

ISTANBUL BILGI UNIVERSITY
INSTITUTE OF SOCIAL SCIENCES
FINANCIAL ECONOMICS MASTER'S DEGREE PROGRAM

**MODELLING MINIMUM HURDLE RATIO FOR
FINANCIAL SECTOR PRICING IN EMERGING MARKET**

KEMAL AĐDAŐ SARGAN
117621001

ASSOC. PROF. SERDA SELİN ÖZTÜRK

ISTANBUL
2021

MODELLING MINIMUM HURDLE RATIO FOR FINANCIAL SECTOR
PRICING IN EMERGING MARKET

GELİŞMEKTE OLAN PİYASALARDA FİNANS SEKTÖRÜ İÇİN
MİNİMUM FİYAT ORANININ MODELLENMESİ

KEMAL ÇAĞDAŞ SARGAN
117621001

Tez Danışmanı: ASSOC. PROF. SERDA SELİN ÖZTÜRK
İstanbul Bilgi Üniversitesi

Jüri Üyesi: ASSOC. PROF. ENDER DEMİR
İstanbul Medeniyet Üniversitesi

Jüri Üyesi: ASSOC. PROF. DR. FATMA DİDİN SÖNMEZ
İstanbul Bilgi Üniversitesi

Tezin Onaylandığı Tarih: 26.01.2021

Toplam Sayfa Sayısı: 56

Key Words

- Fund Transfer Pricing (FTP)
- Pricing
- Interest Rate Risk
- ALM Risk
- Option Risk
- Liquidity Premium
- Credit Risk

Anahtar Kelimeler

- Fon Transfer Fiyatlaması (FTP)
- Fiyatlandırma
- Faiz Riski
- Aktif/Pasif Yönetimi Riski
- Opsiyon Riski
- Likidite Primi
- Kredi Riski

PREFACE

I would like to thank Assoc. Prof. Serda Selin Öztürk for all her support, insightful comments and experience. I believe that we will provide a great working to the literature.

Furthermore, I would also like to thank Alper Kırık, who always shared his generous support throughout the working period and consulted many times with his experience and knowledge.

I would also like to thank to my family for their great support and encouragement by providing perfect environment in which to pursue my academic interests. I dedicate this thesis to them.

Contents

1	INTRODUCTION	1
2	LITERATURE	5
3	METHODOLOGY	10
3.1	FTP Model Strategy in Financial Sector	10
3.1.1	Using Areas of FTP in Pricing	11
3.1.2	The Impacts on Risk Groups and Financials	14
3.2	FTP Model Structure and Methods	20
3.2.1	Single Pool Approach	21
3.2.2	Multiple Pool Approach	23
3.2.3	Matched - Maturity Approach	26
3.3	Advance FTP Model Structure & Components	29
3.3.1	Base Curve	30
3.3.2	Term Liquidity Premium	33
3.3.3	Liquidity Buffer	35
3.3.4	Contingent Liquidity Premium	37
3.3.5	Reserve Requirement Cost	41
3.3.6	Prepayment Risk Adjustment Spread	42
3.4	Credit Risk Adjustment Spread	45
3.4.1	Credit Risk Parameters	46
3.4.2	Credit Risk Adjustment Spread Calculation	48
4	NUMERICAL EXAMPLE	50
5	CONCLUSION AND OUTLOOK	55

Figures

- Figure 1:** Survey Results in terms of processes/systems integration and methodologies evolution 11
- Figure 2:** Components used in the FTP Calculation Process 14
- Figure 3:** 3-month London Interbank Offered Rate (LIBOR), based on U.S. Dollar 15
- Figure 4:** TED* Spread (3 Month LIBOR / 3 Month Treasury Bill) 16
- Figure 5:** Banks Performance Development..... 16
- Figure 6:** Top Three Most Binding Constraints 18
- Figure 7:** Marginal Cost of Fund..... 27
- Figure 8:** FTP Model Parameters 30
- Figure 9:** Nelson-Siegel-Svensson Curve..... 32
- Figure 10:** TRY On Shore Curve 33
- Figure 11:** Term Liquidity Premium Adjusted Base Curve..... 34
- Figure 12:** FTP Components 37

ABSTRACT

One of the most crucial rules for achieving a sustainable and stable growth in financial markets is the development of correct pricing models. Especially in highly volatile markets, firms need to develop advanced pricing models in order to acquire expected return and achieve the sustainable growth trends. Finance sectors in every country are interested in the pricing models more than others. Fund Transfer Pricing (FTP) method for financial institutions has started to be used already, and as a pricing process that increases the importance emerges through the day. FTP model is very efficient method to handle liquidity, interest and option risk for companies, and researchers are focusing to improve this model by developing additional behavioral models (pre payment models, etc.). In particular, it was once again understood how important it is to include risk factors in these strategies after the financial crisis in America. In this study, it is aimed to improve the advanced FTP model with additional factors and to include credit risk models more effectively in the Hurdle model. In the first part, basis interest, liquidity Premium, and other variables that may affect pricing are described, and the second part is the modeling of credit risk factor is studied. Especially the contribution of behavioral and credit risk adjustments to the FTP model is one of the most important outputs of the study. The work will make a significant contribution to banks and financial institutions in emerging markets to manage their risks more efficiently and to create correct pricing strategies.

Key Words: Fund Transfer Pricing (FTP), Pricing, Interest Rate Risk, ALM Risk, Option Risk, Liquidity Premium, Credit Risk

ÖZET

Finansal piyasalarda sürdürülebilir ve istikrarlı bir büyüme elde etmenin en önemli kurallarından birisi doğru fiyatlandırma modellerinin geliştirilmesidir. Özellikle yüksek volatiliteye sahip piyasalarda, firmalar beklenen getirileri elde etmek ve sürdürülebilir büyüme trendlerine ulaşmak için gelişmiş fiyatlandırma modellerine ihtiyaç duymaktadır. Finans sektöründe bu konu üzerinde diğer sektörlerle göre çok daha fazla yatırım yapılmaktadır. Finans kuruluşları için Fon Transferi Fiyatlandırması (FTP) yöntemi kullanılmaya devam eden ve gün geçtikçe önemi artan bir fiyatlandırma süreci olarak ortaya çıkmaktadır. FTP modeli, şirketler için likidite, faiz ve opsiyon riskini ele almak için çok etkili bir yöntemdir, araştırmacılarda ek davranış modelleri geliştirerek bu modeli iyileştirmeye odaklanmaktadır. Özellikle Amerika'daki mali kriz sonrasında risk faktörlerini bu stratejilere dahil etmenin ne kadar önemli olduğu bir kez daha anlaşıldı. Bu çalışmada, gelişmiş FTP modelinin kredi riski faktörüyle geliştirilerek daha verimli bir fiyatlandırma modelinin ortaya çıkarılması amaçlanmıştır. Özellikle davranışsal modellerin analizi ve kredi riski maliyetinin fiyatlandırmaya eklenerek optimum fiyatlamaya ulaşılması tezin en önemli katkılarıdır. Çalışma özellikle gelişmekte olan piyasalardaki banka ve finans kuruluşlarının risklerini daha verimli yönetmelerine ve doğru fiyatlandırma stratejileri oluşturmalarına önemli katkı sağlayacak.

Anahtar Kelimeler: Fon Transfer Fiyatlaması (FTP), Fiyatlandırma, Faiz Riski, Aktif/Pasif Yönetimi Riski, Opsiyon Riski, Likidite Primi, Kredi Riski

1 INTRODUCTION

In order for the countries' economic structure to be able to withstand sound foundations, financial institutions that is operating in the country must also have a sound balance sheet. Especially in countries with a volatile high-volatile economy, crises need to be strengthened and markets need strong financial institutions to enter into a rapid recovery process. The strategies that they form in pricing processes are very important for banks and other financing companies to achieve a structurally sustainable level. In particular, it was once again understood how important it is to include risk factors in these strategies after the financial crisis in America.

The FTP method is already in use in large financial institutions, and increase its' importance as a pricing process. By supporting this method with additional behavioral models, market and credit risk models, it will be possible to create much stronger balance sheet structures. There are many articles, publications and books in the literature examining the pricing processes by FTP method. Pushkina (2013); SHAKIROV (2017); Bledsoe (2008); Burucs (2008); Dermine (2011); Deventer (2002); Dimitriu (2012); Grant (2011). These studies mostly emphasize the importance of pricing by FTP method so that financial institutions can survive, manage their risks and carry out their future projections. "FTP is the key to measuring risk-adjusted profitability, taking into account maturity transformation (interest rate and liquidity) and non-linear effects (e.g. contingent liquidity risk). It enables liquidity (interest rate) costs, benefits and risks to be transferred from Treasury/ALM functions to the originating customers, products and business lines" (Berger, 2017). (Shakirov, 2017) stated in his summary the 2008 crisis mainly occurred due to the lack of information regarding liquidity risk, and the importance of FTP models to handle liquidity risk. Most of the researches is generally focusing on the liquidity and interest rate risk and FTP approach methodology to fix these risks. (Shakirov, 2017) is focusing in his Master thesis about advanced FTP model structure by building stochastic models, he has generated market risk behavioural models, and their impact on accurate pricing.

In this research, the existing methodologies that were published from academics will also be used, but beside these working, customer behavioral models (Sight Stickiness, early payment estimation) and credit default models will be added to FTP model structure, and generating a model to find minimum Hurdle ratio. The consideration of customer behavior models and credit models are crucial to improve FTP approach. This can also be called as risk adjusted FTP model that constitute ALM risk, Credit default risk, and behavioral risk. At this study, both developed and emerging markets will be examined and their comparisons will also analyzed. For emerging markets, the advanced approach for pricing is crucial since the volatility of these markets are unsteady, and the financial sector should be powerful to handle these uncertainties.

Base Rate calculation, which is the first component of the FTP model and allows the inclusion of interest risk in the pricing, is performed. In this context, the interest rates of the relevant currencies are created using the bootstrapping methodology to market data. For bootstrapping technique, Nelson-Siegel-Svensson model will be used which is nonlinear equation. Then, term liquidity premium will be added as granular for each term. In addition to the term liquidity premium, liquidity cushion spread for possible liquidity shock will be analyzed in line with Basel III guidance, the cost of high quality liquid assets held for the purpose of allocating liquidity at the time of stress is added to the cost of borrowing by using the effects of the LCR and NSFR ratios. After the base rate and term liquidity premium are calculated, the discount rates are determined according to the maturity types of products which will form the basis of product pricing. In the next step, reserve requirements are determined by calculating the break points of the reserve option that are kept in the central bank for liabilities. Then, it will be explained how behavioral models should be developed especially to hedge the effect of option risk on pricing. In this context, GBM (Geometric Brownian Motion) method will be used to in order to explain the maturity structure of the products (Sight Stickiness). In addition, the application of Survival method on how to include the prepayment risk of products in pricing and modeling will be explained. Finally, a coefficient is determined according to the risk level of each customer. When assigning this

coefficient, the results of the customer based PD, EAD and LGD models are used. PD models are generally modeled by logistic regression, EAD models are developed by linear regression and LGD models are created by pool level LGD method. The interest rate risk, liquidity risk, option risk and credit risk effects are included in pricing by using this structure.

The most important expected result in this study is to show that, in addition to interest risk, liquidity risk and option risk published in previous academic studies, the credit risk factor is included in the pricing and the pricing results increase with the credit risk spread. High quality credit risk models are developed for last decades with also machine learning algorithms. These are also used for credit risk and assessment strategy at the beginning of day. They should not be used just for provision calculation. Like behavioral models for prepayment and liquidity risk, credit risk factor should be covered in FTP model. In our research, the general information of FTP structures and model details will be analyzed and numeric calculation examples will be provided to see the differences. Other expected results are to reveal the effect of behavioral models (prepayment, contingency of maturity) in the pricing model and to reveal the necessity of the advanced models to be developed for a strong pricing structure.

In this study, the importance of financial markets in the development of national economies is emphasized and the importance of pricing has been explained in the advancement of financial markets on solid foundations. The methods of using FTP methodology, which are used as pricing methodology in banks and financial institutions, and the researches on FTP have examined the borrowing interest components in general and the inclusion of this model in interest and liquidity risk has been analyzed in the recent academic studies. In this study, first, the modeling of the interest rates used by banks in debt instruments are explained and analyzed the behavioral risk, interest rate risk and liquidity risk models of the variables that affect the pricing. In the last part, the credit risk modeling structure, which has not been included in the literature so far, has been added to the pricing model and the modeling of the minimum Hurdle rate ratio has been improved. The planned

empirical model at the end of the study is to enable financial institutions to create a more comprehensive study in their pricing processes. In addition to this study, methodology of behavioral and credit risk models can be developed with machine learning model structures, and a more dynamic pricing model structure can be formed in the future. Credit Risk model algorithms has changed substantially for last five years by using the machine learning algorithms. The development of these processes still continues, and this has a significant impact on credit risk spread. For Option risk calculation, the most popular methods are still Survival and regression approach, machine learning algorithms can be developed for these types of behavioral risks as well that enable decision makers to determine more accurate pricing.

In the following chapters of the thesis, first, studies on FTP published in the literature will be shared. The historical development of FTP and the latest methodologies applied in advanced models will be mentioned. In the next section, information on the usage areas of the model and its importance for financial institutions will be shared. Before starting the content of the model parameters in detail, firstly the risk types covered by the FTP model will be examined and then the historical development of the model will be conveyed with sample applications. In the next section, details of the components required for the Advanced FTP model will be shared, and the content of the credit risk factor, one of the main contributions of the thesis, and detailed modeling and calculation examples will be explained. In the last section, the model created will be calculated for all components that make up the pricing with sample market data, and at the end of the day, the minimum hurdle rate and credit risk factor to be offered for a product will be revealed.

