Residential mortgage loan securitization and the subprime crisis

S. Thomas, M.Sc

Thesis submitted in partial fulfilment of the requirements for the degree Philosophiae Doctor in Applied Mathematics at the Potchefstroom Campus of the North West University (NWU-PC)

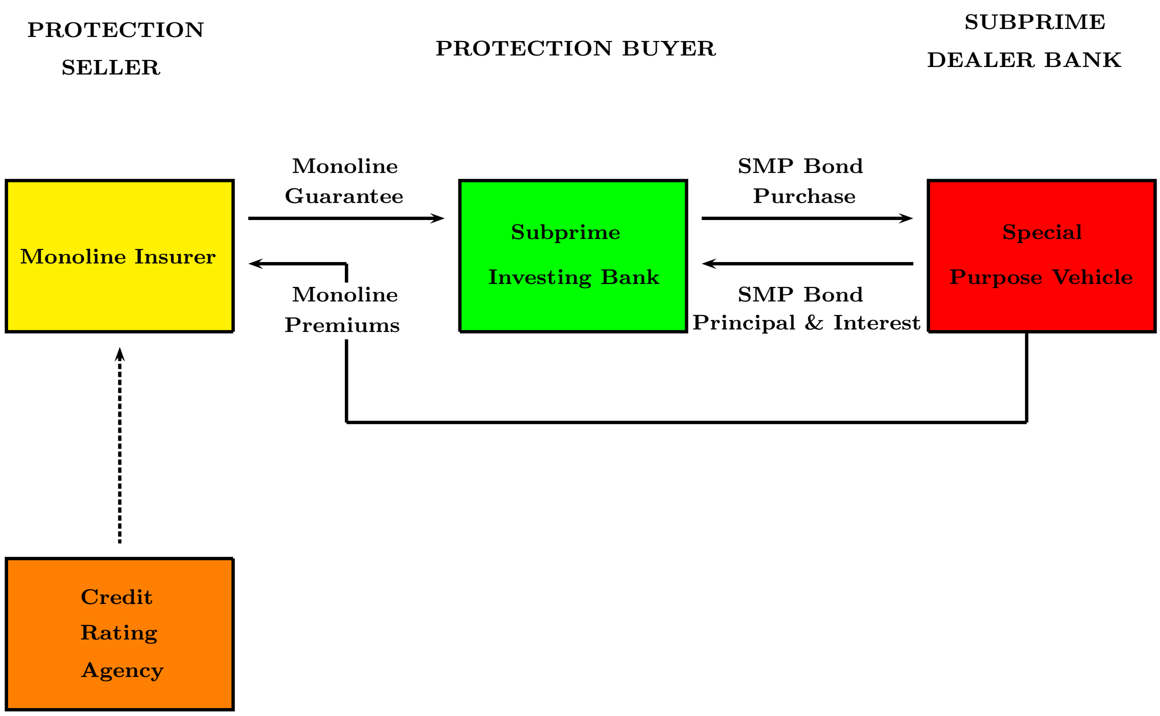


Figure: Structured Mortgage Products Wrapped by Monoline Insurance

Supervisor: **Prof. Mark A. Petersen**
Co-Supervisor: **Dr. Janine Mukuddem-Petersen**
November 2010 **Potchefstroom**

Acknowledgments

Firstly, I thank the Almighty for His grace in enabling me to complete this thesis.

I would like to express my gratitude towards my supervisor Prof. Mark A. Petersen, of the Mathematics and Applied Mathematics Department at NWU-PC, for his splendid guidance, suggestions, explanations and motivation as well as co-supervisor, Dr. Janine Mukuddem-Petersen, for the guidance provided during the completion of this thesis. Also I wish to thank Drs. Thahir Bosch, Hennie Fouche, Frednard Gideon, Mmboniseni Mulaudzi, Ilse Schoeman, and Aaron Tau as well as Charlotte Senosi, Bernadine de Waal, Candice de Ponte, Dingaan Khoza and Sarah Mokoena from the Modeling in Finance, Risk and Banking (MFRB) Research Group at the North-West University for contributing to the various debates about subprime mortgage origination, securitization, risk, data and bailouts from 2008 onwards.

I acknowledge the emotional support provided by my family; daughter Rose, husband Rex and my parents Thomas and Valsamma.

A special thanks to George K John (Gejo) for introducing me to my supervisor.

Furthermore, I am grateful to the National Research Foundation (NRF) for providing me with funding during the duration of my studies. Finally I would like to thank the Business Mathematics and Informatics Research Unit in the School of Computer, Mathematical and Statistical Sciences at NWU-PC for the financial support received.

Preface

One of the contributions made by the NWU-PC to the activities of the stochastic analysis community has been the establishment of an active research group MFRB that has an interest in institutional finance. In particular, MFRB has made contributions about modeling, optimization, regulation and risk management in insurance and banking. Students who have participated in projects in this programme under Prof. Petersen's supervision are listed below.

Level	Student	Graduation	Title
MSc	T Bosch	May 2003 Cum Laude	Controllability of HJMM Interest Rate Models
MSc	CH Fouche	May 2006 Cum Laude	Continuous-Time Stochastic Modelling of Capital Adequacy Ratios for Banks
MSc	MP Mulaudzi	May 2008 Cum Laude	A Decision Making Problem in the Banking Industry
PhD	CH Fouche	May 2008	Dynamic Modeling of Banking Activities
PhD	F Gideon	Sept. 2008	Optimal Provisioning for Deposit Withdrawals and Loan Losses in the Banking Industry
MSc	MC Senosi	May 2009 S2A3 Winner for NWU-PC	Discrete Dynamics of Bank Credit and Capital and their Cyclicality
PhD	T Bosch	May 2009	Management and Auditing of Bank Assets and Capital
PhD	BA Tau	May 2009	Bank Loan Pricing and Profitability and Their Connections with Basel II and the Subprime Mortgage Crisis
PhD	MP Mulaudzi	May 2010	The Subprime Mortgage Crisis: Asset Securitization & Interbank Lending
MSc	B De Waal	May 2011 Cum Laude	Stochastic Optimization of Subprime Residential Mortgage Loan Funding and its Risks
PhD	MC Senosi	May 2011	Discrete-Time Modeling of Subprime Mortgage Credit
PhD	S Thomas	May 2011	Residential Mortgage Loan Securitization and The Subprime Crisis
Postdoc	J Mukuddem-Petersen	2006-9	Finance, Risk and Banking
Postdoc	T Bosch	2010	Finance, Risk and Banking

Declaration

I declare that, apart from the assistance acknowledged, the research presented in this thesis is my own unaided work. It is being submitted in partial fulfilment of the requirements for the degree Philosophiae Doctor in Applied Mathematics at the Potchefstroom Campus of the North West University. It has not been submitted before for any degree or examination to any other University.

Nobody, including Prof. Mark A. Petersen, but myself is responsible for the final version of this thesis.

Signature.................................

Date......................................

Executive Summary

Many analysts believe that problems in the U.S. housing market initiated the 2008-2010 global financial crisis. In this regard, the subprime mortgage crisis (SMC) shook the foundations of the financial industry by causing the failure of many iconic Wall Street investment banks and prominent depository institutions. This crisis stymied credit extension to households and businesses thus creating credit crunches and, ultimately, a global recession. This thesis specifically discusses the SMC and its components, causes, consequences and cures in relation to subprime mortgages, securitization, as well as data. In particular, the SMC has highlighted the fact that risk, credit ratings, profit and valuation as well as capital regulation are important banking considerations. With regard to risk, the thesis discusses credit (including counterparty), market (including interest rate, basis, prepayment, liquidity and price), tranching (including maturity mismatch and synthetic), operational (including house appraisal, valuation and compensation) and systemic (including maturity transformation) risks. The thesis introduces the IDIOM hypothesis that postulates that the SMC was largely caused by the intricacy and design of subprime agents, mortgage origination and securitization that led to information problems (loss, asymmetry and contagion), valuation opaqueness and ineffective risk mitigation. It also contains appropriate examples, discussions, timelines as well as appendices about the main results on the aforementioned topics. Numerous references point to the material not covered in the thesis, and indicate some avenues for further research.

In the thesis, the primary subprime agents that we consider are house appraisers (HAs), mortgage brokers (MBs), mortgagors (MRs), servicers (SRs), SOR mortgage insurers (SOMIs), trustees, underwriters, credit rating agencies (CRAs), credit enhancement providers (CEPs) and monoline insurers (MLIs). Furthermore, the banks that we study are subprime interbank lenders (SILs), subprime originators (SORs), subprime dealer banks (SDBs) and their special purpose vehicles (SPVs) such as Wall Street investment banks and their special structures as well as subprime investing banks (SIBs). The main components of the SMC are MRs, the housing market, SDBs/hedge funds/money market funds/SIBs, the economy as well as the government (G) and central banks. Here, G either plays a regulatory or policymaking role. Most of the aforementioned agents and banks are assumed to be risk neutral with SOR being the exception since it can be risk (and regret) averse on occasion. The main aspects of the SMC – subprime mortgages, securitization, as well as data – that we cover in this thesis and the chapters in which they are found are outlined below.

In Chapter 2, we discuss the dynamics of subprime SORs' risk and profit as well as their valuation under mortgage origination. In particular, we model subprime mortgages that are able to fully amortize, voluntarily prepay or default and construct a discrete-time model for SOR risk and profit incorporating costs of funds and mortgage insurance as well as mortgage losses. In addition, we show how high loan-to-value ratios due to declining housing prices curtailed the refinancing of subprime mortgages, while low ratios imply favorable house equity for subprime MRs.

Chapter 3 investigates the securitization of subprime mortgages into structured mortgage products such as subprime residential mortgage-backed securities (RMBSs) and collateralized debt obligations (CDOs). In this regard, our discussions focus on information, risk and valuation as well as the role of capital under RMBSs and RMBS CDOs. Our research supports the view that incentives to monitor mortgages has been all but removed when changing from a traditional mortgage

model to a subprime mortgage model. In the latter context, we provide formulas for IB's profit and valuation under RMBSs and RMBS CDOs. This is illustrated via several examples. Chapter 3 also explores the relationship between mortgage securitization and capital under Basel regulation and the SMC. This involves studying bank credit and capital under the Basel II paradigm where risk-weights vary. Further issues dealt with are the quantity and pricing of RMBSs, RMBS CDOs as well as capital under Basel regulation. Furthermore, we investigate subprime RMBSs and their rates with slack and holding constraints. Also, we examine the effect of SMC-induced credit rating shocks in future periods on subprime RMBSs and RMBS payout rates. A key problem is whether Basel capital regulation exacerbated the SMC. Very importantly, the thesis answers this question in the affirmative.

Chapter 4 explores issues related to subprime data. In particular, we present mortgage and securitization level data and forge connections with the results presented in Chapters 2 and 3.

The work presented in this thesis is based on 2 peer-reviewed chapters in books (see [99] and [104]), 2 peer-reviewed international journal articles (see [48] and [101]), and 2 peer-reviewed conference proceeding papers (see [102] and [103]).

North-West University, South Africa SOBY THOMAS

Key Definitions

In this section, we provide definitions of some of the key concepts discussed in the thesis. Unless otherwise stated, the terms *mortgage*, *mortgage loan* and *residential mortgage loan* (RML) will have the same meaning.

The *discount rate* is the rate at which the U.S. Federal Reserve lends to banks.

The *federal funds rate* is the interest rate banks charge each other for loans.

The *London Interbank Offered Rate (LIBOR)* is a daily reference rate based on the interest rates at which banks borrow unsecured funds from banks in the London wholesale money market (or interbank market). The *risk premium* is the return in excess of the LIBOR rate that a loan extension is expected to yield.

Mortgage value may be characterized in several different ways. The *face* or *nominal* or *par value* of a mortgage is its stated fixed value as given on the contract. By contrast, the *market value* of a mortgage is its value in the housing market and may fluctuate quite considerably. *Outstanding value* refers to the outstanding payments on mortgages. Mortgages current selling price or current worth is called its *present value* (PV). The *nett present value* (NPV) is the difference between the present value of cash inflows and the present value of cash outflows associated with a mortgage. NPV is used in capital budgeting to analyze the profitability of originating mortgages. *Fair value* is a method of determining what a troubled mortgage would be worth (its present value) if its present owner sold it in the current market. Fair value assumes a reasonable marketing period, a willing buyer and a willing seller. It assumes that the current selling price (its present value) would rise or fall in relation to the asset's future earnings potential.

An *adjustable-rate mortgage* (ARM) is a mortgage loan whose interest rate is adjustable during its term. On the other hand, a *fixed-rate mortgage* (FRM) is a loan whose interest is fixed for the duration of its term.

Mortgage default is a term used to describe mortgages that are not being repaid at all.

The *delinquency rate* includes mortgages that are at least one payment past due but does not include mortgages somewhere in the process of foreclosure. In turn, *foreclosure* is the legal proceeding in which a mortgagee, or other loanholder[1], usually a lender, obtains a court ordered termination of a mortgagor's equitable right of redemption. Usually a lender obtains a security interest from a borrower who mortgages or pledges an asset like a house to secure the loan. If the borrower defaults and the lender tries to repossess the property, courts of equity can grant the owner the right of redemption if the borrower repays the debt. When this equitable right exists, the mortgagor cannot be sure that it can successfully repossess the property, thus the lender seeks to foreclose the equitable right of redemption. Other mortgagors can and do use foreclosure, such as for overdue taxes, unpaid contractors' bills or overdue house appraiser dues or assessments. The foreclosure process as applied to mortgages involves a bank or other secured creditor selling or repossessing a parcel of real property (immovable property) after the owner has failed to comply with an agreement between SOR and MR called a *deed of trust*. Commonly, the violation of the mortgage is a default

[1] In law, a lien is a form of security interest granted over an item of property to secure the payment of a debt or performance of some other obligation. The owner of the property, who grants the lien, is referred to as the loanor and the person who has the benefit of the lien is referred to as the loanee.

in payment of a promissory note, secured by a lien on the property. When the process is complete, SOR can sell the property and keep the proceeds to pay off its mortgage and any legal costs, and it is typically said that "the lender has foreclosed its mortgage or lien." If the promissory note was made with a recourse clause then if the sale does not bring enough to pay the existing balance of principal and fees, the mortgagee can file a claim for a deficiency judgement.

Prepayment is the act of paying a mortgage in full before it is due to be paid. *Voluntary prepayment* takes place when this act is voluntary, while *involuntary prepayment* results when this act is involuntary as in default. *Curtailment* involves the cutting short or reduction of the contracted mortgage term.

Cost of mortgages is the interest cost that a bank must pay for the use of funds to originate mortgages.

Credit crunch is a term used to describe a sudden reduction in the general availability of loans (or credit) or sudden increase in the cost of obtaining loans from banks (usually via raising interest rates).

Subprime residential mortgage origination is the practice of originating mortgages to mortgagors who do not qualify for market interest rates owing to various risk factors, such as income level, size of the down payment made, credit history and employment status. In this regard, a *subprime mortgage* is a loan that meets some of the following criteria. It is extended to a MR with a poor credit history (for instance, with a FICO score below 620), it is originated by a SOR who specializes in high-cost mortgages, became part of a so-called subprime reference mortgage portfolio or is traded on a secondary market. Alternatively, the subprime mortgage is characterized by its origination to mortgagors with *prime* credit characteristics (e.g., a high FICO score) but is a subprime-only contract type, such as a 2/28 hybrid[2] – a product not generally available in the prime mortgage market. Mortgagors may find subprime mortgages to be worse than their prime counterparts because of high interest rates or fees that originators charge. They also may charge larger penalties for late payments or prepayments. Subprime mortgages are worse from originators' perspective because they may be considered to be riskier compared to prime mortgages – there may be a higher probability of default - so originators require those higher rates and fees to compensate for additional risk. These mortgages can also be worse for all role players in the economy if this risk does materialize.

Deadweight loss, also referred as *excess burden* or *allocative inefficiency*, is the cost created by economy inefficiency. Causes of the deadweight loss can include taxes or subsidies. The deadweight cost is dependent on the elasticity of supply and demand for a loan.

A *banking agent* is a person or firm that impacts the operation of the banking sector. A *risk-averse banking agent* is one who avoids risky investments. A *regret-averse agent*[3] reflects an aversion to ex-post comparisons of its realized outcome with outcomes that could have been achieved had it chosen differently.

In structured finance, a *tranche* is one of a number of related securities offered as part of the same transaction. All the tranches together make up what is referred to as the deal's capital structure or

[2]A 2/28 hybrid mortgage carries a fixed rate for the first two years; after that, the rate resets into an index rate [usually a six-month LIBOR] plus a margin.

[3]Alternatively, regret aversion reflects a disproportionate distaste for large regrets and, for a given menu of acts. Such regret aversion distorts the agent's choice behavior relative to the behavior of an expected utility maximizer.

liability structure. They are generally paid sequentially from the most senior to most subordinate (and generally unsecured), although certain tranches with the same security may be paid pari passu. The more senior rated tranches generally have higher bond credit ratings (ratings) than the lower rated tranches. For example, senior tranches may be rated AAA, AA or A, while a junior, unsecured tranche may be rated BB. However, ratings can fluctuate after the debt is issued and even senior tranches could be rated below investment grade (less than BBB). The deal's indenture (its governing legal document) usually details the payment of the tranches in a section often referred to as the waterfall (because the moneys flow down). Tranches with a first lien on the assets of the asset pool are referred to as "senior tranches" and are generally safer investments. Typical investors of these types of securities tend to be conduits, insurance companies, pension funds and other risk averse investors. Tranches with either a second lien or no lien are often referred to as "junior notes". These are more risky investments because they are not secured by specific assets. The natural buyers of these securities tend to be hedge funds and other investors seeking higher risk/return profiles. Tranches allow for the creation of one or more classes of securities whose rating is higher than the average rating of the underlying collateral asset pool or to generate rated securities from a pool of unrated assets. This is accomplished through the use of credit support specified within the transaction structure to create securities with different risk-return profiles. The equity/first-loss tranche absorbs initial losses, followed by the mezzanine tranches which absorb some additional losses, again followed by more senior tranches. Thus, due to the credit support resulting from tranching, the most senior claims are expected to be insulated - except in particularly adverse circumstances - from default risk of the underlying asset pool through the absorption of losses by the more junior claims.

Securitization is a structured finance process, which involves pooling and repackaging of cash-flow producing financial assets into securities that are then sold to investors. In other words, securitization is a structured finance process in which assets, receivables or financial instruments are acquired, classified into pools, and offered for sale to third-party investment. The term "securitization" is derived from the fact that the form of financial instruments used to obtain funds from subprime investing banks (SIBs) are securities.

Asset-backed securities are structured products whose cash flow depends on that of an underlying asset. A special case is the *residential mortgage-backed securities* whose cash flows depend on underlying mortgage repayments.

Structured mortgage product default refers to the situation where reference mortgage portfolio returns do not attain the sum of sen and mezz claims.

Residential mortgage products include RMLs and products derived from them such as RMBSs, CDOs, asset-backed commercial paper (ABCP) etc.

Credit enhancement is the loss on underlying reference mortgage portfolios (collateral) that can be absorbed before the tranche itself absorbs any loss.

Equity is a term used to describe investment in the bank. Two types of equity are described below. *Common equity* is a form of corporation equity ownership represented in the securities. It is a stock whose dividends are based on market fluctuations. It is risky in comparison to preferred shares and some other investment options, in that in the event of bankruptcy, common stock investors receive their funds after preferred stockholders, bondholders, creditors, etc. On the other hand, common shares on average perform better than preferred shares or bonds over time. *Preferred equity*, also called preference equity, is typically a higher ranking stock than voting shares, and its terms are negotiated between the bank and the regulator.

The *leverage* of a bank refers to its debt-to-capital reserve ratio. A bank is *highly leveraged* if this ratio is high.

An *economic equilibrium* is a condition in which all acting economic influences are canceled by others, resulting in a stable, balanced, or unchanging economic system.

Welfare programs are government initiatives that provide financial aid to troubled SORs and are funded by taxpayers. Since the debt market is competitive in period 0, by assumption, SIB receives the entire expected surplus, thus their expected payoff is a measure of social welfare[4].

[4]Social welfare is about how SORs take action to provide certain minimum standards and opportunities.

Index of Abbreviations

ABCP - Asset-Backed Commercial Paper
ABS - Asset-Backed Security
ABX - Asset Backed Securities Index
AFC - Available Funds Cap
AHMIC - American Home Mortgage Investment Corporation
AIG - American International Group
AMLF - Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility
ARM - Adjustable Rate Mortgage
BCBS - Basel Committee for Banking Supervision
BIS - Bank for International Settlements
BOE - Bank of England
bps - basis points
CAP - Capital Assistance Program
CAR - Capital Adequacy Ratio
CE - Credit Enhancement
CEA - Commodity Exchange Act
CDI - Credit Default Insurance
CDS - Credit Default Swap
CDO - Collateralized Debt Obligation
CFC - Countrywide Financial Corporation
CLTVR - Cumulative Loan-to-Value Ratio
COP - Congressional Oversight Panel
CP - Commercial Paper
CPFF - Commercial Paper Funding Facility
CFTC - Commodity Futures Trading Commission
CFPA - Consumer Financial Protection Agency
CPP - Capital Purchase Program
CPR - Constant Prepayment Rate
CRA - Credit Rating Agency
CWN - Credit Watch Negative
DGP - Debt Guarantee Program
DJIA - Dow Jones Industrial Average
EDF - Expected Default Frequency
EESA - Emergency Economic Stabilization Act
ECB - European Central Bank
EL - Expected Loss
ELC - Efficient Lending Constraint
EOD - Event of Default
ESF - Exchange Stabilization Fund
ESP - Economic Stimulus Package
FASB - Financial Accounting Standards Board
Fed - U.S. Federal Reserve

Fannie Mae - Federal National Mortgage Association
FDIC - Federal Deposit Insurance Corporation
FFR - Federal Funds Rate
FHFA - Federal Housing Finance Agency
FICO - Fair Isaac Corporation
FOMC - Federal Open Market Committee
FRB - Federal Reserve Board
FRBNY - Federal Reserve Bank of New York
FRM - Fixed-Rate Mortgage
Freddie Mac - Federal Home Loan Mortgage Corporation
FSC - Financial Stability Council
FSOC - Financial Services Oversight Council
G - Government
GAO - General Accounting Office
GDP - Gross Domestic Product
GFC - Global Financial Crisis
Ginnie Mae - Government National Mortgage Association
GIR - Government and Industry Responses
GSE - Government-Sponsored Enterprises
HASP - Homeowner Affordability and Stability Plan
HFSTHA - Helping Families Save Their Homes Act
HPA - Home Price Appreciation
HSBC - Hongkong and Shanghai Banking Corporation
HSI - Homeowner Stability Initiative
HUD - U.S. Department of Housing and Urban Development
IDS - Insured Depository Institution
IMF - International Monetary Fund
IO - Interest-Only
IOR - Investing Originator
IRB - Internal Ratings Based
LCR - Loss Coverage Ratio
LGD - Loss Given Default
LIBOR - London InterBank Offered Rate
LLP - Loan Loss Provision
LPS - Lender Processing Servicer
LTVR - Loan-to-Value Ratio
MLEC - Master Liquidity Enhancement Conduit
MMFGP - Money Market Funds Guarantee Program
MPR - Monetary Policy Report
MR - Mortgagor
NBER - National Bureau of Economic Research
NIMS - Nett Interest Margin Security
NPR - Notice of Proposed Rulemaking
NPV - Nett Present Value

NR - No Rating
NYSE - New York Stock Exchange
OC - Over-collateralization
OECD - Organization for Economic Co-operation and Development
OMI - Originator Mortgage Insurance
OPB - Outstanding Principal Balance
OTC - Over-the-Counter
OTD - Originate-to-Distribute
OTH - Originate-to-Hold
PD - Probability of Default
PDCF - Primary Dealer Credit Facility
PIF - Paid In Full
PPIP - Legacy Securities Public-Private Investment Program
PV - Present Value
QIS - Quantitative Impact Studies
RBS - Royal Bank of Scotland
RMBS - Residential Mortgage-Backed Security
RML - Residential Mortgage Loan
ROA - Return-on-Assets
ROE - Return-on-Equity
RPMF - U.S. Federal Reserve Primary Money Fund
RWA - Risk-Weighted Asset
SBA - Small Business Administration
SCAP - Supervisory Capital Assessment Program
SDB - Subprime Dealer Bank
SEC - U.S. Securities and Exchange Commission
SIB - Subprime Investing Bank
SIL - Subprime Interbank Lender
SIV - Structured Investment Vehicle
S&L - Savings and Loans
SMC - Subprime Mortgage Crisis
SMP - Structured Mortgage Product
SNB - Swiss National Bank
SOR - Subprime Originator
SPV - Special Purpose Vehicle
S&P - Standard and Poors
SPSPA - Senior Preferred Stock Purchase Agreement
TAF - Term Auction Facility
TALF - Term Asset-Backed Securities Loan Facility
TARP - Troubled Assets Relief Program
TLGP - Temporary Liquidity Guarantee Program
TMMFGP - Temporary Money Market Funds Guarantee Program
TSLF - Term Securities Lending Facility
Treasury - U.S. Treasuries Department

UBS - United Bank of Scotland
VaR - Value-at-Risk
VAR - Vector Autoregressive
VPC - Voluntary Participation Constraint
WAC - Weighted Average Coupon
WAWF - Weighted Average Weighting Factor
WR - Withdrawn Rating
WTIC - Willingness-to-Incur-Costs
XS - Excess Spread

Index of Symbols

M - Face Value of Mortgages
$\mathbf{C}^s$ - Claims by the Sen Tranche
$\mathbf{C}^m$ - Claims by the Mezz Tranche
$\mathbf{C}^e$ - Claims by the Jun Tranche
N - Value at which RMBS Tranches Detach
B - Face Value of RMBSs
$\mathtt{T}$ - Treasuries
$r^{\mathtt{T}}$ - Rates of Return on Treasuries
R - Recovery Amount
r^R - Recovery Rate
D - Deposits
E - Total Equity Capital
K - Total Bank Capital
n - Number of Shares
Π - Profit
r^M - Rates of Return on Subprime Mortgages
c^M - Cost of Monitoring and Screening loans
$r^D D_t$ - Interest Paid to Depositors
$c^D D_t$ - Cost of Taking Deposits
S - Value of Subprime Mortgage Losses
$\mathcal{C}$ - Credit Rating
C - Credit Default Swaps
O^{ci} - Initial Over-collateralization
$\widetilde{O}^c$ - Over-collateralization Target
r^c - CDS Rate
$\mathtt{O}$ - Value of Operational Risk
f^s - Servicing Fee
r^s - Spread/Profit Margin
f_0 - SOR's Initial Funds Available
r^{Ms} - Payments made by Swap Protection Seller Subsequent to a Credit Event
π^*_ρ - Optimal Fraction of SOR's Available Funds Invested in Subprime RMBSs
ϱ - Margin or Risk Premium

r^{ε} - Teaser Interest Rate
r^{i} - Index Rate (6-months LIBOR)
r^{L} - LIBOR
ϱ - Margin or Risk Premium
r^{ψ} - Step-Up Rate
E^{c} - Common Equity
E^{p} - Preferred Equity
H - House Value
r - Market or Economic Rate
$\mathtt{L}$ - Loan-to-Value Ratio
$\mathtt{h}$ - Probability that SOR Hides Mortgage Losses
π - Probability of high LTVR
Φ - Probability of Increasing House Prices
r^{nm} - Fixed Mortgage Rate or Mortgage Rate Without Monitoring
$\mathtt{E}$ - Expected Value
δ - Discount Rate
l - Low Mortgage Demand
h - High Mortgage Demand
$\mathtt{S}$ - Subsidies
β - Deadweight Loss to Society
r^{S} - Default Rate
x_t - Exogenous Stochastic Variable
σ - Zero-mean Stochastic Shock
$\mathtt{N}$ - Cash Reserves
τ - Tax
$\mathbf{N}$ - Nett Cash Flow
c_t^{dw} - Deadweight Cost
$\widetilde{B}$ - Social Benefits
$\widetilde{S}$ - Social Costs
r_t^{p} - Penalty Rate
$\mathbf{O}$ - Subordinated Debt.

Index of Figures

Index of Tables

Contents

Chapter 1

Introduction

”US sub-prime is just the leading edge of a financial hurricane.”

– Bernard Connolly (AIG), 2007.

”As calamitous as the sub-prime blowup seems, it is only the beginning. The credit bubble spawned abuses throughout the system. Sub-prime lending just happened to be the most egregious of the lot, and thus the first to have the cockroaches scurrying out in plain view. The housing market will collapse. New-home construction will collapse. Consumer pocketbooks will be pinched. The consumer spending binge will be over. The U.S. economy will enter a recession.”

– Eric Sprott (Sprott Asset Management), 2007.

”On the face of it, the recent economic turmoil had something to do with foolish borrowers and foolish investors who were persuaded by clever intermediaries to borrow what they could not afford and invest in what they did not understand. Without the benefit of oversight bodies with the necessary sophistication, a significant disruption hit the nerve centre of the financial system in mid-2007 which triggered the problems.”

– Ian Mann (Sunday Times), 2009.

”The ongoing crisis in the global financial markets, which originated in the US subprime mortgage segment and quickly spread into other market segments and countries, is already seen today as one of the biggest financial crises in history. Although the impact of the crisis on the real economy is as yet unclear it has brought some major financial institutions to the brink of collapse, which meant they had to be rescued, while others have been forced to raise fresh capital from existing and new shareholders, including capital injections by governments.”

– Prof. Josef Ackermann (Deutsche Bank, Frankfurt, Germany), 2009.

”These days America is looking like the Bernie Madoff of economies: For many years it was held in respect, even awe, but it turns out to have been a fraud all along.”

– Prof. Paul Krugman (2008 Nobel Memorial Prize Laureate in Economic Sciences, Princeton University, U.S.), 2009.

When U.S. house prices declined in 2006 and 2007, refinancing became more difficult and adjustable-rate mortgages (ARMs)[1] began to reset at higher rates. This resulted in a dramatic increase in residential mortgage loan (RML) delinquencies and subprime mortgage-backed securities losing value. As a consequence, the subprime mortgage crisis (SMC), which has its roots in the last few years of 1990's, became firmly entrenched. The crisis became apparent in 2007 and has exposed gaping deficiencies in financial regulation and the global financial system (see, for instance, [18]). The result has been a large decline in the capital of many banks and U.S. government sponsored enterprises (GSEs) with major consequences for credit and financial markets around the globe.

Subprime mortgages is discussed in Chapter 2 and involves the origination of subprime residential mortgage loans (RMLs) to mortgagors (MRs) who do not qualify for market interest rates due to factors such as income level, size of the down payment made, credit history and employment status. One of the most important aspects of subprime mortgages is the impact of payment reset on the ability of MRs to make monthly repayments on schedule. The term *subprime* describes a mortgage that in some respects may be more exacting than a prime[2] mortgage. In this regard, subprime MRs may find that subprime originators (SORs) may charge higher interest rates, fees or penalties for late payments or prepayments.

The SMC was preceded by a period of favorable macroeconomic conditions with strong growth and low inflation combining with low default rates, high profitability as well as strong capital ratios and innovation involving structured finance[3]. These conditions contributed to the SMC in that they led to overconfidence and increased *regret aversion* among investors. In the search for yield, the growth in structured notes would have been nigh impossible without investors' strong demand for high-margin, high-risk assets such as securities backed by subprime mortgages. This process known as *securitization* was at the heart of the search for yield with Wall Street purchasing subprime mortgages and packaging them as residential mortgage-backed securities (RMBSs) to sell to investors. This process may be separated out into six steps. The first step is where MRs – many first-time buyers – or individuals wanting to refinance seeked to exploit the seeming advantages offered by subprime mortgages. Next, mortgage brokers entered the lucrative subprime market with MRs being charged high fees. Thirdly, SORs offering subprime RMLs solicited mortgages financed by Wall Street money. After extending mortgages, these SORs quickly sold them to

[1]Approximately 80 % of U.S. mortgages issued in recent years to subprime mortgagors (MRs) were ARMs (see, for instance, [38]).

[2]From MR's perspective, the main difference between prime and subprime mortgages is that both the initial and subsequent costs are higher for subprime mortgages. Initial costs include application fees, appraisal fees and other fees associated with originating a mortgage. The continuing costs include mortgage insurance payments, principal and interest payments, late fees for delinquent mortgage payments and fees levied by a locality such as property taxes or special assessments. The price of subprime mortgages, most importantly the interest rate, r^M, is actively based on the risk associated with MR, as measured by MR's credit score, debt-to-income ratio and the documentation of income and assets provided at the time of origination $t = 0$. In addition, the exact pricing may depend on the amount of house equity provided by MR – essentially the LTVR, duration and magnitude of the mortgage, flexibility of r^M (adjustable, fixed or hybrid), the lien position, the property type and whether stipulations are made for any prepayment penalties.

[3]A financial innovation called *structured finance* provide Wall Street with a means of dividng subprime RMBSs into tranches. These tranches allowed credit risk associated with the reference mortgage portfolio to be parceled to investors. Investors who purchased RMBS bonds received a portion of the reference mortgage payments.

investment banks for more profits. The fourth step involved Wall Street investment banks pooling risky subprime mortgages that did not meet the standards of the GSEs such as Fannie Mae and Freddie Mac and sold them as "private label," non-agency securities. Fifthly, credit rating agencies (CRAs) such as Standard and Poors assisted investment banks in structuring RMBSs. In this way these banks received the best possible bond ratings, earned exorbitant fees and made RMBSs attractive to investors including mutual and pension funds. In the sixth step, the RMBSs were sold to investors worldwide thus distributing the risk. In this process, some agents assumed risks beyond their capacities and capital buffer and found themselves in an unsustainable position once SORs became *risk averse*. In this thesis, we specifically investigate the securitization of subprime mortgages as illustrated in Figure 1.1 below.

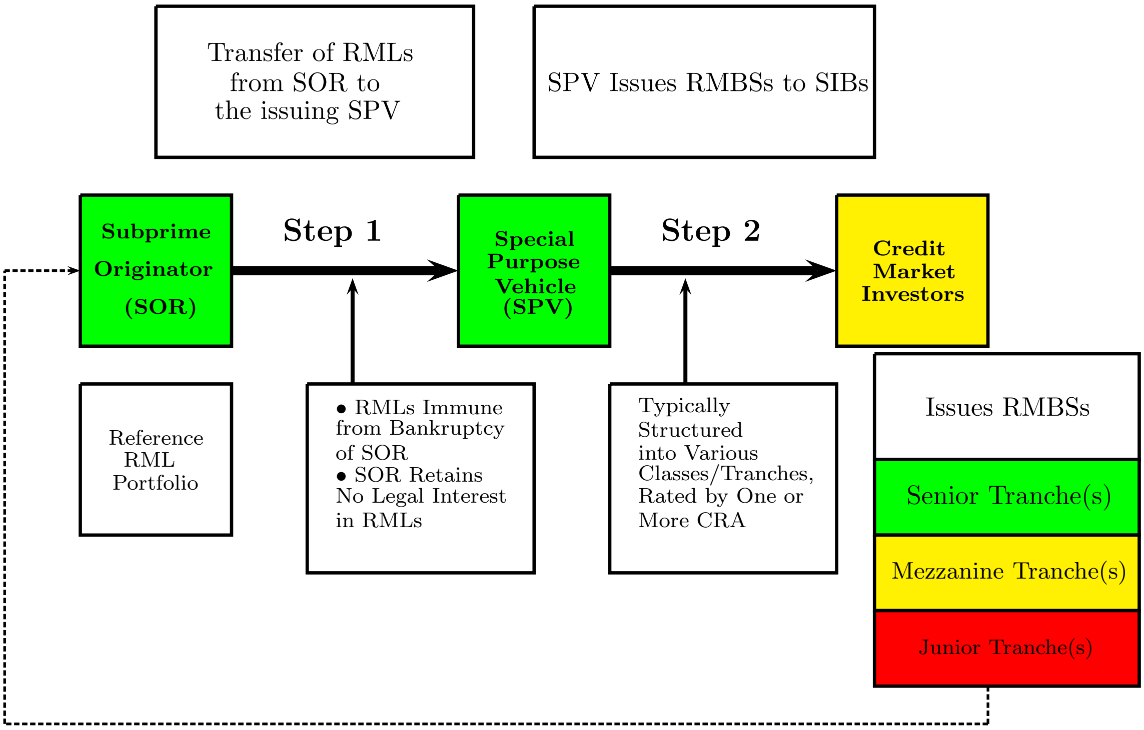


Figure 1.1: Diagrammatic Overview of Mortgage Securitization

The first step in the process involve SORs that extend mortgages that are subsequently removed from their balance sheet and pooled into reference mortgage portfolios. SORs then sells these portfolios to special purpose vehicles (SPVs) – entities set up by financial institutions – specifically to purchase mortgages and realize their off-balance-sheet treatment for legal and accounting purposes. Next, the SPV finances the acquisition of subprime reference mortgage portfolios by issuing tradable, interest-bearing securities that are sold to, for instance, subprime investing banks (SIBs). They receive fixed or floating rate coupons from the SPV account funded by cash flows generated by reference mortgage portfolios. In addition, servicers (SRs) service the mortgage portfolios, collect payments from the original MRs and pass them on – less a servicing fee – directly to SPV. The interest and principal payments from the reference mortgage portfolio are passed through to credit market investors. The risks associated with mortgage securitization are transferred from SORs to

SPVs and securitized mortgage bond holders such as SIBs. Mortgage securitization thus represents an alternative and diversified source of housing finance based on the transfer of credit risk (and possibly also tranching and counterparty risk). The distribution of reference mortgage portfolio losses are structured into *tranches*. As in Figure 1.1, we consider three such tranches, viz., the *senior* (usually AAA rated; abbreviated as sen), *mezzanine* (usually AA, A, BBB rated; abbreviated as mezz) and *junior (equity)* (usually BB, B rated or unrated; abbreviated as jun) tranches in order of contractually specified claim priority. In particular, losses from this portfolio are applied first to the most junior tranches until the principal balance of that tranche is completely exhausted.

As we have mentioned before, the unique securitization structure that contributed to the SMC emanated from subrime mortgages with special features (see Chapter 2 for more information). Most importantly, a design feature of such a mortgage is MRs' ability to reset the payment schedule of their mortgages via financing and refinancing based on house price appreciation over short horizons. These increases in house prices enabled their conversion into collateral for new mortgages or extracting equity for consumption. In turn, the subprime residential mortgage-backed securities (RMBSs) resulting from the securitization of subprime mortgages often ended up in the portfolios of collateralized debt obligations (CDOs). These obligations were usually designed for managing, fully amortizing portfolios of asset-backed securities (ABSs) and RMBSs. As another link in the chain, CDOs[4] were purchased by off-balance sheet vehicles such as structured investment vehicles (SIVs). Risk from CDOs was swapped in negative basis trades or created synthetically via inputted credit default swaps (CDSs) into hybrid and synthetic CDOs (see Chapter 3 for further discussions). Our next area of interest is subprime data (see Chapter 4 for more information).

In short, this thesis will demonstrate that the SMC was caused by procyclicality in the housing market, MR speculation, extension of high-risk mortgages and lending/borrowing practices, securitization practices, inaccurate credit ratings, government policies, policies of central banks, financial institution debt levels and incentives, CDSs, balance of payments as well as procyclicality in the shadow banking system. We identify that the consequences of the SMC include that SORs either shut down, suspended operations or were sold and that panic spread in financial markets thus encouraging investors to withdraw money from risky mortgages and equities and re-invest in commodities. As far as the cures for the SMC are concerned, we will briefly consider the role of central banks, economic stimulus, bank solvency and capital replenishment and failures of financial firms as well as MR assistance.

[4]ABS CDOs can be classified according to their collateral, structure and motivation for the transaction. In this regard, subordination and excess spread as well as other forms of credit enhancement (CE) such as shifting interest, performance triggers and interest rate swaps are important. Such CDOs have the feature that they have mortgages, RMBSs, CMBSs, ABSs, CDOs, CDSs and other structured products as collateral. Another way to distinguish ABS CDOs is by their structure. *Cash flow CDOs* have assets and liabilities that are entirely cash instruments, i.e., physical bonds. Liabilities are paid with the interest and principal payments (cash flows) of the underlying cash collateral. *Hybrid CDOs* combine the funding structures of cash and synthetic CDOs. *Synthetic CDOs* sell credit protection via CDSs rather than purchase cash assets. In this case, liabilities are partially synthetic, in which case some protection is purchased on most senior tranches. Mezzanine tranches are not synthetic, but paid in cash which is deposited in a SPV and used to collateralize its CDS obligations – viz., potential losses resulting in write downs of the issued notes. Note that synthetic funded CDOs are indicative of synthetic subprime risk in the form of credit protection written on a subprime index (ABX index). Finally, we can characterize CDOs based on the motivation for the transaction. Arbitrage CDOs are motivated by the spread difference between higher yielding assets and lower yields paid as financing costs. This is often viewed as a CRA created arbitrage. Another motivation is regulatory bank capital relief or risk management. Balance sheet CDOs remove the risk of assets off ORs' balance sheets, typically synthetically.

1.1 Literature Review

In this section, we consider the association between our contribution and previous literature. The issues that we highlight include subprime mortgages and securitization, connection between Basel capital regulation and the SMC as well as subprime data.

1.1.1 Literature Review of the Subprime Mortgage Crisis

There has been an explosion in the volume of literature on the SMC published subsequent from 2008 onwards. Below we only mention a few contributions that have a direct connection with the contents of this thesis. Some other relevant literature are mentioned in subsequent subsections.

The paper [32] examines the different factors that have contributed to the SMC (see, also, [7], [53] and Sections 2.2 and 2.3 of Chapter 2). These papers have discussions about yield enhancement, investment management, agency problems, lax underwriting standards, credit rating agency (CRA) incentive problems, ineffective risk mitigation, market opaqueness, extant valuation model limitations and structured product intricacy (see Sections 3.2 and 3.3 of Chapter 3 for more details) in common with our contribution. Furthermore, this article discusses the aforementioned issues and offers recommendations to help avoid future crises (compare with [44] and [112]).

1.1.2 Literature Review of Subprime Mortgages

The research conducted on subprime mortgages in this thesis has connections with several strands of existing literature. In [8], light is shed on subprime MRs, mortgage design and their historical performance. Their discussions involve predatory borrowing and lending and are cast within the context of real-life examples. The working paper [37] firstly quantifies how different determinants contributed to high delinquency and foreclosure rates for vintage 2006 mortgages (see, also, [21]. More specifically, they analyze mortgage quality as the performance of mortgages adjusted for differences in MR characteristics (such as credit score, level of indebtedness, ability to provide documentation), mortgage characteristics (such as product type, amortization term, mortgage amount, interest rate) and subsequent house appreciation (see, also, [53]). Their analysis suggests that different mortgage-level characteristics as well as low house price appreciation was quantitatively too small to explain the bad performance of 2006 mortgages. Secondly, they observed a deterioration in lending standards with a commensurate downward trend in mortgage quality and a decrease in the subprime-prime mortgage rate spread during the 2001–2006 period. Thirdly, it is shown in [37] that mortgage quality deterioration could have been detected before the SMC[5] (see, also, [44] and [112]). The recent paper [24] on interest rate reset (from teaser to step-up) attempts to estimate what fraction of resetting mortgages will end up in foreclosure. Cagan presents evidence suggesting that in the case of zero house price appreciation and full employment, 12 % of subprime mortgages will default due to reset. We discuss the issue of teaser to step-up rates in Subsection 2.2.1, Furthermore, [27] shows that the mortgage structure has important implications for tenure decisions, house prices and mortgage pricing.

[5]We consider "before the SMC" to be the period prior to July-August 2007 and "during the SMC" to be the period thereafter.

The article [34] suggests that the reason for mortgage delinquency involves mortgages of short duration extended to low credit score MRs with low or no documentation. This takes place in housing markets with moderately volatile and flat or declining nominal house prices. These mortgages are typically more risky than prime mortgages and are characterized by higher rates of prepayment, delinquency and default (see Subsections 2.2.1, and 2.2.2 for our take on this issue).

The paper [29] examines the choice of subprime MRs to extract equity while refinancing and assesses the prepayment and default performance of these cash-out refinancing mortgages relative to rate refinancing mortgages (see, also, [88] and [89]). In our research, we investigate of whether mortgage amount or cash extracted is a determinant of the incentive to refinance. Also, we investigate the relationship between the recovery amount the SOR receive in the case of default to house prices and the MR mortgage collateral. Consistent with survey evidence, the propensity to extract equity while refinancing is sensitive to interest rates on other forms of consumer debt. After the mortgage is originated, [29] indicates that cash-out refinances perform differently from non-cash-out refinances. For example, cash-outs are less likely to default or prepay, and the termination of cash-outs is more sensitive to changing interest rates and house prices. In this regard, we investigate the LTVR as a measure of the incentive to extract house equity as well as its relationship with delinquencies (see Subsection 2.2.3).

In several respects, the subprime market followed classic lending boom-bust behavior. In particular, this market experienced unsustainable growth prior to its collapse. Evidence of this is provided by the fact that lending was procyclical with new subprime mortgages in 2008 being significantly below new extensions in 2007 (see, for instance, [63]). Also, this period was typified by accelerated market expansion, deteriorating underwriting standards, declining loan performance and decreasing risk premiums. As far as the latter is concerned, in Subsections 2.2.1, we find that the risk premium is a key to mortgage pricing and had an important role to play in the SMC. In this regard, the risk premium acts as an indicator of perceived credit risk and the likeliness to engage in mortgage securitization. Before the SMC, the average difference between prime and subprime mortgage interest rates (the *subprime markup*) declined quite dramatically. The paper [42] claims that, compared with other countries, during the boom, the U.S. built up a larger overhang of excess housing supply, experienced a greater easing in mortgage lending standards and ended up with a household sector more vulnerable to falling housing prices. Some of these outcomes seem to have been driven by regulatory systems that encouraged households to increase their leverage and permitted lenders to enable that development. Given the institutional background, it may have been that the U.S. housing boom was always more likely to end badly than the booms elsewhere. The credit ratings that accompanied booms and busts are discussed in [115] (see, also, [20]). In this regard, in Subsection 2.3.2, we discuss the relationship between credit ratings that are procyclical as well as mortgage losses and SOR mortgage insurance (SOMI) premium rates. Furthermore, SOMI and SOR's valuation are touched on in [43], [59] and [90]. In our thesis, we find a time-independent solution for a SOR's optimal valuation problem (compare with our discussion in Subsection 2.3.2).

1.1.3 Literature Review of Subprime Mortgage Securitization and Bank Capital

The literature about mortgage securitization and the SMC is growing and includes the following contributions. Our contribution has close connections with [8] where the key structural features of a typical subprime mortgage securitization is presented. Also, the paper demonstrates how CRAs assign credit ratings to asset-backed securities (ABSs) and how these agencies monitor the performance of reference mortgage portfolios (see Subsections 3.2.2, 3.2.3 and 3.2.4). Furthermore, this paper discusses RMBS and CDO architecture and is related to [77] that illustrates how misapplied bond ratings caused RMBSs and ABS CDO market disruptions (see Subsections 3.3.1, 3.3.2 and 3.3.3). In [37], it is shown that the subprime (securitized) mortgage market deteriorated considerably subsequent to 2007. We believe that mortgage standards became slack because securitization gave rise to moral hazard, since each link in the securitization chain made a profit while transferring associated credit risk to the next link (see, for instance, [104]). At the same time, some financial institutions retained significant amounts of the RMBSs they originated, thereby retaining credit risk and so were less guilty of moral hazard (see, for instance, [48]). The increased distance between SORs and the ultimate bearers of risk potentially reduced SORs' incentives to screen and monitor MRs (see [97]). The increased intricacy of markets related to mortgages and their securitization also reduces SIB's ability to value them correctly where the value depends on the correlation structure of default events (see, for instance, [48] and [53]). [57] considers parameter uncertainty and the credit risk of ABS CDOs (see, also, [44] and [112]).

