dermine (2013) argues that if you include the bank's specific credit risk, then the bank will not be able to offer competitive rates to customers with a better credit rating than the bank and hence will only attract higher risk customers. Higher credit risk customers for the bank may increase the risks for the bank (though this will depend on the interest rates charged on the loans) and may result in the bank's own credit risk needing to be raised. Hence this may result in a vicious cycle of increasing risk for banks. Therefore, he suggests that the FTP rate should be adjusted for the bank's specific risk so that the bank will be incentivised to lend to lower credit risk customers.

Choudhry (2012) also states that bank's specific credit risk should not be included. Choudhry (2014) explains that this is because credit risk is already assessed by the business units for customers so would effectively be double counting. However, this could be adddressed by the business unit assessing credit risk in relation to the bank's credit risk but this would be a significant change in practice.

If you do not include the bank's own credit risk then the bank could be lending money out cheaper than it could borrow. This would result in the bank making a loss and over time could make the bank insolvent. Alternatively, you could include the bank's own credit risk and then compare customers' credit risk to the banks so it is not getting double counted. For customers with better credit ratings than the bank the credit adjustment will be negative. However provided the bank's commercial margin is greater than the negative credit adjustment it will still be profitable and may help to reduce the bank's credit rating in the future. Also including the bank's credit risk represents the true cost of funds to the bank so it will be able to value the benefits of bringing in deposits better. In this approach, the bank will be making a conscious decision and will decide what is the appropriate risk and return for the business unit.

Plassmann (2015), Cadamagnani et al. (2015) and Pedersen (2012) all expect the bank's specific credit to be included. CEBS (2010) notes that some banks have used the reference rate plus CDS as their FTP rate. This would include an estimate of the bank's credit risk but does not account for the term liquidity premium.

Overall, there is no clear view on whether the bank's credit risk should be included.

3.3.1.3 Term liquidity premium

Grant (2011) notes that term liquidity premium of the corporate bond spread should be included in the FTP rate even if the bank's credit risk is not. There are different ways that the term liquidity premium can be measured.

Two approaches suggested by Choudhry (2011) to measure the term liquidity premium are:

- The difference between the Asset Swap Spread (ASW) and the CDS; and

- A subjective approach.

The difference between the the ASW and the CDS is also known as the CDS-Bond basis i.e: CDS-Bond Basis = CDS - ASW. Choudhry (2007) notes the asset swap spread can be thought of as the credit risk above the LIBOR/swap curve for a bond. This would effectively include liquidity term premium and the bank's own credit risk. CDS provides insurance against the risk of a company defaulting. The premium paid should reflect the credit risk. So if looking at the difference between CDS and ASW, the difference should reflect the term liquidity premium. However, Hull (2012) notes there are number of reasons why this might not be the case:

- CDS may have its own liquidity premium;

- Counterparty risk in CDS;

- CDS pay off may be based on the cheapest to deliver bond;

- CDS only pays out the difference between par and recovery rate and does not allow for accrued interest; and

- LIBOR already includes some credit risk.

The other approach, Choudhry (2011) notes is subjective based on what the bank believes it will cost to raise longer funds excluding credit risk. The approach is subjective and it does not rely on market data. This has lots of risk; if the bank does not update its views on the market regularly, it may be slow to adjust to changes in the market. It would be more transparent to have an approach based on market data.

Choudhry (2012) makes other suggestions for calculating the term liquidity premium, however, he states none of the methods are perfect and there is no clear consensus for a preferred approach.

Therefore it seems that it is very difficult to calculate the term liquidity premium. This would only be required if the bank's specific credit risk should not be included in the FTP rate.

3.3.2 Options

Hanselman (2009) states that early withdrawal costs and prepayment penalties should be included in the FTP rate e.g. the cost for allowing a customer to re-pay their mortgage early. It seems appropriate that options that are made available to customers and the associated costs to manage the interest rate risk and funding liquidity risk should be passed across to the relevant departments rather than rest with the treasury department. Bowers (2006) notes that option costs should be included where a customer's option explicitly change the nature of the cashflows. This means that the departments will think about what options to grant customers and will appreciate that there is an associated cost that will impact their profits. If this was not included, the treasury may suffer a loss from something that was not in their control and will not receive any credit for taking on this risk. Wyle and Tsaig (2011) suggest various ways on how options can be priced within the FTP framework. One approach is the lattice based approach, which takes into account the probability of going into different states. Alternatively, Monte Carlo simulation can be used to simulate different scenarios and estimate the value of the option. Both of these approaches have some benefit to valuing the cost of options from a treasury perspective.

Choudhry (2012) states the FTP rates can be calculated on the expected maturity based on behavioural analysis rather than contractual maturity. Cadamagnani et al. (2015) also note it is common for banks to base their FTP on behavioural modelling. However, Cadamagnani et al. (2015) note that the Prudential Regulation Authority (PRA) have found significant differences in behavioural assumptions amongst banks for a given product. This approach seems to be allowing for the benefits of customers' behaviours but not the associated costs. However, if we allow for customers' behaviours as part of the option cost, the associated costs will be charged and we still get the benefits of behavioural modelling.

3.3.3 Contingency liquidity risk

Pedersen (2012) defines contingency liquidity premium as the cost of holding liquid

assets to protect against a liquidity shock. He notes that these costs should be allocated to the business units that creates them via the FTP framework. He says it is effectively an insurance premium paid to the treasury for taking the risk.

BCBS (2008b) and FSA (2012) both state that liquidity costs, benefits and risk must be included in the new product approval process, performance measurement, be transparent and assigned to business units. FSA (2012) says it should be included in product pricing. BCBS (2008b) states it should be included in internal pricing. This would suggest that the FTP framework is the most suitable place to do this. CEBS (2010) goes one step further and says it should be included in the FTP framework.

Wyle and Tsaig (2011) also suggest that contingency liquidity risk should be incorporated into the FTP framework. It seems sensible to transfer liquidity risk to a central unit to manage it and take responsibility for it while at the same time removing the risk from the various business units. By charging the business units through the FTP framework, the business units will consider liquidity risk when providing options to customers. Grant (2011) highlights the risk of not taking liquidity into account in the FTP framework and how it incentivises the business units to take extra liquidity risk when there is no associated cost to the business units. Grant (2011) proposes that a better way is to examine contingency liquidity risk within each business unit and charge for it appropriately. As such it is important to include liquidity risk within the FTP framework to incentivise the business units in the correct way. Wyle and Tsaig (2011) suggest liquidity risk can be incorporated by calculating adverse situations and estimating the economic cost of holding a liquidity buffer to account for contingency liquidity risk.

It should be noted that there is some difference of opinion as Choudhry (2012) states that liquid asset holding costs should be allocated outwith the FTP framework and charged on a pro-rata basis.

3.3.4 Issues

Cadamagnani et al. (2015) state that banks often apply a management overlay to

the FTP framework. The management overlay is an adjustment to the FTP rates to incentivise business units or change behaviour in line with the bank's strategic goals. For example, by adjusting the FTP so that the bank can offer lower mortgage rates to increase their market share. However, they note this is not always transparent, making it difficult to see what the appropriate performance for the product is. Therefore if this was kept separate from the FTP rate, it would be easier to see the effect of this.

3.4   Conclusion of what to include in FTP

Ideally, the bank's cost of funds would be used in the FTP framework including contingency liquidity risk costs. Whether it needs adjustment for the bank's own specific credit risk is still out for debate and further research needs to be done. If an approximation is used to estimate the cost of funds, this should include the reference rate and term liquidity premium at least. My preference would be to include the bank's own specific credit risk in the FTP framework. This way the bank is assessing the benefits of bringing in deposits compared to the actual cost of borrowing in the wholesale money markets. This will ensure that the bank will opt for the cheapest form of funding available. If the bank's own specific credit risk is included in the FTP rate, then the loan unit will need to assess its customers' credit risk compared to the bank's own credit risk. Otherwise, the bank would be double counting credit risk in their pricing to customers and this may make their loans uncompetitive. This would be a change in approach from what is currently implemented in banks. Overall, I feel this would be beneficial rather than underpricing the benefits of bringing in deposits.

The inclusion of options in products and having a corresponding cost in the FTP framework ensures that various business units are taking the value of options into account when doing business with the customer. Including liquidity risk incentivises the various departments to take this into account when structuring products.

Once we know exactly what the FTP rate is, Cadamagnani et al. (2015) present a nice simple example of how loans and deposits can be priced. This can be seen in

Figure 3.4.1.
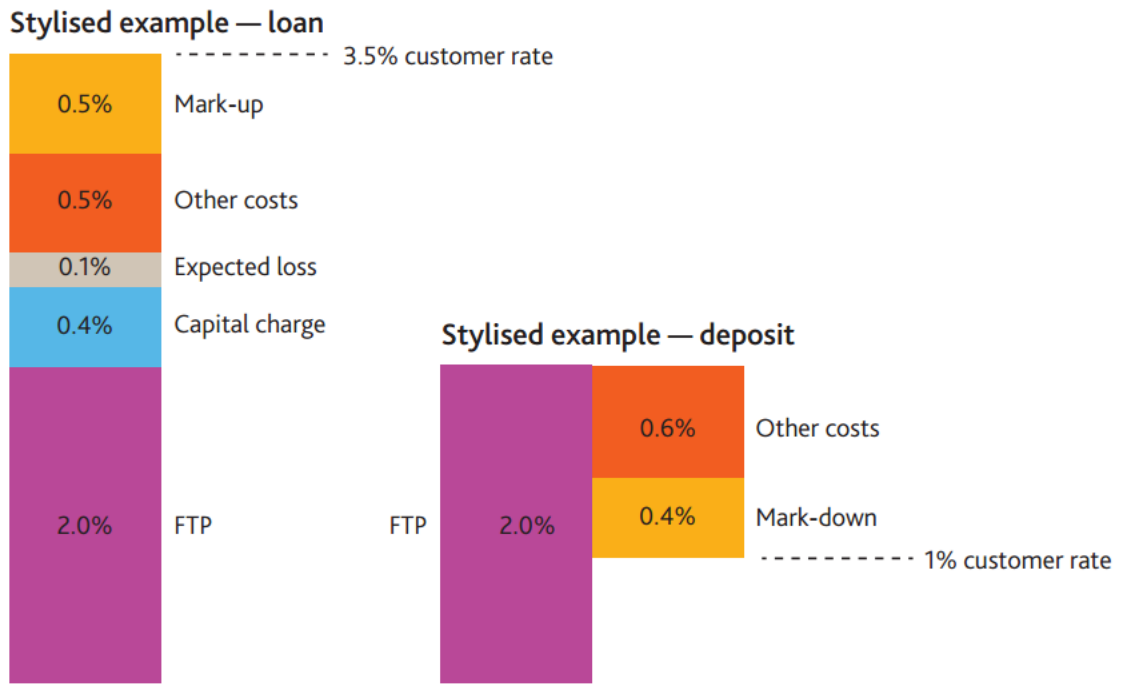
Figure 3.4.1: Stylised example of how loans and deposits can be priced (reproduced from: (Cadamagnani et al., 2015))

Chapter 4

FTP - One time period model

The bank's overall objective is to maximise profits. In this section we are going to look at how the bank can maximise their profits and if this can be achieved through a Fund Transfer Pricing (FTP) framework. Specifically, we want to use the FTP framework to allow us to:

- calculate the profits from deposit and loan units separately;

- optimise deposits and loans independently; and

- derive profits in a way consistent with group level profit optimisation.

There are many complications when assessing a bank's profits so we will look at a simplified case. If it does not work in a simplified case, it is unlikely to work in more complicated situations. The bank's profits can be calculated as follows:

$$P \quad = \quad \underbrace{Li_L + M_L W_L + A i_A}_{\text{Assets multiplied by asset return}} \quad - \quad \underbrace{Di_D - M_B W_B,}_{\text{Liabilities multiplied by rate of return}}$$

where the definition of notation can be found in Table 4.2.1, page 73. We want to assess whether we can still maximse the profits within a FTP framework where:

$$P \quad = \quad L(i_L - FTP_L) + D(FTP_D - i_D),$$

where FTP_L is the appropriate FTP rate for the loan unit and FTP_D is the appropriate FTP rate for the deposit unit.

FTP is an important framework that allows banks to allocate their profits correctly between the different business units. This allows the bank to then concentrate on the business units that are profitable and address the business units that are not.

For an FTP framework to work it must be possible to separate the various business units so that they stand alone and are not dependent on any other business unit. For example, the loan unit's profits must not depend on how much money the deposit unit takes in. Each business unit should be able to maximise their profits independently of what the other business unit is doing. If this is the case, the bank can set the FTP rate and leave the business units to maximise their profits. However, if the profits of a business unit are dependent upon profits from another business unit, then FTP might not be an appropriate framework to use.

Dermine (2013) shows that a simple FTP framework can be separated between business units. In his example he looks at the supply of deposits and demand of loans and the market rate. From this he derives the maximum profit for the bank and shows that it can achieved by looking at the loan unit and deposit unit independently. He then looks at incorporating a liquid asset holding in the FTP. With some constraints he shows that this is possible. However, some of these constraints may not be applicable in practice.

Therefore, it is worthwhile looking at the FTP framework with a liquid asset holding but with fewer constraints to see if it still holds. The model assumes one time period with limited constraints to see if a FTP rate can be derived. If it does not hold for a simple one time period model, it may not work in cases with greater time periods or with additional complications.

4.1 Data

There are a number of items of data that are needed for the model. We will discuss the data requirements in this section.

Firstly, the supply of deposits and the demand for loans at various rates of

interest are required. Lots of different factors will impact on the supply and demand curves such as marketing, competition in the market place and competitiveness of rates. Banks should have an understanding of their supply and demand curves for deposits and loans but this is not publicly available. As such, assumptions will have to be used in this model.

Additionally, the rate that the bank can borrow and lend in the wholesale money markets is an important data item. This will be different for each bank and will depend on many factors such as their credit rating, how often they access the wholesale money markets and the size of their borrowing. This information is privately available to the bank and thus assumptions will have to be used in the model.

Some other key data are the proportion of the deposits and wholesale borrowing that needs to be held as liquid assets. Regulations provide some information on what the regulators view as the minimum required liquid asset holding for deposits and wholesale borrowing. However, the banks should set these rates based on their own circumstances and what they feel is the appropriate amount of liquid assets to hold.

Finally, the return achieved on the liquid asset holding needs to be considered. This will depend on the assets that the bank decides to hold as an appropriate liquidity buffer. The regulators provide information on what they view as appropriate assets. However, these regulations still provide a lot of flexibility to the bank. Therefore, the return on liquid asset holding is only available to the banks and as such assumptions will need to be made in the model.

4.2   Model inputs

As the data described in the previous section is not available, assumptions will have to be made. Table 4.2.1 sets out the inputs for the model.

Figure 4.2.1, shows the supply and demand curves for the deposits and loans in graphical format. In Section 4.5 alternative curves will be considered.

Table 4.2.1: Model inputs

Variable Name	Variable	Value	Notes
Interest rate on loans	i_L		Rate determined from model and demand curve.
			Set between 0% and 20%.
Loan amount	L		Derived from loan demand curve. Formula is:
			$L = \frac{100(0.2 - i_L)}{0.2}$, see Figure 4.2.1.
Interest rate on deposits	i_D		Rate determined from model and supply curve.
			Set between 0% and 10%.
Deposit amount	D		Derived from deposit curve. Formula is:
			$D = \frac{100 i_D}{0.1}$, see Figure 4.2.1.
Wholesale borrowing rate	W_B	5.1%	Rate the bank can borrow from wholesale money markets.
Wholesale lending rate	W_L	4.9%	Rate the bank can achieve by lending in the wholesale money markets.
Return on liquid assets	i_A	3%	Rate of return from liquid asset holdings.
Alpha	α	5%	The proportion of deposits required to be held as liquid assets.
Beta	β	10%	The proportion of market borrowing required to be held as liquid assets.
Amount of wholesale borrowing	M_B		The amount of market borrowing set so assets equal liabilities at time 0.
Amount of wholesale lending	M_L		The amount of market lending set so assets equal liabilities at time 0.
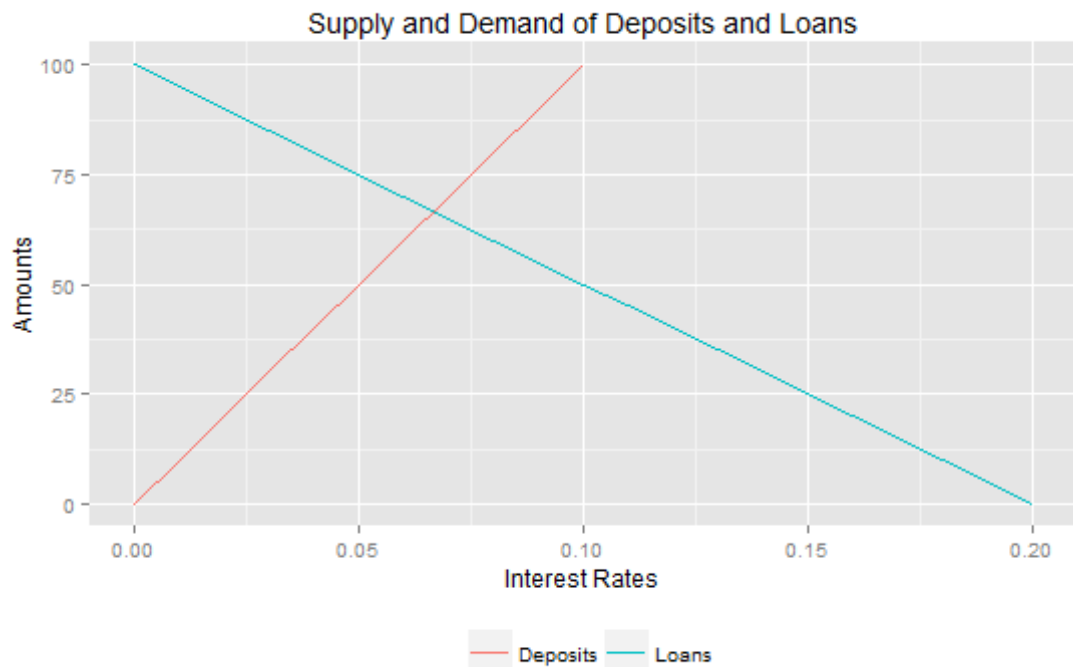
Figure 4.2.1: Supply and demand curves of deposits and loans

4.3 Methodology

In this section, we will set out the following:

- How the bank works;

- Constraints; and

- Goal of the bank.

4.3.1 How the bank works

For a bank to function it needs to raise money that it can then lend out. The bank has the option to either take in money from depositors or borrow money in the wholesale money markets. The bank can lend out the money in the form of loans to customers or in the wholesale money markets. As in most financial markets, there is a bid/ask spread, so that it costs more to borrow money than you can lend money out in the wholesale money markets. This is the cost of transacting in the wholesale money markets. Therefore it would not be beneficial to the bank to borrow from the wholesale money market and then to lend out again in the wholesale money markets. As a result, the bank will either be borrowing from or lending in the wholesale money markets but not doing both. We are only looking at the bank over one time period.

4.3.2 Constraints

The first constraint is that the banks must hold some of their assets as a liquid asset holding. The size of the liquid asset holding depends on the size of deposits and wholesale borrowing. The amount the bank must hold as liquid assets can be calculated in Equation (4.1).

$$A = \underbrace{\alpha D}_{\substack{\text{Deposits times required} \\ \text{liquidity holding for deposits}}} + \underbrace{\beta M_B,}_{\substack{\text{Wholesale borrowing times required} \\ \text{liquidity holding for wholesale borrowing}}} \tag{4.1}$$

where A is the liquid asset holding and M_B is the amount borrowed from the money markets. As mentioned in Table 4.2.1, page 73, α is the proportion of deposits that must be held as liquid assets and β is the proportion of wholesale borrowing that must be held as liquid assets.
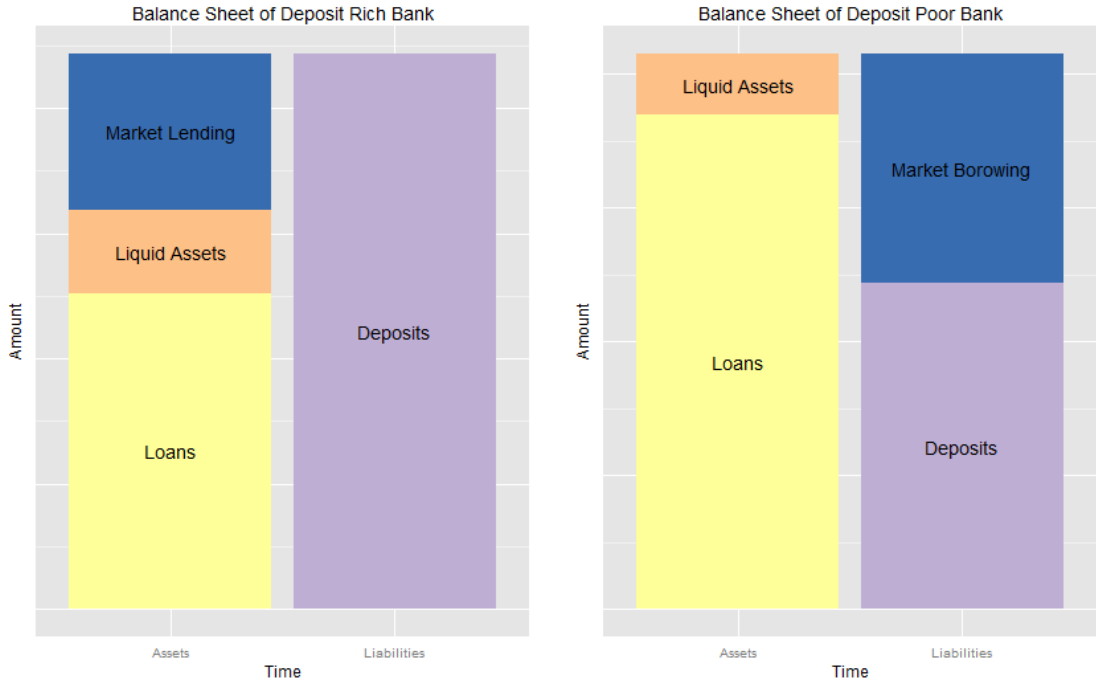
Figure 4.3.1: Simplified balance sheet of a bank

The second constraint is that the balance sheet of the bank must balance. The bank's balance sheet can look like either of two situations. In one situation, the left chart in Figure 4.3.1, the bank is lending in the wholesale money markets. As you can see the assets consist of loans, liquid assets and wholesale lending while the liabilities are just deposits. In this situation, the bank is known as deposit rich. The other situation, the right chart in Figure 4.3.1, the bank is borrowing from the wholesale money markets. In this case, the assets consist of loans and liquid assets while the liabilities are made of deposits and wholesale borrowing. In this situation, the bank is known as deposit poor. At all times the bank's balance sheet must balance i.e. assets must equal liabilities as shown in Equation (4.2).

$$L + M_L + A = D + M_B, \tag{4.2}$$

where M_L is the amount the bank has lent in the wholesale money markets and M_B is the amount borrowed from the wholesale money markets. Either M_L or M_B will be zero depending on whether the bank is deposit rich or deposit poor.

4.3.3   Goal of the bank

The goal of the bank is to maximise profit. Equation (4.3) shows how to calculate the profit we are trying to maximise.

$$P \; = \; \underbrace{Li_L + M_LW_L + Ai_A}_{\text{Assets multiplied by asset return}} \; - \; \underbrace{Di_D - M_BW_B,}_{\text{Liabilities multiplied by rate of return}} \tag{4.3}$$

where P is the Profit achieved by the bank.

4.4   Results

4.4.1   Maximise profits with no liquid asset requirements

4.4.1.1   Deposit rich situation

First, we want to look at the situation where there is no liquid assets requirement to ensure that the FTP framework can be separated between loan and deposit units. We need to consider two different situations, one when the bank is deposit rich and the other when the bank is deposit poor.

Proposition 4.4.1. *The bank's profit can be maximised by maximising $L(i_L - W_L)$ and $D(W_L - i_D)$ when the bank is deposit rich. Assuming that L and D are independent.*

Proof. From Equation (4.3), page 76, we have the following:

$$P = Li_L + M_LW_L + Ai_A - Di_D - M_BW_B.$$

As there is no liquid asset requirements, $Ai_A = 0$. For the balance sheet to balance, any lending in the wholesale markets must must equal $D - L$ and any

borrowing must equal $L - D$.

$$P = Li_L + max(D - L, 0)W_L - Di_D - max(L - D, 0)W_B.$$

As the bank is deposit rich, we know that $D > L$.

$$P = Li_L + (D - L)W_L - Di_D.$$

Rearranging gives:

$$P = Li_L - LW_L - Di_D + DW_L$$

$$P = L(i_L - W_L) + D(W_L - i_D). \tag{4.4}$$

$\square$

Proposition 4.4.1 shows that the loan and deposit units can be separated and hence be maximised independently. This allows each business unit to work independently while still maximising the overall group profit; the units are therefore not dependent on each other and each are able to achieve their maximum potential without having to take into account the actions of the other. Equation (4.4) is the same as the requirements for an FTP framework:

$$P = L(i_L - FTP_L) + D(FTP_D - i_D),$$

where $FTP_L = FTP_D = W_L$.

It also tells us that we are comparing the rate we can achieve on loans with the alternative option of lending money out in the wholesale money markets. One way of considering this is the bank having to decide whether it is better to lend money out as loans or to lend money in the wholesale money markets. The deposit unit is rewarded with the return achieved on the wholesale money markets. The deposit

unit's profit comes from the fact that they are bringing in money that could be lent out directly in the wholesale money markets. The loan unit's profits come from the difference between loans and the alternative of wholesale lending. The FTP rate would be set as W_L for both deposit and loan units. It is worth noting that the FTP rates do not depend on the supply of deposits or the demand for loans.

Table 4.4.1 shows the expected impact that changing W_L will have on the loan and deposit units.

Table 4.4.1: Sensitivities of W_L

Change W_L	Impact on loans	Impact on deposits
↑	↓	↑

Increasing W_L means the bank can lend money in the wholesale money markets at a higher rate. For the loan unit, this means that the demand for loans will reduce as the hurdle rate for loans is higher. For the deposit unit, this means that the bank can lend out the money at a higher rate and hence make a greater profit. The bank can then decide to increase the rate offered to depositors to attract more deposits. Conversely, the opposite is true. The actual impact will depend on the supply and demand curves of deposits and loans.

4.4.1.2 Deposit poor situation

We now need to consider the situation when the bank is deposit poor.

Proposition 4.4.2. *The bank's profit can be maximised by maximising $L(i_L - W_B)$ and $D(W_B - i_D)$ when the bank is deposit poor. Assuming that L and D are independent.*

Proof. From Equation (4.3), page 76, we have the following:

$$P = Li_L + M_L W_L + Ai_A - Di_D - M_B W_B.$$

As there are no liquid asset requirements, $Ai_A = 0$. For the balance sheet to balance, any lending in the wholesale markets must equal $D - L$ and any borrowing

must equal $L - D$.

$$P = Li_L + max(D - L, 0)W_L - Di_D - max(L - D, 0)W_B.$$

As the bank is deposit poor, we know that $L > D$.

$$P = Li_L - Di_D - (L - D)W_B.$$

Rearranging gives:

$$P = Li_L - LW_B - Di_D + DW_B$$

$$P = L(i_L - W_B) + D(W_B - i_D). \tag{4.5}$$

$\square$

Proposition 4.4.2 show us that loans and deposits can be separated and hence maximised independently when the bank is deposit poor. This allows each business unit to work independently while still maximising the overall group profit; the units are therefore not dependent on each other and each are able to achieve their maximum potential without having to take into account the actions of the other. Equation (4.5) is the same as the requirements for an FTP framework:

$$P = L(i_L - FTP_L) + D(FTP_D - i_D),$$

where $FTP_L = FTP_D = W_B$.

It is also tells us that we are comparing the rate we can achieve on loans with the cost of borrowing from the wholesale money markets. One way of considering this, is to determine whether it will benefit the bank to borrow money from the wholesale money market to lend out as loans. The deposits are compared to the cost of borrowing money from the wholesale money markets. From the bank's perspective,

it has to decide whether it should take in deposits or borrow from the wholesale money markets. For a deposit poor bank, the FTP rate would be set as W_B for both loans and deposits.

Table 4.4.2 shows the expected impact that changing W_B will have on the loan and deposit units.

Table 4.4.2: Sensitivities of W_B

Change W_B	Impact on loans	Impact on deposits
↑	↓	↑

Increasing W_B means that it is more expensive to borrow money from the wholesale money market. Therefore, the bank needs a higher return when it lends out the money which will reduce the demand for loans. If borrowing money is more expensive, the bank will want to increase deposits to take in cheaper money and hence it will increase its profits. Conversely, the opposite is true. The actual impact will depend on the supply and demand of deposits and loans.

4.4.1.3 Difference between deposit rich and deposit poor bank

So in both the deposit rich or deposit poor situation, the loan and deposit units can be separated independently. The only difference is that the FTP rate for a deposit rich bank is W_L while for a deposit poor bank the FTP rate is W_B. Ideally, the difference between the FTP rates will be small so there is not a large difference if a bank moves from deposit poor to deposit rich situation or the bank incorrectly assumes the wrong situation. This will be looked at further in a later section. As in most financial markets there is a bid/ask spread which means it costs more to borrow than to lend with all else being equal. Therefore $W_B > W_L$ because of the bid/ask spread. For a deposit rich bank, this implies that the bank will be encouraged to make more loans than a deposit poor bank as the FTP rate will be lower for the loan unit. For a deposit poor bank, this implies that the bank will be encouraged to take in more deposits than a deposit rich bank as the FTP rate will be higher for the deposit unit. This is a good outcome, as in a competitive market, this would mean deposit poor banks will have a competitive advantage to take in deposits and

hence move them closer to a deposit rich situation. While deposit rich banks will have a competitive advantage for loans and will move them closer to a deposit poor situation.

4.4.1.4 Optimal results

We can now try and find the optimal i_L and i_D that maximise the overall profit for the bank based on the assumptions in Table 4.2.1, page 73. Figure 4.4.1 shows a contour plot of the profits of the bank at various i_L and i_D values.

From the contour plot, we can see that the area around $i_L = 12.5\%$ and $i_D = 2.5\%$ contains the maximum profit. The maximum profit for the bank derived from Equation (4.3), page 76, is £3.43m. This occurs when $i_L = 12.55\%$ and $i_D = 2.55\%$. Each business unit can determine these optimal rates using the appropriate FTP rate and their supply or demand curves. The supply or demand curves do not affect the actual FTP rate except for whether the appropriate FTP rate is deposit poor or deposit rich. In this case the optimal solution is for the bank to be deposit poor based on these market conditions. In this example there is one clear area where the maximise profit can be found based on the supply of deposits and demand for loans curves used. Different curves may result in more than one area being identified. However, the supply and demand curves do not impact on the FTP rates; they only influence what the optimal deposit and lending rates are.
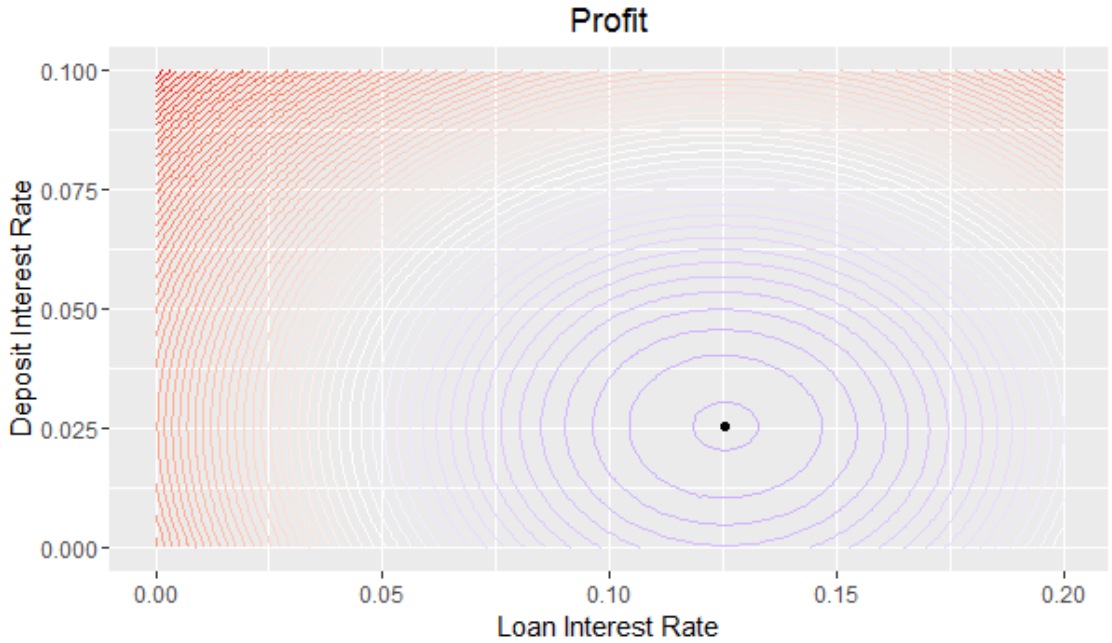
Figure 4.4.1: Contour plot of profits for a bank with no liquid asset requirements. The black dot is the maximum profit when $i_L = 12.55\%$ and $i_D = 2.55\%$. Blue area is profitable for bank, red area is loss

4.4.2 Maximise profits with liquid asset requirements

4.4.2.1 Deposit rich situation

Previously, we had assumed that no liquid assets are required i.e. $\alpha = 0$ and $\beta = 0$. However, banks are now required to hold a proportion of deposits and wholesale borrowing as liquid assets. We can now examine how including a requirement to hold liquid assets impacts on the results. First, we will need to consider whether the Equation (4.3), page 76, can still be separated between deposit and loan units or whether there is some overlap. Again, we will consider the instances of when the bank is deposit rich and deposit poor separately.

Proposition 4.4.3. *The bank's profit can be maximised by maximising $L(i_L - W_L)$ and $D((1-\alpha)W_L + \alpha i_A - i_D)$ when the bank is deposit rich and there is a requirement to hold liquid assets. Assuming that L and D are independent.*

Proof. From Equation (4.3), page 76, we know the following:

$$P = Li_L + M_L W_L + Ai_A - Di_D - M_B W_B.$$

As the bank is deposit rich and is lending to the market and not borrowing from the market then $M_B = 0$.

$$P = Li_L + M_L W_L + Ai_A - Di_D.$$

For the balance sheet to balance then $L + A + M_L = D$ if the bank is lending to the market. So $M_L = D - L - A$.

$$P = Li_L + (D - L - A)W_L + Ai_A - Di_D.$$

From Equation (4.1), page 74, we know that $A = \alpha D + \beta M_B$. But as $M_B = 0$ then $A = \alpha D$.

$$P = Li_L + (D - L - \alpha D)W_L + \alpha Di_A - Di_D.$$

Rearranging gives:

$$P = Li_L - LW_L + DW_L + \alpha DW_L + \alpha Di_A - Di_D$$

$$P = L(i_L - W_L) + D((1 - \alpha)W_L + \alpha i_A - i_D). \tag{4.6}$$

$\square$

As can be seen from Proposition 4.4.3, when we include the requirement to hold liquid assets this still allows each business unit to work independently while maximising the overall group profit. The units are therefore not dependent on each other and each are able to achieve their maximum potential without having to take into account the actions of the other. Equation (4.6) is the same as the requirements for an FTP framework:

$$P = L(i_L - FTP_L) + D(FTP_D - i_D).$$

where $FTP_L = W_L$ and $FTP_D = (1 - \alpha)W_L + \alpha i_A$.

The FTP rate for the loan unit for a deposit rich bank would be set as W_L. This is the same FTP rate derived from Proposition 4.4.1, page 76, for a deposit rich bank with no liquid asset requirements. Therefore, liquid asset holdings for a deposit rich bank does not impact on the loan unit's FTP rate. The FTP for a deposit unit in a deposit rich bank would be set as $(1 - \alpha)W_L + \alpha i_A$. This is different from the FTP rate derived from Proposition 4.4.1, page 76, which is W_L for a deposit unit with no liquid asset requirements. Therefore liquidity requirements do have an impact on the deposit unit FTP. As we expect $W_L > i_A$, then the impact of including liquid asset requirements for a deposit rich bank is that it will decrease the supply of deposits but will have no impact on the bank's loan business unit. The FTP rate for the deposit unit can be thought of as the return achieved from the proportion allowed to be lent in the wholesale money markets and the return from the proportion invested in liquid assets. The loan and deposit units can still be separated and hence maximised independently.

We should consider how the FTP rates differ for a deposit unit and loan unit when the bank is deposit rich. If $W_L \approx i_A$, then the value of α is irrelevant and the two rates will be equal. If $W_L \gg i_A$, then the larger the value of α the closer the deposit unit FTP rate will be to i_A and the difference in FTP rates between the loan and deposit unit will be $W_L - i_A$. This shows the potential for the difference in FTP rates depending on whether the business units are providing or using funds.

Table 4.4.3 shows the expected impact of changing the key variables when $i_A < W_L$.

<div align="center">

Table 4.4.3: Sensitivities of key variables when $i_A < W_L$

Change	Direction	Impact on loans	Impact on deposits
W_L	↑	↓	↑
i_A	↑	-	↑
α	↑	-	↑

</div>

An increase in W_L means the bank can lend money out in the wholesale money markets at a higher rate. This means the loan business unit's profits will be less or they will have to increase the rate they charge for loans which will reduce the

amount of loans. While the deposits unit can make greater profits and therefore can increase the amount of deposits it takes in. If α or i_A change, this has no impact on the loan business unit but does impact on the deposit business unit. Increasing i_A means the bank is getting a higher return from its liquid asset holding so can take in more deposits as the proportion set aside in liquid assets is getting a higher return. Increasing α means that more of the deposits will have to be set aside as liquid assets and will not be able to be lent out. As we expect $W_L > i_A$, this reduces the profit for the deposit unit and therefore the deposit unit may reduce the amount of deposits. Conversely, the opposite is true for W_L, i_A and α. The actual impact will depend on the supply and demand curves of deposits and loans.

4.4.2.2 Deposit poor situation

Now we need to look at the impact on the FTP rate for when the bank is deposit poor and there is a liquid asset holding requirement.

Proposition 4.4.4. *The bank's profit can be maximised by maximising $L\left(i_L - \left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}\right)\right)$ and $D\left((1-\alpha)\left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}\right) + \alpha i_A - i_D\right)$ when the bank is deposit poor and there is a requirement to hold liquid assets. Assuming that L and D are independent.*

Proof. From Equation (4.3), page 76, we know:

$$P = Li_L + M_L W_L + Ai_A - Di_D - M_B W_B.$$

As the bank is deposit poor and is borrowing from the wholesale money market and not lending to the wholesale money markets then $M_L = 0$.

$$P = Li_L + Ai_A - Di_D - M_B W_B.$$

For the balance sheet to balance then $L + B = D + M_B$ if the bank is borrowing from the wholesale money market. So $M_B = L + A - D$. From Equation (4.1), page 74, we know that $A = \alpha D + \beta M_B$. So putting these two formulas together we get the following:

$$M_B = L + \alpha D + \beta M_B - D$$

$$M_B(1 - \beta) = L + \alpha D - D$$

$$M_B = \frac{L + \alpha D - D}{1 - \beta}.$$

If we the combine this with the initial equation to get:

$$P = Li_L + \left(\alpha D + \beta \left(\frac{L + \alpha D - D}{1 - \beta} \right) \right) i_A - Di_D - \left(\frac{L + \alpha D - D}{1 - \beta} \right) W_B.$$

Rearranging gives the following:

$$
\begin{aligned}
P &= Li_L + \beta \left(\frac{L}{1 - \beta} \right) i_A - \frac{L}{1 - \beta} W_B \\
&+ \left(\alpha D - \beta \left(\frac{(1 - \alpha)D}{1 - \beta} \right) \right) i_A - Di + \left(\frac{(1 - \alpha)D}{1 - \beta} \right) W_B
\end{aligned}
$$

$$
\begin{aligned}
P &= L \left(i_L - \frac{W_B}{1 - \beta} + \frac{\beta i_A}{1 - \beta} \right) \\
&+ D \left((1 - \alpha) \left(\frac{W_B}{1 - \beta} - \frac{\beta i_A}{1 - \beta} \right) + \alpha i_A - i_D \right). \tag{4.7}
\end{aligned}
$$

$\square$

From Proposition 4.4.4, including the requirement to hold liquid assets still allows each business unit to work independently while maximising the overall group profit. The units are therefore not dependent on each other and each unit is able to achieve their maximum potential without having to take into account the actions of the other. In Equation (4.7) we can see this is the same as the requirements for an FTP framework:

$$P = L(i_L - FTP_L) + D(FTP_D - i_D),$$

where $FTP_L = \frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}$ and $FTP_D = (1-\alpha)\left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}\right) + \alpha i_A$.

The FTP rate for a loan unit is $\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}$ for a bank which is deposit poor. What this means is that when the bank wants to lend out money in the form of loans it needs to borrow from the wholesale money market. However a proportion of the money borrowed needs to be set aside as liquid assets, so the bank needs to borrow enough to cover the loans and the extra liquid asset requirements. The proportion set aside for liquid asset requirements will achieve the liquid asset return. So if a bank wants to make a profit on the loans the rate has to be higher than the wholesale borrowing rate plus the additional wholesale borrowing required to fund the liquid assets less the liquid asset return.