2 LITERATURE

The FTP method is already in use at large financial institutions, and increase its' importance as a pricing process. By supporting this method with additional behavioral models, market and credit risk models, it will be possible to create much stronger balance sheet structures. There is a wide range of academic studies written on FTP pricing. Significant updates were also experienced in the studies according to market conditions that differ periodically. Intensive studies have been carried out on how to include some concepts that came into our lives especially after crisis periods in the pricing. Apart from academic research, important analyzes by authority institutions and consultancy companies have contributed greatly to the development of the FTP model.

In the literature, intensive studies have been conducted on how to include the liquidity risk that emerged after the 2008 financial crisis in general with advanced FTP model structures. It is of great importance how the concepts of LCR (Liquidity Coverage Ratio) and NSFR (Net Stable Funding Ratio), which came into our lives with Basel-III regulations, should be included in pricing models. Schmaltz (2009) aimed to establish an internal, quantitative and complete liquidity model for banks with the work A Quantitative Liquidity Model for Banks. Schmaltz has grouped the parts that the model aims to cover under four main headings. These; First of all, it is expected that each product structure should be evaluated in detail within the model, meet the short and long-term liquidity needs, create stress scenarios within the model, and lastly, the model will manage and optimize the bank liquidity.

Deventer (2002) explained the historical development of FTP with his study. In particular, it was explained in detail how the Matched-Maturity method was developed and with which project. It was emphasized that the high interest rate in the US markets as of 1969 caused Bank Of America to revalue its pricing strategies and the new FTP model was introduced. Executives decided to build a new structure since the current interest structure is dysfunctional in measuring the interest risk and performing unit-based profitability analysis. Mack Terry, head of the Financial Analysis and Planning Department, who took on this task, was described as "as the

father of the new discipline of" matched maturity transfer pricing "by the bankers of that period, with the new FTP calculation method he developed with his team. Deventer conveyed the details of this new model revealed in the later chapters of the study and how the problems that may arise and its systemic transition were handled.

Dermine (2011) explained the need to create Advanced FTP approach models with the study "Fund transfer pricing for deposits and loans, foundation and advanced, and the article defined the necessary improvements for an advanced FTP model" as "Rationing on the interbank market, the creation of a Basel III contingency liquidity buffer, the necessity to adjust FTP to the credit riskiness of specific assets of the bank, the need to include a liquidity premium in the case of long-term funding, and finally, the choice of a consistent methodology to incorporate the credit spread on the bank's own debt due to the perceived risk of bank default".

Danielsson (2014) worked on modeling short-term interest rates within the FTP model with the article titled as Implementation of a Funds Transfer Pricing model with stochastic interest rates. The model has been developed to estimate the interest rates that will occur in different maturities, and funding rates are calculated separately for each maturity segment. Danielsson (2014) defined the purpose of the study as "how banks can use an interest rate model for simulating future interest rates together with three different historic scenarios for the risk-free interest rate curve and apply the result on an internal transfer pricing model to make projections for the funding costs of financial products in the future ". In the article, while estimating the funding rates, it has been calculated by applying Monte Carlo Simulation to short-term interest rates.

Pushkina (2013) aimed to create an effective simple FTP model in her article titled as "A Simple Funds Transfer Pricing Model for a Commercial Bank". By developing the methods applied in Single Pool, Multiple Pool and Matched Maturity methods more comprehensively, an effective FTP model structure has been revealed. Although the model structure is close to the Matched Maturity

method in terms of content, a more accurate pricing is aimed with the model study, which explains the creation of a much more diverse product pool according to the product characteristics. In the structure where the Treasury has a central function, all funds providing resources and active transactions of the units using these funds are coordinated by the treasury unit. In particular, an advanced matched maturity model was created with the pool method created on the basis of product characteristics.

Shakirov (2017) worked on an advanced FTP model structure for efficient pricing with the thesis titled as “Modeling Advanced Fund Transfer Pricing With An Application Of Hull-White Interest-Rate Tree In Turkish Banking Sector”. Shakirov (2017) includes the NSFR (Net Stable Funding Ratio) effect, which came into our lives after the Basel-III criterias, in the pricing by developing an advanced FTP model. The model structure consists of two important parts. These are benchmark interest rates and liquidity cost calculations developed with stochastic interest rates. Liquidity cost calculation has also been examined in three main items as deterministic, stochastic and regulatory components. Especially, under the title of regulatory components, the effect of NSFR effect on pricing has been examined in detail, and Shakirov (2017) defined this part as the most important contribution of the thesis.

Lindblom, T., & Elliot, V. (2017) aimed to contribute to the FTP model in two scopes with the article they published. They explained their contributions as “First, we analyze the implications of adding a liquidity premium to the FTP. Second, since a majority of the existing banking markets are dominated by a limited number of large banks we also cover the case of kinked demand and supply curves on oligopolistic and oligopsonistic competition, respectively”. It has been examined how the liquidity premium cost added by banks in different market conditions affects their deposit and loan volumes. According to the study, in banks working with the Sweezy-like competition understanding, banks are mostly reluctant to change loan and deposit interest rates because otherwise they fear the banks they compete with to retaliate, it was emphasized that in an oligopoly credit market, the

liquidity premium should only be added to purchasing fund. In oligopsony deposit markets, the liquidity premium should only be added to the funds sold. In both cases, because there is price stickiness in the market, additional liquidity premium can be very costly for banks.

Apart from academic studies, there are very important studies they have published in regulatory institutions on the subject. BIS (Bank For International Settlement) explained in detail the historical development of FTP models and the pricing parameters that banks should apply with its work titled as “Liquidity transfer pricing: a guide to better practice” published in 2011. Even if the model shared in the study focuses mainly on the matched maturity method, it provides important analysis on the examination of the liquidity premium effects. It was aimed to update the pricing strategies of financial institutions by sharing the sample applications regarding the process of adding Liquidity Cushion and Contingent Liquidity parameters to the pricing process. Additionally, one of the studies that most affect the balance sheet analysis and pricing factors is the Basel-III criteria published by the Basel committee in 2013 after the global financial crisis in 2008 (Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools). A study was shared on the liquidity ratio that banks should keep at a minimum, and a new period has been created for adding Risk parameters to FTP pricing in this scope.

In 2010, Basel Committee published the Credit Risk Principles. The published study shared certain principles on how to manage credit risk globally. In this study, which consists of 17 basic principles, the aimed developments: defining credit risk processes and responsible departments with internal procedures, the necessity of establishing a strong credit assessment process, accurate measurement, reporting and monitoring of credit risk exposure, developing systems where necessary analysis and calculations can be made for credit risk and supervisory role for the all process. In 2001, BIS (Bank For International Settlements) published Internal Rating-Based Approach document for the calculation of PD (Probability of Default), LGD (Loss Given Default) and EAD (Exposure at Default) parameters,

which constitute credit risk components. With this study, an international draft has been created on how all financial institutions will create their own internal models and how to make provision calculations for capital adequacy.

3 METHODOLOGY

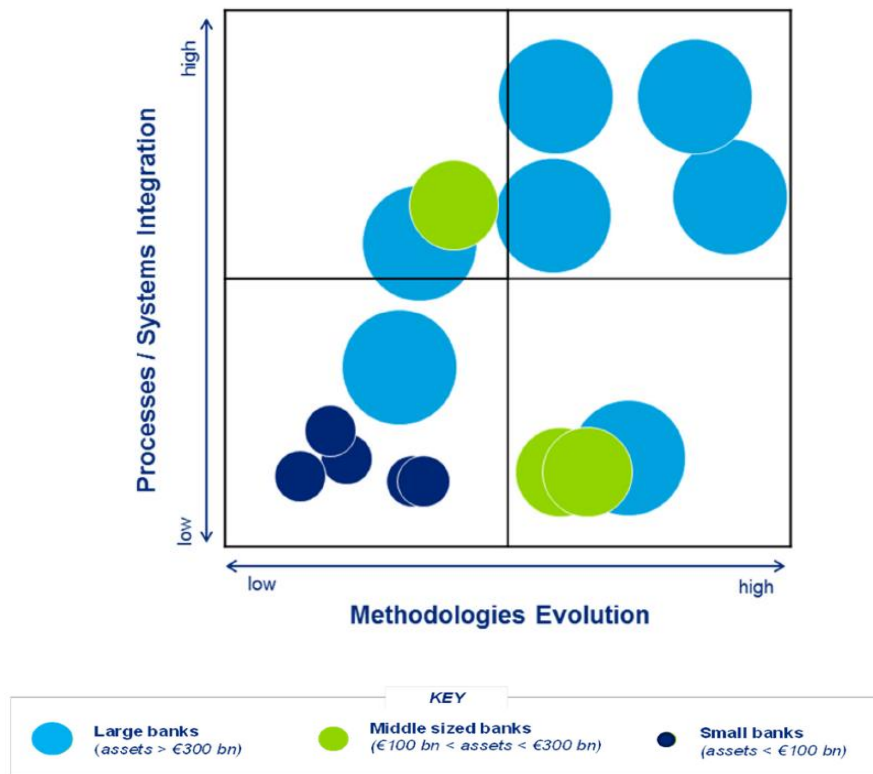
3.1 FTP Model Strategy in Financial Sector

Banks and financial institutions have to plan their pricing strategies comprehensively in order to create efficient, sustainable and profitable business models. The importance of pricing strategies and its structure is recognized at crisis or economic recession period and is considered as the most significant item that protect the balance sheet against unexpected financial situations. Before 2007-2009 global crisis, the number of financial institutions that included risk factors in their pricing strategies except big some corporate banks was quite low. Despite discussing the effects of the concept of risk management in theory, the issue of how the companies will affect their losses after a crisis was not taken into consideration. Risk hedging tools, which are generally thought to cause additional costs to banks, were not considered as a cost item because they reduced competition in pricing.

After the crisis, both the losses experienced and the regulations brought by the authorities, the scope of pricing models has been expanded. More detailed studies have been started and published regarding FTP model which included detailed and risk parameters in pricing model. Basel Committee has published Basel-III criteria in 2010, which are mainly working on the liquidity standards, by focusing the LCR (Liquidity Coverage Ratio) and NSFR (Net Stable Funding Ratio) indicators. Since these indicators are used in FTP models, the needs for the models have significantly increased by financial institutions. The beginning of the period, in which the importance of high liquid assets increased and the effect of the return to liquidity on the crisis and stable markets was included in pricing strategies, have matured after these criteria.

Audit & Consultancy Company Deloitte published a survey in 2013, which has involved 15 Financial Institutions from UK, France, Germany, Italy, the Netherlands and Greece. The survey revealed that there is still a lack of following correct pricing strategies for companies.

Figure 1: Survey Results in terms of processes/systems integration and methodologies evolution



Source: Deloitte (2014). *Fund Transfer Pricing, A Survey to assess the state of European banks' practices*

The survey results in Figure-1 shows that the use of FTP model is very low except banks in large volume, and there is no investment in pricing strategies related to this model yet. One of the most important problems observed in banks that have implemented the systemic integration is that the validation processes of the established model have not been created.

3.1.1 Using Areas of FTP in Pricing

It is possible to construct the FTP model in many banking products. Models that provide accurate pricing and risk measurement to Treasury, Finance and Risk Management professionals for balance sheet management are included in the all pricing processes with system integration. In addition to the pricing of credit products that have been constituted the important majority of the bank portfolio,

FTP model is very crucial and popular tool in order to develop deposit pricing, determine the limit thresholds of credit cards, price short and long term bonds, and develop other products pricing strategies.

Product structure is the factor that affects the entire strategy of pricing. Therefore, when the FTP model is being constructed, all the details of the products that might has an important impact on the pricing should be included in the model. In the pre-crisis periods, pricing figures were created with the margin rates determined in the expense item evaluated with borrowing cost and fixed costs. However, comprehensive pricing models including risk costs are included in the pricing models with the facts revealed after the crisis period effects.

We can divide the FTP usage areas into internal systems and product pricing. In institutions with extended FTP model structure, they actively incorporate the FTP model into their internal systems and processes in asset-liability management, treasury, pricing strategies, balance sheet management and performance measurements. Especially the institutions responsible for regulations give serious advices to financial institutions regarding the use of FTP. Institutions such as BIS (Bank For International Settlement), OECD (Organisation for Economic Co-operation and Development) and Central banks recommend that each bank should design its own FTP procedures for a secure and sustainable balance sheet and asset-liability management, and these should be validated periodically by ensuring integration into the systems. Although financial institutions are large in volume, operating income mostly consists of netting interest income and interest expense positions. In the analysis of realized profit margins, only if these two figures are considered, many variables can be ignored. With the FTP model, banks can accurately and realistically analyse KPI targets and determine their planning and strategies in detail on a product basis. The FTP model usage, which is mostly in the Treasury and Asset/ Liability management sections, is used in determining the net cost figures and including this in the pricing parameters in all processes.

FTP models are generally used by making detail analysis in internal systems, but the most important area of FTP model is the determination of pricing rates.