The literature states that the main reasons for studying the securitization of subprime residential mortgage loans (RMLs) is its significant increase since the late-1990's as well as its role in causing the SMC (see, for instance, [2]). Firstly, prior to the SMC, the emergence of subprime mortgage securitization[6] led to theories about a new banking model known as the *originate-to-distribute* (OTD) model, because banks were no longer the originators and holders of mortgages, but had become the originators and distributors to the capital markets of both credit and related risks (see Subsections 3.2.2, 3.3.1 and our discussion in Subsections 3.6.1 and 3.6.2 for more details). Selling mortgages that were once considered non-marketable assets signalled a fundamental change in banking activity. As a consequence, the typical banking functions of liquidity transformation and delegated monitoring became less important. In this context, banks are no longer the primary holders of illiquid assets and so securitizing banks have less incentive to monitor their MRs. This potentially significant change in activity raises the question as to what induces (or induced) banks to revise one of their basic business activities. Secondly, since the onset of the SMC, the link between securitization and the financial turmoil has become apparent. Indeed, many experts attribute the SMC directly to mortgage securitizations.

The reasons why SOR's securitize mortgages are related to the need for new funding sources and profit opportunities, credit risk transfer and the role of capital (see, for instance, [2] for a literature review). The first reason to securitize is linked to liquidity and funding needs. In order to fund their assets, SORs may extend mortgages without trying to attract more retail deposits owing to their shortage or cost (see, for instance, [92]). Similarly, SORs may securitize mortgages instead of raising deposits because they compete with asset backed commercial paper (ABCP) if these are preferred by investors or in order to attract long-term funds (e.g. [76]). Securitization provides a funding source that has the benefit of not being subject to deposit insurance and reserve requirements. The second determinant of securitization activity suggested by the literature relates to profit opportunities. Securitization allows banks to recognize accounting gains, when mortgage

[6]Securitization is any activity involving the pooling and repackaging of mortgages into securities, which are then sold to different kinds of investors, typically other banks, insurance companies, pension funds, and mutual funds.

market values exceed their book values and overvaluation of the retained interest that is carried at fair market value occurs (see, for instance, [88]). Moreover, banks can redeploy their sold mortgages towards more profitable business opportunities (see, for instance, [111]). In addition, SORs may securitize mortgages designed specifically for an intermediation profit rather than for long-run warehousing (see, for instance, [39]). Thirdly, as is well-known, mortgage securitization represents one of the main instruments for transferring credit risk. Hence, SORs that hold a large proportion of risky mortgages may securitize more in order to reduce the burden on their balance sheets (see, for instance, [36]) or to reduce the related expected losses[7]. Furthermore, [110] showed that capital requirements reduce risk-taking incentives if banks possess a diversified portfolio. In any case, in this debate, the basic effect on securitization would not be due to mortgage quality, but to capital requirements and to profit considerations, which represent specific further determinants of securitization (see, for instance, [39]). Finally, the fourth reason to securitize involves SOR capital. In order to meet both economic capital requirements linked to market discipline, and mandatory capital requirements associated with regulation, SORs traditionally had two choices. Either they altered the numerator, for instance by retaining earnings and issuing equity, or the denominator, by cutting back assets and reducing lending or shifting into low risk-weighted assets (see the numerical example presented in Subsection 3.5.2 and our discussion in Subsection 3.6.4.2). Securitization opens up an additional possibility in which SORs can adjust their capital ratios by engaging in securitization. Mortgage securitizations avoid the disadvantages of warehousing mortgages and automatically decrease regulatory and market capital requirements (see, for instance [5] and [45]).
A significant category of investors in CDOs are off-balance sheet vehicles, known as SIVs[8], asset-backed commercial paper (ABCP) conduits, and SIV-lites (see, Subsections 3.1.3 and 3.6.2.1 for more details). These vehicles differ from each other in several ways (see [81], [80] and [114]). As far as SIVs is concerned, [62] reports that in 2007, SIVs were exposed to RMBSs and commercial

[7]By contrast, some literature suggests that SORs could have an incentive to securitize high-quality mortgages and to retain low-quality mortgages. This happens when economic capital linked to market discipline is much less than regulatory capital and highly risk-weighted assets allow a reasonable balance between return and safety. For example, banks could sell mortgages of high quality and use the proceeds to lend to riskier MRs increasing the expected returns with no change in capital requirements, thus aligning economic and regulated capital. This idea is corroborated by [19], who argued that improperly chosen risk weights increase the riskiness of banks. Nevertheless, their analysis has been roundly criticized.

[8]A SIV is a limited-purpose operating company that undertakes arbitrage activities by purchasing mostly highly rated medium-and long-term fixed income assets and funding itself with cheaper, mostly short-term, highly rated ABCP and medium-term notes (MTNs). An SIV is a leveraged investment company that raises capital by issuing capital market securities (capital notes and medium-term notes) as well as ABCP. ABCP typically comprises around 20 % of the total liabilities for the biggest SIVs. A variant of a SIV is a so-called SIV-lite. SIV-lites share some similarities with CDOs in that they are closed-end investments. SIV-lites issue a greater proportion of their liabilities following the recent turmoil in US mortgage markets. Unlike conduits that issue only ABCP, SIVs and SIV-lites tend not to have committed liquidity lines from banks that cover 100 % of their ABCP. Rather, they use capital and liquidity models approved by ratings agencies to manage liquidity risk. The lack of a full commercial bank guarantee has reportedly led to discrimination against SIV paper by ABCP investors. SIVs are very different from SPVs used in securitization. Standard securitization SPVs are not managed; they are robot companies that are not mark-to-market; they simply follow a set of pre-specified rules (see [54]). Unlike securitization vehicles, these are managed and they are market value vehicles. They raise funds by issuing commercial paper and medium term notes, and they use the proceeds to buy high-grade assets to form diversified portfolios. They borrow short and purchase long assets. They are required by CRAs to mark portfolios to market on a frequent basis (daily or weekly), and based on the marks they are allowed to lever more or required to deliver (for SIVs and ABCPs, see [114]). Money market mutual funds apparently not only purchased various structured assets via liquidity puts (as discussed above), but also sometime invested in SIVs. Later, these money market mutual funds had to be bailed out by their sponsors to prevent them from *breaking the buck*.

mortgage-backed securities (CMBSs), including an 8.3 % exposure to subprime mortgages. Further papers dealing with the securitization of subprime mortgages are [43], [59] and [90] for RMBS CDSs and its valuation, [17] for a broad overview of CDOs as regards the market, their structure and the rating process, [37] for subprime RMBS and CDO design, [53] for subprime securitization architecture and [68] for financial regulation and securitization. These contributions have commonality with some of the issues discussed in Chapter 3.

The working paper [32] asserts that since the end of 2007 monolines have been struggling to keep their triple-A rating. Only the two major ones, MBIA and Ambac, and a few others less exposed to subprime mortgages such as Financial Security Assurance (FSA) and Assured Guaranty, have been able to inject enough new capital to keep their AAA credit rating. In [108] it is claimed that ABS CDOs opened up a whole new category of work for MLIs who insured the senior tranches as part of the CE process. We discuss the monoline insurance model for subprime RMBSs and RMBS CDOs in Subsection 3.1.4.

The most significant innovation of Basel II is the departure from a sole reliance on capital adequacy ratios. Basel II consists of three mutually reinforcing pillars, which together should contribute to safety and soundness in the financial system (see, for instance, [11]). To ensure that risks within an entire banking group are considered, Basel II is extended on a consolidated basis to holding companies of banking groups. The main objective of the Basel II Capital Accord is to promote standards for measurement and management of financial and operational risk in banking. Its approach to such risk issues has been severely criticized in the literature, inevitably leading to doubts about its practical implementation. In particular, many investigations have warned against the procyclicality induced by the Internal Ratings Based (IRB) capital formula (see, for instance, [11] and Section 3.4 together with our discussion on Subsection 3.6.3). Since the release of the Second Consultative Paper [12], many studies have assessed empirically the magnitude of procyclicality in the IRB capital formula (see, for instance, [66]). Also, there is overwhelming evidence to suggest that the movements of subprime mortgage, mortgage loss provisioning, capital and profitability are strongly correlated with the business cycle (compare with Section 3.2 and our discussion in Subsection 3.6.1). While not providing an in-depth discussion of the first of the aforementioned problems (see, for instance, [12] and [11]). Since mid-2007, role players in the banking industry have blamed the Basel II Capital Accord for certain aspects of the SMC. In this regard, the adequacy of capital levels in the banking industry, the role of CRAs in financial regulation, the procyclicality of minimum capital requirements and the fair-value assessment of banking assets have become the most studied topics. The paper [25] poses the following related questions. Is Basel II guilty of causing the SMC ? Is it appropriate to judge Basel II on the basis of features that are unlikely to have caused the SMC ? Should Basel II be completely abandoned or should an attempt rather be made to overcome its shortcomings ? The paper [25] attempts to provide some answers to the questions raised above. After a short review of the main features of the financial crisis as well as of the rationale behind the Basel II rules, the authors try to describe the actual role played by the new prudential regulation in the crisis and discuss the main argument raised in the current debate. They conclude that, while aspects of Basel II need strengthening, there are not good enough reasons for abandoning the accord in its entirety (compare with Subsection 3.6.3).

1.1.4 Literature Review of Subprime Risks

Our discussions in Chapters 2 and 3 are related to several strands of literature on subprime risk such as credit, maturity mismatch, basis, counterparty, liquidity, synthetic, prepayment, interest rate, price, tranching and systemic risks.

The editorial [30] mentions a number of papers on topics related to the contents of this thesis. These include financial regulation and risk management, contagion, securitization and risk management, liquidity risk and housing finance, bank risk management and stability as well as capital flows. The contribution [31] is concerned with the risk management of subprime mortgage portfolios and their relation with default correlation[9] in measuring that risk. Using a large portfolio of subprime mortgages from an anonymous subprime SOR, they show that default correlation can be substantial. In particular, the significance of this correlation increases as the internal credit rating declines. [31] suggests that SORs and regulators should enhance their understanding of default correlation in subprime mortgage portfolios.

The paper [58] analyzes the systemic elements that transformed the SMC into a global crisis. The author explains the role of mortgage securitization in the U.S. as a mechanism for allocating risks from real estate investments and discusses what has gone wrong and why. Also, [58] discusses the incidence of credit, maturity mismatch, interest rate and systemic risk in this crisis (see, the discussion in Subsections 2.3.1.2, 3.2.2.1 and 3.3.1.1). In particular, Hellwig identifies two aspects of systemic risk. Firstly, there was excessive maturity transformation through conduits and SIVs. When this became dysfunctional in August 2007, the overhang of ABSs that had been held by these vehicles put significant additional downward pressure on securities prices. Secondly, as the financial system adjusted to the recognition of delinquencies and defaults in US mortgages and to the breakdown of maturity transformation of conduits and SIVs, the interplay of market malfunctioning or even breakdown, fair value accounting and the insufficiency of equity capital at financial institutions and, finally, systemic effects of prudential regulation created a detrimental downward spiral in the overall financial system (see, for instance, Subsection 3.6.3). The paper argues that these developments have not only been caused by identifiably faulty decisions, but also by flaws in financial system architecture. In relation to regulatory reform, [58] goes beyond considerations of individual incentives and supervision and pay attention to issues of systemic interdependence and transparency (see, also, [82]). [78] also touches on the issue of systemic risk. Mishkin argues that when financial markets experience a significant disruption, a systemic approach to risk management requires policymakers to be pre-emptive in responding to the macroeconomic implications of incoming financial market information, and decisive actions may be required to reduce the likelihood of an adverse feedback loop (see, also, [89]).

According to [52], declines in asset-backed securities exchange (ABX) prices exposed the shock to valuation from subprime risk. Although it did not reveal the location of these risks, the uncertainty caused a loss of confidence in credit. During the SMC, this was evidenced by the disruption in the arbitrage foundation of the ABX.HE indices[10]. The behavior of the basis – the difference in

[9] Default correlation is a measure of the dependence among risks. Along with default rates and recovery rates, it is a necessary input in the estimation of the value of the portfolio at risk due to credit. In general, the concept of default correlation incorporates the fact that systemic events cause the default event to cluster. Coincident movements in default among borrowers may be triggered by common underlying factors.

[10] The ABX indices played several important roles in the panic. Starting in January 2006, the indices were the only

spreads between the ABX index and the underlying cash bonds – shows that the concern about the location of the risks led to fear of counterparty default, especially in the repo markets, where defaults would lead to delivery of bonds that could not be sold. Furthermore, Gorton claims that these problems in the repo market are very significant because the repurchase agreement market in the US is estimated to be $ 12 trillion, larger than the total assets in the US banking system. This market is central to the "shadow banking system" which is the nexus of structured vehicles that issues bonds into the capital markets (see [53] for more information). This short-term financing market became very illiquid during the SMC, and an increase in repo haircuts (the initial margin) caused massive de-leveraging. If no one would accept structured products for repo, then these bonds could not be traded - and then no one would want to accept them in a repo transaction. The extreme stress in the repo market can even be seen in the repo market for US government securities, where the instances of "repo fails" where borrowed securities have not been returned on time have reached a record (see, also, [82]).

1.1.5 Literature Review of Subprime Data

In the article [7], the authors study credit ratings on subprime and Alt-A mortgage-backed-securities (MBS) deals issued between 2001 and 2007, the period leading up to the subprime crisis. They find out that fraction of highly rated securities in each deal is decreasing in mortgage credit risk (measured either ex ante or ex post), suggesting that ratings contain useful information for investors. However, they also find evidence of significant time variation in risk-adjusted credit ratings, including a progressive decline in standards around the MBS market peak between the start of 2005 and mid-2007. Conditional on initial ratings, they observe under performance (high mortgage defaults and losses and large rating downgrades) among deals with observably higher risk mortgages based on a simple ex ante model and deals with a high fraction of opaque low documentation mortgages. Their findings hold over the entire sample period, not just for deal cohorts most affected by the crisis (compare with Subsections 4.1.1 and 4.2.1).

The paper [105] examines whether securitization impacts renegotiation decisions of mortgage servicers, focusing on their decision to foreclose a delinquent mortgage. Conditional on a mortgage becoming seriously delinquent, they find a significantly lower foreclosure rate associated with bank-held mortgages when compared to similar securitized mortgages: across various specifications and origination vintages, the foreclosure rate of delinquent bank-held mortgages is 3% to 7% lower in absolute terms (13% to 32% in relative terms). Authors also discover that there is a substantial heterogeneity in these effects with large effects among borrowers with better credit quality and small effects among lower quality borrowers. The results were confirmed by a quasi-experiment that exploits a plausibly exogenous variation in securitization status of a delinquent mortgage (see Subsections 4.1.2 and 4.2.2).

place where a subprime related instrument traded in a transparent way, aggregating and revealing information about the value of subprime RMBSs. Other subprime-related instruments, RMBS bonds, CDO tranches, SIVs' liabilities, and so on, do not trade in visible markets and there are no secondary markets. Also, the ABX allowed for hedging subprime risk. These two markets are linked by an arbitrage relationship, but this breaks down during the crisis, an indication of the disappearance of the repo market for subprime-related instruments.

1.2 Preliminaries about Subprime Mortgage Models

In this subsection, we provide preliminaries about the SMC, subprime mortgages, the securitization of subprime mortgages, subprime risk, the connection between Basel capital regulation and the SMC, as well as subprime data. The main agents in our models are subprime MRs, SORs, SIBs (swap protection buyer) and SPVs with each participant being risk neutral except for SORs that may be risk-averse. Other agents that are mentioned on occasion are swap protection sellers, depositors and CRAs. All events are scheduled to take place in either of periods $t-1$, t or $t+1$. Period t begins at time instant 0 and ends at time 1, while period $t+1$ begins at time instant 1 and ends at time 2. At certain junctures in the discussion, we drop the time subscripts when the financial variable exhibits recursive behavior.

1.2.1 Preliminaries about the Subprime Mortgage Crisis

In this subsection, we provide a diagrammatic overview and description of the SMC.

1.2.1.1 Diagrammatic Overview of the Subprime Mortgage Crisis

A diagrammatic overview of the SMC may be represented as follows.

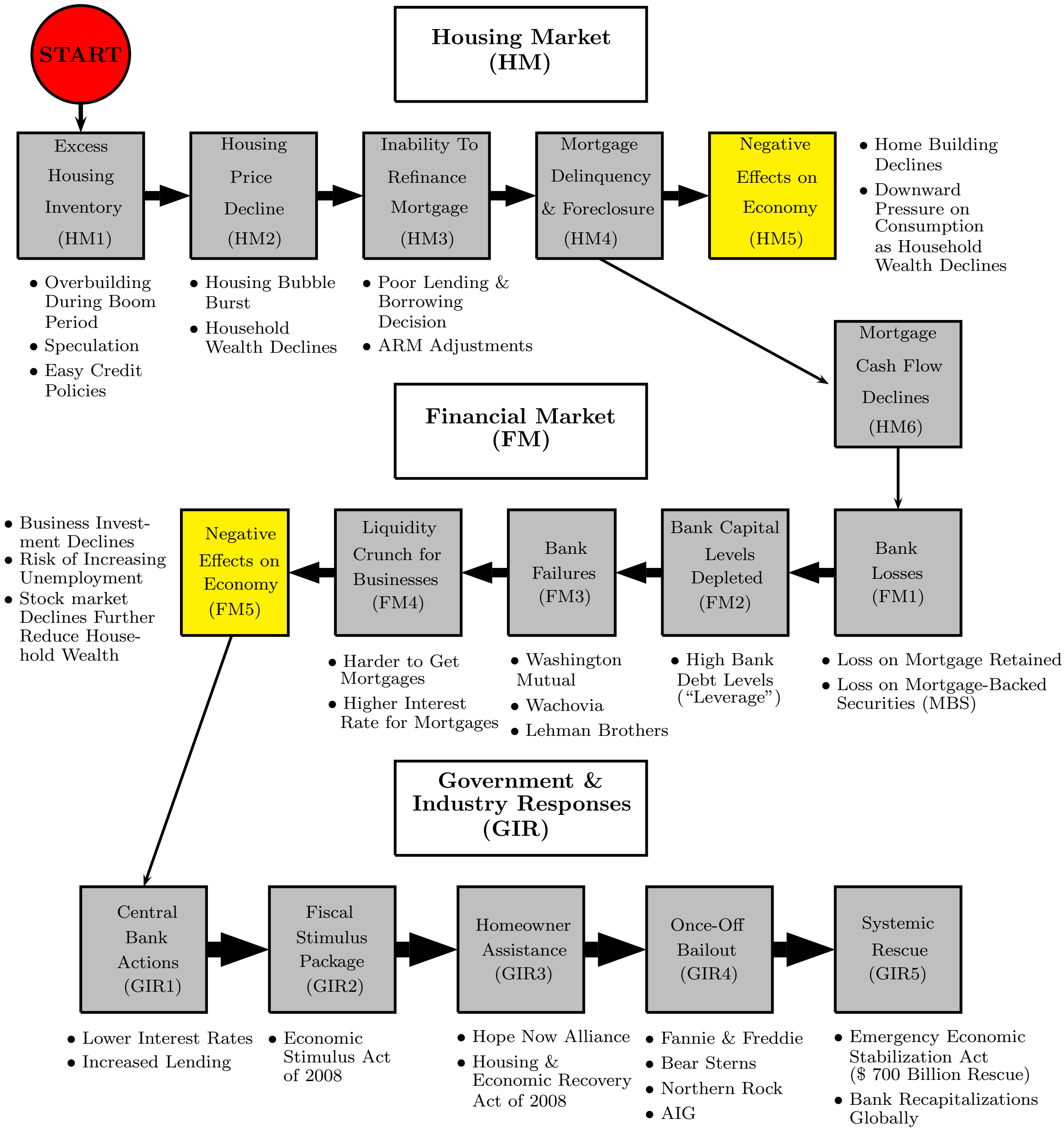


Figure 1.2: Diagrammatic Overview of the Subprime Mortgage Crisis

1.2.1.2 Description of the Subprime Mortgage Crisis

Before the SMC, mortgage incentives, such as easy initial terms and low mortgage rates, in combination with escalating housing prices encouraged MRs to assume difficult mortgages on the belief they would be able to quickly refinance at more favorable terms. Some analysts claim that competition for MRs had greatly increased, causing SORs to reduce mortgage rates and ease credit standards in order to issue new credit (see HM1 in Figure 1.2 and Chapter 2). Others are of the opinion that as the economic expansion continued and past mortgage losses were forgotten, SORs became regret averse. However, once U.S. housing prices started to fall moderately in 2006-2007, refinancing became more difficult (see HM2 and HM3 in Figure 1.2 and Chapter 2). Mortgage defaults and foreclosures increased dramatically, as easy initial terms expired, house prices failed to appreciate as anticipated, and ARM interest rates reset higher. Foreclosures accelerated in the US in late 2006 and triggered a global financial crisis (GFC) from 2007 onwards (see Chapter 3 for timeline of SMC events). During 2007, nearly 1.3 million U.S. housing properties were subject to foreclosure activity, up 79 % from 2006 (see [107] for more details; also HM4 in Figure 1.2 and Chapter 2). SORs that retained credit risk were the first to be affected, as borrowers became unable or unwilling to make payments (see HM5 and HM6 in Figure 1.2 and Chapter 2).

Major SORs around the world reported losses (see [46] and [91]; also FM1 in Figure 1.2 and Chapter 2). Owing to securitization, many SORs had passed the rights to the mortgage payments and related credit risk to third-party investors via RMBSs and CDOs. Corporate, individual and institutional investors holding RMBSs or CDOs faced significant losses, as the value of reference mortgage portfolios declined (see FM1 in Figure 1.2 and Chapter 3) while stock markets in many countries declined significantly. Also, capital adequacy ratios declined as capital levels became depleted while banks were highly leveraged (see FM2 in Figure 1.2 and Chapter 3). In mid-2007, the financial sector began to feel the consequences of this crisis with many prominent banks filing for bankruptcy as a consequence of losses stemming from the SMC (see FM3 in Figure 1.2). Subsequent to this many banks throughout the world also failed. The widespread dispersion of credit risk and the unclear effect on financial institutions caused reduced lending activity and increased spreads on higher interest rates. Similarly, the ability of corporations to obtain funds through the issuance of ABCP was affected. This aspect of the crisis is consistent with a credit crunch (see FM4 in Figure 1.2). There are a number of reasons why banks may suddenly make obtaining a mortgage more difficult or increase the costs of obtaining a mortgage. This may be due to an anticipated decline in the value of the collateral used by the banks when issuing mortgages; an increased perception of risk regarding the solvency of other banks within the banking system; a change in monetary conditions (for example, where the central bank suddenly and unexpectedly raises interest rates or capital requirements); the central government imposing direct credit controls and it instructing the banks not to engage in further lending activity. The SMC has adversely affected several inputs in the economy, resulting in downward pressure on economic growth. Fewer and more expensive mortgages tend to result in decreased business investment and consumer spending (see FM5 in Figure 1.2).

The liquidity concerns drove central banks around the world to take action to provide funds to member banks to encourage lending to worthy borrowers and to restore faith in the ABCP markets (see GIR1 in Figure 1.2). With interest rates on a large number of subprime and other ARMs due to adjust upward during the 2008 period, U.S. legislators, the U.S. Treasury Department, and financial institutions took action. A systemic program to limit or defer interest rate adjustments was implemented to reduce the effect. In addition, lenders and borrowers facing defaults have been encouraged to cooperate to enable borrowers to stay in their homes. The risks to the broader economy created by the financial market crisis and housing market downturn were primary factors in several decisions by the U.S. Federal Reserve to cut interest rates and the passing of the Economic Stimulus Act (ESA) in February 2008 (see, for instance, [9] and [118]; also GIR2 in Figure 1.2). Also, a plan to voluntarily and temporarily freeze the mortgages of a limited number of MRs holding ARMs was announced. A refinancing facility called FHA-Secure was also created. This action is part of an ongoing collaborative effort between the U.S. government and private industry to help some subprime MRs called the Hope Now Alliance (see GIR3 in Figure 1.2). The U.S. government also offered bail outs to key financial institutions, thus raising additional financial commitments (see GIR4 in Figure 1.2). Following a series of ad-hoc market interventions to bailout particular firms, a $ 700 billion systemic rescue plan was accepted by the U.S. House of Representatives on Friday, 3 October 2008. These actions are designed to stimulate economic growth and inspire confidence in financial markets (see GIR5 in Figure 1.2). By October 2008, banks in Europe, Asia, Australia and South America had followed the example of the U.S. government by putting rescue plans in place.

1.2.2 Preliminaries about Subprime Mortgages

In this subsection, we discuss preliminaries about subprime mortgages involving the balance sheet and credit ratings. In particular, we specify the components of total capital and risk-weighted assets that we use in our study. We follow [48] that explores the link between credit ratings and mortgage defaults as well as asset risk-weights. As regarding the first assumption, there is evidence to support the notion that mortgage defaults are higher during than before the SMC. Weak economic conditions are likely to be associated with a deterioration in mortgage quality as MRs' financial health deteriorates. The assumption made in this thesis is that write-offs are related to the current value of $\mathcal{C}$, which can be thought of as a proxy for the level of macroeconomic activity (see Subsubsection 1.2.2.2 for more details). However, they depend on past macroeconomic conditions as well, given that $\mathcal{C}$ is described by an autoregressive process. The second assumption that we introduce is that risk-weights vary with credit ratings. In the revised Basel Accord banks are given the choice between two methodologies for calculating their minimum capital requirements. Under the so-called standardized approach, exposures included in banks' retail portfolios would maintain a constant risk-weight while external credit assessments, such as credit scores by rating agencies, would be used to construct the risk-weights for claims on sovereigns, banks and corporates. In assessing a borrower's creditworthiness, the major rating agencies aim at maintaining a stable rating through the business cycle. There is, however, evidence that credit ratings show a cyclical pattern with more downgrades than upgrades during recessions (see, for example, [87]). Under the alternative method (the internal ratings based approach) some banks will use their own credit ratings to determine capital requirements. This approach might induce more cyclicality in risk-weights. Most internal rating systems use a short-term horizon to measure risk. In particular, borrowers probability of default which is one of the terms in the formula for risk-weights, is determined over a one-year period and borrowers are assigned to rating grades using models. Our assumption reflects the idea that, under the Basel II, risk-weights might become more closely related to current credit ratings.

1.2.2.1 The Balance Sheet

In period t, SOR's on-balance sheet items can be identified as

$$\Lambda_t + \widehat{B}_t + \widehat{R}_t + \widehat{\mathtt{T}}_t = \widehat{D}_t + \widehat{\mathtt{B}}_t + \widehat{K}_t; \ \widehat{K}_t = n_t\widehat{E}_{t-1} + \widehat{O}_t, \ \widehat{E}_{t-1} = \widehat{E}^c_{t-1} + \widehat{E}^p_{t-1},$$

where Λ, $\widehat{B}$, $\widehat{R}$, $\widehat{\mathtt{T}}$, $\widehat{D}$, $\widehat{\mathtt{B}}$, n, $\widehat{E}$, $\widehat{O}$, $\widehat{E}^c_t$ and $\widehat{E}^p_t$ are described in the sequel. Next, we make a realistic assumption about the relationship between $\widehat{R}$ and $\widehat{D}$.

Assumption 1.2.1 (Reserves and Deposits): *Assume that the reserves, $\widehat{R}$, is a factor, γ, of the deposits, $\widehat{D}$, so that $\widehat{R} = \gamma\widehat{D}$.*

Then we have

$$\Lambda_t + \widehat{B}_t + \widehat{\mathtt{T}}_t = (1-\gamma)\widehat{D}_t + \widehat{\mathtt{B}}_t + \widehat{K}_t; \widehat{K}_t = n_t\widehat{E}_{t-1} + \widehat{O}_t, \quad \widehat{E}_{t-1} = \widehat{E}^c_{t-1} + \widehat{E}^p_{t-1}. \tag{1.1}$$

Furthermore, in our case, SOR faces a *Hicksian demand for loans* given by

$$\Lambda_t = \lambda_0 - \lambda_1 r^\Lambda_t + \lambda_2\mathcal{C}_t + \sigma^\Lambda_t. \tag{1.2}$$

where r^Λ_t is the loan rate, $\mathcal{C}_t$ is a variable representing the credit rating (as a proxy for the level of macroeconomic activity via procyclicality) and σ^Λ_t represents a random exogenous shock to the demand for loans, which is defined over the interval $[\underline{\Lambda}, \overline{\Lambda}]$. We consider the possibility that MRs can default on their principal payment.

Moreover, the proportion of defaulted debt is assumed to be a negative function of current credit ratings (macroeconomic conditions), i.e., write-offs are higher when credit ratings are low than when they are high. SOR loan defaults translate into an extra cost term in SOR's profit function.

In our models, SOR is allowed to hold risky marketable securities (such as residential mortgage-backed securities (RMBSs)) and riskless Treasury securities on its balance sheet. Marketable securities, $\widehat{B}$, are important for generating profit, since their returns, r^B, usually exceed the returns from other less risky assets. In the sequel, the all-in costs for holding marketable securities is denoted by c^B_t. Also, *Treasury securities* or *Treasuries* are bonds that are the debt financing instruments of the federal government. There are four types of Treasuries, viz., Treasury bills, Treasury notes, Treasury bonds and savings bonds. All Treasuries besides savings bonds are very liquid and are heavily traded on the secondary market. We denote the value of Treasuries in the t-th period, by $\widehat{\mathtt{T}}_t$, and the Treasury rate by $r^{\mathtt{T}}$. SOR takes deposits, $\widehat{D}_t$, at a constant *marginal cost*, c^D, that may be associated with cheque clearing and bookkeeping. The following assumption is related to this.

Assumption 1.2.2 (Deposit Taking): *We assume that deposit taking is continual even when $r^D < r^{\mathtt{T}}$.*

This assumption ensures that SOR experiences no significant bank runs. We consider the possibility that *unanticipated withdrawals*, u, will occur. SOR hold liquid Treasuries in order to make provision for these withdrawals. For the sake of argument, we also assume the following so that the *cost of liquidation*, c^l, or additional external funding is a quadratic function of $\mathtt{T}$.

Assumption 1.2.3 (Unanticipated Deposit Withdrawals): *Assume that* u *is related to the* probability density function, $f(u)$, *that is independent of time. Suppose that the unanticipated withdrawals have a uniform distribution with support* $[0, \overline{\widehat{D}}]$.

This assumption implies that the *cost of liquidation*, c^l, or additional external funding is a quadratic function of $\mathtt{T}$. In addition, for any t, if we have that $u > \widehat{\mathtt{T}}_t$, then SOR assets are liquidated at some *penalty rate*, r_t^p. In this case, the *cost of Treasuries* is $P^{\widehat{\mathtt{T}}_t}(\widehat{\mathtt{T}}_t) = r_t^p \int_{\widehat{\mathtt{T}}_t}^{\infty}[u - \widehat{\mathtt{T}}_t]f(u)du = \frac{r_t^p}{2\overline{\widehat{D}}}[\overline{\widehat{D}} - \widehat{\mathtt{T}}_t]^2$, with $P^{\widehat{\mathtt{T}}_t}(\widehat{\mathtt{T}}_t)$ being the provisions against deposit withdrawals.

Interbank borrowing including borrowing from the Central Bank provides a further source of funds. In the sequel, the amount borrowed from other banks is denoted by $\widehat{\mathtt{B}}$, while the marginal interbank borrowing rate (for instance, the London interbank borrowing rate (LIBOR), r^L, for banks as in (2.2)) and costs are denoted by $r^{\mathtt{B}}$ and $c^{\mathtt{B}}$, respectively. Of course, when SOR borrows from the Central Bank, we have $r^{\mathtt{B}} = r^L$.

1.2.2.2 Credit Ratings for Subprime Mortgages

Concerns about credit ratings have resurfaced during the SMC, where SIBs have used ratings to determine the risk attached to their subprime mortgage investments. For simplicity, we make the following assumption.

Assumption 1.2.4 (Credit Rating of Subprime Mortgages): *In period* t, *suppose that subprime mortgages with normalized mass are eligible to be rated.*

Under this assumption, we consider A and B that are the two types of mortgages. If no shock occurs, type-A mortgages have a low default probability, p^A, and type-B subprime mortgages have a high default probability, p^B, where $0 < p^A < p^B < 1$. Let Γ_t denote the mass of type-A mortgages in period t, where $0 \leq \Gamma_t \leq 1$. In principle, the value of Γ rises when perceived credit risk (or probability of default) is low and decreases when perceived credit risk is high. In each period t, subprime mortgages are uniformly located along the unit interval according to their type. The credit rating agency (CRA) can observe a mortgage's type and location on the unit interval. The CRA chooses a fee and offers a rating to each subprime mortgage. There are two rating categories, viz., $\mathcal{A}$ and $\mathcal{B}$. Rating category $\mathcal{A}$ indicates that a mortgage securitization is of type A and rating category $\mathcal{B}$ indicates that a securitization is of type B. The CRA chooses fee $f_t \in \Re_0^+$ and rating threshold $a_t \in [0, 1]$. The CRA offers mortgages, who are located on or to the right of a_t on the unit interval, an $\mathcal{A}$ rating, and subprime mortgages, that are located to the left of a_t on the unit interval, a $\mathcal{B}$ rating. In period t, the set of mortgage credit ratings is given by $\mathcal{C}_t = \{\mathcal{A}_t, \mathcal{B}_t\}$. Also, we assume the following.

Assumption 1.2.5 (Credit Rating Process): *Suppose that* $\mathcal{C} = \{\mathcal{C}_t\}_{t \geq 0}$ *follows the first-order autoregressive stochastic process* $\mathcal{C}_{t+1} = \mu_t^{\mathcal{C}}\mathcal{C}_t + \sigma_{t+1}^{\mathcal{C}}$, *where* $\sigma_{t+1}^{\mathcal{C}}$ *denotes zero-mean stochastic shocks to credit rating.*

The uncertainty in credit ratings before and after the SMC is encapsulated in this assumption.

1.2.2.3 Bank Regulatory Capital

For the purposes of our study, *regulatory capital*, $\widehat{K}$, is the value of SOR capital defined as the difference between the accounting value of the assets and liabilities. More specifically, Tier 1 capital is represented by period $t-1$'s market value of the SOR equity, $n_t\widehat{E}_{t-1}$, where n_t is the number of RMBS and $\widehat{E}_t$ is the period t market price of the SOR's common equity. In our contribution, period t, Tier 2 capital and Tier 3 capital are constituted by subordinate debt, $\widehat{O}_t$. To maintain the book value feature of regulatory capital, it is assumed that last period's market value of equity and subordinate debt determines the capital constraint for the present period. The balance sheet reflects the fact that SORs are active in the primary market by raising deposits, $\widehat{D}$, from and extending credit, Λ, to the public. This involves transactions with other commercial banks (interbank lending), with the Central Bank (monetary loans or deposits with the Central Bank) and Treasury (buying and selling Treasury securities) as well as in the financial markets (buying and selling risky marketable securities). Also the bank holds capital, $\widehat{K}$, as required by the regulator, which serves as a cushion against unexpected losses (primarily from its loan portfolio).

In order to describe the binding capital constraint, we consider risk-weighted assets (RWAs) that are defined by placing each on- and off-balance sheet item into a risk category. The more risky assets are assigned a larger weight. Table 1.1 below provides RWA notation, Bank assets and their probable risk-weights.

RWA Notation	**Bank Assets**	**Risk-Weight**
ω^{T}	Treasuries	0 %
ω^{B}	Structured Mortgage Products	20 %
ω^{M}	Mortgages	50 %

Table 1.1: Bank Assets and Their Risk Weights

As a result, RWAs are a weighted sum of the various assets of the SORs. In particular, we can identify a special risk-weight on SOR's loans, $\omega^{\Lambda} = \omega(\mathcal{C}_t)$, that is a decreasing function of current credit rating so that

$$\frac{\partial\omega(\mathcal{C}_t)}{\partial\mathcal{C}_t} < 0.$$

This is in line with the procyclical notion that before the SMC, when credit ratings were high, the risk-weights were low. On the other hand, during the SMC, risk-weights increased because of an elevated probability of default and/or loss given default on loans. From [48] (see, also, [28]), SOR's *total capital constraint* is given by

$$\widehat{K}_t = n_t\widehat{E}_{t-1} + \widehat{O}_t \geq \rho\Big[\omega(\mathcal{C}_t)\Lambda_t + \omega^B\widehat{B}_t + 12.5(mVaR + \mathtt{0})\Big], \tag{1.3}$$

where ρ is the regulatory ratio of regulatory capital to risk-weighted assets. The *nett cash flow generated by SOR* is given by the identity

$$\widehat{N}_t = \widehat{\Pi}_t - \Delta\widehat{F}_t = n_t\widehat{d}_t + (1 + r_t^O)\widehat{O}_t - \widehat{K}_{t+1} + n_t\widehat{E}_t, \tag{1.4}$$

where $\widehat{\Pi}$ is SOR's profit under market value, $\Delta\widehat{F}$ is depreciation, $\widehat{d}$ is dividends paid by SOR and r^O is the interest rate on period t subordinate debt.

1.2.2.4 A Valuation Problem for Subprime Mortgages

In our case, SOR faces a *Hicksian demand for subprime mortgages* given by

$$\Lambda_t = \lambda_0 - \lambda_1 r_t^\Lambda + \lambda_2 \mathcal{C}_t + \sigma_t^\Lambda.$$

where r_t^Λ is the loan rate, $\mathcal{C}_t$ is a variable representing the credit rating (as a proxy for the level of macroeconomic activity via procyclicality) and σ_t^Λ represents a random exogenous shock to the demand for loans, which is defined over the interval $[\underline{\Lambda}, \overline{\Lambda}]$. We consider the possibility that MRs can default on their principal payment. Moreover, the proportion of defaulted debt is assumed to be a negative function of current credit ratings (macroeconomic conditions), i.e., write-offs are higher when credit ratings are low than when they are high. SOR loan defaults translate into an extra cost term in SOR's profit function. As will become clear, the marginal cost curve will now shift downwards (upwards) as credit ratings increase (decrease). In other words, economic conditions affect loan supply as well as demand.

Another assumption introduced is that the risk-weight assigned to mortgages in the capital adequacy ratio (CAR) is not constant, but is a decreasing function of current credit ratings, as implied by Basel II. For the function

$$\begin{aligned} \widehat{J}_t &= \widehat{\Pi}_t + l_t\Big[\widehat{K}_t - \rho\Big(\omega(\mathcal{C}_t)\Lambda_t + \omega^B\widehat{B}_t + 12.5(mVaR + \mathtt{O})\Big)\Big] \\ &\quad -c_t^{dw}\Big[\widehat{K}_{t+1}\Big] + \mathbf{E}_t\Big[\delta_{t,1}\widehat{V}\Big(\widehat{K}_{t+1},\ x_{t+1}\Big)\Big], \end{aligned} \tag{1.5}$$

the optimal SOR valuation problem is to maximize the value of SOR by choosing r^Λ, $\widehat{D}$, $\widehat{\mathtt{T}}$, and $\widehat{K}$, for

$$\widehat{V}(\widehat{K}_t,\ x_t) = \max_{r_t^\Lambda,\ \widehat{D}_t,\ \widehat{\mathtt{T}}_t} \widehat{J}_t, \tag{1.6}$$

subject to the loan demand, balance sheet, cash flow and financing constraints given by

$$\Lambda_t = \lambda_0 - \lambda_1 r_t^{\Lambda} + \lambda_2 \mathcal{C}_t + \sigma_t^{\Lambda}, \tag{1.7}$$

$$\widehat{\mathtt{T}}_t = (1-\gamma)\widehat{D}_t + \widehat{\mathtt{B}}_t + n_t \widehat{E}_{t-1} + \widehat{O}_t - \widehat{B}_t - \Lambda_t, \tag{1.8}$$

$$\begin{aligned} \widehat{\Pi}_t &= \left(r_t^{\Lambda} - \overline{c}_t^{\Lambda\omega}\right)\Lambda_t + r_t^{\mathtt{T}}\widehat{\mathtt{T}}_t - P^{\widehat{\mathtt{T}}}(\widehat{\mathtt{T}}_t) + \left(r_t^{B} - c_t^{B}\right)\widehat{B}_t - \left(r_t^{D} + c_t^{D}\right)\widehat{D}_t \\ &\quad - \left(r_t^{\mathtt{B}} + c_t^{\mathtt{B}}\right)\widehat{\mathtt{B}}_t, \end{aligned} \tag{1.9}$$

and

$$\widehat{K}_{t+1} = n_t(\widehat{d}_t + \widehat{E}_t) + (1 + r_t^{O})\widehat{O}_t - \widehat{\Pi}_t + \Delta \widehat{F}_t, \tag{1.10}$$

respectively. In the value function, l_t is the Lagrange multiplier for the capital constraint, c_t^{dw} is the deadweight cost of capital and $\delta_{t,1}$ is a stochastic discount factor. In the profit function, $\overline{c}^{\Lambda\omega}$ is the constant marginal cost of loans (including the cost of monitoring and screening).

The interest rate on deposits r^D is assumed to follow first-order autoregressive stochastic processes

$$r_{t+1}^{D} = \mu_t^{r^D} r_t^{D} + \sigma_{t+1}^{r^D},$$

where $\sigma_{t+1}^{r^D}$ is a zero-mean stochastic shock to deposit rate.

The main result from [48] is as follows. Suppose that $\widehat{J}$ and $\widehat{V}$ are given by (1.5) and (1.6), respectively. When the capital constraint given by (1.3) holds (i.e., $l_t > 0$), a solution to the optimal bank valuation problem yields an optimal mortgage supply and mortgage rate of the form

$$\Lambda_t^{*} = \frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B \widehat{B}_t + 12.5(mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)} \tag{1.11}$$

and

$$r_t^{\Lambda *} = \frac{1}{\lambda_1}\left(\lambda_0 + \lambda_2\mathcal{C}_t + \sigma_t^{\Lambda} - \frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} + \frac{\omega^B \widehat{B}_t + 12.5(mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)}\right), \tag{1.12}$$

respectively. In this case, the corresponding optimal deposits, provisions for deposit withdrawals and profits are given by

$$\widehat{D}_t^* = \frac{1}{(1-\gamma)}\Big(\overline{\widehat{D}} + \frac{\overline{\widehat{D}}}{r_t^p}\Big[r_t^{\mathtt{T}} + (r_t^B - c_t^B) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Big]$$

$$+\frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B \widehat{B}_t + 12.5(mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)} + \widehat{B}_t - \widehat{K}_t - \widehat{\mathtt{B}}_t\Big),$$

$$\widehat{\mathtt{T}}_t^* = \overline{\widehat{D}} + \frac{\overline{\widehat{D}}}{r_t^p}\Big[r_t^{\mathtt{T}} + (r_t^B - c_t^B) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Big]$$

and

$$\widehat{\Pi}_t^* = \Big(\frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B \widehat{B}_t + 12.5(mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)}\Big)$$

$$\Big\{\frac{1}{\lambda_1}\Big(\lambda_0 - \frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} + \frac{\omega^B \widehat{B}_t + 12.5(mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)} + \lambda_2\mathcal{C}_t + \sigma_t^{\Lambda}\Big)$$

$$-\Big(\overline{c}_t^{\Lambda\omega} + (r_t^D + c_t^D)\tfrac{1}{1-\gamma}\Big)\Big\} - \Big((r_t^D + c_t^D)\tfrac{1}{1-\gamma}\Big)\Big(\widehat{B}_t - \widehat{K}_t - \widehat{\mathtt{B}}_t\Big)$$

$$+\Big(\overline{\widehat{D}} + \tfrac{\overline{\widehat{D}}}{r_t^p}\Big[r_t^{\mathtt{T}} + (r_t^B - c_t^B) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \tfrac{1}{1-\gamma}(r_t^D + c_t^D)\Big]\Big)\Big(r_t^{\mathtt{T}} - (r_t^D + c_t^D)\tfrac{1}{1-\gamma}\Big)$$

$$+\Big(r_t^B - c_t^B\Big)\widehat{B}_t - \Big(r_t^{\mathtt{B}} + c_t^{\mathtt{B}}\Big)\widehat{\mathtt{B}}_t - P^{\widehat{\mathtt{T}}}(\widehat{\mathtt{T}}_t),$$

respectively.

1.2.3 Preliminaries about Subprime Mortgage Securitization

We introduce a subprime mortgage model with default to explain the key aspects of mortgage securitization.

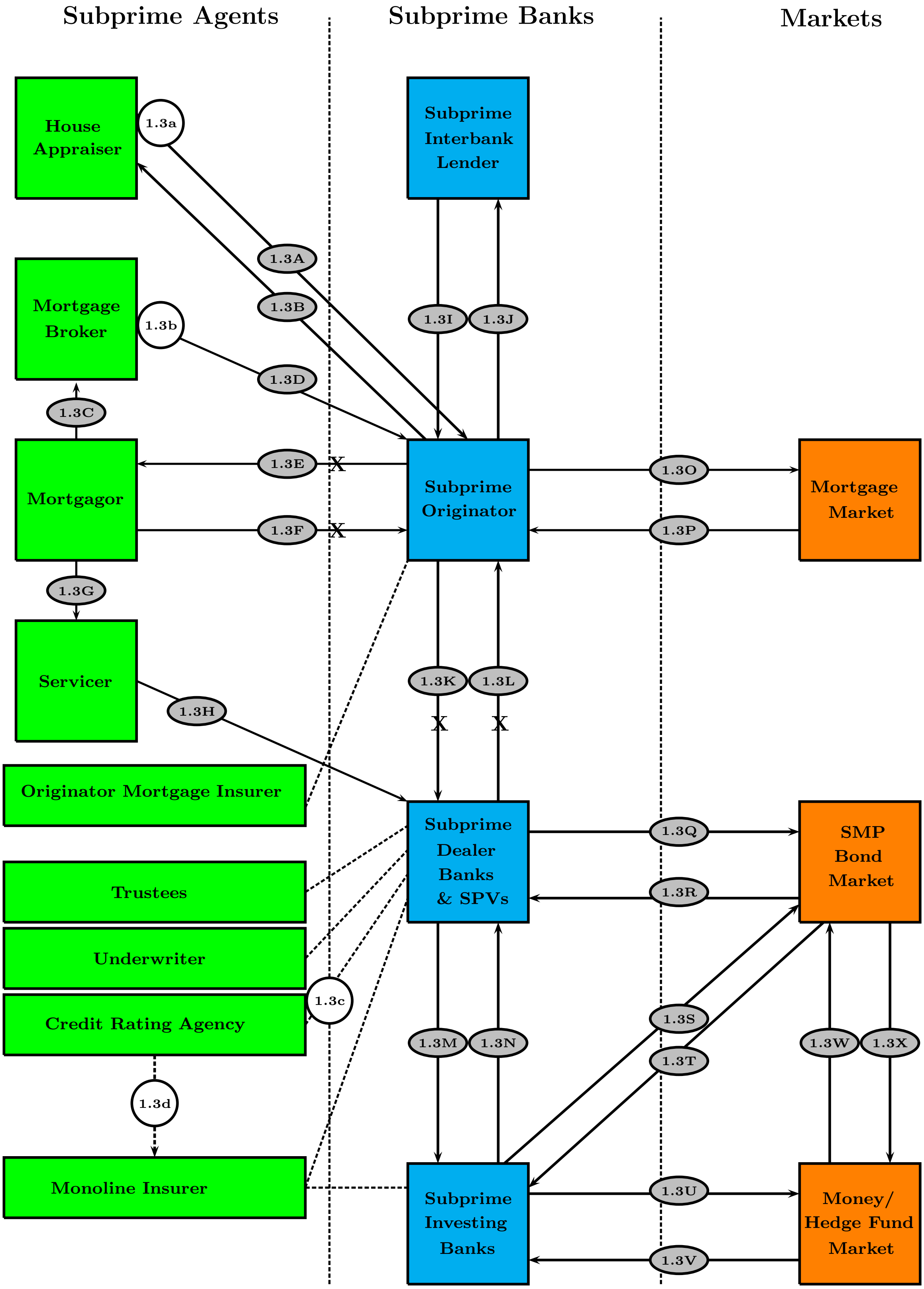


Figure 1.3: Diagrammatic Overview of a Subprime Mortgage Model With Default

Figure 1.3 presents a subprime mortgage model involving nine subprime agents, four subprime banks and three types of markets. As far as subprime agents are concerned, we note that circles **1.3a**, **1.3b**, **1.3c** and **1.3d** represent flawed independent assessments by house appraisers (HAs), mortgage brokers (MBs), credit rating agencies (CRAs) rating SPVs and monline insurers (MLIs) being rated by rating agencies, respectively. Regarding the former agent, the process of subprime mortgage origination is flawed with house appraisers not performing their duties with integrity and independence. According to [23] this type of fraud is the "linchpin of the house buying transaction" and is an example of operational risk. Also, the symbol **X** indicates that the cash flow stops as a consequence of defaults. Before the SMC, HAs estimated house values based on data that showed that the house market would continue to grow (compare with **1.3A** and **1.3B**). In steps **1.3C** and **1.3D**, independent MBs arrange mortgage deals and perform checks of their own while SORs originate mortgages in **1.3E**. Subprime MRs generally pay high mortgage interest rates to compensate for their increased risk from poor credit histories (compare with **1.3F**). Next, the servicer (SR) collects monthly payments from MRs and remits payments to SDBs and SPVs. In this regard, **1.3G** is the mortgage interest rate paid by MRs to the SR of the reference mortgage portfolios while the interest rate **1.3H** (mortgage interest rate minus the servicing fee), is passed by the SR to the SPV for the payout to SIBs. SOR mortgage insurers (SOMIs) compensate SORs for losses due to mortgage defaults. Several subprime agents interact with the SPV. For instance, the trustee holds or manages and invests in mortgages and SMPs for the benefit of another. Also, the underwriter is a subprime agent who assists the SPV in underwriting new SMPs. Monoline insurers (MLIs) guarantee SIBs' timely repayment of bond principal and interest when an SPV defaults. In essence, such insurers provide guarantees to SPVs, often in the form of credit wraps, that enhance the credit rating of the SPV. They are so named because they provide services to only one industry. These insurance companies first began providing wraps for municipal bond issues, but now provide credit enhancement for other types of SMP bonds, such as RMBSs and CDOs. In so doing, MLIs act as credit enhancement providers that reduce the risk of mortgage securitization.