For deposits, the FTP rate is $(1-\alpha)\left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}\right) + \alpha i_A$. This can be viewed as any new deposits reduces the need for wholesale borrowing and the associated costs, i.e. additional borrowing cost to finance liquid assets requirements offset by return on liquid assets. Some of the deposits will need to be held as liquid assets so the whole amount can not be used to offset wholesale borrowing.

We should consider how the FTP rates differ for a deposit unit and loan unit when the bank is deposit poor. If $i_A \approx W_B$ then the value of alpha is largely irrelevant and the two FTP rates will be roughly the same for the loan and deposit unit. If $i_A \ll W_B$ then a larger value of α will make the FTP rate for the deposit unit closer to liquid asset return i_A and the difference between the FTP will increase up to $\frac{W_B - i_A}{1-\beta}$. The maximum difference of $\frac{W_B - i_A}{1-\beta}$ occurs when $\alpha = 100\%$. This shows the potential for the difference in FTP rates depending on whether the business units are providing or using funds.

Table 4.4.4 shows the expected impact of changing the key variables.

Increasing W_B means it costs more to borrow money from the wholesale money markets. Therefore the loan business unit's profits will decrease or they will have to reduce the amount of loans. It will become valuable to take in deposits so the

Table 4.4.4: Sensitivities of key variables

Change	Direction	Impact on loans	Impact on deposits
W_B	↑	↓	↑
i_A	↑	↑	?
α	↑	-	↑
β	↑	↓	↑

deposit business unit's profits will increase and they may take in more deposits. Increasing i_A means the bank is getting a higher return on its liquid asset holding. When the bank borrows money from the market to fund the loans, it has to set aside a proportion for liquid assets. As the liquid asset return is higher the bank's cost of borrowing funds is slightly less. As a result the loan business unit will make slightly more profits or increase the amount of loans. With the deposit unit it is harder to predict the impact. Increasing the liquid asset return decreases the overall costs of borrowing money from the wholesale money markets which decreases profits for the deposit unit. However, a proportion of deposits have to be held as liquid assets and if the return on this increases this will increase the profits for the deposit business unit. Overall, it is not possible to say what will happen to the profits of the deposit business unit without considering α and β. The values of α and β will dictate whether an increase in the liquid asset return will increase or decrease profits in the deposit unit. Generally, a higher value of α and lower value of β will make it more likely that an increase in the liquid asset return will result in an increase in profits for the deposit unit. Increasing α means the proportion that has to be set aside as liquid assets increases. This does not impact on the loan unit business but does impact on the deposit business unit. Setting more deposits aside as liquid assets reduces the profits of the deposit unit so the deposit unit may need to decrease the amount of deposits. If $i_A \approx W_B$ then changing α will not have much impact on the profits of the deposit business unit. β is the proportion of the wholesale money market borrowing that has to be set aside as liquid assets. Increasing β means more of the wholesale money market borrowing needs to be set aside which will increase the overall cost of borrowing from the wholesale money markets. Therefore this will decrease the profits of the loans business and may decrease the amount of

loans. The deposit unit's profits will increase and they may increase the amount of deposits. Conversely, the opposite is true for W_B, i_A, α and β. The actual amounts will depend on the supply and demand curves of deposits and loans.

4.4.2.3 Difference between a deposit rich and deposit poor bank

Ideally we would like the difference between a deposit rich and deposit poor situation to be relatively small so it does not have a large impact on a bank if it decides to move, for example, from a deposit rich to a deposit poor situation or incorrectly assumes the wrong situation. However, we do not want to steer a bank in the direction of having excessive wholesale borrowing.

When we compare FTP rates from a bank that is deposit rich with a bank that is deposit poor, the main difference we need to compare is the cost of borrowing from the wholesale money market including liquid cost of borrowing with the price of lending in the market. From Proposition 4.4.5 we can see the cost of borrowing will be higher than the cost of lending. Therefore if a bank is deposit rich, it will be encouraged to create more loans and be discouraged from creating more deposits as the FTP rate will be lower compared to a deposit poor bank. If the bank is deposit poor, the bank will be encouraged to create more deposits and be discouraged from creating more loans as the FTP rate will be higher. This is the ideal situation as we limit banks in the expansion of their balance sheet to excessive levels.

Proposition 4.4.5. *If $W_B > W_L$ and $W_L > i_A$ then $\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta} > W_L$.*

Proof.
$$\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta} > \frac{W_B}{1-\beta} - \frac{\beta W_L}{1-\beta} > \frac{W_L}{1-\beta} - \frac{\beta W_L}{1-\beta} = W_L.$$

$\square$

However, if $i_A > W_B$ it could be possible that $W_L > \frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}$. This would mean if a bank is deposit rich they would be encouraged to take on more deposits and less loans as the FTP rate will be higher. While a deposit poor bank will be encouraged to take on more loans and less deposits as the FTP rate will be lower. This is counter intuitive and hence not what you would like from a FTP framework.

However, it is unlikely that $i_A > W_B$. i_A is the return on liquid assets and are highly liquid. It is quite implausible to expect more liquidity and a higher return, therefore would expected that $W_B > i_A$.

4.4.2.4 Optimal results

Now let us look at the results of the case for when liquid assets are required. Using the assumptions specified in Table 4.2.1, page 73. We can calculate the maximum profit for the bank. Figure 4.4.2 shows the contour plot for the maximum profit for different values of i_L and i_D.

From the contour plot we can see that the area around i_L =12.5% and i_D =2.5% contains the maximum profit. The maximum profit for the bank derived from Equation (4.3), page 76, is £3.37m. This occurs when i_L =12.67% and i_D =2.61%. The optimal solution is when the bank is deposit poor. Based on these supply of deposits and demand of loans curves, there is one clear area where the maximise profit can be found. Different curves may result in more than one area being identified. Compared to the case with no liquid assets in Figure 4.4.1, page 82, both cases suggest the bank should be deposit poor. We can see that the optimal loan rate is slightly higher for the case with liquid asset requirements. This is because the FTP rate in this case is higher as we need to take into account the cost of the liquid assets for when we borrow money from the wholesale money markets. The optimal deposit rate is slightly higher than the no liquid assets case. This is because the FTP rate in the deposit poor case is higher as the higher cost of borrowing from wholesale money market is not offset from the cost of holding the liquid assets.
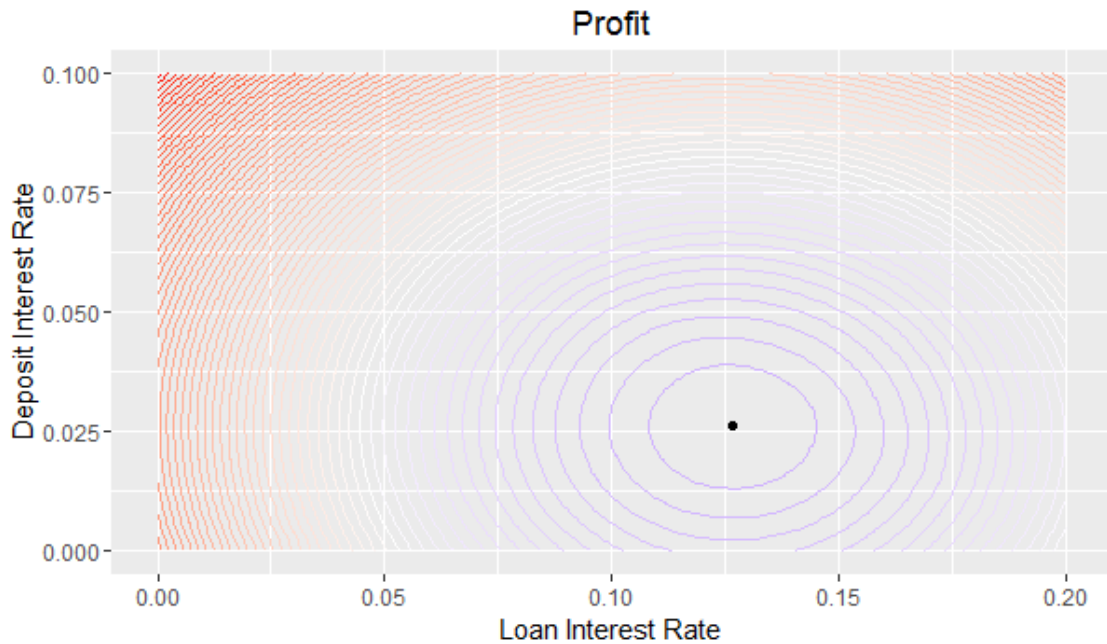
Figure 4.4.2: Contour plot of profits for a bank with liquid asset requirements. The black dot is the maximum profit when i_L =12.67% and i_D =2.61%. Blue area is profitable for bank, red area is loss

4.4.3 Implications

4.4.3.1 No borrowing or lending in the market

There are 3 types of results we can have:

1. Optimal solution is in the deposit rich area;

2. Optimal solution is in the deposit poor area; or

3. Bank is neither borrowing nor lending.

Figure 4.4.3 shows an example when the optimal solution is in the deposit rich situation. The black line indicates the cross over between a deposit rich and deposit poor bank. The red line is the optimal rate for loans based on the loan demand curve and the blue line is the optimal rate for deposits based on the deposit supply curve. Where these lines cross is the optimal rate for deposits and loans. The optimal lines are not perfectly straight as the FTP rate changes depending on whether the bank is in a deposit rich or deposit poor state. However, the optimal lines are straight when they are in the deposit rich or in the deposit poor situation. One of the black dots on the graph shows the optimal rate derived from the FTP rate when in a
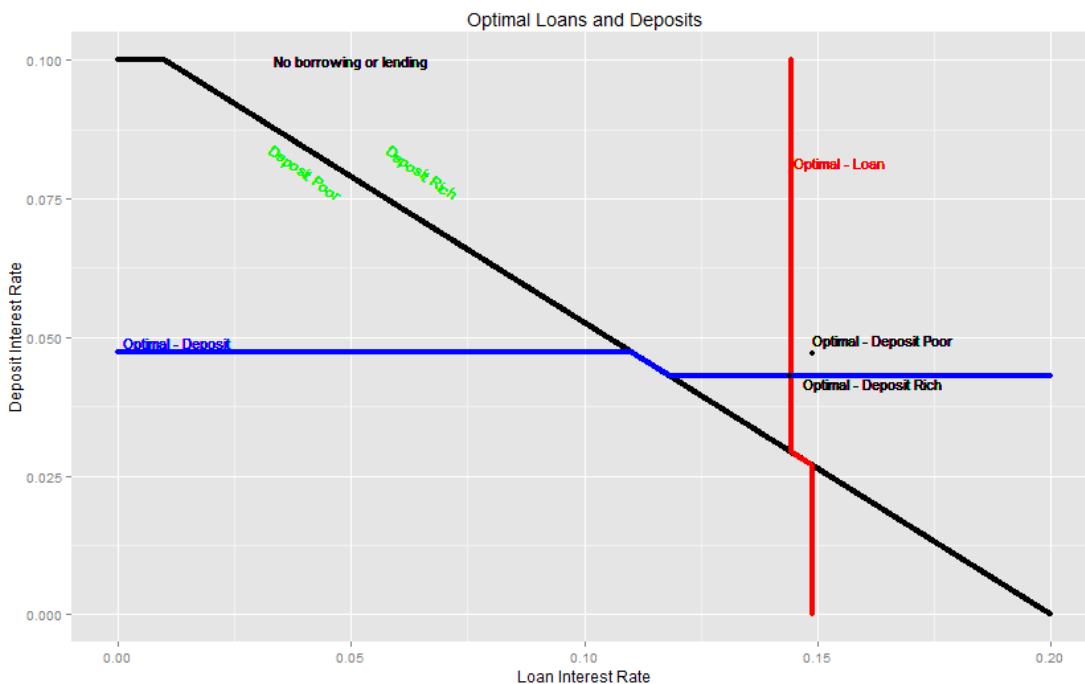
Figure 4.4.3: Optimal deposit rich situation. The black line indicates the crossover between the deposit rich and deposit poor environment. The red line is the optimal loan rate. The blue line is the optimal deposit rate. The black dots indicate the optimal rate when either deposit rich or deposit poor

deposit rich situation. The other black dot shows the optimal rate derived from the FTP rate in a deposit poor situation. When we are in a deposit rich case we would expect the optimal lines to meet at the optimal rate derived from the FTP rate for a deposit rich bank. Likewise, if in a deposit poor situation the optimal lines should meet at the point in the deposit poor area. This can be seen in Figure 4.4.4.

This works fine if we are clearly in a deposit rich or deposit poor situation. However it is more complicated when we are neither borrowing nor lending. In this situation it is not clear which FTP rate to use and it can be seen that neither of the FTP rates are optimal. In this case the FTP framework would not be appropriate. Figure 4.4.5 shows that the optimal lines do not cross over at one of the black dots. This means the optimal rates derived from the FTP is not optimal overall for the bank. This happens because the amount of loans and deposits are linked in this situation i.e. amount of loans equals amount of deposits. Therefore in this situation loans and deposits are dependent on each other and hence the optimal rate can not be calculated independently from the FTP. This dependence can be shown in Proposition 4.4.6.
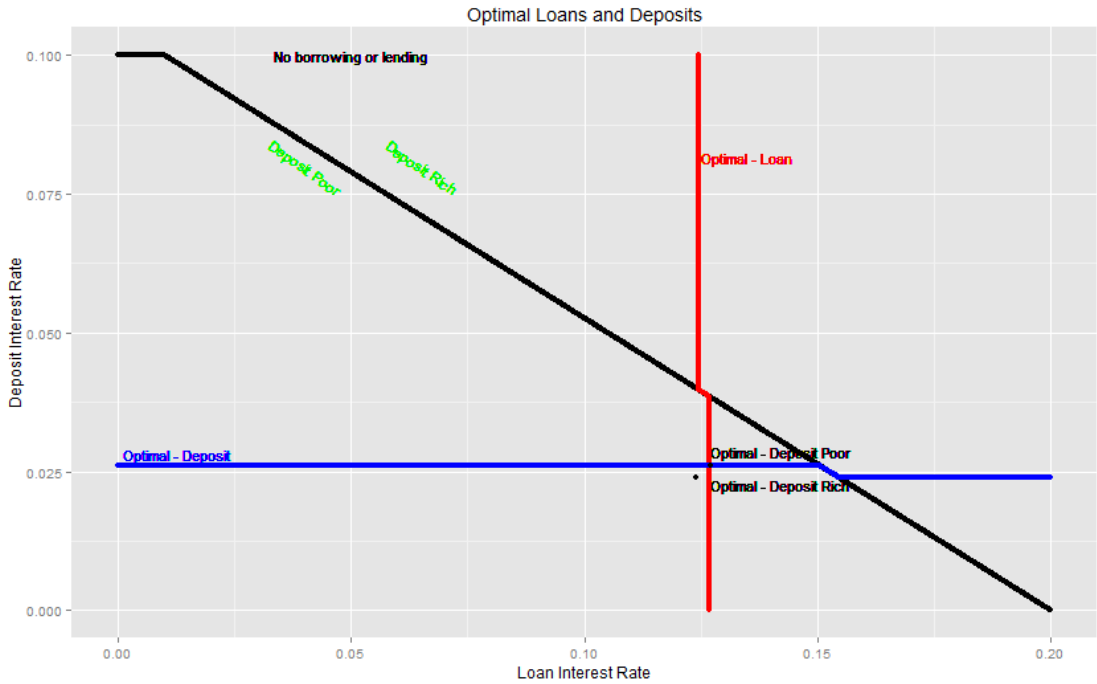
Figure 4.4.4: Optimal deposit poor situation. The black line indicates the crossover between the deposit rich and deposit poor environment. The red line is the optimal loan rate. The blue line is the optimal deposit rate. The black dots indicate the optimal rate when either deposit rich or deposit poor
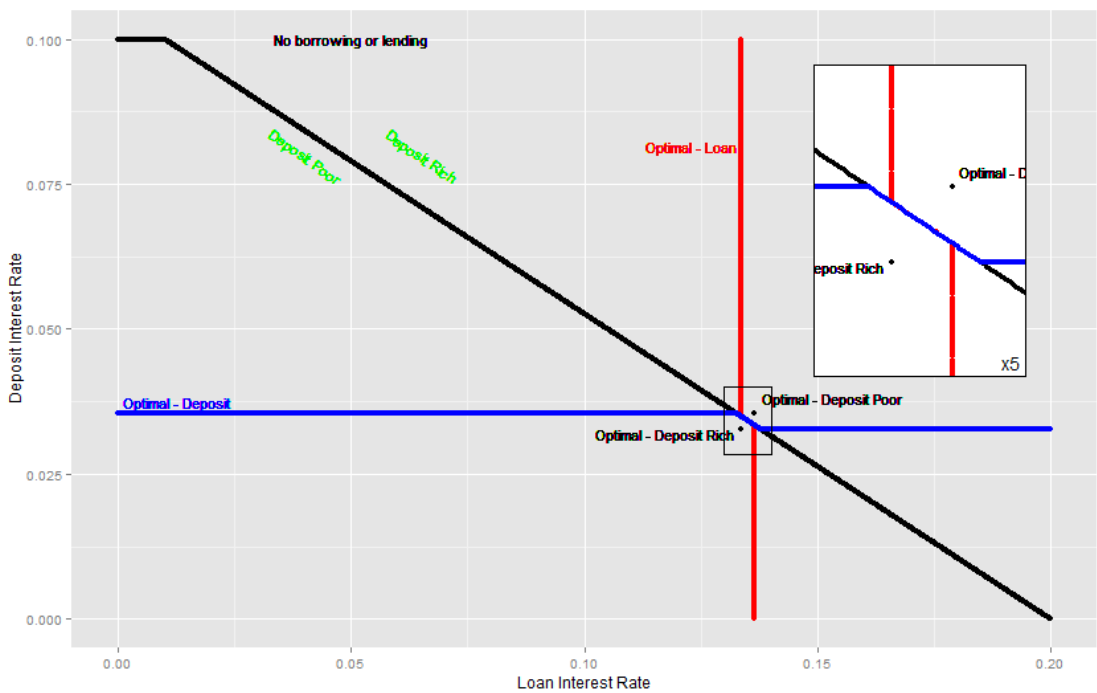
Figure 4.4.5: No appropriate FTP rate. The black line indicates the crossover between the deposit rich and deposit poor environment. The red line is the optimal loan rate. The blue line is the optimal deposit rate. The black dots indicate the optimal rate when either deposit rich or deposit poor

Proposition 4.4.6. *The profit is maximised when $Li_L - Di_D$ is maximised. As L must equal D in this case and D depends on i_D while L depends on i_L. This means they are not independent.*

Proof. From Equation (4.3), page 76, we know:

$$P = Li_L + M_L W_L + Ai_A - Di_D - M_B W_B.$$

If we take the simple case where we assume no requirements for liquid assets, then $A = 0$. Since no borrowing or lending then $M_B = 0$ and $M_L = 0$.

$$P = Li_L - Di_D.$$

This can not be split into two independent cases as L and D must be equal. □

It is very unlikely the bank will be in the situation of neither borrowing nor lending in the wholesale money market. As such this is an issue the bank should be aware of but should not stop it using an FTP framework. If for some very unlikely reason that the bank ends up in this situation, it would not be optimal to use a FTP framework. However, in the next section we will see that still using a FTP framework would mean that the results may still be close to the optimal.

4.4.3.2 Consequences of assuming deposit rich when deposit poor and vice versa

We need to consider the consequences and impact if we happen to set the FTP rate as a deposit rich situation when we should set it as a deposit poor situation; that is, we find that the optimal strategy lies in the deposit poor region. We can examine this by looking at the impact of the deposit business unit. Since loans and deposits are independent from each other, we can fix the loan rate and see the impact on the profit from selecting deposit rich or deposit poor FTP rates. Figure 4.4.6 shows the profit curve for the bank when we fix the loan rate.

In this case, the optimal solution is in the deposit poor area. The blue line shows the optimal deposit rate when set using deposit rich FTP rates. The red line
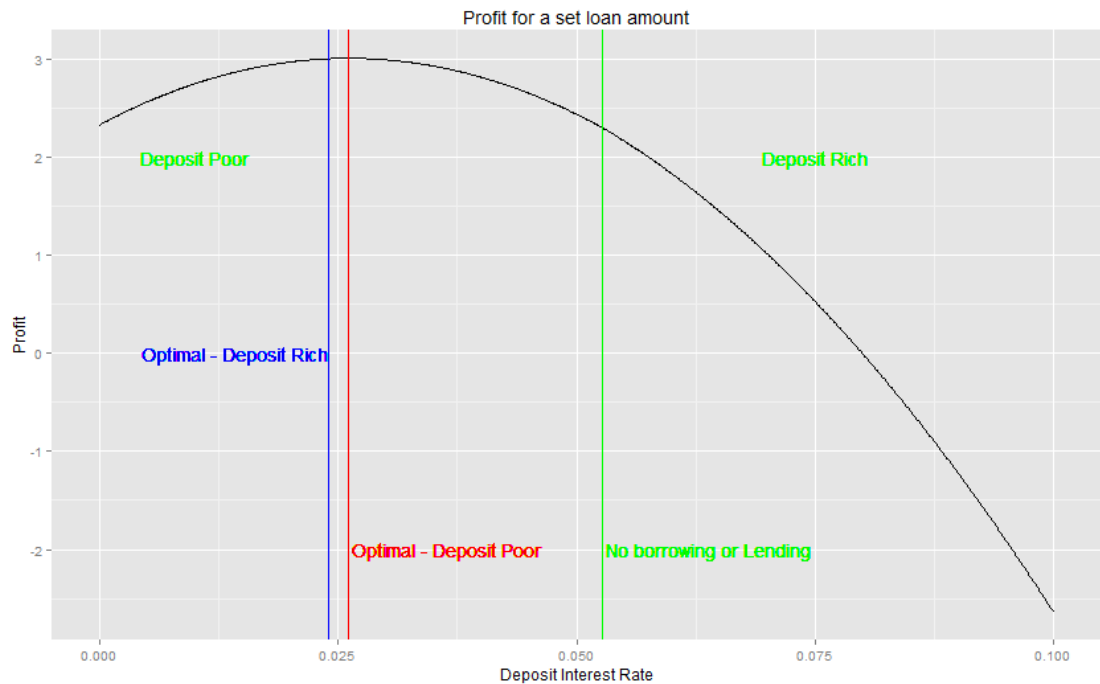
Figure 4.4.6: Profit curve when loan amount is set. Optimal point clearly in deposit poor area

shows the optimal deposit rate when set using the deposit poor FTP rates. We can see that the deposit poor optimal rate meets the profit curve at the maximum point while the deposit rich optimal rate is slightly to the left of this and the profit would be slightly less. However, they are relatively close and using the deposit rich optimal rate when we should be using the deposit poor optimal rate will only have minimum impact on the profits in this example i.e. the difference in optimal deposit interest rate is only 0.2%. If the bank had proposed a restriction that it must never be deposit poor then in this situation the profit would be achieved at the green line where the bank is neither borrowing or lending. This is far from optimal and would mean that using an FTP framework would not be appropriate as loan and deposit units are not independent due to the restriction.

If the optimal point is when the bank should have no borrowing or lending, then neither the FTP rate derived from the deposit rich or deposit poor situation will be optimal. In Figure 4.4.7 we can see that the optimal point is at the point where there is no borrowing nor lending in the wholesale money markets. However, the FTP rates derived from deposit rich and deposit poor are not far away so the impact on the overall profit will be small if one of these rates is used. The situation when

95
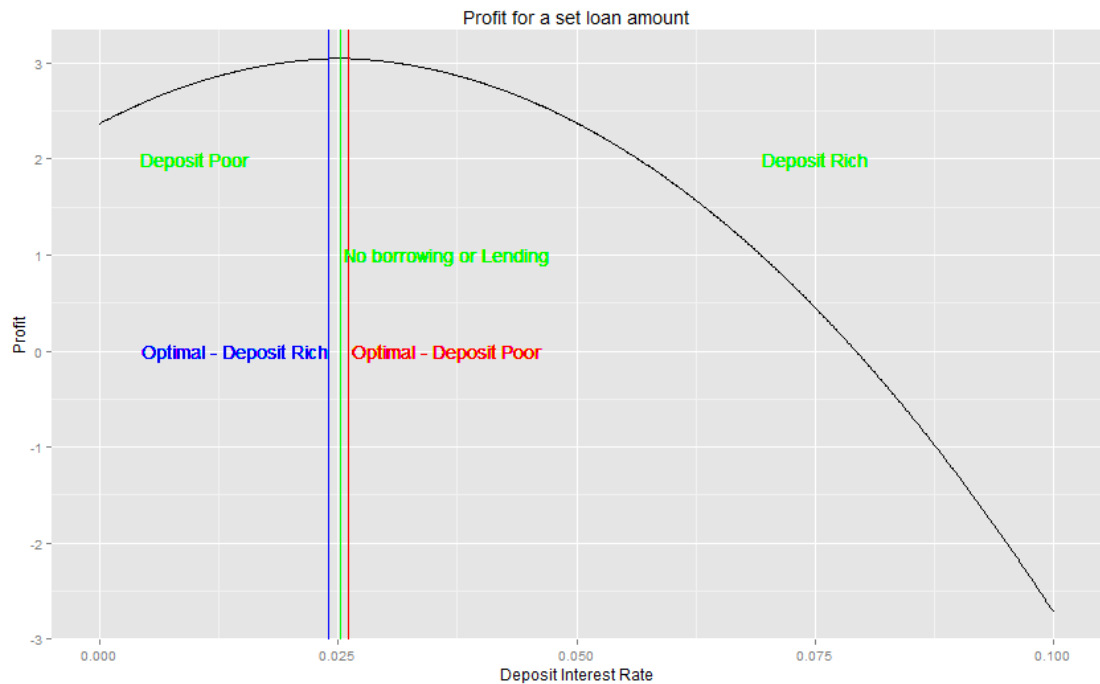
Figure 4.4.7: Profit curve when loan amount is set. Optimal point is when the bank is not borrowing or lending

the bank is not borrowing nor lending is very rare and ideally the bank would not use an FTP framework in this situation. However, we can see in this case if the bank did decide to use an FTP framework derived from deposit rich or deposit poor the impact would be small.

In the examples we have looked at so far the FTP rates for deposit poor and deposit rich banks have been very similar. We need to consider what would lead to a significant difference in the FTP rates derived from a deposit rich or deposit poor situation. The main item that affects the difference in the FTP rates is the bid/ask spread in the wholesale money markets. Currently, the examples have been shown with a bid/ask spread of 0.2%. Generally, you would expect the bid/ask spread to be very small and to be close to 0%. However, it is possible for the bid/ask spread to increase especially during stress market conditions. To highlight the impact of the bid/ask spread, in Figure 4.4.8 we have increased the spread to 4% for illustration purposes. Although 4% is very much outwith the normal parameters, by using this value it is easier to see the nature of the impact the bid/ask spread has on the FTP rates. Firstly we can see that there is a large difference between the FTP rates derived from the deposit rich and the deposit poor situations. The impact this will
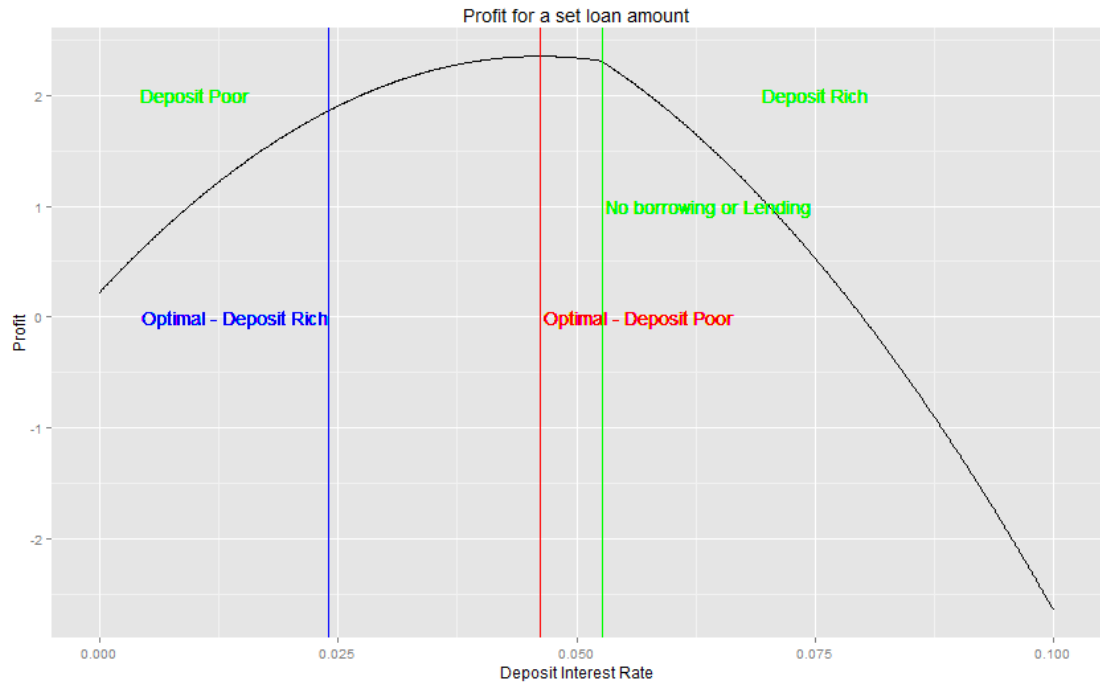
Figure 4.4.8: Profit curve when loan amount is set, bid/ask spread on wholesale borrowing and lending has been increased

have will depend on the supply of deposits curve but we can see that it could lead to a significant impact on the profit. In this situation, we are in the deposit poor environment as it can be seen that the deposit poor FTP is at the maximum profit. The FTP rate derived from a deposit rich bank would result in a lower profit. Also we can see that we have a smooth sloping curve when we are in the deposit poor situation and then there is a change in shape in the curve at the point where the bank is neither borrowing or lending. This is present in Figure 4.4.6 and Figure 4.4.7. However, it can not be seen clearly as the bid/ask spread is so small. As the bid/ask spread increases the difference in the curve at the no borrowing or lending point will become noticeable. As we have seen, an increase in the bid/ask spread between wholesale borrowing and lending will lead to an increase in the difference between FTP rates derived from deposit rich and those from deposit poor situations.

The difference in FTP rates between a deposit poor and deposit rich bank is not simply the bid/ask spread. Although, the bid/ask spread is a key driver for the difference in FTP rates, we need to consider how this interacts with the other variables. From Proposition 4.4.5, page 89, we can look at the effect an increase in the bid/ask spread will have on the FTP rates between a deposit rich and a deposit

poor bank. First, we will look at the case when the liquid asset return is 0% as this will make it easier to understand. The difference between the FTP rates for the loan business unit will be:

$$\text{Difference in the FTP rates for loan unit} = \frac{W_B}{1-\beta} - W_L.$$

Since the bid/ask spread is generally small between W_L and W_B, there will generally be little difference in the the FTP rates for loan business unit. We can see for the loan unit that increasing the bid/ask spread will increase the FTP rates by a greater proportion. The actual amount will depend on the value of β. However, as we would want to borrow from the wholesale money markets to lend out in the form of loans and not to invest in liquid assets, we would expect β to be closer to 0% than 100%. This would then limit the impact of the proportional effect on the change in FTP rates.

For the deposit unit, the impact is smaller as the difference is multiplied by $(1-\alpha)$. Therefore the difference between the FTP rates for the deposit business unit will be:

$$\text{Difference in the FTP rates for deposit unit} = \left(\frac{W_B}{1-\beta} - W_L \right)(1-\alpha).$$

The reason we need to multiple by $(1-\alpha)$ is that this is the amount available for the investment while $\alpha\%$ has to be held as liquid assets. Therefore the difference in the FTP rates for deposits units will depend on α and β as well as the bid/ask spread. The larger the value of α the less effect the bid/ask spread will have on the FTP rates. In an extreme case of $\alpha = 100\%$ then the deposit rich and deposit poor FTP rates would be equal the liquid asset return. As we expect the bid/ask spread to be small, we would expect little difference between the FTP rates for a deposit rich and a deposit poor bank.

If we now consider the impact of what happens when liquid asset return is not 0%. By including a positive liquid asset return this reduces the effect of the bid/ask

spread than previously. The difference between the FTP rates from a deposit rich and a deposit poor bank for the loan business unit will be:

$$\text{Difference in the FTP rates for loan unit} = \frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta} - W_L.$$

If $i_A = W_B$ then the difference in the FTP rates would purely be equal to the bid/ask spread on borrowing and lending from the wholesale money market. Increasing the liquid asset return from 0% upward towards W_B will decrease the difference between the FTP rates until the difference is just the bid/ask spread irrelevant of the value of β . The maximum difference in the FTP rates will depend on the value of β and will be at the point when the liquid asset return is zero. A higher liquid asset return, i_A, will reduce the difference between the FTP rates between the deposit rich and the deposit poor banks. While a higher β will increase the difference between the FTP rates.

Overall, we would expect the FTP rates to be similar. However, there are situations that could arise that could make the difference in the FTP rates significant. Banks will have to be particularly careful when the bid/ask spread on borrowing and lending in the wholesale money market is large, when β is large or when there is low return on liquid asset, i_A, to ensure that the appropriate FTP rates are used. Imposing a restriction that the bank should not be deposit poor when the optimal solution is deposit poor could significantly lead to incorrect results and is not appropriate for a FTP framework.

4.5 Supply of deposits and demand for loans

So far we have considered only linear supply and demand curves of deposits and loans. Although from the results, we do not expect the supply of deposits and demand for loans curves to impact on the FTP rates but they do determine the optimal deposit and lending rates and whether the bank is deposit rich or deposit poor. It ultimately drives the profitability of the bank. Therefore we need to consider if the FTP framework is still suitable for different shapes of supply and

demand curves.

Provided that we are in a deposit rich or a deposit poor situation, then we know that we can separate the profit into the two business units, loan and deposit units. If there is a maximum profit from the loan unit and a maximum profit from the deposit unit, there will be a maximum overall profit.

So far the analysis, has been done using a simple supply of deposits and demand for loans. This is to highlight how the FTP framework interacts and the consequences of changing the inputs. We can also change the supply and demand of deposits and loans curves to see what impact this has on the profits. However, it will not impact on the FTP rates. We can think of what might be a stereotypical graph of supply of deposits and demand for loans. Supply of deposits may still be positive even at zero and will increase very slightly for small increases above this. However, over a certain point supply of deposits will increase rapidly as the rate becomes the best in the market place. At some point, the increase in supply of deposits will increase at a slower rate than the increase in interest rates and will start to flatten out. This is shown as the red line in figure 4.5.1. The opposite is likely to happen for demand for loans. The demand for loans will be maximum for very low rates of interests and small changes in the rate of interest on the loans will only have a small affect on the demand for loans. However, as the rate of interest increases the demand for loans will start to quickly decrease as people find the loans expensive. As we get to higher rates of interest for loans, demand will still decrease but at a slower rate. As we have seen with Payday lenders, some people, because of their circumstances, are prepared to borrow even at very high rates. So we do not expect the demand for loans to reach a zero amount but will decrease towards it. The blue line in the Figure 4.5.1 shows the typical demand for loans.

We can calculate the profit of the bank using the supply and demand curves in Figure 4.5.1. Figure 4.5.2 shows the maximum profit of the bank and the optimal deposit and loan interest rates. The maximum profit of the bank in this case would be £2.86 million and this is when the loan interest rate is $i_L = 10.23\%$ and the deposit rate is $i_D = 0\%$. The reason that the optimal deposit rate is zero is that
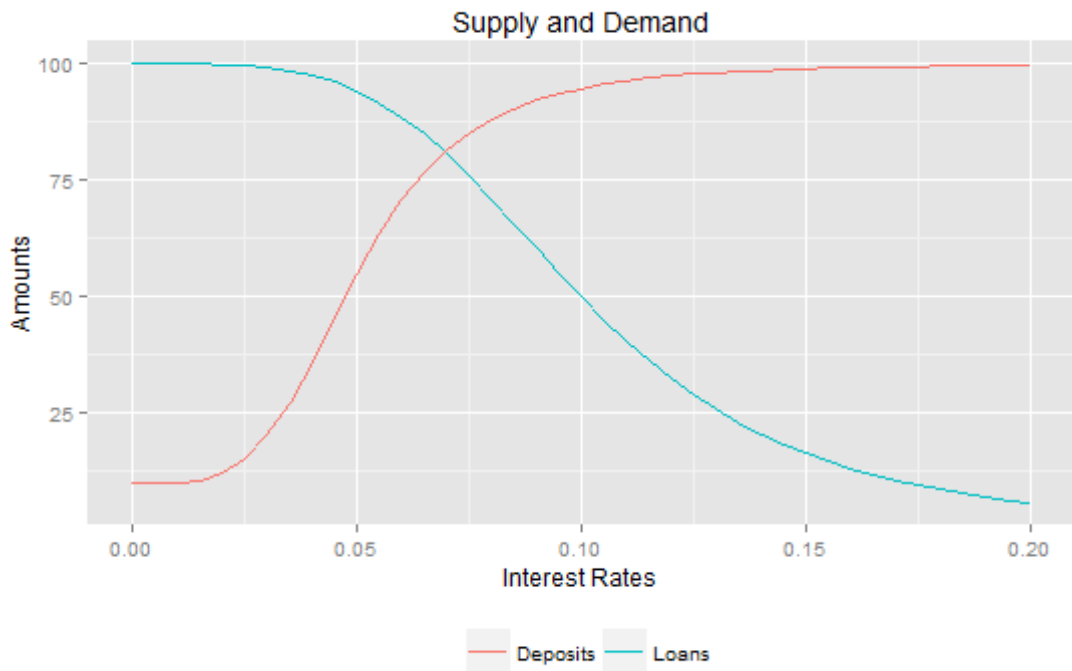
Figure 4.5.1: Realistic supply and demand curves of deposits and loans
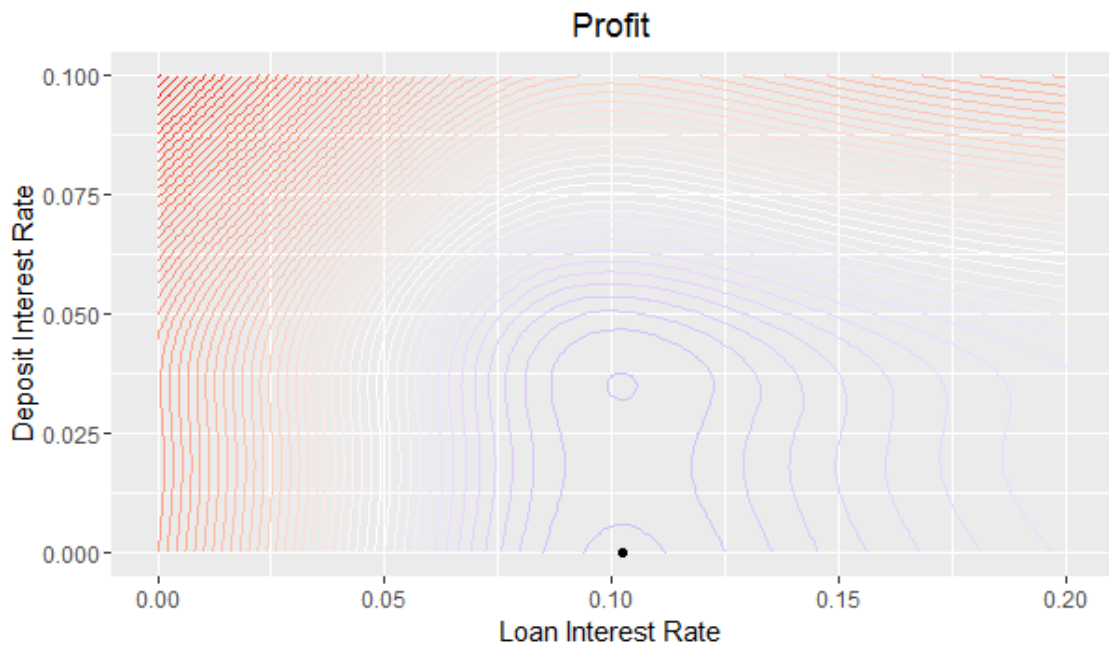
Figure 4.5.2: Contour plot of profit with black dot showing position of maximum profit. Blue area is profitable for bank, red area is loss
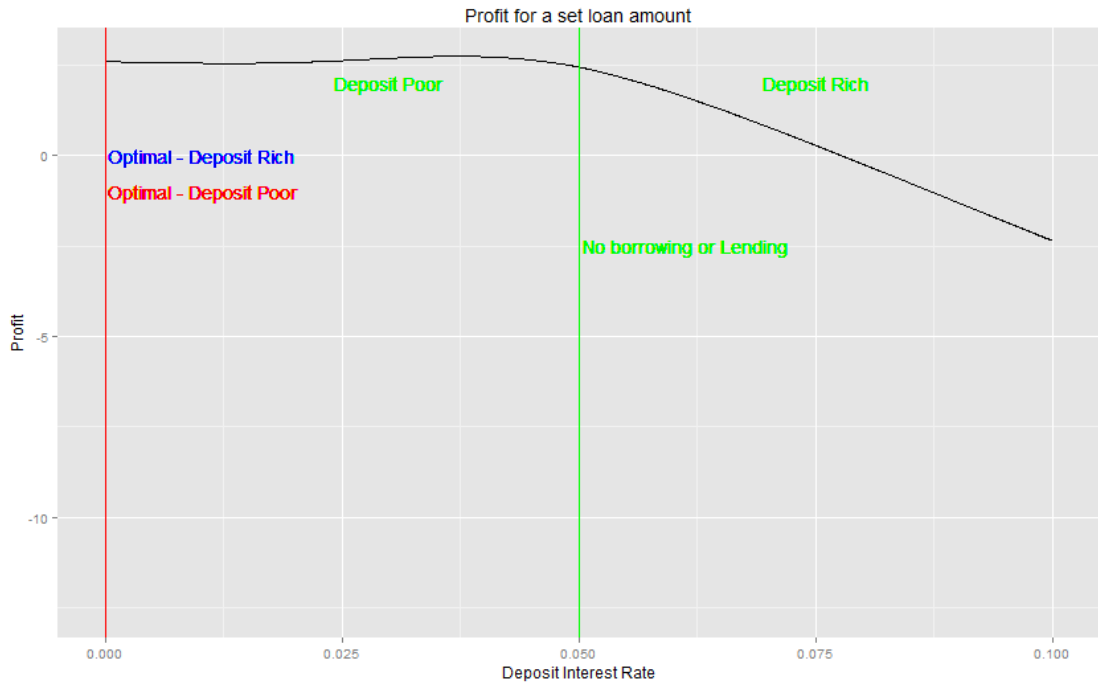
Figure 4.5.3: Profit curve when loan amount is set based on realistic supply of deposits and demand for loans curves.

the bank can take in a certain amount of deposits from customers for free. If it decides to increase deposit rates slightly the increase in deposits will not be worth the extra cost. As the deposit rate is increased significantly, the bank will take in more deposits and this will increase profits compared to low levels of deposits. However this increase is still less than the profits at the point when the bank does not pay any interest to customers. Hence this is why there is another contour circle on the graph but the black dot (maximum point) is not inside this circle. Figure 4.5.3 highlights this concept better. We can see that the maximum profit is when the deposit rate is zero and that the profit decreases as interests rates increase. However after a certain point, the profits start increasing with the interest rates as the bank takes in more deposits. This then forms a local maximum as seen in the graph. In this case the local maximum is not the same as the global maximum. Hence this is why the optimal rate for deposits should be set at the global maximum, which is the case at the point when deposit interest rate is zero. If we adjust the supply of deposits so that the amount borrowed at zero cost is less, we will change the maximum point. Figure 4.5.4 shows the maximum profit if we slightly change the supply of deposits. This time the maximum profit is in the other circle and not
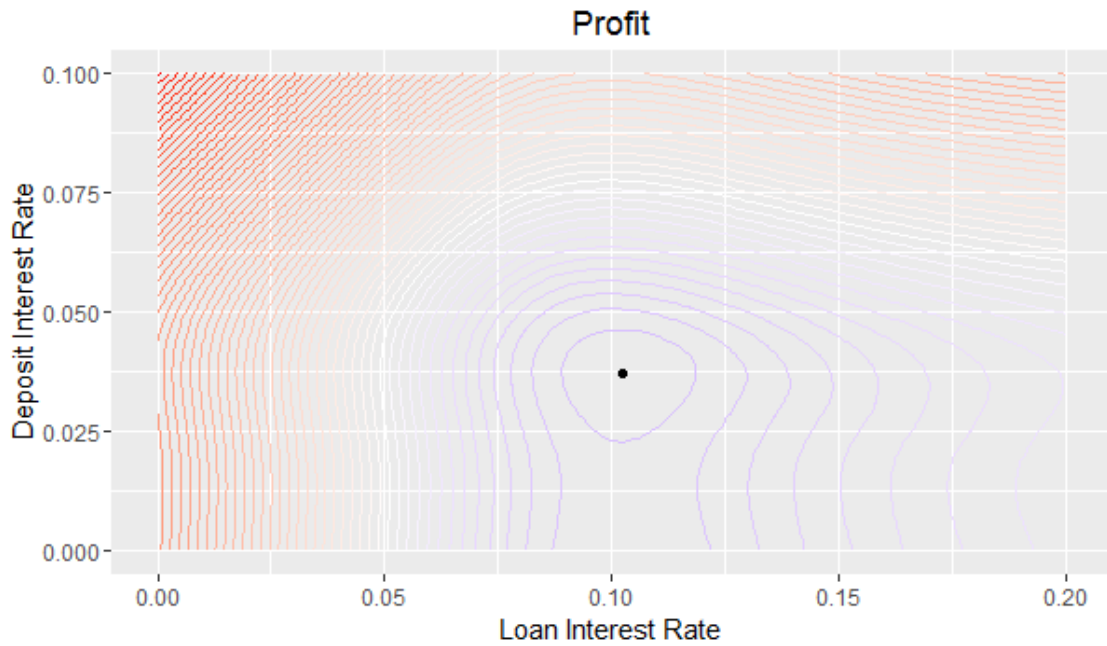
Figure 4.5.4: Contour plot of profit with black dot showing position of maximum profit. Blue area is profitable for bank, red area is loss

at zero. Figure 4.5.5 shows that at at zero it is a local maximum and the global maximum is at 3.73%. Provided we have unique global maximum for supply of deposits and demand for loans we will have a maximum profit overall.