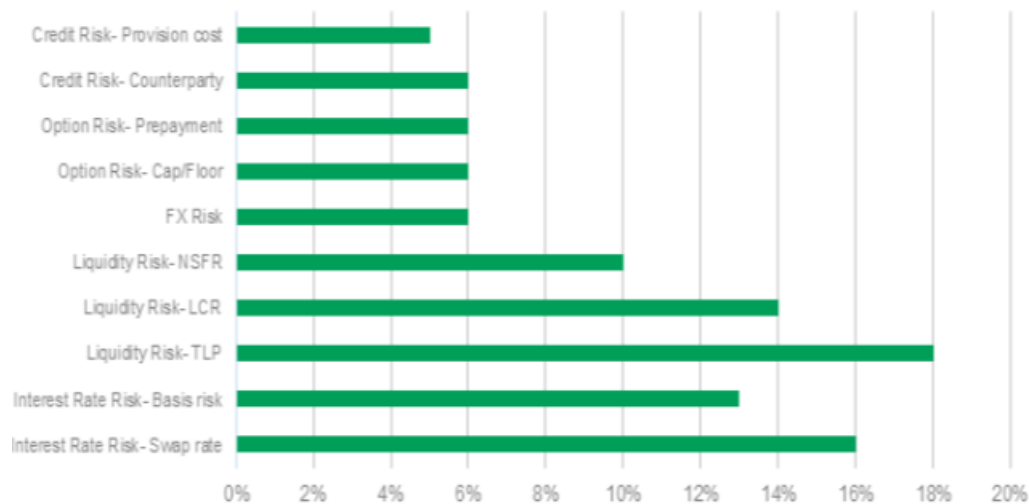
There are many different product groups at banks' product portfolio. The main parts of the portfolio are constituted from loans and deposit products. There are significant differences regarding FTP structures of between loans and deposit products due to the change in their product structure. FTP model should be developed for all products that is sold by financial institutions. It is observed that the structure of FTP also differs in the product structures where the customer characteristic varies. For example, people's credit card payment performance behaviour and home loan payment performance behaviour are quite different. Therefore, financial institutions can continue their pricing in a strong way with FTP models, which do not only see the points where the products differ from each other as the maturity structure, and which also includes customer behaviour and market effects, according to product characteristics.

In the following sections, loans and deposit products' FTP model and their structures will be examined. These products, which are booked in two different parts of the balance sheet, are the most important products that generate the balance sheets of banks and should be got higher attention. As the most important profit-making operation of banks is known, the margin difference between the interest rate that they give for the deposit products and received interest rates from the loans. The most critical issue for pricing is the difference between the deposit product used as a debt instrument and alternative borrowing products. Banks that have permission to collect deposits can make their funding seriously sensitive to the market by using their deposit products, especially in volatile and illiquid markets. In the borrowing instruments that can be purchased through SWAP markets, the interest rates used and the competition rates in the domestic market can also make banks difficult in the domestic market, due to the effects of both base interest rate and country and bank risk premium (CDS Premium) added on the prices. Therefore, banks that are competitive in deposit products have the advantage of using these resources as the base interest rate in their pricing for other products.

3.1.2 The Impacts on Risk Groups and Financials

The period in which the importance of FTP models was mostly discussed was after the global crisis period, as mentioned in previous sections. With the FTP model, in which the effects of risk groups on pricing are discussed in detail, it has been experienced that pricing strategies can be determined by taking into consideration the losses that may occur during crisis periods. With the survey conducted by Moody's Analytic in 2017, we can see more clearly the distribution of risk factors used in the FTP model.

Figure 2: Components used in the FTP Calculation Process

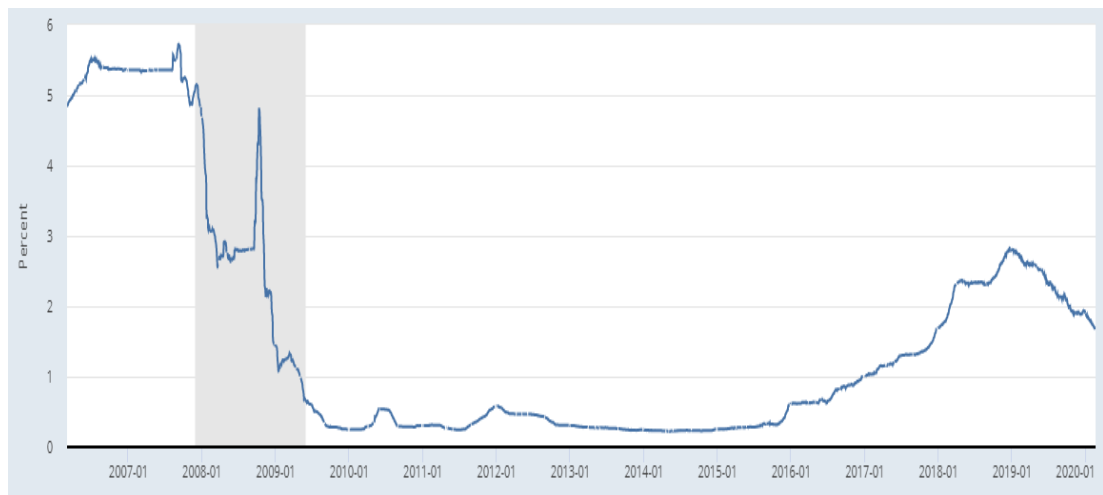


Source: Moss, K. (2018). *Funds-transfer-pricing in Banks: what are the main drivers?* Moody's Analytics.

While each of the risk categories is included in its possible risks in pricing, it is also serious in analysing the risk appetite accepted. In the pre global crisis period, these risk factors were both neglected due to less expectation for any crisis possibility and risk factors' competition impact in pricing. Since the companies considered these risk factors as cost increase items, they didn't include their cost impact to the pricing in order not to lose competitions in market.

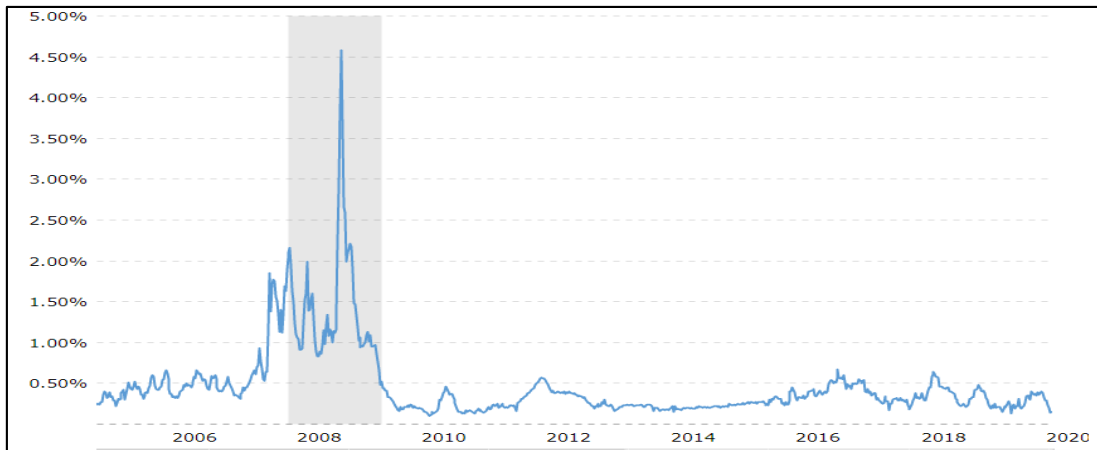
After global crisis, as the figure 2 shows, especially a comprehensive impact regarding liquidity risk is added to FTP models. One of the most important reasons is the liquid money shortage experienced during the global crisis period, and the significant increase in interest rates in the markets during that period. The amounts paid by banks for loan interest rates reached the highest levels and at the same time, there was a serious negative impact on credit lines due to the liquidity problem in the market.

Figure 3: 3-month London Interbank Offered Rate (LIBOR), based on U.S. Dollar



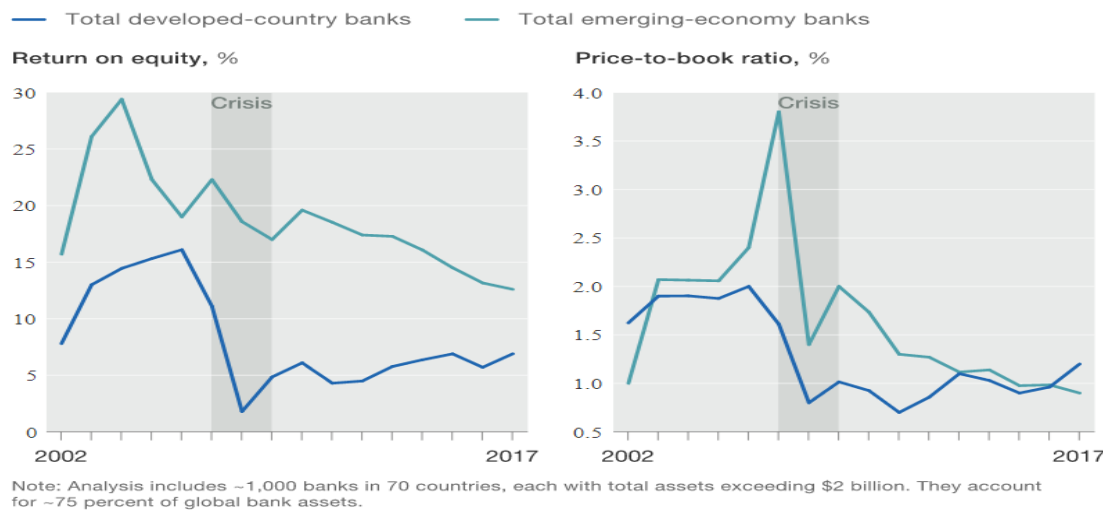
Source: ICE Benchmark Administration Limited (IBA)

Figure 4: TED* Spread (3 Month LIBOR / 3 Month Treasury Bill)
 *: as a measure of the perceived credit risk in the U.S. economy



Source: [macrotrends.net/TED Spreads-Historical Chart](http://macrotrends.net/TED%20Spreads-Historical%20Chart)

Figure 5: Banks Performance Development



Source: Lund, S., Manyika, J., Mehta, A., & Goldshtein, D. (2018). *A decade after the global financial crisis: What has (and hasn't) changed.* McKinsey & Company Briefing Note September 2018

The above figure-3 and 4 shows the serious upward trend in libor rates and TED spreads during and after the crisis. At the same time, banks' balance sheets and market values have been significantly affected by the crisis. Many banks have

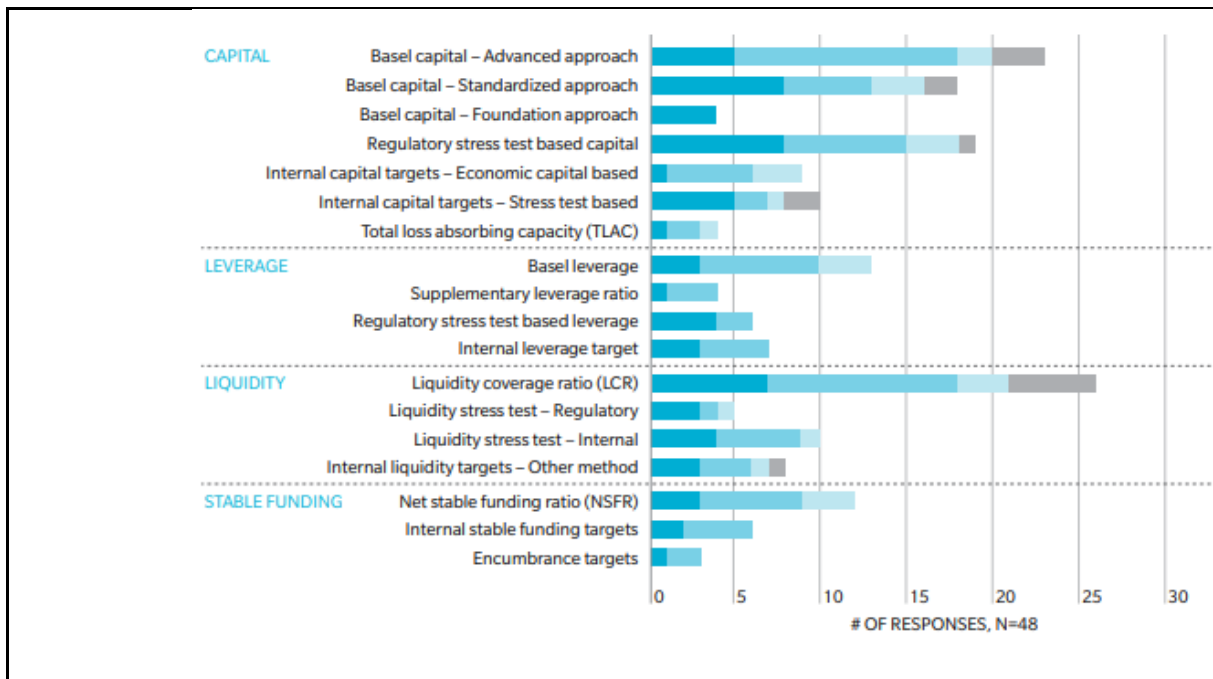
sunk or have come to the point of sinking after this crisis, so much so that the US government has created a \$ 700 billion rescue package to prevent the crisis.

The inclusion of the risk factors mentioned in the FTP models was not only followed by financial institutions' own strategies, but also with the new mandatory rules that they took in regulatory institutions in this direction. One of the most important one is LCR risk measurement, which is evaluated under the liquidity risk. LCR aims to control the asset quality of financial institutions. Basel Committee on Banking Supervision interpret LCR as “it is designed to ensure that banks hold a sufficient reserve of high-quality liquid assets (HQLA) to allow them to survive a period of significant liquidity stress lasting 30 calendar days”. Banks had to face additional costs on their financials for this type of risk, which is followed more strictly after the regulation.

$$LCR = \frac{\text{Stock of HQLA}}{\text{Total Net Cash Outflows Over The Next 30 Calendar Days}} \geq 100 \quad (3.1)$$

“HQLA are cash or assets that can be converted into cash quickly through sales (or by being pledged as collateral) with no significant loss of value”. (BIS, 2018)

Figure 6: Top Three Most Binding Constraints



Source: Khaykin, I., & Koyluoglu, U., & Elliot, D., & Spicer, C. (2017). Oliver Wyman, The Financial Resource Management. Balancing Complex and Competing Constraints On Capital, Liquidity and Funding. Oliver Wyman Working Paper

In figure 6, the survey conducted by Oliver Wyman with 48 financial institutions all over the world in 2016, we see the risk items that affect firms most often on their balance sheets due to the imperatives set by the regulatory agencies. LCR risk is of great importance as seen here.