SOR has access to subprime mortgage investments that may be financed by borrowing from the subprime interbank lender (SIL), represented by **1.3I**. The SIL, acting in the interest of risk-neutral shareholders, either invests its deposits in Treasuries or in SOR's subprime mortgage projects. In return, SOR pays interest on these investments to SIL, represented by **1.3J**. Next, the SOR deals with the mortgage market represented by **1.3O** and **1.3P**, respectively. Also, the SOR pools its mortgages and sells them to SDBs and/or SPVs (see **1.3K**). The SDB or SPV pays the SOR an amount which is slightly greater than the value of the reference mortgage portfolios as in **1.3L**. A SPV is an organization formed for a limited purpose that holds the legal rights over mortgages transferred by SORs during securitization. In addition, the SPV divides this pool into sen, mezz and jun tranches which are exposed to different levels of credit risk. Moreover, the SPV sells these tranches as securities backed by subprime mortgages to SIBs (see **1.3N**) that is paid out at an interest rate determined by the mortgage default rate, prepayment and foreclosure (see **1.3M**). Also, SPVs deal with the SMP bond market for investment purposes (compare with **1.3Q** and **1.3R**). Furthermore, SORs have securitized mortgages on their balance sheets, that have connections with this bond market. SIBs invest in this bond market, represented by **1.3S** and receive returns on SMPs in **1.3T**. The money market and hedge fund market are secondary markets where previously issued marketable securities such as SMPs are bought and sold (compare with **1.3W** and **1.3X**). SIBs invest in these short-term securities (see, **1.3U**) to receive profit, represented by **1.3V**. During the SMC, the model represented in Figure 1.3 was placed under major duress as house prices began to plummet. As a consequence, there was a cessation in subprime agent activities and the cash flows to the markets began to dry up. Thus, causing the whole subprime mortgage model to collapse.

We note that the traditional mortgage model is embedded in Figure 1.3 and consists of the agents, MRs, SILs and SORs as well as the mortgage market. In this model, SIL lends funds to SOR to fund mortgage originations (see, **1.3I** and **1.3J**). Home valuation as well as income and credit checks were done by the SOR before issuing the mortgage. The SOR then extends mortgages and receives repayments that are represented by **1.3E** and **1.3F**, respectively. The SOR also deals with the mortgage market in **1.3O** and **1.3P**. When a MR defaults on repayments, the OR repossesses the house.

1.2.3.1 Design of Subprime Mortgage Securitization

In this subsection, we discuss the main design features of subprime structured mortgage products such as RMBSs and RMBS CDOs. In particular, we provide a description of SPVs, cost of mortgages, default, collateral, adverse selection and residual value (see Chapter 3 for more details).

In terms of the organization of the SPV, there are various states that can be associated with corporate forms such as a trust (denoted by $\mathtt{E}^1$), a limited liability corporation (LLC; denoted by $\mathtt{E}^2$), LLP ($\mathtt{E}^3$) or a C-corporation ($\mathtt{E}^4$). Our interest is mainly in $\mathtt{E}^1$ trusts and $\mathtt{E}^2$ LLCs that have their own unique tax benefits and challenges as well as degree of mortgage protection and legal limited liability. For our purposes, the optimal state during the lifetime of $\mathtt{E}^i, \ \ i \in \{1, 2\}$ is denoted by $\mathtt{E}^*$, such that the deviation from $\mathtt{E}^*$ is given by

$$\left|\mathtt{E}^i_t - \mathtt{E}^*\right|.$$

These deviations measure the loss and opportunity costs arising from the use of suboptimal corporate structures such as SPVs. Usually such loss is in the form of increased legal fees, losses due to low limited liability and the value of additional time spent in dispute resolution. In this case, the formula for $\mathtt{E}$ is given by

$$\mathtt{E}_t = \max\left\{\left|\mathtt{E}^i_t - \mathtt{E}^*\right|, 0\right\}. \tag{1.13}$$

SOR's may monitor MR activities to see whether they are complying with the restrictive agreements and enforce the agreements if they are not by making sure that MRs are not taking on risks at their expense. Securitization dissociates the quality of SOR's original mortgage portfolio from the quality of the cash flows from SOR's reference mortgage portfolio, $f^{\Sigma}M$, to SIBs, where f^{Σ} is the fraction of the face value of mortgages, M, that is securitized. Whether on-balance sheet or in the market, the weighted average of the cost of mortgages summarizes the cost of various funding solutions. It is the weighted average of cost of equity and debt on SOR's balance sheet and the weighted average of the costs of securitizing various mortgages. In both cases, we use the familiar *weighted average cost of capital.* As a consequence, cost of funds via securitization, $\overline{c}^{M\Sigma\omega}$ (includes monitoring and transaction costs for $f^\Sigma M$ denoted by $c^{m\Sigma}$ and $c^{t\Sigma}$, respectively, as well as the cost of funds in the market through securitizing mortgages), does not have to coincide with SOR's cost of mortgages for M, $\overline{c}^{M\omega}$ (includes monitoring and transaction costs for M denoted by c^m and c^t, respectively). We note that c^t may include overhead, fixed costs and variable costs per transaction expressed as a percentage of M. This suggests that if

$$\overline{c}^{M\Sigma\omega} < \overline{c}^{M\omega},$$

then the securitization economics is favorable and conversely.

In the sequel, the notation $r_t^{S\Sigma}$, represents the default rate on securitized mortgages f_t^Σ, denotes the fraction of M that is securitized while $\widehat{f}_t^\Sigma$, denotes the fraction of SOR's reference mortgage portfolio realized as new mortgages in securitization as a result of, for instance, equity extraction via refinancing. In the sequel, collateral is constituted by the reference mortgage portfolio that is securitized and relates to the underlying cash flows. Such flow and credit characteristics of the collateral will determine the performance of the securities and drive the structuring process. Although a wide variety of assets may serve as collateral for securitization, mortgages are the most widely used form of collateral. In the case of a mortgage secured by collateral, if MR fails to make required payments, SOR has the right to seize and sell the collateral to recover the defaulted amount.

RMBSs mainly use one or both of the sen/sub shifting of interest structure, sometimes called the *6-pack* structure (with 3 mezz and 3 sub RMBS bonds junior to the AAA bonds), or an XS/OC structure (see, for instance, [53]). Here, XS and OC denote *excess spread* and *overcollateralization*, respectively. Like sen/sub deals, XS is used to increase OC, by accelerating payments on sen RMBS bonds via sequential amortization – a process known as *turboing*. An *OC target*, $\widetilde{O}^c$, is a fraction of the original mortgage par, M, and is designed to be in the second loss position against collateral losses with the interest-only (IO) strip being first. Typically, the initial OC amount, O^{ci}, is less than 100 % of $\widetilde{O}^c$ and it is then increased over time via the XS until $\widetilde{O}^c$ is reached. When this happens, the OC is said to be *fully funded* and Nett Interest Margin Securities (NIMSs) can begin to receive cash flows from the RMBS bond deal. Once $\widetilde{O}^c$ has been reached, and subject to certain performance tests, XS can be released for other purposes, including payment to residual[11] bond holders. In this contribution, we assume that SOR is also a residual bond holder. For our purposes, the symbol $\overline{r}_t^r$, represents the average residual rate in a period t securitization. It is defined as the difference between the average interest rate paid by MRs on mortgages, $\overline{r}^M$, and the present value of interest paid on securitized mortgages, $r^{p\Sigma}$, so that

$$r^r = \overline{r}^M - r^{p\Sigma}.$$

Adverse selection is the problem created by asymmetric information in the extension of mortgages

[11] *Residual value* is the payout received by the RMBS bond holder – in our case the SOR – when bonds have been paid off and cash flows from the reference mortgage portfolio (collateral) are still being generated. Residual value also arises when the proceeds amount from the sale of this reference portfolio as whole mortgages is greater than the amount needed to pay outstanding bonds.

by SOR. It occurs because high risk (e.g., subprime) MRs that are most likely to default on their mortgages, usually apply for them. In other words, subprime mortgages are extended to MRs who are most likely to produce an adverse outcome. We denote the value of the adverse selection problem by V^a. For sake of argument, we set

$$V_t^a = a f_t^{\Sigma} M_t, \tag{1.14}$$

where V^a is a fraction a, of the face value of mortgages in period t.

1.2.3.2 Financing Subprime Mortgage Origination and Securitization

In this subsection, we discuss the financing of subprime mortgage origination and securitization. Securitization is the main method for financing mortgage origination by subprime SORs[12]. The following table illustrates the extent to which SORs relied on securitization for the financing of subprime mortgages.

Mortgage Originations and Subprime Securitization					
Date	**Total Mortgage Originations (Billions)**	**Subprime Originations (Billions)**	**Subprime Share in Total Originations (% of $ Value)**	**Subprime Mortgage Backed Securities (Billions)**	**Percent Subprime Securitized (% of $ Value)**
2001	$ 2 125	$ 190	8.9 %	$ 95	50.4 %
2002	$ 2 885	$ 231	8.0 %	$ 121	52.7 %
2003	$ 3 945	$ 335	8.5 %	$ 202	60.5 %
2004	$ 2 920	$ 540	18.5 %	$ 401	74.3 %
2005	$ 3 120	$ 625	20.0 %	$ 507	81.2 %
2006	$ 2 980	$ 600	20.1 %	$ 483	80.5 %
2007	$ 2 865	$ 430	15.0 %	$ 325	75.5 %
2008	$ 2 685	$ 360	13.4 %	$ 240	66.7 %
2009	$ 2 495	$ 280	11.2 %	$ 164	58.3 %

Table 1.2: Mortgage Originations and Subprime Securitization; Source: [61]

Table 1.2 provides an indication of the quantitative importance of subprime mortgage securitizations. The said table shows that subprime mortgage origination in 2005 and 2006 was about $ 1.2 trillion of which 80 % was securitized. We assume that financing is denoted by $\mathtt{F}^f$, when the securitization is an assignment ($f_t^{\Sigma} \neq 1$) and $\mathtt{F}^s$, for true sale securitization ($f_t^{\Sigma} = 1$). In the former case, the sponsor does not subsidize SPV, but only substitutes impaired collateral. In this situation, where $\mathtt{F}^f$ is the optimal state but $\mathtt{F}^s$ is being used instead, the transaction incurs losses and vice versa. On the other hand, where the correct transaction format is used, there is neither a gain nor a loss. Hence, in period t, the value of the transaction format choice is

[12]Prominent subprime SORs are Ameriquest, Countrywide Financial, New Century and Option One.

$$F_t = \max\left\{\left|F_t^f - F_t^s\right|, 0\right\}. \quad (1.15)$$

1.2.4 Preliminaries About Subprime Risks

The main risks that arise when dealing with subprime residential mortgage products (RMPs) are credit (including counterparty and default), market (including interest rate, price and liquidity), operational (including house appraisal, valuation and compensation), tranching (including maturity mismatch and synthetic) and systemic (including maturity transformation) risks. For sake of argument, risks falling in the categories described above are cumulatively known as *subprime risks*. In Figure 1.4 below, we provide a diagrammatic overview of the aforementioned subprime risks.

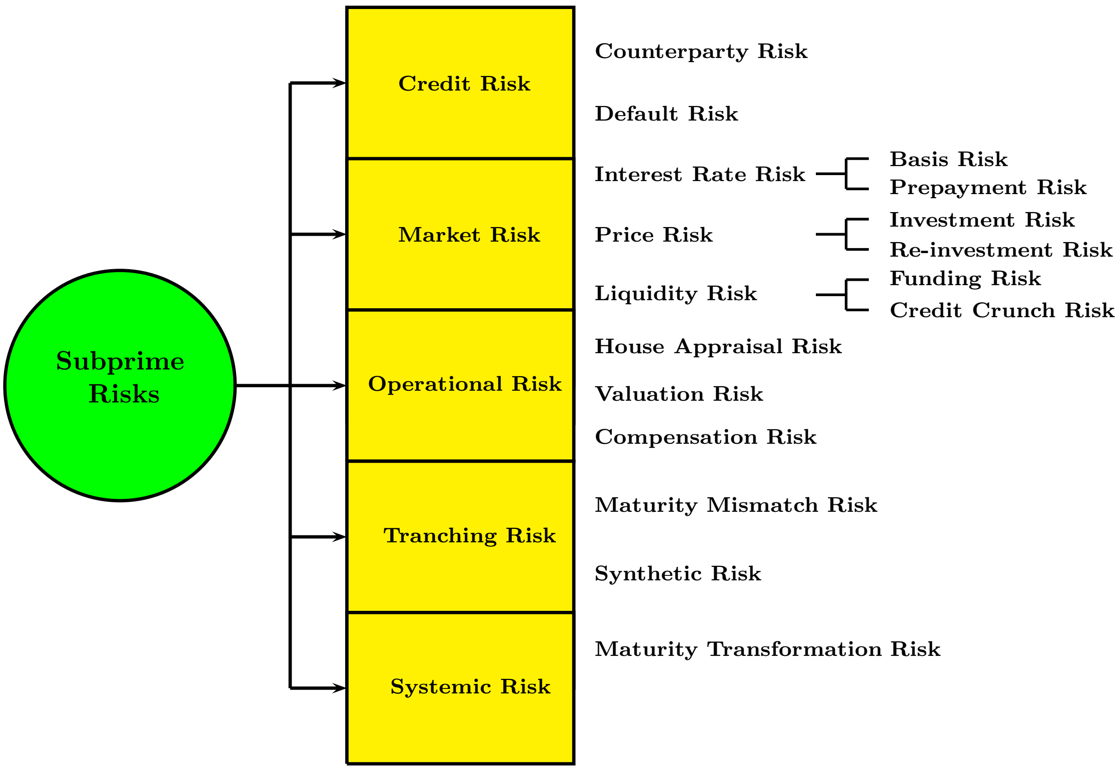


Figure 1.4: Diagrammatic Overview of Subprime Risks

The most fundamental of the above risks is *credit* and *market risk* (refer to Subsections 3.6.1 and 3.6.2). The former involves SOR's risk of loss from a MR who does not make scheduled payments and its securitization equivalent. This risk category generally includes *counterparty risk* that, in our case, is the risk that a banking agent does not pay out on a bond, credit derivative or credit insurance contract (see, for instance, Subsection 3.6.1). It refers to the ability of banking agents – such as SORs, MRs, servicers, SIBs, SPVs, trustees, underwriters and depositors – to fulfill their obligations towards each other (see Section 3.6 for more details). During the SMC, even banking agents who thought they had hedged their bets by buying insurance – via credit default swap (CDS) contracts or MLI insurance – still faced the risk that the insurer will be unable to pay.

In our case, *market risk* is the risk that the value of the mortgage portfolio will decrease mainly due to changes in the value of securities prices and interest rates. *Interest rate risk* arises from the possibility that subprime RMP interest rates will change. Subcategories of interest rate risk are basis and prepayment risk. The former is the risk associated with yields on RMPs and costs on deposits which are based on different bases with different rates and assumptions (discussed in Subsection 3.6.2.2). *Prepayment risk* results from the ability of subprime MRs to voluntarily (refinancing) and involuntarily (default) prepay their mortgages under a given interest rate regime. *Liquidity risk* arises from situations in which a banking agent interested in selling (buying) RMPs cannot do it because nobody in the market wants to buy (sell) those RMPs (see, for instance, Subsections 3.6.1.2, 3.6.1.3 and 3.6.2.2). Such risk includes funding and credit crunch risk. *Funding risk* refers to the lack of funds or deposits to finance mortgages and *credit crunch risk* refers to the risk of tightened mortgage supply and increased credit standards. We consider *price risk* to be the risk that RMPs will depreciate in value, resulting in financial losses, markdowns and possibly margin calls that is discussed in Subsections 3.6.1.3 and 3.6.2.3. Subcategories of price risk are valuation risk (resulting from the valuation of long-term RMP investments) and re-investment risk (resulting from the valuation of short-term RMP investments). Valuation issues are a key concern that must be dealt with if the capital markets are to be kept stable and they involve a great deal of operational risk.

Operational risk is the risk of incurring losses resulting from insufficient or inadequate procedures, processes, systems or improper actions taken (see, also, Subsection 3.6.1). As we have commented before, for subprime mortgage origination, operational risk involves documentation, background checks and progress integrity. Also, mortgage securitization embeds operational risk via mis-selling, valuation and SIB issues. Operational risk related to mortgage origination and securitization results directly from the design and intricacy of mortgages and related structured products. Moreover, SIBs carry operational risk associated with mark-to-market issues, the worth of securitized mortgages when sold in volatile markets and uncertainty involved in investment payoffs. Also, market reactions include increased volatility leading to behavior that can increase operational risk such as unauthorized trades, dodgy valuations and processing issues. Often additional operational risk issues such as model validation, data accuracy and stress testing lie beneath large market risk events (see, for instance, [23]).

Tranching risk is the risk that arises from the intricacy associated with the slicing of securitized mortgages into tranches in securitization deals (refer to Subsections 3.6.1.2 and 3.6.1.3). Prepayment, interest rate, price and tranching risk are also discussed in Subsection 3.6.4 where the intricacy of subprime RMPs is considered. Another tranching risk that is of issue for RMPs is *maturity mismatch risk* that results from the discrepancy between the economic lifetimes of RMPs and the investment horizons of SIBs. *Synthetic risk* can be traded via credit derivatives – like CDSs – referencing individual subprime RMBS bonds, synthetic CDOs or via an index linked to a basket of such bonds. Synthetic risk is discussed in Subsection 3.6.2.2.

In banking, *systemic risk* is the risk that problems at one bank will endanger the rest of the banking system (compare with Subsection 3.6.1). In other words, it refers to the risk imposed by interlinkages and interdependencies in the system where the failure of a single entity or cluster of entities can cause a cascading effect which could potentially bankrupt the banking system or market.

In Table 1.3 below, we identify the links in the chain of subprime risks with comments about the information created and the agents involved.

Chain of Subprime Risk and Securitization		
Step in Chain	**Information Generated**	**Agents Involved**
Mortgage Origination	Underwriting Standards; Mortgage Risk Characteristics; Credit Risk (Mortgage Quality); Operational Risk (Documentation, Creditworthiness, Origination Process)	SORs & MBs
Mortgage Securitization	Reference RML Portfolio Selected; RMBS Structured Credit (Reference Portfolio) Risk; Market (Valuation, Liquidity) Risk; Operational (Mis-selling, SIB Issues) Risk; Tranching (Maturity Mismatch) Risk; Systemic (Maturity Transformation) Risk;	SDBs; SRs; CRAs; SIBs Buying Deal
Securitization of ABSs, RMBSs, CMBSs into ABS CDOs;	ABS Portfolio Selected; Manager Selected; CDO Structured Credit (Reference Portfolio) Risk; Market (Valuation, Liquidity) Risk; Operational (Mis-selling, SIB Issues) Risk; Tranching (Maturity Mismatch) Risk; Systemic (Maturity Transformation) Risk;	SDBs; CDO Managers; CRAs; SIBs Buying Deal
CDO Risk Transfer via CDSs in Negative Basis Trade	CDOs & Tranche Selected; Credit Risk in the form of Market (Basis) Risk Credit (Counterparty) Risk	SDBs; Banks with Balance Sheets; CDOs
CDO Tranches Sale to SIVs & Other Vehicles;	CDOs & Tranche Selected for SIV Portfolio Market (Price and Interest Rate) Risk	SIV Manager; SIV Investors buy SIV Liabilities
Investment in SIV Liabilities by Money Market Funds;	Choice of SIV & Seniority	Only Agents Directly Involved: Buyer & Seller
CDO Tranches Sale to Money Market Funds via Liquidity Puts;	CDOs & Tranche Selected	Dealer Banks; Money Market Funds; Put Writers
Final Destination of Cash RMBS Tranches, Cash CDO Tranches & Synthetic Risk	Location of Risk	Only Agents Directly Involved: Buyer & Seller

Table 1.3: Chain of Subprime Risk and Securitization; Compare with [53]

Table 1.3 implies that IBs purchased tranches of structured products such as RMBSs, ABS CDOs, SIV liabilities and money market funds without an intimate knowledge of the dynamics of the products they were purchasing. These IBs likely relied on repeated relationships, bankers and on credit ratings. Essentially, IBs do not have the resources to individually analyze such complicated structures and, ultimately, rely to a lesser extent on the information about the structure and the fundamentals and more on the relationship with the product seller. Agency relationships are substituted for actual information. To emphasize this is not surprising, and it is not unique to structured products such as RMBSs and ABS CDOs. However, in the SMC case, the length of the chain of subprime risks is a huge problem.

1.2.5 Preliminaries about Subprime Data

In this subsection we discuss the different statistical techniques which are used for data analysis such as time series analysis, linear regression, logit regression, hazard regression, t-statistic as well as F-test. In this thesis, we consider data from LoanPerformance, ABSNET, Bloomberg, Lender Processing Services (LPS), FHFA (Federal Housing Finance Agency) and the Federal Reserve Bank of St Louis database as well as the Financial Service Research Program's (FSRP) subprime mortgage database for selected periods before and during the crisis. Additional parameter choices are made by considering, for instance, [7], [34], [47], [53] and [105]. Some brief preliminaries about time series analysis, linear and logit regression, the Cox-Proportional Hazard Model, t-statistic as well as F-test are considered in the rest of this subsection.

1.2.5.1 Time Series Analysis

A Time series is a sequence of observations which are ordered in time (or space) and are best displayed in a scatter plot. The series value X is plotted on the vertical axis and time t on the horizontal axis. Time is the independent variable. There are two kinds of time series data:

(i) Continuous, where we have an observation at every instant of time. We denote this using observation X at time t, $X(t)$.

(ii) Discrete, where we have an observation at (usually regularly) spaced intervals. We denote this as X_t.

Two main objectives of time series analysis are (i) identifying the nature of the phenomenon represented by the sequence of observations, and (ii) predicting the future values of the time series variable. Both of these objectives require that the pattern of observed time series data is identified and more or less formally described.

Time series data have a natural temporal ordering, this makes time series analysis distinct from other common data analysis problems. Time series trends in deal and mortgage characteristics for subprime and Alt-A deals are given in Table 4.3 of Chapter 4.

1.2.5.2 Linear Regression

Linear regression is used to model the relationship between a scalar variable y and one or more variables denoted X. Under this technique, if parameters of the models are unknown, they can be estimated from the data using linear models. Like all forms of regression analysis, linear regression focuses on the conditional probability distribution of y given X, rather than on the joint probability distribution of y and X, which is the domain of multivariate analysis.

Linear regression has many practical uses. Most applications of linear regression fall into one of the following two broad categories:

1. If the goal is prediction, or forecasting, linear regression can be used to fit a predictive model to an observed data set of y and X values. After developing such a model, if an additional value of X is then given without its accompanying value of y, the fitted model can be used to make a prediction of the value of y.

2. Given a variable y and a number of variables $X_1, \ldots, X_p$ that may be related to y, then linear regression analysis can be applied to quantify the strength of the relationship between y and the X_j, to assess which X_j may have no relationship with y at all, and to identify which subsets of the X_j contain redundant information about y, thus once one of them is known, the others are no longer informative.

The most common method for fitting a regression line is the method of least-squares. This method calculates the best-fitting line for the observed data by minimizing the sum of the squares of the vertical deviations from each data point to the line (if a point lies on the fitted line exactly, then its vertical deviation is 0). when the regression line is linear ($y = ax + b$) the regression coefficient is the constant a that represents the rate of change of one variable (y) as a function of changes in the other (x); b is the slope of the regression line. Linear regression is used in Tables 4.6, 4.7, 4.8 and 4.9.

1.2.5.3 Logit Regression

Logit regression which can also be referred to as logistic or logit model is used to predict the probability of occurrence of an event by fitting data to a logit function (logistic curve). It is a generalized linear model used for binomial regression. Like many forms of regression analysis, it makes use of several predictor variables that may be either numerical or categorical. Logistic regression is a technique for analyzing problems in which there are one or more independent variables that determine an outcome. Dependent variable is binary or dichotomous, i.e. it only contains data coded as 1 (TRUE, success, etc.) or 0 (FALSE, failure, etc.).

The objective of logistic regression is to find the best fitting model to describe the relationship between the dichotomous characteristic of interest (dependent variable = response or outcome variable) and a set of independent (predictor or explanatory) variables. Logistic regression generates the coefficients (and its standard errors and significance levels) of a formula to predict a logit transformation of the probability of presence of the characteristic of interest:

$$\text{logit}(p) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + ... + b_kX_k$$

where p is the probability of presence of the characteristic of interest and b_0, b_1, b_2, b_3 ... b_k are the regression coefficients. The logit transformation is defined as the logged odds:

$$\text{odds} = \frac{p}{1-p} = \frac{\text{probability of presence of characteristics}}{\text{probability of absence of characteristics}}$$

and

$$\text{logit}(p) = \ln\left[\frac{p}{1-p}\right]$$

Logit regression is used in Tables 4.4, 4.5, 4.12, 4.13 and 4.19.

1.2.5.4 Cox-Proportional Hazard Model

Proportional hazard models are a set of models that relate the time that passes before some event occurs to one or more covariates that may be associated with the quantity. The models consist of two parts, the underlying hazard function and the effect parameters. The underlying function explains how the hazard (risk) changes over time at levels of covariates and the effect parameters explains how the hazard varies in response to explanatory covariates.

Cox proportional-hazard regression allows analyzing the effect of several risk factors on survival. The probability of the endpoint (death, or any other event of interest, e.g. recurrence of disease) is called the hazard. The hazard is modeled as:

$$\text{H(t)} = H_0(t) \times \exp(b_1X_1 + b_2X_2 + b_3X_3 + ... + b_kX_k)$$

where $X_1, \ \ldots, \ X_k$ are a collection of predictor variables and $H_0(t)$ is the baseline hazard at time t, representing the hazard for a person with the value 0 for all the predictor variables.

$$\ln\left[\frac{H(t)}{H_0(t)}\right] = b_1X_1 + b_2X_2 + b_3X_3 + ... + b_kX_k$$

where $\frac{H(t)}{H_0(t)}$ is the hazard ratio. The coefficients b_1, b_2, b_3 ... b_k are estimated by Cox regression, and can be interpreted in a similar manner to that of multiple logistic regression. Hazard regression is used in Tables 4.14, 4.15, 4.16 and 4.17.

1.2.5.5 t-Statistic

t-statistic is a parametric statistic whose sampling distribution is Student's t-distribution. It is defined by taking a statistic k, whose sampling distribution is a normal distribution, then subtracting the expected value of the statistic (expected value is the sample mean μ), and dividing by an estimate of its standard error (estimate of the error is the sample standard deviation s, divided by $\sqrt{n}$)

t-statistic is given by,

$$t = \frac{k - \mu}{\left(s/\sqrt{n}\right)}$$

t-statistics are most frequently used in statistical hypothesis testing in Student's t-tests and in the computation of certain confidence intervals. The key property of the t-statistic is that it is a pivotal quantity - while defined in terms of the sample mean, its sampling distribution does not depend on the sample parameters, and thus it can be used regardless of what these parameters may be.
t-statistics is used in Tables 4.12, 4.13, 4.14, 4.15, 4.16, 4.17 and 4.19.

1.2.5.6 F-Test

F-test is a statistical test in which the test statistic has an F-distribution under the null hypothesis. F-test is used when the sample size is small, i.e., $n < 30$. Exact F-tests mainly arise when the models have been fit to the data using least squares. F-test is used to test the hypothesis that the population variances are equal. It does this by comparing the ratio of two variances. So, if the variances are equal, the ratio of the variances will be 1. The formula for F is simply

$$\mathrm{F} = \frac{s_1^2}{s_2^2}$$

The variance are arranged so that $F > 1$. That is; $s_1^2 > s_2^2$. F-test plays an important role in the analysis of variance (ANOVA). The calculated value of the F-test with its associated p-value is used to infer whether one has to accept or reject a null hypothesis. If the associated p-value is small i.e. (< 0.05) we say that the test is significant at 5 % and we reject the null hypothesis and accept the alternative one. On the other hand if associated p-value of the test is > 0.05, we accept the null hypothesis and reject the alternative. Evidence against the null hypothesis will be considered very strong if p-value is less than 0.01. In that case, we say that the test is significant at 1%. F-test is used in Tables 4.5 and 4.9.

1.3 Main Problems, General Questions and Outline of the Thesis

In this section, we identify the main problems solved and give an outline of the thesis. Our general objective is to investigate aspects of subprime mortgages and their securitization, Basel capital regulation and their relationship with the SMC as well as subprime data.

1.3.1 Main Problems

The main problems that are solved in this thesis may be formulated as follows:

Problem 1.3.1 (Modeling of Subprime Mortgages): *Can we model subprime mortgages that are able to fully amortize, voluntarily prepay or involuntarily prepay (default) ? (see Subsection 2.2.2 of Section 2.2 in Chapter 2).*

Problem 1.3.2 (Traditional Mortgage Model with Subprime Elements for Capital, Information, Risk, and Valuation): *Can we construct a discrete-time traditional mortgage model with subprime elements for capital, information, risk, and valuation incorporating costs of funds, originator mortgage insurance and profits as well as mortgage defaults ? (see Subsection 2.3.1 of Section 2.3 in Chapter 2).*

Problem 1.3.3 (Optimal Valuation Problem Under Subprime Mortgages): *In order to obtain an optimal SOR valuation with subprime mortgages at face value which decisions regarding mortgage rates, deposits and treasuries must be made ? (see Theorem 2.3.4 of Subsection 2.3.2 in Chapter 2).*

Problem 1.3.4 (Modeling of Capital, Information, Risk and Valuation Under Mortgage Securitization): *Can we construct a discrete-time subprime mortgage model for capital, information, risk and valuation that incorporates losses, monoline insurance, costs of funds and profits under mortgage securitization ? (see Subsection 3.2.2 of Section 3.2 in Chapter 3).*

Problem 1.3.5 (Optimal Valuation Problem Under Subprime Mortgage Securitization): *In order to obtain an optimal valuation under subprime mortgage securitization which decisions regarding mortgage rates, deposits and treasuries must be made ? (see Theorems 3.2.4 and 3.3.3 of Subsections 3.2.4 and 3.3.3, respectively in Chapter 3).*

Problem 1.3.6 (Mortgage Securitization Intricacy and Design Leading to Information Problems, Valuation Opaqueness and Ineffective Risk Mitigation): *Was the SMC partly caused by the intricacy and design of subprime mortgage securitization that led to information (loss, asymmetry and contagion) problems, valuation opaqueness and ineffective risk mitigation ? (see Sections 3.2, 3.3, 3.4, 3.5 and 3.6 in Chapter 3).*

Problem 1.3.7 (Mortgages and Capital Under Basel Regulation (Securitized Case)): *What is the effect of changes in credit ratings on SOR's subprime mortgages and capital when the mortgages are securitized ? (see Chapter 3).*

Problem 1.3.8 (Basel Capital Regulation and the SMC): *Did Basel capital regulation exacerbate the SMC ? (see Chapter 3).*

Problem 1.3.9 (Examples Involving Subprime Mortgage Securitization): *Can we provide appropriate examples to illustrate the main results about subprime mortgage securitization ? (see Chapter 3).*

Problem 1.3.10 (Examples Involving Subprime Data and the SMC): *How does the data about mortgages and structured mortgage products in the period before, during and after the SMC illustrate the theory developed in Chapters 2, 3 ? (see Chapter 4).*

1.3.2 General Questions

This thesis specifically seeks to answer the questions posed in Problems 1.3.1 to 1.3.10 and a few more general ones such as those listed below.

Question 1.3.11 (Risk Management Techniques): *Why did contemporary risk management techniques not contribute towards the mitigation of the SMC and its severity ?*

Question 1.3.12 (Market Discipline and Regulation): *Why didn't market discipline and regulation prevent the SMC ?*

Question 1.3.13 (Causes and Consequences of the SMC): *What were the root causes of the SMC and what is its consequences for the real economy ?*

Question 1.3.14 (Cures for the SMC): *What short- and long-term policies will ultimately cure the SMC ?*

Question 1.3.15 (Prevention of Future Crises): *What can prevent such a crisis from re-occurring ?*

1.3.3 Outline of the Thesis

The thesis is structured as follows. In Chapter 1, we present a brief literature review of SMC-related banking issues such as subprime mortgages, liabilities, capital, profit and valuation. Furthermore, we review relevant literature on the SMC and Basel capital regulation as well as the RMBS and CDO processes. Here, for instance, we pay special attention to moral hazard and adverse selection problems. Terse preliminaries about the main subprime mortgage-related issues mentioned above are also provided. Chapter 1 includes the identification of specific problems to be solved in the thesis. An outline of the chapters are given below.

1.3.3.1 Outline of Chapter 2: Subprime Mortgages

In Chapter 2, we start by looking at the background to subprime mortgage in Section 2.1 and continue with subprime lending with our focus being on SOR's interest rates, subprime mortgages and LTVRs (see Section 2.2). Also, in Section 2.3, we investigate SOR's capital, information, risk and valuation under mortgage origination.

1.3.3.2 Outline of Chapter 3: Subprime Mortgage Securitization

Chapter 3 commences with a brief background to the securitization of subprime mortgages in Section 3.1. In this regard, we consider a mechanism for subprime mortgage securitization, subprime RMBS bonds as well as a motivating example for such securitization. This is followed by Section 3.2 that contains a discussion of an optimal profit problem under RMBSs. To make this possible, capital, information, risk and valuation for a subprime mortgage model under RMBSs is analyzed. An analogue of this under RMBS CDOs is achieved in Section 3.3. Furthermore, Section 3.5

provides examples involving subprime mortgage securitization while Section 3.6 discusses some of the key issues in this chapter. Finally, a 2007-2010 time-line and an appendix is provided in Sections 3.7 and 3.8, respectively.

Section 3.4 of Chapter 3 contains a discussion of the modeling issues related to the cyclicality of bank credit and capital in a securitized context where risk-weights vary as in Basel regulation. Some of the issues dealt with are the quantity and pricing of subprime RMBSs, RMBS CDOs as well as bank capital under Basel regulation (see Subsection 3.4.1). Furthermore, Subsections 3.4.2 and 3.4.3 investigate subprime RMBSs and their rates in a securitized framework with slack and holding constraints, respectively. We conclude Section 3.4 by examining the effect of a current credit rating shock in future periods on subprime RMBSs, B, and RMBS payout rates, r^B in Subsection 3.4.4.

1.3.3.3 Outline of Chapter 4: More Subprime Data

In Chapter 4, Section 4.1 we present the data from the papers [7] and [105]. The data presented related to credit ratings of subprime and Alt-A mortgage backed security deals (see Subsection 4.1.1) and foreclosure rates of portfolio and securitized mortgages (see Subsection 4.1.2). Furthermore we analyze the data on each subsection presented in Section 4.1. The analysis can be found in Subsections 4.2.1 and 4.2.2 of Section 4.2. We then conclude by investigating the connection the presented data has with our models (see Sections 4.3).

1.3.3.4 Outline of Chapter 5: Conclusions and Future Directions

Chapter 5 presents a few concluding remarks and highlights some possible topics for future research.

1.3.3.5 Outline of Chapter 6: Bibliography

In Chapter 6, we list the articles, books and other sources that is cited in the thesis.

1.4 Format of the Thesis

In this section, we establish the format of the thesis. Chapters 2 to 4 each consist of background, main sections, examples, discussions, a 2007-2010 timeline of SMC-related events as well as an appendix.

1.4.1 Background

In each chapter, this subsection contains a background to the subject matter discussed in the chapter. In particular, we consider the main features of the subprime activity to be studied as well as a 2007-2010 timeline of events.

1.4.2 Main Sections

In each chapter, these sections contain the main results.

1.4.3 Examples

In each chapter, this section contains numerical and illustrative examples of some of the main results.

1.4.4 Discussions

This section is constituted by discussions of the main results and examples.

1.4.5 Timeline of SMC-Related Events

In each chapter, this section contains a timeline of SMC-related events involving the issues discussed in the main results.

1.4.6 Appendix

This section contains additional information and proofs of the main results in each chapter.

Chapter 2

Subprime Mortgages

”It’s now conventional wisdom that a housing bubble has burst. In fact, there were two bubbles, a housing bubble and a financing bubble. Each fueled the other, but they didn’t follow the same course.”

– Wall Street Journal, 2007.

”Certainly the underwriting standards for a large proportion of the U.S. home mortgages originated in 2005 and 2006 would give most people a pause. The no-down payment, no-documents and no-stated income-or-assets loans were unprecedented in the history of mortgage finance and clearly ripe for abuse.”

– Prof. Linus Wilson (Louisiana at Lafayette), 2008.

”If a guy has a good investment opportunity and he can’t get funding, he won’t do it. And that’s when the economy collapses.”

– Prof. Frederic Mishkin, 2008.

”Delinquency rates on commercial loans have doubled in the past year to 7 % as more companies downsize and retailers close their doors, according to the Federal Reserve. In some cases, originators are offering a temporary fix by granting mortgagors an extension on loan maturities. On paper, that looks like a plus for the originator because the mortgagor pays a fee or agrees to pay a higher interest rate, or both. This allows originators to avoid having to foreclose or write down these loans as impaired assets. They also can keep the loans on their books as nothing were amiss.”

– Rachel Beck reporting in the Washington Post on Saturday, 11 July 2009.

”For instance, on Friday, 14 September 2007, Northern Rock, the U.K.’s fifth-biggest mortgage lender, started experiencing a bank run after it was revealed that the bank was having trouble raising liquidity. Within one day, customers had withdrawn an estimated £1 billion resulting in the first bank run in the U.K. since 1866. Earlier, applying Basel II principles, Northern Rock announced it would boost its shareholder dividend by 30 % - a step that depleted its capital even as regulators warned about the lender's condition. Adam Applegarth, Northern Rock's CEO at the time of the crisis, defended the lender's dividend boosting before a parliamentary inquiry on the bank run. He argued that because of the high credit quality of its RMLs in Basel II terms, the lender could opt to hold less capital to cover potential losses. To finance its expansion, Northern Rock began to borrow heavily in global financial markets, rather than relying as much on traditional customer bank deposits. In fact, its deposits-to-total liabilities and equity ratio had decreased from 63 % at the end of 1997 to 22 % at the end of 2006, less than half the level of its fellow mortgage lenders. This meant that Northern Rock had access to insufficient cash when its own liquidity dried up after investors decided to stop financing its growth. Eventually, Northern Rock was nationalized by the British government."

– Adam Applegarth, Northern Rock, 2008.

KEYWORDS: House Prices; Loan-to-Value Ratio (LTVR); Subprime Originators (SORs); Mortgagors (MRs); Subprime Residential Mortgage Loans (RMLs); Mortgage Interest Rates; Credit Risk; Credit Ratings Agency (CRA); Subprime Originator Mortgage Insurance (OMI); Subprime Mortgage Crisis (SMC).

As was mentioned in Chapter 1, subprime residential mortgage lending involves mortgage origination to MRs who do not qualify for market interest rates because of income level, down payment size, credit history and employment status. One of the most important aspects of subprime mortgages is the impact of payment reset on the ability of MRs to make monthly repayments on schedule. MRs may find that subprime mortgages are more demanding since subprime originators (SORs) may charge higher interest rates, fees or penalties for late payments or prepayments. A subprime mortgage is worse from SOR's perspective because it is considered riskier than a prime mortgage – with a higher probability of default - so SORs require those higher rates and fees to compensate for additional risk. These mortgages can also be worse for all role players in the economy if this risk does materialize. Such mortgages are designed in a way that enables MRs to repay mortgages based on the appreciation of house prices. In reality, few other consumer mortgage designs have the characteristic that the appreciation of an underlying asset (in our case, house prices) is so closely associated with repayment capacity. Profit is a major indicator of financial crises for households, companies and financial institutions. An example of this from the SMC, is that both the failure of Lehman Brothers and the September 2008 acquisition of Merrill Lynch and Bear Stearns by Bank of America and JPMorgan Chase, respectively, were preceded by a decrease in profitability and an increase in the price of mortgages and their losses. We use the basic fact that profits can be characterized as the difference between income and expenses that are reported in SOR's income statement. In our subsequent analysis, profit – along with regulatory capital – forms an important component of valuation. The current chapter has strong connections with accomplished research in [53], [84], [85] and [86].

2.1 Background to Subprime Mortgages

In this section, we provide a background to subprime originators mortgage insurance (OMI) and subprime mortgage agents for Chapter 2.

2.1.1 Subprime Originator Mortgage Insurance

SOR mortgage insurance (OMI) contracts involve one of the simplest insurances that can be used to hedge against credit risk. An overview is provided in Figure 2.1 below.

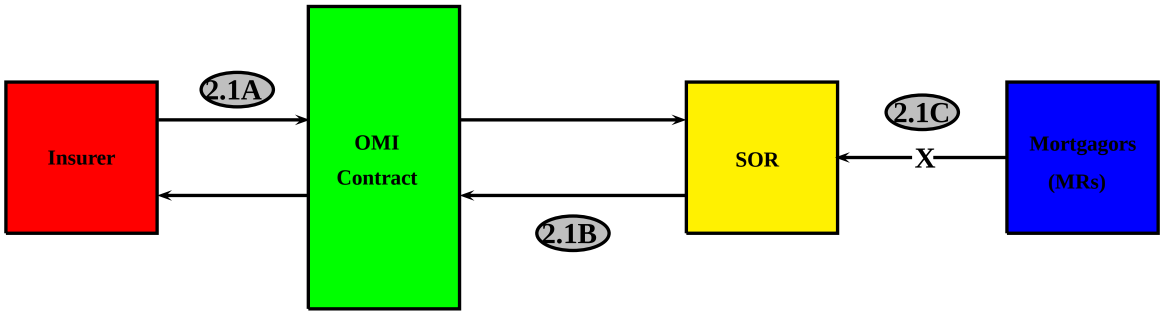


Figure 2.1: Overview of Originator Mortgage Insurance for Subprime Mortgages

In Figure 2.1, **2.1B** is the OMI premium paid by SOR to the insurer. Moreover, **2.1A** represents a settlement by the insurer in the case of a credit event (fails to pay premium **2.1C** or a credit-rating downgrade occurs). In this case, the insurer covers SOR's mortgage losses via **2.1A**.

In this case, we make the following assumption.

Assumption 2.1.1 (Subprime Originator Mortgage Insurance Premium Rate): *Assume that the OMI premium rate is of the form*

$$p_t^i(\mathcal{C}) = h(\Gamma_t(\mathcal{C}), \mathbf{E}[C_t(S)]), \tag{2.1}$$

where Γ_t denote the mass of mortgages in period t, S is SOR's mortgage losses and C_t is SOR's compensation for losses via the protection leg.

This assumption reflects the fact that credit ratings and expected mortgage losses have a role to play in deciding the size of OMI premiums. In general, the OMI procedure follows the steps below. **Step 1:** SOR invests in mortgages which are risky. **Step 2:** SOR decides to hedge this risk by entering into an OMI contract. **Step 3:** SOR makes periodic payments to the insurer. **Step 4:** If mortgages default, the insurer will make a payment against losses faced by SOR. During the SMC some financial institutions that sold OMIs failed to honor some of their obligations due to claim volume. In particular, the insurance companies such as American International Group (AIG), Municipal Bond Insurance Association (MBIA) and Ambac faced ratings downgrades because widespread mortgage defaults increased their potential exposure to OMI losses (see, for instance [119]).

2.1.2 The Economy, Economic Agents and Equilibrium

Throughout this chapter we consider an economy with periods, $t-1$, t and $t+1$, and two main agents, viz., the subprime originator (SOR) and (subprime) mortgagor (MR). In the sequel, SOR and MR are considered to be risk-neutral with stylized interactions. For setting the scene, we assume the following.

Assumption 2.1.2 (Oligopolistic Market, Monopolistic Subprime Originator and Equilibrium): *SOR is assumed to operate in an oligopolistic market for subprime mortgages in which there are several SORs that charge r^M consistent with monopoly power. An individual SOR pre-commits to a quantity of mortgages through its capital holding in period t and mortgage rate competition follows in period $t+1$. To characterize the equilibrium, we analyze the behavior of SOR operating as a monopolist.*

The assumption above implies that competition between monopolistic SORs are fixed in a oligopolistic market. The pre-commitment assumption refers to the fact that the period t choice of capital restricts mortgage in period $t+1$.

2.2 Subprime Mortgages Design

In the U.S., MR's have the option to pay more than the required monthly payment (curtailment), pay off the mortgage in its entirety (voluntary prepayment with the option of refinancing) or to default (involuntary prepayment). The peculiar design features of subprime mortgages are discussed below.

2.2.1 Mortgage Rates

SOR's own mortgage rate, r_t^M, for profit maximizing SORs, may be determined as

$$r_t^M = r_t^L + \varrho_t, \tag{2.2}$$

where r_t^L is, for instance, the 6-month LIBOR rate and ϱ_t is the risk premium.

Extending fully amortizing (two-period) mortgages to subprime MRs may be considered to be too risky so that a mortgage design with special features are needed. In this regard, one of the most important design features of subprime mortgages is payment reset and its impact on the ability of MRs to repay their mortgages. This is understandable if one considers that more than 75 % of the subprime mortgages extended in the period 2004–2006 were hybrid adjustable-rate mortgages (ARMs)[1]. Here the payment reset effect is dependent on the severity of payment reset (depending

[1]Approximately 80 % of U.S. mortgages issued to subprime MRs in the five years up to 2008 were ARMs that are complex financial instruments with payoff features similar to those of interest rate derivatives. By contrast to a fixed-rate mortgage (FRM), MRs holding ARMs retain most of the interest rate risk, subject to a collar (floor and cap). Note that most MRs are not in a position to easily hedge away this interest rate risk. Mortgages are usually hybrid loans since they incorporate the features of both FRMs and ARMs. Another aspect is mortgage payment

on r^M and r^L) as well as MR's house equity at the time of reset (function of initial LTVR and decreases in house prices, H) and market conditions. Before and during the SMC, for an initial period t, low teaser rates, r^{ε}, were charged at the beginning of the mortgage term – that is typically fixed for the first two (for 2/28 mortgages) or three (for 3/27 mortgages) years, and is lower than what MRs would pay for a 30-year FRM. Subsequently, in period $t+1$, higher, market-based step-up rates, r^{ψ}, were charged. As a consequence, for the adjustment periods t and $t+1$ coinciding with r^{ε} and a subsequent r^{ψ}, respectively, we have that

$$r^M = \begin{cases} r_t^{\epsilon} = r_t^L + \varrho_t^{\epsilon}, & \text{Period } t; \\ \\ r_{t+1}^{\psi} = r_{t+1}^L + \varrho_{t+1}^{\psi}, & \text{Period } t+1, \end{cases}$$

where ϱ^{ϵ} and ϱ^{ψ} are the risk premiums for r^{ϵ} and r^{ψ}, respectively.