The supply of deposits and demand for loans will determine the bank's profits and define whether the bank is deposit poor or deposit rich. It does not impact on the actual FTP rates. Therefore from setting the FTP rates we do not need to worry about the supply and demand curves, we just need to consider whether the bank will be deposit rich or deposit poor.
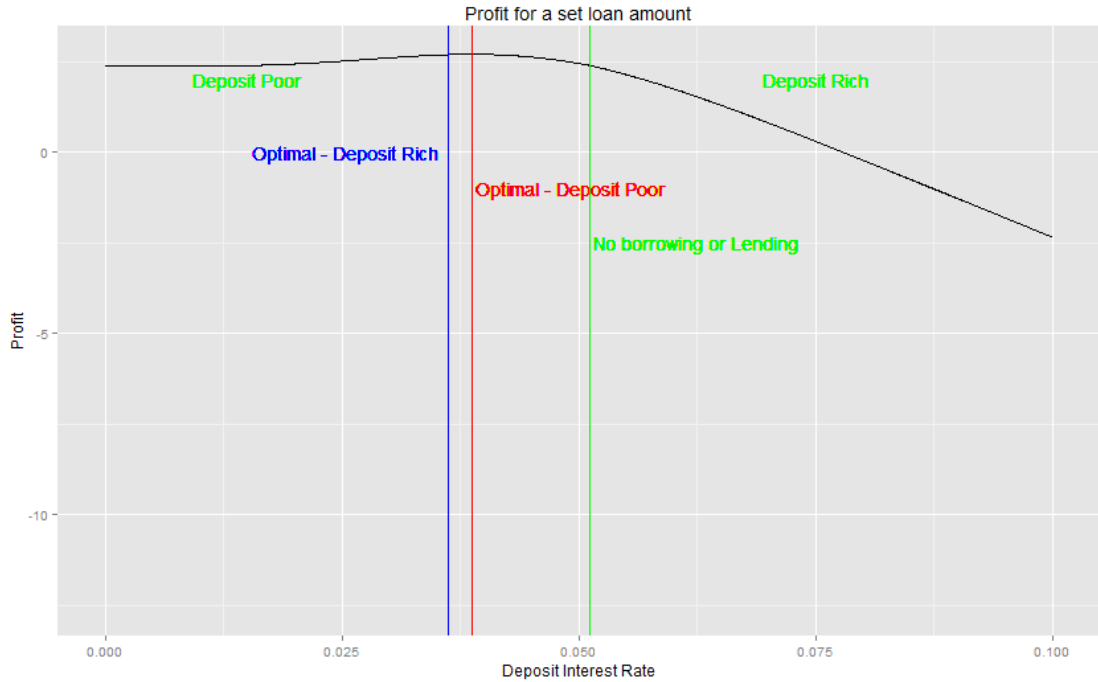
Figure 4.5.5: Profit curve when loan amount is set based on realistic supply of deposits but with only a small amount of deposits at 0% rate

4.6 Shareholder's equity

A bank's balance sheet also includes shareholder's equity. Shareholder's equity is used as a method of protecting the creditors from unexpected losses from any loans that default. Shareholder's equity is reduced first for any unexpected losses. The bank's balance sheet is constructed so assets = liabilities + shareholder's equity. As shareholders face the risk from unexpected losses they require a return from their investments. We will look at including a minimum return, r_E, on shareholder equity, E, and see how this effects the FTP framework. Any profit to the bank is then in excess of the return required by shareholders.

First, we will consider the situation where the bank is deposit rich. Proposition 4.6.1 tells us that including shareholder's equity does not affect the FTP rates when the bank is deposit rich. This is useful as it means we do not need to consider shareholder's equity when considering the FTP rates for a deposit rich bank.

Proposition 4.6.1. *Shareholder's equity does not impact on the results. The bank's profit can be maximised by maximising $L(i_L - W_L)$ and $D((1 - \alpha)W_L + \alpha i_A - i_D)$ when the bank is deposit rich. Assuming that L and D are independent.*

Proof. The profit to the shareholders in excess of the required return on shareholders' capital is:

$$P = Li_L + M_L W_L + Ai_A - Di_D - M_B W_B - Er_E.$$

As the bank is deposit rich and is lending to the market and not borrowing from the market then $M_B = 0$.

$$P = Li_L + M_L W_L + Ai_A - Di_D - Er_E.$$

For the balance sheet to balance then $L + A + M_L = D + E$ if the bank is lending to the market. So $M_L = D + E - L - A$.

$$P = Li_L + (D + E - L - B)W_L + Ai_A - Di_D - Er_E.$$

We know that $A = \alpha D + \beta M_B$. But as $M_B = 0$ then $A = \alpha D$.

$$P = Li_L + (D + E - L - \alpha D)W_L + \alpha Di_A - Di_D - Er_E.$$

Rearranging gives:

$$P = Li_L - LW_L + DW_L + \alpha DW_L + \alpha Di_A - Di_D - E(r_E - W_L)$$
$$P = L(i_L - W_L) + D((1 - \alpha)W_L + \alpha i_A - i_D) - E(r_E - W_L).$$

$\square$

We now need to consider the situation where the bank is deposit poor. Proposition 4.6.2 tells us that including shareholder's equity does not affect the FTP rates when the bank is deposit poor. This is useful as it means we do not need to consider shareholder's equity when considering the FTP rates for a deposit rich or a deposit poor bank.

Proposition 4.6.2. *Shareholder's equity does not impact on the results. The bank's profit can be maximised by maximising*

$L\left(i_L - \left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}\right)\right)$ *and* $D\left((1-\alpha)\left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}\right) + \alpha i_A - i_D\right)$ *when the bank is deposit poor and there is a requirement of holding liquid assets. Assuming that L and D are independent.*

Proof. The profit to the shareholders in excess of the required return on shareholders' capital is:

$$P = Li_L + M_L W_L + Ai_A - Di_D - M_B W_B - Er_E.$$

As the bank is deposit poor and is borrowing from the market and not lending to the market then $M_L = 0$.

$$P = Li_L + Ai_A - Di_D - M_B W_B - Er_E.$$

For the balance sheet to balance then $L + A = D + M_B + E$ if the bank is borrowing from the wholesale money markets. So $M_B = L + A - D - E$. We know that $A = \alpha D + \beta M_B$. So putting these two formulas together we get the following:

$$M_B = L + \alpha D + \beta M_B - D - E$$
$$M_B(1 - \beta) = L + \alpha D - D - E$$
$$M_B = \frac{L + \alpha D - D - E}{1 - \beta}.$$

If we the combine this with the initial equation we get:

$$P = Li_L + \left(\alpha D + \beta\left(\frac{L + \alpha D - D - E}{1 - \beta}\right)\right)i_A - Di_D - \left(\frac{L + \alpha D - D - E}{1 - \beta}\right)W_B - Er_E.$$

Rearranging gives the following:

$$
\begin{aligned}
P &= Li_L + \beta \left(\frac{L}{1-\beta} \right) i_A - \frac{L}{1-\beta} W_B \\
&\quad + \left(\alpha D - \beta \left(\frac{(1-\alpha)D}{1-\beta} \right) \right) i_A - Di + \left(\frac{(1-\alpha)D}{1-\beta} \right) W_B \\
&\quad - \beta \frac{E}{1-\beta} i_A + \frac{E}{1-\beta} W_B - Er_E \\
P &= L \left(i_L - \frac{W_B}{1-\beta} + \frac{\beta i_A}{1-\beta} \right) \\
&\quad + D \left((1-\alpha) \left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta} \right) + \alpha i_A - i_D \right) \\
&\quad - E \left(r_E - \frac{W_B}{1-\beta} + \frac{\beta i_A}{1-\beta} \right).
\end{aligned}
$$

$\square$

4.7 Different deposit characteristics

The FTP rate will be calculated for each product that the different loan and deposit units offer. Each product may have different terms and characteristics. In particular, different deposit products may attract more stable deposits than others.

For example, the bank may have a product that brings in very stable deposits where the appropriate α is 5%. The deposit poor FTP rate for this product would be calculated as follows using the assumption in Table 4.2.1, page 73:

$$
\begin{aligned}
\text{FTP} &= (1-\alpha) \left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta} \right) + \alpha i_A \\
&= (1-0.05) \left(\frac{0.051}{1-0.1} - \frac{0.1 * 0.03}{1-0.1} \right) + 0.05 * 0.03 \\
&= 5.22\%.
\end{aligned}
$$

The bank may have another product that bring in less stable deposits where the appropriate α is 20%. The deposit poor FTP rate for this product would be calculated as:

$$
\begin{aligned}
\text{FTP} &= (1-\alpha)\left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}\right) + \alpha i_A \\
&= (1-0.2)\left(\frac{0.051}{1-0.1} - \frac{0.1*0.03}{1-0.1}\right) + 0.2*0.03 \\
&= 4.87\%.
\end{aligned}
$$

As we can see there is a difference in FTP rates for the products. The product with the lower α value has a higher FTP rate, meaning that all else being equal, this product will bring in the larger profit. The deposit unit may decide to increase the rate offered on this product so that both products bring in the same amount of profit. However, the bank may need to be careful that increasing the rate on the product does not change the characteristics of the depositors by bringing in greater numbers of less stable deposits and hence increasing the value of α.

It is not a straightforward decision to determine an appropriate α as it needs to be a judicious forecast based on the bank's knowledge of their customers. If a bank increases interest rates on a product with a lower α it could then end up being the highest interest rate offering product. This could attract a lot of customers who will switch for the best rates and hence increase the α value on the product. The bank will need to investigate what they think is an appropriate α based on their behaviour modelling and views.

4.8 Alternative approaches

The approach adopted in these sections is similar to Dermine (2013). Dermine (2013) creates the following balance sheet:

Assets	Liabilities and Shareholder Equity
Loans: L (i_L)	Deposits: D (i_D)
	Interbank deposits : I (i_I)
Liquidity bonds: A (i_A)	Long term funding: F (i_F)

Dermine (2013) imposes the requirement that the bank must be deposit poor in his calculations. Whereas the approach adopted in this section is less restrictive and

the bank can be either deposit poor or deposit rich. The other major restriction that Dermine (2013) imposes is that long term funding must finance the liquid asset holding. In other words, $A = F$. However this is not strictly true. For the Net Stable Funding Ratio (NSFR), the definition of available stable funding is defined as:

- capital;

- preferred stock with maturity one year or greater;

- liabilities with effective maturity one year or greater;

- a portion of non-maturity deposits that would be expected to stay during stressed market conditions; and

- a portion of wholesale funding that would be expected to stay during stressed market conditions.

BCBS (2014b) states for the portion of non-maturity deposits that would be expected to stay during stressed market conditions, NSFR sets a factor of 95% for stable deposits and 90% for less stable. For wholesale funding from other banks, if the maturity is greater than 6 months but less than 1 year, the NSFR factor would be 50%. Therefore it is not a requirement that A must equal F. In this section, there is no requirements on how the liquid asset holding must be financed.

Dermine (2013) calculates the following FTP rates:

$$\text{Cost of funds for loans: FTP Rate} = i_I + [\beta(i_F - i_A)];$$
$$\text{Reward for deposits: FTP Rate} = i_I + [(\beta - \alpha)(i_F - i_A)].$$

For borrowing money from the treasury, the FTP rate can be thought of as the rate of borrowing money plus the net cost of holding liquid assets for the increased amount borrowed. Similarly, the FTP rate for deposits, is the cost of borrowing money plus any reduction in the net cost of holding of liquid assets from raising

money from deposits rather than wholesale money market. This is a similar concept to what has been derived in this chapter but the formula in this chapter looks more complex because of the requirement of $A = F$ not being enforced.

Fiedler (2011) suggests that, due to the introduction of the LCR, the cost of holding high quality liquidity assets should be included in the FTP framework. Since some products will only impact on the LCR in some months and not others, the average LCR impact should be included in the product. For example, in case of a deposit with a term of 360 days the bank will only have to hold high quality liquid assets for 1 month in month 12. For the remaining months it will not be required to hold high quality liquid assets. Therefore the cost for 1 month of high quality liquid assets can then be averaged out over the 12 months to calculate the appropriate FTP year.

This can be incorporated into the FTP rates derived in this section via the terms α and β. Instead of α and β representing purely the proportion of money required to be held, these values can include the proportion of the period that liquid assets need to be held. For example, if 5% of deposits needs to be held as liquid asset for 3 months rather than 12 months, α could be set as $\alpha = 5\% \times \frac{3}{12} = 3.75\%$.

Choudhry (2012) suggests that the cost of the liquid asset holding can be allocated outside of the FTP framework. Although this will make the FTP framework simpler, it does have some drawbacks. Firstly, FTP is also used to transfer risk between departments and by not including liquidity we will not be transferring this risk directly from the department. Ideally, we want the liquidity risk team within the treasury to manage this risk for the whole business rather than assign costs for managing liquidity to different departments. By including liquidity risk in the FTP framework will bring it to the forefront of decisions and the bank can easily see the impact liquidity has on different products. From the formulae, we can see that there is a linkage between wholesale money market lending and borrowing and the liquid asset holding and this could be difficult to separate out. Therefore for these reasons it is preferable to include liquidity within the FTP framework.

Grant (2011) states that the cost of the liquid asset holding should be included

in the FTP rate. Grant (2011) suggests calculating the cost of liquid asset holding for a product and adding this amount to the FTP. However, from the formulae we can see that wholesale money market lending and borrowing is dependent upon the liquid asset requirements. Therefore, it would be preferable to look at these both together rather than separately.

4.9 Conclusion

In this section we have looked at how a bank's profits can be maximised over one time period. We have then investigated if this can be done in an FTP framework. The results show that:

- It is possible to maximise the bank's profits with in an FTP framework;

- The FTP framework depends on whether the bank is deposit rich or deposit poor;

- It is not appropriate if the bank is neither deposit rich nor deposit poor but this is an unlikely situation and could make only a small difference dependent on parameters;

- The FTP rates are independent of supply and demand of deposits and loans except for defining whether the bank is deposit rich or deposit poor;

- The liquid asset holding can be incorporated into the FTP framework; and

- It seems appropriate to link liquid assets into the FTP framework as the liquid asset requirements affects the amount that can be borrowed or lent in wholesale money markets.

This suggests that it is appropriate for a bank to use the FTP framework to maximise its profits. This does depend on loan and deposit units being independent of each other. Further work needs to be done on what is the appropriate α and β values and how the Liquidity Coverage Ratio (LCR) can be incorporated into these values. So far we have looked at just one time period model and we need to consider how this can be amended to allow for future time periods.

Chapter 5

FTP - Two time period model

5.1 Introduction

We have seen how a one time period model works and how Fund Transfer Pricing (FTP) can be used to maximise the profits of the bank within this framework. What we learnt from looking at the one period model is:

- The bank's profits can be maximised by using the FTP framework;

- Different FTP rates should be used depending on whether the bank is deposit rich or deposit poor;

- Funding liquidity risk can be incorporated into the FTP framework and does impact on the FTP rates;

- Loan and deposit business units can be managed independently; and

- FTP rates are independent of supply of deposits and demand for loans.

The one period model is a simplified case but does highlight useful information about FTP and how funding liquidity risk can be managed. In reality, banks will operate over multiple time periods. Therefore we need to see how the one period model can be extended to work over multiple periods. To begin with we will look at two periods. It is not straight forward to extend the model and further complications do arise. The main issues are:

- How to define whether the bank is deposit rich or deposit poor;

- How to expand the model to allow for multiple periods; and

- Allowing for uncertainty at the end of each period.

We need to address these issues and consider whether they can be dealt with in line with the goals of FTP. The goals of FTP are:

- Maximise the bank's profits;

- Transfer interest rate risk and liquidity risk to a separate centralised department; and

- Allow the business units to work independently.

In the following sections, we will tackle these issues and address them in the context of the FTP framework. When looking at FTP in multiple time periods, they will be expressed as per annum rates and applied to the cashflow occuring in that period. For example, 2 year FTP of 5% will apply only to the cashflows occuring in year 2 and it is 5% per annum.

5.2 Defining the bank as deposit rich or deposit poor

From the one period model, we discovered that the FTP rates are different depending on whether the bank is deposit rich or deposit poor. Proposition 4.4.3, page 82, shows us the FTP rates for a bank in the deposit rich situation would be:

$$\text{Loan unit: } W_L;$$

$$\text{Deposit unit: } (1 - \alpha)W_L + \alpha i_A.$$

Proposition 4.4.4, page 85, shows us the FTP rates for a bank in the deposit poor situation:

$$\text{Loan unit: } \frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta};$$

$$\text{Deposit unit: } (1-\alpha)\left(\frac{W_B}{1-\beta} - \frac{\beta i_A}{1-\beta}\right) + \alpha i_A.$$

From the analysis in Chapter 4, we can see that it is quite possible for the FTP rates to be different depending on whether a bank is in the deposit poor or deposit rich situation. When we include funding liquidity risk, this increases the difference between FTP rates in a deposit poor and deposit rich situation. As we know funding liquidity risk increases the difference but also adds greater complications, we will begin by considering the FTP rates without funding liquidity risk. Proposition 4.4.1, page 76, shows us the FTP rates for a bank in a deposit rich situation without liquid assets would be:

$$\text{Loan unit: } W_L;$$

$$\text{Deposit unit: } W_L.$$

Proposition 4.4.2, page 78 shows us the FTP rates for a bank in the deposit poor situation without funding liquidity risk would be:

$$\text{Loan unit: } W_B;$$

$$\text{Deposit unit: } W_B.$$

This shows us that in a deposit rich situation, the FTP rates for both loan and deposit units would be W_L - the rate the bank can lend in the wholesale money markets. In a deposit poor situation, the FTP rates for both loan and deposit units would be W_B - the rate the bank can borrow in the wholesale money markets. The difference in the FTP rate would be $W_B - W_L$ which is the bid/ask spread. Generally, it would not have been important enough to worry about whether the bank is in a

deposit rich or deposit poor situation as the bid/ask spread is usually very small. Hence not much consideration has been given to this issue before. However, when we include funding liquidity risk the difference is more important as we have seen from Chapter 4.

We will consider the following examples to help us decide whether the bank is deposit poor or deposit rich. In these examples, we will ignore the requirement to hold liquid assets as this just adds to the complications without giving us any additional information. Including liquid assets just means it is more important to get the deposit rich and deposit poor situations correct.

Example 5.2.1. *Deposits and loans at time 0 maturing at time 1*

In Table 5.2.1, we look at a simple case where the bank has deposits and loans at time 0 which are maturing at time 1. The deposits could be thought of as 1 year fixed maturity deposits and the loans as 1 year bullet loans. The deposits are greater than the loans at time 1. This is exactly the same as the one period model and we can conclude the bank is deposit rich. Therefore the appropriate FTP rates would be the FTP rates in the deposit rich situation.

Table 5.2.1: Example 1: Deposits and loans maturing in period 1

Time	1	2
Loans	80	0
Deposits	100	0

Example 5.2.2. *Deposits and loans at time 0 maturing at time 2*

In Table 5.2.2, we look at a similar case as in Example 5.2.1 but this time the deposits and loans are maturing at time 2. The deposits could be thought of as 2 year fixed maturity deposits and the loans as 2 year bullet loans. The deposits are greater than the loans at time 2. This is similar to the one period model except this time the period is 2 years rather than 1 year. We can conclude the bank is in the deposit rich situation. Therefore the appropriate FTP rates would be the FTP rates in the deposit rich situation.

Example 5.2.3. *Deposits maturing at time 1 and loans maturing at time 2*

Table 5.2.2: Example 2: Deposits and loans maturing in period 2

Time	1	2
Loans	0	80
Deposits	0	100

In Table 5.2.3, we look at a case where the deposits at time 0 are maturing at time 1 while the loans at time 0 are maturing at time 2. The deposits could be thought of as 1 year fixed maturity deposits and the loans as 2 year bullet loans. At time 0, the deposits are greater than the loans but the deposits and loans are maturing at different times. In this situation it is not clear whether the bank is in the deposit rich or deposit poor situation. We could decide the bank is in the deposit rich situation as deposits are greater than loans at time 0. Alternatively, we could decide the bank is in the deposit rich situation in period 1 and in the deposit poor situation in period 2. Depending on what is decided will impact on the FTP rates and will influence the bank's decisions. We will examine the consequences of setting the FTP rates in this section.

Table 5.2.3: Example 3: Deposits maturing at time 1 and loans maturing at time 2

Time	1	2
Loans	0	80
Deposits	100	0

We need to consider what happens when we use the deposit rich FTP rates compared to the deposit poor FTP rates. Using deposit rich FTP rates will encourage more loans and less deposits than if we used deposit poor FTP rates. While deposit poor FTP rates will have the opposite effect; encourage more deposits and less loans. Table 5.2.4 summarises whether the amount of business will increase or decrease when we use the deposit rich FTP rates compared to the deposit poor FTP rates.

Table 5.2.4: Change in loan and deposit amounts depending on FTP rates used

Change in amounts	Deposits	Loans
Deposit rich FTP rates	↓	↑
Deposit poor FTP rates	↑	↓

We could take the decision that the bank is deposit rich at time 0 and use

the deposit rich FTP rates for both loans and deposits. This would mean that the bank would be encouraged to make more 1 year bullet loans and take in less 1 year deposits. This would be a good outcome and it is what we would like to achieve. However, if we use the deposit rate FTP rates at time 2, the bank would be encouraged to take in more loans and less deposits. This would increase funding liquidity risk for the bank. This is the opposite of what we want to achieve. Therefore using the deposit rich FTP rates at time 0 for both loans and deposits for both maturities does not seem appropriate.

We could decide the bank is in the deposit rich situation in period 1 and deposit poor situation in period 2. This would mean using different FTP rates for different time periods. If we decide at time 1 the bank is in the deposit rich situation this would mean that the bank would be encouraged to issue more loans for 1 year duration and less interested in taking in deposits for 1 year. While if time 2 is in the deposit poor situation the bank will be encouraged to take in more deposits for 2 years and issue less loans for 2 years. This seems sensible and incentivises the business units in the correct way but does it meet the objectives of FTP?

In the above approach this would mean that the bank could lend the 1 year deposits in the wholesale money markets with 1 year maturity and borrow from the wholesale money markets with 2 year maturity to match the loan lending. Figure 5.2.1 shows how the treasury would manage this approach. The bank would transfer interest rates risk and funding liquidity risk to a centralised team i.e. the treasury. It would also allow the business units to work independently of each other. The deposits will be perfectly matched against wholesale lending and the loans will be perfectly matched by wholesale borrowing. So the bank will not be exposed to interest rate risk or funding liquidity risk. However, does it maximise the bank's profits?

If the bank adopts this approach as shown in Figure 5.2.1, then the bank will be borrowing and lending in the wholesale money markets at the same time. This may not be the most efficient approach and alternative approaches might be available to increase the bank's profits. The bank may decide to fund the loan unit with the
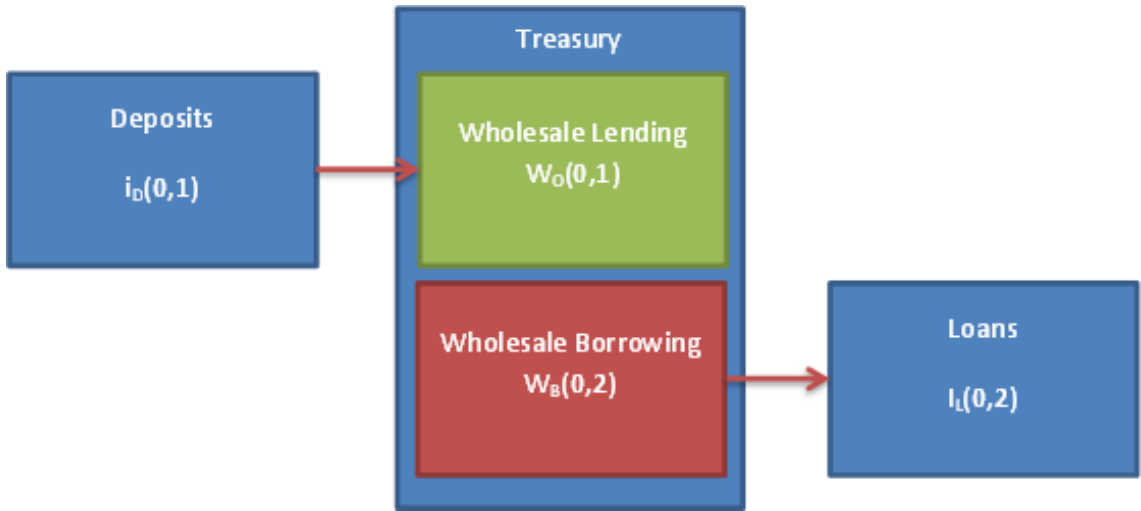
Figure 5.2.1: Deposits and loans perfectly matched with wholesale lending and borrowing respectively

deposits for 1 year and then with wholesale borrowing for 1 year from time 1 to time 2. This is shown in Figure 5.2.2. This would mean the funding cost for the loan unit would be:

$$(1 + W_L(0, 1))(1 + W_B(1, 2)),$$

where:

- $W_L(t, T)$ is the wholesale money market rate per annum for lending in the market at time t until time T; and

- $W_B(t, T)$ is the wholesale money market rate per annum for borrowing in the market at time t until time T.

At future time periods, $W_L(t, T)$ and $W_B(t, T)$ are random variables. The expected value of $W_B(t, T)$ is $\mathbf{E}[W_B(t, T)]$.

The bank could potentially increase profits by funding the loans with deposits for 1 year and then by wholesale borrowing for the next year. The wholesale borrowing in 1 year's time is not risk free; the bank may wait until time 1 before borrowing in the wholesale money markets then $\mathbf{E}[W_B(1, 2)]$ might not necessarily equal $W_B(1, 2)$. If $\mathbf{E}[W_B(1, 2)] > W_B(1, 2)$ then this will increase the bank's profits. However, if
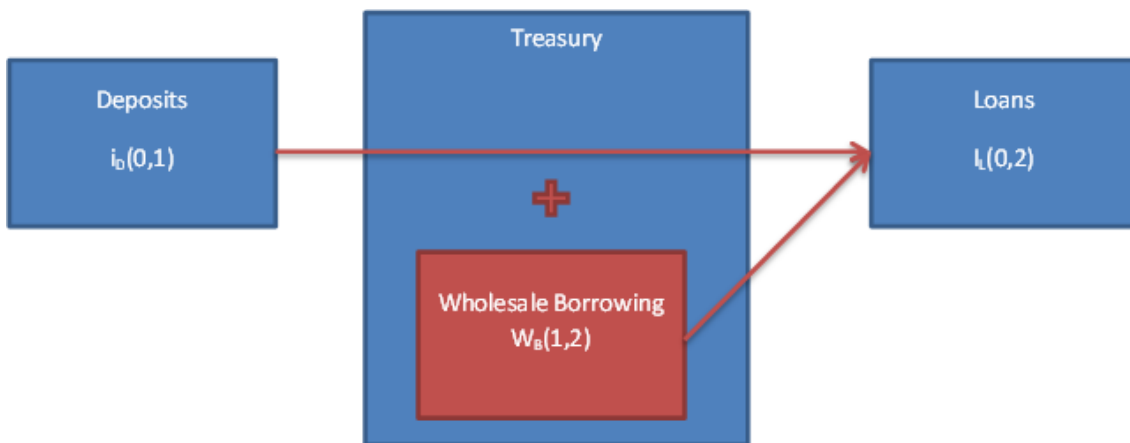
Figure 5.2.2: Deposits and wholesale borrowing from year 1 to 2 used to fund 2 year loans

$\mathbf{E}[W_B(1,2)] < W_B(1,2)$ then this could reduce the bank's profits. The bank would be exposed to interest rate risk and funding liquidity risk. The bank may be happy to take on these risks depending on their views of interest rates and the size of the funding liquidity risk. The bank could reduce the risk by entering into an agreement at time 0 to borrow at time 1 which removes the interest rate risk and reduces the funding liquidity risk. There would still be some funding liquidity risk, in case the counterparty did not stick to the agreement at time 0. The bank would have to decide what is the appropriate risk they would like to take.

If the bank adjusted the FTP rate for the loan unit so it is based on $(1 + W_L(0,1))(1 + \mathbf{E}[W_B(1,2)])$ rather than $(1 + W_B(0,2))^2$, then the FTP rates will be lower for the loan unit. This means that the loan unit's profit will increase and could lend out more in the form of loans. However, the loan unit is not taking any additional risk while the treasury unit would be. Therefore, it seems strange to reward the loan unit for risks that must be borne or managed by the treasury. As such, the additional profit or losses from this approach should be awarded to the treasury unit. This can be done by leaving the FTP rate based on two year borrowing costs, i.e. $(1 + W_B(0,2))^2$. This then allows the treasury unit to decide if it wishes to take interest rate risk and funding liquidity risk, and they will be rewarded or penalised accordingly.

Therefore, it is possible to increase the bank's profits from the approach shown in Figure 5.2.1, where the bank matches deposits with wholesale lending and loans

with wholesale borrowing. However, we do not need to adjust the FTP rates as the loan unit or deposit unit will not be increasing its risk in the hope of increasing profits. The additional profit may arise from the treasury and they will have to manage the risks so they should be rewarded with the credit.

Example 5.2.3 has shown us that it is sensible to use different FTP rates at different time periods. It will still maximise the deposit and loan units' profits and the treasury can also possibly contribute to the profits of the bank. The treasury can decide to take the risk and possibly increase the bank's profits or remove the risk and make no contribution to the bank's profits.

Example 5.2.4. *New deposits at time 1*

Banks often work with an ideal loan to deposit ratio and some banks may target to remain deposit rich. Therefore banks may expect to take in more deposits in a future time period. Table 5.2.5 is the same as Table 5.2.3, with deposits maturing at time 1 and loans expiring at time 2, except new deposits are coming in at time 1. For example, the bank could launch a new product at time 1 and take in new deposits. In this example the bank's loan to deposit ratio will remain the same and the bank will be always be deposit rich. How does this effect the FTP rates?

Table 5.2.5: Example 4: New deposits at time 1

Time	1	2
Loans	0	80
Deposits	100	0
New deposits	0	100

The bank may feel that its business model is in a deposit rich situation and will always be looking at opportunities to lend money out. Therefore they may feel they want to encourage loans by using the deposit rich FTP rates rather than the deposit poor FTP rates. There may be some justification for this. However it does leave the bank exposed to funding liquidity risk. The rewards for the funding liquidity risk would be passed on to the loan unit in the form of lower FTP rates. This does not seem appropriate as the loan unit is not taking a funding liquidity risk itself.

Alternatively, at time 0, we could have assumed that the bank is in a deposit rich situation at time 1 and a deposit poor situation at time 2. We could then use

the same approach as in example 5.2.3. The treasury unit will then know it does not need to borrow in the wholesale money markets and can just lend out the deposit money, making a profit on the difference between W_L and W_B. This seems sensible but the treasury is exposed to funding liquidity risk and is relying on the deposit unit to bring in the deposits expected by the treasury.

At time 1, the bank can then assess whether it views itself as being in a deposit rich situation or deposit poor situation. This will depend on how many deposits the bank expects to take in and it can set the FTP rates accordingly. This will allow the bank to derive the appropriate profits for each unit associated with the risks that unit is taking. Overall it will still maximise the profits of the bank.

Example 5.2.5. *Expected v Actual maturities of deposits and loans*

Depositors often have the right to withdraw their money at any time and loans can be prepaid. We will now look at an example of how the bank may assume a certain amount of deposits withdrawn at time 1 and a certain amount of loans prepaid at time 1.

Table 5.2.6: Example 5: Expected v actual maturities of deposits and loans

Time	1	2
Loans	40	40
Deposits	50	50

(a) Expected maturities

Time	1	2
Loans	0	80
Deposits	100	0

(b) Actual maturities

Members have the option to withdraw their money or prepay loans early, as such, the bank can not be certain when deposits will be withdrawn and loans prepaid. The bank needs to make assumptions of when prepayments and withdrawals will happen. If the bank assumed the cashflows will look like Table 5.2.6a while in fact they turn out to be as in Table 5.2.6b; the bank would be exposed to funding liquidity risk. The treasury department will need to manage this risk. Therefore the treasury should charge a price for taking on this risk which should then be reflected in the

FTP rate. This will mean that deposit and loan units are charged for the options that they grant. These units can pass on these costs to customers by charging the customers for the option.

In these examples, we have seen that we should look at each time period to decide whether the bank is in the deposit rich or deposit poor situation. The FTP rates do not dictate how the bank will manage their interest rate risk and funding liquidity risk. However, it does ensure the appropriate units are rewarded for the risk they face and allows the units to work independently to maximise the bank's profits. When uncertainty arises with the cashflows this results in funding liquidity risk which has costs for the bank. We need to investigate how we can price for this uncertainty. Before we can do that, we need to consider how we can expand the FTP rates to allow for multiple time periods.

5.3   Expanding the model

Once we have decided whether the bank is in the deposit rich or deposit poor situation, we need to know how to extend the FTP framework to future time periods. We want to expand the one period model as shown in Chapter 4, so we can define the appropriate FTP rates in two time periods. We know that the FTP framework can be separated between different units and each unit can work independently. Therefore we can concentrate on expanding the FTP rates for the deposit unit in the deposit rich situation. We can then adopt the same approach for the deposit unit in the deposit poor situation and the loan unit. We will look at three difference approaches on how we can expand the FTP rates. The three approaches are:

A: Annual rebalancing approach;

B: Buy and hold approach; and

C: Forward rate approach.

5.3.1 A: Annual rebalancing approach

Under the annual rebalancing approach the Present Value (PV) of the deposit unit would be calculated as:

$$PV = \gamma D \left(\frac{W_L(0,1)(1 - \alpha(0,1)) + \alpha(0,1)i_A(0,1) - i_D(0,1)}{1 + E(0,1)} \right)$$

$$+ (1 - \gamma)D \left(\frac{\begin{array}{c}((1 + W_L(0,2)(1 - \alpha(0,2)) + \alpha(0,2)i_A(0,2))^2 - 1) \\ - ((1 + i_D(0,2))^2 - 1)\end{array}}{(1 + E(0,2))^2} \right).$$

where γ is the proportion withdrawn at time 1 and $E(t,T)$ is the required return by the bank between time t and T.

If we think about the underlying assets i.e. lending in wholesale money markets and liquid assets, then this approach assumes that each year the allocation is annually rebalanced so the proportion between liquid assets and lending in wholesale money markets is constant each year. In this approach it is easy to calculate the FTP rate and the two year FTP for the deposit unit would simply be:

$$W_L(0,2)(1 - \alpha(0,2)) + \alpha(0,2)i_A(0,2).$$

This applies only to cashflow occuring in year 2, i.e. $(1 - \gamma)D$ and is expressed as a per annum rate.

However, this approach requires annual rebalancing to keep the proportions constant but this would not be possible in practice as rates may have changed. The FTP rates can not be accurately hedged and this means that there will be some risk. This approach will increase the FTP rate so it does not seem appropriate to reward the deposit team for risk that the treasury has to take. The profit to the bank will be released at maturity of the deposits.

5.3.2 B: Buy and hold approach

Under the buy and hold approach the PV of an opportunity would be priced as:

$$PV = \gamma D \left(\frac{W_L(0,1)(1-\alpha(0,1)) + \alpha(0,1)i_A(0,1) - i_D(0,1)}{1+E(0,1)} \right)$$

$$+ (1-\gamma)D \left(\frac{\begin{aligned}((1+W_L(0,2))^2(1-\alpha(0,2)) + \alpha(0,2)(1+i_A(0,2))^2 - 1) \\ - ((1+i_D(0,2))^2 - 1)\end{aligned}}{(1+E(0,2))^2} \right).$$

If we consider the underlying assets, i.e lending in wholesale money markets and liquid assets, then this approach assumes that the 2 year assets are held for 2 years. The bank could easily replicate this with a buy and hold investment strategy and therefore the FTP rates can be hedged. However, the proportion of liquid assets will reduce over time as wholesale lending will achieve a higher return than the return on liquid assets. The bank will need to ensure the α value is appropriate and consider the consequences of a reduction in liquid assets. The FTP rates are also more complicated to calculate than the constant rebalancing approach. The 2 year FTP rate for the deposit unit would be calculated as follows:

$$((1+W_L(0,2))^2(1-\alpha(0,2)) + \alpha(0,2)(1+i_A(0,2))^2)^{0.5} - 1.$$

This applies only to cashflow occuring in year 2, i.e. $(1-\gamma)D$ and is expressed as a per annum rate. Although the FTP rate is more difficult to calculate it can still be done and shown as a single number. The profit to the bank will be released at maturity of the deposits.