Apart from liquidity risk, another risk item included in the FTP model is the interest risk effect. The concept of interest risk, like liquidity risk, has a serious impact on the balance sheets of financial institutions, especially during volatile market periods. Since interest risk is a type of risk directly linked to liquidity risk, companies that have mismatches especially in active and passive cash flow in their balance sheet structure then it is considered that there might be an interest rate risk problem. In the measurement of the risk due to maturity mismatch problem of portfolio, the concept of duration allows us to make a simple measurement.

The balance sheet with the same duration results between asset and liability positions does not have an interest rate risk, while in balance sheets with different levels of duration, are sensitive to interest rate according to the rate of the differences. Especially with the Basel-III criteria, it has been decided that financial institutions make measures and risk measurements related to interest rate risk, as well as liquidity risk. Stress tests are carried out with interest scenarios in different structures for these measurements. After these calculations, hedging operations are carried out to prevent possible risks. One of the most important factors in the diversification of treasury products is the need for hedge transactions that can be performed against these risk situations. Especially with the Swap market, it is possible to prevent risk situations and cost calculations that can be experienced with every stress scenario.

In addition to liquidity and interest rate calculations, there are also early payment risk, credit risk and operational risk concepts should be included in the model. The methodology used in prepayment risk factor calculations is different from the Value at Risk calculation analysed for liquidity and interest rate risk. This risk factor, which institutions mostly calculate on their local strategies, is a very important risk type, especially when banks add any cost of credit to the pricing when the customers close their loans earlier than its normal termination.

As mentioned in the previous sections, since banks do not have the opportunity to see the all-risk items at their balance sheet in great detail, evaluating each risk element separately in the FTP model is considered as a critical issue. Coffey (2001), and Kocakulah & Egler (2006) stated that the net interest income indicator, which constitutes approximately 80% of the profitability of financial institutions, is formed only by summing up interest income and interest expense items in a certain period, and the breakdown of any above-mentioned risk item cannot be specified separately in this account. Therefore, it is very important to evaluate each of the risk factors separately within the scope of its importance and to show the decision-maker and balance sheet readers the risks that may or may be experienced.

In the following sections, the details of the calculation of risk factors within the model will be given more comprehensively and their analysis will be evaluated through their applications. Apart from the concepts of Liquidity and Interest risk, which are mostly emphasized in its current structure and academic studies, Credit Risk and Prepayment risk type, which is one of the important types of behavioural risk concepts will be examined in next chapters. This enable FTP model to strengthen, and thereby enabling the cost per head to be found in pricing. The methodologies to be used in the calculation of the effects of risk factors will be mainly transferred through algorithms that can be developed with open source tools.

3.2 FTP Model Structure and Methods

FTP models continued to be used by developing from simple to complex algorithms throughout the period of use. The details of models acts together with the diversified product structure and developing pricing techniques in financial markets. When models established with relatively simple algorithms lost their competence in complex structures after a while, more comprehensive advanced FTP models have been developed.

FTP model management and responsibility is followed in banks under the responsibility of ALM unit, which is generally under the Treasury department. According to the Shakirov (2017), “FTP is a process where the central unit (ALM) of a bank collects funds and redistributes them among the business units, acting as an internal bank”. ALM departments determine the transfer pricing of the units that generate the Asset and Liability items of the balance sheet via FTP models. Banks need funding sources in order to create their asset items. These funding sources are mostly provided by the deposits are obtained from the customers or borrowings from the market. FTP models are used to determine the transfer rates of both sides of balance sheet. Customer deposits are used as most important funding sources and ALM units first determine transfer rates of deposit accounts by FTP models. After collecting deposits, next step is generating the transfer rates of Asset side. ALM units create a bridge between the units where the resources are generated and used for creating new business. Active account transfer rates are generated by gathering

all funding sources rates and additional adjustments via FTP models. Models enable financial institutions to calculate each unit profitability by using transfer rates.

FTP model structure is used in four different ways in financial markets. **Single Pool Approach, Multiple Pool Approach, Matched-Maturity Approach** and **Advanced FTP Model** structures created by large financial institutions with their own pricing strategies. In this section, the details of the first three methods and their usage areas will be examined. In the following chapters, it will be explained how to construct an Advance FTP model.

3.2.1 Single Pool Approach

In this method, a common transfer rate is determined for all products in Asset and Liability accounts. Complex models are not used, transfer rate is calculated without taking into account the variations in product structures. The transfer price of the products for which funds are created and all products that generate returns are determined as a single price. A common transfer price occurs by taking weighted averages of the return and cost ratios of all active and passive products in a common model according to their volume. The profitability of all units is evaluated over this price. Before examining the advantages and disadvantages of this model, we will look at the details of the calculation based on an example.

Example: Bank A extended a mortgage loan of 100 Million USD at an average interest rate of 3% and a consumer loan with a 5% interest rate of 65 Million USD last month. For the funding of these loans, 90 Million USD deposit with 1% cost was created, and a 2.5% borrowing was used for the remaining 75 Million USD. The FTP model, which is used to create a fund, create a loan portfolio and measure the profitability of the Treasury unit, calculates the profitability of business units as follows.

Asset			Liability		
	Volume	Yield		Volume	Cost
Mortgage Loan	\$ 100,000,000	3%	Deposit	\$ 90,000,000	1%
Consumer Loan	\$ 65,000,000	5%	Borrowing	\$ 75,000,000	3%

$$\text{Avr.Int. Rate (\%)} = \frac{(\text{Mortg.Loan Vol.} * \text{Mortg.Loan Yield}) + (\text{Cons.Loan Vol.} * \text{Cons.Loan Yield})}{(\text{Mort.Loan Vol.} + \text{Cons.Loan Vol.})} \quad (3.2)$$

$$\text{Avr.Fund. Rate (\%)} = \frac{(\text{Deposit Vol.} * \text{Deposit Yield}) + (\text{Borrow.Vol.} * \text{Borrow.Yield})}{(\text{Deposit Vol.} + \text{Borrow.Vol.})} \quad (3.3)$$

$$\text{Transfer Price (\%)} = \frac{\text{Avr.Int.Rate} - \text{Avr.Fund.Rate}}{2} \quad (3.4)$$

$$\text{Avr. Asset Transfer Rate (\%)} = \text{Avr. Interest Rate} - \text{Transfer Price} \quad (3.5)$$

$$\text{Avr. Funding Transfer Rate (\%)} = \text{Transfer Price} - \text{Avr. Fund. Rate} \quad (3.6)$$

If the equations are solved as above:

$$\text{Avr. Interest Rate (\%)} = \frac{\$ 100,00,000 * 3\% + \$ 65,000,000 * 5\%}{(\$ 100,00,000 + \$ 65,00,000)} = \mathbf{3.8\%} \quad (3.7)$$

$$\text{Avr. Funding Rate (\%)} = \frac{\$ 90,00,000 * 1\% + \$ 75,000,000 * 3\%}{(\$ 90,00,000 + \$ 75,00,000)} = \mathbf{1.7\%} \quad (3.8)$$

$$\text{Transfer Price (\%)} = \frac{(3.8\% - 1.7\%)}{2} = \mathbf{1.05\%} \quad (3.9)$$

$$\text{Avr. Asset Transfer Rate (\%)} = (3.8\% - 1.05\%) = \mathbf{2.75\%} \quad (3.10)$$

$$\text{Avr. Funding Transfer Rate (\%)} = (1.7\% + 1.05\%) = \mathbf{2.75\%} \quad (3.11)$$

The unit-based profitability results are the profitability of the unit that creates the deposit portfolio $(2.75\% - 1.7\%) = 1.05\%$, the profitability of the marketing unit that creates the loan portfolio $(3.8\% - 2.75\%) = 1.05\%$, the profitability of the Treasury unit $(2.75\% - 3.0\%) = -0.25\%$ unit-based profitability amounts are calculated over these rates.

Since all active and passive accounts in the model structure are evaluated in the same pool, and have the same margin, pricing made without considering the differences on product basis will not be accurate. The most important factors that products can be separated from each other are; term structure of products, interest

structure (fixed / float) and liquidity structure. It can be concluded that ALM risk may be exposed in single pool model structures developed without taking these factors into account. Apart from this, not making transaction-based pricing will not give a fair result in transaction and product-based analysis. The most important advantages of using the Single Pool Model algorithm are; it is easy to implement to systems, required low investment cost, and it is easier to develop for financial institutions with small volume and less product range.

With today's complex financial product structure, we cannot state that this model has a structure that can be preferred by all financial institutions. Although there is still sustainability for organizations where product characteristics are leaner, but the accuracy of the model should be validated periodically.

3.2.2 Multiple Pool Approach

Multiple Pool Approach can be defined as the advanced version of Single Pool Approach. In this method, Active and Passive products are divided into groups according to their certain similarities. The transfer price determined over a single group in Single Pool Approach is determined separately in each group created in the multiple pool approach method, so there are more than one transfer price in this model, and each group has one Transfer price. With this method, product, maturity structure and product characteristics can be handled separately. Developing separate transfer prices on a product group basis instead of a single transfer price allows more accurate results in product-based evaluations. The model algorithm is very simple as Single Pool Approach, and the model implementation costs to IT systems are not expensive.

In the Multiple Pool Approach method, the most important issue that needs to be analyzed and determined are the rule sets that should be created when grouping portfolios. If the product features are analyzed incorrectly and portfolios that should be in different groups are included in the same group, incorrect transfer prices may be determined. For this reason, before determining groupings, rule sets are developed by the relevant teams, these rule sets are run on the basis of each product,

and the matching portfolio groups are located in the same pool. Periodically, validation of the model and groups should be tested. We will look at the details of the calculation based on an example.

Example: Bank X extended a Car loan of 70 Million USD at an average interest rate of 5.2% with 2 year duration and a consumer loan with a 6.0% interest rate of 80 Million USD with 1 year duration in last month. For the funding of these loans, 82 Million USD deposit with 2.5% funding rate and 2 year duration, 38 Million USD short deposit with 2.0% funding rate and 1 year duration were created. Additionally, borrowing was used for the remaining 30 Million USD with 3.2% funding rate. The FTP model, which is used to create a fund, create a loan portfolio and measure the profitability of the Treasury unit, calculates the profitability of business units as follows.

Asset			Liability		
	Volume	Yield		Volume	Cost
Car Loan - 2 year duration	\$ 70,000,000	5.2%	Deposit - 2 year duration	\$ 48,000,000	2.5%
Consumer Loan - 1 year duration	\$ 80,000,000	6.0%	Short Term Deposit - 1 year duration	\$ 72,000,000	2.0%
			Bank Debts	\$ 30,000,000	2.8%

If we solve Equation-3.4 and Equation-3.5 respectively for Group-1 (coloured in red), we get:

$$Avr. Transfer Price (\%) - Group 1 = \frac{(5.2\% - 2.5\%)}{2} = 1.35\% \quad (3.12)$$

$$Avr. Transfer Rate(\%) - Group 1 = (5.2\% - 1.35\%) = 3.85\% \quad (3.13)$$

or

$$= (2.5\% + 1.35\%) = 3.85\%$$

If we solve Equation-3.4 and Equation-3.5 respectively for Group-2 (coloured in blue), we get:

$$\text{Avr. Transfer Price (\%)} - \text{Group 2} = \frac{(6.0\% - 2.0\%)}{2} = \mathbf{2.0\%} \quad (3.14)$$

$$\begin{aligned} \text{Avr. Transfer Rate(\%)} - \text{Group 2} &= (6.0\% - 2.0\%) = \mathbf{4.0\%} \quad (3.15) \\ &\text{or} \\ &= (2.0\% + 2.0\%) = \mathbf{4.0\%} \end{aligned}$$

Each group profitability results will be evaluated according to the products' yield/cost ratios and average transfer rate of related groups. For Group 1, Car Loan Profitability is $(5.2\% - 3.85\%) = 1.35\%$, and for Group 2 Consumer Loan Profitability is $(6.0\% - 2.0\%) = 4.0\%$. Treasury unit profitability can calculate as follows; $(3.85\% - 2.8\%)* (\$ 70,000,000 - \$ 48,000,000) + (2.0\% - 2.8\%)* (\$ 80,000,000 - \$ 72,000,000) = \$ 16,700,000$

As can be seen in the example above, a separate TP is determined for each group and product profitability is established. Although the advantages of ease of use come to the fore as in the Single Pool Model method, it is not widely used in financial institutions with a complex product structure because it does not include risk management elements. Even if the duration results are examined especially for maturity analysis when using the products in the same group, we know that the duration results may also vary within the period in most portfolios. In today's product characteristics, these variables are modelled separately. As a result, although the Pool Approach method provides suitable solutions for ease of application and system integration to the user, it is not efficient for companies of all sizes because it does not deal with the difficulty and all risk factors in the formation of complex product structures in detail. Although it seems beneficial to use them in organizations with smaller and lean product structures, they are not healthy models for large structures.

3.2.3 Matched - Maturity Approach

Products that are grouped and priced in the pool approach are analyzed individually in this method. On the basis of each transaction, products are analyzed with respect to their cash flows and have separate funding rates according to their product structure and terms. The funding center creates the curves where the cost rates are taken separately for each term. If these curves cannot be created, it can be progressed with a swap curve which is constructed from the LIBOR (London Interbank Offered Rate) and Euribor rates traded in the market. Prices are created for each term by adding a liquidity premium, if necessary, on the determined cost ratios. Thus, unique funding rates are assigned from the beginning of the day on each product basis and analyzed over this cost until maturity.