2.2.2 Subprime Mortgages

We decompose the face value of subprime mortgages denoted by M into distinct components that are fully amortizing, refinancing and defaulting. In this regard, in period t, we consider the decomposition $M_t = (1 - r^f - r^S)M_t + r^f M_t + r^S M_t$, where r^f and r^S are the fractions of M that refinance and default, respectively. In period t, for *nett subprime mortgage losses*, S, we have that $S_t = (1 - r_t^R) r_t^S M_t$, where

$$R_t = \min[aH_t,\ r_t^R r_t^S M_t], \quad a \in [0,1], \tag{2.3}$$

is the recovery amount. S increases when credit ratings, $\mathcal{C}$, deteriorate according to $\dfrac{\partial S_t}{\partial \mathcal{C}_t} < 0$. We note that the above description of S is consistent with empirical evidence that suggests that losses on subprime mortgage portfolios are correlated with credit ratings under any capital adequacy regime (see, for instance, [48]).

From (1.2), we have that

$$M_t = m_0 - m_1 r_t^M + m_2 \mathcal{C}_t + \sigma_t^M, \tag{2.4}$$

where $m_0 = f^M \lambda_0$, $m_1 = f^M \lambda_1$ and $m_2 = f^M \lambda_2$ with f^M being the fraction of the face value of SOR's subprime mortgages to the mortgage demand of all SOR's mortgages and λ_0, λ_1 and λ_2 are as in (1.2) of Subsection 1.2.2.1. We note that M in (2.4) is an increasing function of $\mathcal{C}$ and a decreasing function of r_t^M. Further, we make the next assumption.

---

reset that depends on a number of factors, including but not limited to: the amount of equity that these MRs have in their homes at the time of reset (which itself is a function of LTVR at origination and the severity of the decline in house prices), the severity of payment reset (which depends not only on the loan but also on the 6-month LIBOR interest rate), and of course conditions in the labor market.

Assumption 2.2.1 (Random Shock to Mortgages): *Assume that* σ_t^M *is the* random shock to M *with support* $[\underline{M}, \overline{M}]$ *that is independent of an exogenous stochastic variable,* x_t*, to be characterized below. Also, suppose that* M *follows the first-order autoregressive stochastic process*

$$M_{t+1} = \mu_t^M M_t + \sigma_{t+1}^M, \quad \mu_t^M = g(\overline{c}_t^{M\omega}, p^i(\mathcal{C}_t)), \tag{2.5}$$

where $\overline{c}_t^{M\omega}$ *and* $p^i(\mathcal{C}_t)$ *are the average weighted cost of mortgages and OMI premium rate, respectively. Furthermore,* σ_{t+1}^M *denotes zero-mean stochastic shocks to the mortgage process.*

In Assumption 2.2.1, equation (2.5) embeds the fact that mortgage losses, $S(\mathcal{C}_t)$, and OMI premium rates, $p^i(\mathcal{C}_t) \in [0,1]$, (see (2.1)) are correlated with credit rating. As a result, if $\mathcal{C}$ decreases then p^i increases according to $0 \leq p^i(\mathcal{C}_t) \leq 1, \quad \dfrac{\partial p^i(\mathcal{C}_t)}{\partial \mathcal{C}_t} < 0$. Empirical data supports the claim that p^i is correlated with credit ratings (see, for instance, [22] and [71]).

2.2.3 Subprime Loan-to-Value Ratios

For the purpose of subsequent discussions, in period t, we define the LTVR, L, by the formula

$$L_t = \frac{M_t}{H_t}, \tag{2.6}$$

where M and H are the mortgage and house values, respectively. From the above formulation it is clear that high L results from declining house prices that ultimately curtail the refinancing of mortgages. On the other hand, low ratios imply favorable house equity for subprime MRs.

2.3 Subprime Mortgage Origination and its Connections with Capital, Information, Risk and Valuation

In this section, we firstly discuss SOR's profit with subprime mortgages at face values and then consider its valuation. In this context, we discuss a traditional mortgage model with subprime elements for SOR's profit and valuation. From (1.1), we are able to obtain a corresponding balance sheet involving the face value of SOR's subprime mortgages as

$$M_t + B_t + \mathtt{T}_t = (1-\gamma)D_t + \mathtt{B}_t + K_t, \tag{2.7}$$

where $M = f^M\Lambda$, $B = f^M\widehat{B}$, $\mathtt{T} = f^M\widehat{\mathtt{T}}$, $D = f^M\widehat{D}$, $\mathtt{B} = f^M\widehat{\mathtt{B}}$ and $K = f^M\widehat{K}$, with f^M as before. The rest of SOR's balance sheet items are analogously defined. As a consequence of these relationships, analogues of results for Λ can easily be obtained when attention is restricted to M.

2.3.1 Risk and Profit Under Subprime Mortgages

In this subsection, we discuss SOR's retained earnings and a traditional mortgage model with subprime elements for SOR's profit.

2.3.1.1 Retained Earnings Under Subprime Mortgages

We suspect that SOR's profit, Π, is an increasing function of credit ratings, $\mathcal{C}$, so that $\dfrac{\partial \Pi_t}{\partial \mathcal{C}_t} > 0$. This is connected with procyclicality where profitability increased in the boom prior to the SMC, when credit ratings increased. By contrast, profitability decreased during the SMC because of, among many other factors, an increase in provisioning for bad mortgages.

To establish the relationship between bank profitability and the Basel Accord, a model of bank financing is introduced that is based on [4]. In period t, we know that *bank profits*, Π_t, are used to meet SOR's obligations that include *dividend payments on equity*, $n_t d_t$, where n_t and d_t are the number of SOR's shares and their dividends as well as *interest and principal payments on subordinate debt*, $(1 + r_t^O)O_t$, where O_t is subordinate debt in the case where M is at face value. The *retained earnings*, E_t^r, subsequent to these payments may be computed by using

$$\Pi_t = E_t^r + n_t d_t + (1 + r_t^O)O_t. \tag{2.8}$$

In standard usage, retained earnings refer to earnings that are not paid out in dividends, interest or taxes. They represent wealth accumulating in the bank and should be capitalized in the value of the bank's equity. Retained earnings also are defined to include bank charter value income. Normally, *charter value* refers to the present value of anticipated profits from future lending.

In each period, banks invest in fixed assets (including buildings and equipment) which we denote by F_t. For simplicity, we assume the following.

Assumption 2.3.1 (Depreciation of Fixed Assets): *Assume that SOR maintains fixed assets, F_t, throughout its existence so that it must only cover the costs related to the* depreciation of fixed assets*, ΔF_t.*

These activities are financed through retaining earnings and the eliciting of additional debt and equity, E_t, so that

$$\Delta F_t = E_t^r + (n_{t+1} - n_t)E_t + O_{t+1}. \tag{2.9}$$

We can use (2.8) and (2.9) to obtain an expression for bank capital of the form

$$K_{t+1} = n_t(d_t + E_t) + (1 + r_t^O)O_t - \Pi_t + \Delta F_t, \tag{2.10}$$

where K_t is defined by $K_t = f^M \widehat{K}_t$ with $\widehat{K}$ being defined as in (1.1).

2.3.1.2 A Traditional Mortgage Model With Subprime Elements for Profit Under Subprime Mortgages

A traditional mortgage model with subprime elements for SOR's profit at face value can be built by considering the difference between cash inflow and outflow. For this profit, in period t, *cash inflow* is constituted by returns on risky marketable securities, $r_t^B B_t$, mortgages, $r_t^M M_t$, Treasuries, $r_t^{\mathtt{T}}\mathtt{T}_t$, recovery amount, R_t, OMI protection leg payments, $C(S(\mathcal{C}_t))$, and Π_t^p is the present value of future profits from additional mortgages based on current mortgages. Furthermore, we consider the cost of funds for M, $\overline{c}^{M\omega}M_t$, face value of mortgages in default, $r_t^S M_t$, recovery value of mortgages in default, $r_t^R M_t$, OMI premium, $p^i(\mathcal{C}_t)M_t$, the all-in cost of holding risky marketable securities, $c_t^B B_t$, interest paid to depositors, $r_t^D D_t$, cost of taking deposits, $c_t^D D_t$, interest paid to borrowers, $r_t^{\mathtt{B}}\mathtt{B}_t$, the cost of borrowing, $c_t^{\mathtt{B}}\mathtt{B}_t$, provisions against deposit withdrawals, $P^{\mathtt{T}}(\mathtt{T}_t)$, and the value of mortgage losses $S(\mathcal{C}_t)$, as *cash outflow*. Here r^D and c^D are the deposit rate and marginal cost of deposits, respectively, while $r^{\mathtt{B}}$ and $c^{\mathtt{B}}$ are the borrower rate and marginal cost of borrowing, respectively. In this case, we have that a traditional mortgage model with subprime elements for SOR's profit with all SOR's mortgages at market value may be expressed as

$$\begin{aligned}\Pi_t &= \left(r_t^M - \overline{c}_t^{M\omega} - p_t^i + c_t^p r_t^f - (1-r_t^R)r_t^S\right)M_t + C(\mathbf{E}[S(\mathcal{C}_t)]) \qquad (2.11)\\ &\quad + \left(r_t^B - c_t^B\right)B_t + r_t^{\mathtt{T}}\mathtt{T}_t - P^{\mathtt{T}}(\mathtt{T}_t) - \left(r_t^D + c_t^D\right)D_t - \left(r_t^{\mathtt{B}} + c_t^{\mathtt{B}}\right)\mathtt{B}_t + \Pi_t^p.\end{aligned}$$

Below we roughly attempt to associate different risk types to different cash inflow and outflow terms in (2.11). We note that the cash inflow term $r_t^M M_t$ embed credit and market risk (in particular, interest rate risk) while $c_t^p r_t^f M_t$ can be associated with market risk (in particular, prepayment risk). Also, $(r_t^B - c_t^B)B_t$ mainly embeds market risk. Furthermore, $C(\mathbf{E}[S(\mathcal{C}_t)])$ and Π_t^p involve at least credit risk (particularly, counterparty risk) and market risk (more specifically, interest rate, basis, prepayment, liquidity and price risk), respectively. In (2.11), the cash outflow terms $\overline{c}_t^{M\omega}M_t$ and $p^i(\mathcal{C}_t)M_t$ carry credit and operational risks. Also, $(1-r_t^R)r_t^S M_t$ carries credit and market risk (including valuation risk). Deposit withdrawals, $P^{\mathtt{T}}(\mathtt{T}_t)$, carries systemic and market risk. Finally, the term $\left(r_t^{\mathtt{B}} + c_t^{\mathtt{B}}\right)\mathtt{B}_t$ embeds market and credit risk. In reality, the risks that we associate with each of the cash inflow and outflow terms in (2.11) are more complicated than presented above. For instance, these risks are inter-related and may be strongly correlated with each other. All of the above risk-carrying terms contribute to systemic risk that affects the entire banking system.

2.3.2 Valuation Under Subprime Mortgages

In this subsection, we discuss SOR's nett cash flow and optimal valuation under subprime mortgages.

2.3.2.1 Nett Cash Flow Under Subprime Mortgages

If the expression for retained earnings given by (2.8) is substituted into (2.9), SOR's *nett cash flow generated* is given by $N_t = \Pi_t - \Delta F_t = n_t d_t + (1 + r_t^O)O_t - K_{t+1} + n_t E_t$, where n_t is the number of shares in SOR's equity. In addition, we have the relationship

Bank Value for a Shareholder = Nett Cash Flow + Ex-Dividend Bank Value

This translates to the expression $N_t + K_{t+1}$. Furthermore, the stock analyst evaluates the expected future cash flows in j periods based on a *stochastic discount factor*, $\delta_{t,j}$ such that the value of the bank is

$$N_t + \mathbf{E}_t\left[\sum_{j=1}^{\infty} \delta_{t,j} N_{t+j}\right]. \tag{2.12}$$

2.3.2.2 Optimal Valuation Under Subprime Mortgages

In this subsection, we make use of the modeling of banking activities from previous discussions to solve SOR's optimal valuation problem. From [48], we have that SOR's total capital constraint for subprime mortgages at face value is given by

$$K_t = n_t E_{t-1} + O_t \geq \rho\left[\omega(\mathcal{C}_t)M_t + \omega^B B_t + 12.5 f^M (mVaR + \mathsf{0})\right], \tag{2.13}$$

where $\omega(\mathcal{C}_t)$ and ω^B are the risk-weights related to SOR's subprime mortgages at face value and risky marketable securities, respectively, while ρ – Basel II pegs ρ at approximately 0.08 – is the Basel capital regulation ratio of regulatory capital to risk-weighted assets. In order to state an SOR's optimal valuation problem, it is necessary to assume the following.

Assumption 2.3.2 (Subprime Originator's Performance Criterion): *Suppose that SOR's performance criterion, J, at t is given by*

$$\begin{aligned} J_t &= \Pi_t + l_t\left[K_t - \rho\Big(\omega(\mathcal{C}_t)M_t + \omega^B B_t + 12.5 f^M (mVaR + \mathsf{0})\Big)\right] \\ &\quad - c_t^{dw}\Big[K_{t+1}\Big] + \mathbf{E}_t\Big[\delta_{t,1} V\Big(K_{t+1},\ x_{t+1}\Big)\Big], \end{aligned} \tag{2.14}$$

where l_t is the Lagrangian multiplier for the total capital constraint, K_t is defined by $K_t = f^M \widehat{K}_t$ with $\widehat{K}$ being defined as in (1.1), $\mathbf{E}_t[\cdot]$ is the expectation conditional on the bank's information at time t and x_t is the deposit withdrawals in period t with probability distribution $f(x_t)$. Also, c_t^{dw} is the deadweight cost of total capital that consists of common and preferred equity as well as subordinate debt, V is the value function with a discount factor denoted by $\delta_{t,1}$.

SOR's optimal valuation problem is to maximize the *bank value* given by (2.12). We can now state SOR's optimal valuation problem as follows.

Problem 2.3.3 (Statement of Subprime Originator's Optimal Valuation Problem): *Suppose that the total capital constraint and the performance criterion, J, are given by* (2.13) *and* (2.14), *respectively. SOR's optimal valuation problem is to maximize the value of the bank given by* (2.12) *by choosing the mortgage rate, deposits and regulatory capital for*

$$V(K_t,\ x_t) \quad = \quad \max_{r_t^M,\ D_t,\ \Pi_t} J_t, \tag{2.15}$$

subject to the mortgages, balance sheet, cash flow and financing constraints given by (2.4), (2.7), (2.11) *and* (2.10), *respectively.*

Next, we find a solution to Problem 2.3.3 when the capital constraint (2.13) holds as well as when it does not. In this regard, the main result can be stated as follows.

Theorem 2.3.4 (Solution to Subprime Originator's Optimal Valuation Problem (Holding)): *Suppose that J and V are given by* (2.14) *and* (2.15), *respectively. When the capital constraint given by* (2.13) *holds (i.e., $l_t > 0$), a solution to SOR's optimal valuation problem yields an optimal M and r^M of the form*

$$M_t^* = \frac{K_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B B_t + 12.5 f^M (mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)} \tag{2.16}$$

and

$$r_t^{M*} = \frac{1}{m_1}\biggl(m_0 + m_2\mathcal{C}_t + \sigma_t^M - M_t^*\biggr), \tag{2.17}$$

respectively. In this case, SOR's corresponding optimal deposits, provisions for deposit withdrawals and profits are given by

$$\begin{aligned} D_t^* \quad &= \quad \frac{1}{1-\gamma}\biggl(\overline{D} + \frac{\overline{D}}{r_t^p}\Bigl[r_t^{\mathtt{T}} + (r_t^B - c_t^B) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Bigr] \\ &\quad + \frac{K_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B B_t + 12.5 f^M (mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)} + B_t - K_t - \mathtt{B}_t\biggr), \end{aligned} \tag{2.18}$$

$$\mathtt{T}_t^* \quad = \quad \overline{D} + \frac{\overline{D}}{r_t^p}\Bigl[r_t^{\mathtt{T}} + (r_t^B - c_t^B) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Bigr] \tag{2.19}$$

and

$$\Pi_t^* = \left(\frac{K_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B B_t + 12.5 f^M (mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)}\right)$$

$$\left\{\frac{1}{m_1}\left(m_0 - \frac{K_t}{\rho\omega(\mathcal{C}_t)} + \frac{\omega^B B_t + 12.5 f^M (mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)} + m_2\mathcal{C}_t + \sigma_t^M\right)\right.$$

$$\left. - \left(\overline{c}_t^{M\omega} - c_t^p r_t^f + p_t^i + (1 - r_t^R) r_t^S + (r_t^D + c_t^D)\frac{1}{(1-\gamma)}\right)\right\} \quad (2.20)$$

$$- \left((r_t^D + c_t^D)\frac{1}{(1-\gamma)}\right)\left(B_t - K_t - \mathtt{B}_t\right)$$

$$+ \left(\overline{D} + \frac{\overline{D}}{r_t^p}\left[r_t^{\mathtt{T}} + (r_t^B - c_t^B) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\right]\right)\left(r_t^{\mathtt{T}} - (r_t^D + c_t^D)\frac{1}{(1-\gamma)}\right)$$

$$+ \left(r_t^B - c_t^B\right) B_t - \left(r_t^{\mathtt{B}} + c_t^{\mathtt{B}}\right)\mathtt{B}_t + C(\mathbf{E}[S(\mathcal{C}_t)]) - P^{\mathrm{T}}(\mathtt{T}_t) + \Pi_t^p,$$

respectively.

In the case where the capital constraint (2.13) does not hold, the following corollary follows directly.

Corollary 2.3.5 (Solution to the Optimal Valuation Problem (Not Holding)): *Suppose that J and V are given by (2.14) and (2.15), respectively. When the capital constraint (2.13) does not hold (i.e., $l_t = 0$), a solution to SOR's optimal valuation problem stated in Problem 2.3.3 yields optimal M and r^M of the form*

$$M_t^{n*} = \frac{1}{2}(m_0 + m_2\mathcal{C}_t + \sigma_t^M) - \frac{m_1}{2}\left[\overline{c}_t^{M\omega} + p_t^i + (1 - r_t^R) r_t^S + \frac{1}{1-\gamma}(r_t^D + c_t^D) - c_t^p r_t^f\right] \quad (2.21)$$

and

$$r_t^{M^{n*}} = \frac{1}{2m_1}(m_0 + m_2\mathcal{C}_t + \sigma_t^M) + \frac{1}{2}\left[\overline{c}_t^{M\omega} + p_t^i + (1 - r_t^R) r_t^S + \frac{1}{1-\gamma}(r_t^D + c_t^D) - c_t^p r_t^f\right], \quad (2.22)$$

respectively. In this case, the corresponding $\mathtt{T}_t$, deposits and profits are given by

$$\mathtt{T}_t^{n*} = \overline{D} + \frac{\overline{D}}{r_t^p}\left[r_t^{\mathtt{T}} + (r_t^B - c_t^B) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\right] \quad (2.23)$$

$$D_t^{n*} = \frac{1}{1-\gamma}\Big(\overline{D} + \frac{\overline{D}}{r_t^p}\Big[r_t^{\mathtt{T}} + (r_t^B - c_t^B) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Big]$$
$$+M_t^{n*} + B_t - K_t - \mathtt{B}_t\Big). \tag{2.24}$$

and

$$\Pi_t^{n*} = \Big(\frac{1}{2}(m_0 + m_2\mathcal{C}_t + \sigma_t^M)$$
$$-\frac{m_1}{2}\Big[\overline{c}_t^{M\omega} + p_t^i + (1-r_t^R)r_t^S + \frac{1}{1-\gamma}(r_t^D + c_t^D) - c_t^p r_t^f\Big]\Big)$$
$$\Big\{\frac{1}{2m_1}(m_0 + m_2\mathcal{C}_t + \sigma_t^M)$$
$$-\frac{1}{2}\Big[\overline{c}_t^{M\omega} + p_t^i + (1-r_t^R)r_t^S + \frac{1}{1-\gamma}(r_t^D + c_t^D) - c_t^p r_t^f\Big]\Big\}$$
$$-\Big((r_t^D + c_t^D)\frac{1}{1-\gamma}\Big)\Big(B_t - K_t - \mathtt{B}_t\Big) + \Big(\overline{D} \tag{2.25}$$
$$+\frac{\overline{D}}{r_t^p}\Big[r_t^{\mathtt{T}} + (r_t^B - c_t^B) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Big]\Big)$$
$$\Big(r_t^{\mathtt{T}} - (r_t^D + c_t^D)\frac{1}{1-\gamma}\Big) + \Big(r_t^B - c_t^B\Big)B_t - \Big(r_t^{\mathtt{B}} + c_t^{\mathtt{B}}\Big)\mathtt{B}_t$$
$$+C(\mathbf{E}[S(\mathcal{C}_t)]) - P^{\mathtt{T}}(\mathtt{T}_t) + \Pi_t^p,$$

respectively.

2.3.3 Optimal Valuation and Loan-to-Value Ratios

In this subsection, we connect the results from Subsection 2.3.2 with LTVRs, subprime mortgage rates and prepayment costs. The following corollary about LTVRs follows immediately from Theorem 2.3.4.

Corollary 2.3.6 (Loan-to-Value Ratios from Subprime Originator's Optimal Valuation Problem): *Suppose that the hypothesis of Theorem 2.3.4 holds and that the LTVR is given by* (2.6). *When* $l_t > 0$, *then the LTVR corresponding to the optimal* M *from* (2.16) *is given by*

$$L_t^* = \frac{K_t}{\rho\omega(\mathcal{C}_t)H_t} - \frac{\omega^B B_t + 12.5 f^M(mVaR + \mathtt{O})}{\omega(\mathcal{C}_t)H_t}. \tag{2.26}$$

On the other hand, when $l_t = 0$*, then the LTVR corresponding to an optimal* M *from* (2.21) *is given by*

$$L_t^{n*} = \frac{1}{2H_t}(m_0 + m_2\mathcal{C}_t + \sigma_t^M) - \frac{m_1}{2H_t} \left[\overline{c}_t^{M\omega} + p_t^i + (1 - r_t^R)r_t^S + \frac{1}{1-\gamma}(r_t^D + c_t^D) - c_t^p r_t^f\right]. \tag{2.27}$$

Proof. The proof follows from the hypotheses of Theorem 2.3.4 and Corollary 2.3.5. □

The paper [41] provides a relationship between SOR's subprime mortgage rate, r^M, the LTVR, L, and a prepayment cost, c^p, by means of the simultaneous equations model

$$\begin{aligned} r_t^M &= \alpha^0 L_t + \alpha^1 c_t^p + \alpha^2 X_t + \alpha^3 Z_t^{r^M} + u_t \\ L_t &= \beta^1 r_t^M + \beta^2 X_t + \beta^3 Z_t^L + v_t \\ c_t^p &= \gamma^1 r_t^M + \gamma^2 X_t + \gamma^3 Z_t^{c^p} + w_t. \end{aligned} \tag{2.28}$$

MRs typically have a choice of r^M and L, while the choice of c^p triggers an adjustment to r^M. Thus, L and c^p are endogenous variables in the r^M-equation. There is no reason to believe that L and c^p are simultaneously determined. Therefore, c^p does not appear in the L-equation and L does not make an appearance in the c^p-equation. From [41], matrix X comprises exogenous explanatory variables such as mortgage characteristics (owner occupied, mortgage purpose, documentation requirements); MR characteristics (income and Fair Isaac Corporation (FICO) score) and distribution channel (broker origination). The last term in each equation Z^{r^M}, Z^L or Z^{c^p} comprises the instruments excluded from either of the other equations. [41] points out that the model is a simplification with other terms such as type of interest rate, the term to maturity and distribution channel possibly also being endogenous. Nevertheless, by consideration of simultaneity in the choice of r^M and c^p, it is possible to address the issue of possible bias in estimates of the effect of c^p on r^M.

The next result follows from Theorem 2.3.4 and relates the subprime mortgage rate, r^M, prepayment cost, c^p and LTVR, L.

Corollary 2.3.7 (Subprime Mortgage Rate, Prepayment Cost and Loan-to-Value Ratio)*: Suppose that the hypothesis of Theorem 2.3.4 holds and that* (2.6) *and* (2.28) *hold. On the other hand, when* $l_t = 0$*, then the LTVR corresponding to an optimal* M *from* (2.21) *and the optimal prepayment cost are given by*

$$L_t^* = \frac{\beta^1}{2m_1}(m_0 + m_2\mathcal{C}_t + \sigma_t^M) + \frac{\beta^1}{2}\left[(1 - r_t^R)r_t^S + \frac{1}{1-\gamma}(r_t^D + c_t^D) + (\overline{c}_t^{M\omega} + p_t^i - c_t^p r_t^f)\right] + \beta^2 X_t + \beta^3 Z_t^L + v_t, \tag{2.29}$$

and

$$c_t^{p*} = \frac{\gamma^1}{2m_1}(m_0 + m_2\mathcal{C}_t + \sigma_t^M) + \frac{1}{2}\Big[(1 - r_t^R)r_t^S + \frac{1}{1-\gamma}(r_t^D + c_t^D) \qquad (2.30)$$

$$+(\overline{c}_t^{M\omega} + p_t^i - c_t^p r_t^f)\Big] + \gamma^2 X_t + \gamma^3 Z_t^{c^p} + w_t,$$

respectively.

Derived equations in this chapter are applied in Chapter 3.

Chapter 3

Subprime Mortgage Securitization

"The current credit crisis will come to an end when the overhang of inventories of newly built homes is largely liquidated, and home price deflation comes to an end. That will stabilize the now-uncertain value of the home equity that acts as a buffer for all home mortgages, but most importantly for those held as collateral for residential MBSs. Very large losses will, no doubt, be taken as a consequence of the crisis. But after a period of protracted adjustment, the U.S. economy, and the world economy more generally, will be able to get back to business."

– Alan Greenspan, 2007.

"Although there are only a few studies, the evidence to date is consistent with the experience of a quarter century of securitization working very well. The assertions of the *originate-to-distribute* view simply are not consistent with what we know. The idea that there is a moral hazard due to the alleged ability of originators to sell loans without fear of recourse, and with no residual risk, also assumes that the buyers of these loans are irrational. That may be but the irrationality, it turns out, had to do with the belief that house prices would not fall."

– Prof. Gary Gorton, Yale University, 2008.

"I view the rating agencies as one of the key culprits. ...They were the party that performed the alchemy that converted the securities from F-rated to A-rated. The banks could not have done what they did without the complicity of the rating agencies."

– Prof. Joseph Stiglitz, Columbia University, 2009.

KEYWORDS: Subprime Originators (SORs); Mortgagors (MRs); Subprime Investing Banks (SIB); Credit Ratings Agency (CRA); Servicers (SRs); Special Purpose Vehicles (SPVs); Special Investment Vehicles (SIVs); Residential Mortgage Loans (RMLs); Residential Mortgage-Backed Securities (RMBSs); Collateralized Debt Obligations (CDOs); Asset-Backed Commercial Paper (ABCP); Subprime Mortgage Crisis (SMC); Basel Capital Regulation; Slack Constraints; Holding Constraints; Mortgage Quantity and Pricing.

Under normal circumstance, the securitization of mortgages is an efficient, incentive compatible response to bankruptcy costs and capital requirements. However, when these securitized mortgages are subprime, several problems arise. In this chapter, we investigate the structural features of subprime RMBSs, CDOs and other structured notes. Our deliberations separately focus on capital, information, risk and valuation under RMBSs and RMBS CDOs. With regard to the latter, this chapter discusses credit (including counterparty and default), market (including interest rate, price and liquidity), operational (including house appraisal, valuation and compensation), tranching (including maturity mismatch and synthetic) and systemic (including maturity transformation) risks.

This chapter also addresses issues related to bank capital regulation and the SMC. Some of the world's top banking experts spent nearly a decade designing regulation in the form of the Basel capital accords to ensure the health of the global banking industry.

> What if some of their suppositions were inaccurate ?

The possibility that this is true was debated during the SMC that started unraveling from 2007 onwards. This crisis in world financial markets, initiated by mortgage losses in the U.S., brought into question the effectiveness of global credit rating policy, financial stability and financial regulation such as the new Basel II capital adequacy framework for banks (see, for instance, [11]).

Chapter 3 supports the IDIOM hypothesis that postulates that the SMC was mainly caused by the intricacy and design of subprime mortgage origination, securitization and systemic agents that led to information (loss, asymmetry and contagion) problems and valuation opaqueness. As a consequence, subprime agents could not implement effective risk management policies. This claim is illustrated via several examples. More specifically, information was lost due to intricacy resulting from an inability to look through the chain of mortgages and structured products – reference mortgage portfolios and RMBSs, ABS CDOs, structured investment vehicles (SIVs) etc. This situation was exacerbated by a lack of understanding of how subprime securities and structures are designed and intertwined. It is our opinion that the interlinked or nested unique security designs that were necessary to make the subprime market function resulted in information loss among SIBs as the chain of structured products stretched longer and longer. Also, asymmetric information arose because SIBs could not penetrate the portfolio far enough to make a determination of the exposure to the financial sector. An additional problem involved information contagion that played a crucial role in shaping defensive retrenchment in interbank as well as mortgage markets during the SMC. The valuation opaqueness problem related to structured products results from the dependence of valuation on house prices and its independence from the performance of the reference mortgage portfolios. Finally, we claim that SMC partly resulted from mortgage agents' appetite for rapid growth and search for high yields – both of which were very often pursued at the expense of risk mitigation practices. The subprime structure described above is unique to the SMC and will be elaborated upon in the sequel.

3.1 Background to the Securitization of Subprime Mortgages

In this section, we discuss the basic securitization mechanism, background to subprime RMBS bonds (sen/sub 6-pack and XS/OC structures, lock-out and step-down provisions, delinquency and loss triggers as well as RMBS principal and interest waterfalls), background to collateralized debt obligations (CDOs) and other structured notes (design of CDOs as well as structured investment vehicles (SIVs) and asset-backed commercial paper (ABCP)) and a motivating example for the securitization of subprime mortgages.

3.1.1 Mechanism for Subprime Mortgage Securitization

Figure 3.1 below provides a diagrammatic overview of the structure of a subprime mortgage securitization as it is discussed in this thesis.

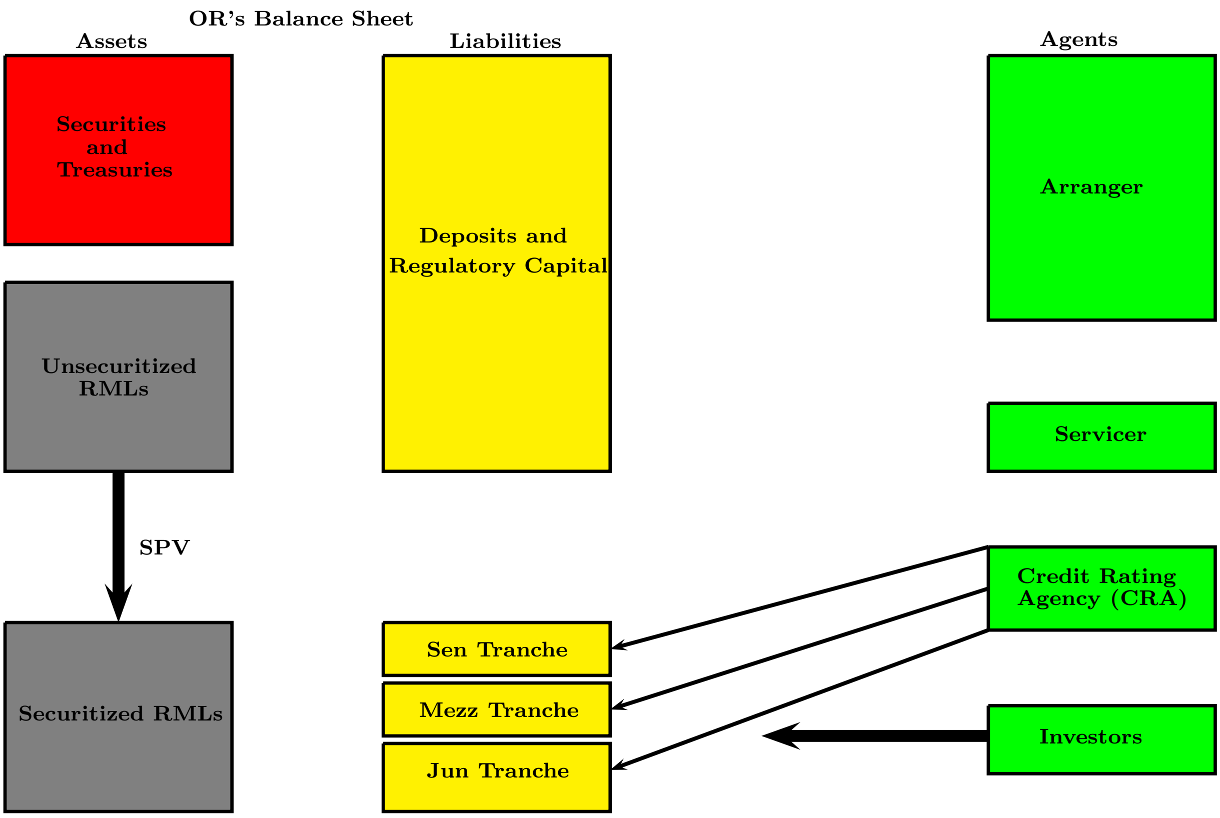


Figure 3.1: Diagrammatic Overview of a Subprime Mortgage Securitization Structure

Figure 3.1 shows that securitized mortgages are sliced into 3 *tranches*, viz., *senior* (usually AAA rated and abbreviated as sen), *mezzanine* (usually AA, A, BBB rated and abbreviated as mezz) and *junior (equity) tranches* (usually BB, B rated and unrated and abbreviated as jun) in order of contractually specified claim priority. CRAs provide a rating for each tranche and necessary information to investors to make them tradeable. Tranches have different risk-return profiles and different maturities. The securitized mortgages owned by SPV generate cash flows that serve to pay RMBS bond holders. The arranger structures the transaction while the servicer takes care of day-to-day operations during the lifetime of the RMBS deal. The SPV isolates the reference mortgage portfolio from SOR. A non-recourse mortgage sale implies that SOR is not responsible for losses by bond holders. The structuring of the RMBS deal relies on covenants that rule the governance of the SPV during its lifetime.

3.1.2 Background to Subprime RMBS Bonds

Subprime mortgage securitization reflects the design of the subprime mortgages. This meant that credit risk was spread in a particular way and that additional complexity arose when assessing the relative value of a particular subprime RMBS. Importantly, credit risk from RMBSs is inextricably linked to the particular bond and transaction structure of which it is a part. In this subsection, we discuss RMBS bond structure as it pertains to sen/sub 6-Pack and XS/OC structures, lock-out and step-down provisions, delinquency and loss triggers as well as principal and interest rate waterfalls.

3.1.2.1 Sen/Sub 6-Pack and XS/OC Structures

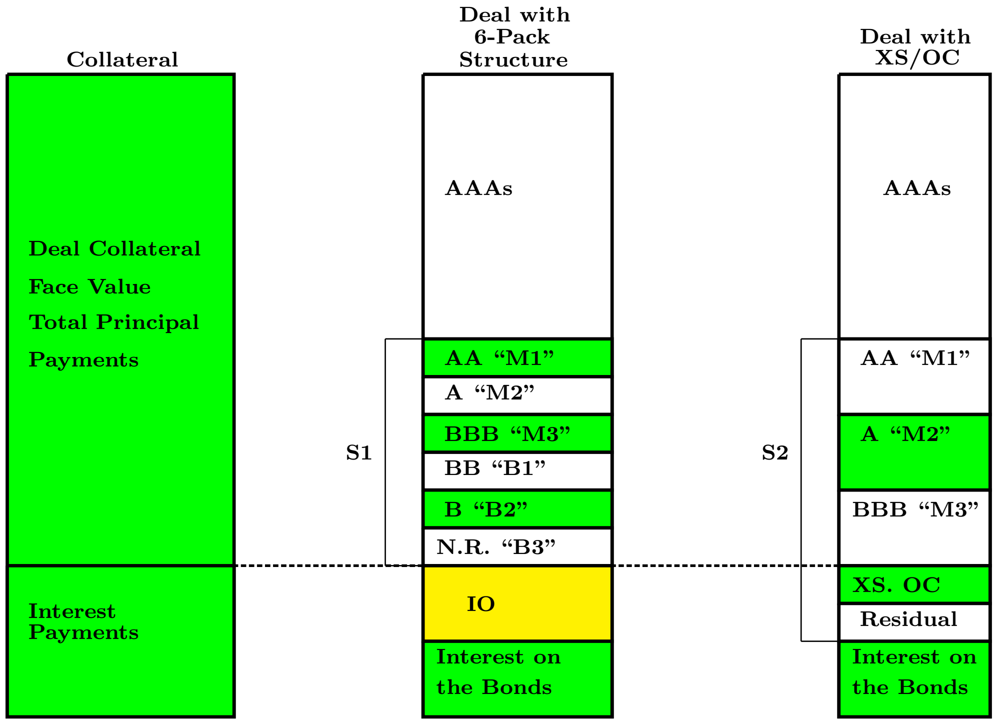
As was mentioned before, RMBSs mainly use one or both of the sen/sub shifting interest structure – known as the *6-pack* structure (with 3 mezz and 3 sub RMBS bonds junior to the AAA bonds) – or XS/OC (excess spread/over-collateralization) structure (see, for instance, [13]). Figure 3.2 below displays these two types of RMBS deal structures.

XS/OC deals are more complicated than straight sen/sub deals. For instance, additional complexity arises from the *available funds cap* (AFC) risk. Generally, RMBS bonds in XS/OC deals pay a floating coupon, r^B, while subprime reference mortgage portfolios (collateral) typically pay a fixed rate, r^M, until the reset date on hybrid ARMs. In this case, the risk that interest paid into the deal from the reference mortgage portfolio, r^M, is not sufficient to make coupon payments, r^B, to RMBS bond holders may arise. To mitigate this situation, the deal may be subject to an AFC. Here, SORs receive interest as the minimum of the sum of the index rate, r^L, (i.e., 6-month LIBOR) and margin, ϱ, or the weighted average AFC, $\overline{r}^{a\omega}$. Symbolically, this means that

$$r^B = \min[r^L + \varrho, \overline{r}^{a\omega}]. \tag{3.1}$$

3.1.2.2 Lock-Out and Step-Down Provisions

The lock-out and step-down provisions are common structural features of RMBS deals. Subsequent to deal initiation, the *lock-out* provision locks out the mezz and sub bonds from receiving principal, $\varpi^1 f^\Sigma M$, and prepayments, $\varpi^2 f^p f^\Sigma M$, where ϖ^1 and ϖ^2 are the fraction of the reference mortgage portfolio, $f^\Sigma M$, that is paid as principal to the RMBS bond and the fraction of the prepaying



S1 = Classic 6-Pack Credit Enhancement
S2 = Excess-Spread O/C-Based Credit Enhancement

Figure 3.2: Sen/Sub 6-Pack Structure vs. XS/OC Structure; Source: UBS

reference mortgage portfolio, $f^p f^\Sigma M$, that is paid as prepayment to the RMBS bond, respectively. This means that during the lock-out period, amortization is sequential[1]. The lock-out period, and other details, differ depending on the characteristics of the reference mortgage portfolio (collateral). During the deal, the XS/OC feature of RMBSs leads to an accumulation of credit enhancement (CE) equity from the reference portfolio itself. Prior to the step-down date, sen tranches receive 100 % of $\varpi^1 f^\Sigma M$. When the sen bonds are completely amortized away, prepayments, $\varpi^2 f^p f^\Sigma M$, continue to sequentially amortize, with the next class being the outstanding mezz bonds. After the lock-out period, deals are allowed to *step-down*, i.e., principal payments, $\varpi^1 f^\Sigma M$, can be distributed to the sub tranches provided that CE limits are twice the original levels and the deal passes other performance criteria, measured by triggers. The *step-down date* in an XS/OC deal is the latter of a specified month (e.g., 36 months) and the date at which the sen CE reaches a specified level (e.g., 52 %).

3.1.2.3 Delinquency and Loss Triggers

The allocation of CE over time depends on triggers that reflect the credit quality of the subprime reference mortgage portfolios. Under certain circumstances, triggers will cause a reallocation of $\varpi^1 f^\Sigma M$ to protect or increase subordination levels. Generally speaking, the two types of triggers are *delinquency* and *loss* triggers. A trigger is said to *pass* if the collateral does not breach the specified constraints, and to *fail* if those conditions are hit or breached. If a trigger fails, $\varpi^1 f^\Sigma M$ to mezz and sub bonds are delayed or stopped, preventing a reduction of CE for the sen bonds.

[1]Sequential amortization means that there is a sequential elimination of RMBS bond liabilities in regular payments over a specified period of time.

Loss triggers are target levels of cumulative losses as of specific dates after the RMBS deal was initiated. XS builds up throughout the deal with a CE threshold (target) level eventually being attained. Once this threshold is breached, XS can be paid to the residual holder, thus becoming unavailable to cover reference mortgage portfolio losses. The aforementioned triggers have many complicated features[2] that are partially explained, for instance, in [81], [80] and [79]. Moreover, cross-collateralization may occur where some deals contain multiple mortgage types. In this regard, after interest payments are made on RMBS bonds of one type, funds that remain can be used to pay interest to bonds in another.

3.1.2.4 RMBS Principal and Interest Waterfalls

As is shown in Figure 3.3 (see, also, Figures 3.4 and 3.5), invariably principal waterfalls are paid sequentially for the first 36 months. This means that all scheduled principal, $\varpi^1 f^\Sigma M$, and prepayments, $\varpi^2 f^p f^\Sigma M$, are utilized to repay the sen bond holders first, until they are paid in full. Then, these payments go to the next senior RMBS bond holder until they are fully paid. This process repeats itself until eventually all bond holders are fully compensated.

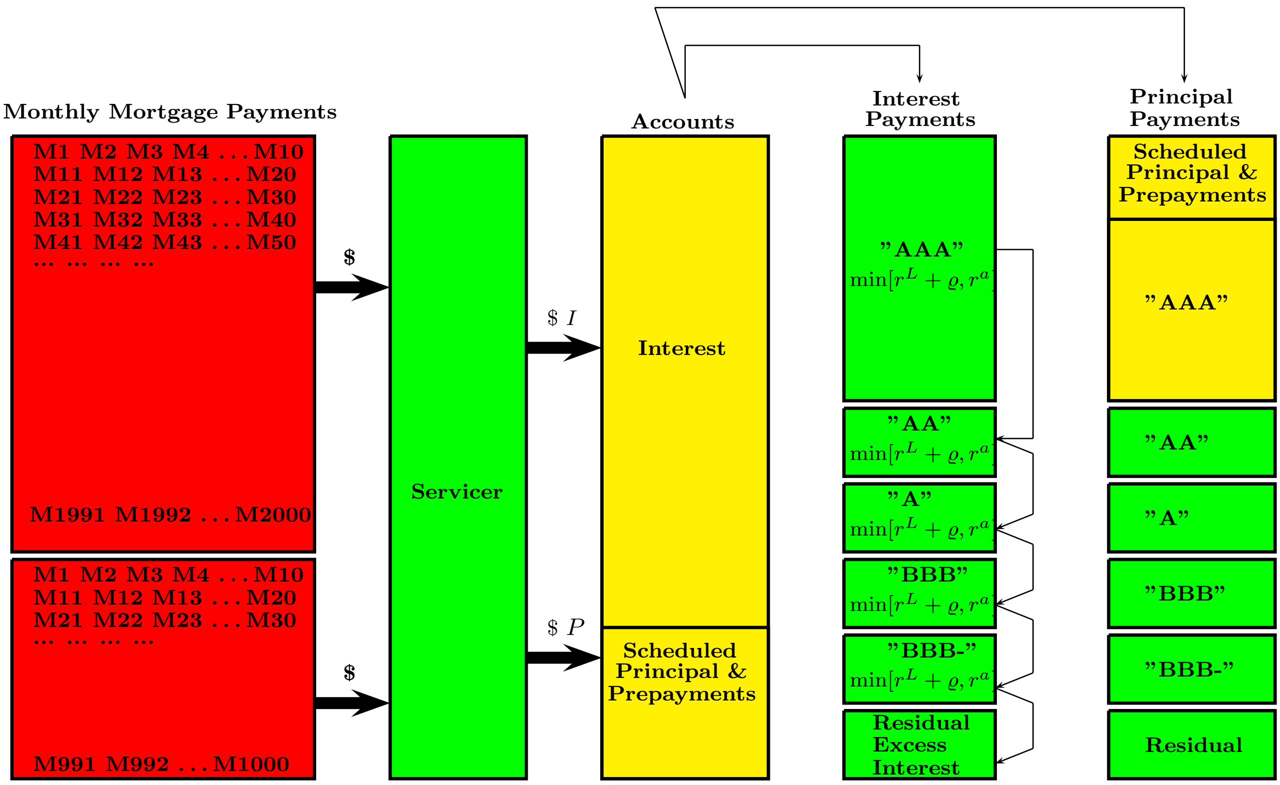


Figure 3.3: Sample Subprime RMBS Payments; Source: [67]

[2]For example, the loss trigger in months 1-36 might be 3.75 %, rise to 6.75 % in months 37-50, 6.85 % in months 51-72, and stay flat at 7.25 % thereafter.

As discussed before, usually after the first 36 months (Situation 1 below), CE steps down if certain performance tests have been met (Situation 2 below). For example, if $\widetilde{O}^c$ has been met, CE steps down by repaying sub tranche bond holders, where $\widetilde{O}^c$ is fixed at double the original subordination.

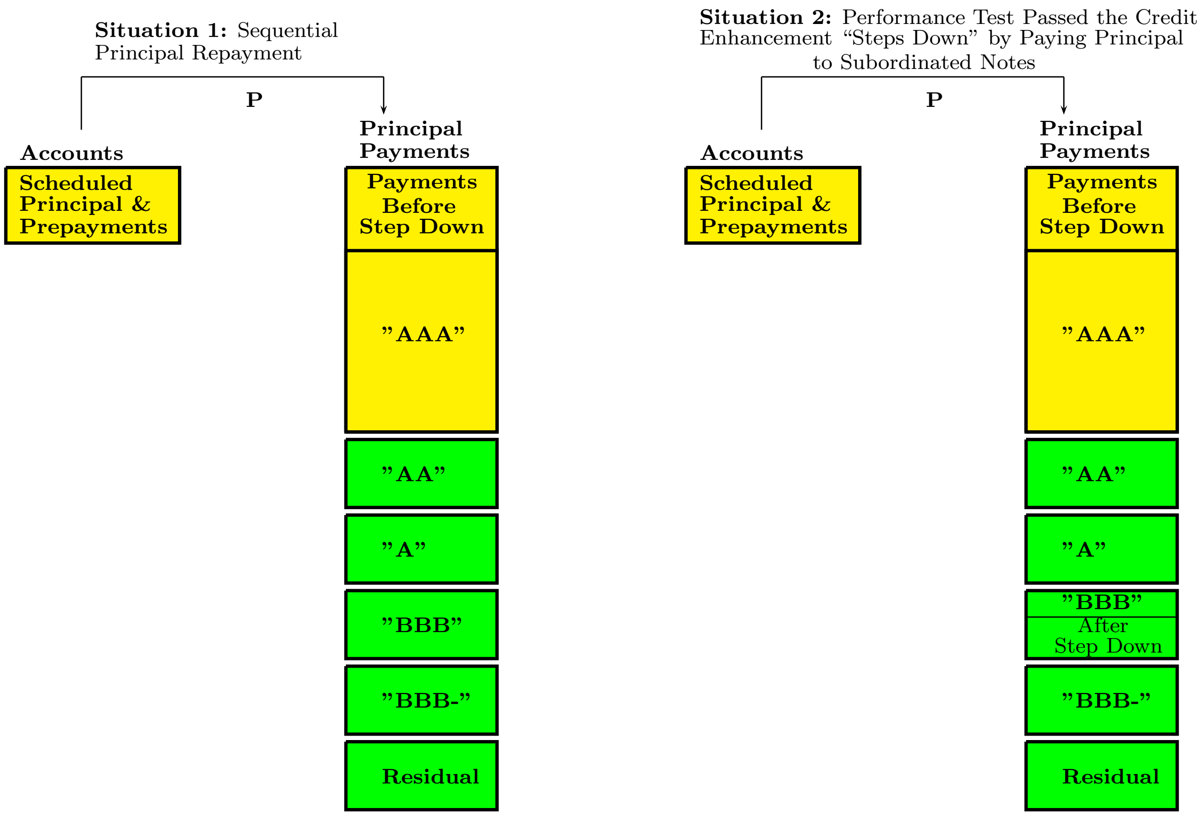


Figure 3.4: Subprime RMBS Interest Waterfall; Source: [67]

Interest waterfalls involve sequential interest payouts to RMBS bond holders, r^B, capped at the weighted average mortgage coupon nett expenses (Nett WAC) denoted by $\overline{r}^{Mn\omega}$ or available funds cap (AFC), r^a, so that

$$r^B = \max[\overline{r}^{Mn\omega}, r^a].$$

In addition, XS is the remaining interest, r^x, which contributes to the interest collection account, after paying RMBS bond holders regular interest. The first use of XS is to cover realized reference mortgage portfolio (collateral) losses. Secondly, r^x is used to cover any interest shortfalls in the situation where

$$\overline{r}^{Mn\omega} \leq r^B,$$

with $\overline{r}^{Mn\omega}$ and r^B as before. Lastly, the remaining XS accrues to the holder of the residual bond which in our case is the subprime OR.