5.3.3 C: Forward rate approach

An alternative approach is to look at forward rates rather than spot rates to calculate the FTP rate. The PV could be calculated in the following way:

$$PV = D\left(\frac{W_L(0,1)(1-\alpha(0,1)) + \alpha(0,1)i_A(0,1) - i_D(0,1)}{1 + E(0,1)}\right)$$
$$+(1-\gamma)D\left(1 + i_D(0,1))(\frac{W_L(1,2)(1-\alpha(1,2)) + \alpha(1,2)i_A(1,2)}{(1 + E(0,2))^2} - i_D(1,2)}\right).$$

If we concentrate on the underling assets, then this approach assumes annual rebalancing as in the annual rebalancing approach mentioned in Section 5.3.1. However, this approach releases the profit earlier while the annual rebalancing approach releases the profit at maturity.

The forward rate approach is based on forward rates, so the FTP rate between year 1 and year 2 applying to $(1-\gamma)D$ cashflow would be calculated as follows:

$$W_L(1,2)(1-\alpha(1,2)) + \alpha(1,2)i_A(1,2).$$

The FTP is simple to calculate but it would not be possible to hedge. At time 1, when we want to rebalance, interest rates may have moved and we may not be able to purchase bonds with the forward rate assumed at time 0. This approach releases the profits each year rather than waiting for the maturity of the deposits. This is a useful feature. However, it is only possible if the approach is not hedged. If hedging was involved the profits will only be released at maturity. As the business units are effectively charged by the treasury as if the risks are hedged, it would make sense to wait for the profits to be released when the hedge expires.

5.3.4 Difference between approaches

Each approach gives a sightly different answer. We can compare the difference between approaches if we assume yield curves are flat, α is a constant and the appropriate discount rate is simply W_L:

$$W_L = W_L(0,1) = W_L(0,2) = W_L(1,2) = E(0,1) = E(0,2);$$

$$i_A = i_A(0,1) = i_A(0,2) = i_B(1,2);$$

$$\alpha = \alpha(0,1) = \alpha(0,2) = \alpha(1,2);$$

$$i_D = i_D(0,1) = i_D(0,2) = i_D(1,2).$$

It can be done without these assumptions but that makes it more complicated and less easy to see what the difference will be. By changing these assumptions it will likely increase the difference between approaches.

To make it easier for the comparison, we will define i_A and i_D in relation to W_L:

$$i_A = W_L + j_A;$$

$$i_D = W_L + j_D.$$

The difference between annual rebalancing approach FTP rate (FTP_{AR}) and buy and hold approach FTP rate (FTP_{BH}) is:

$$FTP_{AR} - FTP_{BH}$$

$$\alpha(1-\gamma)D\frac{(\alpha j_A^2 - j_A^2)}{(1+W_L)^2}.$$

The difference between annual rebalancing approach FTP rate and forward rate approach FTP rate (FTP_{FR}) is:

$$FTP_{AR} - FTP_{FR}$$

$$\alpha(1-\gamma)D\frac{(\alpha j_A^2 - j_D j_A)}{(1+W_L)^2}.$$

The difference between buy and hold approach and forward rate approach is:

$$FTP_{BH} - FTP_{FR}$$

$$\alpha(1-\gamma)D\frac{(j_A^2 - j_A j_D)}{(1+W_L)^2}.$$

In all cases the difference is expected to be a very small percentage of D. The details for how the difference has been derived is in Appendix A.1.

5.3.5 Conclusion

There are different ways that the FTP rates can be extended so they can be used over multiple time periods. We have looked at three approaches here and none of them are perfect. The preferred approach is the buy and hold strategy as this one can be replicated from the market from the outset. Although it is a bit more difficult to calculate it can still be simplified into a single number for FTP purposes. However, further consideration will be needed for the appropriate α value and the implications this has for liquid assets. We will use the buy and hold approach in Section 5.4 when considering how to calculate the appropriate FTP rates for loan and deposit products.

5.4 Allowing for uncertainty

We have seen how we can extend the model to future time periods and that we need to take into consideration whether the bank is in the deposit rich or deposit poor situation. We will now look at how we can price for uncertainty. We will look at different types of products and how the FTP rates for the business units can be derived under the following situations:

1. Deposit unit when the bank is deposit rich;

2. Deposit unit when the bank is deposit poor;

3. Loan unit when the bank is deposit rich; and

4. Loan unit when the bank is deposit poor.

5.5 Deposits when the bank is deposit rich

We will begin by looking at the products for the deposit unit when the bank is deposit rich. This means we should be deriving the deposit rich FTP rates for these products. Firstly, we will look at products with no uncertainty and then we will look at how uncertainty can be incorporated into products.

One product the bank may offer is fixed term deposits, say for 2 years. Here the customer will only be able to withdraw their money at the end of the 2 year period. Under this approach there is no uncertainty. The money will remain within the bank for 2 years. The PV of the profit from the deposit unit would be calculated as:

$$PV = D \left(\frac{((1 + W_L(0,2))^2(1 - \alpha(0,2)) + \alpha(0,2)(1 + i_A(0,2))^2 - 1)}{(1 + E(0,2))^2} \right).$$

This is a simple extension of the one period model. We could define the period as 2 years so in effect this would be the same as the one period model. The FTP Rate would be:

$$((1 + W_L(0,2))^2(1 - \alpha(0,2)) + \alpha(0,2)(1 + i_A(0,2))^2)^{0.5} - 1.$$

Another product we will look at is where deposits are offered with a fixed proportion of γ withdrawn at time 1. This type of product is not common in the banking industry but an example would be a product where the interest is paid out each year and then the lump sum returned at the end of the duration. Again there would be no uncertainty involved as we know exactly when the money would be withdrawn. The PV of the surplus for the deposit unit when the bank is deposit rich would be calculated as:

$$PV = \gamma D \left(\frac{W_L(0,1)(1 - \alpha(0,1)) + \alpha(0,1)i_A(0,1) - i_D(0,1)}{1 + E(0,1)} \right)$$

$$+ (1-\gamma)D \left(\frac{\begin{array}{r}((1 + W_L(0,2))^2(1 - \alpha(0,2)) + \alpha(0,2)(1 + i_A(0,2))^2 - 1) \\ - ((1 + i_D(0,2))^2 - 1)\end{array}}{(1 + E(0,2))^2} \right).$$

This can simply be thought of as splitting the model into two different time periods. There would be an FTP rate for each time period. In this case the FTP rates would be:

$$\text{Time } 1 = W_L(0,1)(1 - \alpha(0,1)) + \alpha(0,1)i_A(0,1) - 1;$$

$$\text{Time } 2 = ((1 + W_L(0,2))^2(1 - \alpha(0,2)) + \alpha(0,2)(1 + i_A(0,2))^2)^{0.5} - 1.$$

This product would become more difficult if γ is random, i.e. we do not know what proportion of deposits are going to be withdrawn at time 1. For example, a bank may offer a current account with a bonus rate of interest in the first year with the hope that many customers will not change after the first year. The actual proportion of customers remaining will not be known until time 1. Similarly, the bank might offer a one year fixed interest product that automatically rolls over if the customer does not take action. Again, we will not know many will remain until after the first year. However, based on experience and customers' behaviours we can estimate the proportion that will be withdrawn. Let's start with the premise:

$$PV = (1-x)D \left(\frac{W_L(0,1)(1 - \alpha(0,1)) + \alpha(0,1)i_A(0,1) - i_D(0,1)}{1 + E(0,1)} \right)$$

$$+ xD \left(\frac{\begin{array}{r}((1 + W_L(0,2))^2(1 - \alpha(0,2)) + \alpha(0,2)(1 + i_A(0,2))^2 - 1) \\ - ((1 + i_D(0,2))^2 - 1)\end{array}}{(1 + E(0,2))^2} \right),$$

where x is a random variable.

This will cause uncertainty and could cause funding liquidity risk. If withdrawals are more than expected this would cause funding liquidity risk. If withdrawals are less than expected, this will not cause funding liquidity problems. However, overestimating withdrawals will mean that the bank's deposit products may not be competitively priced in the market. We need to consider how to fairly price this uncertainty while penalising the deposit unit for creating funding liquidity risk by offering this option. To do this we need to consider the impact of bringing in deposits and what we can do with these deposits. In this case the bank is deposit rich so will be lending in the wholesale money markets. Therefore we need to consider if it is profitable to bring in deposits and then lend the money in the wholesale money markets. We need to consider the fair investment rather than what the bank will do in practice. As discussed in Section 5.2, the treasury may decide to do things differently to increase profits by increasing the risk. We will investigate the impact of lending in the wholesale money markets when there is uncertainty with the deposits. Firstly, we will define some terminology:

x is the random proportion withdrawn at time 1 and will be known at time 1. γ will be the proportion assumed withdrawn at time 1.

Let:

$\overline{P}_X(t, T)$ be the value at time t of an asset X, expiring at time T; where X equals A, liquid assets, or B, wholesale bonds. Due to the bid/ask spread and liquidity premium, the value will depend on whether the bank is buying or selling. Therefore $\overline{P}$ means buying price and $\underline{P}$ means selling price.

$U_X(S, T)$ be the number of units of X which expire at time T and purchased at time S.

So:

- $\overline{P}_B(0, 1) = \frac{1}{1 + \overline{W}_L(0,1)}$;

- $\overline{P}_A(0, 1) = \frac{1}{1 + \overline{i}_A(0,1)}$;

- $\overline{P}_B(0, 2) = \frac{1}{(1 + \overline{W}_L(0,2))^2}$;

- $\overline{P}_A(0,2) = \frac{1}{(1+\overline{i}_A(0,2))^2}$;

- $P_B(1,1) = 1$;

- $P_A(1,1) = 1$;

- $\underline{P}_B(1,2) = \frac{1}{(1+\underline{W}_L(1,2))}$;

- $\underline{P}_A(1,2) = \frac{1}{(1+\underline{i}_A(1,2))}$;

- $\overline{P}_B(1,2) = \frac{1}{(1+\overline{W}_L(1,2))}$;

- $\overline{P}_A(1,2) = \frac{1}{(1+\overline{i}_A(1,2))}$;

- $P_B(2,2) = 1$;

- $P_A(2,2) = 1$.

λ_B be the proportion of 2 year bonds sold at time 1 and λ_A be the proportion of 2 year liquid assets sold at time 1.

Using this information we can look to see what happens in regard to wholesale lending at each time period. We can see how the uncertainty impacts on the profits and use this to help derive the appropriate cost. There are two different approaches to the treatment of wholesale money market lending at time 1. The difference in approaches focuses around the treatment of profits when withdrawals differ from what is expected. In one approach, any profits at time 1 may be used to cover the excess withdrawals therefore postponing the profit until time 2. The other approach, looks at the assets that have been set aside to cover these deposits, therefore if this money is withdrawn the assets are sold to fund it. Any profits made will be recognised when deposits are withdrawn. We will look at both these approaches in more detail.

5.5.1 Approach 1: Using profit to meet excess withdrawals

Firstly, we look at how it could work if the profits at time 1 are used to meet any excess withdrawals at time 1. We will look at how the mathematics of this approach works and then work through a few examples. This might not be what the bank

does in practice but represents a fair approach for calculating the value of the option. At time 0, units of liquid assets and bonds are assumed to be purchased with the money from deposits. This would represent the fair investment of the deposits based on the expected withdrawal at time 1. The split between liquid bonds and bonds will depend on the value of α. The split between 1 year and 2 year bond holdings is based on γ. Table 5.5.1 shows the expected inflows and asset allocation at time 0.

Table 5.5.1: Cashflows at time 0 for new deposits for a deposit rich bank

Inflow		Asset Allocation	
Deposits	$= D$	$U_B(0,1)\overline{P}_B(0,1)$	$= \gamma D(1 - \alpha(0,1))$
		$U_A(0,1)\overline{P}_A(0,1)$	$= \gamma D\alpha(0,1)$
		$U_B(0,2)\overline{P}_B(0,2)$	$= (1 - \gamma)D(1 - \alpha(0,2))$
		$U_A(0,2)\overline{P}_A(0,2)$	$= (1 - \gamma)D\alpha(0,2)$

The reason for wanting to match assets to the expected duration is because of interest rates and the bid/ask spread of buying and selling bonds. Generally, interest rates slope upwards with duration as shown in Figure 5.5.1. Therefore the bank can make a greater return by purchasing and holding assets for longer duration. The downside is that if these assets need to be sold before expiry then they could experience a significant loss. Due to bond dynamics such as bid/ask spread and market liquidity premia, it would generally be better (on average) for the bank to hold a 1 year bond rather than a 2 year bond that is sold at time 1. Similarly, a bank would expect to get a better return from holding a 2 year bond rather than rolling 1 year bonds due to the market liquidity premium. Therefore, ideally the bank would like to match the assets holding perfectly with the expiry of the liabilities.

At time 1, customers withdraw some of their money. x is the proportion withdrawn and the amount withdrawn will be:

$$\text{Withdrawals} = xD(1 + i_D(0,1)).$$

The initial 1 year assets purchased at time 0 will mature:

$$1 \text{ year assets maturing} = U_B(0,1)P_B(1,1) + U_A(0,1)P_A(1,1).$$

Depending on the amount withdrawn, one of three situations will occur:
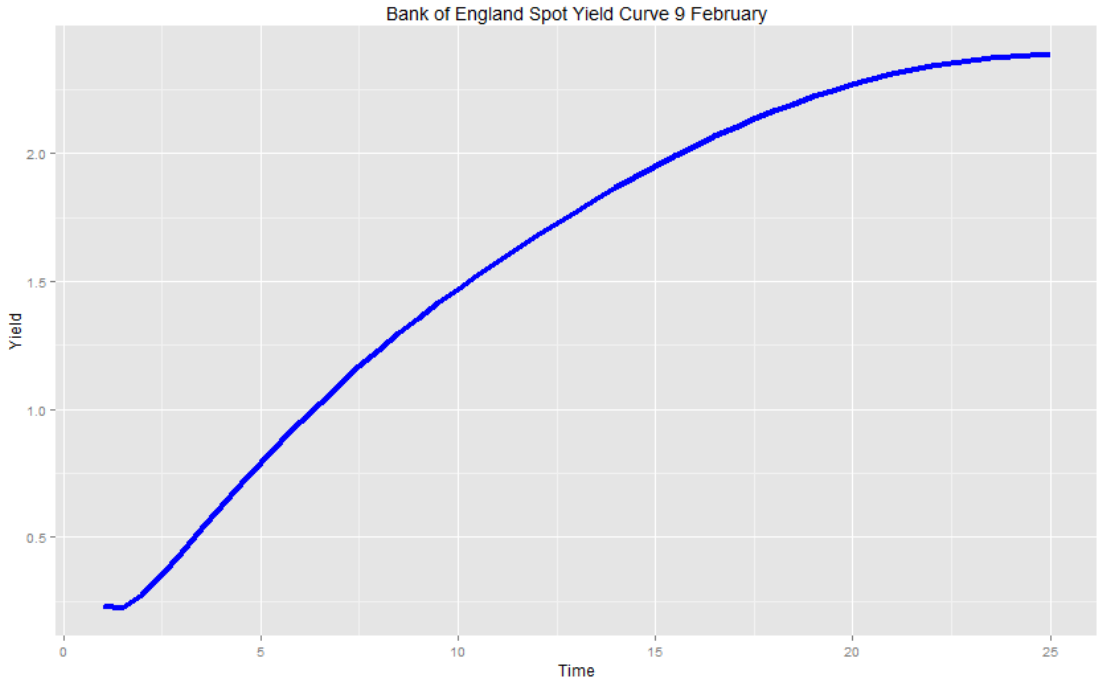
Figure 5.5.1: Bank of England spot yield curve based on UK Government yields at 9 February 2016

1. **Withdrawals in line with expectations i.e. $x = \gamma$:** The bank will be expected to make a profit as the return on the 1 year maturing assets will be greater than the interest paid on deposits:

$$\text{Surplus} = U_B(0,1)P_B(1,1) + U_A(0,1)P_A(1,1) - xD(1 + i_D(0,1)).$$

2. **Withdrawals less than expected i.e. $x < \gamma$:** Additional 1 year bonds and liquid assets will need to be purchased to meet the extra withdrawals at time 2. The amount purchased will equal the difference between the actual and expected withdrawals. The split between 1 year bonds and liquid assets will depend on the value of α. Therefore:

$$1 \text{ year bonds purchased at time } 1 = U_B(1,2)\overline{P}_B(1,2)$$
$$= I(\gamma \geq x)(\gamma - x)D(1 + i_D(0,1))(1 - \alpha(1,2));$$

1 year liquid assets purchased at time $1 = U_A(1,2)\overline{P}_A(1,2)$

$$= I(\gamma \geq x)(\gamma - x)D(1 + i_D(0,1))\alpha(1,2).$$

As the amount of assets purchased equals the difference between the actual and expected withdrawals, the surplus for the bank at time 1 will just be the excess return over the expected withdrawal at time 1:

$$\text{Surplus} = U_B(0,1)P_B(1,1) + U_A(0,1)P_A(1,1) - \gamma D(1 + i_D(0,1)).$$

3. **Withdrawals greater than expected i.e.** $x > \gamma$**:** The profit at time 1 can be used to fund any excess withdrawals. If this is not sufficient, then the remaining balance can be funded by enforced selling of 2 year bonds and liquid assets. The proportion of 2 year bonds and liquid assets sold will be based on α. Therefore:

2 year bonds sold at time $1 = \lambda_B U_B(0,2)\underline{P}_B(1,2)$

$= \max(xD(1 + i_D(0,1)) - U_B(0,1)P_B(1,1) - U_A(0,1)P_A(1,1)),0)(1 - \alpha(1,2)));$

2 year liquid assets sold at time $1 = \lambda_A U_A(0,2)\underline{P}_A(1,2)$

$= \max(xD(1 + i_D(0,1)) - U_B(0,1)P_B(1,1) - U_A(0,1)P_A(1,1)),0)\alpha(1,2)).$

There will only be a surplus at 1 if the excess withdrawals are less than the additional return from the 1 year asset holding:

$$\text{Surplus} = \max(U_B(0,1)P_B(1,1) + U_A(0,1)P_A(1,1) - xD(1 + i_D(0,1)),0).$$

These situations are combined and summarised in Table 5.5.2.

Table 5.5.2: Cashflows at time 1 for new deposits for a deposit rich bank

Cash inflows from maturing assets and sale of assets		Cash outflow via reinvestment and withdrawal	
$U_B(0,1)P_B(1,1)$		Withdrawals	$= xD(1+i_D(0,1))$
$U_A(0,1)P_A(1,1)$		$U_B(1,2)\overline{P}_B(1,2)$	$= I(\gamma \geq x)(\gamma - x)$
			$D(1+i_D(0,1))(1-\alpha(1,2))$
$\lambda_B U_B(0,2)\underline{P}_B(1,2)$	$= \max(xD(1+i_D(0,1))$	$U_A(1,2)\overline{P}_A(1,2)$	$= I(\gamma \geq x)(\gamma - x)$
	$-U_B(0,1)P_B(1,1)$		$D(1+i_D(0,1))\alpha(1,2)$
	$-U_A(0,1)P_A(1,1)),0)(1-\alpha(1,2)))$		
$\lambda_A U_A(0,2)\underline{P}_A(1,2)$	$= \max(xD(1+i_D(0,1))$		
	$-U_B(0,1)P_B(1,1)$		
	$-U_A(0,1)P_A(1,1)),0)\alpha(1,2))$		
Surplus	$= \max(U_B(0,1)P_B(1,1)$		
	$+U_A(0,1)P_A(1,1)$		
	$-I(\gamma \geq x)\gamma D(1+i_D(0,1))$		
	$-I(x > \gamma)xD(1+i_D(0,1)),0)$		

At time 2, we will look to see how these three situations have developed. All the assets will mature and all the remaining deposits are withdrawn. The amount of deposits withdrawn are:

$$\text{Withdrawals} = (1-x)D(1+i_D(0,2))^2.$$

1. **Withdrawals in line with expectations i.e.** $x = \gamma$**:** The bank will be expected to make a profit as the return on the 2 year maturing assets will be greater than the interest paid on deposits:

   $$\text{Assets maturing at time 2} = (1-\lambda_B)U_B(0,2)P_B(2,2)+(1-\lambda_A)U_A(0,2)P_A(2,2).$$

   Note that $\lambda_B = \lambda_A = 0$ as no 2 year assets are sold at time 1. The bank will be expected to make a profit as the return on the 2 year maturing assets will be greater than the interest paid on deposits:

   $$\text{Surplus} = (1 - \lambda_B)U_B(0,2)P_B(2,2) + (1 - \lambda_A)U_A(0,2)P_A(2,2)$$
   $$- (1-x)D(1+i_D(0,2))^2.$$

2. **Withdrawals less than expected i.e. $x < \gamma$:** The assets that mature at time 2 will be the additional assets purchased at time 1 plus the initial 2 year assets purchased at time 0:

$$\text{Assets maturing at time } 2 = (1-\lambda_B)U_B(0,2)P_B(2,2)+(1-\lambda_A)U_A(0,2)P_A(2,2)$$
$$+ U_B(1,2)P_B(2,2)U_A(1,2)P_A(2,2).$$

Note that $\lambda_B = \lambda_A = 0$ as no 2 year assets are sold at time 1. The difference between the value of the assets maturing and the amount withdrawn will be the surplus for the bank at time 2:

$$\text{Surplus} = (1 - \lambda_B)U_B(0,2)P_B(2,2) + (1 - \lambda_A)U_A(0,2)P_A(2,2)$$
$$+ U_B(1,2)P_B(2,2) + U_A(1,2)P_A(2,2) - (1 - x)D(1 + i_D(0,2))^2.$$

The bank's surplus is expected to be higher under this situation than the previous one. This is because the bank is expected to make a greater return from the assets than it pays the deposits in interest, the longer deposits stay within the bank the greater the bank's surplus will be.

3. **Withdrawals greater than expected i.e. $x > \gamma$:** Only the remaining 2 year assets that were purchased at time 0, and which were not sold at time 1, will mature at time 2:

$$\text{Assets maturing at time } 2 = (1-\lambda_B)U_B(0,2)P_B(2,2+(1-\lambda_A)U_A(0,2)P_A(2,2).$$

The surplus will be the difference between these assets and the amount withdrawn at time 2:

$$\text{Surplus} = (1 - \lambda_B)U_B(0,2)P_B(2,2) + (1 - \lambda_A)U_A(0,2)P_A(2,2)$$

$$- (1 - x)D(1 + i_D(0,2))^2.$$

Comparing this with the situation where withdrawals are less than expected, the value of the assets at time 2 will be less but so will the amount withdrawn at time 2. This will lead to less profits at time 2 for the bank when withdrawals are greater than expected.

These situations are combined and summarised in Table 5.5.3.

Table 5.5.3: Cashflows at time 2 for new deposits for a deposit rich bank

Cash inflows from maturing assets		Cash outflow via withdrawal
$(1 - \lambda_B)U_B(0,2)P_B(2,2)$ $(1 - \lambda_A)U_A(0,2)P_A(2,2)$ $U_B(1,2)P_B(2,2)$ $U_A(1,2)P_A(2,2)$		Withdrawals $= (1 - x)D(1 + i_D(0,2))^2$
Surplus	$\begin{aligned}&= (1 - \lambda_B)U_B(0,2)P_B(2,2)\\ &+(1 - \lambda_A)U_A(0,2)P_A(2,2)\\ &+U_B(1,2)P_B(2,2)\\ &+U_A(1,2)P_A(2,2)\\ &-(1 - x)D(1 + i_D(0,2))^2\end{aligned}$	

It will be easier to see how these approaches work by looking at examples. We will now look at three examples:

- Example 5.5.1: When withdrawals are in line with expectations

- Example 5.5.2: When withdrawals are less than expected

- Example 5.5.3: When withdrawals are greater than expected

In these examples we will use the assumptions shown in Table 5.5.4. The assumptions have been chosen to emphasise the impact and markets conditions may not represent the same magnitude. Important points regarding the assumptions are that:

- the rolling 1 year return on bonds is less than the 2 year bond holding return; and

- the return on 2 year bond holding when sold at time 1 is less than the return on 1 year bond holding.

These two conditions ensure that the deposit unit is penalised for the uncertainty and for causing funding liquidity risk.

Table 5.5.4: Assumptions for the examples when looking at deposits when the bank is deposit rich

Variables	Values
D	£100m
$\overline{W}_L(0,1)$	5.4%
$\overline{W}_L(0,2)$	5.9%
$\overline{W}_L(1,2)$	5.9%
$\underline{W}_L(1,2)$	7.9%
$i_A(0,1) = i_A(0,2) = \bar{i}_A(1,2) = \underline{i}_A(1,2)$	3.0%
$i_D(0,1) = i_D(0,2)$	2.5%
$\alpha(0,1) = \alpha(0,2) = \alpha(1,2)$	5%
$E(0,1) = E_{1,2} = E(0,2)$	5.4%

Example 5.5.1. *When withdrawals are in line with expectations*
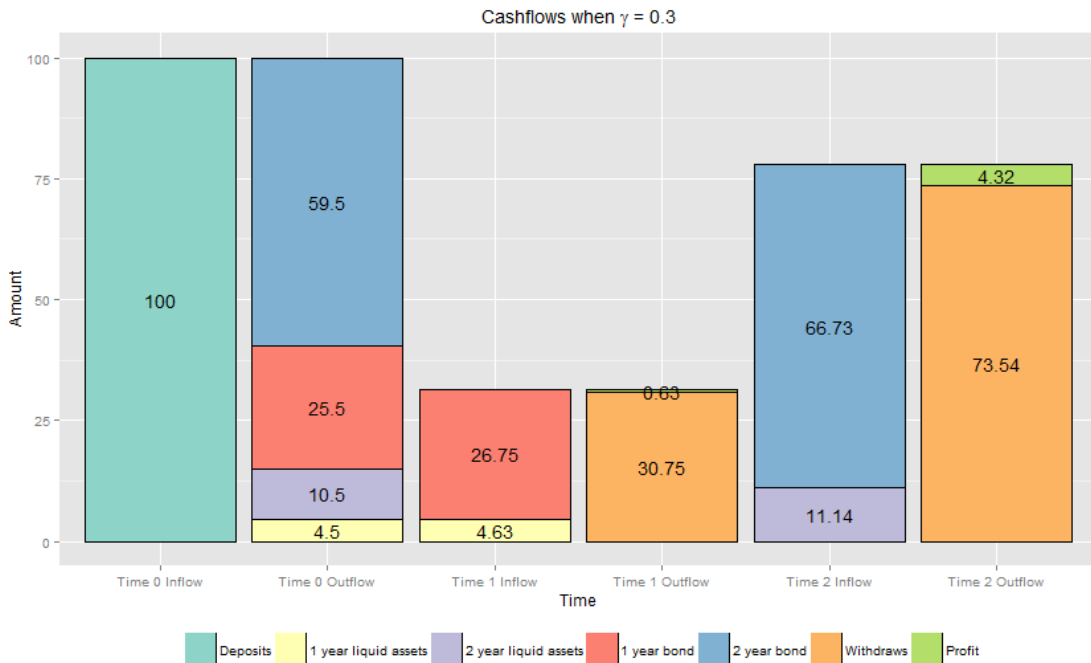
Figure 5.5.2: Chart showing the cashflows for new deposits for a deposit rich bank when $x = \gamma$

We will first look at an example of when cashflows are in line with expectations. Figure 5.5.2 shows the expected cashflows at each time period. At time 0, the initial

deposits are £100m, these deposits are used to purchase bonds and liquid assets of durations 1 and 2 years. The proportion between bonds and liquid assets depends on α and we will set this as $\alpha = \alpha(0,1) = \alpha(0,2) = \alpha(1,2) = 5\%$. If we assume that at time 1, 30% of deposits are withdrawn, so $\gamma = 30\%$. Table 5.5.5 shows the expected cashflows at time 0, while Table 5.5.6 shows the balance sheet at time 0.

Table 5.5.5: Cashflows at time 0 for new deposits for a deposit rich bank when $x = \gamma$

Inflow		Asset Allocation		
Deposits	100	1 Year Bonds	$U_B(0,1)\overline{P}_{B0,1}(0)$	$= 0.3 \times 100 \times (1 - 0.05) = 25.5$
		1 Year Liquid assets	$U_A(0,1)\overline{P}_{L0,1}(0)$	$= 0.3 \times 100 \times 0.05 = 4.5$
		2 Year Bonds	$U_B(0,2)\overline{P}_{B0,2}(0)$	$= (1 - 0.3) \times 100 \times (1 - 0.05) = 59.5$
		2 Year Liquid assets	$U_A(0,2)\overline{P}_{L0,2}(0)$	$= (1 - 0.3) \times 100 \times 0.05 = 10.5$

Table 5.5.6: Balance sheet at time 0 for new deposits for a deposit rich bank when $x = \gamma$

Balance Sheet			
Time 0			
Assets	100	Liabilities	100
Recognised Profit	0	Unrecognised Profit	0
		Shareholder Equity	0
Total	100	Total	100

At time 1, the 1 year asset holdings will mature and these will be used to pay 30% of the deposits that are withdrawn at time 1. The 1 year asset holdings will have generated a return which is assumed to be greater than the interest on deposits. As such, the bank will also make a profit at time 1. This can be seen in Figure 5.5.2 and Table 5.5.7. Table 5.5.8 shows the impact on the balance sheet.

Table 5.5.7: Cashflows at time 1 for new deposits for a deposit rich bank when $x = \gamma$

Cash inflows from maturing assets		Cash outflow via withdrawal	
$U_B(0,1)P_B(1,1)$	26.75	Withdrawals	30.75
$U_A(0,1)P_A(1,1)$	4.63		
Surplus	0.63		

At time 2, the 2 year assets holdings will mature and the remaining deposits will be withdrawn. The bank will make a profit of the difference between the value of assets and the amount withdrawn. The impact on cashflows is shown in Figure 5.5.2 and Table 5.5.9. Table 5.5.10 shows the effect on the balance sheet.

Table 5.5.8: Balance sheet at time 1 for new deposits for a deposit rich bank when $x = \gamma$

Balance Sheet					
Time 1 Before			Time 1 After		
Asset	104.4	Liabilities	102.50	Assets	72.66	Liabilities	71.75
Recognised Profit	0	Unrecongised Profit	1.54	Recognised Profit	0.63	Unrecognised Profit	0.91
		Shareholder Equity	0			Shareholder Equity	0.63
Total	104.4	Total	104.04	Total	73.29	Total	73.29

Table 5.5.9: Cashflows at time 2 for new deposits for a deposit rich bank when $x = \gamma$

Cash inflows from maturing assets		Cash outflow via withdrawal	
$U_B(0,2)P_B(2,2)$	66.73	Withdrawals	73.54
$U_A(0,2)P_A(2,2)$	11.14		
Surplus	4.32		

Table 5.5.10: Balance sheet at time 2 for new deposits for a deposit rich bank when $x = \gamma$

Balance Sheet					
Time 2 Before			Time 2 After		
Asset	77.87	Liabilities	73.54	Assets	0	Liabilities	0
Recognised Profit	0.67	Unrecognised Profit	4.32	Recognised Profit	4.99	Unrecognised Profit	0
		Shareholder Equity	0.67			Shareholder Equity	4.99
Total	78.54	Total	78.54	Total	4.99	Total	4.99

Example 5.5.2. *When withdrawals are less than expected*

Figure 5.5.3: Chart showing the cashflows for new deposits for a deposit rich bank when $x < \gamma$

We will now look at the example when withdrawals are less than expected. In this example, we will assume that 30% of deposits are expected to be withdrawn at time 1, when in fact only 20% are actually withdrawn. Figure 5.5.3 shows the cashflows at each time period. At time 0, the initial allocation between 1 year and 2 year assets will be the same as in Example 5.5.1. The balance sheet at time 0 will also be the same as in Example 5.5.1. It is at time 1 when things will change.

At time 1, the year 1 assets holdings will mature. These will be more than sufficient to cover the actual withdrawal at time 1. However, some of these assets were set aside to meet certain deposits which have not been withdrawn. Therefore some of the assets will need to be reinvested for another year. We reinvest the difference between actual and expected withdrawal for another year. The expected rate of return on these reinvested assets will not be known until time 1. The cashflows can be seen in Figure 5.5.3 and Table 5.5.11. Table 5.5.12 shows the balance sheet at time 1.

If we compare Table 5.5.12 and Table 5.5.8 from Example 5.5.1, we can see that

Table 5.5.11: Cashflows at time 1 for new deposits for a deposit rich bank when $x < \gamma$

Cash inflows from maturing assets and sale of assets		Cash outflow via reinvestment and withdrawal	
$U_B(0,1)P_B(1,1)$	26.75	Withdrawals	20.5
$U_A(0,1)P_A(1,1)$	4.63	$U_B(1,2)\overline{P}_B(1,2)$	8.71
		$U_A(1,2)\overline{P}_A(1,2)$	1.54
Surplus	0.63		

Table 5.5.12: Balance sheet at time 1 for new deposits for a deposit rich bank when $x < \gamma$

Balance Sheet							
Time 1 Before				Time 1 After			
Asset	104.4	Liabilities	102.50	Assets	82.91	Liabilities	82.00
Recognised Profit	0	Unrecognised Profit	1.54	Recognised Profit	0.63	Unrecognised Profit	0.91
		Shareholder Equity	0			Shareholder Equity	0.63
Total	104.4	Total	104.04	Total	83.54	Total	83.54

at time 1 before the withdrawals happen the balance sheets are the same. It is after the withdrawal happens that the difference occurs. The assets and liabilties are higher in Table 5.5.12, since less money is withdrawn at time 1. The profit is still the same at time 1 as the the excess assets are reinvested at time 1 to cover the extra deposits that will be now withdrawn at time 2.

At time 2, the 2 year assets, as well as the additional 1 year assets purchased at time 1, will mature. This will be used to fund the higher withdrawal at time 2 since less money was withdrawn at time 1. The difference between the assets values and the amount of deposits withdrawn at time 2 will be the profit for the bank. This can be seen in Figure 5.5.3 and Table 5.5.13. Table 5.5.14 shows the balance sheet at time 2.

Table 5.5.13: Cashflows at time 2 for new deposits for a deposit rich bank when $x < \gamma$

Cash inflows from maturing assets		Cash outflow via withdrawal	
$U_B(0,2)P_B(2,2)$	66.73	Withdrawal	84.05
$U_A(0,2)P_A(2,2)$	11.14		
$U_B(1,2)P_B(2,2)$	9.23		
$U_A(1,2)P_A(2,2)$	1.58		
Surplus	4.63		

Table 5.5.14 shows higher profits at time 2 than compared to Table 5.5.10. This is due to the deposits remaining in the bank for longer. Since assets generate returns higher than the interest paid on deposits, it increases the bank's profits. Therefore it is better for the bank if deposits remain in the bank for longer. We will see later

Table 5.5.14: Balance sheet at time 2 for new deposits for a deposit rich bank when $x < \gamma$

Balance Sheet							
Time 2 Before				Time 2 After			
Asset	88.68	Liabilities	84.05	Assets	0	Liabilities	0
Recognised Profit	0.67	Unrecognised Profit	4.63	Recognised Profit	5.3	Unrecognised Profit	0
		Shareholder Equity	0.67			Shareholder Equity	5.3
Total	89.35	Total	89.35	Total	5.3	Total	5.3

that the bank could have generated higher profits if it had predicted the withdrawal correctly.

Example 5.5.3. *When withdrawals are greater than expected*

In this example, we will look at what happens when withdrawals are greater than expected at time 1. We will assume that expected withdrawals at time 1 are 30% when the actual withdrawals turn out to be 40%. The assets are split into bonds and liquid assets in the same way as Example 5.5.1 since the expectation of withdrawals is the same. Therefore the initial balance sheet will be the same. Figure 5.5.4 shows the cashflows when withdrawals are greater than expected.
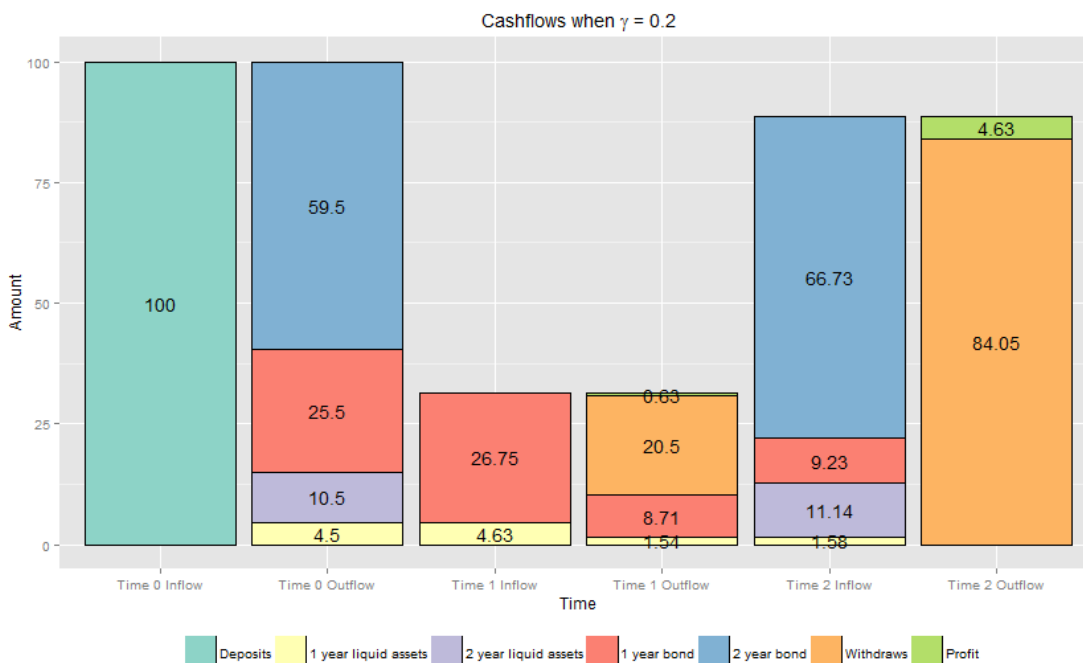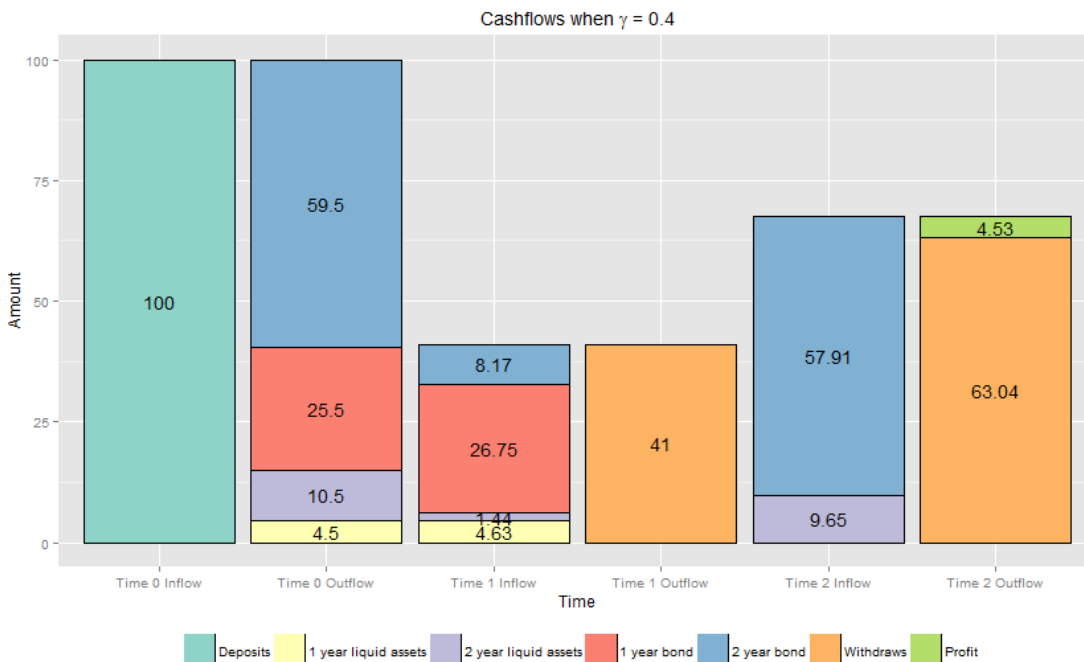

Figure 5.5.4: Chart showing the cashflows for new deposits for a deposit rich bank when $x > \gamma$

At time 1, the assets maturing will not be enough to cover the withdrawal. Even with the additional return on the assets, this will still not be enough to cover the

withdrawals at time 1. Therefore, some of the 2 year bond holdings will need to be sold at time 1. The exact price of selling will be unknown as it will depend on interest rates at time 1. Also the bank will have to sell at the selling price which is penal compared to the buying price due to the bid/ask spread and market liquidity premium. The bank will sell just enough assets to meet the withdrawal demands after the 1 year assets have been exhausted. This can be seen in Figure 5.5.4 and in Table 5.5.15.

Table 5.5.15: Cashflows at time 1 for new deposits for a deposit rich bank when $x > \gamma$

Cash inflows from maturing assets and sale of assets		Cash outflow via withdrawal	
$U_B(0,1)P_B(1,1)$	26.75	Withdrawal	41
$U_A(0,1)P_A(1,1)$	4.63		
$\lambda_B U_B(0,2)\underline{P}_B(1,2)$	8.17		
$\lambda_A U_A(0,2)\underline{P}_A(1,2)$	1.44		
Surplus	0		

Table 5.5.16: Balance sheet at time 1 for new deposits for a deposit rich bank when $x > \gamma$

Balance Sheet							
Time 1 Before				Time 1 After			
Asset	104.4	Liabilities	102.50	Assets	63.04	Liabilities	61.50
Recognised Profit	0	Unrecognised Profit	1.54	Recognised Profit	0	Unrecognised Profit	1.54
		Shareholder Equity	0			Shareholder Equity	0
Total	104.4	Total	104.04	Total	63.04	Total	63.04

Table 5.5.16 shows the balance sheet at time 1. When we compare this to Table 5.5.8 in Example 5.5.1, we see that the assets and liabilities are less because more withdrawals have occurred at time 1. We can also see that no profit has been recognised at time 1, this is because it has been used to fund the withdrawals and help reduce the amount of 2 year bond holdings that need to be sold.