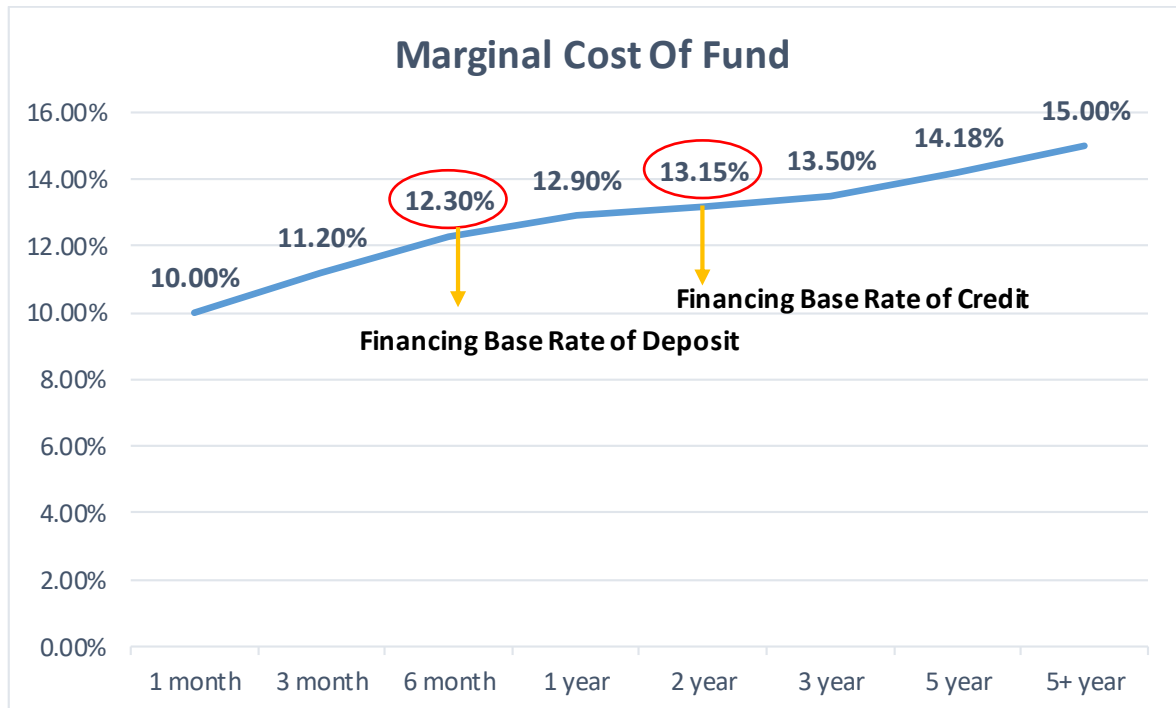
This method is also called the Co-Terminus method. The model was developed by Bank of America in the 1970s on the grounds that accurate profitability analyzes could not be made and the interest risk factor could not be adequately addressed in periods when high interest volatility emerged. Matched-Maturity model structure, which was actively used by all banks until the 2008 financial crisis, resulted in healthier product pricing than Pool methods. However, after the crisis, the use of this model only in FTP calculation has started to be questioned. Shakirov (2017) emphasized that this model structure was insufficient in observing the risk factors encountered during the crisis period, especially liquidity risk, and stated that the legal authorities and the FED requested extra improvements in this model.

Before examining the positive and negative aspects of the model, we can see how it works with a simple example in the example below.

Example: Bank A extends a 3-year consumer loan at 17% annual interest. On the other hand, it formed a 1-year time deposit product with an annual interest rate of 10.5%. Financing center determine minimum interest rate of 3 year credit portfolio as 14.8%, and 11.5% for 1-year deposit product. The profitability ratios of the unit that provides the loan product and the unit that collects the deposit together with the funding center are as follows.

In Figure 7, we can see the cost rates determined by the Funding Center according to the maturity structure.

Figure 7: Marginal Cost of Fund



3-year Mortgage Loan Yield = 17%, the related financing rate from Marginal Cost of Fund table is 13.5%.

The NIM of Credit gatherer is $(17\% - 14.8\%) = 2.2\%$, Financing Center Profit from the credit is $(14.8\% - 13.5\%) = 1.3\%$.

1-year Deposit rate = 10.5%, the related financing rate from Marginal Cost of Fund table is 12.9%.

The NIM of Deposit gatherer is $(11.5\% - 10.5\%) = 1.0\%$, Financing Center Profit from the deposit is $(12.9\% - 11.5\%) = 1.4\%$.

As we can see in the example above, funding center determines each terms' financing rates separately by building a cost of fund curve. While developing this curve, it is generated by considering the maturity mismatch problem. Thus, at the origination of products, the treasury unit includes the interest risk problem in pricing and includes this factor in the profitability analysis of the units. In the

following chapters, more detailed analyzes will be made about how these curves are developed, and how the liquid and illiquid maturity ratios are determined and the active and passive aspects of the balance sheet will be hedged. The Treasury unit shares these costs with the business units and announces the minimum rates that they can use. The profit / loss amount between the customer utilization and these prices are transferred to the business units' profit/loss performance, and the profit/loss amount between the market prices drawn at the curve and the rates shared by the units is transferred to the treasury unit.

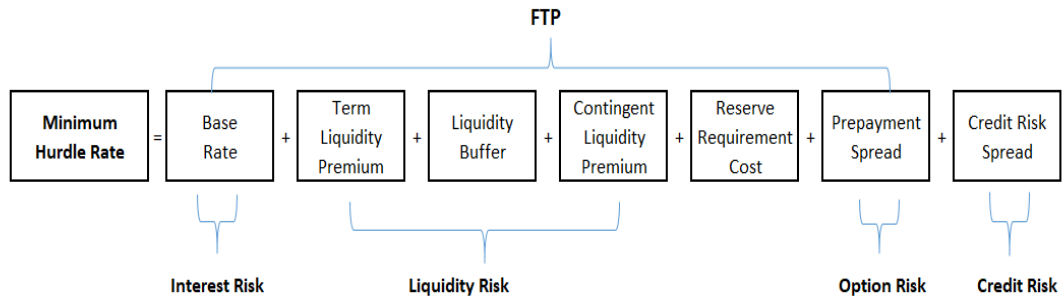
In the Matched - Maturity method FTP pricing, they are much more complex models than Pool approach models and offer pricing on a transaction basis for each term. Even if the system integration is more comprehensive than the Pool approach models, the model is also very simple to use. It has been a recommended model for many years until the financial crisis period, since it includes all historical interest rates in the calculation and considers the interest risk factor seriously. However, after the global liquidity crisis in 2008, all pricing models needed to be developed, since none of the models used took liquidity risk factors into account. Bank For International Settlement (BIS) (2011) stated that“ Many banks treated liquidity as a free good for transfer pricing purposes, and this was one cause for the very poor liquidity outcomes experienced during the GFC (Global Financial Crisis)”. In addition to liquidity risk, there have been comments that behavioral factors are also an important variable in pricing in today's markets. With these considerations, model approaches based on early termination risk, credit risk and customer behavior have increased their importance. Matched-Maturity model structures that do not contain these factors have started to be considered as FTP pricing models that can be accepted by the markets at a minimum level.

3.3 Advance FTP Model Structure & Components

In this section, it will be explained in detail how to develop an advanced FTP model. As stated in previous chapters, FTP model structures have changed over time, especially after financial crises. Legal institutions have published various regulations and documents in order to construct more effective model structures. The most important difference of Advanced FTP model structure is behavioral factors are included in pricing models. Since there is a wide range of product for customers in finance sector, financial institutions should consider different behavioral models for each product in their pricing. In this section, besides basic pricing parameters' explanation, predominantly explain what types of behavioral models should be developed in an advanced model. It is aimed to explain in detail all the components that is required for a financial institution to create its own Advanced FTP model.

First of all, how the Base curve generation process will be explained in detail, then the term liquidity Premium calculation will be explained where the base curve needs to be adjusted with these rates. Afterwards, the details of Contingent Liquidity Risk calculation, which entered the literature after the 2008 financial crisis, and how it should be included in the pricing will be explained. In the following parts, behavioral models will be explained. These models are predominantly prepayment risk measurement models and credit risk models that will enable the measurement of credit risk performance of customers. Especially the credit risk factor has not been discussed in detail in the published articles so far, so the details of the calculation methodology will be shared comprehensively in this section. You can find the summary of the pricing parameters in the Figure 8 as below.

Figure 8: FTP Model Parameters



3.3.1 Base Curve

Base Curve is generated from Libor or Swap rates traded in the markets for each currency. These rates are announced on a daily basis for each term. LIBOR (London Interbank Offered Rate) is the interbank lending rate set by member banks in the London money market. Today, benchmark rates, especially for USD and EUR, are determined over these rates. As a brief warning here, ISDA (International Swaps and Derivatives Association) published a new roadmap for the use of LIBOR in 2018 and announced that the use of LIBOR interest rates will be stopped by the end of 2021. Instead, it was decided to use the SOFR set by the Federal Reserve of New York for USD benchmark interest rates and the rates to be published in the ESTER for the EUR determined by the European Central Bank.

On shore and off shore swap rates are used in the creation of base curves for other currencies. Especially in developing country markets, the prices are generated for each currency and each term in the offshore market, and are considered as curves that will create base curve rates of pricing. Since the interest rates in the published curves are not shared for each maturity day, different forecast models are used to calculate the required maturity prices. Although yield curves are created with the interpolation methodology, which is mostly simpler to use, the Nelson-Siegel-Svensson model, which is accepted in academic and financial markets and has been included in systems especially by central banks and large financial institutions, produces much more accurate results. While calculating on a linear function in the interpolation model, the model developed by Nelson and Siegel in 1987 creates a

non-linear, exponential polynomial function and Svensson (1994) extended this model and provided the opportunity for a more accurate model. In Figure 9, the equation of interpolation and the Nelson-Siegel model functions and the comparison of the curve formed by Nelson-Siegel-Svensson to pricing rates are presented.

Linear Interpolation Formula

$$y = y_1 + \frac{y_2 - y_1}{x_2 - x_1} * (x - x_1) \quad (3.16)$$

where two points are known as (x_1, y_1) and (x_2, y_2)

Nelson-Siegel-Svensson Equation Formula

$$f(m, \beta) = \beta_0 + \beta_1 \exp\left(\frac{-m}{\tau_1}\right) + \beta_2 * \frac{m}{\tau_1} * \exp\left(\frac{-m}{\tau_1}\right) + \beta_3 * \frac{m}{\tau_2} * \exp\left(\frac{-m}{\tau_2}\right) \quad (3.17)$$

where;

β_0 is long run levels of interest rates

β_1 is short run component (slope)

β_2 is medium term component; determines magnitude and the direction of hump (curvature)

τ_1 is decay parameter

τ_2 a positive non-negative parameter that determines the position of the second hump or the depression on the curve.

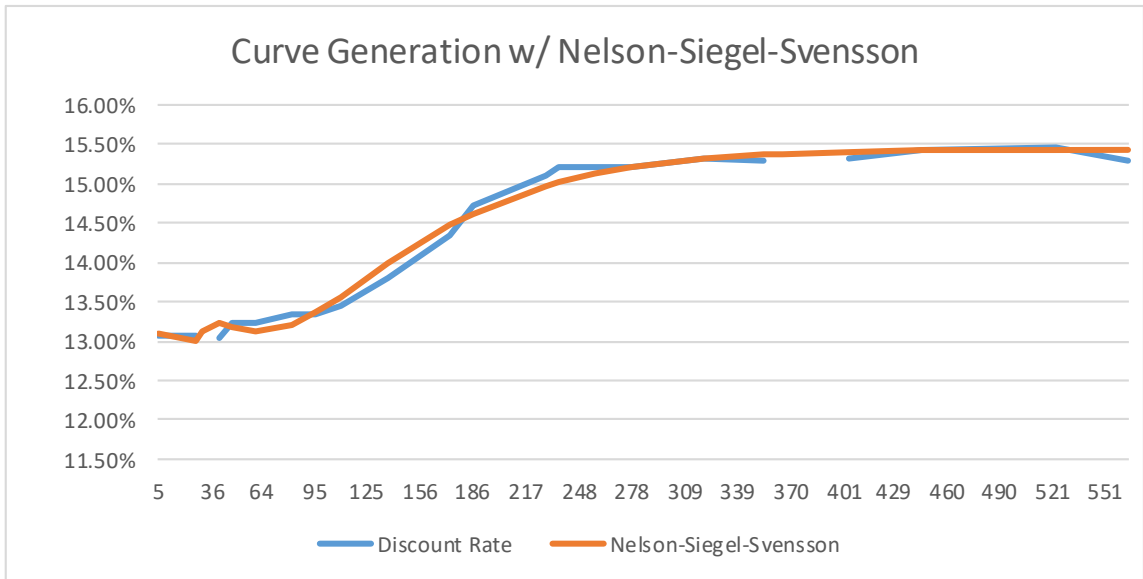
β_3 decides the direction and magnitude of the hump

m = time to maturity,

$\beta = (\beta_0, \beta_1, \beta_2, \beta_3, \tau_1, \tau_2)$ is the parameters to estimated,

and β_0, τ_1, τ_2 and $\beta_0 + \beta_1$ are assumed to be greater than 0.