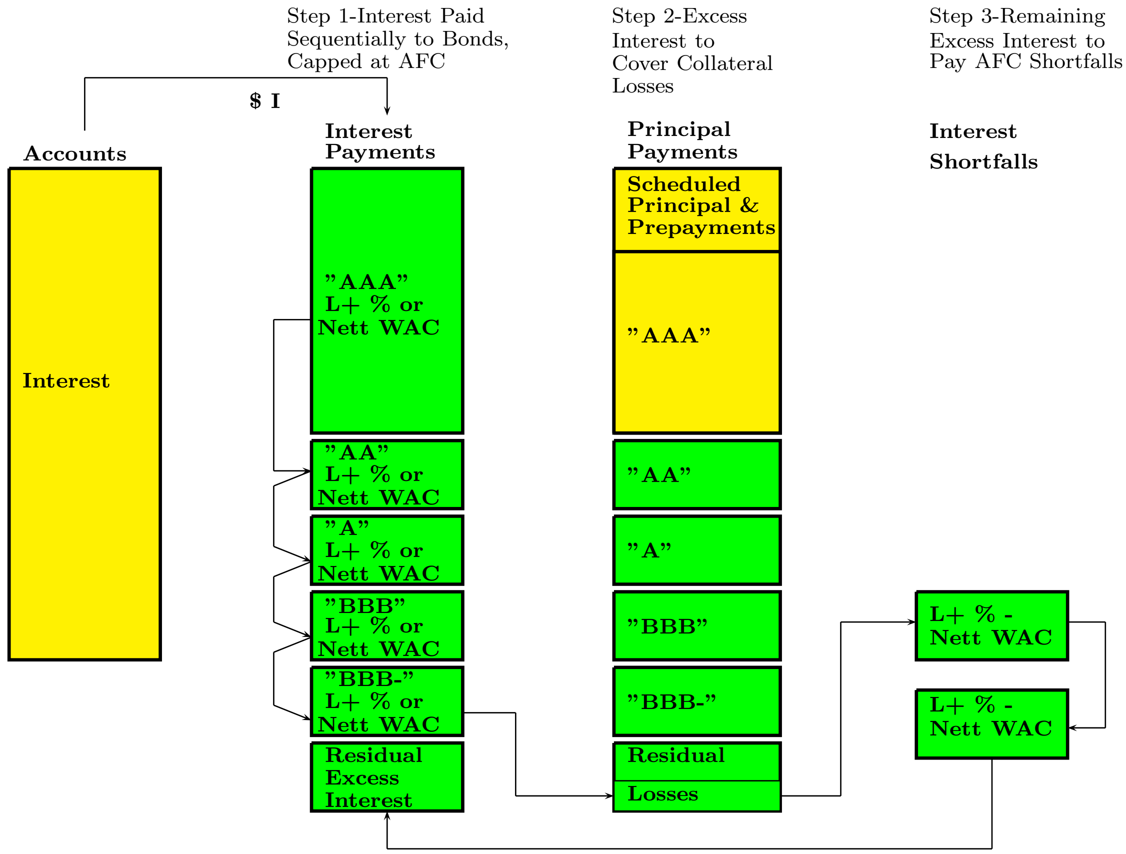


Figure 3.5: Allocation of Interest; Source: [67]

3.1.3 Background to Collateralized Debt Obligations (CDOs)

RMBSs are usually bought by SIVs and ABCP conduits. In particular, SIVs issue short-term ABCP and medium-term notes for purchase by money market funds and other risk-averse investors. The returns from the sale of this paper and notes, in turn, fund the buying of collateral, including structured notes. In essence, this means that long-term reference mortgage portfolios are converted into supposedly less risky, shorter-term instruments. In addition, SIVs hold a large proportion of CDOs that invest in asset-backed securities (ABSs) such as RMBSs (see, for instance, [67]).

3.1.3.1 ABS CDOs

As was the case for RMBSs in Subsection 3.1.2, ABS CDOs constitute a reference portfolio sliced into tranches of differing risk-return profiles. SIVs assist hedge funds and banks to pool a number of single RMBS tranches to create one CDO. As with RMBSs, risk associated with CDOs is shifted from sen to sub tranches. The funds generated by the sale of CDOs enable CDO issuers to continue to underwrite the securitization of subprime mortgages or continue to purchase RMBSs. Major depository banks around the world had also used financial innovations such as SIVs to circumvent capital ratio regulations. This type of activity resulted in the failure of Northern Rock, which was nationalized at an estimated cost of $ 150 billion.

We concentrate on ABS CDOs[3] with underlying portfolios mainly constituted by RMBSs and CMBSs. The chain formed by subprime mortgages, RMBSs and RMBS CDOs is portrayed in Figure 3.6 below.

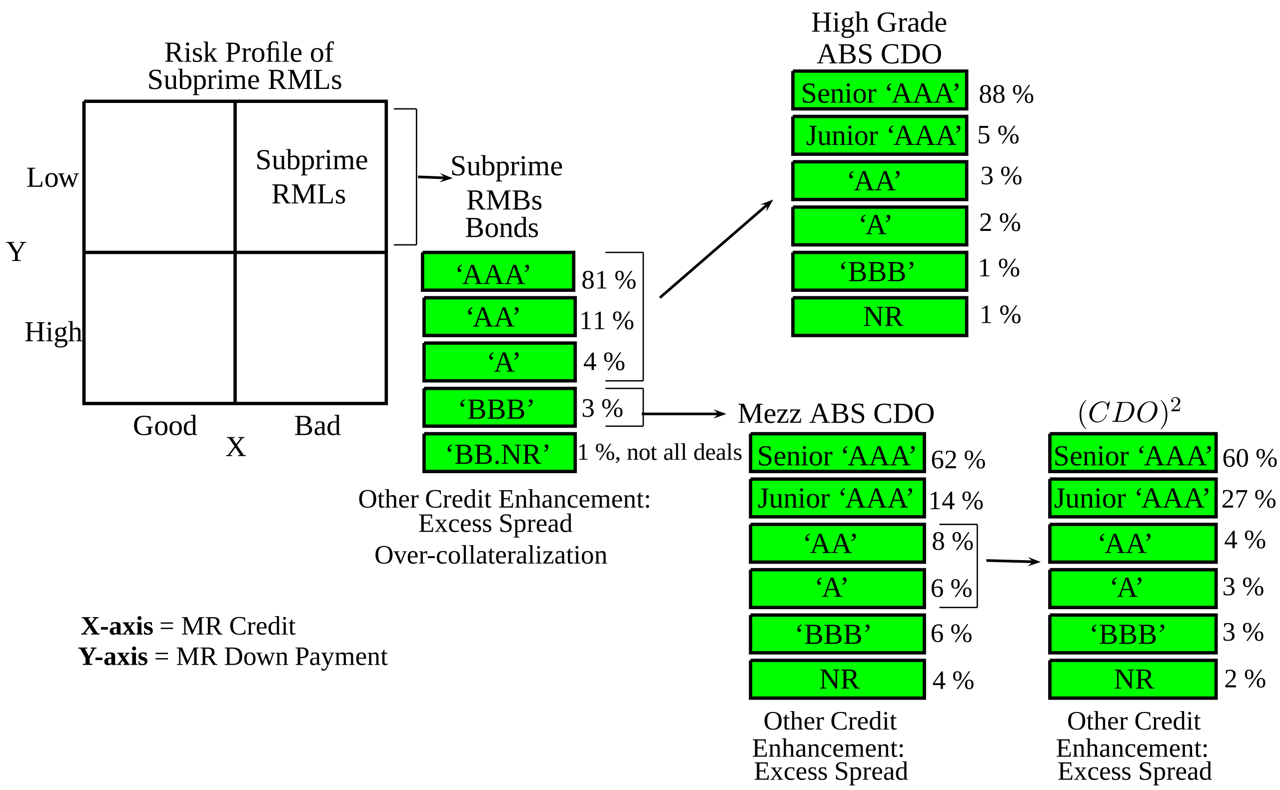


Figure 3.6: Chain of Subprime Mortgages, RMBSs and RMBS CDOs; Source: UBS

As we proceed from left to right in Figure 3.6, subprime mortgages are securitized into RMBSs and eventually RMBSs go into ABS CDOs. As far as the latter is concerned, it is clearly shown that RMBS bonds rated AAA, AA, and A constitute the *high grade* CDO portfolio. On the other hand, the BBB rated RMBS bonds are securitized into a *mezz CDO*, since its portfolio mainly consists of BBB rated ABS and RMBS tranches. Moreover, if bonds issued by mezz CDOs are put into CDO portfolios, then a type of CDO known as *CDO squared* or CDO^2.

[3]By contrast, a cash CDO is a SIV that purchases fixed income asset portfolios that are financed via issuing sen tranches (rated Aaa/AAA), mezz tranches (rated Aa/AA to Bb/BB) and jun tranches (unrated) – compare with RMBSs in Subsection 3.1.2. CDO portfolios usually included significant proportions of tranches of subprime and Alta-A deals.

3.1.3.2 Features of ABS CDOs

There are some important features to ABS CDOs that make their design more complicated in the subprime context. Most importantly, many cash ABS CDOs are managed, which means that there is a manager that oversees the CDO portfolio. In particular, this manager is allowed to trade-buy and sell-bonds, to a limited extent – say 10 % of the notional amount per year – over a limited period of time – say the first 3 years of the transaction. The putative reason for this is that structured products amortize, so to achieve a longer maturity for the CDO, managers need to be allowed to reinvest. They can take cash that is paid to the CDO from amortization and reinvest it, and with limitations, as mentioned, they can sell bonds in the portfolio and buy other bonds. There are restrictions on portfolio that must be maintained, however. CDO managers typically owned part or all of the CDO equity, so they would benefit from higher yielding assets for a given liability structure. Essentially, think of a managed fund with term financing and some constraints on the manager in terms of trading and portfolio composition. The restriction on the portfolio composition would limit structured product asset categories to certain maximum amounts of the portfolio. Other restrictions would include maximums and minimum by rating category, restrictions on weighted average life (WAL), correlation factors, weighted average weighting factors (WARF), numbers of obligors, etc.

3.1.3.3 Illustration of the Structure of ABS CDOs

Loss from any structured note depends on the aggregate level of losses in the reference mortgage portfolio. Losses flow to structured notes according to their seniority. Another benefits from the protection of all subordinate notes, whose total size determines the level of OC of the structured note, characterizing its seniority. The total size of all sub notes under a specific note is a loss franchise being the next senior tranche.

The loss allocation is very simple. A mortgage portfolio has a size 100. There are five types of structured notes, each having an equal size of 20. A tranche becomes more senior as we move up the structure. The lowest tranche is the jun tranche, sub 1 serving as equity for the other tranches by being hit by any first loss of the reference mortgage portfolio. The most senior tranche is sen 3 (see Table 3.1 for more information).

Example of the Structuring of a CDO Note	
Structured CDO Notes	**Value**
sen 3	20
sen 2	20
sen 1	20
mezz 1	20
jun 1	20
Total	100

Table 3.1: Example of the Structuring of a CDO Note

The exercise is to allocate loss. The reference mortgage portfolio loss can range from 0 up to 100 with a loss of 100 never happening. If the loss is lower than 20, it hits jun 1. If it is above the excess over 20 hits the next highest tranche, viz., mezz 1. Hence a 25 portfolio loss results in a charge of 20 for jun 1 and 25 - 20 = 5 for mezz 1. Following the same rationale, the allocation of a large portfolio loss of 45 would be 20 for jun 1, 20 for mezz 1, 5 for sen 1 and zero for both sen 2 and 3. Of course, the likelihood of these losses vary, with high losses exceptional and small losses frequent.

3.1.4 Monoline Insurance for Subprime RMBSs and RMBS CDOs

In this subsection, a diagrammatic overview of SMPs being wrapped by an MLI is provided.

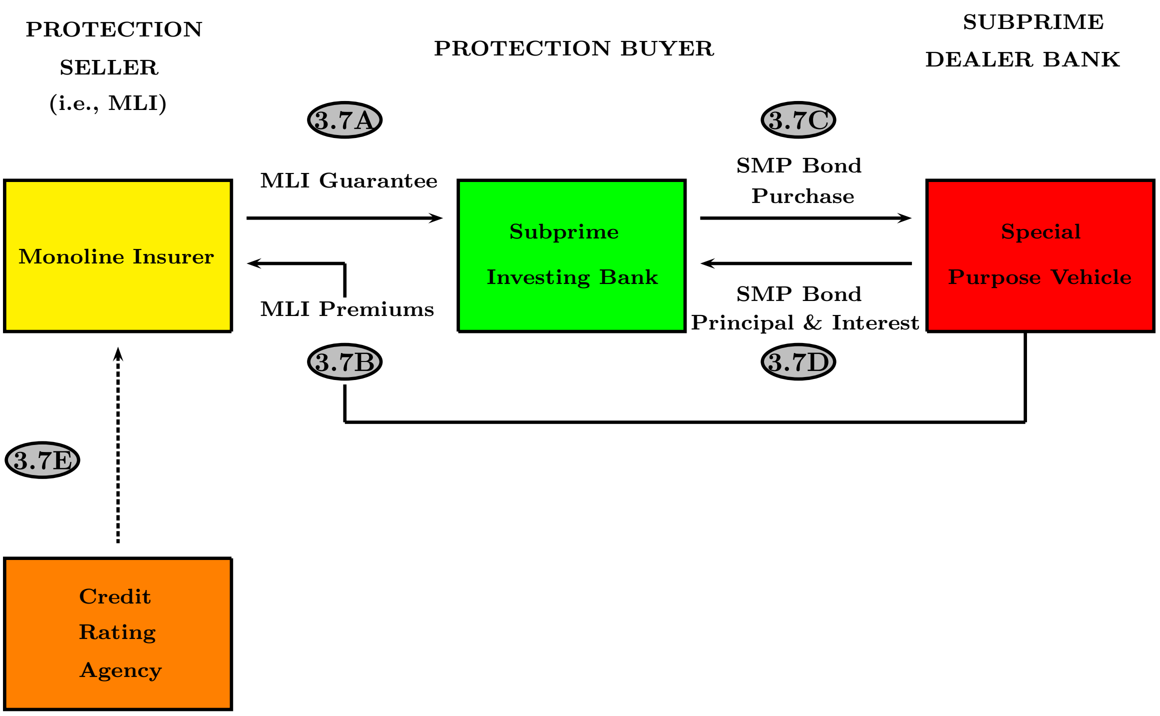


Figure 3.7: Structured Mortgage Products Wrapped by Monoline Insurance

The monoline insurance model in Figure 3.7 allows for (senior tranches of) SMPs to be wrapped by MLIs. In this process, MLIs offer SIBs a guarantee on returns from SMP bonds (refer to **3.7A**). There are many reasons why such guarantees are viable in the real world. Differences in access to information and in demand for credit risk are but two of them. To make this possible, the SPV – the protection buyer – makes a regular stream of payments, to MLI in order to guarantee principal and interest payments on the SMP bonds issued to SIB (see **3.7C**). The effect of MLI insurance – having the character of a guarantee - is that the risk premium on the bond shrinks thus reducing the return SIBs receive (refer to **3.7D**). However, the SPV has to pay a price for this as the MLI premium must be paid. Before the SMC, given the low perceived risk of structured mortgage products, MLIs generally have very high leverage, with outstanding guarantees often amounting to 150 times capital. In this type of insurance, default risk is transferred from the bondholders - in our case SIBs - to MLIs. SIBs are only left with the residual risk that the MLI will default. MLIs carry enough capital to earn AAA ratings from CRAs and as a result often do not have to post collateral (refer to **3.7E**). As a consequence, MLIs make available SMP bonds easy to market, as the credit risk is essentially that of the highly rated MLI simplifying analysis for most SIBs. In this case, the analysis of the MLI is closely connected with the analysis of the default risk of all bonds they insured.

3.1.5 Mortgage Securitization and Capital Regulation

Basel II aims to address weaknesses in the Basel I capital adequacy framework for banks by incorporating more detailed calibration of credit risk and by requiring the pricing of other forms of risk such as operational risk. However, the 2007–2008 implementation of Basel II corresponded to major losses suffered by some of the world's major banks. Furthermore, the risk models that underpin Basel II are similar to the ones many of those banks are currently using. Under the Basel II framework, regulators allow large banks with sophisticated risk management systems to use risk assessment based on their own models in determining the minimum amount of capital they are required to hold by the regulators as a buffer against unexpected losses. Of concern is that by the end of 2008, non risk-weighted capital adequacy ratios (CARs) were near historically low levels of about 7.0 %. Naturally, these facts challenge the usefulness of important elements in the Basel II accord.

At the beginning of 2008, it appeared that the SMC had caused a higher degree of problems for non-U.S. financial institutions. The write-downs that British, European and Asian institutions had to make on U.S. subprime mortgage debt was something that some analysts attributed to Basel II that gave institutions some carte blanche when it came to raising capital for securities with top credit ratings. Even in Switzerland, where Basel II was devised, regulators have questioned capital regulation. For instance, UBS AG wrote down $ 18 billion in losses due to risk mismanagement and exposure to subprime mortgages and other risky assets. In December 2007, UBS disclosed plans to boost its capital with a $ 12.1 billion injection from the Government of Singapore Investment Corp. and an unidentified Middle Eastern investor. In short, the Basel rules are being questioned for containing inadequate prescriptions for monitoring a bank's liquidity - in other words, its ability to readily sell assets, or borrow affordably, to cover obligations. In principle, Basel II regulators worldwide are required to track a bank's risk-taking and to check how the bank monitors itself. Traditionally, it is not their task to prescribe to banks about the size and type of risks they can take. In the U.S., some regulators have recently shown a willingness to tighten Basel capital regulation. They are motivated by the failure of more than 1 000 banks amid unforeseen risks related to interest rates and real estate during the 1980's S&L crisis. In addition, regulators both in the U.S. and elsewhere are gearing themselves to amend Basel II. In all likelihood, this will involve enforcing a higher level of capital against assets that may be construed to be risky in the wake of the SMC.

Undergirded by the analysis in [48], we extend aspects of the literature mentioned in Subsection 1.1 in several important directions. Firstly, in a Basel II framework, we investigate the dynamics of bank capital and credit and their sensitivity to changes in the level of RMBS credit ratings. Here mortgage risk-weights are kept constant and we consider credit and market risk as well as operational risk. Next we include a discussion of subprime RMBSs and their reduced risk premiums.

Finally, we consider the effect that Basel capital regulation has had on the SMC.

3.2 Risk, Profit and Valuation Under RMBSs

In this section, we provide more details about securitized mortgages and related issues such as risk, profit and valuation. In the sequel, we assume that the notation Π, r^M, M, $\overline{c}^{M\omega}$, p^i, c^p, r^f, r^R, r^S, S, $\mathcal{C}$, $C(\mathbf{E}[S(\mathcal{C})])$, r^B, c^B, B, $r^{\mathtt{T}}$, $\mathtt{T}$, $P^{\mathtt{T}}(\mathtt{T})$, r^D, c^D, D, $r^{\mathtt{B}}$, $c^{\mathtt{B}}$, $\mathtt{B}$, Π^p, K, n, E, O, $\omega(\mathcal{C})$, ω^B, f^M, $mVaR$ and $\mathtt{O}$ corresponds to that of Subsection 2.3.1.2. Furthermore, the notation $r^{S\Sigma}$, represents the loss rate on securitized mortgages, f^Σ, is the fraction of M that is securitized and $\widehat{f}^\Sigma$ denotes the fraction of M, realized as new securitized mortgages, where $\widehat{f}^\Sigma \in f^\Sigma$. The following assumption about the relationship between SIB's and SOR's profit is important for subsequent analysis.

Assumption 3.2.1 (Relationship between Subprime Originator and Subprime Investing Banks): *We suppose that SIB and SOR share the same balance sheet given by (2.7). Furthermore, we assume that SIB is the only recipient of SORs securitized mortgages and that SIB's profit can be expressed as a function of the components of this securitization.*

This assumption enables us to subsequently derive an expression for SIB's profit under mortgage securitization as in (3.2) from SOR's profit formula given by (2.11).

3.2.1 Subprime RMBSs

The process of mortgage securitization into RMBSs takes a portfolio of illiquid mortgages – called the reference mortgage portfolio – with high yields and places them into a SPV. To finance the purchase of this portfolio, the SPV plans to issue highly rated bonds paying lower yields. The trust issues bonds that are partitioned into tranches with covenants structured to generate a desired credit rating in order to meet SIBs' demand for highly rated assets. The usual trust structure results in a majority of the bond tranches being rated investment grade. This is facilitated by running the reference mortgage portfolio's cash flows through a *waterfall* payment structure. The cash flows are allocated to the bond tranches from the top down: the senior bonds get paid first, and then the junior bonds, and then the equity. To insure a majority of the bonds get rated AAA, the waterfall specifies that the senior bonds get accelerated payments (and the junior bonds get none), if the reference mortgage portfolio appears to be under stress[4]. As was mentioned before, this credit ratings can also be assured via the use of a MLI surety wrap. In addition, the super senior tranches are often unfunded, making them more attractive to SIBs.

The costs related to mortgage securitization emanate from managerial time, legal fees and rating agency fees. The RMBS equity holders would only perform securitization if the process generated a positive nett present value. This could occur if the other tranches were mispriced. For example, if AAA rated tranches added a new RMBS that attracted new sources of funds. However, asset securitization started in the mid 1980s, so it is difficult to attribute the demand that we have witnessed over the last few years for AAA rated tranches to new sources of funds. After this length

[4]Stress is usually measured by collateral/liability and cashflow/bond-payment ratios remaining above certain trigger levels.

of time, SIBs should have learnt to price tranches in a way that reflects the inherent risks. If RMBS bond mispricing occurred, why ? The AAA rated liabilities could be over-priced due to either mispricing liquidity or the rating of the SPV's bonds were inaccurate.

3.2.2 Risk and Profit Under RMBSs

In this subsection, we discuss a subprime mortgage model for capital, information, risk and valuation and its relation to retained earnings.

3.2.2.1 A Subprime Mortgage Model for Risk and Profit Under RMBSs

In this thesis, a subprime mortgage model for capital, information, risk and valuation under RMBSs can be constructed by considering the difference between cash inflow and outflow. In period t, *cash inflow* is constituted by returns on the residual from mortgage securitization, $r^r_t \widehat{f}^\Sigma_t f^\Sigma_t M_t$, securitized subprime mortgages, $r^M_t(1-\widehat{f}^\Sigma_t)f^\Sigma_t M_t$, unsecuritized mortgages, $r^M_t(1-f^\Sigma_t)M_t$, unsecuritized mortgages that are prepaid, $c^p_t r^f_t(1-f^\Sigma_t)M_t$, $r^{\mathtt{T}}_t\mathtt{T}_t$, $(r^B_t - c^B_t)B_t$, as well as $C(\mathbf{E}[S(\mathcal{C})])$ and the present value of future gains from subsequent mortgage origination and securitizations, $\Pi^{\Sigma p}_t$. On the other hand, in period t, we consider the average weighted cost of funds to securitize mortgages, $\overline{c}^{M\Sigma\omega}\widehat{f}^\Sigma_t f^\Sigma_t M_t$, losses from securitized mortgages, $r^{S\Sigma}_t\widehat{f}^\Sigma_t f^\Sigma_t M_t$, forfeit costs related to MLI insurance wrapping RMBSs, $c^{i\Sigma}_t\widehat{f}^\Sigma_t f^\Sigma_t M_t$, transaction cost to extend mortgages, $c^t_t(1-\widehat{f}^\Sigma_t)f^\Sigma_t M_t$, and transaction costs from securitized mortgages $c^{t\Sigma}_t(1-\widehat{f}^\Sigma_t)f^\Sigma_t M_t$ as part of *cash outflow*. Additional components of outflow are weighted average cost of funds for extending mortgages, $\overline{c}^{M\omega}_t(1-f^\Sigma_t)M_t$, MI premium for unsecuritized mortgages, $p^i(\mathcal{C}_t)(1-f^\Sigma_t)M_t$, nett losses for unsecuritized mortgages, $(1-r^R_t)r^S_t(1-f^\Sigma_t)M_t$, decreasing value of adverse selection, $af^\Sigma_t M_t$, losses from suboptimal SPVs, $\mathtt{E}_t$ and cost of funding SPVs, $\mathtt{F}_t$. From the above and (2.11), we have that a subprime mortgage model for profit under subprime RMBSs may have the form

$$\begin{aligned}
\Pi^\Sigma_t \;=\; & \Big(r^r_t - \overline{c}^{M\Sigma\omega}_t - r^{S\Sigma}_t - c^{i\Sigma}_t\Big)\widehat{f}^\Sigma_t f^\Sigma_t M_t + \Big(r^M_t - c^t_t - c^{t\Sigma}_t\Big)(1-\widehat{f}^\Sigma_t)f^\Sigma_t M_t \\
& + \Big(r^M_t - \overline{c}^{M\omega}_t - p^i_t(\mathcal{C}_t) + c^p_t r^f_t - (1-r^R_t)r^S_t\Big)(1-f^\Sigma_t)M_t - af^\Sigma_t M_t + r^{\mathtt{T}}_t\mathtt{T}_t \\
& - \Big(r^{\mathtt{B}}_t + c^{\mathtt{B}}_t\Big)\mathtt{B}_t + \Big(r^B_t - c^B_t\Big)B_t - \Big(r^D_t + c^D_t\Big)D_t + C(\mathbf{E}[S(\mathcal{C}_t)]) - P^{\mathtt{T}}(\mathtt{T}_t) \\
& + \Pi^{\Sigma p}_t - \mathtt{E}_t - \mathtt{F}_t,
\end{aligned} \tag{3.2}$$

where $\Pi^{\Sigma p}_t = \Pi^p_t + \widetilde{\Pi}^\Sigma_t$. Furthermore, by considering $\dfrac{\partial S(\mathcal{C}_t)}{\partial \mathcal{C}^B_t} < 0$ and (3.2), Π^Σ is an increasing function of RMBS credit rating $\mathcal{C}^B$ so that $\dfrac{\partial \Pi^\Sigma_t}{\partial \mathcal{C}^B_t} > 0$. Furthermore, the MI forfeit cost term, $c^{i\Sigma}$, is a function of SPV's MLI premium and payment terms.

Below we roughly attempt to associate different risk types to different cash inflow and outflow terms in (3.2). We note that the cash inflow terms $r^r_t\widehat{f}^\Sigma_t f^\Sigma_t M_t$ and $r^M_t(1-\widehat{f}^\Sigma_t)f^\Sigma_t M_t$ embed credit, market (in particular, interest rate), tranching and operational risks while $r_t^M(1-f_t^\Sigma)M_t$ carries market (specifically, interest rate) and credit risks. Also, $c_t^p r_t^f(1-f_t^\Sigma)M_t$ can be associated with market (in particular, prepayment) risk while $(r_t^B - c_t^B)B_t$ mainly embeds market risk. $C(\mathbf{E}[S(\mathcal{C})])$ and $\Pi_t^{\Sigma p}$ involve at least credit (particularly, counterparty) and market (more specifically, interest rate, basis, prepayment, liquidity and price), respectively. In (3.2), the cash outflow terms $\overline{c}^{M\Sigma\omega}\widehat{f}_t^\Sigma f_t^\Sigma M_t$, $c_t^t(1-\widehat{f}_t^\Sigma)f_t^\Sigma M_t$ and $c_t^{t\Sigma}(1-\widehat{f}_t^\Sigma)f_t^\Sigma M_t$ involve credit, tranching and operational risks while $\overline{c}_t^{M\omega}(1-f_t^\Sigma)M_t$ and $p^i(\mathcal{C}_t)(1-f_t^\Sigma)M_t$ carry credit and operational risks. Also, $r_t^{S\Sigma}\widehat{f}_t^\Sigma f_t^\Sigma M_t$ embeds credit, market (including valuation), tranching and operational risks and $c_t^{i\Sigma}\widehat{f}_t^\Sigma f_t^\Sigma M_t$ involves credit (in particular, counterparty), tranching and operational risks. Furthermore, $(1-r_t^R)r_t^S(1-f_t^\Sigma)M_t$ and $af_t^\Sigma M_t$ both carry credit and market (including valuation) risks. Finally, $\mathtt{E}_t$ and $\mathtt{F}_t$ embed credit (in particular, counterparty and valuation) and market and operational risks, respectively. In reality, the risks that we associate with each of the cash inflow and outflow terms in (3.2) are more complicated than presented above. For instance, these risks are inter-related and may be strongly correlated with each other. All of the above risk-carrying terms contribute to systemic risk that affects the entire banking system.

3.2.2.2 Profit Under RMBSs and Retained Earnings

As for SOR's profit under mortgages, Π, we conclude that SIB's profit under RMBSs, Π^Σ, are used to meet its obligations, that include dividend payments on equity, $n_t d_t$. The retained earnings, E_t^r, subsequent to these payments may be computed by using

$$\Pi_t = E_t^r + n_t d_t + (1+r_t^O)O_t. \tag{3.3}$$

After adding and subtracting $\left(r_t^M - \overline{c}_t^{M\omega} - p_t^i + c_t^p r_t^f - (1-r_t^R)r_t^S\right)M_t$ from (3.2), we obtain

$$\begin{aligned}\Pi_t^\Sigma &= \Pi_t + \left(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\right)f_t^\Sigma \widehat{f}_t^\Sigma M_t \\ &\quad + \left(\overline{c}_t^{M\omega} + p_t^i + (1-r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f - a\right)f_t^\Sigma M_t - \mathtt{E}_t - \mathtt{F}_t + \widetilde{\Pi}_t^\Sigma.\end{aligned}$$

If we replace Π_t by using (3.3), Π_t^Σ is given by

$$\begin{aligned}\Pi_t^\Sigma &= E_t^r + n_t d_t + (1+r_t^O)O_t + \left(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\right)f_t^\Sigma \widehat{f}_t^\Sigma M_t \qquad (3.4) \\ &\quad + \left(\overline{c}_t^{M\omega} + p_t^i + (1-r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f - a\right)f_t^\Sigma M_t - \mathtt{E}_t - \mathtt{F}_t + \widetilde{\Pi}_t^\Sigma.\end{aligned}$$

From (2.10) and (3.4) we may derive an expression for SIB's capital of the form

$$
\begin{aligned}
K_{t+1}^{\Sigma} &= n_t(d_t+E_t) - \Pi_t^{\Sigma} + \Delta F_t + (1+r_t^O)O_t + \bigg(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M \qquad (3.5)\\
&\quad + c_t^t + c_t^{t\Sigma}\bigg) f_t^{\Sigma}\widehat{f}_t^{\Sigma} M_t + \bigg(\overline{c}_t^{M\omega} + p_t^i + (1-r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f - a\bigg) f_t^{\Sigma} M_t\\
&\quad - \mathtt{E}_t - \mathtt{F}_t + \widetilde{\Pi}_t^{\Sigma}.
\end{aligned}
$$

where K_t is defined by (2.7).

3.2.3 Valuation Under RMBSs

If the expression for retained earnings given by (3.4) is substituted into (2.9), the nett cash flow under RMBSs generated by SIB is given by

$$
\begin{aligned}
N_t^{\Sigma} &= \Pi_t^{\Sigma} - \Delta F_t\\
&= n_t(d_t+E_t) - K_{t+1}^{\Sigma} + (1+r_t^O)O_t \qquad (3.6)\\
&\quad + \bigg(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\bigg) f_t^{\Sigma}\widehat{f}_t^{\Sigma} M_t\\
&\quad + \bigg(\overline{c}_t^{M\omega} + p_t^i + (1-r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f - a\bigg) f_t^{\Sigma} M_t - \mathtt{E}_t - \mathtt{F}_t + \widetilde{\Pi}_t^{\Sigma}.
\end{aligned}
$$

We know that valuation is equal to SIB's nett cash flow plus ex-dividend value. This translates to the expression

$$
V_t^{\Sigma} = N_t^{\Sigma} + K_{t+1}^{\Sigma}, \qquad (3.7)
$$

where K_t is defined by (2.7). Furthermore, the stock analyst evaluates the expected future cash flows in j periods based on a *stochastic discount factor*, $\delta_{t,j}$ such that SIB's value is

$$
V_t^{\Sigma} = N_t^{\Sigma} + \mathbf{E}_t\Bigg[\sum_{j=1}^{\infty} \delta_{t,j} N_{t+j}^{\Sigma}\Bigg]. \qquad (3.8)
$$

3.2.4 Optimal Valuation Under RMBSs

In this subsection, we make use of the modeling of assets, liabilities and capital of the preceding section to solve an optimal valuation problem. SIB's total capital constraint for subprime RMBSs at face value is given by

$$K_t^{\Sigma} = n_t E_{t-1} + O_t \geq \rho\Big[\omega^M M_t + \omega(\mathcal{C}_t^B) B_t + 12.5 f^M (mVaR + \mathtt{O})\Big], \quad (3.9)$$

where $\omega(\mathcal{C}_t^B)$ and ω^M are the risk-weights related to subprime RMBSs and mortgages, respectively, while ρ – Basel II pegs ρ at approximately 0.08 – is the Basel capital regulation ratio of regulatory capital to risk-weighted assets. In order to state SIB's optimal valuation problem, it is necessary to assume the following.

Assumption 3.2.2 (Subprime Investing Bank's Performance Criterion): *Suppose that SIB's valuation performance criterion, J^{Σ}, at t is given by*

$$\begin{aligned} J_t^{\Sigma} &= \Pi_t^{\Sigma} + l_t^b \Big[K_t^{\Sigma} - \rho\Big(\omega^M M_t + \omega(\mathcal{C}_t^B) B_t + 12.5 f^M (mVaR + \mathtt{O})\Big)\Big] \quad (3.10) \\ &\quad - c_t^{dw}\Big[K_{t+1}^{\Sigma}\Big] + \mathbf{E}_t\Big[\delta_{t,1} V\Big(K_{t+1}^{\Sigma},\ x_{t+1}\Big)\Big], \end{aligned}$$

where l_t^b is the Lagrangian multiplier for the total capital constraint, K_t^{Σ} is defined by (3.9), $\mathbf{E}_t[\cdot]$ is the expectation conditional on SIB's information in period t and x_t is the deposit withdrawals in period t with probability distribution $f(x_t)$. Also, c_t^{dw} is the deadweight cost of total capital that consists of common and preferred equity as well as subordinate debt, V is the value function with a discount factor denoted by $\delta_{t,1}$.

The optimal valuation problem is to maximize the *SIB value* given by (3.8). We can now state the optimal valuation problem as follows.

Problem 3.2.3 (Statement of the Optimal Valuation Problem Under RMBSs): *Suppose that the total capital constraint and the performance criterion, J^{Σ}, are given by (3.9) and (3.10), respectively. The optimal valuation problem under RMBSs is to maximize SIB's value given by (3.8) by choosing the RMBS rate, deposits and regulatory capital for*

$$V^{\Sigma}(K_t^{\Sigma},\ x_t) = \max_{r_t^B,\ D_t,\ \Pi_t^{\Sigma}} J_t^{\Sigma}, \quad (3.11)$$

subject to RMBS, balance sheet, cash flow and financing constraints given by

$$B_t = b_0 + b_1 r_t^B + b_2 \mathcal{C}_t^B + \sigma_t^B, \quad (3.12)$$

$$D_t = \frac{B_t + M_t + \mathtt{T}_t - \mathtt{B}_t - K_t}{1-\gamma}, \quad (3.13)$$

(3.2) and (3.5), respectively.

3.2.4.1 Solution to Optimal Valuation Problem Under RMBSs

In this subsection, we find a solution to Problem 3.2.3 when the capital constraint (3.9) holds as well as when it does not. In this regard, the main result can be stated and proved as follows.

Theorem 3.2.4 (Solution to the Optimal Valuation Problem Under RMBSs): *Suppose that J^Σ and V^Σ are given by (3.10) and (3.11), respectively. When the capital constraint given by (3.9) holds (i.e., $l_t^b > 0$), a solution to the optimal valuation problem under RMBSs yields an optimal B and r^B of the form*

$$B_t^* = \frac{K_t^\Sigma}{\rho\omega(\mathcal{C}_t^B)} - \frac{\omega^M M_t + 12.5 f^M (mVaR + \mathtt{O})}{\omega(\mathcal{C}_t^B)} \tag{3.14}$$

and

$$r_t^{B^*} = -\frac{1}{b_1}\left(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B - B_t^*\right), \tag{3.15}$$

respectively. In this case, SIB's optimal deposits and provisions for deposit withdrawals via Treasuries and optimal profits under RMBSs are given by

$$\begin{aligned} D_t^{\Sigma*} &= \frac{1}{1-\gamma}\Bigg(\overline{D} + \frac{\overline{D}}{r_t^p}\left[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) + (r_t^B - c_t^B) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\right] \\ &\quad + \frac{K_t^\Sigma}{\rho\omega(\mathcal{C}_t^B)} - \frac{\omega^M M_t + 12.5 f^M (mVaR + \mathtt{O})}{\omega(\mathcal{C}_t^B)} + M_t - K_t - \mathtt{B}_t\Bigg), \end{aligned} \tag{3.16}$$

$$\mathtt{T}_t^{\Sigma*} = \overline{D} + \frac{\overline{D}}{r_t^p}\left[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) + (r_t^B - c_t^B) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\right] \tag{3.17}$$

and

$$
\begin{aligned}
\Pi_t^{\Sigma *} \;=\; & \left[\tfrac{K_t^{\Sigma}}{\rho\omega^M} - \tfrac{\omega(\mathcal{C}_t^B)B_t + 12.5 f^M(mVaR+\mathtt{0})}{\omega^M}\right]\Bigg[\widehat{f}_t^{\Sigma} f_t^{\Sigma}\Bigg(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} \\
& - r_t^M + c_t^t + c_t^{t\Sigma}\Bigg) + f_t^{\Sigma}\Bigg(\overline{c}_t^{M\omega} + p_t^i + (1 - r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f - a\Bigg) \\
& + \Bigg(r_t^M - \overline{c}_t^{M\omega} - p_t^i + c_t^p r_t^f - (1 - r_t^R)r_t^S\Bigg)\Bigg] + \left[\tfrac{K_t^{\Sigma}}{\rho\omega(\mathcal{C}_t^B)} - \tfrac{\omega^M M_t + 12.5 f^M(mVaR+\mathtt{0})}{\omega(\mathcal{C}_t^B)}\right] \\
& \Bigg[\Bigg(\tfrac{1}{b_1}\Big[\tfrac{K_t^{\Sigma}}{\rho\omega(\mathcal{C}_t^B)} - \tfrac{\omega^M M_t + 12.5 f^M(mVaR+\mathtt{0})}{\omega(\mathcal{C}_t^B)} - b_0 - b_2\mathcal{C}_t^B - \sigma_t^B\Big] - c_t^B\Bigg) \\
& - (r_t^D + c_t^D)\tfrac{1}{1-\gamma}\Bigg] + \Bigg(\overline{D} + \tfrac{\overline{D}}{r_t^p}\Bigg[r_t^{\mathtt{T}} + \Bigg(\tfrac{1}{b_1}\Big[\tfrac{K_t^{\Sigma}}{\rho\omega(\mathcal{C}_t^B)} - \tfrac{\omega^M M_t + 12.5 f^M(mVaR+\mathtt{0})}{\omega(\mathcal{C}_t^B)} \\
& - b_0 - b_2\mathcal{C}_t^B - \sigma_t^B\Big] - c_t^B\Bigg) + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \tfrac{1}{1-\gamma}(r_t^D + c_t^D)\Bigg]\Bigg)\Bigg(r_t^{\mathtt{T}} - (r_t^D + c_t^D)\tfrac{1}{1-\gamma}\Bigg) \\
& - \Bigg((r_t^D + c_t^D)\tfrac{1}{1-\gamma}\Bigg)\Bigg(M_t - K_t - \mathtt{B}_t\Bigg) - (r_t^{\mathtt{B}} + c_t^{\mathtt{B}})\mathtt{B}_t + C(\mathbf{E}[S(\mathcal{C}_t)]) \\
& - P^{\mathtt{T}}(\mathtt{T}_t) + \Pi_t^{\Sigma p} - \mathtt{E}_t - \mathtt{F}_t,
\end{aligned} \tag{3.18}
$$

respectively.

Proof.

An immediate consequence of the prerequisite that the capital constraint (3.9) holds, is that RMBS supply is closely related to the capital adequacy constraint and is given by (3.14). Also, the dependence of changes in the RMBS rate on credit rating may be fixed as

$$\frac{\partial r_t^{B*}}{\partial \mathcal{C}_t^B} = \frac{b_2}{b_1}.$$

Equation (3.14) follows from (3.9) and the fact that the capital constraint holds. This also leads to equality in (3.9). In (3.15) we substituted the optimal value for B_t into control law (3.12) to get the optimal default rate. We obtain the optimal T_t using the following steps. Firstly, we rewrite (2.7) to make deposits the dependent variable so that

$$D_t = \frac{M_t + B_t + \mathtt{T}_t - \mathtt{B}_t - K_t}{1-\gamma}.$$

Next, we note that the first-order conditions (for verification of these conditions see the appendix in Section 3.8) are given by

$$\frac{\partial \Pi_t^\Sigma}{\partial r_t^B}\left[1+c_t^{dw}-\mathbf{E}_t\left\{\int_{\underline{B}}^{\overline{B}}\delta_{t,1}\frac{\partial V^\Sigma}{\partial (K_{t+1}^\Sigma)}dF(\sigma_{t+1}^B)\right\}\right]-l_t^b\rho b_1\omega(\mathcal{C}_t^B)=0; \tag{3.19}$$

$$\frac{\partial \Pi_t^\Sigma}{\partial D_t}\left[1+c_t^{dw}-\mathbf{E}_t\left\{\int_{\underline{B}}^{\overline{B}}\delta_{t,1}\frac{\partial V^\Sigma}{\partial (K_{t+1}^\Sigma)}dF(\sigma_{t+1}^B)\right\}\right]=0; \tag{3.20}$$

$$\rho\left[\omega(\mathcal{C}_t^B)B_t+\omega^M M_t+12.5f^M(mVaR+\mathtt{O})\right]\le K_t^\Sigma; \tag{3.21}$$

$$-c_t^{dw}+\mathbf{E}_t\left\{\int_{\underline{B}}^{\overline{B}}\delta_{t,1}\frac{\partial V^\Sigma}{\partial (K_{t+1}^\Sigma)}dF(\sigma_{t+1}^B)\right\}=0. \tag{3.22}$$

Here $F(\cdot)$ is the cumulative distribution of the shock to the RMBS. Using (3.22) we can see that (3.20) becomes

$$\frac{\partial \Pi_t^\Sigma}{\partial D_t}=0.$$

Looking at the form of Π_t^Σ given in (3.2)and the equation

$$P^{\mathtt{T}}(\mathtt{T}_t)=\frac{r_t^p}{2\overline{D}}[\overline{D}-T_t]^2 \tag{3.23}$$

it follows that

$$\begin{aligned}\Pi_t^\Sigma \;=\; & \left(r_t^r-\overline{c}_t^{M\Sigma\omega}-r_t^{S\Sigma}-c_t^{i\Sigma}\right)\widehat{f}_t^\Sigma f_t^\Sigma M_t+\left(r_t^M-c_t^t-c_t^{t\Sigma}\right)(1-\widehat{f}_t^\Sigma)f_t^\Sigma M_t \\ & +\left(r_t^M-\overline{c}_t^{M\omega}-p_t^i+c_t^p r_t^f-(1-r_t^R)r_t^S\right)(1-f_t^\Sigma)M_t-af_t^\Sigma M_t+r_t^{\mathtt{T}}\mathtt{T}_t \\ & +\left(r_t^B-c_t^B\right)B_t-\left(r_t^{\mathtt{B}}+c_t^{\mathtt{B}}\right)\mathtt{B}_t-\left(r_t^D+c_t^D\right)D_t+C(\mathbf{E}[S(\mathcal{C}_t)])-\frac{r_t^p}{2\overline{D}}[\overline{D}-T_t]^2 \\ & +\Pi_t^{\Sigma p}-\mathtt{E}_t-\mathtt{F}_t.\end{aligned} \tag{3.24}$$

Finding the partial derivatives of SIB's profit, Π_t^Σ, with respect to deposit, D_t, we have that

$$\frac{\partial \Pi_t^\Sigma}{\partial D_t}=(1-\gamma)\left(r_t^{\mathtt{T}}+(r_t^{\mathtt{B}}+c_t^{\mathtt{B}})+(r_t^B-c_t^B)+\frac{r_t^p}{\overline{D}}(\overline{D}-\mathtt{T}_t)\right)-(r_t^D+c_t^D) \tag{3.25}$$

This would then give us the optimal value for D_t. Using (2.7) and all the optimal values calculated to date, we can find optimal deposits as well as optimal profits. □

The next corollary follows immediately from Theorem 3.2.4.