At time 2, the remaining 2 year assets, that were not sold at time 1, will mature. This will be used to pay back the deposits at time 2. The difference between the assets and the deposits at time 2 will be the profit for the bank. The cashflows can be seen in Figure 5.5.4 and Table 5.5.17. The balance sheet can be seen in Table 5.5.18.

When we compare Table 5.5.18 to Table 5.5.10 in Example 5.5.1, we see that the profit for the bank is lower. This is due to deposits remaining in the bank for less

Table 5.5.17: Cashflows at time 2 for new deposits for a deposit rich bank when $x > \gamma$

Cash inflows from maturing assets		Cash outflow via withdrawal	
$(1 - \lambda_B)U_B(0,2)P_B(2,2)$	57.91	Withdrawals	63.04
$(1 - \lambda_A)U_A(0,2)P_A(2,2)$	9.65		
Surplus	4.53		

Table 5.5.18: Balance sheet at time 2 for new deposits for a deposit rich bank when $x > \gamma$

Balance Sheet							
Time 2 Before				Time 2 After			
Asset	67.56	Liabilities	63.04	Assets	0	Liabilities	0
Recognised Profit	0	Unrecognised Profit	4.53	Recognised Profit	4.53	Unrecognised Profit	0
		Shareholder Equity	0			Shareholder Equity	4.53
Total	67.56	Total	67.56	Total	4.53	Total	4.53

time and also having to sell 2 year assets at time 1, which may generate less return due to market liquidity premium.

These three examples demonstrate what happens when we set expected withdrawal at 30% and the actual withdrawal is equal, less than and greater than expected at time 1. Figure 5.5.5 shows what the profit would be for each withdrawal level. As we would expect, less withdrawal the higher the profits and more withdrawal the lower the profits. In this example, we have emphasised the market liquidity premium so you can clearly see the difference in the slope of line when withdrawals are less and greater than expected. If we look closely, there are two kinks in the line. The first kink is at the expected withdrawal, the blue line. Before this point the line is a straight slope, due to deposits staying longer and having to purchase additional assets at time 1 using the surplus cash. The second kink is very close to the expected withdrawal, the red line. Between the blue and red lines, the profits are used to finance the additional withdrawals but no sale of assets is required. After this point, the line slopes down more steeply and in this section this is due to the 2 year asset holdings being sold to cover the additional withdrawals.

Figure 5.5.6 shows the profit when we set different values of γ as our expected withdrawal. As can be seen there is no one line, or expectation of γ, that generates the best profit for the bank. For a given withdrawal amount, the profits are maximised when the expected withdrawal is set equal to the withdrawal amount. If the expected withdrawal is different from the actual withdrawal, this will be less
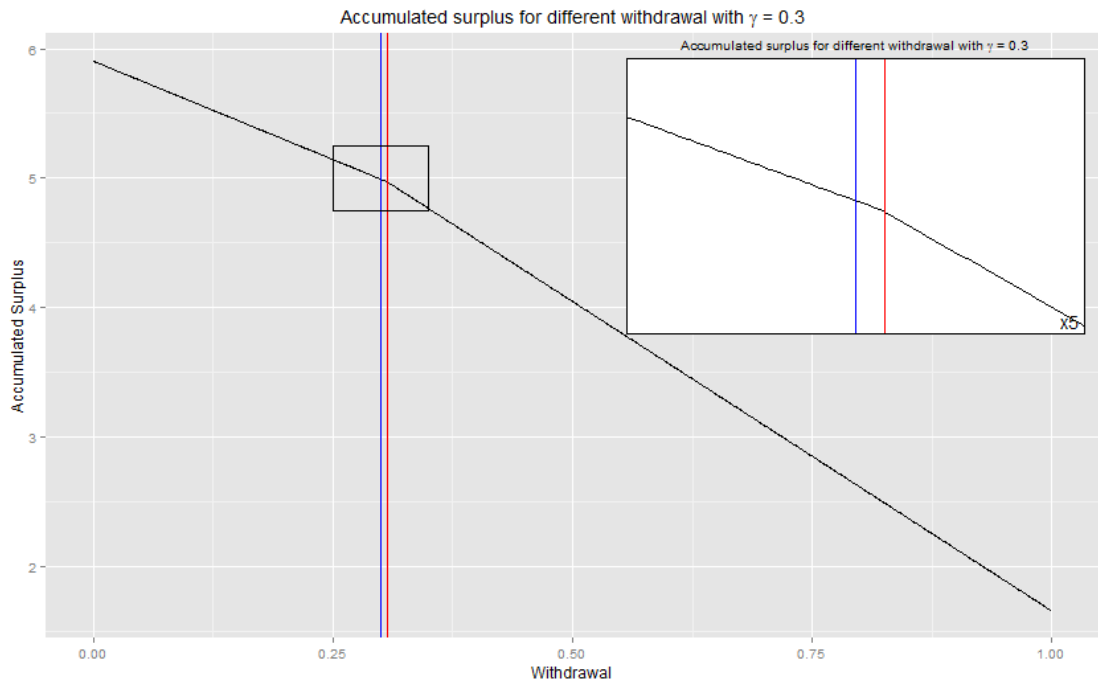
Figure 5.5.5: Surplus for the deposit unit at various levels of withdrawal when the bank is deposit rich and $\gamma = 0.3$

optimal. This shows why the bank wants to get their expectation of withdrawal correct.

This approach tries to ensure that the bank has to take a minimal amount of action. If withdrawals are less than expected then the bank will purchase assets just sufficient to cover the difference between actual and expected withdrawal. This would be the minimum amount the bank would need to cover the additional deposits to be paid at time 2. If withdrawals are greater than expected the bank will initially use the profits to fund the extra withdrawal. If this is not sufficient, the bank will then sell 2 year assets. The bank is selling the minimum amount of assets to meet the withdrawal. Therefore the bank is reducing the penalty effect. The downside is that the bank may end up holding more 2 year bonds and liquid assets than required.
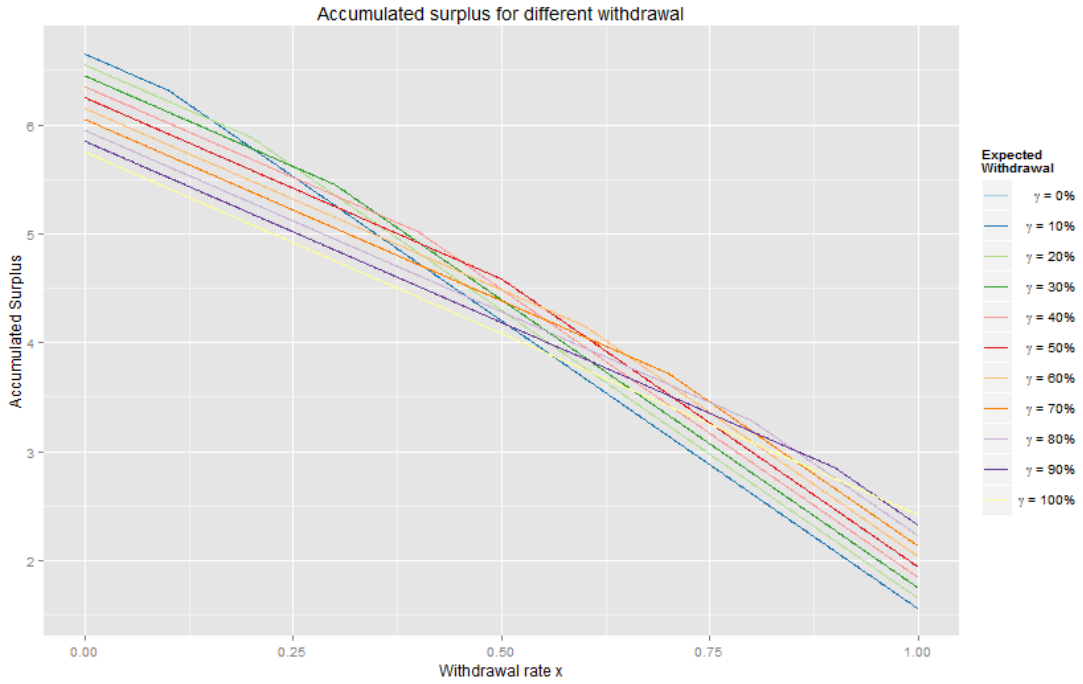
Figure 5.5.6: Accumulated surplus for different expected withdrawals for the deposit unit when bank is deposit rich

5.5.2   Approach 2: Assets assigned to deposits

We have described how approach 1 works where the profits at time 1 are initially used to fund withdrawals before 2 year assets have to be sold. An alternative approach, is where the initial assets are assigned to a liabilty. So when the money is withdrawn the assets are sold. We will go through the mathematics and look at an example of how this works. As in approach 1, units of liquid assets and bonds are assumed to be purchased with the money from deposits. This would represent the fair investment of the deposits based on the expected withdrawal at time 1. There is no difference here between approach 1 or approach 2. This is shown in Table 5.5.19.

Table 5.5.19: Cashflows at time 0 for new deposits for a deposit rich bank under approach 2

Inflow	Asset Allocation	
Deposits $= D$	$U_B(0,1)\overline{P}_{B0,1}(0)$	$= \gamma D(1 - \alpha(0,1))$
	$U_A(0,1)\overline{P}_A(0,1)$	$= \gamma D\alpha(0,1)$
	$U_B(0,2)\overline{P}_B(0,2)$	$= (1 - \gamma)D(1 - \alpha(0,2))$
	$U_A(0,2)\overline{P}_A(0,2)$	$= (1 - \gamma)D\alpha(0,2)$

At time 1, there is a difference in the approaches. We will look at three situations to see how the approaches differs.

1. **Withdrawals in line with expectations i.e. $x = \gamma$:** This is the same as approach 1. The bank will be expected to make a profit as the return on the 1 year maturing assets will be greater than the interest paid on deposits:

$$\text{Surplus} = U_B(0,1)P_B(1,1) + U_A(0,1)P_A(1,1) - xD(1 + i_D(0,1)).$$

2. **Withdrawals less than expected i.e. $x < \gamma$:** the initial assets that were used to back these deposits will be reinvested for another year:

$$\text{1 year bonds purchased at time } 1: U_B(1,2)\overline{P}_B(1,2) = I(\gamma \geq x)\frac{(\gamma - x)}{\gamma};$$

$$\text{1 year liquid assets purchased at time } 1: U_A(1,2)\overline{P}_A(1,2) = I(\gamma \geq x)\frac{(\gamma - x)}{\gamma}.$$

The surplus for the bank at time 1 will be the return on the 1 year assets less the amount withdrawn, less the amount reinvested:

$$\text{Surplus} = U_B(0,1)P_B(1,1) + U_A(0,1)P_A(1,1) - U_B(1,2)\overline{P}_B(1,2) - U_A(1,2)\overline{P}_A(1,2)$$
$$- xD(1 + i_D(0,1)).$$

This means the surplus is only released when withdrawal occurs.

3. **Withdrawals greater than expected i.e. $x > \gamma$:** The initial assets that were used to back these deposits will be sold:

$$\text{2 year bonds sold at time } 1: \lambda_B U_B(0,2)\underline{P}_B(1,2) = I(\gamma < x)\frac{(x - \gamma)}{(1 - \gamma)};$$

$$\text{2 year liquid assets sold at time } 1: = I(\gamma < x)\frac{(x - \gamma)}{(1 - \gamma)}.$$

The amount of assets of 2 year assets that are sold at time 1 are the assets that were set aside for these deposits. It is as if we had anticipated this withdrawal was going to happen at time 2 rather than time 1. The bank will receive the profit or loss at time 1 for the excess withdrawals at time 1. This is useful as it releases the profit for the bank when the deposits leave the bank. The surplus at time 1 would be:

$$\text{Surplus} = U_B(0,1)P_B(1,1) + U_A(0,1)P_A(1,1) + \lambda_B U_B(0,2)\underline{P}_B(1,2)$$
$$+ \lambda_A U_A(0,2)\underline{P}_A(1,2) - xD(1 + i_D(0,1)).$$

These approaches are combined and summarised in Table 5.5.20.

Table 5.5.20: Cashflows at time 1 for new deposits for a deposit rich bank under approach 2

Cash inflows from maturing assets and sale of assets		Cash outflow via reinvestment and withdrawal	
$U_B(0,1)P_B(1,1)$		Withdrawals	$= xD(1 + i_D(0,1))$
$U_A(0,1)P_A(1,1)$		$U_B(1,2)\overline{P}_B(1,2)$ $= I(\gamma \ge x)\frac{(\gamma - x)}{\gamma}$	
$\lambda_B U_B(0,2)\underline{P}_B(1,2)$ $= I(\gamma < x)\frac{(x-\gamma)}{(1-\gamma)}$		$U_A(1,2)\overline{P}_A(1,2)$ $= I(\gamma \ge x)\frac{(\gamma - x)}{\gamma}$	
$\lambda_A U_A(0,2)\underline{P}_A(1,2)$ $= I(\gamma < x)\frac{(x-\gamma)}{(1-\gamma)}$			
Surplus	$= U_B(0,1)P_B(1,1)$ $+U_A(0,1)P_A(1,1)$ $+\lambda_B U_B(0,2)\underline{P}_B(1,2)$ $+\lambda_A U_A(0,2)\underline{P}_A(1,2)$ $-U_B(1,2)\overline{P}_B(1,2)$ $-U_A(1,2)\overline{P}_A(1,2)$ $-xD(1 + i_D(0,1))$		

At time 2, the assets will mature and these will be used to pay back the remaining deposits. This is the same as in approach 1. Table 5.5.21 shows the cashflows calculations at time 2.

We will now look at an example of how this works. Approach 2 is the same as approach 1 for when actual withdrawals are equal to expected withdrawals. Therefore we will look at what happens when withdrawals are less than or greater than expected. We will also comment on the difference between this approach and approach 1.

Example 5.5.4. *When withdrawals are less than expected under approach 2*

Table 5.5.21: Cashflows at time 2 for new deposits for a deposit rich bank under approach 2

Cash inflows from maturing assets		Cash outflows via withdrawal
$(1 - \lambda_B)U_B(0,2)P_B(2,2)$		Withdrawals $= (1-x)D(1+i_D(0,2))^2$
$(1 - \lambda_A)U_A(0,2)P_A(2,2)$		
$U_B(1,2)P_B(2,2)$		
$U_A(1,2)P_A(2,2)$		
Surplus	$= (1-\lambda_B)U_B(0,2)P_B(2,2)$	
	$+(1-\lambda_A)U_A(0,2)P_A(2,2)$	
	$+U_B(1,2)P_B(2,2)$	
	$+U_A(1,2)P_A(2,2)$	
	$-(1-x)D(1+i_D(0,2))^2$	

We will work through the same case as in Example 5.5.2. This is the case when withdrawals are less than expected at time 1. We will assume that expected withdrawals at time 1 are 30% when the actual withdrawal turns out to be 20%. The assets are split into bonds and liquid assets in the same way as in Example 5.5.1 since the expected withdrawals are the same. Therefore the initial balance sheet will be the same. Figure 5.5.7 shows the cashflows when withdrawals are less than expected.

Figure 5.5.7: Chart showing the cashflows for new deposits for a deposit rich bank when $x < \gamma$ under approach 2

At time 1, withdrawals are less than expected so some 1 year assets will need to be reinvested. At time 0, each deposit is perfectly matched with assets, we will

now reinvest the 1 year assets holdings that initially covered these deposits that were expected to be withdrawn. The cashflows can be seen in Figure 5.5.8 and Table 5.5.22. The balance sheet is shown in Table 5.5.27.

Table 5.5.22: Cashflows at time 1 for new deposits for a deposit rich bank when $x < \gamma$ under approach 2

Cash inflows from maturing assets		Cash outflows via reinvestment and withdrawal	
$U_B(0,1)P_B(1,1)$	26.75	Withdrawals	20.5
$U_A(0,1)P_A(1,1)$	4.64	$U_B(1,2)\overline{P}_B(1,2)$	8.92
		$U_A(1,2)\overline{P}_A(1,2)$	1.55
Surplus	0.42		

Table 5.5.23: Balance sheet at time 1 for new deposits for a deposit rich bank when $x < \gamma$ under approach 2

Balance Sheet							
Time 1 Before				Time 1 After			
Asset	104.4	Liabilities	102.50	Assets	83.12	Liabilities	82.00
Recognised Profit	0	Unrecognised Profit	1.54	Recognised Profit	0.42	Unrecognised Profit	1.12
		Shareholder Equity	0			Shareholder Equity	0.42
Total	104.4	Total	104.04	Total	83.54	Total	83.54

If we compare Table 5.5.23 with Table 5.5.12 we can see the impact on the balance sheet at time 1. Table 5.5.23 shows that the assets are greater at time 1 as we have reinvested more of the 1 year asset holdings. The profit at time 1 is less as we are only recognising the profit when the deposits are withdrawn.

At time 2, the additional 1 year assets and 2 year assets will mature. This will be used to pay back the deposits at time 2. The difference between the assets and the deposits at time 2 will be the profit for the bank. The cashflows can be seen in Figure 5.5.8 and Table 5.5.28. The balance sheet is shown in Table 5.5.29.

Table 5.5.24: Cashflows at time 2 for new deposits for a deposit rich bank when $x < \gamma$ under approach 2

Cash inflows from maturing assets		Cash outflows via withdrawal	
$(1 - \lambda_B)U_B(0,2)P_B(2,2)$	57.20	Withdrawals	63.04
$(1 - \lambda_A)U_A(0,2)P_A(2,2)$	9.55		
Surplus	3.71		

If we compare the balance sheets in Table 5.5.25 and Table 5.5.14, we can see in this example the overall profit for the bank is similar. This is because the extra profit at time 2 has offset the lower profit at time 1. Due to the assumptions, this

Table 5.5.25: Balance sheet at time 2 for new deposits for a deposit rich bank when $x < \gamma$ under approach 2

Balance Sheet							
Time 2 Before				Time 2 After			
Asset	88.90	Liabilities	84.05	Assets	0	Liabilities	0
Recognised Profit	0.45	Unrecognised Profit	4.85	Recognised Profit	5.30	Unrecognised Profit	0
		Shareholder Equity	0.45			Shareholder Equity	5.30
Total	89.35	Total	89.35	Total	5.30	Total	5.30

has meant the overall profit is similar for the bank. If different assumptions are used, these could be different.

Example 5.5.5. *When withdrawals are greater than expected under approach 2*

We will work through the same case as Example 5.5.3. This is the case when withdrawals are greater than expected at time 1. We will assume that expected withdrawals at time 1 are 30% when the actual withdrawal turns out to be 40%. The assets are split into bonds and liquid assets in the same way as in Example 5.5.1 since the expected withdrawals are the same. Therefore the initial balance sheet will be the same. Figure 5.5.8 shows the cashflows when withdrawals are greater than expected.
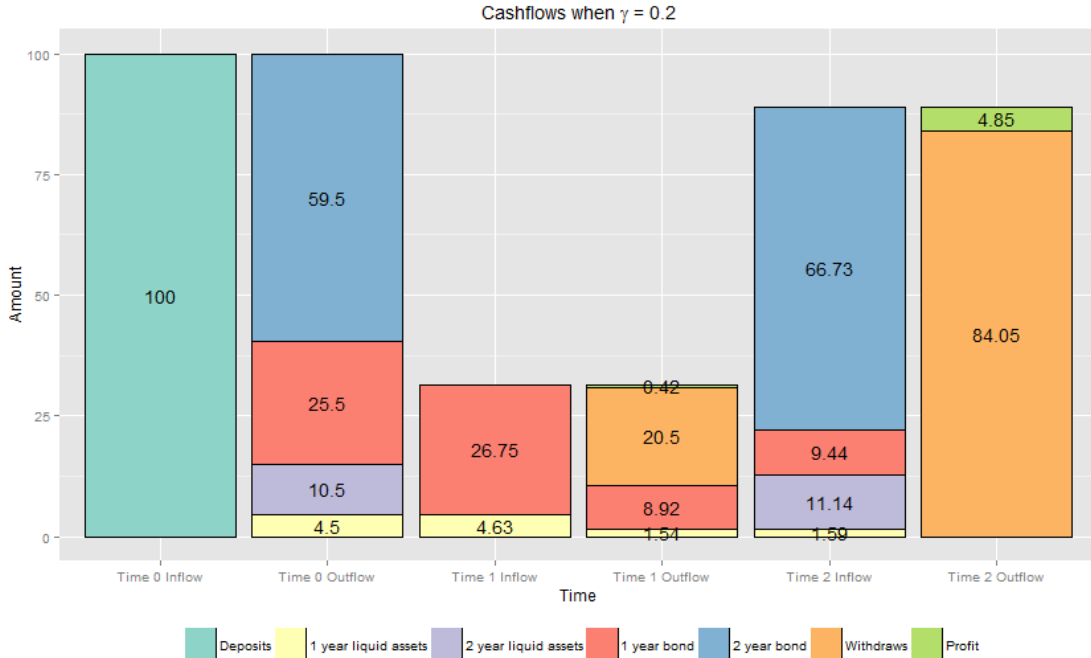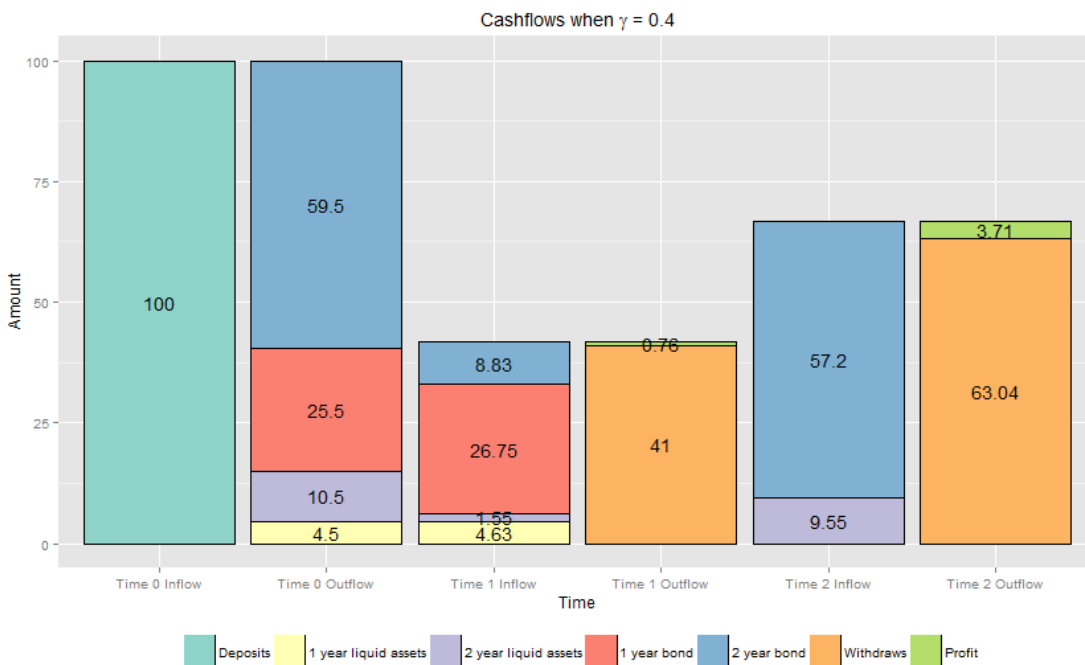

Figure 5.5.8: Chart showing the cashflows for new deposits for a deposit rich bank when $x > \gamma$ under approach 2

At time 1, withdrawals are more than expected so some 2 year assets holdings

will need to be sold. At time 0, each deposit is perfectly matched with assets, so we will now sell the 2 year assets holdings that initially covered these deposits that were withdrawn. The cashflows can be seen in Figure 5.5.8 and Table 5.5.26. The balance sheet is shown in Table 5.5.27.

Table 5.5.26: Cashflows at time 1 for new deposits for a deposit rich bank when $x > \gamma$ under approach 2

Cash inflows from maturing assets and sale of assets		Cash outflow via withdrawal
$U_B(0,1)P_B(1,1)$	26.75	Withdrawals 41
$U_A(0,1)P_A(1,1)$	4.63	
$\lambda_B U_B(0,2)\underline{P}_B(1,2)$	8.83	
$\lambda_A U_A(0,2)\underline{P}_A(1,2)$	1.55	
Surplus	0.76	

Table 5.5.27: Balance sheet at time 1 for new deposits for a deposit rich bank when $x > \gamma$ under approach 2

Balance Sheet					
Time 1 Before			Time 1 After		
Asset	104.4	Liabilities	102.50	Assets	62.28	Liabilities	61.50
Recognised Profit	0	Unrecognised Profit	1.54	Recognised Profit	0.76	Unrecognised Profit	0.78
		Shareholder Equity	0			Shareholder Equity	0.76
Total	104.4	Total	104.04	Total	63.04	Total	63.04

If we compare Table 5.5.27 with Table 5.5.16 we can see the impact on the balance sheet at time 1. Table 5.5.27 shows that the assets are slightly less at time 1 as we have sold more of the 2 year asset holdings. In addition, we are recognising the profit made for the withdrawals at time 1.

At time 2, the remaining 2 year assets, that were not sold at time 1, will mature and this will be used to pay back the deposits at time 2. The difference between the assets and the deposits at time 2 will be the profit for the bank. The cashflows can be seen in Figure 5.5.8 and Table 5.5.28. The the balance sheet is shown in Table 5.5.29.

Table 5.5.28: Cashflows at time 2 for new deposits for a deposit rich bank when $x > \gamma$ under approach 2

Cash inflows from maturing assets		Cash outflow via withdrawal
$(1-\lambda_B)U_B(0,2)P_B(2,2)$	57.20	Withdrawals 63.04
$(1-\lambda_A)U_A(0,2)P_A(2,2)$	9.55	
Surplus	3.71	

There is not that much difference in final recognised profit between the approaches in this example. That is because in approach 2, we recognise profits earlier

Table 5.5.29: Balance sheet at time 2 for new deposits for a deposit rich bank when $x > \gamma$ under approach 2

Balance Sheet						
Time 2 Before				Time 2 After		
Asset	66.74	Liabilities	63.04	Assets	0	Liabilities	0
Recognised Profit	0.81	Unrecognised Profit	3.71	Recognised Profit	4.51	Unrecognised Profit	0
		Shareholder Equity	0.80			Shareholder Equity	4.51
Total	67.55	Total	67.55	Total	4.51	Total	4.51

which will still receive a return from time 1 to time 2. However, the assets are lower so will generate less return and hence have a lower return at time 2. With approach 1, we do not recognise any profits at time 1 as it is used to fund withdrawals. This then means we do not need to sell as much 2 year asset holdings. In this example, the difference is cancelled out but it could potentially be larger if the liquidity market premium is significant at time 1 or return on equity is different.

Figure 5.5.9 shows the profits at different withdrawal levels based on expected withdrawal at 30%. Figure 5.5.9 is similar to Figure 5.5.5 except there is only one kink. The kink occurs at the expected withdrawal level. This is the point where we go from purchasing additional bonds at time 1 to selling 2 year assets holdings at time 1. We see that profits are consistently increasing when actual withdrawals are less than expected. Similarly, we see a consistent decrease in profits when actual withdrawals are greater than expected.

Approach 2 is the preferred approach as it releases the profit when the deposits are withdrawn. Also, this approach keeps the liquid assets in line with the intended purpose. Under approach 1, we could be holding more liquid assets than needed since we are only selling 2 year assets when needed. This means we are keeping a higher proportion of 2 year assets than we need to. This can be seen as positive as we are reducing the amount of 2 year assets we need to sell and so avoid the implications of unfavourable rates and market liquidity premium. While in approach 2, we are selling more 2 year assets as they are no longer needed which could be at a penal rate. However, it is easier to adopt a consistent method to approach 2 to the deposit poor situations and for loans. Therefore the preferred method is approach 2.
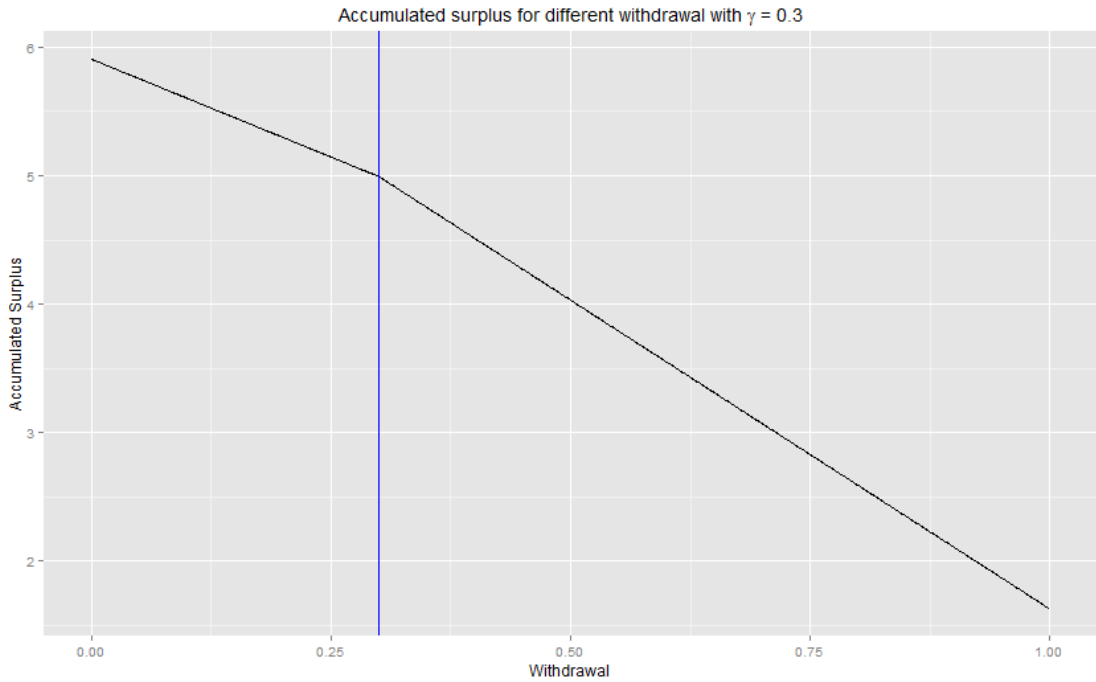
Figure 5.5.9: Surplus for the deposit unit at various levels of withdrawal when the bank is deposit rich and $\gamma = 0.3$ under approach 2

5.5.3 Cost of Option

We have looked at the mechanics of how the FTP rate would be derived and the consequences if the actual withdrawal is different from expectation. We can use this to attempt to price the cost of the option to withdraw deposits. We can plot a graph with multiple assumptions for γ as shown in Figure 5.5.10. For a given withdrawal rate, x, we can see that the profit is maximised when γ equals the withdrawal. This means we should be setting γ in line with our expectations but how do we account for the cost of the uncertainty?

If we first assume that x is fixed, we can calculate the expected profit. Next we can take the distribution of x and calculate the expected profit. The difference between the two is the cost for uncertainty and we can call this the cost for providing the option. This can be shown as:

Cost of Option $= \mathrm{Profit}(\mathbf{E}(x)) - \mathbf{E}(\mathrm{Profit}(x))$.

As the profit function is concave we know from Jensen's inequality:

$\mathbf{E}(f(x)) \leq f(\mathbf{E}[x])$.

Therefore in our case:
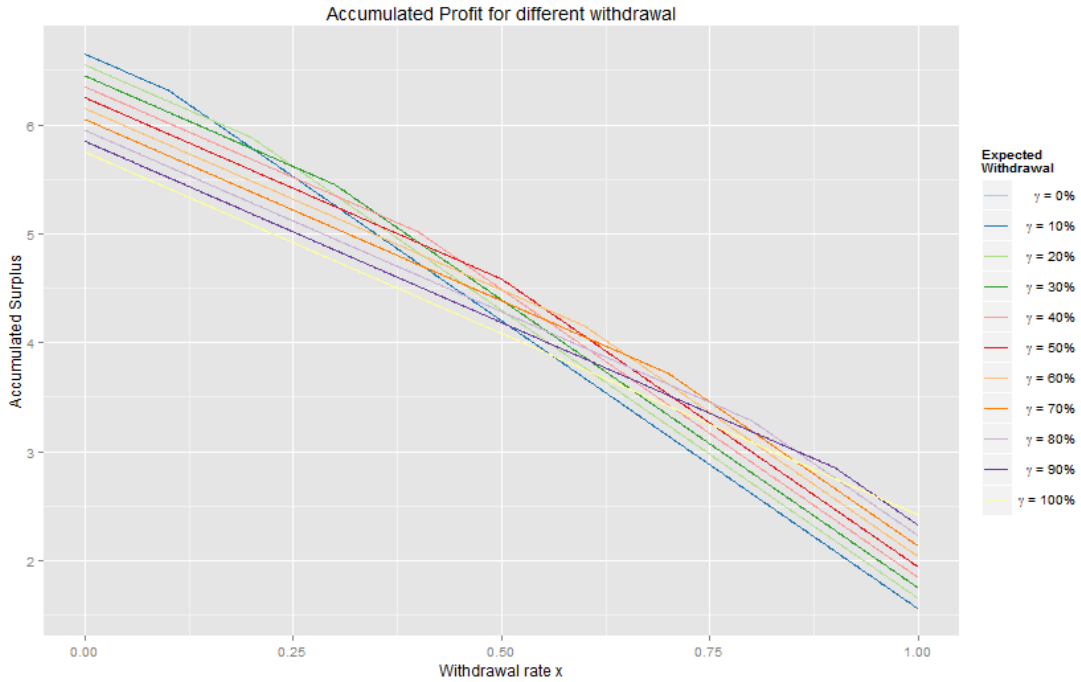
Figure 5.5.10: Accumulated surplus for different expected withdrawals for the deposit unit when the bank is deposit rich under approach 2

$\mathbf{E}(\text{Profit}(x)) \leq \text{Profit}(\mathbf{E}(x))$.

Let's look at an example. If we assume x has a beta distribution with parameters $alpha = 2.5$ and $beta = 5.83$. This would equate to a mean of 0.3 and standard deviation 0.15. This is plotted in Figure 5.5.11.

We can then calculate that:

$\text{Profit}(\mathbf{E}(x)) = £4.99\text{m};$

$\mathbf{E}(\text{Profit}(x)) = £4.89\text{m}.$

Therefore, the cost of the option would be:

Cost of Option $= £0.1\text{m}.$

This means we now have a price for the uncertainty. We would expect greater uncertainty to lead to a higher price and lower uncertainty to lead to a cheaper price. We will now investigate this by varying the distribution of x. If we now adopt a distribution of x assuming a beta distribution with parameters $alpha = 1.275$ and $beta = 2.975$. This would equate to a mean of 0.3 and standard deviation 0.20. This is plotted in Figure 5.5.12. As we can see there is a lot more variance in x so greater uncertainty. We would expect the option price to go up. We can calculate the following:
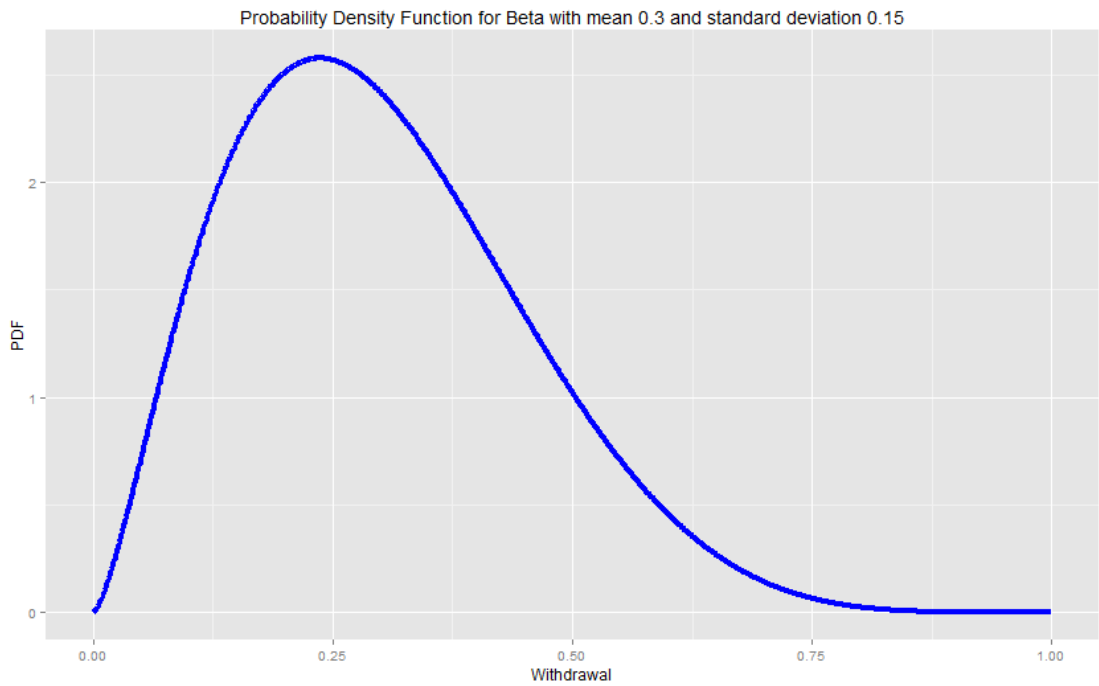
Figure 5.5.11: Probability density function for beta distribution with mean 0.3 and standard deviation of 0.15
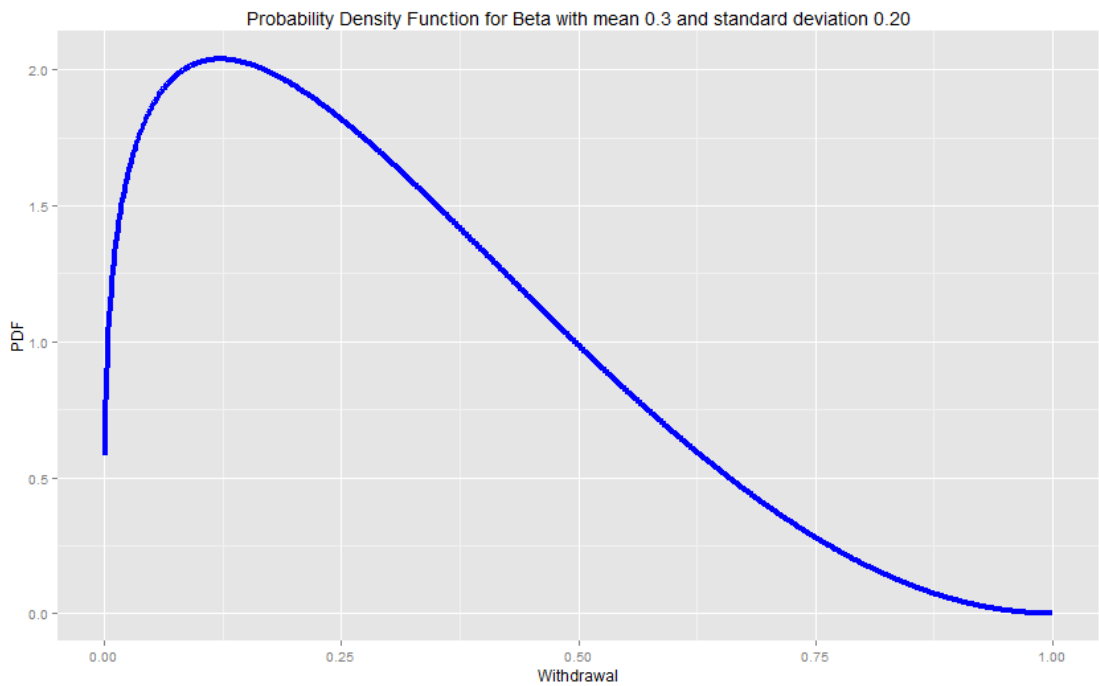
Figure 5.5.12: Probability density function for beta distribution with mean 0.3 and standard deviation of 0.20

Profit($\mathbf{E}(x)$) = £4.99m;

$\mathbf{E}$(Profit(x)) = £4.85m.

Therefore, the cost of the option would be:

Cost of Option = £0.14m.