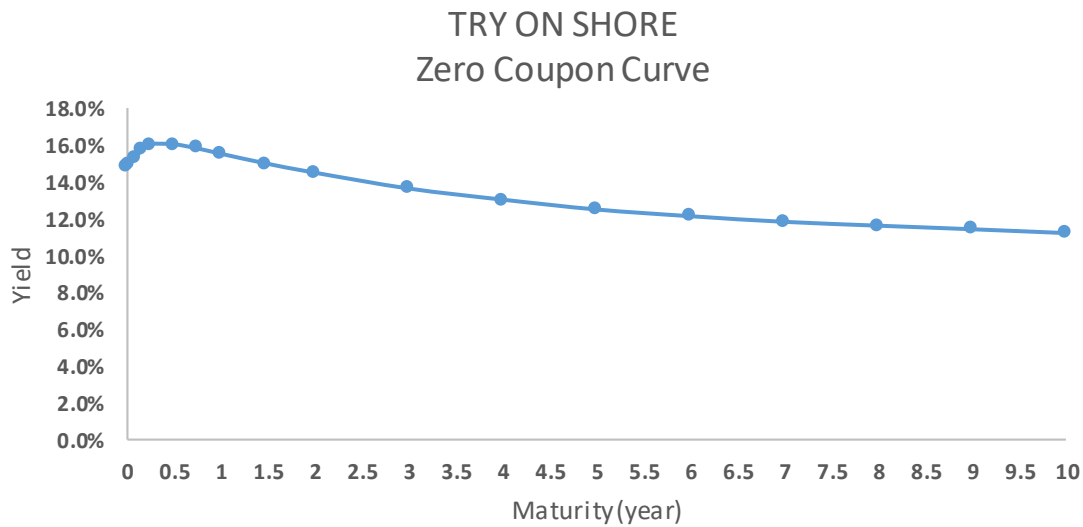
Figure 9: Nelson-Siegel-Svensson Curve



The example below shows how prices can be created on the basis of all terms with a Swap curve (risk-free curve). In the example below, the TRY Onshore curve was used to create a TL (Turkish Lira) base curve. In the previous sections, we have stated that base curves are created over Off shore or On shore Swap rates in emerging markets. The reason why on shore interest rates were taken for TL is that onshore rates are more liquid in TL pricing. This factor must be taken into account when determining the base rate of the currency subject to pricing.

Maturity	Rate	Maturity	Rate
O/N	14.80%	2Y	14.50%
1W	14.90%	3Y	13.60%
1M	15.30%	4Y	13.00%
2M	15.80%	5Y	12.50%
3M	16.00%	6Y	12.10%
6M	16.00%	7Y	11.80%
9M	15.80%	8Y	11.60%
1Y	15.50%	9Y	11.40%
18M	15.00%	10Y	11.20%

Figure 10: TRY On Shore Curve



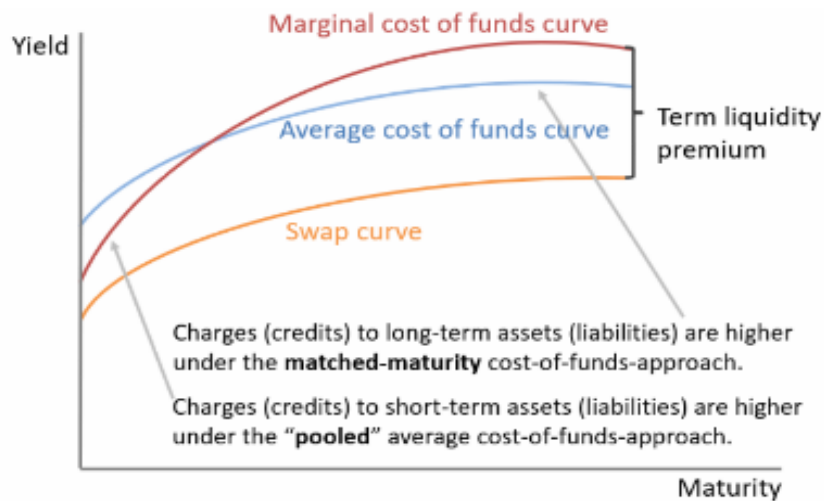
As stated above, in the process of preparing base curves in each currency, after Zero Curves (risk free rates) are withdrawn from treasury systems, the relevant terms that are not found are derived with the Nelson-Siegel-Svensson model (Equation-2) and the prices that will base the FTP model are created.

3.3.2 Term Liquidity Premium

Term liquidity premium defined by BIS (Bank For International Settlements) (2011) as “a spread between the swap curve and the bank’s marginal cost of funds curve as per the contractual/ behavioral asset’s maturity”. Banks' borrowing rates do not directly consist of pricing on the Swap curve (risk-free rates). Funding costs may vary within the scope of each financial institution's own ratings, risk status and market making. Apart from the funding spread on risk-free rates, if the maturity of the funds borrowed by banks for loans or products differs, they are required to add spread to their pricing due to maturity mismatch. For example, if a bank that will provide corporate loans at a 3-year variable interest rate, and take 1-month term deposit portfolio as a source of funds in return, a term liquidity premium must be calculated due to the monthly replenishment of the deposits. Generally, such risks

are hedged with derivatives. IRS (Interest Rate Swap) and CCS (Cross Currency Swap) transactions are the most used hedge instruments. Term Liquidity Premium spread is added on the Swap curve on maturity basis, adding the bank's real borrowing spread rates to the pricing.

Figure 11: Term Liquidity Premium Adjusted Base Curve



Source: BIS (2011), Liquidity Transfer Pricing: a guide to better practice

As the second step after the funding curve is obtained, the interest rates resulting from the addition of term liquidity premium on each maturity basis are dissolved on cash flow basis for each product and the transfer pricing of the products is calculated.

Since the cash flow of each product differs in addition to the maturity structure, it is necessary to obtain effective product rates from the spot rates. Since the interest rate of an amortized loan and a loan with balloon payments should be different for the same term, the funding curve we have, the discount factors are determined and the interest rate that equates the current value of the payments of the relevant product with the nominal amount is calculated. The interest structure can be different as fixed and float, so two different equations are used.

Cash flow with Fixed interest rate

$$\text{Interest Rate} = \frac{\sum_{k=0}^n \text{Notional}_k * DF_k - \sum_{k=0}^n \text{Amortisation}_k * DF_k}{\sum_{k=1}^n \left(\frac{\text{Day Period}_k}{360} \right) * \text{Residual Capital}_k * DF_k} \quad (3.18)$$

Cash flow with Float interest rate

$$\text{Interest Rate} = \frac{\sum_{k=0}^n \text{Notional}_k * DF_k - \sum_{k=0}^n \text{Amortisation}_k * DF_k - \sum_{k=1}^n \left(\frac{\text{Day Period}_k}{360} \right) * \text{Reset Rate}_{k-1} * \text{Residual Capital}_{k-1} * DF_k}{\sum_{k=1}^n \left(\frac{\text{Day Period}_k}{360} \right) * \text{Residual Capital}_{k-1} * DF_k} \quad (3.19)$$

Notional: Credit Amount

DF: Discount Factor

Amortization: Principal Payment of Credit

Day Period: Number of days between two monthly payments

Reset Date: Forward Fixing Rate

Residual Capital: Residual Amount of Credit

Interest Rate: Base Rate + Term Liquidity Premium

3.3.3 Liquidity Buffer

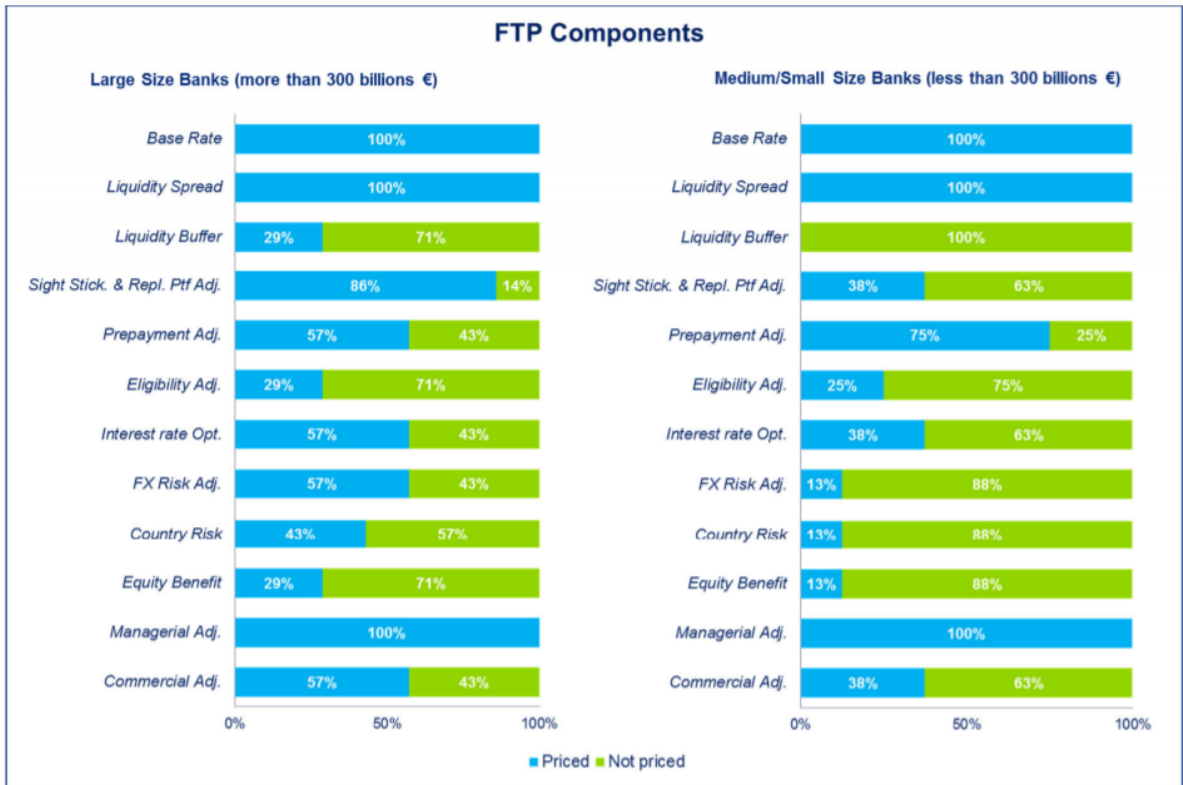
The importance of the concept of liquidity has emerged after the 2008 financial crisis, as has been mentioned in previous sections. It has been understood that the situation of obtaining liquidity, which banks regarded as zero cost until this period, was a much more costly process with the crisis than originally thought. The ease of creating liquidity is the most important element that financial institutions should have in order to stand strong both in their growth and during the financial recession. Many items classified as asset items in the balance sheets may not be liquid in terms of liquidity. For example, land, housing, vehicle or investment areas will not be very useful instruments in an emergency liquidity crunch. However, cash assets, or items such as bonds, bills and stocks that can be converted into cash can serve as a serious source of liquidity in times of crisis.

Legal institutions developed very comprehensive parameters to monitor the liquidity status of financial institutions after the 2008 crisis. The liquidity status

reports, which were not stated in the activity reports in the previous periods, aimed to achieve a more robust structure of the financial markets with the Basel III: International Framework for Liquidity Risk Measurement, Standards and Monitoring procedure published by the Basel Committee at the end of 2010. BIS (Bank for International Settlements) (2011) explained the details of framework as “Two global standards for liquidity risk were developed. First, a Liquidity Coverage Ratio (LCR) to ensure banks have sufficient high quality liquid assets to survive an idiosyncratic shock and, second, a Net Stable Funding Ratio (NSFR) to encourage banks to fund their business activities using more stable sources of funding. As these new ratios produced, additional central regulations were issued in many countries such as America. Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 is an important example of this. With this new procedure, which obliges liquidity cushion for banks above a certain size level, it is aimed to prevent the financial crisis situation experienced in 2008 at high levels again.

Even though financial institutions are actively analyzing their balance sheets on LCR, NSFR and similar stress tests, they do not actively include this parameter in FTP models. The most important reasons for this are that it is difficult to calculate on a product basis, and there is no exemplary study that has yet been published and accepted academically, and it is seen as an item that will cause additional costs in banks' balance sheets. As financial institutions generally have shorter-term borrowing than their active portfolio, they must continuously create funding. As a liquid asset, the instrument mostly kept by banks in their balance sheets is the bonds and bills portfolio that can be used as repo or collateral. However, since the cost of holding this portfolio is higher than other assets, it is sufficient for banks to be at a level to meet the internal stress tests. In Figure 14, in the results of the survey conducted by Deloitte Company with 15 financial institutions in Europe in 2014, the rate of adding Liquidity Buffer to FTP models is shared. As can be seen in the graph, this parameter has not been taken into account in FTP models sufficiently.

Figure 12: FTP Components



Source: Deloitte (2014). Fund Transfer Pricing, A Survey to assess the state of European banks' practices.

Although it is not an item that is actively included in the FTP model it is necessary to add a certain amount of liquidity buffer for each product in response to the liquidity crisis that may occur in the coming periods in order to create an efficient pricing.

3.3.4 Contingent Liquidity Premium

Bank balance sheets contain products whose product maturity structure is unknown at the beginning of the day. Expected contract periods for these products that are evaluated within the scope of Sight Stickiness are calculated with separate models. Deposit products and credit products opened with credit lines are the most common product structures. We can evaluate the models made for these product structures in two scopes. Although the models vary according to the product structure and characteristics, firstly, it enables to calculate how much of the product will continue to live and how long it will be on the balance sheet. For example, a

bank that will use the non-maturity deposit to create a loan portfolio should model how long this product will live on its balance sheet and how its nominal amount will remain. Just as with deposit products, some credit products are modelled with these models. A line of credit is the most known example where customers can use credits at any time within their credit limits. For these products, it is necessary to estimate the rate that will turn into average credit and add a cost accordingly. These liquidity premiums added within the scope of Contingent Liquidity Premium are the same as the liquidity premium rate I described in the previous section, the only difference is to calculate how much of the product and for which term a liquidity premium should be added.

The most used method in order to estimate the deposit products' maturity and its core part is Geometric Brownian Motion (GBM) method. GBM is a stochastic model used for volatility approximation estimation. The model is basically built on two parameters.

$$\partial St = St \mu \partial t + St \sigma \partial Bt$$

The following function, which is the differential solution of the formula above, is the basic function of the GBM method.

$$St = \left[\exp(Z_\alpha(\sigma\sqrt{t}) + \left(\mu - \frac{\sigma^2}{2}\right)t) \right] * (1 - 2\sigma)$$

μ : the mean term is assumed to be 0

σ : constant variance of logarithmic returns

t : the number of months between the date the analysis started and the date when the withdrawn of cash flow will be calculated

α : confidence level

In order to use the GBM method, some assumptions must be provided. These assumptions are important in terms of the model's ability to make meaningful and fair estimates. In addition to the assumptions required for using the GBM method, additional assumptions accepted during model development. These assumptions:

- Returns have a normal distribution
- The maximum auto correlation level of returns is 1.
- The volatility of returns is constant
- The average value (μ) of returns is 0.