Corollary 3.2.5 (Solution to the Optimal Valuation Problem Under RMBSs (Slack)): *Suppose that J^{Σ} and V^{Σ} are given by (3.10) and (3.11), respectively and $P(\mathcal{C}_t) > 0$. When the capital constraint (3.9) does not hold (i.e., $l_t^b = 0$), a solution to the optimal valuation problem under RMBSs stated in Problem 3.2.3 yields optimal RMBS supply and its rate*

$$\begin{aligned} B_t^{\Sigma n^*} &= \frac{2}{3}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) + \frac{b_1}{3}\Bigg[r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f + 2c_t^B \\ &\quad -(1 - r_t^R)r_t^S + \frac{(r_t^D + c_t^D)}{(1-\gamma)} + \Big(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\Big)\widehat{f}_t^{\Sigma} f_t^{\Sigma} \\ &\quad + \Big(\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) - c_t^p r_t^f + (1 - r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - a\Big)f_t^{\Sigma}\Bigg] \end{aligned} \tag{3.26}$$

and

$$\begin{aligned} r_t^{B\Sigma n^*} &= -\frac{1}{3b_1}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) + \frac{1}{3}\Bigg[r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f + 2c_t^B \\ &\quad -(1 - r_t^R)r_t^S + \frac{(r_t^D + c_t^D)}{(1-\gamma)} + \Big(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\Big)\widehat{f}_t^{\Sigma} f_t^{\Sigma} \\ &\quad + \Big(\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) - c_t^p r_t^f + (1 - r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - a\Big)f_t^{\Sigma}\Bigg], \end{aligned} \tag{3.27}$$

respectively. In this case, the corresponding T_t, deposits and profits under RMBSs are given by

$$\mathtt{T}_t^{\Sigma n^*} = \overline{D} + \frac{\overline{D}}{r_t^p}\Big[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) + (r_t^B - c_t^B) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Big] \tag{3.28}$$

$$\begin{aligned} D_t^{\Sigma n^*} &= \frac{1}{1-\gamma}\Bigg(\overline{D} + \frac{\overline{D}}{r_t^p}\Big[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) + (r_t^B - c_t^B) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Big] \\ &\quad + B_t^{\Sigma n^*} + M_t - K_t - \mathtt{B}_t\Bigg) \end{aligned} \tag{3.29}$$

and

$$\begin{aligned}
\Pi_t^{\Sigma n^*} &= M_t\Bigg[\Big(r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f - (1 - r_t^R) r_t^S\Big) + \Big(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c^t \\
&\quad + c_t^{t\Sigma}\Big)\widehat{f}_t^\Sigma f_t^\Sigma + \Big(\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) + (1 - r_t^R) r_t^S - c^t - c_t^{t\Sigma} - c_t^p r_t^f - a\Big) f_t^\Sigma\Bigg] + \Bigg[\frac{2}{3}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) \\
&\quad + \frac{b_1}{3}\Bigg(r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f + 2c_t^B - (1 - r_t^R) r_t^S + \frac{(r_t^D + c_t^D)}{(1-\gamma)} + \Big(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} \\
&\quad - r_t^M + c_t^t + c_t^{t\Sigma}\Big)\widehat{f}_t^\Sigma f_t^\Sigma + \Big(\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) - c_t^p r_t^f + (1 - r_t^R) r_t^S - c_t^t - c_t^{t\Sigma} - a\Big) f_t^\Sigma\Bigg)\Bigg] \\
&\quad \Bigg\{\Bigg[\frac{1}{3}\Bigg(r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f + 2c_t^B - (1 - r_t^R) r_t^S + \frac{(r_t^D + c_t^D)}{(1-\gamma)} + (r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} \\
&\quad - r_t^M + c_t^t + c_t^{t\Sigma})\widehat{f}_t^\Sigma f_t^\Sigma + (\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) - c_t^p r_t^f + (1 - r_t^R) r_t^S - c_t^t - c_t^{t\Sigma} - a) f_t^\Sigma\Bigg) \\
&\quad - \frac{1}{3b_1}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) - c_t^B\Bigg] - (r_t^D + c_t^D)\frac{1}{1-\gamma}\Bigg\} + \Bigg(\overline{D} + \frac{\overline{D}}{r_t^p}\Bigg[r_t^{\mathtt{T}} - \Bigg[\frac{1}{3b_1}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) \\
&\quad - \frac{1}{3}\Bigg(r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f + 2c_t^B - (1 - r_t^R) r_t^S + \frac{(r_t^D + c_t^D)}{(1-\gamma)} + (r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} \\
&\quad - r_t^M + c_t^t + c_t^{t\Sigma})\widehat{f}_t^\Sigma f_t^\Sigma + (\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) - c_t^p r_t^f + (1 - r_t^R) r_t^S - c_t^t - c_t^{t\Sigma} - a) f_t^\Sigma\Bigg) + c_t^B\Bigg] \\
&\quad + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Bigg]\Bigg)\Bigg(r_t^{\mathtt{T}} - (r_t^D + c_t^D)\frac{1}{1-\gamma}\Bigg) - \Bigg((r_t^D + c_t^D)\frac{1}{1-\gamma}\Bigg)\Bigg(M_t - K_t - \mathtt{B}_t\Bigg) \\
&\quad - (r_t^{\mathtt{B}} + c_t^{\mathtt{B}})\mathtt{B}_t + C(\mathbf{E}[S(\mathcal{C}_t)]) - P^{\mathtt{T}}(\mathtt{T}_t) + \Pi_t^{\Sigma p} - \mathtt{E}_t - \mathtt{F}_t,
\end{aligned} \tag{3.30}$$

respectively.

Proof.
For the situation where capital constraint (3.9) does not hold (i.e., $l_t^b = 0$), using equation (3.22) and the fact that $l_t^b = 0$, we can see that (3.19) becomes $\dfrac{\partial \Pi_t^\Sigma}{\partial r_t^B} = 0$. As in the proof of Theorem 3.2.4, looking at the form of Π_t^Σ given in (3.2) and (3.23), we have equation (3.24). Therefore

$$\frac{\partial \Pi_t^{\Sigma}}{\partial r_t^B} = B_t - b_1\Big[\Big(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\Big)\widehat{f}_t^{\Sigma} f_t^{\Sigma} \tag{3.31}$$
$$+\Big(\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) - c_t^p r_t^f + (1 - r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - a\Big)f_t^{\Sigma}$$
$$+\Big(r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f - (1 - r_t^R)r_t^S\Big)\Big]$$
$$+b_1\Big[(r_t^B - c_t^B) - r_t^{\mathtt{T}} - (r_t^{\mathtt{B}} + c_t^{\mathtt{B}})\Big] - \frac{r_t^p}{\overline{D}}(\overline{D} - \mathtt{T}_t)b_1 = 0.$$

Substituting (3.25) into (3.31) and using (3.12) would give us optimal RMBSs and RMBS rate given by (3.26) and (3.27), respectively. Furthermore we can find SIB's optimal deposit, deposit withdrawals and profits. □

Further discussions of the key aspects of Section 3.2 is provided in Subsection 3.6.1.

3.3 Risk, Profit and Valuation Under RMBS CDOs

In this section, we discuss SIB's risk, profit and valuation under RMBS CDOs. In the sequel, we assume that the notation Π, r^M, M, $\overline{c}^{M\omega}$, p^i, c^p, r^f, r^R, r^S, S, $\mathcal{C}$, $C(\mathbf{E}[S(\mathcal{C})])$, r^B, c^B, B, $r^{\mathtt{T}}$, $\mathtt{T}$, $P^{\mathtt{T}}(\mathtt{T})$, r^D, c^D, D, $r^{\mathtt{B}}$, $c^{\mathtt{B}}$, $\mathtt{B}$, Π^p, K, n, E, O, $\omega(\mathcal{C})$, ω^B, f^M, $mVaR$, $\mathtt{O}$, $r^{S\Sigma}$, f^{Σ} and $\widehat{f}^{\Sigma}$, corresponds to that of Sections 2.3 and 3.2. Further suppositions about notation are that r^r, $\overline{c}^{M\Sigma\omega}$, $c^{i\Sigma}$, c^t, $c^{t\Sigma}$, a, $\Pi^{\Sigma p}$, $\mathtt{E}$ and $\mathtt{F}$ denote the same parameters as in Section 3.2.

Assumption 3.3.1 (Senior Tranches of RMBSs): *We assume that risky marketable securities, B, appearing in the balance sheet (2.7), consist entirely of the senior tranches of RMBSs that are wrapped by an MLI. Also, SIB has an incentive to retain an interest in these tranches.*

This assumption implies that the CDO structure depends on the securitization of senior tranches of RMBSs in particular.

3.3.1 Risk and Profit Under RMBS CDOs

In this subsection, we investigate a subprime mortgage model for profit under RMBS CDOs and its relationship with retained earnings.

3.3.1.1 A Subprime Mortgage Model for Risk and Profit Under RMBS CDOs

In this thesis, a subprime mortgage model for profit under RMBS CDOs can be constructed by considering the difference between cash inflow and outflow. For this profit, in period t, *cash inflow* is constituted by returns on the residual from RMBSs securitization, $r_t^{rb}\widehat{f}_t^{\Sigma b} f_t^{\Sigma b}B_t$, securitized subprime RMBSs, $r_t^B(1 - \widehat{f}_t^{\Sigma b})f_t^{\Sigma b}B_t$, unsecuritized securities, $r_t^B(1 - f_t^{\Sigma b})B_t$, Treasuries, $r_t^{\mathtt{T}}\mathtt{T}_t$, and mortgages, $r_t^M M_t$, as well as the recovery amount, R_t, MLI protection leg payments, $C(S(\mathcal{C}_t))$, and the present value of future gains from subsequent RMBS purchases and their securitizations, $\Pi_t^{\Sigma p}$. On the other hand, we consider the average weighted cost of funds to securitize RMBSs, $\overline{c}^{M\Sigma\omega b}\widehat{f}_t^{\Sigma b}f_t^{\Sigma b}B_t$, losses from securitized RMBSs, $r_t^{S\Sigma b}\widehat{f}_t^{\Sigma b}f_t^{\Sigma b}B_t$, forfeit costs related to MLI insurance wrapping RMBS CDOs, $c_t^{i\Sigma b}\widehat{f}_t^{\Sigma b}f_t^{\Sigma b}B_t$, transaction cost to extend RMBSs, $c_t^{tb}(1-\widehat{f}_t^{\Sigma b})f_t^{\Sigma b}B_t$, and transaction costs from securitized RMBSs $c_t^{t\Sigma b}(1-\widehat{f}_t^{\Sigma b})f_t^{\Sigma b}B_t$ as part of *cash outflow*. Additional components of outflow are weighted average cost of funds for extending RMBSs, $\overline{c}_t^{M\omega b}(1-f_t^{\Sigma b})B_t$, fraction of the face value of unsecuritized RMBSs corresponding to $f_t^{\Sigma b}(1-f_t^{\Sigma b})B_t$, MLI premium for unsecuritized RMBSs losses, $p_t^{ib}(1-f_t^{\Sigma b})B_t$, decreasing value of adverse selection, $a^b f_t^{\Sigma b}B_t$, the all-in cost of holding RMBSs, $c_t^M M_t$, interest paid to depositors, $r_t^D D_t$, the cost of taking deposits, $c^D D_t$, provisions against deposit withdrawals, $P^{\mathtt{T}}(\mathtt{T}_t)$, while $r^{\mathtt{B}}$ and $c^{\mathtt{B}}$ are the borrower rate and marginal cost of borrowing, respectively, losses from suboptimal SPVs, $\mathtt{E}_t$ and costs for funding RMBS securitization, $\mathtt{F}_t$. From the above, we have that model for profit under subprime RMBS CDOs may have the form

$$\begin{aligned}
\Pi_t^{\Sigma b} &= \left(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma}\right)\widehat{f}_t^{\Sigma}f_t^{\Sigma}M_t + \left(r_t^M - c_t^t - c_t^{t\Sigma}\right)(1-\widehat{f}_t^{\Sigma})f_t^{\Sigma}M_t \\
&+\left(r_t^M - \overline{c}_t^{M\omega} - p_t^i + c_t^p r_t^f - (1-r_t^R)r_t^S\right)(1-f_t^{\Sigma})M_t - af_t^{\Sigma}M_t \\
&+\left(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b}\right)\widehat{f}_t^{\Sigma b}f_t^{\Sigma b}B_t + \left(r_t^B - c_t^{tb} - c_t^{t\Sigma b}\right)(1-\widehat{f}_t^{\Sigma b})f_t^{\Sigma b}B_t \\
&+\left(r_t^B - \overline{c}_t^{M\omega b} - p_t^{ib} + c_t^{bp}r_t^{fb} - (1-r_t^{Rb})r_t^{Sb}\right)(1-f_t^{\Sigma b})B_t - a^b f_t^{\Sigma b}B_t + r_t^{\mathtt{T}}\mathtt{T}_t \\
&-\left(r_t^{\mathtt{B}} + c_t^{\mathtt{B}}\right)\mathtt{B}_t - \left(r_t^D + c_t^D\right)D_t + C(\mathbf{E}[S(\mathcal{C}_t)]) - P^{\mathtt{T}}(\mathtt{T}_t) + \Pi_t^{\Sigma p} - \mathtt{E}_t - \mathtt{F}_t,
\end{aligned} \tag{3.32}$$

where $\Pi_t^{\Sigma p} = \Pi_t^p + \widetilde{\Pi}_t^{\Sigma}$. Furthermore, by considering $\dfrac{\partial S(\mathcal{C}_t)}{\partial \mathcal{C}_t^B} < 0$ and (3.32), we know that $\Pi^{\Sigma b}$ is an increasing function of current RMBS credit rating, $\mathcal{C}^B$.

From the above, we note that in (3.32) the cash inflow terms $r_t^{rb}\widehat{f}_t^{\Sigma b}f_t^{\Sigma b}B_t$ and $r_t^B(1-\widehat{f}_t^{\Sigma b})f_t^{\Sigma b}B_t$ carry credit, market (in particular, interest rate), tranching and operational risks while $r_t^B(1-f_t^{\Sigma b})B_t$ embed credit (in particular, counterparty) and market (in particular, interest rate) risks. In (3.32), the cash outflow terms $\overline{c}^{M\Sigma\omega b}\widehat{f}_t^{\Sigma b}f_t^{\Sigma b}B_t$, $r_t^{S\Sigma b}\widehat{f}_t^{\Sigma b}f_t^{\Sigma b}B_t$, $c_t^{i\Sigma b}\widehat{f}_t^{\Sigma b}f_t^{\Sigma b}B_t$, $c_t^{tb}(1-\widehat{f}_t^{\Sigma b})f_t^{\Sigma b}B_t$ and $c_t^{t\Sigma b}(1-\widehat{f}_t^{\Sigma b})f_t^{\Sigma b}B_t$ involve credit (for instance, counterparty), market (specifically, liquidity and valuation), tranching and operational risks. Also, $\overline{c}_t^{M\omega b}(1-f_t^{\Sigma b})B_t$ and $p_t^{ib}(1-f_t^{\Sigma b})B_t$ carry credit, market (particularly, liquidity) and operational risks while $a^b f_t^{\Sigma b}B_t$ embeds credit and market (in the form of liquidity and valuation) risks. As before, the risks that we associate with each of the cash inflow and outflow terms in (3.32) are less straightforward. For instance, strong correlations may exist between each of the aforementioned risks. Also, the risk-carrying terms found in (3.32) affect the entire banking system via systemic risk.

3.3.1.2 Profit Under RMBS CDOs and Retained Earnings

We know that profits, Π_t, are used to meet its obligations, that include *dividend payments on equity*, $n_t d_t$. The *retained earnings*, E^r_t, subsequent to these payments may be computed by using (3.3). After adding and subtracting $\left(r^B_t - \overline{c}^{M\omega b}_t - p^{ib}_t + c^{pb}_t r^{fb}_t - (1 - r^{Rb}_t) r^{Sb}_t\right) B_t$ from (3.32), we get

$$\begin{aligned}
\Pi^{\Sigma b}_t &= \Pi_t + \left(r^r_t - \overline{c}^{M\Sigma\omega}_t - r^{S\Sigma}_t - c^{i\Sigma}_t - r^M_t + c^t_t + c^{t\Sigma}_t\right) f^{\Sigma}_t \widehat{f}^{\Sigma}_t M_t \\
&+ \left(\overline{c}^{M\omega}_t + p^i_t + (1 - r^R_t) r^S_t - c^t_t - c^{t\Sigma}_t - c^p_t r^f_t - a\right) f^{\Sigma}_t M_t \\
&+ \left(r^{rb}_t - \overline{c}^{M\Sigma\omega b}_t - r^{S\Sigma b}_t - c^{i\Sigma b}_t - r^B_t + c^{tb}_t + c^{t\Sigma b}_t\right) f^{\Sigma b}_t \widehat{f}^{\Sigma b}_t B_t \\
&+ \left(\overline{c}^{M\omega b}_t + p^{ib}_t + (1 - r^{Rb}_t) r^{Sb}_t - c^{tb}_t - c^{t\Sigma b}_t - c^{pb}_t r^{fb}_t - a^b\right) f^{\Sigma b}_t B_t \\
&+ \left(r^B_t - \overline{c}^{M\omega b}_t - p^{ib}_t + c^{pb}_t r^{fb}_t - (1 - r^{Rb}_t) r^{Sb}_t\right) B_t \\
&- \mathtt{E}_t - \mathtt{F}_t + \widetilde{\Pi}^{\Sigma}_t.
\end{aligned}$$

Replace Π_t by using (3.3). In this case $\Pi^{\Sigma b}_t$ is given by

$$\begin{aligned}
\Pi^{\Sigma b}_t &= E^r_t + n_t d_t + (1 + r^O_t) O_t + \left(r^r_t - \overline{c}^{M\Sigma\omega}_t - r^{S\Sigma}_t - c^{i\Sigma}_t - r^M_t + c^t_t\right. \\
&\left. + c^{t\Sigma}_t\right) f^{\Sigma}_t \widehat{f}^{\Sigma}_t M_t + \left(\overline{c}^{M\omega}_t + p^i_t + (1 - r^R_t) r^S_t - c^t_t - c^{t\Sigma}_t - c^p_t r^f_t - a\right) f^{\Sigma}_t M_t \\
&+ \left(r^{rb}_t - \overline{c}^{M\Sigma\omega b}_t - r^{S\Sigma b}_t - c^{i\Sigma b}_t - r^B_t + c^{tb}_t + c^{t\Sigma b}_t\right) f^{\Sigma b}_t \widehat{f}^{\Sigma b}_t B_t \\
&+ \left(\overline{c}^{M\omega b}_t + p^{ib}_t + (1 - r^{Rb}_t) r^{Sb}_t - c^{tb}_t - c^{t\Sigma b}_t - c^{pb}_t r^{fb}_t - a^b\right) f^{\Sigma b}_t B_t \\
&+ \left(r^B_t - \overline{c}^{M\omega b}_t - p^{ib}_t + c^{pb}_t r^{fb}_t - (1 - r^{Rb}_t) r^{Sb}_t\right) B_t \\
&- \mathtt{E}_t - \mathtt{F}_t + \widetilde{\Pi}^{\Sigma}_t.
\end{aligned} \tag{3.33}$$

For (3.33) and (2.10) to obtain an expression for capital of the form

$$
\begin{aligned}
K_{t+1}^{\Sigma b} &= n_t(d_t+E_t) - \Pi_t^{\Sigma b} + \Delta F_t + (1+r_t^O)O_t + \Big(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M \\
&\quad + c_t^t + c_t^{t\Sigma}\Big) f_t^{\Sigma}\widehat{f}_t^{\Sigma} M_t + \Big(\overline{c}_t^{M\omega} + p_t^i + (1-r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f - a\Big) f_t^{\Sigma} M_t \\
&\quad + \Big(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b} - r_t^B + c_t^{tb} + c_t^{t\Sigma b}\Big) f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} B_t \\
&\quad + \Big(\overline{c}_t^{M\omega b} + p_t^{ib} + (1-r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb} r_t^{fb} - a^b\Big) f_t^{\Sigma b} B_t \\
&\quad + \Big(r_t^B - \overline{c}_t^{M\omega b} - p_t^{ib} + c_t^{pb} r_t^{fb} - (1-r_t^{Rb})r_t^{Sb}\Big) B_t - \mathtt{E}_t - \mathtt{F}_t + \widetilde{\Pi}_t^{\Sigma}.
\end{aligned}
\tag{3.34}
$$

where K_t is defined by (2.7).

3.3.2 Valuation Under RMBS CDOs

If the expression for retained earnings given by (3.33) is substituted into (2.9), the nett cash flow generated for a shareholder is given by

$$
\begin{aligned}
N_t^{\Sigma b} &= \Pi_t^{\Sigma b} - \Delta F_t = n_t(d_t+E_t) - K_{t+1}^{\Sigma b} + (1+r_t^O)O_t + \Big(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} \\
&\quad - r_t^M + c_t^t + c_t^{t\Sigma}\Big) f_t^{\Sigma}\widehat{f}_t^{\Sigma} M_t + \Big(\overline{c}_t^{M\omega} + p_t^i + (1-r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f \\
&\quad - a\Big) f_t^{\Sigma} M_t + \Big(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b} - r_t^B + c_t^{tb} + c_t^{t\Sigma b}\Big) f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} B_t \\
&\quad + \Big(\overline{c}_t^{M\omega b} + p_t^{ib} + (1-r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb} r_t^{fb} - a^b\Big) f_t^{\Sigma b} B_t \\
&\quad + \Big(r_t^B - \overline{c}_t^{M\omega b} - p_t^{ib} + c_t^{pb} r_t^{fb} - (1-r_t^{Rb})r_t^{Sb}\Big) B_t - \mathtt{E}_t - \mathtt{F}_t + \widetilde{\Pi}_t^{\Sigma}.
\end{aligned}
\tag{3.35}
$$

We know that valuation is equal to the nett cash flow plus ex-dividend value. This translates to the expression

$$
V_t^{\Sigma b} = N_t^{\Sigma b} + K_{t+1}^{\Sigma b}, \tag{3.36}
$$

where K_t is defined by (2.7). Furthermore, under RMBS CDOs, the analyst evaluates the expected future cash flows in j periods based on a *stochastic discount factor*, $\delta_{t,j}$, such that SIB's value is

$$V_t^{\Sigma b} = N_t^{\Sigma b} + \mathbf{E}_t\Big[\sum_{j=1}^{\infty}\delta_{t,j}N_{t+j}^{\Sigma b}\Big]. \tag{3.37}$$

3.3.3 Optimal Valuation Under RMBS CDOs

In this subsection, we make use of the modeling of assets, liabilities and capital of the preceding section to solve an optimal valuation problem.

3.3.3.1 Statement of Optimal Valuation Problem Under RMBS CDOs

Suppose that SIB's valuation performance criterion, $J^{\Sigma b}$, at t is given by

$$\begin{aligned} J_t^{\Sigma b} &= \Pi_t^{\Sigma b} + l_t^b\Big[K_t^{\Sigma b} - \rho\Big(\omega^M M_t + \omega(\mathcal{C}_t^B)B_t + 12.5f^M(mVaR + 0)\Big)\Big] \\ &\quad -c_t^{dw}\Big[K_{t+1}^{\Sigma b}\Big] + \mathbf{E}_t\Big[\delta_{t,1}V\Big(K_{t+1}^{\Sigma b},\ x_{t+1}\Big)\Big], \end{aligned} \tag{3.38}$$

where l_t^b is the Lagrangian multiplier for the total capital constraint, K_t^{Σ} is defined by (3.9), $\mathbf{E}_t[\cdot]$ is the expectation conditional on SIB's information in period t and x_t is the deposit withdrawls in period t with probability distribution $f(x_t)$. Also, c_t^{dw} is the deadweight cost of total capital that consists of equity.

The optimal valuation problem is to maximize the *value* given by (3.37). We can now state the optimal valuation problem as follows.

Problem 3.3.2 (Statement of Optimal Valuation Problem Under RMBS CDOs): *Suppose that the total capital constraint, $K^{\Sigma b}$, and the performance criterion, $J^{\Sigma b}$, are given by (3.9) and (3.38), respectively. SIB's optimal valuation problem is to maximize its value given by (3.37) by choosing the RMBS rate, deposits and regulatory capital for*

$$V^{\Sigma b}(K_t^{\Sigma b},\ x_t) \;=\; \max_{r_t^B,\ D_t,\ \Pi_t^{\Sigma b}} J_t^{\Sigma b}, \tag{3.39}$$

subject to RMBS, balance sheet, cash flow and financing constraints given by (3.12), (3.13), (3.32) and (3.34), respectively.

3.3.3.2 Solution of Optimal Valuation Problem Under RMBS CDOs

In this subsection, we find a solution to Problem 3.3.2 when the capital constraint (3.9) holds as well as when it does not. In this regard, the main result can be stated and proved as follows.

Theorem 3.3.3 (Solution to an Optimal Valuation Problem Under RMBS CDOs): *Suppose that $J^{\Sigma b}$ and $V^{\Sigma b}$ are given by (3.38) and (3.39), respectively. When the capital constraint given by (3.9) holds (i.e., $l_t^b > 0$), a solution to the optimal valuation problem yields an optimal RMBS supply and rate given by (3.14) and (3.15), respectively. In this case, optimal deposits, provisions for deposit withdrawals via Treasuries and profits under RMBS CDO securitization are given by*

$$D_t^{\Sigma b*} = \frac{1}{1-\gamma}\Big(\overline{D} + \frac{\overline{D}}{r_t^p}\Big[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Big] + \frac{K_t^{\Sigma b}}{\rho\omega(\mathcal{C}_t^B)} - \frac{\omega^M M_t + 12.5 f^B(mVaR + \mathtt{O})}{\omega(\mathcal{C}_t^B)} + M_t - K_t - \mathtt{B}_t\Big), \quad (3.40)$$

$$\mathtt{T}_t^{\Sigma b*} = \overline{D} + \frac{\overline{D}}{r_t^p}\Big[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\Big] \quad (3.41)$$

and

$$
\begin{aligned}
\Pi_t^{\Sigma b^*} \;=\; & \left[\frac{K_t^{\Sigma b}}{\rho\omega^M} - \frac{\omega(\mathcal{C}_t^B)B_t + 12.5f^M(mVaR + \mathtt{0})}{\omega^M}\right]\left[\widehat{f}_t^{\Sigma} f_t^{\Sigma}\left(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma}\right.\right. \qquad (3.42)\\
& \left. -r_t^M + c_t^t + c_t^{t\Sigma}\right) + f_t^{\Sigma}\left(\overline{c}_t^{M\omega} + p_t^i + (1 - r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f - a\right)\\
& \left. + \left(r_t^M - \overline{c}_t^{M\omega} - p_t^i + c_t^p r_t^f - (1 - r_t^R)r_t^S\right)\right] + \left[\frac{K_t^{\Sigma b}}{\rho\omega(\mathcal{C}_t^B)}\right.\\
& \left. - \frac{\omega^M M_t + 12.5f^M(mVaR + \mathtt{0})}{\omega(\mathcal{C}_t^B)}\right]\left[\widehat{f}_t^{\Sigma b} f_t^{\Sigma b}\left(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b}\right.\right.\\
& \left. + \frac{1}{b_1}\left(b_0 - \frac{K_t^{\Sigma b}}{\rho\omega(\mathcal{C}_t^B)} + \frac{\omega^M M_t + 12.5f^M(mVaR + \mathtt{0})}{\omega(\mathcal{C}_t^B)} + b_2\mathcal{C}_t^B + \sigma_t^B\right) + c_t^{tb} + c_t^{t\Sigma b}\right)\\
& + f_t^{\Sigma b}\left(\overline{c}_t^{M\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb} r_t^{fb} - a^b\right)\\
& - \left(\frac{1}{b_1}\left(b_0 - \frac{K_t^{\Sigma b}}{\rho\omega(\mathcal{C}_t^B)} + \frac{\omega^M M_t + 12.5f^M(mVaR + \mathtt{0})}{\omega(\mathcal{C}_t^B)} + b_2\mathcal{C}_t^B + \sigma_t^B\right)\right.\\
& \left.\left. + \overline{c}_t^{M\omega b} + p_t^{ib} - c_t^{pb} r_t^{fb} + (1 - r_t^{Rb})r_t^{Sb}\right) - (r_t^D + c_t^D)\frac{1}{1-\gamma}\right]\\
& + \left(\overline{D} + \frac{\overline{D}}{r_t^p}\left[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\right]\right)\\
& \left(r_t^{\mathtt{T}} - (r_t^D + c_t^D)\frac{1}{1-\gamma}\right) - \left((r_t^D + c_t^D)\frac{1}{1-\gamma}\right)\left(M_t - K_t - \mathtt{B}_t\right)\\
& - (r_t^{\mathtt{B}} + c_t^{\mathtt{B}})\mathtt{B}_t + C(\mathbf{E}[S(\mathcal{C}_t)]) - P^{\mathtt{T}}(\mathtt{T}_t) + \Pi_t^{\Sigma p} - \mathtt{E}_t - \mathtt{F}_t,
\end{aligned}
$$

respectively.

Proof. A complete proof is provided in Subsection 3.8.2 of Section 3.8. □

The next corollary follows immediately from Theorem 3.3.3.

Corollary 3.3.4 (Solution to the Optimal Valuation Problem Under RMBS CDOs (Slack)): *Suppose that $J^{\Sigma b}$ and $V^{\Sigma b}$ are given by (3.38) and (3.39), respectively and $P(\mathcal{C}_t) > 0$. When the capital constraint (3.9) does not hold (i.e., $l_t^b = 0$), a solution to the optimal valuation problem under RMBS CDOs stated in Problem 3.3.2 yields optimal RMBS CDO supply and its rate*

$$
\begin{aligned}
B_t^{\Sigma bn^*} &= \frac{1}{2}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) + \frac{b_1}{2(1 - f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})}\Bigg[\overline{c}_t^{M\Sigma\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb} \\
&\quad - c_t^{pb}r_t^{fb} + \frac{(r_t^D + c_t^D)}{2(1-\gamma)} - \left(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b} + c_t^{tb} + c_t^{t\Sigma b}\right) f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} \\
&\quad - \left(\overline{c}_t^{M\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\right) f_t^{\Sigma b}\Bigg]
\end{aligned} \tag{3.43}
$$

and

$$
\begin{aligned}
r_t^{B^{\Sigma bn^*}} &= -\frac{1}{2b_1}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) + \frac{1}{2(1 - f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})}\Bigg[\overline{c}_t^{M\Sigma\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb} \\
&\quad - c_t^{pb}r_t^{fb} + \frac{(r_t^D + c_t^D)}{2(1-\gamma)} - \left(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b} + c_t^{tb} + c_t^{t\Sigma b}\right) f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} \\
&\quad - \left(\overline{c}_t^{M\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\right) f_t^{\Sigma b}\Bigg],
\end{aligned} \tag{3.44}
$$

respectively. In this case, the corresponding T_t, deposits and profits under RMBS CDOs are given by

$$
\mathtt{T}_t^{\Sigma bn^*} = \overline{D} + \frac{\overline{D}}{r_t^p}\left[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\right] \tag{3.45}
$$

$$
\begin{aligned}
D_t^{\Sigma bn^*} &= \frac{1}{1-\gamma}\Bigg(\overline{D} + \frac{\overline{D}}{r_t^p}\left[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\right] \\
&\quad + B_t^{\Sigma bn^*} + M_t - K_t - \mathtt{B}_t\Bigg).
\end{aligned} \tag{3.46}
$$

and

$$
\begin{aligned}
\Pi_t^{\Sigma bn^*} = {} & M_t\Bigg[\bigg(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\bigg)\widehat{f}_t^{\Sigma} f_t^{\Sigma} + \bigg(\overline{c}_t^{M\omega} + p_t^i \\
& +(1-r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f - a\bigg)f_t^{\Sigma} + \bigg(r_t^M - \overline{c}_t^{M\omega} - p_t^i + c_t^p r_t^f - (1-r_t^R)r_t^S\bigg)\Bigg] \\
& +\Bigg[\frac{1}{2}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) + \frac{b_1}{2(1-f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})}\bigg(\overline{c}_t^{M\Sigma\omega b} + p_t^{ib} + (1-r_t^{Rb})r_t^{Sb} - c_t^{pb}r_t^{fb} \\
& +\frac{(r_t^D + c_t^D)}{2(1-\gamma)} - \bigg(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b} + c_t^{tb} + c_t^{t\Sigma b}\bigg)f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} - \bigg(\overline{c}_t^{M\omega b} + p_t^{ib} \\
& +(1-r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\bigg)f_t^{\Sigma b}\bigg)\Bigg]\Bigg\{\widehat{f}_t^{\Sigma b} f_t^{\Sigma b}\bigg(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} \\
& -c_t^{i\Sigma b} + \Bigg[\frac{1}{2b_1}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) - \frac{1}{2(1-f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})}\bigg(\overline{c}_t^{M\Sigma\omega b} + p_t^{ib} + (1-r_t^{Rb})r_t^{Sb} \\
& -c_t^{pb}r_t^{fb} + \frac{(r_t^D + c_t^D)}{2(1-\gamma)} - \bigg(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b} + c_t^{tb} + c_t^{t\Sigma b}\bigg)f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} \\
& -\bigg(\overline{c}_t^{M\omega b} + p_t^{ib} + (1-r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\bigg)f_t^{\Sigma b}\bigg)\Bigg] + c_t^{tb} + c_t^{t\Sigma b}\bigg) \\
& +f_t^{\Sigma b}\bigg(\overline{c}_t^{M\omega b} + p_t^{ib} + (1-r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\bigg) \\
& -\Bigg(\Bigg[\frac{1}{2b_1}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) - \frac{1}{2(1-f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})}\bigg(\overline{c}_t^{M\Sigma\omega b} + p_t^{ib} + (1-r_t^{Rb})r_t^{Sb} \\
& -c_t^{pb}r_t^{fb} + \frac{(r_t^D + c_t^D)}{2(1-\gamma)} - \bigg(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b} + c_t^{tb} + c_t^{t\Sigma b}\bigg)f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} \\
& -\bigg(\overline{c}_t^{M\omega b} + p_t^{ib} + (1-r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\bigg)f_t^{\Sigma b}\bigg)\Bigg] \\
& +\overline{c}_t^{M\omega b} + p_t^{ib} - c_t^{pb}r_t^{fb} + (1-r_t^{Rb})r_t^{Sb}\Bigg) - (r_t^D + c_t^D)\frac{1}{1-\gamma}\Bigg\} \\
& +\bigg(\overline{D} + \frac{\overline{D}}{r_t^p}\bigg[r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\bigg]\bigg) \\
& \bigg(r_t^{\mathtt{T}} - (r_t^D + c_t^D)\frac{1}{1-\gamma}\bigg) - \bigg((r_t^D + c_t^D)\frac{1}{1-\gamma}\bigg)\bigg(M_t - K_t - \mathtt{B}_t\bigg) \\
& -(r_t^{\mathtt{B}} + c_t^{\mathtt{B}})\mathtt{B}_t + C(\mathbf{E}[S(\mathcal{C}_t)]) - P^{\mathtt{T}}(\mathtt{T}_t) + \Pi_t^{\Sigma p} - \mathtt{E}_t - \mathtt{F}_t,
\end{aligned}
\tag{3.47}
$$

Further discussion of important issues raised in Section 3.3 is provided in Subsection 3.6.2.

3.4 Mortgage Securitization and Capital Under Basel Regulation

In this section, we deal with a model where both subprime RMBS default and risk-weights are a function of the current level of credit rating, $\mathcal{C}_t^B$. The capital constraint is described by the expression in (2.13), where the risk-weights on RMBSs, $\omega^B \neq 0$, are considered. Also, in this situation, the risk-weight on RMBSs, $\omega(\mathcal{C}_t^B)$, is a decreasing function of the current level of credit rating, i.e, $\dfrac{\partial \omega(\mathcal{C}_t^B)}{\partial \mathcal{C}_t^B} < 0$. In particular, the risk-weights for mortgages are kept constant, i.e., $\omega^M = 1$. In this case, the capital constraint (2.13) becomes

$$K_t \geq \rho\Big[\omega^M M_t + \omega(\mathcal{C}_t^B)B_t + 12.5f^M(mVaR + 0)\Big]. \tag{3.48}$$

3.4.1 Quantity and Pricing of RMBSs, RMBS CDOs and Capital Under Basel Regulation (Securitized Case)

In this subsection, we firstly examine how capital, K, and the quantity and price of RMBSs, B, are affected by changes in the level of credit rating, $\mathcal{C}^B$, when risk-weight on RMBSs, $\omega(\mathcal{C}_t^B)$, are allowed to vary as in Section 3.2. Secondly, we will provide an analogue of this result for RMBS CDOs.

Theorem 3.4.1 (Mortgage Securitization and Capital under Basel Regulation (Securitized Case)): *Suppose that the assumptions in Section 3.2 hold and that $B(\mathcal{C}_t^B) > 0$ and the RMBS risk-weight, $\omega(\mathcal{C}_t^B)$, are allowed to vary. In this case, we have that*

1. *if* $\dfrac{\partial \sigma_{t+1}^{B*}}{\partial \mathcal{C}_t^B} < 0$ *then* $\dfrac{\partial K_{t+1}^{\Sigma}}{\partial \mathcal{C}_t^B} > 0$;
2. *if* $\dfrac{\partial \sigma_{t+1}^{B*}}{\partial \mathcal{C}_t^B} > 0$ *then* $\dfrac{\partial K_{t+1}^{\Sigma}}{\partial \mathcal{C}_t^B} < 0$.

Proof.

We equate SIB's optimal RMBSs for the problems with $l_t^b = 0$ and $l_t^b > 0$ in order to obtain

$$\begin{aligned}
&\frac{2}{3}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) + \frac{b_1}{3}\Bigg[r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f + 2c_t^B - (1 - r_t^R)r_t^S + \frac{(r_t^D + c_t^D)}{(1-\gamma)} \\
&\quad + \left(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\right)\hat{f}_t^{\Sigma} f_t^{\Sigma} + \Big(\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) - c_t^p r_t^f \\
&\quad + (1 - r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - a\Big)f_t^{\Sigma}\Bigg] = \frac{K_t^{\Sigma}}{\rho\omega(\mathcal{C}_t^B)} - \frac{M_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t^B)}.
\end{aligned}$$

Solving for σ_t^B, we obtain

$$
\begin{aligned}
\sigma_t^{B^*} &= 3\left(\frac{K_t^\Sigma}{\rho\omega(\mathcal{C}_t^B)} - \frac{M_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t^B)}\right) - 2(b_0 + b_2\mathcal{C}_t^B) - b_1\Bigg[r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) \\
&+ c_t^p r_t^f + 2c_t^B - (1 - r_t^R)r_t^S + \frac{(r_t^D + c_t^D)}{(1-\gamma)} + \left(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\right)\widehat{f}_t^\Sigma f_t^\Sigma \\
&+ \left(\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) - c_t^p r_t^f + (1 - r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - a\right)f_t^\Sigma\Bigg]
\end{aligned}
$$

Using equation (3.19) and substituting equation (3.17), we obtain

$$
\begin{aligned}
b_1\rho\omega(\mathcal{C}_t^B)l_t^b &= b_1\Bigg[2(r_t^B - c_t^B) - \left(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} - r_t^M + c_t^t + c_t^{t\Sigma}\right)\widehat{f}_t^\Sigma f_t^\Sigma \\
&- \left(\overline{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) - c_t^p r_t^f + (1 - r_t^R)r_t^S - c_t^t - c_t^{t\Sigma} - a\right)f_t^\Sigma \\
&- \left(r_t^M - \overline{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f - (1 - r_t^R)r_t^S\right) - \frac{(r_t^D + c_t^D)}{1-\gamma}\Bigg] + B_t^*.
\end{aligned}
$$

Substitute $r_t^{B^*}$ and B_t^* into the expression above to obtain

$$
l_t^{b^*} = \frac{2\sigma_t^B - \sigma_t^{B^*}}{\omega(\mathcal{C}_t^B)\rho b_1}.
$$

Using equation (3.11) to find the partial derivative of the value function with respect to SIB capital we obtain

$$
\frac{\partial V^\Sigma}{\partial K_t^\Sigma} = \begin{cases} l_t^b + \dfrac{1}{1-\gamma}(r_t^D + c_t^D), & \\ \dfrac{1}{1-\gamma}(r_t^D + c_t^D), & \text{for } \ \underline{B} \le \sigma_t^B \le \sigma_t^{B^*}, \\ \dfrac{1}{1-\gamma}(r_t^D + c_t^D) + \dfrac{2\sigma_t^B - \sigma_t^{B^*}}{\omega(\mathcal{C}_t^B)\rho b_1}, & \text{for } \ \sigma_t^{B^*} \le \sigma_t^B \le \overline{B}. \end{cases}
$$

By substituting the above expression into the optimal condition for total capital (3.22), we obtain

$$
c_t^{dw} - \mathbf{E}_t\left[\delta_{t,1}\frac{1}{1-\gamma}(r_t^D + c_t^D)\right] - \frac{1}{\omega(\mathcal{C}_{t+1}^B)\rho b_1}\mathbf{E}_t\left[\int_{\sigma_{t+1}^{B^*}}^{\overline{B}} \delta_{t,1}\left(2\sigma_{t+1}^B - \sigma_{t+1}^{B^*}\right)dF(\sigma_{t+1}^B)\right] = 0.
$$

We denote the left-hand side of the above expression by Y, so that

$$Y = \frac{1}{\omega(\mathcal{C}_{t+1}^B)\rho b_1}\mathbf{E}_t\Big[\int_{\sigma_{t+1}^{B*}}^{\overline{B}} \delta_{t,1}\Big(2\sigma_{t+1}^B - \sigma_{t+1}^{B*}\Big)dF(\sigma_{t+1}^B)\Big]. \qquad (3.49)$$

From the Implicit Function Theorem, we can calculate $\frac{\partial Y}{\partial \mathcal{C}_t^B}$ by using equation (3.49) in order to obtain

$$\begin{aligned}\frac{\partial Y}{\partial \mathcal{C}_t^B} &= -\frac{1}{\rho b_1}\frac{(-\mu^{\mathcal{C}_t^B})\frac{\partial \omega}{\partial \mathcal{C}_{t+1}^B}}{[\omega(\mathcal{C}_{t+1}^B)]^2}\mathbf{E}_t\Big[\int_{\sigma_{t+1}^{B*}}^{\overline{B}} \delta_{t,1}(2\sigma_{t+1}^B - \sigma_{t+1}^{B*})dF(\sigma_{t+1}^B)\Big] \\ &\quad -\frac{1}{\rho b_1\omega(\mathcal{C}_{t+1}^B)}\frac{\partial \sigma_{t+1}^{B*}}{\partial \mathcal{C}_t^B}\mathbf{E}_t\Big[\int_{\sigma_{t+1}^{B*}}^{\overline{B}} \delta_{t,1}dF(\sigma_{t+1}^B)\Big],\end{aligned}$$

where

$$\begin{aligned}\frac{\partial \sigma_{t+1}^{B*}}{\partial \mathcal{C}_t^B} &= -\frac{3}{\rho}\Big(\frac{K_t^\Sigma - \rho(M_t + 12.5f^M(mVaR + 0))}{[\omega(\mathcal{C}_{t+1}^B)]^2}\Big)\mu^{\mathcal{C}_t^B}\frac{\partial \omega}{\partial \mathcal{C}_{t+1}^B} \\ &\quad -2b_2\mu^{\mathcal{C}_t^B} + b_1\mu^{\mathcal{C}_t^B}(1 - f_t^\Sigma)\Big[\frac{\partial p_t^i}{\partial \mathcal{C}_{t+1}^B} + \frac{\partial r_t^S}{\partial \mathcal{C}_{t+1}^B}\Big]\end{aligned} \qquad (3.50)$$

and

$$\frac{\partial Y}{\partial K_{t+1}^\Sigma} = \frac{3}{b_1[\omega(\mathcal{C}_{t+1}^B)\rho]^2}\mathbf{E}_t\Big[\int_{\sigma_{t+1}^{B*}}^{\overline{B}} \delta_{t,1}dF(\sigma_{t+1}^B)\Big].$$

As a consequence, we have that $\frac{\partial K_{t+1}^\Sigma}{\partial \mathcal{C}_t^B} > 0$ only if $\frac{\partial \sigma_{t+1}^{B*}}{\partial \mathcal{C}_t^B} < 0$.

□

The following corollary represents an analogue of Theorem 3.4.1 in the case of RMBS CDOs as discussed in Section 3.3 and follows immediately.

Corollary 3.4.2 (Mortgage Securitization and Capital under Basel Regulation (Securitized Case)): *Suppose that the assumptions in Section 3.3 hold and that $B(\mathcal{C}_t^B) > 0$ and the RMBS risk-weight, $\omega(\mathcal{C}_t^B)$, are allowed to vary. In this case, we have that*

1. *if* $\frac{\partial \sigma_{t+1}^{B*}}{\partial \mathcal{C}_t^B} < 0$ *then* $\frac{\partial K_{t+1}^{\Sigma b}}{\partial \mathcal{C}_t^B} > 0$;
2. *if* $\frac{\partial \sigma_{t+1}^{B*}}{\partial \mathcal{C}_t^B} > 0$ *then* $\frac{\partial K_{t+1}^{\Sigma b}}{\partial \mathcal{C}_t^B} < 0$.

Proof.

We equate SIB's optimal RMBS CDOs for the problems with $l_t^b = 0$ and $l_t^b > 0$ in order to obtain

$$\frac{1}{2}(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B) + \frac{b_1}{2(1 - f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})}\Bigg[\overline{c}_t^{M\Sigma\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb} - c_t^{pb}r_t^{fb} + \frac{(r_t^D + c_t^D)}{2(1-\gamma)} - \Big(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b} + c_t^{tb} + c_t^{t\Sigma b}\Big)f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} - \Big(\overline{c}_t^{M\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\Big)f_t^{\Sigma b}\Bigg] = \frac{K_t^{\Sigma b}}{\rho\omega(\mathcal{C}_t^B)} - \frac{M_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t^B)}.$$

Solving for σ_t^B, we obtain

$$\begin{aligned}\sigma_t^{B^*} &= 2(1 - f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})\Big(\frac{K_t^{\Sigma b}}{\rho\omega(\mathcal{C}_t^B)} - \frac{M_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t^B)}\Big) - (1 - f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})(b_0 + b_2\mathcal{C}_t^B)\\ &\quad -b_1\Bigg[\overline{c}_t^{M\Sigma\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb} - c_t^{pb}r_t^{fb} + \frac{(r_t^D + c_t^D)}{2(1-\gamma)} - \Big(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b}\\ &\quad +c_t^{tb} + c_t^{t\Sigma b}\Big)f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} - \Big(\overline{c}_t^{M\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb} - c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\Big)f_t^{\Sigma b}\Bigg]\end{aligned}$$

Using equation (3.61) and substituting equation (3.41), we obtain

$$\begin{aligned}b_1\rho\omega(\mathcal{C}_t^B)l_t^b &= 2b_1\Bigg[\Big(r_t^B - \overline{c}_t^{M\omega b} - p_t^{ib} + c_t^{pb}r_t^{fb} - (1 - r_t^{Rb})r_t^{Sb}\Big) + \Big(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b}\\ &\quad -r_t^{S\Sigma b} - c_t^{i\Sigma b} - r_t^B + c_t^{tb} + c_t^{t\Sigma b}\Big)f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} + \Big(\overline{c}_t^{M\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb}\\ &\quad -c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\Big)f_t^{\Sigma b} - \frac{(r_t^D + c_t^D)}{2(1-\gamma)}\Bigg] + 2(1 - f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})B_t^*.\end{aligned}$$

Substitute $r_t^{B^*}$ and B_t^* into the expression above to obtain

$$l_t^{b^*} = \frac{\sigma_t^B - \sigma_t^{B^*}}{\omega(\mathcal{C}_t^B)\rho b_1}.$$

Using equation (3.39) to find the partial derivative of the value function with respect to SIB capital we obtain

$$\frac{\partial V^{\Sigma b}}{\partial K_t^{\Sigma b}} = \begin{cases} l_t^b + \frac{1}{1-\gamma}(r_t^D + c_t^D), & \\ \frac{1}{1-\gamma}(r_t^D + c_t^D), & \text{for} \quad \underline{B} \leq \sigma_t^B \leq \sigma_t^{B^*}, \\ \frac{1}{1-\gamma}(r_t^D + c_t^D) + \frac{\sigma_t^B - \sigma_t^{B^*}}{\omega(\mathcal{C}_t^B)\rho b_1}, & \text{for} \quad \sigma_t^{B^*} \leq \sigma_t^B \leq \overline{B}. \end{cases}$$

By substituting the above expression into the optimal condition for total capital (3.64), we obtain

$$c_t^{dw} - \mathbf{E}_t\left[\delta_{t,1}\frac{1}{1-\gamma}(r_t^D + c_t^D)\right] - \frac{1}{\omega(\mathcal{C}_{t+1}^B)\rho b_1}\mathbf{E}_t\left[\int_{\sigma_{t+1}^{B^*}}^{\overline{B}} \delta_{t,1}\left(\sigma_{t+1}^B - \sigma_{t+1}^{B^*}\right)dF(\sigma_{t+1}^B)\right] = 0.$$

We denote the left-hand side of the above expression by Y, so that

$$Y = \frac{1}{\omega(\mathcal{C}_{t+1}^B)\rho b_1}\mathbf{E}_t\left[\int_{\sigma_{t+1}^{B^*}}^{\overline{B}} \delta_{t,1}\left(\sigma_{t+1}^B - \sigma_{t+1}^{B^*}\right)dF(\sigma_{t+1}^B)\right]. \tag{3.51}$$

From the Implicit Function Theorem, we can calculate $\frac{\partial Y}{\partial \mathcal{C}_t^B}$ by using equation (3.51) in order to obtain

$$\begin{aligned} \frac{\partial Y}{\partial \mathcal{C}_t^B} &= -\frac{1}{\rho b_1}\frac{(-\mu^{\mathcal{C}_t^B})\frac{\partial \omega}{\partial \mathcal{C}_{t+1}^B}}{[\omega(\mathcal{C}_{t+1}^B)]^2}\mathbf{E}_t\left[\int_{\sigma_{t+1}^{B^*}}^{\overline{B}} \delta_{t,1}(\sigma_{t+1}^B - \sigma_{t+1}^{B^*})dF(\sigma_{t+1}^B)\right] \\ &\quad -\frac{1}{\rho b_1 \omega(\mathcal{C}_{t+1}^B)}\frac{\partial \sigma_{t+1}^{B^*}}{\partial \mathcal{C}_t^B}\mathbf{E}_t\left[\int_{\sigma_{t+1}^{B^*}}^{\overline{B}} \delta_{t,1}dF(\sigma_{t+1}^B)\right], \end{aligned}$$

where

$$\begin{aligned} \frac{\partial \sigma_{t+1}^{B^*}}{\partial \mathcal{C}_t^B} &= -\frac{2}{\rho}\left(\frac{K_t^{\Sigma b} - \rho(M_t + 12.5 f^M(mVaR + 0))}{[\omega(\mathcal{C}_{t+1}^B)]^2}\right)\mu^{\mathcal{C}_t^B}\frac{\partial \omega}{\partial \mathcal{C}_{t+1}^B} \\ &\quad -b_2\mu^{\mathcal{C}_t^B} - b_1\mu^{\mathcal{C}_t^B}(1 - f_t^{\Sigma b})\left[\frac{\partial p_t^{ib}}{\partial \mathcal{C}_{t+1}^B} + \frac{\partial r_t^{Sb}}{\partial \mathcal{C}_{t+1}^B}\right] \end{aligned} \tag{3.52}$$

and

$$\frac{\partial Y}{\partial K_{t+1}^{\Sigma b}} = \frac{2}{b_1[\omega(\mathcal{C}_{t+1}^B)\rho]^2}\mathbf{E}_t\left[\int_{\sigma_{t+1}^{B^*}}^{\overline{B}} \delta_{t,1}dF(\sigma_{t+1}^B)\right].$$

As a consequence, we have that $\dfrac{\partial K^{\Sigma b}_{t+1}}{\partial \mathcal{C}^B_t} > 0$ only if $\dfrac{\partial \sigma^{B^*}_{t+1}}{\partial \mathcal{C}^B_t} < 0$. □

3.4.2 Subprime RMBSs and Their Rates Under Basel Capital Regulation (Slack Constraint; Securitized Case)

Next, we consider the effect of a shock to the current level of RMBS credit rating, $\mathcal{C}^B_t$ on RMBSs, B, and the subprime RMBS rate, r^B. In particular, we analyze the case where the capital constraint (3.48) is slack.