As we can see, increasing the variance in x leads to a higher cost of the option. Similarly, if we reduce the variance, so we now assume a beta distribution with parameters $alpha = 6$ and $beta = 14$ for x. This would equate to a mean of 0.3 and standard deviation 0.1. This is plotted in Figure 5.5.13. As we can see there is a lot less variance in x so less uncertainty. We would expect the option price to reduce. We can calculate the following:
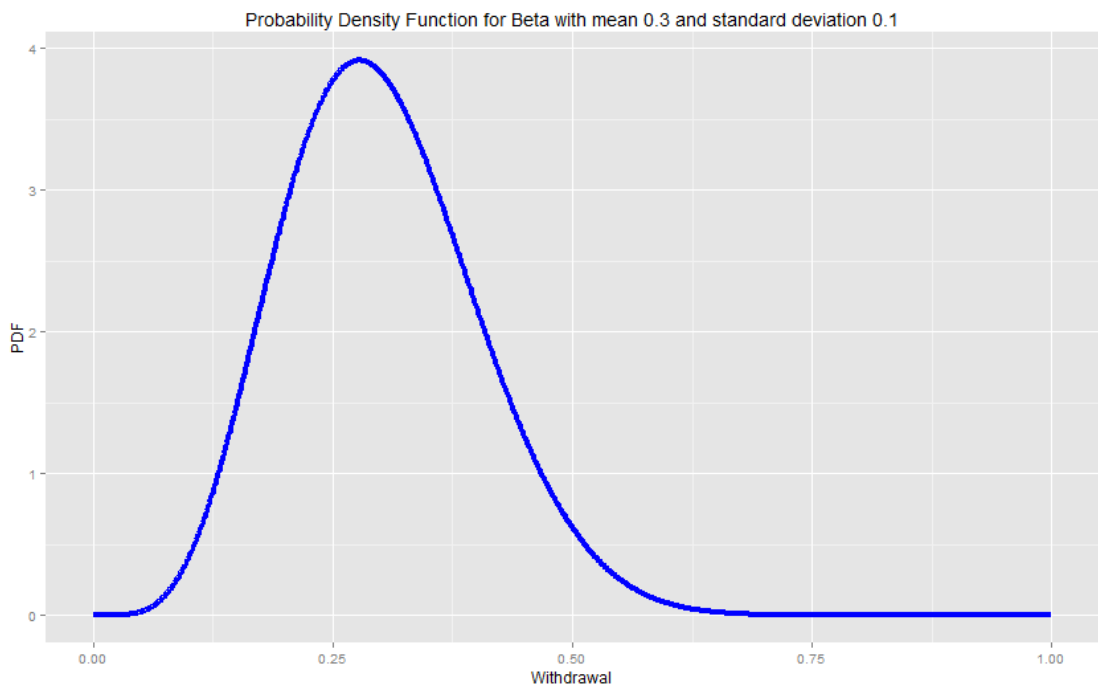
Figure 5.5.13: Probability density function for beta distribution with mean 0.3 and standard deviation of 0.10

Profit($\mathbf{E}(x)$) = £4.99m;

$\mathbf{E}$(Profit(x)) = £4.93m.

Therefore, the cost of the option would be:

Cost of Option = £0.06m.

This gives us a nice result in that the cost of the option varies with the uncertainty of x. The greater the uncertainty the higher the cost of the option. This will then reward the deposit unit for reducing variation. This option approach only works if

the following conditions hold:

- the rolling 1 year return on bonds is less than the 2 year bond holding return; and

- the return on 2 year bond holding when sold at time 1 is less than the return on 1 year bond holding.

Otherwise, there is no penalty for funding liquidity risk which means that the strategy of matching duration of assets with liabilities may not be appropriate.

We need to consider whether the option price approach works in line with the incentives of the bank or whether will it be manipulated by the parties involved. If it is a fair price, then the treasury should be rewarded appropriately for the risks and the deposit unit charged appropriate for the options they are providing their customers. In practice, the treasury and deposit unit will have to agree on the appropriate price. This will be based on customers' behaviour and experience data. From the deposit unit perspective, they want a low value of x and low option cost. They could try to manipulate the option price by claiming a low x with minimum variance. The treasury might accept it the first time around but then will charge more for the option next time when they realise the unfair price of the option. Therefore, you would expect over time, that it will lead to a fair price so that the treasury and deposit unit agree.

The option takes into account the upside and downside potential and the treasury gets the outcome of this. From the bank's perspective, it wants to retain deposits but is the deposit unit rewarded for this? The immediate answer under this approach is no. Any benefits from retaining deposits greater than expected go to the treasury. However, if the deposits unit improves it ability to retain deposits, this will influence customers' behaviour and experience data. As such, this will then be reflected in future products where the deposit unit will be able to adjust the expectation of γ and hopefully reduce the cost of the option.

The option approach works well to incentivise the business units in line with the bank's objectives. The downside is that the deposit unit does not get rewarded

for current products when retaining deposits but by favourable terms on future products. An alternative approach would be to reward the business units at the end of the period with the actual profit rather than pricing an option. In this case the deposit unit will be rewarded at the end of the period with the actual profit. Therefore there will be incentives to retain deposits and they will be rewarded for it. This will mean there is no incentive for the deposit unit to manipulate the system as they would receive the profit at the end of the period. This would be quite a significant change to how banks work where deposit and loan unit are usually rewarded upfront for their products rather than at the end of the product. In addition, the consequences of granting the customer options such as any time withdrawals will only be reflected in the final retained deposits and will not be a direct cost to the business unit.

Although this approach could be adopted it is a significant change from how things work at the moment in banks. Also, it does not necessarily help the bank understand upfront that the option they offer their customers has financial consequences. Therefore the preferable approach is to use the option price but to appreciate that it has its flaws.

5.6 Deposits when the bank is deposit poor

In the deposit rich situation, the bank was bringing in deposits that could be lent out in the wholesale money markets. Therefore deposits were looked at from the point of view of lending in the wholesale money markets. We are now going to look at the deposit poor situation. In this case deposits brought in allow the bank to reduce its existing wholesale borrowing and potentially reduce its liquid asset holding. Therefore, we need to compare the deposits brought in to the costs of borrowing from the wholesale money markets. The strategic cost is the potential cost of borrowing from the wholesale money market if the bank did not have the deposits. The profits for the bank will be the difference between the cost of borrowing in wholesale money markets and the cost of bringing in deposits. First, we will look at the FTP rates when we have a fixed proportion of deposits, γ, withdrawn at time

1. We will use the same methodology used to derive the FTP rates when the bank is deposit rich situation. So for a fixed rate γ product, the PV from the deposit unit when the bank is deposit poor would be:

$$PV = \gamma D \left(\frac{(1 - \alpha(0,1)) \left(\frac{W_B(0,1)}{1-\beta(0,1)} - \frac{\beta(0,1)i_A(0,1)}{1-\beta(0,1)} \right) + \alpha(0,1)i_A(0,1) - i_D(0,1)}{1 + E(0,1)} \right)$$

$$+ (1-\gamma)D \left(\frac{\begin{array}{c}(1 - \alpha(0,2)) \left(\frac{(1+W_B(0,2))^2}{1-\beta(0,2)} - \frac{\beta(1+i_A(0,2))^2}{1-\beta} \right) \\ + \alpha(0,2)(1 + i_A(0,2))^2 - (1 + i_D(0,2))^2\end{array}}{(1 + E(0,2))^2} \right).$$

This then equates to the following FTP rates at each time:

$$\text{Time 1: } (1 \quad - \quad \alpha(0,1)) \left(\frac{W_B(0,1)}{1 - \beta(0,1)} - \frac{\beta(0,1)i_A(0,1)}{1 - \beta(0,1)} \right) \quad + \quad \alpha(0,1)i_A(0,1);$$

$$\text{Time 2: } ((1 - \alpha(0,2)) \left(\frac{(1 + W_B(0,2))^2}{1 - \beta(0,2)} - \frac{\beta(1 + i_A(0,2))^2}{1 - \beta(0,2)} \right)$$

$$+ \alpha(0,2)(1 + i_A(0,2))^2)^{0.5} - 1.$$

For products with no uncertainty, it is straight forward to derive the FTP rates. Note from the FTP rates, bringing in deposits could potentially reduce the liquid assets holding. The liquid assets holding will reduce if $\alpha < \beta$. We will look at this in more detail later. As before, the difficulty arises when there is uncertainty and having to price this uncertainty.

Before we can price this uncertainty, we will need to derive some notation. This will be the similar notation as used for deposit rich banks in Section 5.5 except this time it will relate to wholesale borrowing rather than lending. This means we will change the following terms so they relate to wholesale borrowing:

Let $\underline{\overline{Q}}_X(t,T)$ be the value at time t of X, expiring at time T; where X equals

A, liquid assets, or B, wholesale bonds. As we are looking at strategic costs here, $\overline{Q}_B$ would be the issue of wholesale bonds (i.e. borrowing) and $\underline{Q}_B$ would be the prepayment of wholesale bonds. $\overline{Q}_A$ would be the change in amount of liquid assets that need to be purchased. This can be positive or negative. $\underline{Q}_A$ would be the change in the amount of liquid assets that need to be sold. This can be also be positive or negative. Due to the bid/ask spread and market liquidity premium, the value will depend whether the bank is issuing or prepaying wholesale borrowing or buying or selling liquid bonds. In this situation we are looking at strategic cost so this is what would be happening if the bank did not bring in deposits.

Let $U_X(S,T)$ be the number of units of X which expire at time T and purchased at time S.

So:

- $\overline{Q}_B(0,1) = \frac{1}{1+W_B(0,1)}$;

- $\overline{Q}_A(0,1) = \frac{1}{1+i_A(0,1)}$;

- $\overline{Q}_B(0,2) = \frac{1}{(1+W_B(0,2))^2}$;

- $\overline{Q}_A(0,2) = \frac{1}{(1+i_A(0,2))^2}$;

- $Q_B(1,1) = 1$;

- $Q_A(1,1) = 1$;

- $\underline{Q}_B(1,2) = \frac{1}{(1+\underline{W}_B(1,2))}$;

- $\underline{Q}_A(1,2) = \frac{1}{(1+\underline{i}_A(1,2))}$;

- $\overline{Q}_B(1,2) = \frac{1}{(1+\overline{W}_B(1,2))}$;

- $\overline{Q}_A(1,2) = \frac{1}{(1+\overline{i}_A(1,2))}$;

- $Q_B(2,2) = 1$;

- $Q_A(2,2) = 1$.

λ_B be the proportion of 2 year bonds prepaid at time 1 and λ_A be the proportion of 2 year liquid assets sold at time 1.

Let's look at how the mechanics of this approach work. As before, this may not necessarily be the way the bank decides to operate but represents a fair investment approach. At time 0, the bank is already assumed to be borrowing in the wholesale money markets. When we bring in deposits this allows the bank to reduce their borrowing from the wholesale money markets. The FTP rate is set in relation to the reduction in borrowing from the wholesale money markets that can be achieved by bringing in deposits. So we need to consider the impact bringing in deposits will have on borrowing from wholesale money markets. The actual impact will depend on the values of β, proportion of wholesale borrowing set aside as liquid assets, and α, proportion of deposits set aside as liquid assets. It is usually expected that $\alpha < \beta$ since most deposits will require a bank to hold less liquid assets than borrowing from the wholesale money markets. However, this might not be the case all the time. We will first concentrate on the case where $\alpha < \beta$ and then discuss $\alpha > \beta$.

If $\alpha < \beta$, then this will mean any new deposits will reduce borrowing from wholesale money markets by a larger amount than what is brought in as deposits. This is because more deposits can be lent out than the equivalent borrowing from wholesale money markets. It will also reduce the liquid asset holding of the bank as deposits will require less liquid assets than borrowing from wholesale money markets. We will look at this further in Section 5.6.1. If $\alpha > \beta$, then this will mean any new deposits will reduce borrowing from wholesale money markets by a lesser amount than what is brought in as deposits. It will also increase the liquid asset holding of the bank as deposits will required more liquid assets than borrowing from wholesale money markets. We will look at this further in Section 5.6.2

We would split the deposits into 1 and 2 year depending on expected withdrawal. We need to consider the strategic cost of what would be the impact if we did not bring in deposits. We can calculate the appropriate impact in wholesale borrowing and liquid assets which depends on α and β. Table 5.6.1 shows the strategic cost when new deposits are brought in at time 0. In this case, the strategic costs would

be the need to borrow from the wholesale money markets and the required change in liquid assets from funding by wholesale borrowing rather than deposits.

Table 5.6.1: Strategic cost at time 0 for new deposits for a deposit poor bank

Strategic cost		
1 year wholesale borrowing	$U_B(0,1)\overline{Q}_B(0,1)$	$= \gamma D(\frac{1-\alpha(0,1)}{1-\beta(0,1)})$
1 year liquid assets	$U_A(0,1)\overline{Q}_A(0,1)$	$= \gamma D(-\frac{(1-\alpha(0,1))\beta(0,1)}{1-\beta(0,1)} + \alpha(0,1))$
2 year wholesale borrowing	$U_B(0,2)\overline{Q}_B(0,2)$	$= (1-\gamma)D(\frac{1-\alpha(0,2)}{1-\beta(0,2)})$
2 year liquid assets	$U_A(0,2)\overline{Q}_A(0,2)$	$= (1-\gamma)D(-\frac{(1-\alpha(0,2))\beta(0,2)}{1-\beta(0,2)} + \alpha(0,2))$

At time 1, the bank will have made savings from not having to borrow from the wholesale money markets. If $\alpha < \beta$, the bank will make less of return from liquid assets as liquid asset holding will be lower. It will have to pay interest to the deposits and some of the deposits will be withdrawn. If deposits withdrawn are less than expected, the bank will have more deposits to save on wholesale borrowing for another year. So the bank will make savings from not having to borrow form the wholesale money markets between year 1 and 2. There will also be an impact on liquid assets. If withdrawals of deposits are greater than expected, the bank will have less deposit debt. In order to compare like with like wholesale borrowing will have to be repurchased. We will also have to take into account the impact on liquid assets. Table 5.6.2 shows the strategic cost and expected savings.

Table 5.6.2: Strategic cost at time 1 for new deposits for a deposit poor bank

Strategic cost		
Withdraw		$= xD(1 + i_D(0,1))$
1 year wholesale borrowing	$U_B(0,1)Q_B(1,1)$	
1 year liquid assets	$U_A(0,1)Q_A(1,1)$	
1-2 year wholesale borrowing	$U_B(1,2)\overline{Q}_B(1,2)$	$= I(\gamma \geq x)\frac{(\gamma-x)}{\gamma}$
		$U_B(0,1)Q_B(1,1)$
1 to 2 year liquid assets	$U_A(1,2)\overline{Q}_A(1,2)$	$= I(\gamma \geq x)\frac{(\gamma-x)}{\gamma}$
		$U_A(0,1)Q_A(1,1)$
Change in 2 year wholesale borrowing	$\lambda_B U_B(0,2)\underline{Q}_B(1,2)$	$= I(\gamma < x)\frac{(x-\gamma)}{(1-\gamma)}$
Change in 2 year liquid assets	$\lambda_A U_A(0,2)\underline{Q}_A(1,2)$	$I = (\gamma < x)\frac{(x-\gamma)}{(1-\gamma)}$
Savings		$U_B(0,1)P_B(1,1)$
		$+U_A(0,1)P_A(1,1)$
		$+\lambda_B U_B(0,2)P_B(1,0,2)$
		$+\lambda_A U_A(0,2)P_A(1,0,2)$
		$-U_B(1,2)\overline{Q}_B(1,2)$
		$U_A(1,2)\overline{Q}_A(1,2)$
		$-xD(1 + i_D(0,1))$

At time 2, the bank will have made further savings from not having to borrow as much from the wholesale money markets but instead by taking in deposits at a lower cost. As at time 1, we will need to take into account the impact of liquid assets as this will impact on the savings. The savings are derived from the strategic cost less the cost of deposits. The calculation for savings at time 2 is shown in Table 5.6.3. It will be easier to understand if we look at a few examples. We look at examples when $\alpha < \beta$ in Section 5.6.1 and when $\alpha > \beta$ in Section 5.6.2. In these examples we will use the assumptions shown in Table 5.6.4. The assumptions have been chosen to emphasise the impact and market conditions may not represent the same magnitude. Important points regarding the assumptions are that:

- The rolling 1 year return on bonds is less than the 2 year bond holding return; and

- The return on 2 year bond holding when sold at time 1 is less than the return on 1 year bond holding.

These two conditions ensure that the deposit unit is penalised for the uncertainty and for causing funding liquidity risk.

Table 5.6.3: Strategic cost at time 2 for new deposits for a deposit poor bank

Strategic cost	
Withdraw	$= (1 - x)D(1 + i_D(0, 2)^2)$
1-2 year wholesale borrowing	$U_B(1, 2)P_B(2, 2)$
1 to 2 year liquid assets	$U_A(1, 2)P_A(2, 2)$
2 year wholesale borrowing	$(1 - \lambda_B)U_B(0, 2)P_B(2, 2)$
2 year liquid assets	$(1 - \lambda_A)U_A(0, 2)P_A(2, 2)$
Savings	$(1 - \lambda_B)U_B(0, 2)P_B(2, 2)$
	$(1 - \lambda_A)U_A(0, 2)P_A(2, 2)$
	$+U_B(1, 2)P_B(2, 2)$
	$+U_A(1, 2)P_A(2, 2)$
	$-(1 - x)D(1 + i_D(0, 2)^2)$

Table 5.6.4: Assumptions for the examples when looking at deposits when the bank is deposit poor

Variables	Values
D	£100m
$\overline{W}_B(0,1)$	5.4%
$\overline{W}_B(0,2)$	5.9%
$\overline{W}_B(1,2)$	5.9%
$\underline{W}_B(1,2)$	7.9%
$i_A(0,1) = i_A(0,2) = \bar{i}_A(1,2) = \underline{i}_A(1,2)$	3.0%
$i_D(0,1) = i_D(0,2)$	2.5%
$E(0,1) = E_{1,2} = E(0,2)$	5.4%

5.6.1 Examples when the bank is in a deposit poor situation and $\alpha < \beta$

In this section we will look at what happens when the bank is in the deposit poor situation and $\alpha < \beta$. As the bank is in deposit poor situation, we need to consider the strategic costs. The bank will be able to reduce its wholesale borrowing from bringing in deposits. When $\alpha < \beta$ this means that by bringing in deposits that bank will be able to reduce its liquid assets holding. To understand this, we will look at a simple example. We will assume the following for all the examples in this section: 5.6.1

- $\alpha = \alpha(0,1) = \alpha(1,2) = \alpha(0,2) = 5\%$

- $\beta = \beta(0,1) = \beta(1,2) = \beta(0,2) = 10\%$

Since the bank is in the deposit poor situation, it means that it will be expected to be borrowing in the wholesale money markets. In this example, we will assume it is already lending £180m. This would mean the bank needs to borrow £200m from wholesale money markets as proportion β has to be set aside as liquid assets. Table 5.6.5 shows the initial balance sheet.

Table 5.6.5: Balance sheet before new deposits when $\alpha < \beta$

Assets		Liabilities	
Lending	180	Wholesale borrowing	200
Liquid assets	20		
Total	200	Total	200

If we take in £100m in deposits, this will not impact on the amount we are

lending out at £180m but will allow us to reduce our wholesale money market borrowing and liquid asset holding. Table 5.6.6 shows the impact on the balance sheet. As we can see liquid assets are reduced by £5.6m and wholesale borrowing is reduced by £105.6m. This means that taking in £100m in deposits allows us to reduce wholesale money market borrowing by £105.6m which will allow us to save on costs but we lose £5.6m on liquid assets which will reduce our returns.

Table 5.6.6: Balance sheet after new deposits when $\alpha < \beta$

Assets		Liabilities	
Lending	180	Wholesale borrowing	94.4
Liquid assets	14.4	Deposits	100
Total	194.4	Total	194.4

Now, we understand how bringing in deposits allows us to reduce our borrowing from wholesale money markets and will also reduce our liquid asset holding. We will now look at three examples to understand how different withdrawals will impact on the savings:

- Example 5.6.1: When withdrawals are in line with expectations

- Example 5.6.2: When withdrawals are less than expectations

- Example 5.6.3: When withdrawals are greater than expectations

Example 5.6.1. *Bank in deposit poor situation, $\alpha < \beta$ and withdrawals as expected*

In this example we will look at when the bank is in the deposit poor situation. $\alpha < \beta$ which means liquid assets will be reduced by bring in deposits. We look at the consequences if withdrawals are in line with expectations. We will assume the expected withdrawal rate is $\gamma = 30\%$. We can calculate the impact on wholesale money market borrowing and liquid assets for 1 and 2 year assets holdings. This is shown in Table 5.6.7. As we can see, by bringing in deposits, we can reduce wholesale borrowing by more than we take in deposits and we also reduce liquid asset holding.

At time 1, if withdrawals are in line with expectations, we then will have made savings from not having to borrow from wholesale money markets for a year but

Table 5.6.7: Strategic cost at time 0 for new deposits for a deposit poor bank when $x = \gamma$ and $\alpha < \beta$

Strategic cost		
1 year wholesale borrowing	$U_B(0,1)\overline{Q}_B(0,1)$	31.67
1 year liquid assets	$U_A(0,1)\overline{Q}_A(0,1)$	-1.67
2 year wholesale borrowing	$U_B(0,2)\overline{Q}_B(0,2)$	73.89
2 year liquid assets	$U_A(0,2)\overline{Q}_A(0,2)$	-3.89

we will have lost some return on liquid assets as they are less. This would give us the savings shown in Table 5.6.8. The saving is calculated by not borrowing from the wholesale money markets less the lost return on liquid assets less the deposits withdrawn.

Table 5.6.8: Strategic cost at time 1 for new deposits for a deposit poor bank when $x = \gamma$ and $\alpha < \beta$

Strategic cost		
Withdraw		30.75
1 year wholesale borrowing	$U_B(0,1)Q_B(1,1)$	33.22
1 year liquid assets	$U_A(0,1)Q_A(1,1)$	-1.72
Savings		0.75

At time 2, we will then make savings from not having to issue 2 year wholesale borrowing but will lose the return on 2 year liquid assets. This would give us the savings shown in Table 5.6.9.

Table 5.6.9: Strategic cost at time 2 for new deposits for a deposit poor bank when $x = \gamma$ and $\alpha < \beta$

Strategic cost		
Withdraw		73.54
2 year wholesale borrowing	$(1-\lambda_B)U_B(0,2)P_B(2,2)$	82.86
2 year liquid assets	$(1-\lambda_A)U_A(0,2)P_A(2,2)$	-4.13
Savings		5.19

Example 5.6.2. *Bank in deposit poor situation, $\alpha < \beta$ and withdrawals are less than expected*

We have looked at the case where withdrawals are in line with expectations. We will now look at an example where withdrawals are less than expected. The initial expected allocation for the savings will be the same in Example 5.6.1. It will only be at time 1 when things will change. At time 1, we will have more deposits remaining

than we expected to have since withdrawals are less than expected. This means at time 1, we can repeat the process of reducing our wholesale borrowing. Table 5.6.10 shows the impact of this.

Table 5.6.10: Strategic cost at time 1 for new deposits for a deposit poor bank when $x < \gamma$ and $\alpha < \beta$

Strategic cost		
Withdrawals		20.5
1 year wholesale borrowing	$U_B(0,1)Q_B(1,1)$	33.22
1 year liquid assets	$U_A(0,1)Q_A(1,1)$	-1.72
1-2 year wholesale borrowing	$U_B(1,2)\overline{Q}_B(1,2)$	11.07
1 to 2 year liquid assets	$U_A(1,2)\overline{Q}_A(1,2)$	-0.57
Savings		0.50

At time 2, the saving from not having to borrow from the wholesale money markets will come through. The bank makes additional savings from having less withdrawals which allows the bank to save from not having to borrow from the wholesale money markets. However, the bank will make less on their liquid assets as these will be smaller. Table 5.6.11 shows the savings that will be made.

Table 5.6.11: Strategic cost at time 2 for new deposits for a deposit poor bank when $x < \gamma$ and $\alpha < \beta$

Strategic cost		
Withdraw		84.05
1-2 year wholesale borrowing	$U_B(1,2)P_B(2,2)$	11.73
1 to 2 year liquid assets	$U_A(1,2)P_A(2,2)$	-0.59
2 year wholesale borrowing	$(1-\lambda_B)U_B(0,2)P_B(2,2)$	82.86
2 year liquid assets	$(1-\lambda_A)U_A(0,2)P_A(2,2)$	-4.13
Savings		5.83

Example 5.6.3. *Bank in deposit poor situation, $\alpha < \beta$ and withdrawals are greater than expected*

We will now look at the third example when withdrawals are greater than expected. The initial expected allocation for the savings will be the same in Example 5.6.1. It will only be at time 1 when things will change. At time 1, we will have less deposits remaining than we expected which means we will have to adjust the wholesale borrowing accordingly by repaying some the wholesale borrowing. The liquid asset holding will also be reduced. We are reducing the expected benefits

from the wholesale borrowing and liquid assets that we had expected to achieve. Table 5.6.12 shows the impact of this.

Table 5.6.12: Strategic cost at time 1 for new deposits for a deposit poor bank when $x > \gamma$ and $\alpha < \beta$

Strategic cost		
Withdraw		41.00
1 year wholesale borrowing	$U_B(0,1)Q_B(1,1)$	33.22
1 year liquid assets	$U_A(0,1)Q_A(1,1)$	-1.72
Change in 2 year wholesale borrowing	$\lambda_B U_B(0,2)\underline{Q}_B(1,2)$	10.97
Change 2 year liquid assets	$\lambda_A U_A(0,2)\underline{Q}_A(1,2)$	-0.57
Savings		0.90

At time 2, the saving from not having to borrow from the wholesale money markets will come through. However this will be less than the case where withdrawals are in line with expectation as shown Example 5.6.1. This is because more deposits were withdrawn at time 1 than expected meaning we had to reduce the benefits of wholesale borrowing. This also meant that the liquid asset holding increased so the reduction in our liquid assets holding was smaller. Table 5.6.13 shows the savings that will be made.

Table 5.6.13: Strategic cost at time 2 for new deposits for a deposit poor bank when $x > \gamma$ and $\alpha < \beta$

Strategic cost		
Withdraw		63.04
2 year wholesale borrowing	$(1 - \lambda_B)U_B(0,2)P_B(2,2)$	71.03
2 year liquid assets	$(1 - \lambda_A)U_A(0,2)P_A(2,2)$	-3.54
Savings		4.45

From these examples, we can see that the less withdrawals that customers make the greater the profit. Figure 5.6.1 shows the profit for all possible withdrawals rate when $\gamma = 0.3$. As we can see there is a kink at the point when actual withdrawal equals expected withdrawal. Before this point, you can see the that profits increase linearly as withdrawals are less. This is because the bank can make further savings by not having to borrow from the wholesale money markets. When withdrawals are greater than expected, the profits decrease quickly due to the bank having to restore borrowing from the wholesale money markets at less favourable rates.

Figure 5.6.2 shows the profit for the bank for multiple assumptions for γ. For
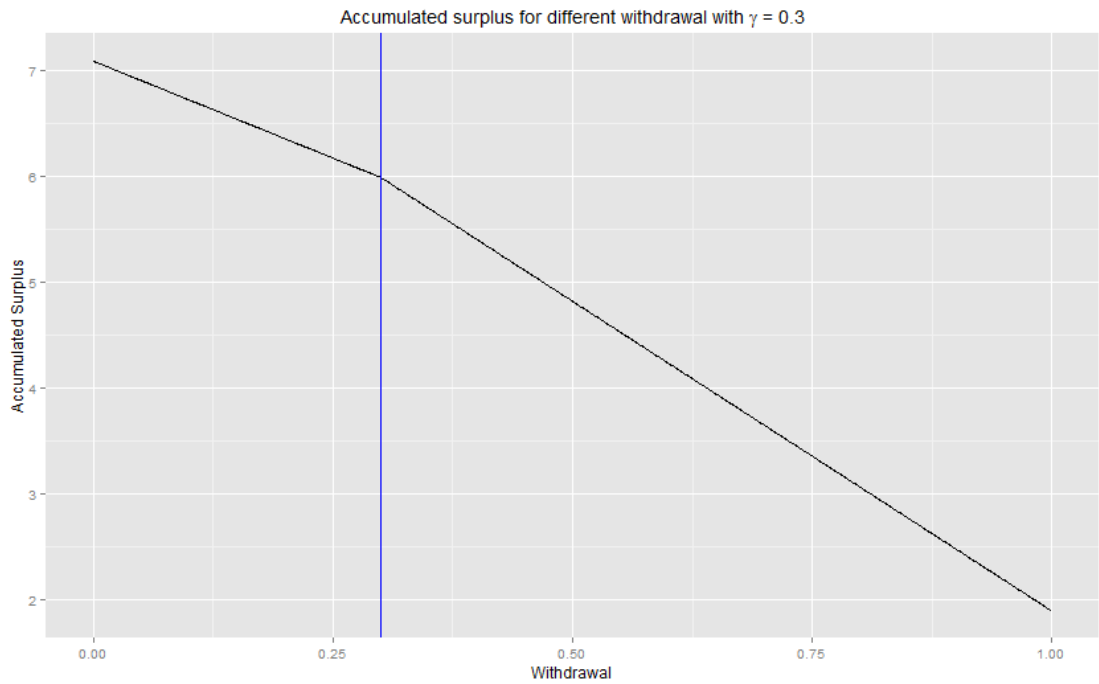
Figure 5.6.1: Surplus for the deposit unit at various levels of withdrawals when the bank is deposit poor, $\gamma = 0.3$ and $\alpha < \beta$
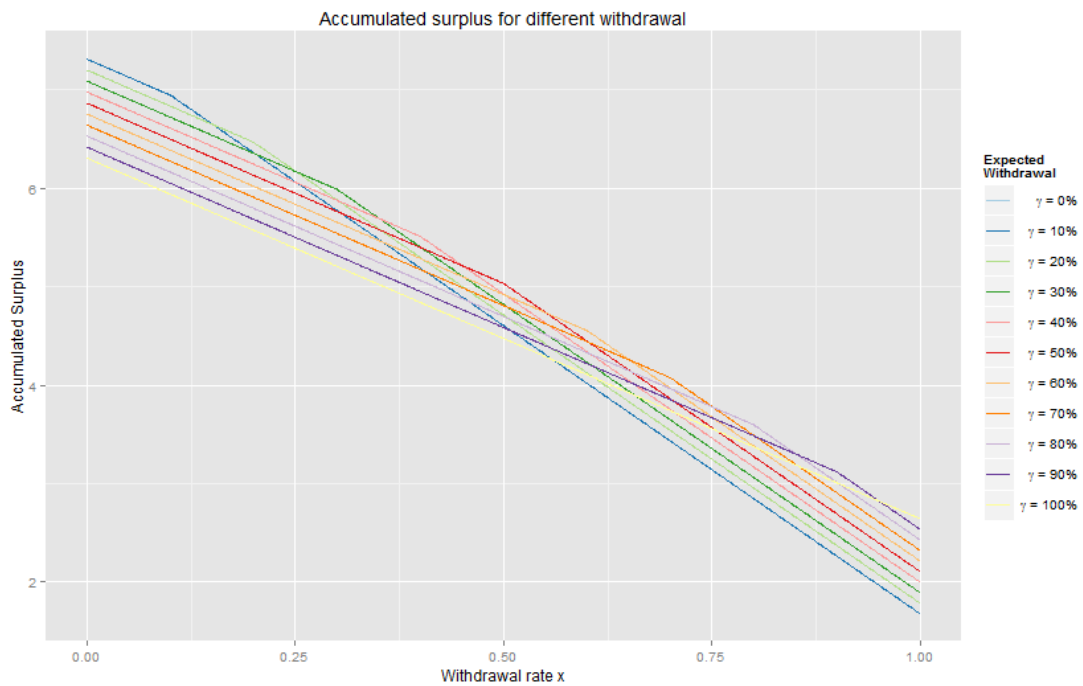
Figure 5.6.2: Accumulated surplus for different expected withdrawals for the deposit unit when the bank is deposit poor and $\alpha < \beta$

a given withdrawal rate, x, we can see that the profit is maximised when γ equals the actual withdrawal. This means we can use the same method as defined in Section 5.5.3, to price the cost of the option. The cost of the option is given as:

Cost of Option = $\text{Profit}(\mathbf{E}(x)) - \mathbf{E}(\text{Profit}(x))$.

If we assume x has a beta distribution with parameters $alpha = 2.5$ and $beta = 5.83$. This would equate to a mean of 0.3 and standard deviation 0.15. This is plotted in Figure 5.5.11, page 157. We can then calculate that:

$\text{Profit}(\mathbf{E}(x)) = £5.99\text{m}$;

$\mathbf{E}(\text{Profit}(x)) = £5.85\text{m}$.

Therefore, the cost of the option would be:

Cost of Option = $£0.14\text{m}$.

We can vary the distribution of x and higher uncertainty will lead to a higher cost for the option. For example, if we assume x has a beta distribution with parameters $alpha = 1.275$ and $beta = 2.976$. This would equate to a mean of 0.3 and standard deviation 0.20. This is plotted in Figure 5.5.12, page 157. The cost of the option would be £0.18m. Reducing the uncertainty will reduce the price of the option. For example, if we assume x has a beta distribution with parameters $alpha = 6$ and $beta = 14$. This would equate to a mean of 0.3 and standard deviation 0.10. This is plotted in Figure 5.5.13, page 158. The cost of the option would be £0.09m. Note as discussed in Section 5.5.3, this approach of pricing the uncertainty of withdrawal only works when these conditions are met:

- The rolling 1 year return on bonds is less than the 2 year bond holding return; and

- The return on 2 year bond holding when sold at time 1 is less than the return on 1 year bond holding.

This is to ensure that there is a penalty for funding liquidity risk and the bank is penalised when expectations are not in line with actual withdrawals.

5.6.2 Examples when the bank is in a deposit poor situation and $\alpha > \beta$

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So far the examples in the deposit poor situation have concentrated on the case where $\alpha < \beta$. We are now going to look at the less likely case where $\alpha > \beta$. If $\alpha > \beta$, this means the bank has to set aside a greater proportion of this type of deposit as liquid assets than if the bank borrowed from the wholesale money markets. We will look at three examples to see the impact this has. The examples we will look at are:

- Example 5.6.4: When withdrawals are in line with expectations;

- Example 5.6.5: When withdrawals are less than expectations; and

- Example 5.6.6: When withdrawals are greater than expectations.

For all the examples, we will assume the following:

- $\alpha = \alpha(0,1) = \alpha(1,2) = \alpha(0,2) = 15\%$; and

- $\beta = \beta(0,1) = \beta(1,2) = \beta(0,2) = 10\%$.

First, we will go through a simple case as in Section 5.6.1. Since the bank is in the deposit poor situation, it means that it will be expected to be borrowing in the wholesale money markets. In this example, we will assume it is already lending £180m. This would mean the bank needs to borrow £200m from wholesale money markets as proportion β has to be set aside as liquid assets. Table 5.6.14 shows the initial balance sheet.

Table 5.6.14: Balance sheet before new deposits when $\alpha > \beta$

Assets		Liabilities	
Lending	180	Wholesale borrowing	200
Liquid assets	20		
Total	200	Total	200

If we take in £100m in deposits, this will not impact on the amount the bank is lending out at £180m but will allow us to reduce our wholesale money market

borrowing. However the bank will have to increase their liquid asset holding. Table 5.6.15 shows the impact on the balance sheet. As we can seen liquid assets are increased by £5.6m and wholesale borrowing is reduced by £94.4m. What this means is that by taking in £100m in deposits allows us to reduce wholesale money market borrowing by £94.4m which will allow us to save on costs but liquid assets will increase by £5.6m.

Table 5.6.15: Balance sheet after new deposits when $\alpha > \beta$

Assets		Liabilities	
Lending	180	Wholesale borrowing	105.6
Liquid assets	25.6	Deposits	100
Total	205.6	Total	205.6

We can compare the Table 5.6.15, the case where $\alpha > \beta$, with Table 5.6.6, the case where $\alpha < \beta$. When $\alpha < \beta$, this allows the bank to reduce its wholesale borrowing more significantly then the case $\alpha > \beta$. This means the banks makes greater savings when $\alpha < \beta$. Although liquid assets decrease, which reduces the banks return, the savings from the wholesale borrowing easily outweigh this. Therefore the bank prefers it when $\alpha < \beta$ as the savings will be greater and this is the most likely situation. However there are still benefits even if $\alpha > \beta$. We will now demonstrate this by looking at the three examples mentioned above.

Example 5.6.4. *Bank in deposit poor situation, $\alpha > \beta$ and withdrawals as expected*

In the first example, we look at the bank in the deposit poor situation, $\alpha > \beta$ and withdrawals in line with expectations. We will assume the expected withdrawal rate is $\gamma = 30\%$. We can calculate the impact on wholesale money market borrowing and liquid assets for 1 and 2 year assets holdings. This is shown in Table 5.6.16. As we can see, by bringing in deposits, we can reduce wholesale borrowing by less than the deposits the bank brings in and we also increase liquid asset holding.

At time 1, if withdrawals are in line with expectation, we then will have made savings from not borrowing from the wholesale money markets for a year and from the return on the increased holding of liquid assets. This would give us the savings shown in Table 5.6.17. The saving is calculated by the saving from not borrowing

Table 5.6.16: Strategic cost at time 0 for new deposits for a deposit poor bank when $x = \gamma$ and $\alpha > \beta$

Strategic cost		
1 year wholesale borrowing	$U_B(0,1)\overline{Q}_B(0,1)$	28.33
1 year liquid assets	$U_A(0,1)\overline{Q}_A(0,1)$	1.67
2 year wholesale borrowing	$U_B(0,2)\overline{Q}_B(0,2)$	66.11
2 year liquid assets	$U_A(0,2)\overline{Q}_A(0,2)$	3.89

from the wholesale money market plus the return on liquid assets less the deposits withdrawn.

Table 5.6.17: Strategic cost at time 1 for new deposits for a deposit poor bank when $x = \gamma$ and $\alpha > \beta$

Strategic cost		
Withdraw		30.75
1 year wholesale borrowing	$U_B(0,1)Q_B(1,1)$	29.72
1 year liquid assets	$U_A(0,1)Q_A(1,1)$	1.72
Savings		0.69

At time 2, we will then make savings from not having to issue 2 year wholesale borrowing plus the extra return on 2 year liquidity assets. This would give us the savings shown in Table 5.6.10. When we compare this example with Example 5.6.1, where $\alpha < \beta$, we see that the savings are less. This is because the reduction in wholesale borrowing is less when $\alpha > \beta$.

Table 5.6.18: Strategic cost at time 2 for new deposits for a deposit poor bank when $x = \gamma$ and $\alpha > \beta$

Strategic cost		
Withdraw		73.54
2 year wholesale borrowing	$(1 - \lambda_B)U_B(0,2)P_B(2,2)$	74.14
2 year liquid assets	$(1 - \lambda_A)U_A(0,2)P_A(2,2)$	4.13
Savings		4.72

Example 5.6.5. *Bank in deposit poor situation, $\alpha > \beta$ and withdrawals are less than expected*

This time we will look at an example when withdrawals are less than expected. The initial expected allocation for the savings will be the same in Example 5.6.4. It will only be at time 1 when things will change. At time 1, we will have more deposits remaining than we expect to have since withdrawals are less than expected. This

means at time 1, we can repeat the process of reducing our wholesale borrowing. Table 5.6.19 shows the impact of this.

Table 5.6.19: Strategic cost at time 1 for new deposits for a deposit poor bank when $x < \gamma$ and $\alpha > \beta$

Strategic cost		
Withdraw		20.50
1 Year wholesale borrowing	$U_B(0,1)Q_B(1,1)$	29.72
1 year liquid assets	$U_A(0,1)Q_A(1,1)$	1.72
1-2 year wholesale borrowing	$U_B(1,2)\overline{Q}_B(1,2)$	9.91
1 to 2 year liquid assets	$U_A(1,2)\overline{Q}_A(1,2)$	0.57
Savings		0.46

At time 2, the saving from not having to borrow from the wholesale money markets will come through. The bank makes additional savings from having less withdrawals which allows the bank to save from not having to borrow from the wholesale money markets. Table 5.6.20 shows the savings that will be made.

Table 5.6.20: Strategic cost at time 2 for new deposits for a deposit poor bank when $x < \gamma$ and $\alpha > \beta$

Strategic cost		
Withdraw		84.05
1-2 year wholesale borrowing	$U_B(1,2)P_B(2,2)$	10.49
1 to 2 year liquid assets	$U_A(1,2)P_A(2,2)$	0.59
2 year wholesale borrowing	$(1-\lambda_B)U_B(0,2)P_B(2,2)$	74.14
2 year liquid assets	$(1-\lambda_A)U_A(0,2)P_A(2,2)$	4.13
Savings		5.30

Example 5.6.6. *Bank in deposit poor situation, $\alpha > \beta$ and withdrawals are greater than expected*

This time we will look at an example when withdrawals are greater than expected. The initial expected allocation for the savings will be the same in Example 5.6.4. It will only be at time 1 when things will change. At time 1, we will have less deposits remaining than we expect which means we will not make the anticipated savings from wholesale borrowing. The bank will no longer have the deposits so will have to adjust the wholesale borrowing accordingly. This means at time 1, the bank will increase wholesale borrowing but their liquid assets will decrease. This can be achieved by reducing the expected benefits from the wholesale borrowing and liquid assets. Table 5.6.21 shows the impact of this.

Table 5.6.21: Strategic cost at time 1 for new deposits for a deposit poor bank when $x > \gamma$ and $\alpha > \beta$

Strategic cost		
Withdraw		41.00
1 year wholesale borrowing	$U_B(0,1)Q_B(1,1)$	29.72
1 year liquid assets	$U_A(0,1)Q_A(1,1)$	1.72
Change in 2 year wholesale borrowing	$\lambda_B U_B(0,2)\underline{Q}_B(1,2)$	9.82
Change 2 year liquid assets	$\lambda_A U_A(0,2)\underline{Q}_A(1,2)$	0.57
Savings		0.44

At time 2, the saving from not having to borrow from the wholesale money markets will come through. However this will be less than the case where withdrawals are in line with expectation as shown Example 5.6.4. This is because more deposits were withdrawn at time 1 so we had to reduce the benefits from not having to issue wholesale borrowing.. This also meant that the liquid asset holding decreased so the return on liquid assets is smaller. Table 5.6.22 shows the savings that will be made.

Table 5.6.22: Strategic cost at time 2 for new deposits for a deposit poor bank when $x > \gamma$ and $\alpha > \beta$

Strategic cost		
Withdraw		63.04
2 year wholesale borrowing	$(1-\lambda_B)U_B(0,2)P_B(2,2)$	63.55
2 year liquid assets	$(1-\lambda_A)U_A(0,2)P_A(2,2)$	3.54
Savings		4.05

From these examples, we can see that the less withdrawals that customers make the greater the profit. Figure 5.6.3 shows the profit for all possible rates of withdrawals when $\gamma = 0.3$. As we can see there is a kink at the point when actual withdrawals equals expected withdrawals. Before this point, you can see that the profits increase linearly as withdrawals are less. This is because the bank can make further savings by not having to borrow from the wholesale money markets. When withdrawals are greater than expected, the profits decreases quickly due to the bank having to restore borrowing from the wholesale money markets at less favourable rates.