As an example for the Contingent Liquidity Premium calculation, let's assume that bank A is pricing a 1 month Deposit product. The pricing of the currency of Turkish lira (TRY) and the deposit product with a nominal amount of 100 Million TRY will be as follows.

	Assumption	Notation
<i>Deposit Amount</i>	100,000,000	D
<i>Expected Core Ratio</i>	70%	CR
<i>1 month TRY Base Rate</i>	15.0%	BR
<i>Estimated Life time</i>	1 year	LT
<i>LP Rate for 1 year</i>	0.3%	LP
Transfer Rate = 15% + 0.3% * 70%		

$$\text{Transfer Rate} = \text{BR} + \text{LP} * \text{CR} \quad (3.20)$$

In the calculation shared in the example above, although the customer has made a 1-month deposit agreement, it has been calculated by the additional models that the product will continue with a nominal of 70% for 1 year. Thus, the product is evaluated as a product that will roll after 1 month, but with a liquidity term of 1 year. The reason for taking 70% of the liquidity premium calculated for the product is due to this calculation of the core ratio expected to live on the balance sheet within an average of 1 year.

Just like the time deposit example, the contingent liquidity Premium calculation of limit-defined loan products is calculated with the same methodology. The core volume calculation used in term deposits is created by calculating how much of the loan will be used in limit-defined loan products. The formula example that should be used is as follows (Bank for International Settlements) (2011):

Contingent Liquidity Premium = (Limit - Drawn Amount) / Limit *
Likelihood of Drawdown * LP

where LP is the term liquidity Premium rate for expected maturity.

The only item that differentiates the calculation of non-maturity deposit products is the maturity of the transfer price. Since there is a certain maturity in term deposit products or loan products, the transfer price is calculated based on this term. Since there is no specific maturity in non-maturity deposit products, the transfer price is generally determined over the shortest term benchmark rate used for the relevant currency. For example, if we go again in TRY, the 1-week policy rate is taken as the base rate, and an LP rate over the expected maturity period is included in the pricing as in the calculation of time deposits.

The most important factor to be considered in Contingent liquidity premium calculations is the development of models that accurately estimate maturity structures and core volume expectations. Although there are not very detailed academic studies in this field, models are developed specifically for product structures by financial institutions' own modeling teams and included in the pricing.

3.3.5 Reserve Requirement Cost

Financial institutions are required to keep a certain amount of reserves in the central bank of the countries for the deposits, loans and similar liabilities they hold in their balance sheets. These rates used within the scope of monetary policy management are a cost item for banks. These rates, which vary on each country basis, are items that should be added to the pricing actively. For example, if a bank has to reserve a 10% reserve for the deposit amount of 1,000,000 USD it holds, it can only use 900,000 USD of this resource to create asset and it should keep the amount of 100,000 USD in the central bank as reserve. A cost for 100,000 USD to be allocated should be calculated and added as a cost in the pricing of a deposit portfolio of 1,000,000 USD. If we want to calculate a reserve holding cost based on this example, assuming that the base interest rate we set for the relevant product is 4% and the central bank provides an interest yield of 2% for this reserve amount, the calculation of the additional reserve cost rate for a total of \$ 1,000,000 is as follows:

	Assumption	Notation
Deposit Amount	1,000,000	D
Deposit Maturity	1 month	m
Reserve Ratio	10%	rr
Reserve Requirement	100,000	
3-Month Deposit Transfer Rate	4%	tr
Central Bank Return Rate for Reserve	2%	y
Cost of Reserve Requirement	0.2%	c

$$c = rr * (tr - y) \quad (3.21)$$

Since reserve rates vary in each country and are actively used as a monetary policy tool, they should be addressed separately under each regulation. There are country-specific regulations that give the opportunity to hold required reserves on a different currency basis, not just the cost rate. For example, the amount of reserves that should be kept in an emerging market can be held at the central bank

in USD, EUR, gold or a combination of these. Before proceeding to cost calculations, organizations need to create the optimum reserve portfolio for themselves and then calculate their costs. There is a detailed article published by Central Bank of Turkey in 2013 on this subject. (Reserve Option Mechanism, 2013).

3.3.6 Prepayment Risk Adjustment Spread

One of the most important risk parameters tried to be included in the pricing by banks is the prepayment risk of credits. Customers can close their loans before due date for many reasons. Especially in products that do not incur penalty fees in early payment, customers use the option to close their products early if they get more favorable interest rates from other banks. For loans to be used as a long-term and collateral-based funding product such as mortgages, banks set certain penalty fees in case of early closing.

The possibility of early payment, which is seen as a very important opportunity when considered by the customer side, creates both liquidity and interest risk for financial institutions. Re-funding needs of banks may arise because of the deterioration in cash flow due to closing loans. Since the funding source used at the beginning of the day to create these portfolios cannot be closed as early as a loan, banks may have to find a higher-interest source to pay back this funding. Apart from liquidity risk, interest risk is also one of the risks faced due to customer early closing. Interest rate risk arises because derivative transactions such as IRS (Interest Rate Swap), which are made to fix the return on the loan portfolio, will become dysfunctional as a result of the early closing of the loan. Since market interest rates may differ from the period when the IRS was created, early closing of the loan causes banks to bear the cost of this interest rate change. Additionally, the early closing of loan products, which are subject to hedge accounting processes, may cause over hedging risk and it will disrupt the banks' balance sheets and ALM management strategies.

Since the prepayment risk causes a significant risk to the expected return in pricing made at the beginning of the day, banks reflect an additional cost in their pricing for this risk. While determining prepayment risk adjusted spread, banks need to develop a model that will estimate customers' early payment risks. In these models like Survival model algorithm, banks calculate the prepayment rate by comparing the expected loan collection rate in 1 month and the actual loan collection rate based on product segment based for each loan. As historical data, it can be proceeded with the average of the last 1 year or longer data. Then, these rates for each segment are evaluated as the possibility of early closing at the beginning of the day for new customers. For example, if the monthly loan prepayment rate experienced in mortgage loans in the last 1 year in the current customer portfolio is 0.5%, the probability of early closing in new mortgage loan applications will be evaluated as 0.5%. This calculation can be produced more comprehensively by differentiating it in segment and different product characteristics. Prepayment calculation formula is as in the formula below.

$$\text{Prepayment Rate} = 1 - \frac{\text{Actual Remaining Principle of Credits}}{\text{Expected Remaining Principle of Credits}} \quad (3.22)$$

Apart from the calculated prepayment rate, how this should be added to the pricing is also calculated with a separate process. Option Adjusted Spread (OAS) method is used in the calculation. OAS is especially used to calculate the embedded option that occurs due to the early closing of loans included in mortgage backed securities. Since the cash flow of the bond issued based on the mortgage credits will change in case of early payment of loan, OAS premium is included the pricing to cover the prepayment risk. Therefore, the rate is also defined as the differences between the spread of a fixed-income security and the risk-free rate of return.

Prepayment adjustment spread calculation steps to be used in pricing are as follows:

- As explained in the previous sections (Chapter 4.2), the interest rate of the relevant loan (base rate + term liquidity Premium) is calculated and resolved with discount factors according to the term structure.

- The cash flow obtained from the loan is re-generated with the early payment ratios that are developed by the prepayment models.

- Due to the prepayment amounts in the new cash flow, the remaining principal amount will decrease, resulting in less interest income than the interest income expected at the beginning of the day.

- The calculated interest rate difference is added to the loan amount in the cash flow in the initial pricing, and the interest rate that will compensate the estimated interest loss is calculated.

- The difference between the new calculated interest rate and the interest rate calculated before adding the prepayment risk is added to the pricing as prepayment adjusted spread.

If we proceed through the example, Bank A has 4% monthly average early payment ratio (Equation-3.22) from existing auto loan portfolio in the last 1 year according to prepayment model. Bank A calculates the interest rate as 15.2% without the possibility of early closing of the loan via FTP model for a 3-year amortizing auto loan application with current market interest rates. The new interest rate, which should be required to compensate the loss of interest caused by the new loan cash flow expectation with a monthly early payment rate of 4%, is calculated as 15.6%. Bank A includes a prepayment adjustment spread rate of 0.4% for this term auto loan in its pricing. Thus, the interest loss that will occur after the estimated early closing is included in the pricing at the beginning of the day.

A prepayment adjusted spread rate must be added to the FTP model for all portfolio products that cannot be charged penalties in case of early closing. However, if there is a fee that can be reflected to the customer after early closing

in product contracts, this return should be taken into account when adding to the FTP calculation.

In the study explained up to this section, information was given about the details of the FTP model, its usage areas and the calculation of pricing components. The pricing components that should be used in an advanced FTP model are explained with examples and applications in financial markets. In the last part of the thesis, credit risk-adjusted spread, which has not been given in detail before in the FTP models and is not included as a pricing component in financial markets except for banks with very large volumes, will be explained. After adding this variable, the minimum hurdle rate to be used in pricing will be calculated as a result of the FTP + Credit Risk Adjusted spread.

3.4 Credit Risk Adjustment Spread

In the FTP pricing explained in the previous sections, the effects of three important risk types on pricing are explained. These are Base Rate covering interest risk, Liquidity premium calculations covering liquidity risk and prepayment risk adjustment spread section where option risk pricing is explained. These risk concepts are already three comprehensive types of risk that are considered to be required in an Advanced FTP model. In this section, in addition to these risks, the effect of the credit risk factor on pricing will be analyzed, which significantly affects bank balance sheets and P&L figures.

The concept of credit risk is defined by the Basel Committee on Banking Supervision (BIS, 2010) as “the potential that a bank borrower or counterparty will fail to meet its obligations in accordance with agreed terms”. Since it covers the entire customer portfolio and may differ depending on the product characteristics, it is the most emphasized risk factor for banks. Provision amount calculated for credit risk has also been the most important component of this KPI. Banks initially saw this type of risk as an important factor affecting the provision amount and capital adequacy ratio calculated in the balance sheet. However, in the following

periods, within the scope of the strategy of reaching the right customer, the stage of setting up advanced credit risk models was started.

In the next section, the detailed explanation of the credit risk factor parameters that constitute the concept of credit risk and for which provision calculations are made, how they should be modeled and how they will be set up in customer pricing will be explained.

3.4.1 Credit Risk Parameters

Managing a bank's risks accurately and adequately requires appropriate risk measurement tools and systems that provide basic risk parameter estimates. The risk parameters are defined as probability of default (PD), exposure at default (EAD) and loss given default (LGD). These parameters can be calculated based on various sub-portfolios and product types. Generally, after the parameters are calculated on the basis of each customer, a common parameter value is obtained for certain portfolios and risk groups.

The first credit risk parameter is probability of default (PD) that can be defined as the likelihood of inability of customers' payment. Inability of payment is the target of PD models and it is stated as more than 90 days delinquency on any credit obligation or unlikeliness to pay debt according to the bank in the consultative document "The Internal Ratings-Based Approach" published by BIS (2001). Customers are flagged as default or non-default based on 12 months period after scoring time to be included in the model development data. The target value of the model is binary and there are different types of model algorithms used to predict probability of default parameter. The most common PD model technique is logistic regression that is based on sigmoid function. PD calculations are calculated by creating separate models both in the loan applications made by the customers at the beginning of the day and at the stage after the loan is provided.

The second credit risk parameter is the exposure at default. In addition to probability of default, it is also important the amount of debt when the obligor has defaulted. The calculation methodology differs related to structure of the product.

Revolving products such as credit cards may have more or less risk/limit in the future or noncash products may be converged to cash products. For this purpose, different conversion parameters have been defined and calculated based on the past data of the customers. Exposure at default is calculated with using current debt amount and conversion parameters such as Limit Conversion Factor (LCF), Risk Conversion Factor (RCF), Non-existing Limit Conversion Factor (NLCF) and Conversion Probability (CP) regarding to product.

According to Basel literature, LGD is defined as the percentage of loss to occur from default events happening in the next 12 months. The LGD hence must represent the loss on all events classified in default according to the Basel compliant default definition. The banks are adopted a methodology to find the final loss percentage of each sub-portfolio and risk group defined for LGD. The methodology is mainly aims to find final loss of each default event including all the costs and collections. For the resolved events, in other words the events with a final result such as full repayment, restructure or write-off, it is easy to calculate final loss with using discounted amount of costs and transaction between default time and the closing time of the products. On the other hand, there are unresolved default events in the model development data because seven years data are required for corporate asset classes as specified in Article 40 and 43 of BRSA regulation, the “Statement for Credit Risk Calculation through IRB approach- Attachment II”. According to regulations especially article 6.4.3 of the EBA Consultation Paper on Guidelines on PD-LGD estimation and treatment of defaulted assets, resolved and unresolved defaults must be considered in the modeling. Unresolved events are integrated after calculation of final loss of resolved events. Nevertheless, the final loss on those defaults cannot be observed as more recovery/costs are expected in the future. These records however are still a part of the sample and have to be included to reflect the proper loss rate of the portfolio. There are several methods to address them, including:

- Excluding all unresolved cases: Any default which has not been resolved by the end of development sample will be excluded. However, this method is not conservative as open cases have typically higher LGD average.

- Assuming that beyond a certain point all recoveries have been made: After a certain point, all unresolved cases are considered as closed. This method is conservative and treats some of the unresolved cases, however part of the sample is still taken out of the model.

- Inference on unresolved cases: Information from resolved cases is used to adjust the marginal recovery rate of unresolved sample, by assigning additional transactions to virtually close the defaults.

The average of resolved and unresolved cases produced the expected LGD.