Proposition 3.4.3 (Subprime RMBSs under Basel Capital Regulation (Slack Constraint; Securitized Case)): *Under the same hypothesis as Theorem 3.4.1 when $l^b_t = 0$ we have that*

$$\frac{\partial B^{\Sigma n^*}_{t+j}}{\partial \mathcal{C}^B_t} = \frac{1}{3}\mu_j{}^{\mathcal{C}^B}\left[2b_2 - b_1(1 - f^{\Sigma}_t)\left(\frac{\partial p^i(\mathcal{C}^B_{t+j})}{\partial \mathcal{C}^B_{t+j}} + \frac{\partial r^S_t(\mathcal{C}^B_{t+j})}{\partial \mathcal{C}^B_{t+j}}\right)\right] \tag{3.53}$$

and

$$\frac{\partial r^{B^{\Sigma n^*}}_{t+j}}{\partial \mathcal{C}^B_t} = -\frac{1}{3}\mu_j{}^{\mathcal{C}^B}\left[\frac{b_2}{b_1} + (1 - f^{\Sigma}_t)\left(\frac{\partial p^i(\mathcal{C}^B_{t+j})}{\partial \mathcal{C}^B_{t+j}} + \frac{\partial r^S_t(\mathcal{C}^B_{t+j})}{\partial \mathcal{C}^B_{t+j}}\right)\right]. \tag{3.54}$$

Proof.
In order to prove Proposition 3.4.3, we find the partial derivatives of SIB's RMBS supply, $B^{\Sigma n^*}$, and the subprime RMBS rate, $r^{B^{\Sigma n^*}}$, with respect to the current RMBS credit rating, $\mathcal{C}^B_t$. Here, we consider (3.26), (3.27) and the conditions $\dfrac{\partial r^S_t(\mathcal{C}^B_{t+j})}{\partial \mathcal{C}^B_{t+j}} < 0$, and $r^R_t = 0$. We are now able to calculate

$$\begin{aligned}\frac{\partial B^{\Sigma n^*}_{t+j}}{\partial \mathcal{C}^B_t}&\left[\frac{2}{3}(b_0 + b_2\mathcal{C}^B_t + \sigma^B_t) + \frac{b_1}{3}\left[\left(r^M_t - \overline{c}^{M\omega}_t - p^i_t(\mathcal{C}_t) + c^p_t r^f_t + 2c^B_t - (1 - r^R_t)r^S_t + \frac{(r^D_t + c^D_t)}{1-\gamma}\right)\right.\right.\\ &+\left(r^r_t - \overline{c}^{M\Sigma\omega}_t - r^{S\Sigma}_t - c^{i\Sigma}_t - r^M_t + c^t_t + c^{t\Sigma}_t\right)\hat{f}^{\Sigma}_t f^{\Sigma}_t + \left(\overline{c}^{M\omega}_t + p^i_t(\mathcal{C}_t) - c^p_t r^f_t\right.\\ &\left.\left.\left.+(1 - r^R_t)r^S_t - c^t_t - c^{t\Sigma}_t - a\right)f^{\Sigma}_t\right]\right] = \frac{1}{3}\mu_j{}^{\mathcal{C}^B}\left(2b_2 - b_1(1 - f^{\Sigma}_t)\left[\frac{\partial p^i(\mathcal{C}^B_{t+j})}{\partial \mathcal{C}^B_{t+j}} + \frac{\partial r^S_t(\mathcal{C}^B_{t+j})}{\partial \mathcal{C}^B_{t+j}}\right]\right)\end{aligned}$$

and

$$\frac{\partial r_{t+j}^{B^{\Sigma n^*}}}{\partial \mathcal{C}_t^B}\Bigg[-\frac{1}{3b_1}(b_0+b_2\mathcal{C}_t^B+\sigma_t^B)+\frac{1}{3}\Bigg[\Bigg(r_t^M-\overline{c}_t^{M\omega}-p_t^i(\mathcal{C}_t)+c_t^p r_t^f+2c_t^B-(1-r_t^R)r_t^S$$

$$+\frac{(r_t^D+c_t^D)}{1-\gamma}\Bigg)+\Bigg(r_t^r-\overline{c}_t^{M\Sigma\omega}-r_t^{S\Sigma}-c_t^{i\Sigma}-r_t^M+c_t^t+c_t^{t\Sigma}\Bigg)\hat{f}_t^\Sigma f_t^\Sigma+\Bigg(\overline{c}_t^{M\omega}+p_t^i(\mathcal{C}_t)-c_t^p r_t^f$$

$$+(1-r_t^R)r_t^S-c_t^t-c_t^{t\Sigma}-a\Bigg)f_t^\Sigma\Bigg]\Bigg]=-\frac{1}{3}\mu_j{}^{\mathcal{C}^B}\left(\frac{b_2}{b_1}+(1-f_t^\Sigma)\left[\frac{\partial p^i(\mathcal{C}_{t+j}^B)}{\partial \mathcal{C}_{t+j}^B}+\frac{\partial r_t^S(\mathcal{C}_{t+j}^B)}{\partial \mathcal{C}_{t+j}^B}\right]\right).$$

□

3.4.3 Subprime RMBSs and Their Rates Under Basel Capital Regulation (Holding Constraint; Securitized Case)

Next, we present results about the effect of changes in the level of credit rating, $\mathcal{C}^B$, on RMBSs when the capital constraint (3.48) holds.

Proposition 3.4.4 (Subprime RMBSs under Basel Capital Regulation (Holding Constraint; Securitized Case)): *Assume that the same hypothesis as in Theorem 3.4.1 holds. If $l_t^b > 0$ then by taking the first derivatives of equation (3.14) with respect to $\mathcal{C}_t^B$ and using the fact that the risk-weights for mortgages, ω^M, are constant we obtain*

$$\frac{\partial B_t^*}{\partial \mathcal{C}_t^B}=-\frac{K_t^\Sigma-\rho\Big(\omega^M M_t+12.5f^M(mVaR+0)\Big)}{[\omega(\mathcal{C}_t^B)]^2\rho}\frac{\partial \omega(\mathcal{C}_t^B)}{\partial \mathcal{C}_t^B}. \tag{3.55}$$

In this situation, the subprime RMBS payout rate response to changes in the level of credit rating is given by

$$\frac{\partial r_t^{B^*}}{\partial \mathcal{C}_t^B}=-\frac{b_2}{b_1}-\frac{K_t^\Sigma-\rho\Big(\omega^M M_t+12.5f^M(mVaR+0)\Big)}{[\omega(\mathcal{C}_t^B)]^2\rho b_1}\frac{\partial \omega(\mathcal{C}_t^B)}{\partial \mathcal{C}_t^B}. \tag{3.56}$$

Proof.
In order to prove Proposition 3.4.4, we find the partial derivatives of the optimal RMBS supply, B^*, and subprime RMBS rate, r^B, with respect to $\mathcal{C}_t^B$. This involves using the equations (3.14) and (3.15) and the condition $\frac{\partial \omega(\mathcal{C}_{t+j}^B)}{\partial \mathcal{C}_{t+j}^B}<0$ in order to find $\frac{\partial B_t^*}{\partial \mathcal{C}_t^B}$ and $\frac{\partial r_t^{B^*}}{\partial \mathcal{C}_t^B}$, respectively. We are now able to determine that

$$\frac{\partial B_t^*}{\partial \mathcal{C}_t^B}\left(\frac{K_t^{\Sigma}}{\rho\omega(\mathcal{C}_t^B)} - \left[\frac{\omega^M M_t + 12.5 f^M(mVaR + 0)}{\omega(\mathcal{C}_t^B)}\right]\right)$$
$$= -\frac{K_t^{\Sigma} - \rho(12.5 f^M(mVaR + 0) + \omega^M M_t)}{[\omega(\mathcal{C}_t^B)]^2\rho}\frac{\partial\omega(\mathcal{C}_t^B)}{\partial \mathcal{C}_t^B}$$

and

$$\frac{\partial r_t^{B^*}}{\partial \mathcal{C}_t^B}\left(-\frac{1}{b_1}\left(b_0 + b_2\mathcal{C}_t^B + \sigma_t^B - \frac{K_t^{\Sigma}}{\rho\omega(\mathcal{C}_t^B)} + \frac{\omega^M M_t + 12.5 f^M(mVaR + 0)}{\omega(\mathcal{C}_t^B)}\right)\right)$$
$$= -\frac{b_2}{b_1} - \frac{K_t^{\Sigma} - \rho(12.5 f^M(mVaR + 0) + \omega^M M_t)}{[\omega(\mathcal{C}_t^B)]^2\rho b_1}\frac{\partial\omega(\mathcal{C}_t^B)}{\partial \mathcal{C}_t^B}$$

as required to complete the proof of Proposition 3.4.4. □

3.4.4 Subprime RMBSs and Their Rates Under Basel Capital Regulation (Future Time Periods; Securitized Case)

In the sequel, we examine the effect of a current credit rating shock in future periods on subprime RMBSs, B, and their payout rates, r^B. If the capital constraint is slack, the response of subprime RMBSs and their rates in period $j \geq 1$ to current fluctuations in the level of credit rating is described by Theorem 3.4.1. Nevertheless, as time goes by, the impact of the credit rating shock is minimized since $\mu_j^{\mathcal{C}^B} < 1$. In future, if the capital constraint holds, the response of subprime RMBSs and their rates to a change in the level of credit rating, $\mathcal{C}_t^B$, is described by

$$\frac{\partial B_{t+j}^*}{\partial \mathcal{C}_t^B} = \frac{\mu_{j-1}^{\mathcal{C}^B}}{\omega(\mathcal{C}_{t+j}^B)\rho}\left[\frac{\partial(K_{t+j}^{\Sigma} - \rho(\omega^M M_{t+j} + 12.5 f^M(mVaR + 0)))}{\partial \mathcal{C}_{t-1+j}^B}\right] \tag{3.57}$$
$$-\frac{\mu_{j-1}^{\mathcal{C}^B}}{\omega(\mathcal{C}_{t+j}^B)\rho}\left[\frac{\mu^{\mathcal{C}^B}}{\omega(\mathcal{C}_{t+j}^B)}(K_{t+j}^{\Sigma} - \rho(\omega^M M_{t+j} + 12.5 f^M(mVaR + 0)))\frac{\partial\omega(\mathcal{C}_{t+j}^B)}{\partial \mathcal{C}_{t+j}^B}\right]$$

and

$$\frac{\partial r_{t+j}^{B^*}}{\partial \mathcal{C}_t^B} = -\frac{b_2}{b_1}\mu_j^{\mathcal{C}^B} + \frac{\mu_{j-1}^{\mathcal{C}^B}}{\omega(\mathcal{C}_{t+j}^B)\rho b_1}\frac{\partial(K_{t+j}^{\Sigma} - \rho(\omega^M M_{t+j} + 12.5 f^M(mVaR + 0)))}{\partial \mathcal{C}_{t-1+j}^B}$$
$$-\frac{\mu_j^{\mathcal{C}^B}}{[\omega(\mathcal{C}_{t+j}^B)]^2\rho}(K_{t+j}^{\Sigma} - \rho(\omega^M M_{t+j} + 12.5 f^M(mVaR + 0)))\frac{\partial\omega(\mathcal{C}_{t+j}^B)}{\partial \mathcal{C}_{t+j}^B}.$$

From the equation (3.57), it can be seen that future subprime RMBSs can either rise or fall in response to positive credit rating shocks. This process depends on the relative magnitudes of the terms in equation (3.57). If capital rises in response to positive credit rating shocks, subprime

RMBSs can fall provided that the effect of the shock on capital is greater than the effect of the shock on subprime RMBS risk-weights.

Further discussions on important issues emphasized in Section 3.4 is given in Subsection 3.6.3.

3.5 Examples Involving Subprime Mortgage Securitization

In this section, we provide examples to illustrate some of the results obtained in the preceding sections. In one way or the other all of the examples in this section support the claim that the SMC was mainly caused by the intricacy and design (refer to Subsections 3.5.1, 3.5.3 and 3.5.4) of systemic agents (refer to Subsection 3.5.1), subprime mortgage origination (refer to Subsections 3.5.3 and 3.5.4) and securitization (refer to Subsections 3.5.1, 3.5.3 and 3.5.4) that led to information (loss, asymmetry and contagion) problems, valuation opaqueness and ineffective risk mitigation (refer to Subsections 3.5.1, 3.5.3 and 3.5.4).

3.5.1 Numerical Example Involving Subprime Mortgage Securitization

In this subsection, we present a numerical example to highlight some issues in Sections 3.2 and 3.3. In particular, we address the role of valuation in house prices. Here we bear in mind that we solve a subprime mortgage securitization maximization problem subject to the financing and regulatory capital constraints, with and without CDO tranching.

The choices of the values of the economic variables in this subsection are justified by considering data from LoanPerformance (LP), Bloomberg, ABSNET, Federal Housing Finance Agency (FHFA; formerly known as OFHEO), Federal Reserve Bank of St Louis (FRBSL) database, Financial Service Research Program's (FSRP) subprime mortgage database, Securities Industry and Financial Markets Association (SIFMA) Research and Statistics as well as Lender Processing Services (LPS; formerly called McDash Analytical) for selected periods before and during the crisis. Additional parameter choices are made by looking at, for instance, [7] and [53]. These provide enough information to support the choices for prices, rates and costs while the parameter amounts are arbitrary.

3.5.1.1 Choices of Subprime Mortgage Securitization Parameters

In Table 3.2 below, we make choices for subprime securitization, profit and valuation parameters.

Parameter	Period t	Period $t+1$	Parameter	Period t	Period $t+1$	Parameter	Period t	Period $t+1$
M	\$ 10 000	\$ 12 000	m_0	\$ 5 000	\$ 5 000	L	0.909	1.043
ω^M	0.05	0.05	m_1	\$ 5 000	\$ 5 000	L^{1*}	0.9182	1.0554
r^M	0.051	0.082	m_2	\$ 5 000	\$ 5 000	L^{n*}	0.3802	0.4439
$\overline{c}^{M\omega}$	0.0414	0.0414	$\mathcal{C}^{\mathcal{B}}$	0.5	0.5	L^{2*}	0.9201	1.0563
p^i	0.01	0.01	a	0.05	0.05	c^{p*}	0.0611	0.0633
c^p	0.05	0.05	$C(\mathbf{E}[S(\mathcal{C}_t)])$	400	400	ΔF	2 062.3	–
r^f	0.01	0.01	r^p	0.1	0.1	b_0	\$ 5 000	\$ 5 000
r^R	0.5	0.5	K	\$ 500	\$ 650	b_1	\$ 5 000	\$ 5 000
r^S	0.15	0.25	$\mathtt{O}$	\$ 150	\$ 150	b_2	\$ 5 000	\$ 5 000
H	\$ 11 000	\$ 11 500	$r^{\mathtt{O}}$	0.101	0.101	$c^{i\Sigma}$	0.05	0.06
Λ	\$ 50 000	\$ 63 157.89	E	\$ 250	\$ 250	$\overline{c}^{M\Sigma\omega}$	0.045	0.045
ρ	0.08	0.08	E^p	\$ 150	\$ 150	c^t	0.03	0.03
C	\$ 1 000	\$ 1 000	E^c	\$ 100	\$ 100	$c^{t\Sigma}$	0.04	0.04
r^B	0.105	0.105	$r^{\mathtt{B}}$	0.1	0.1	r^r	0.041	0.072
c^B	0.101	0.101	$c^{\mathtt{B}}$	0.09	0.09	$r^{S\Sigma}$	0.15	0.25
B	\$ 1 300	\$ 1 500	$\mathtt{B}$	\$ 5 200	\$ 6 200	$\widehat{f}^{\Sigma}$	0.3	0.2
ω^B	0.5	0.5	Π^p	\$ 6 000	\$ 6 000	f^{Σ}	0.65	0.5
$r^{\mathtt{T}}$	0.036	0.04	D	\$ 9 300	\$ 11 100	$\mathtt{F}$	700	500
$\mathtt{T}$	\$ 2 000	\$ 2 000	r^D	0.105	0.105	$\mathtt{E}$	500	300
O	150	150	r^O	0.101	0.101	a^b	0.05	0.05
n	1.75	2	r^L	0.02	0.05	$\Pi^{\Sigma p}$	\$ 8 000	\$ 8 000
d	5.4	5.4	f^M	0.08	0.19	$\widetilde{\Pi}^{\Sigma}$	2 000	2 000
$mVar$	400	400	$\omega(\mathcal{C}^{\mathcal{B}})$	0.5	0.5	r^{rb}	0.041	0.072
$P^{\mathtt{T}}$	\$ 800	\$ 1 200	c^D	0.101	0.101	$\overline{c}^{M\Sigma\omega b}$	0.05	0.05
γ	0.1828	0.2207	ϱ	0.031	0.032	$c^{i\Sigma}$	0.05	0.06
S	750	1 500	R	550	575	$r^{S\Sigma b}$	0.15	0.25
E^r	\$ 1 849.8	\$ 518.65	σ^M	2 755	4 910	c^{tb}	0.035	0.035
u	0.03621	0.06587	v	0.90329	0.90329	$c^{t\Sigma b}$	0.045	0.045
w	0.04429	0.04398	Π	\$ 2 024.4	\$ 694.6	$f^{\Sigma b}$	0.4	0.3
M^*	\$ 10 100	\$ 12 137.5	r^{M^*}	0.031	0.0545	$\widehat{f}^{\Sigma b}$	0.2	0.15
D^*	\$ 15 387.34	\$ 18 631.82	T^*	\$ 7 246.53	\$ 7 732.28	p^{ib}	0.01	0.01
Π^*	\$ 656.02	- \$ 974.36	M^{n^*}	\$ 4 182.55	\$ 5 104.4	r^{Rb}	0.5	0.5
$r^{M^{n^*}}$	0.8365	1.0209	T^{n^*}	\$ 7 246.53	\$ 7 732.28	r^{Sb}	0.15	0.25
D^{n^*}	\$ 8 601.42	\$ 9 606.93	Π^{n^*}	\$ 7 659.27	\$ 8 918.64	c^{pb}	0.05	0.05
r^{fb}	0.01	0.01	f^B	0.08	0.08	$c^{i\Sigma b}$	0.05	0.06
$\overline{c}^{M\omega b}$	0.05	0.055	c^M	0.04	0.06	$r^{p\Sigma}$	0.01	0.01

Table 3.2: Choices of Capital, Information, Risk and Valuation Parameters Under Securitization

3.5.1.2 Computation of Subprime Mortgage Securitization Parameters

We compute important equations by using the values from Table 3.2. For $\widehat{E}_{t-1} = (500-150)/1.75 = 200$ and $\widehat{E}_t = (650-150)/2 = 250$, in period t, SIB's profit under RMBSs and retained earnings in (3.4) is given by $\Pi_t^{\Sigma} = 2502$. SIB's capital in (3.5) is given by $K_{t+1}^{\Sigma} = 650$ while the nett cash flow under RMBSs given by (3.6) is computed as $N_t^{\Sigma} = 439.7$. Furthermore, valuation in (3.7) is equal to $V_t^{\Sigma} = 1089.7$, while total capital constraint in (3.9) is given by $K_t^{\Sigma} = 500 \geq 136$. SIB's optimal valuation problem under RMBSs is to maximize the value by choosing the RMBS rate, deposits and regulatory capital for (3.11) subject to RMBS, balance sheet, cash flow and financing constraints given by (3.12), (3.13), (3.2) and (3.5), respectively. Here, we have $\sigma_t^B = -6725$ and $D_t = 9300$. SIB's optimal RMBS supply (3.14) and its rate (3.15) are given by $B_t^* = 10400$ and $r_t^{B^*} = 1.925$, respectively. In this case, optimal deposits (3.16), provisions for deposit withdrawals via Treasuries (3.17) and profits under RMBS securitization (3.18) are given by $D_t^{\Sigma^*} = 26855.77$, $\mathtt{T}_t^{\Sigma^*} = 7246.53$ and $\Pi_t^{\Sigma^*} = -28284.7$, respectively.

When the capital constraint (3.9) does not hold, then the solutions for SIB's optimal RMBSs

(3.26) and RMBS rate (3.27) are given by $B_t^{\Sigma n^*} = 1094.9$ and $r_t^{B^{\Sigma n^*}} = 0.064$, respectively. In this case, corresponding optimal deposits (3.29) and profits (3.30) are given by $D_t^{\Sigma n^*} = 15469.2$ and $\Pi_t^{\Sigma n^*} = 2198.6$, respectively.

The following values are computed in period t under RMBS CDOs. SIB's profit under RMBS CDOs and retained earnings in (3.33) is given by $\Pi_t^{\Sigma b} = 2463.5$, while SIB's capital in (3.34) is given by $K_{t+1}^{\Sigma b} = 650$. SIB's nett cash flow (3.35) for a shareholder is given by $N_t^{\Sigma b} = 401.2$ Furthemore SIB's valuation in (3.36) is equal to $V_t^{\Sigma b} = 1051.2$ respectively. Optimal deposits (3.40), provisions for deposit withdrawals via Treasuries (3.41) and profits under RMBS CDO securitization (3.42) are given by $D_t^{\Sigma b^*} = 26400.56$, $\mathtt{T}_t^{\Sigma b^*} = 6874.53$ and $\Pi_t^{\Sigma b^*} = 6330.82$,. If capital constraint (3.9) does not hold, then SIB's optimal RMBS CDO supply (3.43) and rate (3.44) are given by $B_t^{\Sigma bn^*} = 1118.64$ and $r_t^{B^{\Sigma bn^*}} = 0.0687$,. In this case, corresponding optimal deposits (3.46) and profits (3.47) under RMBS CDO securitization are given by $D_t^{\Sigma bn^*} = 15043$ and $\Pi_t^{\Sigma bn^*} = 1399.96$, respectively.

In period $t+1$, profit under RMBSs and retained earnings in (3.4) is given by $\Pi_{t+1}^{\Sigma} = 1876$, while $\sigma_{t+1}^{B} = -6525$. Optimal RMBS supply (3.14) and its rate (3.15) are given by $B_{t+1}^{*} = 12437.5$ and $r_{t+1}^{B^*} = 2.2925$, respectively. The corresponding Treasuries (3.17), deposits (3.16) and profits under RMBS securitization (3.18) are given by $\mathtt{T}_{t+1}^{\Sigma^*} = 7732.28$, $D_{t+1}^{\Sigma^*} = 32490.42$ and $\Pi_{t+1}^{\Sigma^*} = -39962.7$, respectively. When the capital constraint (3.9) does not hold, then $B_{t+1}^{\Sigma n^*} = 1268.15$ and $r_{t+1}^{B^{\Sigma n^*}} = 0.0586$, respectively. In this case, corresponding optimal deposits (3.29) and profits (3.30) are given by $D_{t+1}^{\Sigma n^*} = 18157.9$ and $\Pi_{t+1}^{\Sigma n^*} = 1746.33$, respectively.

The following values are computed in period $t+1$ under RMBS CDOs. SIB's profit under RMBS CDOs and retained earnings in (3.33) is given by $\Pi_{t+1}^{\Sigma b} = 1769.07$, SIB's optimal deposits (3.40), provisions for deposit withdrawals via Treasuries (3.41) and profits under RMBS CDO securitization (3.42) are given by $D_{t+1}^{\Sigma b^*} = 31920.68$, $\mathtt{T}_{t+1}^{\Sigma b^*} = 7288.28$ and $\Pi_{t+1}^{\Sigma b^*} = 12331.2$, respectively. If the capital constraint (3.9) does not hold, then $B_{t+1}^{\Sigma bn^*} = 1294.25$ and $r_{t+1}^{B^{\Sigma bn^*}} = 0.0639$, respectively. In this case, corresponding optimal deposits (3.46) and profits (3.47) are given by $D_{t+1}^{\Sigma bn^*} = 17621.6$ and $\Pi_{t+1}^{\Sigma bn^*} = 582.72$, respectively.

We provide a summary of computed profit and valuation parameters under RMBSs and RMBS CDOs in Table 3.3 below.

Parameter	Period t	Period $t+1$	Parameter	Period t	Period $t+1$
Π^{Σ}	\$2 502	\$1 876	K^{Σ}	500	\$650
N^{Σ}	\$439.7	-\$186.3	V^{Σ}	\$1 089.7	\$463.7
σ^{B}	-6 725	-6 525	B^{*}	\$10 400	\$12 437.5
$r^{B^{*}}$	1.925	2.2925	$D^{\Sigma^{*}}$	\$26 855.77	\$32 490.42
$T^{\Sigma^{*}}$	\$7 246.53	\$7 732.28	$\Pi^{\Sigma^{*}}$	-\$28 284.7	-\$39 962.7
$B^{\Sigma n^{*}}$	\$1 094.9	\$1 268.15	$r^{B^{\Sigma n^{*}}}$	0.064	0.0586
$D^{\Sigma n^{*}}$	\$15 469.2	\$18 157.9	$\Pi^{\Sigma n^{*}}$	\$2 198.6	\$1 746.33
$\Pi^{\Sigma b}$	\$2 463.5	\$1 769.07	$D^{\Sigma b^{*}}$	\$26 400.56	\$31 920.68
$T^{\Sigma b^{*}}$	\$6 874.53	\$7 288.28	$\Pi^{\Sigma b^{*}}$	\$6 330.82	\$12 331.2
$B^{\Sigma bn^{*}}$	\$1 118.64	\$1 294.25	$r^{B^{\Sigma bn^{*}}}$	0.0687	0.0639
$D^{\Sigma bn^{*}}$	\$15 043	\$17 621.6	$\Pi^{\Sigma bn^{*}}$	\$1 399.96	\$5 82.72

Table 3.3: Computed Capital, Information, Risk and Valuation Parameters Under Securitization

3.5.2 Example Involving Profit from Mortgage Securitization

The ensuing example illustrates issues involving mortgage securitization and its connections with profit and capital. In particular, we look at some of the incentives for securitizing subprime mortgages and how the process can go wrong as was evidenced by the events before and during the SMC.

The sale of SOR's original mortgage portfolio via securitization is intended to save economic capital[5], K^e, where $K^e \geq E$. K^e differs from regulatory capital, K, in the sense that the latter is the mandatory capital that regulators require to be maintained while K^e is the best estimate of required capital that SORs use internally to manage their own risk and the cost of maintaining K (compare with (2.10)). In the ensuing example, we assume that SOR's profit from mortgage securitization, $\Pi^{\Sigma} \propto \Pi$, where Π is expressed as return-on-equity (ROE[6]; denoted by r^E) and return-on-assets (ROA[7]; denoted by r^A).

Subsection 3.5.2 contains the following discussions. The purpose of the analysis in Subsection 3.5.2.1 is to determine the costs and benefits of securitization and to assess the impact on ROE. The three steps involved in this process are the description of SOR's unsecuritized mortgage portfolio, calculation of SOR's weighted cost of funds for on-balance sheet items, $c^{M\omega}$, as well as SOR's weight cost of funds for securitization, $c^{M\Sigma\omega}$. In Subsection 3.5.2.2, the influence on ROE results from both lower level E and reduced $c^{M\Sigma\omega}$. The value gained is either the present value or an improvement of annual margins averaged over the life of the securitization. In our example, capital saving, K^{es}, is calculated with a preset forfeit percentage of 4 % used as an input. In this regard, the impact on ROE follows in Subsection 3.5.2.3. Under a forfeit valuation of capital as a function of $f^{\Sigma}M$, we are able to determine whether securitization enhances r^E, by how much and what

[5]Economic capital is the amount of risk capital (equity, E) which SOR requires to mitigate against risks such as market, credit, operational and subprime risk. It is the amount of money which is needed to secure survival in a worst case scenario.

[6]Ratio of profit after tax to equity capital employed.

[7]Ratio which measures the return SOR generates from its total assets.

the constraints are. Under full economic capital analysis, K^e results from a direct calculation involving a mortgage portfolio model with and without securitization. The enhancement issue involves finding out whether the securitization enhances the risk-return profile of SOR's original mortgage portfolio and, more practically, whether post-securitization $r^{E\Sigma}$ is higher or lower than the pre-securitization r^E.

3.5.2.1 Cost of Funds

In the sequel, we show how K^{es} results from securitization, where $K^{es} \propto f^{\Sigma}M$ is valid for K under Basel capital regulation. For sake of illustration, we assume that the balance sheet (2.7) can be rewritten as

$$M_t = D_t + n_t E_{t-1} + O_t.$$

For SOR's original mortgage portfolio, $M = 10000$, suppose that the weight $\omega^M = 0.5$ and the market cost of equity, $c^E = 0.25$ before tax. In the case where $\rho = 0.08$ (see [99] for more information), regulatory capital is given by

$$K_t = n_t E_{t-1} + O_t = 1.25 \times 200 + 150 = 400 = 0.08 \times 0.5 \times 10000,$$

with $n_t = 1.25$. Furthermore, we assume that c^E is equivalent to a minimum accounting $r^E = 0.25$ and SOR considers mortgage securitization for $M = 6500$ while K includes subordinate debt with $r^O = 0.101$ and deposits (liabilities) cost $c^D = 0.101$. We suppose that SOR's original mortgage portfolio, M, has an effective duration of 7 years despite its 10 year theoretical duration due to early voluntary prepayments as before and during the SMC. The return nett of statistical losses and direct monitoring and transaction costs is $r^M = 0.102$. $K^{es} = 260 = 0.04 \times 6500$, where the K^{es} calculation uses a 4 % forfeit applied to $f^{\Sigma}M$. K^{es} is constituted by 130 of equity and 130 subordinate debt and is the marginal risk contribution of $f^{\Sigma}M$ as evaluated with a portfolio model. The resulting K^{es} would depend on the selection of $f^{\Sigma}M$ and its correlation with M.

In the following table, we provide an example of a subprime mortgage securitization with two classes of tranches, viz., sen (AAA rating) and sub (including mezz and jun tranches; BBB rating). Given such ratings, the required rate of return for sub tranches is $r^{BSub} = 0.1061$ and that of sen tranches is $r^{BS} = 0.098 \leq c^D = 0.101$. However, in order to obtain a BBB rating, the CRA imposes that the sub tranches, $B^{sub} \geq 0.101 \times f^{\Sigma}M$. The direct costs include the initial cost of organizing the structure, c^i, plus the servicing fees, f^s. The annual servicing fees, $f^s = 0.002 \times f^{\Sigma}M$.

For $f^{\Sigma}M = 6500$, the sen tranches fund 5 850 and sub tranches fund 650 with M decreasing from 10 000 to 3 500, where the weighted mortgages, $M^{\omega} = 1750 = 0.5 \times 3500$. The capital required against this portfolio is $K = 140 = 0.08 \times 1750$. With an initial $K^e = 400$, the deal saves and frees $K^{es} = 260$ for further utilization. This is shown in the next table.

The cost of funds structure consists of K at 4 % – divided into 2 % E at $c^E = 0.25$ and 2 % O at $c^{SD} = 0.102$ – as well as 96 % deposits at $c^D = 0.101$. We consider the face value of D by using

SOR's Original Mortgage Portfolio	
Current Funding	
Cost of Equity (c^E)	0.25
Cost of Subordinate Debt (c^{SD})	0.102
Cost of Deposits (c^D)	0.101
Structure	
Cost of Sen Tranches (c^{BS})	0.098
Weight of Sen Tranches (ω^{BS})	0.9
Maturity of Sen Tranches (m^{BS})	10 years
Cost of Sub Tranches (c^{BSub})	0.1061
Weight of Sub Tranches (ω^{BSub})	0.1
Maturity of Sub Tranches (m^{BSub})	10 years
Direct Costs of the Structure (c^{Σ})	0.002
Original Assets	
Reference RML Portfolio Rate of Return (r^M)	0.102
Reference RML Portfolio Duration (y^M)	7 years
Outstanding Balances	
Outstanding RMLs (M)	10 000
Securitized RML Amount ($f^{\Sigma}M$)	6 500

Table 3.4: SOR's Original Mortgage Portfolio

SOR's Required Capital Before and After Securitization			
Outstanding Balances	**Value**		**Required Capital**
SOR's Original RML Portfolio (M)	10 000		400
SOR's Reference RML Portfolio ($f^{\Sigma}M$)	6 500		260
Sen Tranches (B^S)	5 850	Sold	
Sub Tranches (B^{Sub})	650	Sold	
Final RML Portfolio ($(1-f^{\Sigma})M$)	3 500		140
Total RMLs ($(1-f^{\Sigma})M$)	3 500	–	
Total Weighted RMLs (M^{ω})	1 750		140

Table 3.5: SOR's Required Capital Before and After Securitization

book values for weights, so that the weighted cost of funds is

$$\overline{c}^{M\omega} = 0.96 \times 0.101 + 0.08 \times 0.5 \times (0.25 \times 0.5 + 0.102 \times 0.5) = 0.104,$$

where $\overline{c}^{M\omega}$ is consistent with $r^E = 0.25$ before tax, where r^E is the ROE. If SOR's original mortgage portfolio fails to generate this required return, r^E adjusts. Since SOR's original mortgage portfolio generates only $r^M = 0.102 < \overline{c}^{M\omega} = 0.104$, the actual $r^E < 0.25$. The return actually obtained by shareholders is such that the average cost of funds is identical to $r^A = 0.102$. If $r^A = \overline{c}^{M\omega}$, then effective r^E may be computed as in

$$r^A = 0.96 \times 0.101 + 0.08 \times 0.5 \times (r^E \times 0.5 + 0.102 \times 0.5).$$

After calculation, $r^E = 0.15 < 0.25$ before tax. In this case, it would be impossible to raise new capital since the portfolio return does not compensate its risk. Therefore, SOR cannot originate any additional mortgages without securitization. In addition, the securitization needs to improve the return to shareholders from $(1 - f^{\Sigma})M$.

The potential benefit of securitization is a reduction in $\overline{c}^{M\omega}$. The cost of funds via securitization, $\overline{c}^{M\Sigma\omega}$, is the weighted cost of the sen and sub tranches (denoted by $c^{BS\omega}$ and $c^{BSub\omega}$, respectively) plus any additional cost of the structure $c^{\Sigma} = 0.002$. Without considering differences in duration, the cost of sen notes is $c^{BS\omega} = 9.8$ % and that of sub notes is $c^{BSub\omega} = 10.61$ %. The weighted average is $\overline{c}^{M\Sigma\omega}$ before monitoring and transaction costs, so that

$$\overline{c}^{M\Sigma\omega} = 0.09881 = 0.9 \times 0.098 + 0.1 \times 0.1061.$$

The overall cost of securitization, $\overline{c}^{M\Sigma\omega A}$, is the sum of $\overline{c}^{M\Sigma\omega}$ and the annual $c^{\Sigma} = 0.002$ averaged over the life of the deal. The overall costs, $\overline{c}^{M\Sigma\omega A}$, becomes the aggregate weighted cost of funds via securitization so that

$$\overline{c}^{M\Sigma\omega A} = 0.10081 = \overline{c}^{M\Sigma\omega} + 0.002 = 0.09881 + 0.002.$$

From the above, we draw the following preliminary conclusions. Firstly, we note that $\overline{c}^{M\Sigma\omega A} = 0.10081 < \overline{c}^{M\omega} = 0.104$. This is sufficient to make mortgage securitization beneficial. Also, $\overline{c}^{M\Sigma\omega A} = 0.10081 < r^M = 0.102$. Therefore, selling SOR's reference mortgage portfolio to SPV generates a capital gain which improves SOR's profitability. However, the change in r^E remains to be quantified.

3.5.2.2 Return on Equity (ROE)

The value of SOR's reference mortgage portfolio, $f^{\Sigma}M$, is the discounted value of cash flows calculated at a rate equal to the required return to SORs, r^B. The average required return to SORs who buy SPV's securities is $\overline{r}^B = 0.10081 = \overline{c}^{M\Sigma\omega A}$. For SOR's lenders and shareholders, the average return on SOR's unsecuritized mortgage portfolio is $r^{ls} = 0.102$. Nevertheless, existing shareholders would like to have $r^E = 0.25$ instead of $r^E = 0.15$ resulting from insufficient $r^A = 0.102$. In order to obtain $r^E = 0.25$, SOR's ROA should be higher and reach $r^A = 0.104$. The present value of $f^{\Sigma}M$ for SORs is the discounted value of future flows at $\delta = 0.1008$. The value of this mortgage portfolio for those who fund it results from discounting the same cash flows at $\delta = 0.102$, either with the current effective $r^E = 0.15$ or $\delta = 0.104$, with a required $r^E = 0.25$. In both cases, $\overline{c}^{M\Sigma\omega} > \overline{c}^{M\omega}$. Therefore, the price of SOR's reference mortgage portfolio, at the $\delta = 0.1008$ discount rate required by SORs, will be higher than the price calculated with either $\delta = 0.102$ or $\delta = 0.104$. The difference is a capital gain for SOR's existing shareholders. Since the details of projected cash flows generated by $f^{\Sigma}M$ are unknown, an accurate calculation of its present value is not feasible. In practice, a securitization model generates the entire cash flows, with all interest received from SOR's reference mortgage portfolio, r^M, voluntary and involuntary prepayments as well as recoveries.

For this example, we simplify the entire process by circumventing model intricacy for capital structure. The *duration formula* offers an easier way to get a valuation for SOR's reference mortgage portfolio. We know that the discounted value of future flows generated by SOR's reference mortgage portfolio at $r^A = 0.102$ is exactly 1000 because its return is 0.102. With another discount rate, the present value differs from this face value. An approximation of this new value can be obtained from the duration formula via

$$\frac{p^1 f^\Sigma M - 100}{100} = \frac{-\text{Duration}}{(1+i)(\delta - r^M)},$$

where the present value of SOR's reference mortgage portfolio is denoted by $p^1 f^\Sigma M$. In this case, the rate of return from $f^\Sigma M$ is r^M and the discount rate is δ, while the ratio $(p^1 f^\Sigma M - 100)/100$ provides this value as a percentage of the face value, M. The duration formula provides $p^1 f^\Sigma M$ given all three other parameters so that

$$p^1 f^\Sigma M(\% \text{ of Face Value}) = 100\ \% + \text{Duration}(r^M\ \% - \delta\ \%).$$

Since $r^M = 0.102$, the value of $f^\Sigma M$ at the discount rate $\delta = 10.08$ % is

$$p^1 f^\Sigma M = 1 + 7 \times (0.102 - 0.1008) = 1.0084.$$

This means that the sale of mortgages to the securitization structure generates $K^{es} = 0.0084$ over an amount of 6 500 or 54.6 in value.

The sale SOR's reference mortgage portfolio will generate a capital gain only when $\overline{c}^{M\Sigma\omega A} < \mu^M = 0.102$, so that

$$\overline{c}^{M\Sigma\omega A} < \overline{c}^{M\omega}.$$

In this case, the capital gain from the sale of $f^\Sigma M$ will effectively increase revenues, thereby increasing the average r^A on the balance sheet. This is a sufficient condition to improve r^E under present assumptions. The reason is that the effective ROE remains a linear function of the effective r^M inclusive of capital gains from the sale of $f^\Sigma M$ to SPV, as long as the weights used to calculate it from r^A as a percentage of SOR's original mortgage portfolio remain approximately constant. This relation remains

$$r^A = 0.96 \times 0.101 + 0.08 \times 0.5 \times (r^E \times 0.5 + 0.102 \times 0.5).$$

This is true as long as $E \propto f^{\Sigma}M$, which is the case in this example. However, in general, $K^e \not\propto f^{\Sigma}M$, and the linear relationship collapses. One has to take uncertainty into account if one is required to determine the effective r^E. Note that current $\overline{c}^{M\omega} = 0.102$, by definition, since it equates r^M with the weighted average cost of capital: effective percentage of r^A of effective percentage of $\overline{c}^{M\omega}$. The implied return to shareholders is $r^{ls} = 0.15$. Whenever, $\overline{c}^{M\Sigma\omega A} < r^M$, it is by definition lower than the effective $\overline{c}^{M\omega}$. If the shareholders obtain $r^E = 0.25$, instead of the effective $r^E = 0.15$ only, $\overline{c}^{M\omega} = 0.104$. This securitization would be profitable as long as $\overline{c}^{M\Sigma\omega A} < 0.104$. Since, in this case, $\overline{c}^{M\Sigma\omega A} = 0.1008$, the deal meets both conditions. However, the first one only is sufficient to generate capital gain. Using the current effective $r^E = 0.15$, we find that SOR's capital gain from selling mortgages is 0.0084 as shown in Table 3.6 below.

SOR's Cost Benefits from Mortgage Securitization	
$\overline{c}^{M\omega}$	0.102
c^{BSub}	0.1061
$\overline{c}^{M\Sigma\omega}$	0.0988
$\overline{c}^{M\Sigma\omega A}$	0.1008
SOR's Reference RML Portfolio Value at $\overline{c}^{M\omega}$	1
SOR's Reference RML Portfolio Value at $\overline{c}^{M\Sigma\omega A}$	1.0084
K^{es}	0.0084

Table 3.6: SOR's Costs and Benefits from Mortgage Securitization

It is possible to convert K^{es} from securitization into an additional annualized margin obtained over the life of the deal. A simple proxy for this annual margin is equal to the instantaneous capital gain averaged over the life of the deal (ignoring the time value of money). The gain is $K^{es} = 54.6 = 0.0084 \times 6500$. This implies that subsequent to securitization, SOR's reference mortgage portfolio provide $r^M = 0.102$ plus an annual return of $K^{es} = 0.0084$ applicable only to $f^{\Sigma}M = 6500$. Once SOR's original mortgage portfolio have been securitized, the size of the balance sheet drops to 3 500 that still provides $r^M = 0.102$. There is an additional return due to the capital gain. Since this annualized capital gain is $K^{es} = 0.0084$ of 6 500, it is $(0.0084/6500) \times 3500$ in percentage of $(1 - f^{\Sigma})M$ or 0.000001292 applicable to 3 500. Accordingly $r^M = 0.102$ increases to $r^M = 0.102001292$ after mortgage securitization. This increased r^M also implies a higher r^E (see Subsection 3.5.2.3 below).

3.5.2.3 Enhancing ROE Via Securitization

Under a forfeit valuation of capital as a function of $f^{\Sigma}M$, it is relatively easy to determine whether the securitization enhances r^E, by how much and what the limitations are. Under full economic analysis, the capital results from a direct calculation of SOR's reference and unsecuritized mortgage portfolios. The enhancement issue consists of finding out whether the securitization enhances the risk-return profile of SOR's original mortgage portfolio and, more practically, whether post-securitization r^E is higher or lower than pre-securitization r^E. We address both these issues in the sequel.

Table 3.7 shows the income statement under SOR's reference and unsecuritized mortgage portfolios. The deposits, subordinate debt and equity represent the same percentages of SOR's original mortgage portfolio, viz., 96 %, 2 % and 2 %, respectively. Their costs are identical to the above.

Effect of Securitization on SOR's Return on Capital			
	Balances	**Returns and Costs (%)**	**Returns and Costs**
Pre-Securitization of 6 500			
RMLs	10 000	0.102	1020
Deposits	9 600	-0.101	-969.6
Equity Capital	200		30
Subordinate Debt	200	-0.101	-20.2
Return on Capital			0.15
RMLs	3 500	0.102001292	357.0
Deposits	3 360	-0.101	-339.36
Equity Capital	70		
Subordinate Debt	70	-0.101	-7.07
Return on Capital			0.20263
RMLs	3 500	0.102001292	357.0
Deposits	3 360	-0.101	-339.36
Equity Capital	190		29.9991
Subordinate Debt	190	-0.101	-19.19
Return on Capital			0.15789

Table 3.7: Effect of Securitization on SOR's Return on Capital

Before SOR's original mortgage portfolio is securitized, $r^M = 0.102$ while thereafter $r^M = 0.102001292$. This gain influences the ROE directly with an increase from $r^E = 0.15$ to $r^E = 0.20263$. In general, an increase in r^M causing an increase in r^E is not guaranteed since K^{es} is the marginal risk contribution of $f^{\Sigma}M$. Therefore, an increase in r^M due to K^{es} from the sale of SOR's reference mortgage portfolio to SPV might not increase the r^E if K^{es} is lower. For instance, if K decreases to 190 and subordinate debt does also, the remaining deposits being the complement to 9 000 or 9 620, the same calculations would show that the new ROE becomes $r^E = 0.15789 = 30/190$. It is necessary to determine K^e before and after SOR's original mortgage portfolio is securitized in order to determine the size of K^{es} and to perform return calculations on new capital subsequent to securitization. Once K^e is determined and converted into a percentage of SOR's original mortgage portfolio, we have the same type of formula as in the above.

3.5.3 Example of a Subprime RMBS Bond Deal

The example contained in this subsection explains a subprime RMBS bond deal related to the Structured Asset Investment Loan Trust 2005-6 (SAIL 2005-6) issued in July 2005 (compare with [53]). The example considers the evolution of different tranches' riskiness with the refinancing of reference mortgage portfolios affecting the loss triggers for subordinated tranches. This changes the sensitivity of the values of different claims to house prices that drive collateral values. Later the example goes on to discuss the Structured Asset Investment Loan Trust 2006-2 (SAIL 2006-2). The bond capital structure is outlined in Table 3.8 below.