Figure 5.6.4 shows the profit for the bank for multiple assumptions for γ. For a given withdrawal rate, x, we can see that the profit is maximised when γ equals the actual withdrawal. This means we can use the same method as defined in
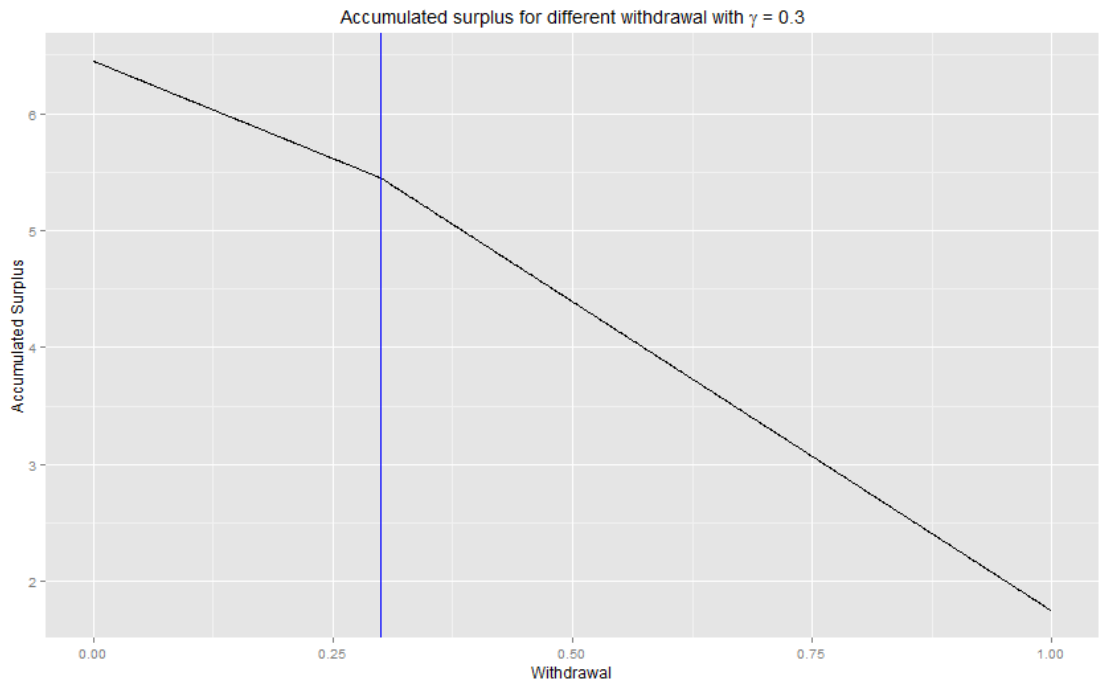
Figure 5.6.3: Surplus for the deposit unit at various levels of withdrawals when the bank is deposit poor, $\gamma = 0.3$ and $\alpha > \beta$
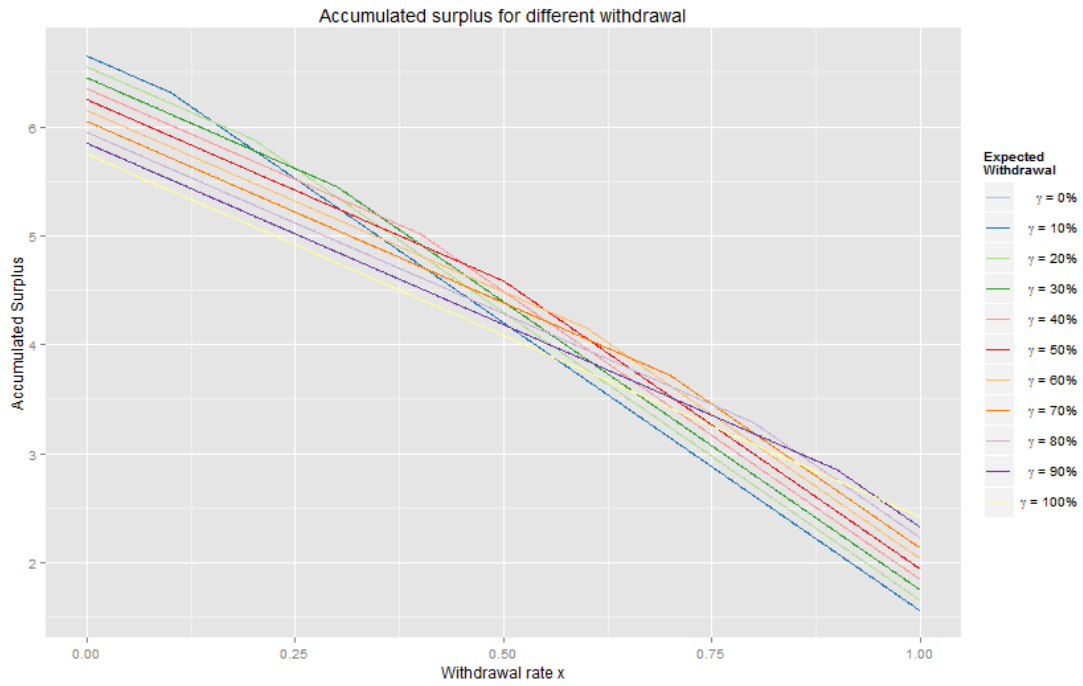
Figure 5.6.4: Accumulated surplus for different expected withdrawals for the deposit unit when the bank is deposit poor and $\alpha > \beta$

Section 5.5.3, to price the cost of the option. The cost of the option is given as:

Cost of Option $=$ Profit$(\mathbf{E}(x)) - \mathbf{E}(\text{Profit}(x))$

If we assume x has a beta distribution with parameters $alpha = 2.5$ and $beta = 5.83$. This would equate to a mean of 0.3 and standard deviation 0.15. This is plotted in Figure 5.5.11, page 157. We can then calculate that:

Profit$(\mathbf{E}(x)) = $ £5.45m

$\mathbf{E}(\text{Profit}(x)) = $ £5.33m

Therefore, the cost of the option would be:

Cost of Option $= $ £0.12m

We can vary the distribution of x and higher uncertainty will lead to a higher cost for the option. For example, if we assume x has a beta distribution with parameters $alpha = 1.275$ and $beta = 2.976$. This would equate to a mean of 0.3 and standard deviation 0.20. This is plotted in Figure 5.5.12, page 157. The cost of the option would be £0.16m. Reducing the uncertainty will reduce the price of the option. For example, if we assume x has a beta distribution with parameters $alpha = 6$ and $beta = 14$. This would equate to a mean of 0.3 and standard deviation 0.10. This is plotted in Figure 5.5.13, page 158. The cost of the option would be £0.08m. Again, this approach of pricing the uncertainty of withdrawals only works when these conditions are met:

- The rolling 1 year return on bonds is less than the 2 year bond holding return; and

- The return on 2 year bond holding when sold at time 1 is less than the return on 1 year bond holding.

This is to ensure that there is a penalty for funding liquidity risk and the bank is penalised when expectations are not in line with actual withdrawals.

5.7   Loans when the bank is deposit rich

We have looked at the strategic costs for taking in deposits and how bringing in deposits can increase the profits of the bank. We know need to consider the strategic

costs of lending money out in the form of loans. How we calculate the strategic costs for new deposits depends on whether the bank is deposit rich or deposit poor. A similar approach is required when calculating the strategic cost of loans. When the bank is deposit rich, we will need to compare the return on loans to lending in the wholesale money markets. When the bank is deposit poor, we will need to compare the return on loans to borrowing from the wholesale money markets. Firstly, we will look at how we can extend the FTP rates for the loan unit when the bank is in the deposit rich situation.

The FTP rates for the loan unit can be extended in a similar way as in the case of the deposit unit. For example, if we have a two year bullet loan, the PV can be calculated as:

$$PV = L \left(\frac{(1 + i_L(0,2))^2 - (1 + W_L(0,2))^2}{(1 + E(0,2))^2} \right).$$

This is a simple extension of the one period model. We could define the period as 2 years so in effect this would be the same as the one period model. The FTP Rate for the loan unit would be:

$$W_L(0,2).$$

We can introduce a set repayment amount, ρ, at end of year 1. This can be thought of as a fixed loan schedule where a certain payment has to be made each year. The PV can be calculated as:

$$PV = \rho L \left(\frac{i_L(0,1) - W_L(0,1)}{1 + E(0,1)} \right)$$
$$+ (1 - \rho)L \left(\frac{(1 + i_L(0,2))^2 - (1 + W_L(0,2))^2}{(1 + E(0,2))^2} \right).$$

This can simply be thought as splitting the model into two different time periods. This would then equate to the following FTP rates:

$$\text{Time 1: } W_L(0,1);$$

$$\text{Time 2: } W_L(0,2).$$

So far both these loan products do not have any uncertainty. We will now consider a product where the customer can decide if they wish to repay the loan earlier. y is the percentage of the loan the customer decides to prepay at time 1. The PV can be calculated as:

$$PV = yL\left(\frac{i_L(0,1) - W_L(0,1)}{1 + E(0,1)}\right)$$
$$+ (1-y)L\left(\frac{(1+i_L(0,2))^2 - (1+W_L(0,2))^2}{(1+E(0,2))^2}\right),$$

where y is the proportion of loans prepaid at time 1 and is a random variable.

To understand the consequences of this we need to compare this to the strategic cost in the market. We need to consider what is a fair alternative and the costs associated with this. It is not necessarily what the bank will do in practice as the bank may want to take interest rate risk or funding liquidity risk. When the bank is deposit rich, it is either deciding to lend the money in wholesale money markets or in the form of loans. For it to be in the bank's interest, the bank needs to make at least a greater return from lending in the form of loans rather then lending in the wholesale money markets. Therefore we will look at the dynamics of how the loan can be compared to the strategic cost in the market. We will use the same notation as derived in Section 5.5.

At time 0, the bank would lend in the wholesale money market based in line with the expected y i.e. $\mathbf{E}(y) = \rho$. This can be seen in Table 5.7.1.

Table 5.7.1: Strategic cost at time 0 for new loans for a deposit rich bank

Strategic cost		
1 year lending	$U_B(0,1)\overline{P}_B(0,1)$	$= \rho L$
2 year lending	$U_B(0,2)\overline{P}_B(0,2)$	$= (1-\rho)L$

At time 1, we can compare the loan return to what we would have received in the market. If $y > \rho$, then more 2 year loans than expected are held for only 1 year rather than 2 years. For strategic comparison, we need to consider same proportion of 2 year bond holdings be sold at time 1. $y < \rho$ then we will be able to lend for longer in the market, and this will be compared to lending in the market for another year. This is summarised in Table 5.7.2.

Table 5.7.2: Strategic cost at time 1 for new loans for a deposit rich bank

Strategic cost		
Loan prepaid		$= yL(1 + i_L(0,1))$
1 year lending expiring	$U_B(0,1)P_B(1,1)$	
Additional lending in market	$U_B(1,2)\overline{P}_B(1,2)$	$= I(\rho \geq y)\frac{(\rho-y)}{\rho}$
		$U_B(0,1)P_B(1,1)$
Sale of 2 year lending	$\lambda_A U_A(0,2)\underline{P}_A(1,2)$	$= I(\rho < y)\frac{(y-\rho)}{1-\rho}$
Surplus	$yL(1 + i_L(0,1))$	
	$-U_B(0,1)P_B(1,1)$	
	$-\lambda_A U_A(0,2)\underline{P}_A(1,2)$	
	$+U_B(1,2)\overline{P}_B(1,2)$	

At time 2, the loan will be fully repaid. Therefore, we will compare this to the return that could have been made in lending in the wholesale money markets. This can be seen in Table 5.7.3.

Table 5.7.3: Strategic cost at time 2 for new loans for a deposit rich bank

Strategic cost	
Loan expiring	$= (1-y)L(1 + i_L(0,1))^2$
Additional lending expiring	$U_B(1,2)P_B(2,2)$
2 year lending expiring	$(1-\lambda_A)U_A(0,2)P_A(2,2)$
Surplus	$= (1-y)L(1 + i_L(0,1))^2$
	$-U_B(1,2)P_B(2,2)$
	$-(1-\lambda_A)U_A(0,2)P_A(2,2)$

We will go through three examples to get a better understanding of how this works:

- Example 5.7.1: Prepayments are as expected;

- Example 5.7.2: Prepayments are less than expected; and

- Example 5.7.1: Prepayments are greater than expected.

In these examples, we will use the assumptions as shown in Table 5.7.4. The assumptions have been chosen to emphasise the impact and market conditions may not represent the same magnitude. Important points regarding the assumptions are that:

- Prepayments are likely to decrease when interest rates rise; and

- Prepayments are likely to increase when interest rates fall.

The assumptions in these examples reflect this. This is to ensure that the bank is penalised for taking funding liquidity risk.

Table 5.7.4: Assumptions for the examples when looking at loans when the bank is deposit rich

Variables	Values
L	£100m
$i_L(0,1) = i_L0,2$	9.0%
$\overline{W}_L(0,1)$	5.4%
$\overline{W}_L(0,2)$	5.9%
$\overline{W}_L(1,2)$	7.9%
$\underline{W}_L(1,2)$	3.9%
$i_A(0,1) = i_A(0,2) = \overline{i}_A(1,2) = \underline{i}_A(1,2)$	3.0%
$i_D(0,1) = i_D(0,2)$	2.5%
$\alpha(0,1) = \alpha(0,2) = \alpha(1,2)$	5%
$E(0,1) = E_{1,2} = E(0,2)$	5.4%

Example 5.7.1. *Impact of loans in Deposit rich situation - Prepayments are as expected*

In this example, we will look at strategic costs for lending out in the form of loans or lending in the wholesale money markets. The bank is assumed to be deposit rich and prepayments are in line with expectations. At time 0, the money can be invested in loans or 1 and 2 year bonds. This is shown in Table 5.7.5.

Table 5.7.5: Strategic cost at time 0 for new loans for a deposit rich bank when $y = rho$

Strategic cost		
1 year lending	$U_B(0,1)\overline{P}_B(0,1)$	30
2 year lending	$U_B(0,2)\overline{P}_B(0,2)$	70

At time 1, some of the loan is repaid and the 1 year bond will expire. We can compare the difference to see the profit that the bank will make from lending out money in the form of loans. This is shown in Table 5.7.6.

Table 5.7.6: Strategic cost at time 1 for new loans for a deposit rich bank when $y = rho$

Strategic cost		
Loan prepaid		32.70
1 year lending expiring	$U_B(0,1)P_B(1,1)$	31.47
Surplus		1.23

At time 2, the remaining loans expire and will be repaid. The 2 year bond will also mature. We can compare the difference to see the profit for the bank.

Table 5.7.7: Strategic cost at time 2 for new loans for a deposit rich bank when $y = rho$

Strategic cost	
loan expiring	83.17
2 year lending expiring	78.51
Surplus	4.67

Example 5.7.2. *Impact of loans in Deposit rich situation - Prepayments are less than expected*

We have looked at the example, where deposits are in line with expectations. We will now consider the case where prepayments are less than expected. At time 0, the money can be lent in the form of loans or in the wholesale money markets. This will be the same as in Example 5.7.1. The difference happens at time 1, where prepayments are less than expected. This means that the bank can lend the difference between actual and expected prepayments in the wholesale money markets for another year. This is shown in Table 5.7.8.

Table 5.7.8: Strategic cost at time 1 for new loans for a deposit rich bank when $y < rho$

Strategic cost		
Loan prepaid		21.80
1 year lending expiring	$U_B(0,1)P_B(1,1)$	31.47
Additional lending in market	$U_B(1,2)\overline{P}_B(1,2)$	10.49
Surplus		0.82

At time 2, the full loan will be repaid. For the opportunity of lending in the wholesale money markets, the 2 year bond and the additional 1 year bond purchased at time 1 will expire. The difference betweent the loan and the opportunity of lending in the wholesale money markets will be the profit for the bank. This is shown in Table 5.7.9.

Table 5.7.9: Strategic cost at time 2 for new loans for a deposit rich bank when $y < rho$

Strategic cost	
loan Expiring	95.05
Additional lending expiring	11.32
2 year lending expiring	78.50
Surplus	5.23

As can be seen the profit for the bank is higher in Example 5.7.2 than in Example 5.7.1. The bank makes profits from lending the money out in the form of loans. The longer the bank lends out money the greater the bank's profits will be.

Example 5.7.3. *Impact of loans in Deposit rich situation - Prepayments are more than expected*

In this example we will look at the case where prepayments are more than expected. At time 0, the opportunity of lending in the markets will be split between 1 and 2 year bonds based on expected prepayment. This will be the same as Example 5.7.1. It is only at time 1, where things are different. At time 1, the prepayments will be greater than expected, therefore the bank will not be able to lend in the market for as long as originally intended and will need to sell some of its 2 year bond holding. This is shown in Table 5.7.10.

Table 5.7.10: Strategic cost at time 1 for new loans for a deposit rich bank when $y > rho$

Strategic cost		
Loan prepaid		43.6
1 year lending expiring	$U_B(0,1)P_B(1,1)$	31.47
Sale of 2 year lending	$\lambda_A U_A(0,2)\underline{P}_A(1,2)$	10.79
Surplus		1.34

At time 2, the loans will expire. The opportunity of lending in the market for 2 years will also expire. The difference will be the profit for the bank. This is shown

in Table 5.7.11.

Table 5.7.11: Strategic cost at time 2 for new loans for a deposit rich bank when $y > rho$

Strategic cost	
Loan expiring	71.29
2 year lending expiring	67.29
Surplus	4.00

If we now put these three examples all together, we can calculate the profit for the bank for any prepayment at time 1 based on on the initial assumption of a prepayment rate of 30%. The surplus for the bank at various levels of prepayments in shown in Figure 5.7.1. As we can see less prepayments results in a greater surplus for the bank and more prepayments for a smaller surplus.
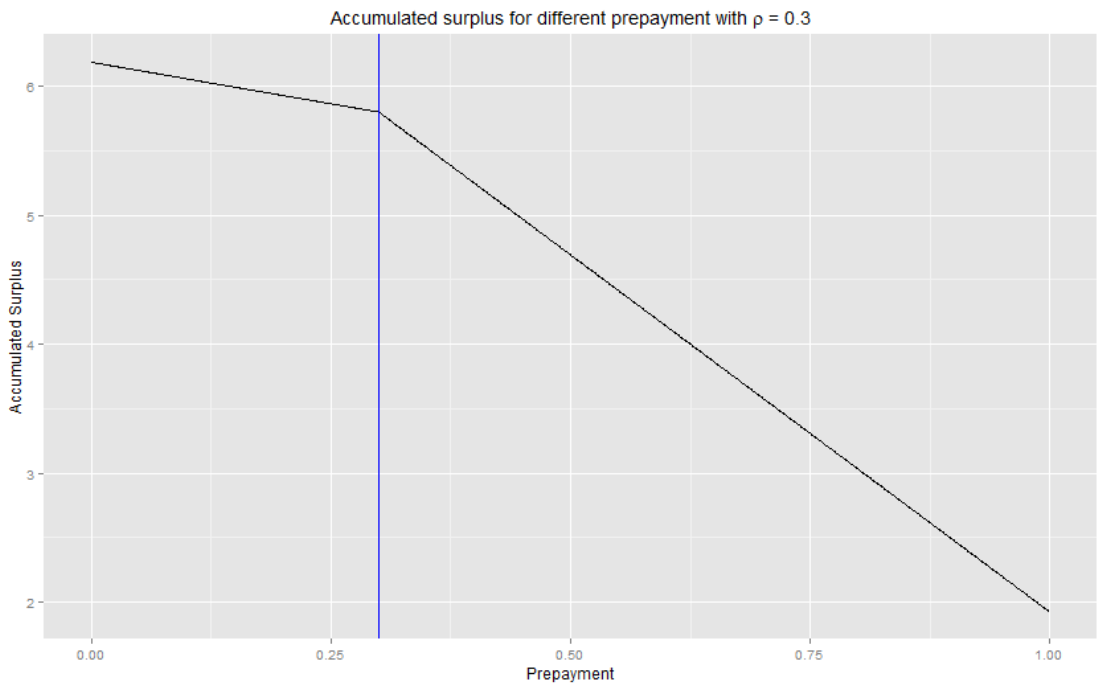
Figure 5.7.1: Accumulated surplus for the loan unit when the bank is deposit rich and $\rho = 0.3$

We can repeat this process for different assumptions for the initial prepayment at time 1. This is shown in Figure 5.7.2. As we can see the bank's surplus is maximised when the initial assumption for prepayments is equal to the actual prepayment amount. We can then use a similar approach as in Section 5.5.3 to price the cost of this uncertainty. So:

Cost of Prepayment Option $= \text{Profit}(\mathbf{E}(y)) - \mathbf{E}(\text{Profit}(y))$.
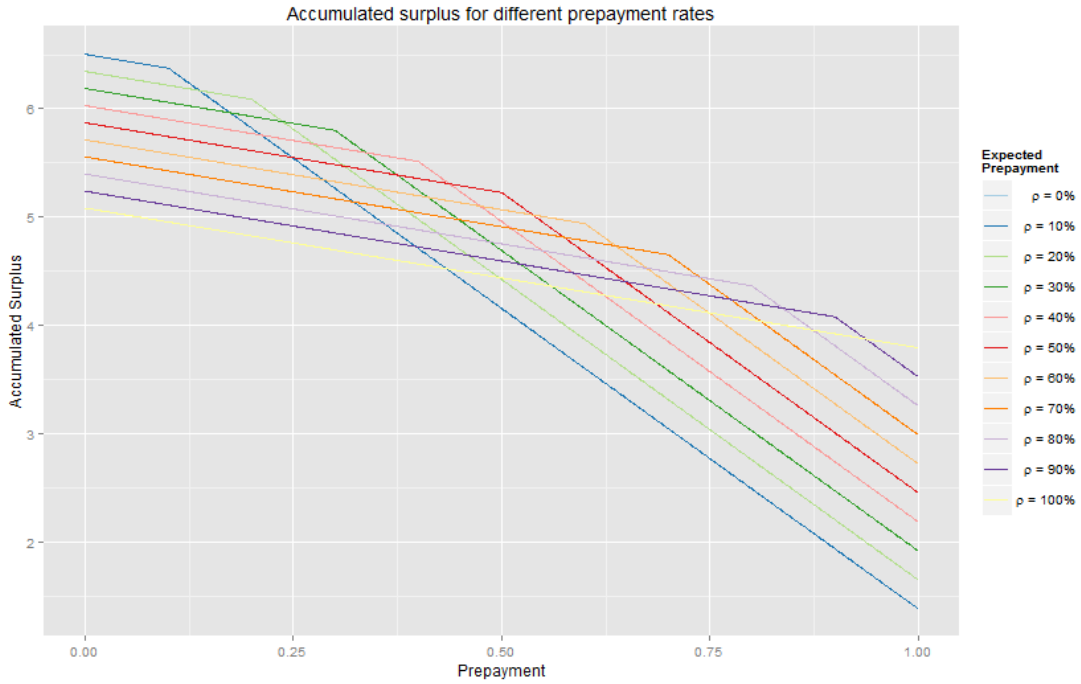
Figure 5.7.2: Accumulated surplus for different expected prepayments for the loan unit when the bank is deposit rich

If we assume a distribution for y as we did for x in Section 5.5.3, we can calculate the expected cost of the prepayment option. If we assume y has a beta distribution with parameters $alpha = 2.5$ and $beta = 5.83$. This would equate to a mean of 0.3 and standard deviation 0.15. This is the same as what was assumed for x in Section 5.5.3. The distribution is plotted in Figure 5.5.11, page 157. The cost of the prepayment option would be:

$$
\begin{aligned}
\text{Cost of Prepayment Option} &= \text{Profit}(\mathbf{E}(y)) - \mathbf{E}(\text{Profit}(y)) \\
&= \pounds5.96\text{m} - \pounds5.70\text{m} \\
&= \pounds0.26\text{m}.
\end{aligned}
$$

Ideally, we want to encourage less uncertainty and this would be reflected in the price of the option. If we reduce the variance of y, we want to reduce the cost of the option. If we assume y has a beta distribution with parameters $alpha = 6$ and $beta = 14$, this would equate to a mean of 0.3 and standard deviation 0.10.

This is another distribution we looked at for x in Section 5.5.3. The graph of this distribution is plotted in Figure 5.5.13, page 158. The expected cost of the option in this case would be:

$$
\begin{aligned}
\text{Cost of Prepayment Option} \quad &= \quad \text{Profit}(\mathbf{E}(y)) - \mathbf{E}(\text{Profit}(y)) \\
&= \quad £5.96\text{m} - £5.79\text{m} \\
&= \quad £0.17\text{m}.
\end{aligned}
$$

As we can see less uncertainty results in a lower cost of the prepayment option. We can also increase the uncertainty which would increase the option. If we assume y has a beta distribution with parameters $alpha = 1.275$ and $beta = 2.975$. This would equate to a mean of 0.3 and standard deviation 0.20. This is another distribution we looked at for x in Section 5.5.3. The graph of this distribution is plotted in Figure 5.5.12, page 157. The expected cost of the option in this case would be:

$$
\begin{aligned}
\text{Cost of Prepayment Option} \quad &= \quad \text{Profit}(\mathbf{E}(y)) - \mathbf{E}(\text{Profit}(y)) \\
&= \quad £5.96\text{m} - £5.61\text{m} \\
&= \quad £0.35\text{m}.
\end{aligned}
$$

This sets out an approach for calculating the cost of the prepayment option. The cost of the prepayment option will need to be agreed between the loan unit and the treasury unit. Using the option approach, this fixes the profit for the loan from the outset. The treasury unit will receive the profit or loss from the change in actual prepayment rate from the expected prepayment rate. This is the same as the approach discussed in Section 5.5.3. The cost of the prepayment option encourages the loan unit to accurately assess prepayment risk and to reduce the uncertainty in

prepayments. The loan is rewarded for this in future products in the form of lower option premiums. The treasury unit is rewarded for the risk they face in managing interest rate risk and funding liquidity risk. This approach should lead to good behaviour in the long term because if one party tries to 'game' the system they will be penalised in future products.

For the cost prepayment option approach to work it requires the following to be true:

- Prepayments are likely to decrease when interest rates rise; and

- Prepayments are likely to increase when interest rates fall.

The assumptions in the previous examples reflect this. This option price approach falls down if these conditions are not met. If we adopt the assumptions used for the deposit examples in Section 5.5 and shown in Table 5.5.4, page 138, then Figure 5.7.3 shows the profit for various expected prepayment assumptions.
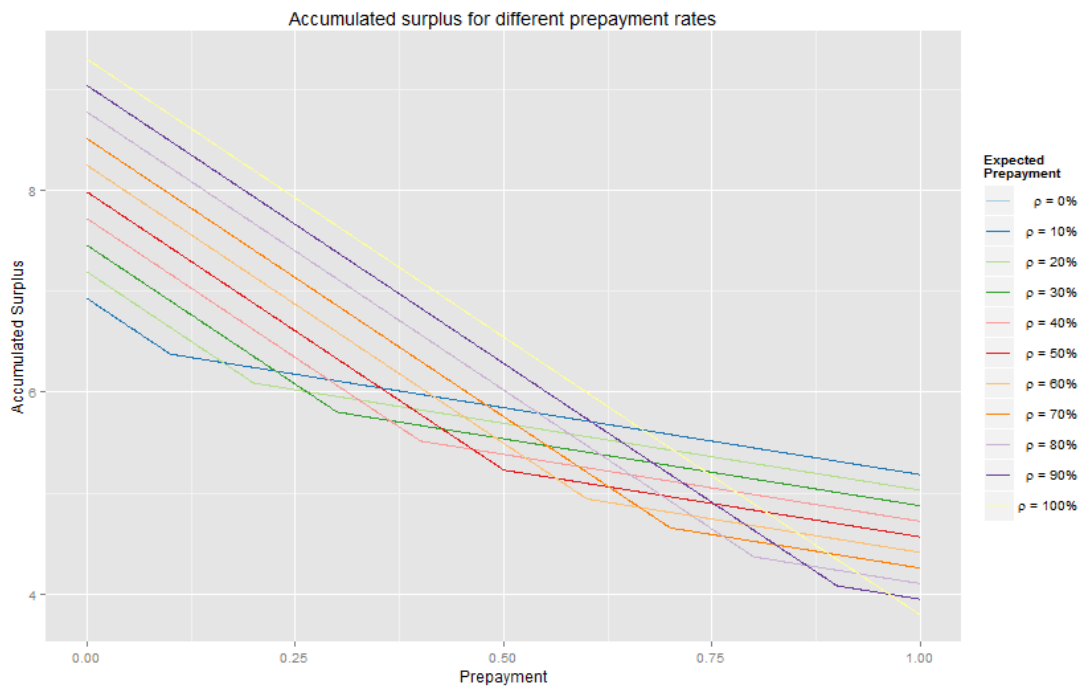
Figure 5.7.3: Accumulated surplus for different expected prepayments for the loan unit when the bank is deposit rich using assumptions that are not appropriate i.e. prepayments increasing when interest rates rise

The concept of the approach is to penalise to loan unit when funding liquidity risk arises. If we use the assumptions shown in Table 5.5.4, this would result in

a reward for funding liquidity risk. This is because we assume when lending in the wholesale money markets that taking action at time 1 by reinvesting or selling assets results in a a lower return than would have been achieved from holding the appropriate bond maturity from the outset. If we applied this approach for loans this would incentivise the loan unit to take funding liquidity risk as their strategic costs are reflected against lending in the wholesale money markets. Figure 5.7.3 shows us that the loan unit would set prepayment assumption at time 1 at either 100% or 0% depending on their view of the expected prepayment to maximise profits. This would not be in the interest of the bank as this would increase funding liquidity risk when prepayments are assumed to be 100%. Goodarzi et al. (1998) note prepayments do increase when interest rates fall and prepayments decrease when interest rates rise. This helps justify the assumptions used in these examples.

5.8   Loans when the bank is deposit poor

The final situation we need to look at is loan products when the bank is in the deposit poor situation. In this situation, we need to compare loans with borrowing in the wholesale money markets. The bank is effectively asking itself whether it is worth borrowing from the wholesale money market to fund loan products. We will first look at products with no uncertainty with their cashflows and then include the option of prepayment.

For a loan product with no uncertainty when the the bank is deposit poor, we can derive the FTP by using a similar method as used for loan products when the bank is deposit rich. For example, a 2 year loan with set prepayments, we can calculate the PV as:

$$
PV = \rho L \left(\frac{i_L(0,1) - \frac{W_B(0,1)}{1-\beta(0,1)} - \frac{\beta(0,1)i_A(0,1)}{1-\beta(0,1)}}{1 + E(0,1)} \right)
$$
$$
+ (1-\rho)L \left(\frac{(1 + i_L(0,2))^2 - \frac{(1+W_B(0,2))^2}{1-\beta(0,2)} - \frac{\beta(0,2)(1+i_A(0,2)^2)}{1-\beta(0,2)}}{(1 + E(0,2))^2} \right).
$$

This would equate to the following FTP rates:

$$\text{Time 1: } \frac{W_B(0,1)}{1-\beta(0,1)} - \frac{\beta(0,1)i_A(0,1)}{1-\beta(0,1)};$$

$$\text{Time 2: } \left(\frac{(1+W_B(0,2))^2}{1-\beta(0,2)} - \frac{\beta(0,2)(1+i_A(0,2)^2)}{1-\beta(0,2)}\right)^{0.5} - 1.$$

In the deposit poor situation, the bank needs to ask itself whether it is worth borrowing from the wholesale money markets to lend out in the form of loans. This is different from the deposit rich situation, as the bank is considering whether to lend out in the wholesale money markets or lend out in loans. Therefore, for the deposit poor situation we need to compare loans to the costs of borrowing money from wholesale money markets.

The complications arise when there is uncertainty with the proportion prepaid at time 1, for example when the customer has the option to prepay their loan. To be able to calculate the prepayment option, we need to look at the dynamics of the impact on wholesale money markets borrowing when we have uncertain prepayments, y. As in previous sections, this is not necessarily the approach the bank may adopt in practice but represents a fair comparison. We use the same notation as defined in Section 5.6. Initially, the bank will borrow from the wholesale money markets in line with the expected payments of the loan. When the bank borrows from the wholesale money markets it needs to set aside some of the money in the form of liquid assets. The liquid assets are an asset for the bank that generates a return. The liquid asset return will help offset some of the additional cost of the need to borrow more from the wholesale money markets to finance the loan and liquid asset requirements. Table 5.8.1 shows the strategic cost of borrowing from the wholesale money markets to finance loans at time 0.

Table 5.8.1: Strategic cost at time 0 for new loans for a deposit poor bank

Strategic cost		
Borrowing for 1 year	$U_B(0,1)\overline{Q}_B(0,1)$	$= \rho L\frac{1}{1-\beta(0,1)}$
Liquid asset for 1 year	$U_A(0,1)\overline{Q}_A(0,1)$	$= \rho L\frac{\beta0,1}{1-\beta(0,1)}$
Borrowing for 2 year	$U_B(0,2)\overline{Q}_B(0,2)$	$= (1-\rho)L\frac{1}{1-\beta(0,2)}$
Liquid asset for 2 year	$U_B(0,2)\overline{Q}_B(0,2)$	$= (1-\rho)L\frac{1}{1-\beta(0,2)}$

At time 1, some of the loans will be repaid. If $y < \rho$ then prepayments are less than expected. This means that the bank will need to borrow more from the wholesale money market to finance the loan. If $y > \rho$ then prepayments are greater than expected. This means that the bank will need to pay off some of its 2 year borrowings earlier. This is shown in Table 5.8.2.

Table 5.8.2: Strategic cost at time 1 for new loans for a deposit poor bank

Strategic cost		
Prepaid loans		$yL(1 + i_L(0, 1))$
1 year borrowing expired	$U_B(0, 1)Q_B(1, 1)$	
1 year liquid asset	$U_A(0, 1)Q_A(1, 1)$	
Additional 1 year borrowing	$U_B(1, 2)\overline{Q}_B(1, 2)$	$= I(\rho \geq y)\frac{(\rho - y)}{\rho}$
		$U_B(0, 1)Q_B(1, 1)$
Additional 1 year liquid asset	$U_A(1, 2)\overline{Q}_A(1, 2)$	$= I(\rho \geq y)\frac{(\rho - y)}{\rho}$
		$U_A(0, 1)Q_A(1, 1)$
Repay 2 year borrowing	$\lambda_B U_B(0, 2)\underline{Q}_B(1, 2)$	$= I(\rho < y)\frac{(y - \rho)}{(1 - \rho)}$
Selling 2 year liquid asset	$\lambda_A U_A(0, 2)\underline{Q}_A(1, 2)$	$= I(\rho < y)\frac{(y - \rho)}{(1 - \rho)}$
Surplus	$yL(1 + i_L(0, 1))$	
	$-U_B(0, 1)Q_B(1, 1)$	
	$+U_A(0, 1)Q_A(1, 1)$	
	$-\lambda_B U_B(0, 2)\underline{Q}_B(1, 2)$	
	$+\lambda_A U_A(0, 2)\underline{Q}_A(1, 2)$	
	$-U_B(1, 2)\overline{Q}_B(1, 2)$	
	$-U_A(1, 2)\overline{Q}_A(1, 2)$	

At time 2, the remaining loans will be repaid. The remaining 2 year borrowing and any additional borrowing at time 1 will expire. The bank will make a surplus between the return on loans less the cost on borrowing from the wholesale money markets. This is shown in Table 5.8.3.

Table 5.8.3: Strategic cost at time 2 for new loans for a deposit poor bank

Strategic cost	
Loans expiring	$(1 - y)L(1 + i_L(0, 1))$
Additional borrowing expiring	$U_B(1, 2)Q_B(2, 2)$
Additional liquid asset expiring	$U_A(1, 2)P_A(2, 2)$
2 year borrowing expiring	$(1 - \lambda_B)U_B(0, 2)Q_B(2, 2)$
2 year liquid asset expiring	$(1 - \lambda_A)U_A(0, 2)P_Q(2, 0, 2)$
Surplus	$(1 - y)L(1 + i_L(0, 1))$
	$-(1 - \lambda_B)U_B(0, 2)Q_B(2, 2)$
	$+(1 - \lambda_A)U_A(0, 2)Q_B(2, 2)$
	$-U_B(1, 2)Q_B(2, 2)$
	$+U_A(1, 2)Q_A(2, 2)$

We will now look at three examples to get a better understanding of what is going on:

- Example 5.8.1: Impact on loans when bank is in deposit poor situation and loan prepayments are in line with expectations;

- Example 5.8.2: Impact on loans when bank is in deposit poor situation and loan prepayments are less than expected; and

- Example 5.8.3: Impact on loans when bank is in deposit poor situation and loan prepayments are greater than expected.

In these examples we will use the assumptions shown in Table 5.8.4. The assumptions have been chosen to emphasis the impact and market conditions may not represent the same magnitude. Important points regarding the assumptions are that:

- Prepayments are likely to decrease when interest rates rise; and

- Prepayments are likely to increase when interest rates fall.

The assumptions in these examples reflect this. This is to ensure that the bank is penalised for taking funding liquidity risk.

Table 5.8.4: Assumptions for the examples when looking at loans when the bank is deposit poor

Variables	Values
L	£100m
$i_L(0,1) = i_L(0,2)$	9%
$\overline{W}_B(0,1)$	5.4%
$\overline{W}_B(0,2)$	5.9%
$\overline{W}_B(1,2)$	7.9%
$\underline{W}_B(1,2)$	3.9%
$i_A(0,1) = i_A(0,2) = \bar{i}_A(1,2) = \underline{i}_A(1,2)$	3.0%
$E(0,1) = E_{1,2} = E(0,2)$	5.4%
$\beta(0,1) = \beta(1,2) = \beta(0,2)$	10%

Example 5.8.1. *Impact on loans when bank is in deposit poor situation and loan prepayments are in line with expectations*

In this example, we will look at the situation where the bank is in the deposit poor situation and loan prepayments are in line with expectations. At time time 0, the bank will borrow from the wholesale money markets based on ρ. This is shown in the Table 5.8.5.

Table 5.8.5: Strategic cost at time 0 for new loans for a deposit poor bank and when $y = rho$

Strategic cost		
Borrowing for 1 year	$U_B(0,1)\overline{Q}_B(0,1)$	33.33
Liquid asset for 1 year	$U_A(0,1)\overline{Q}_A(0,1)$	3.33
Borrowing for 2 year	$U_B(0,2)\overline{Q}_B(0,2)$	77.77
Liquid asset for 2 year	$U_B(0,2)\overline{Q}_B(0,2)$	7.77

At time 1, some of the loans will be repaid. The one year borrowing from the wholesale money markets and liquid assets will mature. The prepayment of the loan can be used to repay the borrowing from the wholesale money market and the liquid asset holding will no longer be required. Any prepayment of the loan exceeding this amount will be the surplus to the bank. This is shown in Table 5.8.6.

Table 5.8.6: Strategic cost at time 1 for new loans for a deposit poor bank and when $y = rho$

Strategic cost		
Prepaid loans		32.7
1 year borrowing expired	$U_B(0,1)Q_B(1,1)$	35.13
1 year liquid asset	$U_A(0,1)Q_A(1,1)$	3.43
Surplus		1.00

At time 2, the the remaining loans will expire. The 2 year borrowing will also be due to be paid back. The bank will also have made a return on its 2 years liquid asset holding. We can calculate the surplus for the bank and this is shown in Table 5.8.7.

Table 5.8.7: Strategic cost at time 2 for new loans for a deposit poor bank and when $y = rho$

Strategic cost	
Loans expiring	83.17
2 year borrowing expiring	87.23
2 year liquid asset expiring	8.25
Surplus	4.19

Example 5.8.2. *Impact on loans when bank is in deposit poor situation and loan prepayments are less than expected*

In this example, we will look at the situation where the bank is in the deposit poor situation and loan prepayments are less than expected. At time 0, the borrowing is based on ρ. Therefore the starting position is the same as in Example 5.8.1. It is only at time 1, when things start to differ. At time 1, when prepayments are less than expected the bank will need to borrow for another year in the market. This also means the bank will also have to increase liquid assets holding for another year. This is shown in the Table 5.8.8.

Table 5.8.8: Strategic cost at time 1 for new loans for a deposit poor bank and $y < rho$

Strategic cost		
Prepaid loans		21.8
1 year borrowing expired	$U_B(0,1)Q_B(1,1)$	35.13
1 year liquid asset	$U_A(0,1)Q_A(1,1)$	3.43
Additional 1 year borrowing	$U_B(1,2)\overline{Q}_B(1,2)$	11.71
Additional 1 year liquid asset	$U_A(1,2)\overline{Q}_A(1,2)$	1.14
Surplus		0.67

At time 2, the loans will expire. The 2 year borrowing and additional 1 year borrowing will be paid back. The bank will also have made a return on its 2 year and extra 1 year liquid asset holding. Table 5.8.9 shows the surplus for the bank.