3.4.2 Credit Risk Adjustment Spread Calculation

Modeled PD, LGD and EAD models will be included in the pricing with the rate they use in the provision calculation on product / credit basis. In July 2014, the International Accounting Standards Board (IASB) issued International Financial Reporting Standard 9 – Financial Instruments (IFRS 9), which introduced an “expected credit loss” (ECL) framework for the recognition of impairment. The formulation of ECL is:

$$ECL = EAD * PD * LGD \quad (3.23)$$

Calculated amount on product / credit basis is recorded as the credit risk provision figure in the bank balance sheets. As explained in the previous sections, it continues to differ throughout the life of the product / credit. The calculation of credit risk, which has not yet been added to the models in detail as a pricing element, should be calculated as follows:

$$Credit\ Risk\ Adjusted\ Spread = \frac{EAD * PD * LGD}{Notional} \quad (3.24)$$

where

EAD: Exposure at Default

PD: Probability of Default

LGD: Loss Given Default

Notional: Credit Amount

If we proceed through the example, for an individual customer who applied for a loan of 100 Million USD from bank A, the PD rate calculated by the bank's models is 2%, LGD is 60% and EAD is 48 Million USD. The Credit Risk Adjusted Spread that should be included in the pricing is as follows (**Equation-3.24**):

$$\textit{Credit Risk Adjusted Spread} = \frac{48,000,000 * 0.02 * 0.60}{100,000,000}$$

$$\textit{Credit Risk Adjusted Spread} = 0.58\%$$

Bank A must add an additional 0.58% cost for the Credit Risk Adjusted Spread to its pricing.

4 NUMERICAL EXAMPLE

In this section, I will proceed through a prefix pricing, how to create the FTP model components described in the previous sections and the example of calculating the credit risk cost. It will be explained how to calculate all parameters except for the calculation of behavioral models (Prepayment, Sight Stickiness, Credit Risk Model), and for behavioral models, the assumption ratios will be proceeded. The minimum hurdle rate will be determined with the all variables estimation for specific product pricing. Calculations to be applied;

- Creating discount rates with market interest rates and determining the transfer price (Base Rate + term liquidity Premium)
- Contingent liquidity Premium calculation (Core Volume and Maturity will be assumed)
- Calculation of reserve requirement cost
- For prepayment spread calculation (assuming the early payment rates that is normally developed with Survival model approach), calculating the additional cost to be incurred by the Option Adjusted Spread (OAS) method
- Calculation of credit risk costs by assuming the ratios to be formed from PD, LGD and EAD models

We will get the all variables in order to estimate minimum hurdle rate.

Minimum Hurdle Rate	=	Base Rate	+	Term Liquidity Premium	+	Liquidity Buffer	+	Contingent Liquidity Premium	+	Reserve Requirement Cost	+	Prepayment Spread	+	Credit Risk Spread
----------------------------	---	-----------	---	------------------------	---	------------------	---	------------------------------	---	--------------------------	---	-------------------	---	--------------------

Example: Bank A will provide a monthly equal pay car loan of TRY 500,000 with a 2-year term. The cost rate of the bank, which includes all risk factors for this loan product, is as follows.

➤ TRY Market Rate with term liquidity premium as of application date:

Days to Maturity	Discount Rate
5	13.08%
26	13.06%
30	
40	13.04%
47	13.24%
61	13.23%
82	13.35%
96	13.34%
110	13.46%
138	13.81%
173	14.34%
187	14.71%
229	15.10%
236	15.20%
257	15.21%
278	15.20%
320	15.31%
355	15.30%
365	
404	15.33%
446	15.42%
523	15.46%
565	15.30%

As you can see, since there are no market interest rates for all maturities, we obtain the forecast rates by the Nelson-Siegel-Svensson method.

$$f(m, \beta) = \beta_0 + \beta_1 \exp\left(\frac{-m}{\tau_1}\right) + \beta_2 * \frac{m}{\tau_1} * \exp\left(\frac{-m}{\tau_1}\right) + \beta_3 * \frac{m}{\tau_2} * \exp\left(\frac{-m}{\tau_2}\right) \quad (3.17)$$

When we solved the Equation-3.3.1.2 with given market rate then we obtain:

$$\beta_0 = 0.154317, \quad \beta_1 = 0.02, \quad \beta_2 = -0.0799, \quad \beta_3 = -0.10412, \\ \tau_1 = 54.09, \tau_2 = 7.937$$

The equation is solved by minimizing the sum of squared error between the market rates and estimated rates. We used solver function to get the independent variables. The most important rules that should be added to Solver are:

$$\beta_0 \geq 0, \beta_0 + \beta_1 \geq 0, \tau_1 \geq 0, \tau_2 \geq 0$$

➤ After the cash flow of the loan in all related terms is established, we solve the following formula with the estimated discount rates.

$$\text{Transfer Rate} = \frac{\sum_{k=0}^n \text{Notional}_k * DF_k - \sum_{k=0}^n \text{Amortisation}_k * DF_k}{\sum_{k=1}^n \left(\frac{\text{Day Period}_k}{360} \right) * \text{Residual Capital}_k * DF_k} \quad (3.18)$$

$$\text{Transfer Rate} = \text{Base Rate} + \text{Term Liquidity Premium}$$

After we solve the Equation-3.18 with goal seek function, we get 15.14% Transfer Rate for related maturity.

➤ There is no sight stickiness problem for this product because cash out activities was realized at start date. Therefore, the core volume of the product for term liquidity premium calculation is 100%. However, if there is a line of credit, then we just add the term liquidity premium for core volume. Let assume if 80% of the credit amount is core and our average term liquidity premium for each maturity is 2% then our Contingent Liquidity Premium should be equal to 1.6% (2%*0.8).

➤ For Reserve Requirement spread, bank has to borrow the credit notion from any source. The known regulatory reserve rate of the funding is 8%, average funding rate of this reserve in market for bank A is 13% and Central bank return rate for reserve amount is 4%. Then the reserve requirement spread can be calculated as follows:

$$\text{Reserve Requirement} = 8\% * (13\% - 7\%) = 0.48\% \quad (3.21)$$

➤ Prepayment factor is calculated according to the behavioral model results of Bank A for the possibility of early closing estimation of existing customer data. The Survival results show us that on average 0.75% of residual credit amount

has been closed early each month from Equation-3.22. Survival model formula on Bank A existing customer is as follow:

$$Prepayment\ Rate = 1 - \frac{Actual\ Remaining\ Principle\ of\ Credits}{Expected\ Remaining\ Principle\ of\ Credits} \quad (3.22)$$

Therefore, the bank take the early payment option rate as 0.75% on monthly average. Its pricing impact is calculated as follows:

Before early termination factor is considered, bank A expect 15.14% transfer rate from customer (by solving Equation-3.19). After adjusting credit cash flow with monthly 0.75% early termination factor from Equation-3.22, then we estimate 580 TL less interest due to early closing of monthly payment by solving Equation-3.19 with adjusted payment plan with prepayment factor. In order to compensate the expected loss amount, we calculate the minimum transfer rate as 15.26% by solving goal seek calculation for Equation-3.19 with non-adjusted (excluding prepayment factor) payment plan. Therefore, we add 0.12% prepayment adjustment rate to FTP model.

➤ For credit risk spread calculation, Bank A has 1.8% PD (Probability of Default) rate from their PD model for auto loan, and 40% LGD (Loss Given Default) rate from LGD model and 58% EAD (Exposure at Default) ratio from EAD model. Then Bank A estimate credit risk spread for the customer as follows;

$$Credit\ Risk\ Adjusted\ Spread = \frac{1.8\% * 40\% * 58\% * 500,000}{500,000} = 0.42\% \quad (3.24)$$

From all calculation, the minimum hurdle rate is as follow:

Minimum Hurdle Rate	=	Base Rate	+	Term Liquidity Premium	+	Liquidity Buffer	+	Contingent Liquidity Premium	+	Reserve Requirement Cost	+	Prepayment Spread	+	Credit Risk Spread
= 15.14% + 0.48% + 0.12% + 0.42														
= 16.16%														

The minimum rate for Bank A to give for 2-year auto loan should be higher than 16.16%.

If we had not included the credit risk factor (Equation-3.24) in the pricing, the minimum pricing rate would have been **15.74%** as shared below. Net interest income would have been calculated approximately **0.42%** (Equation-3.24) lower. This ratio may increase or decrease according to customer and product characteristics.

$$\begin{aligned}
 \boxed{\text{Minimum Hurdle Rate}} &= \boxed{\text{Base Rate}} + \boxed{\text{Term Liquidity Premium}} + \boxed{\text{Liquidity Buffer}} + \boxed{\text{Contingent Liquidity Premium}} + \boxed{\text{Reserve Requirement Cost}} + \boxed{\text{Prepayment Spread}} \\
 &= 15.14\% + 0.48\% + 0.12\% \\
 &= 15.74\%
 \end{aligned}$$

As explained in the numeric example, credit risk factor is an important cost item that has to be added in pricing model. The most important outcome of the thesis is credit risk calculation and a methodological approach was examined in the example. For behavioral models, the prepayment model algorithm setup and sight stickiness model structure were mentioned, and it was emphasized that pricing should be supported not only with market data but also with advanced models that should be developed internally by financial intuitions. Since the creation of the results with the algorithms of behavioral models requires a more comprehensive analysis, the example was proceeded with assumptions, and how to develop these kinds of models were explained in the previous sections.

5 CONCLUSION AND OUTLOOK

In our thesis, the most basic point that is intended to be explained in general terms is how to create a correct pricing model and how to include the credit risk factor, which has not been considered at the required level in many literatures, in the pricing. While explaining this, first, information has been given about FTP methodology and its usage areas. In particular, its position in the banking sector and its historical development have been examined, and the developments experienced by financial markets that need an advanced model setup have been analyzed. In addition, detailed information has been given on all risk types to explain why and how to add them to pricing. Later, all the variables that should be required for an advanced FTP model have been shared and how to create their pricing has been conveyed through both theoretical and examples.

On the example of the shared Advanced FTP model, the pricing concepts of Interest Risk, Liquidity Risk and Option Risk, which are needed mostly after the 2008 global crisis and added to pricing, has been examined. For the interest risk, it has been shared which curves will be used in the Base rate calculation and how this will vary according to the currency and the state of the country's economy. Within the scope of liquidity risk, examples have been shared on how to include both the term liquidity premium and the contingent liquidity premium amount that should be calculated with behavioral models in the pricing. For option risk, how prepayment risk adjusted spreads should be modeled and calculation examples, in which the most dynamic calculations are made in financial markets, are given in detail. In the last part, Credit Risk Premium calculation, which is the main contribution of our thesis, has been emphasized. In this context, first of all, the content of credit risk concept, studies published by legal institutions and the importance on financial markets have been explained. Then, after general information about credit risk parameters, the current modeling techniques of these concepts have been examined. After transferring the part about how to add model results to pricing, a Credit Risk Adjusted Spread factor has been calculated through a sample example.

In the analysis that emerged at the end of the thesis, the minimum hurdle rate to be used for pricing was calculated with the credit risk factor added on the FTP. Since the concepts of FTP and credit risk contain too much scope in their own structures, I hope that our thesis will be a model that draws the main lines of this and shed light on the construction of more complex models. In particular, analyzing the effects of behavioral factors on pricing will allow financial markets to make correct pricing and achieve a strong balance sheet view. Therefore, every study published in this context will be an important road map for financial market.

REFERENCES

- Pushkina, N. (2013). A simple funds transfer pricing model for a commercial bank (Doctoral dissertation).
- Shakirov, B. (2017). Modeling advanced fund transfer pricing with an application of hull-white interest-rate tree in Turkish banking sector (Master's thesis, MIDDLE EAST TECHNICAL UNIVERSITY).
- Deventer, D. (2002). Transfer pricing systems design: building clarity in the responsibility for and measurement of risk. Kamakura Corporation.
- Dermine, J. (2011). Fund transfer pricing for deposits and loans. *Foundation and Advanced*, 1-21.
- Burucs, J. (2008). Thoughts about employing funds transfer pricing. International Finance Corporation.
- Bledsoe, C. (2008). Funds-transfer pricing? Just say no. *American Banker*.
- Dimitriu, M. C., & Oaca, S. C. (2010). Funds transfer pricing in banking. *Economia. Seria Management*, 13(1), 119-127.
- Grant, J. (2011). Liquidity transfer pricing: a guide to better practice. Financial Stability Institute [and] Bank for International Settlements.
- Basel Committee on Banking Provision (2000). Principles for the Management of Credit Risk.
- Deloitte (2014). Fund Transfer Pricing, A Survey to assess the state of European banks' practices.
- Choudhry, M. (2018). Bank Internal Funds Transfer Pricing best-practice.
- Wyle, R. J., & Tsaig, Y. (2011). Implementing high value funds transfer pricing systems. Moody's Analytics.

Amoako, B. K. O., & Acheampong, I., & Hassan, B. W. (2005). Svensson (1994) model and the Nelson & Siegel (1987) model. Mälardalens University, Department of Mathematics and Physics.

Lindblom, T., & Elliot, V. (2017). Funds transfer pricing, liquidity premium and market structure. Liquidity Premium and Market Structure (July 3, 2017).

Khaykin, I., & Koyluoglu, U., & Elliot, D., & Spicer, C. (2017). Oliver Wyman, The Financial Resource Management. Balancing Complex and Competing Constraints On Capital, Liquidity and Funding. Oliver Wyman Working Paper.

Lund, S., Manyika, J., Mehta, A., & Goldshtein, D. (2018). A decade after the global financial crisis: What has (and hasn't) changed. McKinsey&Company Briefing Note September 2018.

Adam, A. (2008). Handbook of asset and liability management: from models to optimal return strategies. John Wiley & Sons.

Matz, L., & Neu, P. (Eds.). (2006). Liquidity Risk Measurement and Management: A practitioner's guide to global best practices (Vol. 408). John Wiley & Sons.

Basel Committee on Banking Provision (2001). The Internal Ratings-Based Approach.