Table 5.8.9: Strategic cost at time 2 for new loans for a deposit poor bank and $y < rho$

Strategic cost	
Loans expiring	95.05
Additional borrowing expiring	12.99
Additional liquid asset expiring	1.18
2 year borrowing expiring	87.23
2 year liquid asset expiring	8.25
Surplus	4.26

Example 5.8.3. *Impact on loans when bank is in deposit poor situation and loan prepayments are greater than expected*

In this example, we will look at the situation where the bank is in the deposit poor situation and loan prepayments are greater than expected. At time 0, the borrowing

is based on ρ. Therefore the starting position is the same as in Example 5.8.1. It is only at time 1 when things will differ. At time 1, when prepayments are greater than expected the bank will not require to borrow so much from the wholesale money markets so can pay back some of the borrowing. This will also mean the bank can reduce their liquid assets holding. This is shown in the Table 5.8.10.

Table 5.8.10: Strategic cost at time 1 for new loans for a deposit poor bank and $y > rho$

Strategic cost		
Prepaid loans		43.60
1 year borrowing expired	$U_B(0,1)Q_B(1,1)$	35.13
1 year liquid asset	$U_A(0,1)Q_A(1,1)$	3.43
Repay 2 year borrowing	$\lambda_B U_B(0,2)\underline{Q}_B(1,2)$	8.40
Selling 2 year liquid asset	$\lambda_A U_A(0,2)\underline{Q}_A(1,2)$	0.80
Surplus		4.30

At time 2, the remaining loans will expire. The remaining 2 year borrowing will be paid back. The bank will also have made a return on its 2 year liquid asset holding. We can then calculate the surplus for the bank and this can be seen in Table 5.8.11.

Table 5.8.11: Strategic cost at time 2 for new loans for a deposit poor bank and $y > rho$

Strategic cost	
Loans expiring	71.29
2 year borrowing expiring	78.51
2 year liquid asset expiring	7.43
Surplus	0.21

If we put all these three examples together, we can calculate the surplus for the bank at different prepayment levels when the initial expected prepayment is 0.3. Figure 5.8.1 shows the surplus for the bank when the expected prepayment is 0.3.

We can take this further by looking at the surplus for the bank when we vary the expected prepayment rate, ρ. Figure 5.8.2 shows the surplus for the bank when we vary ρ. As can be seen the surplus is maximised when the expected prepayment equals the actual prepayment rate.

Using this information, we can calculate the cost of the option to prepay. We can adopt the same approach for calculating the option of prepayment for a loan
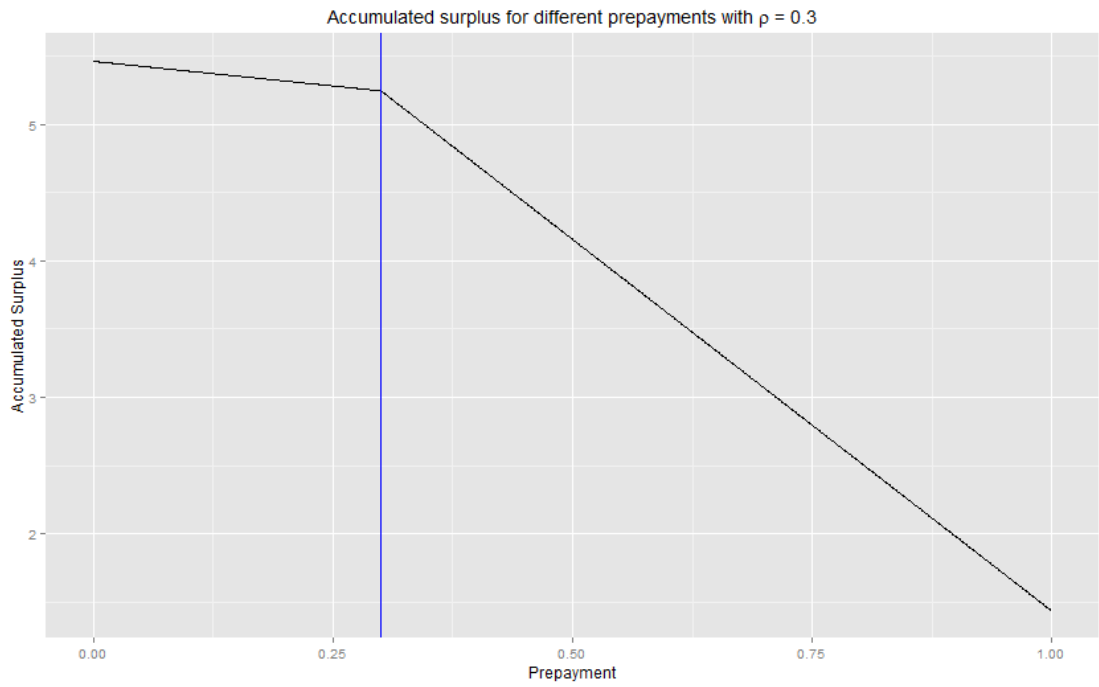
Figure 5.8.1: Surplus for the loan unit at various levels of prepayment when the bank is deposit poor and $\rho = 0.3$
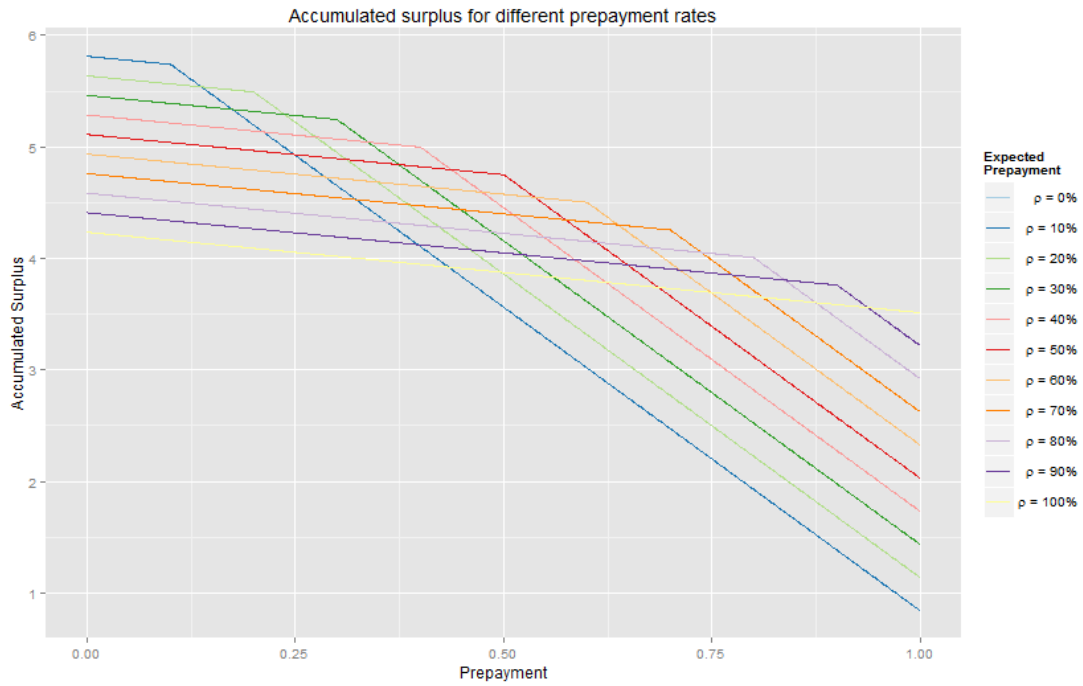
Figure 5.8.2: Accumulated surplus for different expected prepayments for the loan unit when the bank is deposit poor

product when the bank is deposit rich. Therefore the cost of the option would be:

$$
\begin{aligned}
\text{Cost of Prepayment Option} \;&=\; \text{Profit}(\mathbf{E}(y)) - \mathbf{E}(\text{Profit}(y)) \\
&=\; £5.25\text{m} - £4.96\text{m} \\
&=\; £0.29\text{m}
\end{aligned}
$$

This approach only works if the following conditions are true:

- Prepayments are likely to decrease when interest rates rise; and

- Prepayments are likely to increase when interest rates fall.

The assumptions in these examples reflect this. This option price approach falls down if these conditions are not met i.e. we will get a similar outcome as discussed in Section 5.7 when looking at the option price when the bank is deposit rich.

5.9 Alternative approaches

In this section, we have looked at how FTP rates can be extended to two time periods. Dermine (2009) has also looked at extending FTP rates into two time periods. Dermine (2009) shows:

$$
\text{PV} = (b_1 - d_1)D(d_1) + \frac{(b_2 - d_2)D(d_1, d_2)}{1 + b_2};
$$

where:

- b_i is the bond rate in year i;

- d_i is the deposit rate in year i; and

- D is the amount of deposits.

Dermine (2009) goes on to show:

$$\text{Marginal PV } = (b_1 - d_1) + \frac{(b_2 - d_2)\frac{\partial D_2}{\partial D1}}{1 + b_2};$$

with α = persistence factor = $\frac{\partial D_2}{\partial D_1}$.

This approach does not allow for funding liquidity risk. Therefore it is not easy to determine how complicated this approach will be if funding liquidity risk was included. It is not possible to compare this approach with the methodology discussed in this chapter. This is because Dermine (2009) has looked at a simplified case where it is not possible to see how exactly it would apply in more complicated situations. If funding liquidity risk is included we can start to compare methodology. Dermine (2009) has not commented whether the bank is deposit rich or deposit poor so we do not know how this will effect the outcome. From Section 5.2, we have seen how defining a bank as deposit rich or deposit poor is more important when funding liquidity risk is included. Although Dermine (2009) is looking at PV, the calculation seems to show the value a time 1 as he has only discounted for one period. Therefore without further information it is difficult to say how this approach could be expanded. Using a persistence factor is similar to allowing an amount, γ, to be withdrawn at time 1.

Dermine (2009) has set out the steps to start on an approach for two periods. However, including funding liquidity risk is going to add much more complexity to this approach.

5.10   FTP - Multi time period model

So far we have looked at the one time period model and expanded it into a two time period model. As can be seen this added complexity showed alternative approaches could be adopted. In reality, the bank will work over multiple time periods. The bank may define a time period as a month or a year depending on their need for accuracy. Using multiple time periods will add further complications to the modelling.

If the bank is expanding the model for a product with known cashflows, it should

be relatively straightforward to expand the model. The same methodology for expanding the model for two time periods can be used. The cashflows are effectively divided up into the different time periods. For example, we can look at a deposit product with known withdrawal at time 1 and time 2. We can calculate the expected PV of the profit for the deposit unit and derive the appropriate FTP rates. If we let γ_1 be the known withdrawal at time 1 and γ_2 be the known withdrawal at time 2. We will assume the bank is in the deposit rich situation, then the expected PV for the deposit unit would be:

$$
PV = \gamma_1 D \left(\frac{W_L(0,1)(1 - \alpha(0,1)) + \alpha(0,1)i_A(0,1) - i_D(0,1)}{1 + E(0,1)} \right)
$$

$$
+ \gamma_2 D \left(\frac{\begin{array}{c}((1 + W_L(0,2))^2(1 - \alpha(0,2)) + \alpha(0,2)(1 + i_A(0,2))^2 - 1) \\ - ((1 + i_D(0,2))^2 - 1)\end{array}}{(1 + E(0,2))^2} \right)
$$

$$
+ (1 - \gamma_1 - \gamma_2) D \left(\frac{\begin{array}{c}((1 + W_L(0,3))^3(1 - \alpha(0,3)) + \alpha(0,3)(1 + i_A(0,3))^3 - 1) \\ - ((1 + i_D(0,3))^3 - 1)\end{array}}{(1 + E(0,3))^3} \right).
$$

This would then translate into the following FTP rates for the deposit unit in a deposit rich bank:

$$
\text{Time 1: } W_L(0,1)(1 - \alpha(0,1)) + \alpha(0,1)i_A(0,1) - 1;
$$

$$
\text{Time 2: } ((1 + W_L(0,2))^2(1 - \alpha(0,2)) + \alpha(0,2)(1 + i_A(0,2))^2)^{0.5} - 1;
$$

$$
\text{Time 3: } ((1 + W_{L0,3})^3(1 - \alpha_{0,3}) + \alpha_{0,3}(1 + i_{B0,3})^3)^{\frac{1}{3}} - 1.
$$

The bank will need to consider what are the appropriate α and β values. There may be difficulty in calculating the appropriate rate for borrowing or lending in the wholesale money markets. The bank may not regularly trade or they may have limited transactions at the longer duration. This should be investigated further as

we want the borrowing and lending to represent the fair value to the bank.

However, the real difficulty is going to be where the deposit and loan units' cashflows are unknown and calculating a price for this uncertainty. For example, allowing customers to withdraw their money when they wish. Customers' behaviours might change at each time period. Also the decision at time 2 may be dependent on the decision at time 1. These decisions may need to be taken into consideration which could increase the complexity of modelling the option. This will need to be considered in more detail. It would be worth looking at actual customers' behaviours to help model the option.

Similarly, including the option of prepayment for loans will become more difficult to model. Repaying in one period may increase the probability of prepayment in the next period. Prepaying does reduce funding liquidity risk for the bank. The problem is that if we assume a certain level of prepayment and this does not materialise it increases the funding liquidity risk. For products to be priced competitively the bank will need to consider customers' behaviours and prepayments so this will increase the complexity.

The two time period model is a good starting point for increasing the model to allow for multiple time periods. Multi time periods will add to the complexity. In particular around costing for customer options and behaviours. In addition consideration will need to given for borrowing and lending in the wholesale money markets at the longer duration. Hopefully, these two time period model will help move the discussion forward in this area.

5.11 Conclusion

FTP can be extended to two time periods although it does increase the complexity. It is not straightforward to say whether a bank is deposit rich or deposit poor. Instead we need to look at the cashflows and decide for each time period whether the bank is in the deposit rich or deposit poor situation. This increases the complexity but it is needed to incentivise the business units in the bank appropriately. As discussed in Section 4.4.3.2 we would expect the FTP rates to be similar for a deposit rich or

deposit poor bank. However, there are situations that could arise that could make the difference in FTP rates significant. Banks will have to be particularly careful when the bid/ask spread on borrowing and lending in the wholesale money market is large, when β is large or when there is a low return on liquid asset, i_A, to ensure that the appropriate FTP rates are used.

There are different approaches that can be used to extend the FTP rates from one time period to two time periods. No approach is perfect but the preferable approach is the buy and hold approach. This allows the bank to hedge their risk if they wish. This approach has been used to look at different products the bank could issue.

How the product is priced from a FTP framework depends on whether the bank is deposit rich or deposit poor. For products with fixed cashflows it is relatively straightforward to calculate the expected profits for the business units. It is more complicated when there is uncertainty with the cashflows.

There is uncertainty with cashflows when customers have the option to withdraw their deposits from the bank when they wish. This option needs to be priced. This can be achieved by looking at the strategic cost of bringing in deposits to the bank. We can calculate the strategic cost of the option of flexible withdrawal granted to customers.

Ideally, we want to incentivise the deposit and treasury units to work in the best interests of the bank. Therefore we do not want them to 'game' the FTP framework for their own interests at the expense of the bank. There are different ways the cost of the option could be charged to the business units. The preferred approach is to charge a premium for the option upfront and for the treasury to receive the actual profit or loss. This approach has its pros and cons, but in the long run should incentivise the business units to work in the interest of the bank overall.

It is also complicated when we look at prepayment risk for loans. By offering a prepayment option, this reduces funding liquidity risk. However, if we allow for prepayments to make the pricing of the product more competitive this increases funding liquidity risk if the prepayments do not materialise. The pricing of the

prepayment risk requires different conditions to the pricing requirements of withdrawal risk. These conditions are justifiable as they are based on the likelihood of prepayments occurring. However it does mean the results are dependent on the assumptions used.

We have looked at extending the model to two time periods. In reality the bank works over multi time periods. The same methodology can be used to extend the model for multi time periods. However, the complexity does increase especially as regards the pricing of how to price the uncertainty of the cashflows.

Overall, FTP can be used in the two time period framework to help the bank manage their funding liquidity risk. This is a good first step to help the bank ensure it takes funding liquidity risk into account in their products. However, it is not perfect and there is potential for different approaches to be used.

Chapter 6

Conclusion

Funding liquidity risk is a very important risk for banks. Not assessing the risks properly can lead to the downfall of a bank or result in significant government assistance. In the UK some examples are Northern Rock, HBOS and RBS.

There are different approaches to managing funding liquidity risk. For example, the bank can use maturity ladders, rank liquid assets, scenario and stress testing. No single value can adequately explain the bank's exposure to funding liquidity risk and a range of methods have to be investigated.

Regulation has been strengthened in light of the global financial crisis in 2007-2008. The introduction of the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) in Basel III will help make funding liquidity risk more transparent. However it is important that banks embrace all of the liquidity considerations and have appropriate contingency plans in place. Funding liquidity risk can strike quickly so banks need to act fast. By ensuring that banks fully assess funding liquidity risk and the risk is monitored appropriately by senior management this will help to reduce funding liquidity risk.

One way to assess funding liquidity risk is through the use of Fund Transfer Pricing (FTP). FTP is used to incentivise business units and transfer the risk to a centralised business unit to manage. We have seen that FTP has developed over time and the next step is to include funding liquidity risk. Business units will always try to maximise their profits and will try to 'game' the FTP framework to do this. Therefore it is important to ensure that FTP continues to keep developing with

changes in business practice.

There are many discussions on what should be included in the FTP framework. Certainly more work could be done in this area. In particular whether the bank's own credit risk should be included in the FTP framework. There are pros and cons to the different views. Including the bank's own credit risk may result in a significant change to how the loan department assess credit risk. This is because it would be appropriate to assess customers' credit risk in relation to the bank's own credit risk rather than as a stand alone credit risk. More work is needed to be done in this area.

In this thesis, we have looked at how FTP can be used to incentivise a bank in a one time period model. The FTP rates will depend on whether the bank is deposit rich or deposit poor. The FTP framework can be used to maximise the bank's profits. Consideration needs to be given to what is the appropriate α and β - the amount of deposits and borrowing from wholesale money markets that needs to be set aside as liquid assets. The new LCR has some consequences for this. However regulation is a minimum and the bank will need to assess what is appropriate for itself. Further work assessing the appropriate α and β would be most welcome.

This leads on to liquid asset holdings. Basel III has set out what can be included in their requirements for High Quality Liquid Assets (HQLA). There is a significant range of assets that can be included and we need to consider the appropriate return on these assets. Further research into the optimal liquid asset holding and how the bank plans to structure their return from these assets would be interesting research. This will impact on the FTP rates so it will be interesting to see the research developments in this area.

We have also seen how the FTP framework can be extended to two time periods. This adds further complications. It is no longer straight forward to determine whether the bank is deposit rich or deposit poor. We need to consider the cashflows and determine whether the bank is deposit rich or deposit poor for each time period. There are different approaches for extending the model to two time periods but the preferred approach is one that can be replicated and hedged with financial instru-

ments. The greatest complication arises with pricing the uncertainty of cashflows because of the options granted to customers. To allow for this uncertainty we can consider the impact this has on the potential profits of the bank and calculate the expected cost of granting these options to customers. This allows the business units to be charged appropriately, via the FTP framework, for the uncertainty caused by providing customers with the option of loan prepayment and the option of the right to withdrawal of deposits. There is the possibility of the cost being incorrectly calculated if a business unit is trying to increase their profits. However, this will mean that either the business unit or treasury unit will have reduced profits at the expense of the other unit. This possibility should be removed over time as both units, business and treasury, have to agree the appropriate value of the option. More work needs to be done in this area in particular by looking at the relationship of factors that influence customers' behaviours and how this interacts with the value of the option.

When extending the model to multi time periods, this will increase the complexity of the uncertainty of cashflows and make it more difficult to calculate the appropriate cost. Further work needs to be done investigating customers' behaviours and how this uncertainty can be priced and included in the FTP framework.

Overall, FTP is a good approach for helping banks assess their funding liquidity risk. By charging the business units for funding liquidity risk, this helps to ensure it is at the forefront of business decisions. In this thesis, I have set out the initial steps for implementing FTP and highlighting some of the complexities involved. However, further work is needed before it can be fully implemented in a retail bank.

Glossary

Asset is an economic resource owned by the bank

Balance sheet shows the assets compared to the liabilities and shareholder's equity of the bank

Bank of England is the central bank in the UK

Banker's acceptance is short term debt issued by a company and guaranteed by a bank

Basel II is the set of reforms published by the Basel Committee on Banking Supervision to strengthen the regulation, supervision and risk management of banks in 2004

Basel III is the set of reforms published by the Basel Committee on Banking Supervision to strengthen the regulation, supervision and risk management of banks in 2014

Bid/ask spread is the difference between buying or selling an asset in the financial markets

Bill of exchange is where one party agrees to pay another party a certain amount at a fixed time i.e. a bill due at a future time

Bunds are government bonds issued by the German government with a maturity up to 30 years

Central bank is a national bank that is responsible for overseeing a nation's monetary system

Certificate of deposit is a tradable receipt which specifies a payment of money at a certain time from a bank

Commercial paper is a short term unsecured promissory note that promises to pay a certain amount at a fixed date and trades in the market at a discount to this value

Contingency liquidity risk is the risk that cash is demanded from a promise that the bank has made such as use of credit cards or credit facilities

Covered bond is an issue of a bond which has been guaranteed against loans

Credit risk is the risk that the indebted may not be able to pay the money due to the bank

Customer is usually an individual or an SME who engages in transactions with a retail bank

Default is when the payee does not pay the amount required when due

Deposit is money lent to the bank from its customers

Deposit poor is where the bank's assets are greater than the customers' deposits and as such the bank needs to borrow from wholesale money markets to make up the difference

Deposit rich is where the customers' deposits are more than sufficient to cover the assets of the bank

Funding liquidity risk is the risk that a bank can not pay its liabilities as they fall due

GILTS are government bonds issued by the UK government with a maturity up to 50 years.

Global financial crisis in 2007-2008 was a financial crisis which resulted in a significant fall in the world stock market and resulted in many banks worldwide needing assistance from their central banks and governments

Global liquidity indicators are signals that suggest a potential problem could arise that would affect the amount of liquidity available in the financial system

Government bond is debt issued by the government in the financial markets

Haircut is the difference between the market value of an asset and the value of the loan that can be secured against the asset

Insolvency is where the bank's liabilities are greater than their assets

Interest rate risk is the risk of movement in interest rates

Liability is money that the bank owes

Liquid asset is an asset that has very low market liquidity risk

Liquidity risk refers to market liquidity and/or funding liquidity risk

Loan is money lent to customers for various reasons such as cars and mortgages

Market liquidity risk is the risk that the assets can not be sold in the financial markets without offering a discount

Market risk is the risk of movements in the financial markets, in particular those which may lead to a loss

Operational risk is the risk that systems and procedures are not adequate or abused and this could lead to financial loss

Repurchasing agreement is an agreement where one party agrees to sell an asset to another party and agrees to buy it back at a fixed price and time in the future

Retail bank is a bank that specialise in lending and borrowing from retail customers

Risk appetite is the ability and willingness of investors to take risk

Securitisation is a financial product that is sold in the market where the assets are used to raise funds and the repayment depends on the performance of the assets

T-Bills are government bonds issued by the US government with a maturity up to 1 year

T-Bonds are government bonds issued by the US government with a maturity over 10 years

T-Notes are government bonds issued by the US government with a maturity from 1 to 10 years

Time deposit is money deposited at the bank for a specific period of time

Wholesale money market is a market where the bank is able to borrow or lend money to other banks or large corporations

Acronyms

ALM Asset Liability Modelling

ASF Available amount of Stable Funding

ASW Asset Swap Spread

BCBS Basel Committee on Banking Supervision

BIS Bank for International Settlements

CDS Credit Default Swaps

CFP Contingency Funding Plan

ECB European Central Bank

FSA Financial Services Authority

FSCS Financial Services Compensation Scheme

FTP Fund Transfer Pricing

HQLA High Quality Liquid Assets

LCR Liquidity Coverage Ratio

LIBOR London Interbank Offered Rate

NII Net Interest Income

NIM Net Interest Margin

NSFR Net Stable Funding Ratio

OAS Option Adjusted Spread

OTC Over The Counter

PRA Prudential Regulation Authority

PV Present Value

RBS Royal Bank of Scotland

Repo Repurchasing Agreement

RMBS Retail Mortgage Backed Securities

RSF Required amount of Stable Funding

SME Small to Medium Enterprises

SPV Special Purpose Vehicles

VAR Value at Risk

VIX Chicago Board Options Exchange Index

Appendix A

Appendix

A.1 Comparison of the different FTP approaches

We can calculate the difference between the different approaches for expanding the FTP framework. To make the calculations easier we will assume that the yield curves are flat and that the appropriate discount rate for the profit is W_L. Having an increasing yield curve will make the comparison more difficult and will likely lead to an even larger difference. We will assume α is simply a fixed number and the W_L is the appropriate discount rate.

The assumptions we are assuming are:

$$W_L = W_L(0,1) = W_L(0,2) = W_L(1,2) = E(0,1) = E(0,2)$$

$$i_A = i_A(0,1) = i_A(0,2) = i_A(1,2)$$

$$\alpha = \alpha(0,1) = \alpha(0,2) = \alpha(1,2)$$

$$i_D = i_D(0,1) = i_D(0,2) = i_D(1,2)$$

A.1.1 Proof of the difference between the annual rebalancing approach and the buy and hold approach

The difference between the annual rebalancing approach FTP rate (FTP_{AR}) and the buy and hold approach FTP rate (FTP_{BH}) is:

$$FTP_{AR} - FTP_{BH}$$

$$\alpha(1-\gamma)D\frac{(\alpha j_A^2 - j_A^2)}{(1+W_L)^2}.$$

Proof. Incorporating the assumptions, the annual rebalancing approach is:

$$
\begin{aligned}
PV \;=\; & \gamma D\big(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{1+W_L}\big) \\
& +(1-\gamma)D\big(\frac{((1+W_L(1-\alpha)+\alpha i_A)^2 - 1) - ((1+i_D)^2 - 1)}{(1+W_L)^2}\big)
\end{aligned}
$$

The buy and hold approach is:

$$
\begin{aligned}
PV \;=\; & \gamma D\big(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{1+W_L}\big) \\
& +(1-\gamma)D\big(\frac{((1+W_L)^2(1-\alpha)+\alpha(1+i_A)^2 - 1) - ((1+i_D)^2 - 1)}{(1+W_L)^2}\big)
\end{aligned}
$$

If we let $y = W_L(1-\alpha)+\alpha i_A$.

If we look at the difference between the approaches we can see how similar they are. So:

$$\gamma D(\frac{y - i_D}{1 + W_L}) + (1 - \gamma)D(\frac{((1 + y)^2 - 1) - ((1 + i_D)^2 - 1)}{(1 + W_L)^2})$$

$$-\gamma D(\frac{y - i_D}{1 + W_L})$$

$$-(1 - \gamma)D(\frac{((1 + W_L)^2(1 - \alpha) + \alpha(1 + i_A)^2 - 1) - ((1 + i_D)^2 - 1)}{(1 + W_L)^2})$$

Simplifying:

$$(1 - \gamma)D(\frac{((1 + y)^2 - 1) - ((1 + i_D)^2 - 1)}{(1 + W_L)^2})$$

$$-(1 - \gamma)D(\frac{((1 + W_L)^2(1 - \alpha) + \alpha(1 + i_A)^2 - 1) - ((1 + i_D)^2 - 1)}{(1 + W_L)^2})$$

Multiply by $(1 + W_L)^2$:

$$(1 - \gamma)D(((1 + y)^2 - 1) - ((1 + i_D)^2 - 1))$$

$$-(1 - \gamma)D(((1 + W_L)^2(1 - \alpha) + \alpha(1 + i_A)^2 - 1) - ((1 + i_D)^2 - 1))$$

Divide by $(1 - \gamma)D$ and simplifying:

$$(1 + y)^2 - ((1 + W_L)^2(1 - \alpha) + \alpha(1 + i_A)^2)$$

Rearranging:

$$1 + 2y + y^2 - ((1 + 2W_L + W_L^2)(1 - \alpha) + \alpha(1 + 2i_A + i_A^2))$$

$$1 + 2(W_L(1-\alpha) + \alpha i_A) + (W_L(1-\alpha) + \alpha i_A)^2 - ((1 + 2W_L + W_L^2)(1-\alpha) + \alpha(1 + 2i_A + i_A^2))$$

$$1 + 2W_L(1-\alpha) + 2\alpha i_A + (W_L(1-\alpha) + \alpha i_A)^2 - (1-\alpha) - 2W_L(1-\alpha) - (1-\alpha)W_L^2 - \alpha(1 + 2i_A + i_A^2)$$

$$(W_L(1-\alpha) + \alpha i_A)^2 - (1-\alpha)W_L^2 - \alpha i_A^2$$

$$W_L^2(1-\alpha)^2 + \alpha^2 i_A^2 + 2W_L(1-\alpha)\alpha i_A - (1-\alpha)W_L^2 - \alpha i_A^2$$

$$W_L^2(1-2\alpha+\alpha^2) + \alpha^2 i_A^2 + 2W_L(1-\alpha)\alpha i_A - W_L^2 + \alpha W_L^2 - \alpha i_A^2$$

$$W_L^2\alpha^2 - \alpha W_L^2 + 2W_L(1-\alpha)\alpha i_A + \alpha^2 i_A^2 - \alpha i_A^2$$

Let $i_A = W_L + j_A$:

$$W_L^2\alpha^2 - \alpha W_L^2 + 2W_L(1-\alpha)\alpha(W_L + j_A) + \alpha^2(W_L + j_A)^2 - \alpha(W_L + j_A)^2$$

$$W_L^2\alpha^2 - \alpha W_L^2 + 2W_L^2(1-\alpha)\alpha + 2W_L(1-\alpha)\alpha j_A + \alpha^2(W_L^2 + j_A^2 + 2W_L j_A) - \alpha(W_L^2 + j_A^2 + 2W_L j_A)$$

$$W_L^2\alpha^2 - \alpha W_L^2 + 2\alpha W_L^2 - 2\alpha^2 W_L^2 + 2\alpha W_L j_A - 2\alpha^2 W_L j_b + \alpha^2(W_L^2 + j_A^2 + 2W_L j_A) - \alpha(W_L^2 + j_A^2 + 2W_L j_A)$$

$$\alpha^2 j_A^2 - \alpha j_A^2$$

We now need to add back the terms that we have removed.

Multiply by $\alpha(1-\gamma)D$:

$$\alpha(1-\gamma)D(\alpha j_A^2 - j_A^2)$$

Divide by $(1+W_L)^2$:

$$\alpha(1-\gamma)D\frac{(\alpha j_A^2 - j_A^2)}{(1+W_L)^2}$$

The absolute difference is $\alpha(1-\gamma)D\frac{(\alpha j_A^2 - j_A^2)}{(1+W_L)^2}$. This is expected to be a very small percentage of D.

$\square$

A.1.2 Proof of the difference between the annual rebalancing approach and the forward rate approach

The difference between the annual rebalancing approach FTP rate and the forward rate approach FTP rate (FTP_{FR}) is:

$$FTP_{AR} - FTP_{FR}$$

$$\alpha(1-\gamma)D\frac{(\alpha j_A^2 - j_D j_A)}{(1+W_L)^2}.$$

Proof. Incorporating the assumptions, the annual rebalancing approach is:

$$
\begin{aligned}
PV &= \gamma D(\frac{W_L(1-\alpha) + \alpha i_A - i_D}{1 + W_L}) \\
&\quad + (1-\gamma)D(\frac{((1 + W_L(1-\alpha) + \alpha i_A)^2 - 1) - ((1+i_D)^2 - 1)}{(1+W_L)^2})
\end{aligned}
$$

The forward rate approach is:

$$
\begin{aligned}
PV &= D(\frac{W_L(1-\alpha) + \alpha i_A - i_D}{1 + W_L}) \\
&\quad + (1-\gamma)D(1+i_D)(\frac{W_L(1-\alpha) + \alpha i_A - i_D}{(1+W_L)^2})
\end{aligned}
$$

If we let $y = W_L(1-\alpha) + \alpha i_A$

So the annual rebalancing approach:

$$
\begin{aligned}
PV &= \gamma D(\frac{y - i_D}{1 + W_L}) \\
&\quad + (1-\gamma)D(\frac{((1+y)^2 - 1) - ((1+i_D)^2 - 1)}{(1+W_L)^2})
\end{aligned}
$$

The forward rate approach is:

$$PV = D(\frac{y - i_D}{1 + W_L})$$
$$+ (1 - \gamma)D(1 + i_D)(\frac{y - i_D}{(1 + W_L)^2})$$

If we look at the difference between the approaches we can see how similar they are. So:

$$\gamma D(\frac{y - i_D}{1 + W_L}) + (1 - \gamma)D(\frac{((1 + y)^2 - 1) - ((1 + i_D)^2 - 1)}{(1 + W_L)^2})$$
$$- D(\frac{y - i_D}{1 + W_L}) - (1 - \gamma)D(1 + i_D)(\frac{y - i_D}{(1 + W_L)^2})$$

Multiple through by $(1 + W_L)^2$:

$\gamma D(1 + W_L)(y - i_D) + (1 - \gamma)D(((1 + y)^2 - 1) - ((1 + i_D)^2 - 1)) - D(1 + W_L)(y - i_D) - (1 - \gamma)D(1 + i_D)(y-$

Expand $(1 + y)^2 - 1) - ((1 + i_D)^2 - 1)$:

$\gamma D(1 + W_L)(y - i_D) + (1 - \gamma)D(y^2 + 2y - i_D^2 - 2i_D) - D(1 + W_L)(y - i_D) - (1 - \gamma)D(1 + i_D)(y - i_D)$

$\gamma D(1 + W_L)(y - i_D) + (1 - \gamma)D(y - i_D)(y + i_D + 2) - D(1 + W_L)(y - i_D) - (1 - \gamma)D(1 + i_D)(y - i_D)$

Divide by $(y - i_D)$:

$$\gamma D(1 + W_L) + (1 - \gamma)D(y + i_D + 2) - D(1 + W_L) - (1 - \gamma)D(1 + i_D)$$

Rearrange:

$$(\gamma - 1)D(1 + W_L) + (1 - \gamma)D(y + i_D + 2 - 1 - i_D)$$

$$-(1 - \gamma)D(1 + W_L) + (1 - \gamma)D(y + 1)$$

$$-(1 - \gamma)D - (1 - \gamma)DW_L + (1 - \gamma)Dy + (1 - \gamma)D$$

$$-(1 - \gamma)DW_L + (1 - \gamma)Dy$$

$$-(1 - \gamma)DW_L + (1 - \gamma)D(W_L(1 - \alpha) + \alpha i_A)$$

$$-(1 - \gamma)DW_L + (1 - \gamma)D(W_L(1 - \alpha) + \alpha i_A)$$

$$-\alpha(1 - \gamma)DW_L + (1 - \gamma)D\alpha i_A$$

Divide by $\alpha(1 - \gamma)D$:

$$-W_L + i_A$$

Let $i_A = W_L + j_A$, where j_A is the difference between W_L and i_A.

$$-W_L + W_L + j_A$$

$$j_A$$

We now need to add back the terms that we have removed.

Multiply by $\alpha(1 - \gamma)D$:

$$\alpha(1 - \gamma)Dj_A$$

Multiply by $(y - i_D)$

$$\alpha(1 - \gamma)Dj_A(y - i_D)$$

$$\alpha(1 - \gamma)Dj_A((1 - \alpha)W_L + (\alpha)(W_L + j_A) - (W_L + j_D))$$

$$\alpha(1 - \gamma)Dj_A(W_L - \alpha W_L + \alpha W_L + \alpha j_A - W_L - j_D)$$

$$\alpha(1 - \gamma)Dj_A(\alpha j_A - j_D)$$

$$\alpha(1 - \gamma)D(\alpha j_A^2 - j_D j_A)$$

Multiply by $(1 + W_L)^2$:

$$\alpha(1 - \gamma)D\frac{(\alpha j_A^2 - j_D j_A)}{(1 + W_L)^2}$$

The absolute difference is $\alpha(1 - \gamma)D\frac{(\alpha j_A^2 - j_D j_A)}{(1 + W_L)^2}$. This is expected to be a very small percentage of D. $\qquad\square$

A.1.3 Proof of the difference between the buy and hold approach and the forward rate approach

The difference between the buy and hold approach and the forward rate approach is:

$$FTP_{BH} - FTP_{FR}$$

$$\alpha(1 - \gamma)D\frac{(j_A^2 - j_A j_D)}{(1 + W_L)^2}.$$

Proof. Incorporating the assumptions, the buy and hold approach is:

$$
\begin{aligned}
PV \;=\; & \gamma D\left(\frac{W_L(1 - \alpha) + \alpha i_A - i_D}{1 + W_L}\right) \\
& + (1 - \gamma)D\left(\frac{((1 + W_L)^2(1 - \alpha) + \alpha(1 + i_A)^2 - 1) - ((1 + i_D)^2 - 1)}{(1 + W_L)^2}\right)
\end{aligned}
$$

The forward rate approach is:

$$
\begin{aligned}
PV \quad = \quad & D(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{1+W_L}) \\
& +(1-\gamma)D(1+i_D)(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{(1+W_L)^2})
\end{aligned}
$$

If we look at the difference between the approaches we can see how similar they are. So:

$$
\begin{aligned}
& \gamma D(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{1+W_L}) \\
+(1-\gamma)D & (\frac{((1+W_L)^2(1-\alpha)+\alpha(1+i_A)^2-1)-((1+i_D)^2-1)}{(1+W_L)^2}) \\
& -D(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{1+W_L}) \\
& -(1-\gamma)D(1+i_D)(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{(1+W_L)^2})
\end{aligned}
$$

Simplify:

$$
\begin{aligned}
& -(1-\gamma)D(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{1+W_L}) \\
+(1-\gamma)D & (\frac{((1+W_L)^2(1-\alpha)+\alpha(1+i_A)^2-1)-((1+i_D)^2-1)}{(1+W_L)^2}) \\
& -(1-\gamma)D(1+i_D)(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{(1+W_L)^2})
\end{aligned}
$$

Divide by $(1-\gamma)D$:

$$-(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{1+W_L})$$

$$+(\frac{((1+W_L)^2(1-\alpha)+\alpha(1+i_A)^2-1)-((1+i_D)^2-1)}{(1+W_L)^2})$$

$$-(1+i_D)(\frac{W_L(1-\alpha)+\alpha i_A - i_D}{(1+W_L)^2})$$

Multiply by $(1+W_L)^2$:

$$-(1+W_L)(W_L(1-\alpha)+\alpha i_A - i_D)$$

$$+((1+W_L)^2(1-\alpha)+\alpha(1+i_A)^2-1)-((1+i_D)^2-1)$$

$$-(1+i_D)(W_L(1-\alpha)+\alpha i_A - i_D)$$

Expand:

$$-W_L(1-\alpha)-\alpha i_A + i_D$$

$$-W_L^2(1-\alpha)-\alpha i_A W_L + i_D W_L$$

$$+((1+2W_L+W_L^2)(1-\alpha)+\alpha(1+2i_A+i_A^2)-1)-((1+2i_D+i_D^2)-1)$$

$$-W_L(1-\alpha)-\alpha i_A + i_D$$

$$-i_D W_L(1-\alpha)-\alpha i_A i_D + i_D^2$$

Simplify:

$$-2W_L(1-\alpha) - 2\alpha i_A + 2i_D$$

$$-W_L^2(1-\alpha) - \alpha i_A W_L + i_D W_L$$

$$+(1-\alpha) + 2W_L(1-\alpha) + W_L^2(1-\alpha) + \alpha + 2\alpha i_A + \alpha i_A^2 - 1 - 2i_D - i_D^2$$

$$-i_D W_L(1-\alpha) - \alpha i_A i_D + i_D^2$$

Rearrange:

$$-2W_L(1-\alpha) + 2W_L(1-\alpha) - 2\alpha i_A + 2\alpha i_A + 2i_D - 2i_D$$

$$-W_L^2(1-\alpha) + W_L^2(1-\alpha) - \alpha i_A W_L + i_D W_L$$

$$+(1-\alpha) + \alpha - 1 + \alpha i_A^2$$

$$-i_D W_L(1-\alpha) - \alpha i_A i_D + i_D^2 - i_D^2$$

Simplify:

$$-\alpha i_A W_L + i_D W_L + \alpha i_A^2 - i_D W_L(1-\alpha) - \alpha i_A i_D$$

Expand:

$$-\alpha i_A W_L + i_D W_L + \alpha i_A^2 - i_D W_L + \alpha i_D W_L - \alpha i_A i_D$$

Simplify:

$$-\alpha i_A W_L + \alpha i_A^2 + \alpha i_D W_L - \alpha i_A i_D$$

Divide by α:

$$-i_A W_L + i_A^2 + i_D W_L - i_A i_D$$

Let $i_A = W_L + j_A$, where j_A is the difference between W_L and i_A. Let $i_D = W_L + j_D$, where j_D is the difference between W_L and i_D.

So:

$$-(W_L + j_A)W_L + (W_L + j_A)^2 + (W_L + j_D)W_L - (W_L + j_A)(W_L + j_D)$$

$$-W_L^2 - j_A W_L + W_L^2 + 2j_A W_L + j_A^2 + W_L^2 + j_D W_L - W_L^2 - j_A W_L - j_D W_L - j_A j_D$$

$$j_A^2 - j_A j_D$$

We now need to add back the terms that we have removed.

Multiply by $\alpha(1 - \gamma)D$:

$$\alpha(1 - \gamma)D(j_A^2 - j_A j_D)$$

Divide by $(1 + W_L)^2$:

$$\alpha(1 - \gamma)D\frac{(j_A^2 - j_A j_D)}{(1 + W_L)^2}$$

The absolute difference is $\alpha(1 - \gamma)D\frac{(j_A^2 - j_A j_D)}{(1+W_L)^2}$. This is expected to be a very small percentage of D. $\qquad\square$

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