Structured Asset Investment Loan Trust 2005-6 Capital Structure							
Class	**RML Reference Portfolios**	**Principal Type**	**Principal Amount (Dollars)**	**Tranche Thickness (%)**	**Moody's**	**S&P**	**Fitch**
A1	1	Senior	455 596 000	20.18 %	Aaa	AAA	AAA
A2	1	Senior	50 622 000	2.24 %	Aaa	AAA	AAA
A3	2	Senior	506 116 000	22.42 %	Aaa	AAA	AAA
A4	3	Senior Seqntl Pay	96 977 000	4.30 %	Aaa	AAA	AAA
A5	3	Senior Seqntl Pay	45 050 000	2.00 %	Aaa	AAA	AAA
A6	3 3	Senior Seqntl Pay	23 226 000	1.03 %	Aaa	AAA	AAA
A7	4	Senior Seqntl Pay	432 141 000	19.14 %	Aaa	AAA	AAA
A8	4	Senior Seqntl Pay	209 009 000	9.26 %	Aaa	AAA	AAA
A9	4	Senior Seqntl Pay	95 235 000	4.22 %	Aaa	AAA	AAA
M1	1,2,3,4	Subordinated	68 073 000	3.02 %	Aa1	AA+	AA+
M2	1,2,3,4	Subordinated	63 534 000	2.81 %	Aa2	AA	AA
M3	1,2,3,4	Subordinated	38 574 000	1.71 %	Aa3	AA-	AA-
M4	1,2,3,4	Subordinated	34 036 000	1.51 %	A1	A+	A+
M5	1,2,3,4	Subordinated	34 036 000	1.51 %	A2	A	A
M6	1,2,3,4	Subordinated	26 094 000	1.16 %	A3	A-	A-
M7	1,2,3,4	Subordinated	34 036 000	1.51 %	Baa2	BBB	BBB
M8	1,2,3,4	Subordinated	22 691 000	1.01 %	Baa3	BBB-	BBB-
M9	1,2,3,4	Subordinated	11 346 000	0.50 %	N/R	BBB-	BBB-
M10-A	1,2,3,4	Subordinated	5 673 000	0.25 %	N/R	BBB-	BB+
M10-F	1,2,3,4	Subordinated	5 673 000	0.25 %	N/R	BBB-	BB+

Table 3.8: Structured Asset Investment Loan Trust 2005-6 Capital Structure; Source: [116]

From Table 3.8 we see that the majority of tranches in SAIL 2005-6 have an investment-grade rating of BBB- or higher with Class A1 to A9 certificates being rated AAA. On a pro rata basis, Class A1 and A2 certificates receive principal payments, $\varpi^1 f^\Sigma M$, concurrently, unless cumulative reference mortgage portfolio losses or delinquencies exceed specified levels. In the latter case, these classes will be treated as senior, sequential pay tranches.

The classes of certificates listed in Table 3.8 were offered publicly by the SAIL 2005-6 prospectus supplement while others like Class P, Class X and Class R certificates were not. Four types of reference mortgage portfolios constitute the deal with limited cross-collateralization. Principal payments, $\varpi^1 f^\Sigma M$, on the senior certificates will mainly depend on how the reference mortgage portfolios are constituted. However, the senior certificates will have the benefit of CE in the form of overcollateralization (OC) and subordination from each mortgage portfolio. As a consequence, if the rate of loss per reference mortgage portfolio related to any class of sen certificates is low, losses in unrelated mortgages may reduce the loss protection for those certificates.

At initiation, we note that the mezz tranches (AA+ to BBB-) were very thin with minimal defaults. This thinness may be offset by a significant prepayment amount, $\varpi^2 f^p f^\Sigma M$, entering the deal at the outset. An example of this is the M9 tranche with a thickness of 50 bps, but with a BBB- investment-grade rating. Although the rating may not necessarily be wrong, the underlying assumption is that the cash flow dynamics of SAIL 2005-6 has a high probability of success.

Some of the characteristics of the reference mortgage portfolios are shown below.

Summary of the Reference RML Portfolios' Characteristics				
	Pool 1	**Pool 2**	**Pool 3**	**Pool 4**
% First Lein	94.12 %	98.88 %	100.00 %	93.96 %
% 2/28 ARMs	59.79 %	46.68 %	75.42 %	37.66 %
% 3/27 ARMs	20.82 %	19.14 %	19.36 %	9.96 %
% Fixed Rate	13.00 %	8.17 %	2.16 %	11.46 %
% Full Doc	59.98 %	56.74 %	44.05 %	35.46 %
% Stated Doc	39.99 %	37.47 %	34.30 %	33.17 %
% Primary Residence	90.12 %	90.12 %	80.61 %	82.59 %
WA FICO	636	615	673	635

Table 3.9: Summary of the Reference Mortgage Portfolios' Characteristics; Source: [53]

3.5.4 Comparisons Between Two Subprime RMBS Deals

In this subsection, we follow [53] by considering the subprime securitization deals Ameriquest Mortgage Securities Inc. 2005-R2 (AMSI 2005-R2) and Structured Assets Investment Loan Trust 2006-2 (SAIL 2006-2). Both AMSI 2005-R2 and SAIL 2006-2 possess the basic structures of securitization deals outlined in Subsection 3.5.3, with OC and various triggers determining the features of CE. In this regard, we provide an argument about how the speed of securitization effects the optionality of RMBS CDO tranches with respect to the underlying house prices in both deals. We note that AMSI 2005-R2 consists of three reference portfolios while both deals have OC. Our aim is to compare the performance of AMSI 2005-R2 and SAIL 2006-2 with 2005 vintage mortgages and 2006 vintage mortgages, respectively. For instance, we demonstrate that the latter vintage subprime mortgages under-performed as house prices began to decline in that year. The ensuing examples also demonstrate how the extent of refinancing of the reference mortgage portfolios affects securitization.

3.5.4.1 Details of AMSI 2005-R2 and SAIL 2006-2

Tables 3.10 and 3.11 present AMSI 2005-R2 deal structure, tranche thickness and ratings at the outset as well as in Q1:07. The initial thickness of the BBB tranches – measured as a percentage of collateral – are extremely thin. CRAs do not usually allow such thin tranches, but it was anticipated that these tranches will grow as more sen tranches amortize as a result of refinancing and sequential amortization. Further, we note the subordination percentages for BBB tranches at inception. For instance, the M9 tranche of AMSI 2005-R2 was only 2.95 % of subordination. However, as amortization occurs, CE accumulates and reference mortgages refinance, this situation could improve. In that case, the deals shrink as amortization occurs. Also, after the step-down date, the BBB tranches will seem attractive – depending on H.

Ameriquest Mortgage Securities Inc. 2005-R2 (AMSI 2005-R2) At Issue in 2005					
	Size	**Related Mortgage Pool(s)**	**Ratings (Fitch, Moody's S&P)**	**% of Collateral**	**Subordination**
Publicly-Offered Certificates					
A-1A	258 089 000	I	AAA/Aaa/AAA	21.5 %	35.48 %
A-1B	64 523 000	I	AAA/Aaa/NR	5.4 %	19.35 %
A-2A	258 048 000	II	AAA/Aaa/AAA	21.5 %	35.48 %
A-2B	64 511 000	II	AAA/Aaa/NR	5.4 %	19.35 %
A-3A	124 645 000	III	AAA/Aaa/AAA	10.4 %	19.35 %
A-3B	139 369 000	III	AAA/Aaa/AAA	11.6 %	19.35 %
A-3C	26 352 000	III	AAA/Aaa/AAA	2.2 %	19.35 %
A-3D	32 263 000	III	AAA/Aaa/NR	2.7 %	19.35 %
M1	31 200 000	I,II,III	AA+/Aa1/AA+	2.6 %	16.75 %
M2	49 800 000	I,II,III	AA/Aa2/AA	4.1 %	12.6 %
M3	16 800 000	I,II,III	AA-/Aa3/AA-	1.4 %	11.2 %
M4	28 800 000	I,II,III	A+/A1/A+	2.4 %	8.8 %
M5	16 800 000	I,II,III	A/A2/A	1.4 %	7.4 %
M6	12 000 000	I,II,III	A-/A3/A-	1.0 %	6.4 %
M7	19 200 000	I,II,III	BBB+/Baa1/BBB+	1.6 %	4.8 %
M8	9 000 000	I,II,III	BBB/Baa2/BBB	0.7 %	4.05 %
M9	13 200 000	I,II,III	BBB/Baa2/BBB-	1.1 %	2.95 %
Non-Publicly-Offered Certificates					
M10	7 800 000	I,II,III	BB+/Ba1/BB+	1.0 %	1.3 %
M11	12 000 000	I,II,III	BB/Ba2/BB	1.3 %	0.0 %
CE	15 600 000		NR/NR/NR		
Total	1 200 000 000				
Collateral	1 200 000 147				

Table 3.10: Ameriquest Mortgage Securities Inc. 2005-R2 (AMSI 2005-R2) At Issue in 2005; Source: [6]

Ameriquest Mortgage Securities Inc. 2005-R2 (AMSI 2005-R2) In Q1:07					
	Size	**Related Mortgage Pool(s)**	**Ratings (Fitch, Moody's S&P)**	**% of Collateral**	**Subordination**
Publicly-Offered Certificates					
A-1A	30 091 837	I	AAA/Aaa/AAA	8.3 %	91.67 %
A-1B	7 523 047	I	AAA/Aaa/NA	2.1 %	89.58 %
A-2A	43 208 414	II	AAA/Aaa/AAA	12.0 %	77.62 %
A-2B	10 801 936	II	AAA/Aaa/NA	3.0 %	63.56 %
A-3A	–	III	PIF/WR/NR	0.0 %	63.56 %
A-3B	9 597 506	III	AAA/Aaa/AAA	2.7 %	63.56 %
A-3C	26 352 000	III	AAA/Aaa/AAA	7.3 %	63.56 %
A-3D	3 994 403	III	AAA/Aaa/AAA	1.1 %	63.56 %
M1	31 200 000	I,II,III	AA+/Aa1/AA+	8.6 %	54.92 %
M2	49 800 000	I,II,III	AA/Aa2/AA	13.8 %	41.13 %
M3	16 800 000	I,II,III	AA-/Aa3/AA-	4.7 %	36.48 %
M4	28 800 000	I,II,III	A+/A1/A+	8.0 %	28.50 %
M5	16 800 000	I,II,III	A/A2/A	4.7 %	23.85 %
M6	12 000 000	I,II,III	BBB/A3/A-	3.3 %	20.53 %
M7	19 200 000	I,II,III	B/Baa1/BBB+	5.3 %	15.21 %
M8	9 000 000	I,II,III	B/Baa2/BBB	2.5 %	12.72 %
M9	13 200 000	I,II,III	B/Baa3/BBB-	3.7 %	9.06 %
Non-Publicly-Offered Certificates					
M10	7 800 000	I,II,III	CCC/Ba1/BB+	2.2 %	6.90 %
M11	12 000 000	I,II,III	CCC/Ba2/BB	3.3 %	3.58 %
CE	12 928 188		NR/NR/NR	3.6 %	0.00 %
Total	361 097 331				
Collateral	361 097 430				

Table 3.11: Ameriquest Mortgage Securities Inc. 2005-R2 (AMSI 2005-R2) In Q1:07; Source: [6]

In Tables 3.10 and 3.11, the abbreviations PIF, WR and NR are for tranche *paid in full*, *withdrawn rating* and *no rating*, respectively.

Tables 3.12 and 3.13 present SAIL 2006-2 deal structure, tranche thickness and ratings at the outset as well as in Q1:07. Once again, the initial thickness of the BBB tranches – measured as a percentage of collateral – are extremely thin. As far as the subordination percentages for BBB tranches at inception are concerned, for instance, the M8 tranche of SAIL 2006-2 has only 0.7 % subordination. As before, as amortization occurs, CE accumulates and reference mortgages refinance, this situation could improve.

Structured Asset Investment Loan Trust 2006-2 (SAIL 2006-2) At Issue in 2006					
	Size	**Related Mortgage Pool(s)**	**Ratings (Fitch, Moody's S&P)**	**% of Collateral**	**Subordination**
Publicly-Offered Certificates					
A1	607 391 000	I	Aaa/AAA/AAA	45.3 %	16.75 %
A2	150 075 000	I	Aaa/AAA/AAA	5.4 %	19.35 %
A3	244 580 000	II	Aaa/AAA/AAA	21.5 %	35.48 %
A4	114 835 000	II	Aaa/AAA/AAA	5.4 %	19.35 %
M1	84 875 000	III	Aa2/AA/AA	10.4 %	19.35 %
M2	25 136 000	III	Aa3/AA-/AA-	11.6 %	19.35 %
M3	20 124 000	III	A1/A+/A+	2.2 %	19.35 %
M4	20 124 000	III	A2/A/A	2.7 %	19.35 %
M5	15 428 000	I,II,III	A3/A-/A-	2.6 %	16.75 %
M6	15 428 000	I,II,III	Baa1/BBB+/BBB+	4.1 %	12.6 %
M7	11 404 000	I,II,III	Baa2/BBB/BBB	1.4 %	11.2 %
M8	10 733 000	I,II,III	Baa3/BBB-/BBB-	0.7 %	4.05 %
Non-Publicly-Offered Certificates					
B1	7 379 000	I,II,III	Ba1/?/?	0.6 %	1.05 %
B2	7 379 000	I,II,III	Ba2/?/?	0.6 %	0.5 %
CE	6 708 733				
Total	1 341 599 733				

Table 3.12: Structured Asset Investment Loan Trust 2006-2 (SAIL 2006-2) At Issue in 2006; Source: [116]

Structured Asset Investment Loan Trust 2006-2 (SAIL 2006-2) In Q1:07					
	Size	**Related Mortgage Pool(s)**	**Ratings (Fitch, Moody's S&P)**	**% of Collateral**	**Subordination**
Publicly-Offered Certificates					
A1	89 285 238	I	Aaa/AAA/AAA	11.0 %	26.16 %
A2	150 075 000	I	Aaa/AAA/AAA	18.5 %	26.16 %
A3	244 580 000	II	Aaa/AAA/AAA	30.2 %	26.16 %
A4	114 835 000	II	Aaa/A/A	14.2 %	26.16 %
M1	84 875 000	III	Ba3/CCC/B	10.5 %	15.70 %
M2	25 136 000	III	B3/CCC/CCC	3.1 %	12.60 %
M3	20 124 000	III	Caa2/CCC/CCC	2.5 %	10.12 %
M4	20 124 000	III	Caa3/CC/CC	2.5 %	7.36 %
M5	15 428 000	I,II,III	Ca/CC/CC	1.9 %	5.73 %
M6	15 428 000	I,II,III	C/CC/CC	1.9 %	3.83 %
M7	11 404 000	I,II,III	C/CC/C	1.4 %	2.42 %
M8	10 733 000	I,II,III	C/D/C	1.3 %	1.10 %
Non-Publicly-Offered Certificates					
B1	7 379 000	I,II,III	C/D/C	0.9 %	0.19 %
B2	1 534 646	I,II,III	WR/NR/NR	0.2 %	0.09 %
CE	98	I,II,II		11.0 %	88.99 %
Total	810 940 982				

Table 3.13: Structured Asset Investment Loan Trust 2006-2 (SAIL 2006-2) In Q1:07; Source: [116]

In Tables 3.12 and 3.13, in addition, there are Class X, P, LT-R and R certificates. The former are entitled to any monthly excess cashflow left over after contracted payouts to offered certificates and Class B1 and B2 certificates and payments to the SPV (includes paying swap counterparties) as well as on and after the distribution date on April 2016 to deposit any final maturity reserve amount in the final maturity reserve account. On the other hand, Class P certificates will solely be intitled to receive all prepayment premiums received in relation to the reference mortgage portfolios. Such amounts are not available for payouts to holders of other certificate classes or to SRs as additional servicing compensation. The Class LT-R and R certificates will represent the remaining interest in the assets of the SPV after the required payouts to all other classes of certificates are made. These classes will evidence the residual interests in the REMIC[8].

3.5.4.2 Comparisons Between AMSI 2005-R2 and SAIL 2006-2

Judging from Q1:07, the two deals differ dramatically. AMSI 2005-R2 is older than SAIL 2006-2 and by Q1:07, AMSI 2005-R2 has passed its triggers. As expected, the tranche thicknesses and subordination levels have increased. For example, initially M9 from the AMSI 2005-R2 deal had a 2.95 % subordination (1.1 % collateral) level, but by Q1:07 its subordination (collateral) is 9.06 % (3.7 %). Despite this, at the time Fitch downgraded the BBB tranches to B. By contrast, SAIL

[8] A REMIC (Real Estate Mortgage Investment Conduit) is an investment vehicle – a legal structure that can hold CMLs and mortgages, in trust, and issue securities representing undivided interests in these mortgages. Besides a trust, a REMIC can be a corporation, association or partnership.

2006-2 is younger than AMSI 2005-R2 and took place during a period where house prices were flat and it was more difficult to refinance. By Q1:07, neither tranche thickness nor subordination had increased significantly since inception in 2006 thus weakening the SAIL 2006-2 deal. This is reflected by the mezz tranche ratings.

3.6 Discussions on Subprime Mortgage Securitization and the SMC

In this section, we discuss the relationships between the SMC and risk, profit and valuation under RMBSs and RMBS CDOs. Also, we comment on examples involving subprime mortgage securitization and its relationships with valuation. In particular, we focus our discussion on the main hypothesis of this thesis that the SMC was partly caused by the intricacy and design of subprime mortgage securitization and systemic components that led to information (loss, asymmetry and contagion) problems, valuation opaqueness and ineffective risk mitigation (compare with Problem 1.3.6 in Section 1.3).

3.6.1 Risk, Profit and Valuation Under RMBSs and the SMC

In this subsection, we discuss the relationships between the SMC and risk, profit and valuation under RMBSs.

3.6.1.1 Subprime RMBSs and the SMC

The key design feature of subprime mortgages was the ability of MRs to finance and refinance their houses based on capital gains due to house price appreciation over short horizons and then turning this into collateral for a new mortgage or extracting equity for consumption. As is alluded to in Subsection 3.2.1, the unique design of subprime mortgages resulted in unique structures for their securitizations (response to Problem 1.3.6). During the SMC, CRAs were reprimanded for giving investment-grade ratings to RMBSs backed by risky subprime mortgages. Before the SMC, these high ratings enabled such RMBSs to be sold to SIBs, thereby financing and exacerbating the housing boom. The issuing of these ratings were believed justified because of risk reducing practices, such as monoline insurance and equity investors willing to bear the first losses. However, during the SMC, it became clear that some role players in rating subprime-related securities knew at the time that the rating process was faulty. Uncertainty in financial markets spread to other subprime agents, increasing the counterparty risk which caused interest rates to increase. Refinancing became almost impossible and default rates exploded. All these operations embed systemic risk which finally caused the banking system to collapse (compare with Subsection 3.2.1).

Clearly, during the SMC, the securitization of credit risks was a source of moral hazard that compromised global banking sector stability. Before the SMC, the practice of splitting the claims to a reference mortgage portfolio into tranches was a response to this concern. In this case, sen and mezz tranches can be considered to be senior and junior debt, respectively. *If* SORs held equity tranches and *if*, because of packaging and diversification, the probability of default, i.e., the probability that reference portfolio returns do not attain the sum of sen and mezz claims, were (close to) zero, we would (almost) be neglecting moral hazard effects. How the banking system failed despite the preceding scenario is explained next (compare with Subsection 3.2.1). Unfortunately, in reality, both *ifs* in the statement above were not satisfied. SORs did not, in general, hold the equity tranches of the portfolios that they generated. In truth, as time went on, ever greater portions of equity tranches were sold to external SIBs. Moreover, default probabilities for sen and mezz tranches were significant because packaging did not provide for sufficient diversification of returns on the reference mortgage portfolios in RMBS portfolios (see, for instance, [58]).

3.6.1.2 Risk and Profit Under RMBSs and the SMC

In the early '80s, house financing in the U.S. and many European countries changed from fixed-rate (FRMs) to adjustable-rate mortgages (ARMs) resulting in an interest rate risk shift to MRs. However, when market interest rates rose again in the late '80s, SORs found that many MRs were unable or unwilling to fulfil their obligations at the newly adjusted rates. Essentially, this meant that the interest rate (market) risk that SORs thought they had eradicated had merely been transformed into counterparty credit risk. Presently, it seems that the lesson of the '80s that ARMs cause credit risk to be higher, seems to have been forgotten or neglected since the credit risk would affect the RMBS bondholders rather than the SORs (see, for instance, [58]). Subsection 3.2.2.1 of Subsection 3.2.2 implies that the system of house financing based on RMBSs has some eminently reasonable features. Firstly, this system permits SORs to divest themselves from the interest rate risk that is associated with such financing. The experience of the U.S. Savings & Loans debacle has shown that banks cannot cope with this risk. The experience with ARMs has also shown that debtors are not able to bear this risk and that the attempt to burden them with it may merely transform the interest rate risk into counterparty credit risk. Securitization shifts this risk to a third party.

A subprime mortgage model for profit under subprime RMBSs from (3.2) and (3.4) reflects the fact that SOR sells mortgages and distributes risk to SIBs through RMBSs. This way of mitigating risks involves at least operational (including valuation and compensation), liquidity (market) and tranching (including maturity mismatch) risk that returned to SORs when the SMC unfolded. SORs are more likely to securitize more mortgages if they hold less capital, are less profitable and/or liquid and have mortgages of low quality. This situation was prevalent before the SMC when SORs' pursuit of yield did not take decreased capital, liquidity and mortgage quality into account. The investors in RMBSs also embed credit risk which involves bankruptcy if SIBs can't raise funds.

In Subsection 3.2.2.2, Π^{Σ} is given by (3.4) while K^{Σ} has the form (3.5). It is interesting to note that the formulas for Π^{Σ} and K^{Σ} depend on Π and K, respectively, and are far more intricate than the latter. Defaults on RMBSs increased significantly as the crisis expanded from the housing market to other parts of the economy, causing Π^{Σ} (as well as retained earnings in (3.3)) to decrease. During the SMC, capital adequacy ratios declined as K^{Σ} levels became depleted while banks were highly leveraged. As a consequence, methods and processes which embed operational risk failed. In this period, such risk rose as banks succeeded in decreasing their capital requirements. Operational risk was not fully understood and acknowledged which resulted in loss of liquidity and failed risk mitigation management (compare with Problem 1.3.6).

3.6.1.3 Valuation Under RMBSs and the SMC

When U.S. house prices declined in 2006 and 2007, refinancing became more difficult and ARMs began to reset at higher rates. This resulted in a dramatic increase in subprime mortgage delinquencies so that RMBSs began to lose value. Since these mortgage products are on the balance sheet of most banks, their valuation given by (3.8) in Subsection 3.2.3 began to decline (see, also, formulas (3.6) and (3.7)). Before the SMC, moderate reference mortgage portfolio delinquency did not affect valuation in a significant way. However, the value of mortgages and related structured products such as RMBSs decreased significantly due incidences of operational, tranching and liquidity risks during the SMC. The yield from these structured mortgage products decreased as a consequence of high default rates (credit risk) which caused liquidity problems with a commensurate rise in the instances of credit crunch and funding risk (see Subsection 1.2.4 for more details about these risks).

The imposition of fair value accounting for subprime mortgages and their structured products enhances the scope for systemic risk that involves the malfunctioning of the entire banking system. Under this type of accounting, the values at which securities are held in banks' books depend on the prices that prevail in the market (see formulas (3.6), (3.7) and (3.8) for valuations of banks holding such securities). In the event of a change in securities prices, the bank must adjust its books even if the price change is due to market malfunctioning and it has no intention of selling the security, but intends to hold it to maturity. Under currently prevailing capital adequacy requirements, this adjustment has immediate implications for the bank's financial activities. In particular, if market prices of securities held by the bank have decreased, the bank must either recapitalize by issuing new equity or retrench its overall operations. The functioning of the banking system thus depends on how well credit markets are functioning. In short, impairments of the ability of markets to value mortgages and related structured products such as RMBSs can have a large impact on bank valuation (compare with Subsection 3.2.3).

3.6.1.4 Optimal Valuation Under RMBSs and the SMC

In Subsection 3.2.4, SIB's valuation performance criterion, J^{Σ}, at t is given by (3.10). During the SMC, when valuation was a major issue, J^{Σ} was difficult to compute since the valuation of components such as B was not easy to determine. In addition, before the SMC, CRAs used idiosyncratic valuation techniques to give investment-grade ratings to RMBSs despite the fact the mortgages at face value, mortgage rate, SIB's optimal deposits and provisions for deposit withdrawals via Treasuries of the form (3.14), (3.15), (3.16) and (3.17), respectively, computed in Theorem 3.2.4 – subject to RMBS, balance sheet, cash flow and financing constraints given by (3.12), (3.13), (3.2) and (3.5), respectively – were clearly suboptimal.

When the capital constraint given by (3.9) holds (i.e., $l_t^b > 0$), a solution to the optimal valuation problem under RMBSs yields optimal profit under RMBSs of the form (3.18). With hindsight, it is clear that the aforementioned subprime parameters did not compare favorably with their optimal counterparts. Also, during the SMC, the financing constraint was violated with not enough capital being held. When the capital constraint (3.9) does not hold (i.e., $l_t^b = 0$) and $P(\mathcal{C}_t) > 0$, then optimal RMBS supply and its rate, (3.26) and (3.27) respectively, are solutions to the optimal valuation problem stated in Corollary 3.2.5.

3.6.2 Risk, Profit and Valuation Under RMBS CDOs and the SMC

In this subsection, we discuss the relationships between the SMC and capital, information, risk and valuation under RMBS CDOs. In this regard, Table 3.14 below shows CDO issuance with Column 1 showing total issuance of CDOs while the next column presents total issuance of ABS CDOs. This table suggests that CDO issuance has been significant both before and after the SMC with the majority being CDOs with structured notes as collateral. In addition, Table 3.14 suggests that the motivation for CDO issuance has primarily been arbitrage.

From Table 3.14, we note that issuance of ABS CDOs roughly tripled over the period 2005-07 and ABS CDO portfolios became increasingly concentrated in subprime RMBSs. In this regard, by 2005, spreads on subprime BBB tranches seemed to be wider than other structure mortgage products with the same rating, creating an incentive to arbitrage the ratings between subprime RMBS and CDO tranches ratings. Subprime RMBSs increasingly dominated CDO portfolios, suggesting that the pricing of risk was inconsistent with the ratings. Also, concerning the higher rated tranches, CDOs may have been motivated to buy large amounts of structured mortgage products, because their AAA tranches would input profitable negative basis trades[9]. As a consequence, the willingness of CDOs to purchase subprime RMBS bonds increased. In the period 2008-2009, during the height of the SMC, there was a dramatic decrease in CDO issuance. During Q1:10 there was a marked increase in ABS CDO issuance by comparison with Q3:09 and Q4:09 indicating an improvement in the CDO market.

[9] According to [53], in a negative basis trade, a bank buys the AAA-rated CDO tranche while simultaneously purchasing protection on the tranche under a physically settled CDS. From the bank's viewpoint, this is the simultaneous purchase and sale of a CDO security, which meant that IL could book the NPV of the excess yield on the CDO tranche over the protection payment on the CDS. If the CDS spread is less than the bond spread, the basis is negative. An example of this is given below. Suppose the bank borrows at LIBOR + 5 and buys a AAA-rated CDO tranche which pays LIBOR + 30. Simultaneously, SIB buys protection (possibly from a monoline insurer) for 15 bps (basis points). So SIB makes 25 bps over LIBOR nett on the asset, and they have 15 bps in costs for protection, for a 10 bps profit. Note that a negative basis trade swaps the risk of the AAA tranche to a CDS protection writer. Now, the subprime-related risk has been separated from the cash host. Consequently, even if we were able to locate the AAA CDO tranches, this would not be the same as finding out the location of the risk. We do not know the extent of negative basis trades.

Global CDO Issuance ($ Millions)						
	Total Issuance	**Structured Finance**	**Cash Flow & Hybrid**	**Synthetic Funded**	**Arbitrage**	**Balance Sheet**
Q1:04	24 982.5	NA	18 807.8	6 174.7	23 157.5	1 825.0
Q2:04	42 864.6	NA	25 786.7	17 074.9	39 715.5	3 146.1
Q3:04	42 864.6	NA	36 106.9	5 329.7	38 207.7	3 878.8
Q4:04	47 487.8	NA	38 829.9	8 657.9	45 917.8	1 569.9
2004 Tot.	157 418.5	NA	119 531.3	37 237.2	146 998.5	10 419.8
% of Tot.			75.9 %	23.7 %	93.4 %	6.6 %
Q1:05	49 610.2	28 171.1	40 843.9	8 766.3	43 758.8	5 851.4
Q2:05	71 450.5	46 720.3	49 524.6	21 695.9	62 050.5	9 400.0
Q3:05	52 007.2	34 517.5	44 253.1	7 754.1	49 636.7	2 370.5
Q4:05	98 735.4	67 224.2	71 604.3	26 741.1	71 957.6	26 777.8
2005 Tot.	271 803.3	176 639.1	206 225.9	64 957.4	227 403.6	44 399.7
% of Tot.		65.0 %	75.9 %	23.9 %	83.7 %	16.3 %
Q1:06	108 012.7	66 220.2	83 790.1	24 222.6	101 153.6	6 859.1
Q2:06	124 977.9	65 019.6	97 260.3	24 808.4	102 564.6	22 413.3
Q3:06	138 628.7	89 190.2	102 167.4	14 703.8	125 945.2	12 683.5
Q4:06	180 090.3	93 663.2	131 525.1	25 307.9	142 534.3	37 556.0
2006 Tot.	551 709.6	314 093.2	414 742.9	89 042.7	472 197.7	79 511.9
% of Tot.		56.9 %	75.2 %	16.1 %	85.6 %	14.4 %
Q1:07	186 467.6	101 074.9	140 319.1	27 426.2	156 792.0	29 675.6
Q2:07	175 939.4	98 744.1	135 021.4	8 403.0	153 385.4	22 554.0
Q3:07	93 063.6	40 136.8	56 053.3	5 198.9	86 331.4	6 732.2
Q4:07	47 508.2	23 500.1	31 257.9	5 202.3	39 593.7	7 914.5
2007 Tot.	502 978.8	263 455.9	362 651.7	46 230.4	436 102.5	66 8769.3
% of Tot.		52.4 %	72.1 %	9.1 %	86.8 %	13.3 %
Q1:08	12 846.4		12 771.0	75.4	18 607.1	1 294.6
Q2:08	16 924.9		15 809.7	1 115.2	15 431.1	6 561.4
Q3:08	11 875.0		11 875.0	–	10 078.4	4 255.0
Q4:08	3 290.1		3 140.1	150.0	3 821.4	1 837.8
2008 Tot.	44 936.4		43 595.8	1 340.6	47 938.0	13 948.8
% of Tot.		32.4 %	91.2.1 %	1.6 %	89.4 %	10.6 %
Q1:09	296.3		196.8	99.5	658.7	99.5
Q2:09	1 345.5		1 345.5	–	1 886.4	–
Q3:09	442.9		337.6	105.3	208.7	363.5
Q4:09	730.5		681.0	49.5	689.5	429.7
2009 Tot.	2 815.2		2 560.9	254.3	3 443.3	892.7
% of Tot.		40.4 %	91.2.1 %	1.6 %	89.4 %	10.6 %
Q1:10	2 420.8		2 378.5	42.3	–	2 420.7
Q2:10	1 655.8		1 655.8	–	598.1	1 378.9
Q3:10	2 002.7		2 002.7	–	2002.7	–
Q4:10			–	–	–	–
2010 Tot.	6 079.3		6 037.0	42.3	2 600.8	3 799.6
% of Tot.		44.1 %	91.2.1 %	1.6 %	89.4 %	10.6 %

Table 3.14: Global CDO Issuance ($ Millions); Source: [113]

Table 3.15 shows estimates of the typical collateral composition of sen and mezz ABS CDOs before the SMC. It is clear that subprime and other RMBS tranches make up a sizeable percentage of both these tranche types.

Typical Collateral Composition of ABS CDOs (%)		
	High Grade ABS CDOs	**Mezzanine ABS CDOs**
Subprime RMBS Tranches	50 %	77 %
Other RMBS Tranches	25	12
CDO Tranches	19	6
Other	6	5

Table 3.15: Typical Collateral Composition of ABS CDOs (%); Source: Citigroup

Table 3.16 below demonstrates that increased volumes of origination in the subprime mortgage market led to an increase in subprime RMBSs as well as CDO issuance.

Subprime-Related CDO Volumes			
Vintage	**Mezz ABS CDOs**	**High Grade ABS CDOs**	**All CDOs**
2005	27	50	290
2006	50	100	468
2007	30	70	330
2008	30	70	330

Table 3.16: Subprime-Related CDO Volumes; Source: [117]

3.6.2.1 Subprime ABS CDOs and the SMC

Certain features of RMBS CDOs portrayed in Figure 3.6 from Subsection 3.1.3.1 make their design more intricate (compare with Problem 1.3.6). For instance, many such CDOs are managed by managers that are to a limited extent allowed to buy and sell RMBS bonds over a given period of time. The reason for this is that CDOs amortize with a longer maturity able to be achieved by re-investment. In particular, managers are able to use cash that is paid to the CDO from amortization for re-investment. Under the conditions outlined in Subsection 3.1.3.1, they can sell bonds in the portfolio and buy other bonds with restrictions on the portfolio that must be maintained. CDO managers typically owned all or part of the CDO equity, so they would benefit from higher yielding assets for a given liability structure. In short, CDOs are managed funds with term financing and some constraints on the manager in terms of trading and the portfolio composition.

Table 1.3 implies that SIBs purchased tranches of structured mortgage products such as RMBSs, ABS CDOs, SIV liabilities and money market funds without an intimate knowledge of the dynamics of the products they were purchasing. In all likelihood, these SIBs relied on information generated by repeated relationships, bankers and credit ratings. In reality, many such SIBs do not have the resources to individually analyze such complicated structures and, ultimately, rely less on the information about the structure and the fundamentals and more on the relationship with the SDB selling the structured product. In this way, agency relationships are substituted for actual information which is a situation not unique to structured mortgage products such as RMBSs and ABS CDOs. However, in the SMC case, the length of the chain of subprime risks is a huge problem (compare with Table 1.3). All of the above is aligned with the main hypothesis of this contribution involving intricacy and design and their exacerbation of information and opaqueness problems (compare with Problem 1.3.6).

3.6.2.2 Risk and Profit Under RMBS CDOs and the SMC

A subprime mortgage model for profit under subprime RMBS CDOs has the form (3.32) given in Subsection 3.3.1. Under RMBS CDOs, $\Pi_t^{\Sigma b}$ is given by (3.33) while capital is of the form (3.34). In this regard, before the SMC, SIBs sought higher profits than those offered by U.S. Treasury bonds. Continued strong demand for RMBSs and RMBS CDOs began to drive down lending standards related to originating mortgages destined for reference portfolios in securitization. RMBS CDOs lost most of their value which resulted in a large decline in the capital of many banks and GSEs, with a resultant tightening of credit globally.

As we have seen before, subprime risks and profit play a key role in Subsection 3.3.1. In this regard, before the SMC, CDOs purchased subprime RMBS bonds because it was profitable. At first, lower-rated BBB tranches of subprime RMBS were difficult to sell since they were thin and, hence, unattractive. Later the thickness of these tranches increased and investment in them became more alluring for SIBs (compare with the examples contained in Subsections 3.5.3 and 3.5.4). Despite this, a purchasing CDO may not be aware of the subprime risks inherent in the RMBS deal, including credit and synthetic risk. In this way, risks were underestimated and mortgages and structured mortgage products were over-rated. In particular, tranching added intricacy to securitization. This assertion has resonance with the main hypothesis of this contribution involving the intricacy and design of subprime structured mortgage products and their role in information and opaqueness problems as well as risk mismanagement (compare with Problem 1.3.6).

3.6.2.3 Valuation Under RMBS CDOs and the SMC

In Subsection 3.3.2, we note that SIB's value under RMBS CDOs is given by (3.37). In this regard, to our knowledge, there is no standardization of triggers across CDOs with some having sequential cash flow triggers while others have OC trigger calculations based on ratings changes. As far as performing valuations is concerned, in reality, each RMBS CDO must be separately valued which may not be possible (compare with formula (3.35) for nett cash flow under RMBS CDOs). During the SMC, this played a role in the problems SIBs faced when they attempted a valuation of CDO tranches. Furthermore, RMBS CDOs widely held by SDBs and SIBs lost most of their value during this period. Naturally, this led to a dramatic decrease in SIB's valuation from holding such structured mortgage products which, in turn, increased the subprime risks in mortgage markets (refer to formulas (3.36) and (3.37) for SIB's valuation under RMBS CDOs).

3.6.2.4 Optimal Valuation Under RMBS CDOs and the SMC

In Subsection 3.3.3, valuation performance criterion, $J^{\Sigma b}$, in period t is given by (3.38) while the total capital constraint may be represented by (3.9). The optimal valuation problem under RMBSs is to maximize value given by (3.37) by choosing the RMBS rate, deposits and regulatory capital for (3.39) subject to RMBS, balance sheet, cash flow and financing constraints given by (3.12), (3.13), (3.32) and (3.34), respectively. When the capital constraint given by (3.9) holds (i.e., $l_t^b > 0$), a solution to the optimal valuation problem yields optimal RMBSs and RMBS rates of the form

(3.14) and (3.15), respectively. Most importantly, all the comments in Subsection 3.6.1.4 about optimal valuation under RMBSs can be repeated for RMBS CDOs.

The optimal valuation formulas mentioned above can be used to illustrate how information is lost due to intricacy. For RMBS CDO investors, the fact that information is lost implies that it is impossible for them to penetrate the chain backwards and value the chain based on the reference mortgage portfolios. RMBS CDO design itself does not allow for valuation based on the reference mortgage portfolio. This is due to the fact that there are at least two layers of structured products in CDOs. Information is lost because of the difficulty of penetrating to the core assets. Nor is it possible for those at the start of the chain to use their information to value the chain "forwards" in a manner of speaking (compare with the analysis in Subsection 3.3.3).

3.6.3 Mortgage Securitization and Capital Under Basel Regulation and the SMC

In this subsection, we discuss the connections between Basel capital regulation and the SMC. The capital constraint in Section 3.4 for the securitized case is described by the expression in (2.13). In particular, we keep the risk-weights for mortgages are kept constant, i.e., $\omega^M = 1$. In this case, the capital constraint (2.13) becomes (3.48).

An example of the fact that capital was in short supply at the outset of the SMC in the second half of 2007 is given below. In this period, Citigroup Inc. had its worst-ever quarterly loss of $ 9.83 billion and had to raise more than $ 20 billion in capital from outside investors, including foreign-government investment funds. This was done in order to augment the depleted capital on its balance sheet after bad investments in structured mortgage products. According to the Federal Deposit Insurance Corporation (FDIC), at the time, Citigroup held $ 80 billion in core capital on its balance sheet to protect against its $ 1.1 trillion in assets. In the second half of 2007, Citigroup wrote down about $ 20 billion. Amazingly, at the end of 2007, major U.S. banks like J.P. Morgan Chase & Co., Wachovia Corp., Washington Mutual Inc. and Citigroup lobbied for leaner, European-style capital cushions. These banks argued that tighter rules would make it tougher for them to compete globally, since more of their money would be tied up in the capital cushion. Eventually, in July 2008, the U.S. Federal Reserve and regulators acceded to the banks' requests by allowing them to follow rules similar to those in Europe. That ruling enabled U.S. banks to hold looser, European-style capital. However, by then, cracks in the global banking system were already spreading rapidly.

3.6.3.1 Quantity and Pricing of Mortgages and Capital Under Basel Regulation (Securitized Case) and the SMC

In Subsection 3.4.1, we considered how capital, K, and the quantity and price of RMBSs, B, are affected by changes in the level of credit rating, $\mathcal{C}^B$, when risk-weight on RMBSs, $\omega(\mathcal{C}_t^B)$, are allowed to vary.

During the SMC, as banks adjusted to mortgage delinquencies and defaults and the breakdown of maturity transformation, the interplay of market malfunctioning or even breakdown, fair value accounting and the insufficiency of equity capital, and, finally, systemic effects of prudential regulation created a detrimental downward spiral in the banking system. By contrast, critical securities are now being traded in markets, and market prices determine the day-to-day assessments of equity capital positions of institutions holding them.

Systemic risk explains why the SMC has turned into a worldwide financial crisis unlike the S&L crisis of the late eighties. There were warnings at the peak of the S&L crisis that overall losses of US savings institutions might well amount to $ 600-800 billion. This is no less than the IMF's estimates of losses in subprime RMBSs. However, these estimates never translated into market prices and the losses of the S&Ls were confined to the savings institutions and to the deposit insurance institutions that took them over. This difference in institutional arrangements explains why the fallout from the current crisis has been so much more severe than that of the S&L crisis.

3.6.3.2 Subprime Mortgages and Their Rates Under Basel Capital Regulation (Slack Constraint; Securitized Case) and the SMC

In Subsection 3.4.2 we consider the effect of a shock to RMBS credit rating $\mathcal{C}_t^B$, on B, and r^B. In particular, we analyze the case where the capital constraint (3.48) is slack. When $l_t^b = 0$ we have (3.53) and (3.54).

Before the SMC, there was a relative decline in equity related to the capital that banks held in fulfilment of capital adequacy requirements as well as the buffers that they held in excess of required capital. A decline in required capital was made possible by changes in statutory rules relating to the prudential regulation of bank capital. The changes in rules provided banks with the option to determine regulatory capital requirements by assessing value-at-risk in the context of their own quantitative risk models, which they had developed for their own risk management. In particular, internationally active banks were able to determine capital requirements for market risks on the basis of these internal models. The amount of capital they needed to hold against any given asset was thereby greatly reduced.

3.6.3.3 Subprime Mortgages and Their Rates Under Basel Capital Regulation (Holding Constraint; Securitized Case) and the SMC

Subsection 3.4.3 present results about the effect of changes in the level of credit rating, $\mathcal{C}^B$, on RMBSs when the capital constraint (3.48) holds. If $l_t^b > 0$ then by taking the first derivatives of equation (3.14) with respect to $\mathcal{C}_t^B$ and using the fact that the risk-weights for mortgages, ω^M, are constant we obtain (3.55). In this situation, the subprime RMBS payout rate response to changes in the level of credit rating is given by (3.56).

Unlike in the 19th century, there is no modern equivalent to clearing houses that allowed information asymmetry to dissipate. During the SMC, there was no information producing mechanism that was implemented. Instead, accountants follow rules by, for instance, enforcing "marking." Even for earlier vintages, accountants initially seized on the ABX indices in order to determine "price," but were later willing to recognize the difficulties of using ABX indices. However, marking-to-market implemented during the SMC, has very real effects because regulatory capital and capital for CRA purposes is based on generally accepted accounting principles (GAAP). The GAAP measure of capital is probably a less accurate measure of owner-contributed capital than the Basel measure of capital since the latter takes into account banks' exposure to credit, market and operational risk and their off-balance sheet activities. There are no sizeable platforms that can operate ignoring GAAP capital. During the SMC, partly as a result of GAAP capital declines, banks are selling large amounts of assets or are attempting to sell assets to clean up their balance sheets, and in so doing raise cash and de-levering. This pushes down prices, and another round of marking down occurs and so on. This downward spiral of prices – marking down then selling then marking down again – is a problem where there is no other side of the market (see, for instance, [58]).

3.6.3.4 Subprime Mortgages and Their Rates Under Basel Capital Regulation (Future Time Periods; Securitized Case) and the SMC

In Subsection 3.4.4 we examine the effect of a current credit rating shock in future periods on subprime RMBSs, B, and their payout rates, r^B. The response of subprime RMBSs and RMBS rates to a change in the level of credit rating, $\mathcal{C}_t^B$, is described by (3.57) if the capital constraint holds. Most importantly, all the comments about subprime mortgages and their rates under Basel capital regulation for RMBSs can be repeated for RMBS CDOs.

The incidence of systemic risk in the SMC has been exacerbated by an insufficiency of equity capital held against future mortgage losses. As the system of risk management on the basis of quantitative risk models was being implemented, banks were becoming more conscious of the desirability of "economizing" on equity capital and of the possibility of using the quantitative risk models for this purpose. Some of the economizing on equity capital involved improvements in the attribution of equity capital to different activities, based on improvements in the awareness and measurement of these activities' risks. Some of the economizing on equity capital led to the relative decline in equity that is one of the elements shaping the dynamics of the downward spiral of the financial system since August 2007. One may assume that the loss of resilience that was caused by the reduction in equity capital was to some extent outweighed by the improvements in the quality of risk management and control. However, there may also have been something akin to the effect that the instalment of seat belts or anti-blocking systems in cars induces people to drive more daringly. A greater feeling of protection from harm or a stronger sense of being able to maintain control may induce people to take greater risks.

3.6.4 Examples Involving Subprime Mortgage Securitization and the SMC

In this subsection, we discuss the relationships between the SMC and a numerical example involving mortgage securitization, securitization economics, an example of a subprime RMBS deal as well as a comparison between two typical subprime deals.

3.6.4.1 Numerical Example Involving Subprime Mortgage Securitization and the SMC

The example in Subsection 3.5.1 shows that under favorable economic conditions (for instance, where RMBS default rates are low and $\mathcal{C}^B$ is high) huge profits can be made from securitizing subprime RMBSs as was the case before the SMC. On the other hand, during the SMC, when conditions are less favorable (for instance, where RMBS default rates are high and $\mathcal{C}^B$ is low), SIBs suffer large mortgage securitization losses.

We observe from the numerical example that costs of funds and capital constraints from Basel capital regulation have important roles to play in subprime mortgage securitization, profit and valuation. We see that the profit under securitization in period $t+1$ is less than the profit under securitization in period t. This is mainly due to higher reference RMBS portfolio defaults as a result of higher RMBS rates in period $t+1$. This was a major cause of the SMC.

3.6.4.2 Example Involving Profit from Mortgage Securitization and the SMC

The part of our example of mortgage securitization in Subsection 3.5.2.1, does not suggest that it is generally true that all outcomes will be favorable, because it is possible that $\overline{c}^{M\Sigma\omega} < \overline{c}^{M\omega}$, but is still higher than the reference mortgage portfolio return, r^M, thereby generating a loss when selling mortgages to SPV. Even if $\overline{c}^{M\Sigma\omega} > \overline{c}^{M\omega}$, there would be room to improve SOR's portfolio r^E because of K^{es}. As a consequence the discussion presented in Subsection 3.5.2.1 is not representative of all possible situations.

In Subsection 3.5.2.2, we note that the influence on r^E is from both lower level E and reduced $\overline{c}^{M\Sigma\omega A}$. The gain value is either present value or an improvement of annual margins averaged over the life of the deal. In the example, K^{es} is a present forfeit percentage of 4 % used as an input. When considering the SMC, this same percentage of mortgages could result from modeling K^e and could be an output of a mortgage portfolio model. In both cases, an analysis of the securitization economics should strive to determine whether securitization improves the risk-return profile of SOR's original mortgage portfolio. Enhancing the risk-return profile means optimizing the efficient frontier or increasing r^E for SOR's reference mortgage portfolio. We may ascertain whether this is true by calculating r^E and $r^{E\Sigma}$ as well as comparing them.

From Subsection 3.5.2.3, if securitization improves r^E, SOR's might be inclined to increase $f^\Sigma M$. Potentially, SOR could benefit even more from the good relationship between $f^\Sigma M$ and r^E – known as the *leverage effect of securitization*. Leverage is positive as long as $\overline{c}^{M\Sigma\omega} = 0.1008$ remains fixed with a higher $f^\Sigma M$ leading to a higher final r^E subsequent to securitization. For instance, using the example in Subsection 3.5.2.3, securitizing 2 000 instead of 1 000, and keeping the same proportions of mortgages to D and K, would automatically increase r^E. This increase does not result from an additional capital gain in $f^\Sigma M$, since this gain remains 0.00833 of mortgages. Instead it results from the fact that the additional annualized rate of return, r^a, is proportional to the ratio of mortgages before and after securitization. In the example, with $f^\Sigma M = 1000$, r^a as a percentage of $f^\Sigma M$ is

$$r^a = 0.000926 = 0.00833 \times 1000/9000$$

of mortgages. Should SOR sell 2 000, the same percentage of $f^\Sigma M$ would increase to $0.001851 = 0.00833 \times 2000/9000$, the earnings before tax (EBT) would become $r^E = 0.33346$ and the return on capital (now 160) would be $r^K = 0.0020841 = 0.33346/160$. Another simulation will demonstrate that $f^\Sigma M = 5000$, would provide an $r^E = 0.23965$ and $r^K = 0.23965$. In fact, $f^\Sigma M = 5553$, would allow hitting the 25 % target return on $(1 - f^\Sigma)M$. This is the leverage effect of securitization, which is more than proportional to $f^\Sigma M$. We note that there are limits to this leverage effect. Firstly, an SOR securitizing all mortgages (i.e., $f^\Sigma = 1$ as in true-sales securitization) changes its core operations by becoming a pure SOR reselling new business to SPVs. As in the OTH model, origination and lending, collecting deposits and providing financial services to customers are the core business of commercial banking. Keeping mortgages on the balance sheet is part of the core business. This is a first reason for SOR not going to the extreme by securitizing its entire balance sheet. Secondly, SORs need to replenish the portfolio of securitized receivables. In order to do so, they need to keep assets on the balance sheet. This happens, for instance, when securitizing credit cards that amortize much quicker than mortgages. In such cases, the pool of credit card receivables rolls over with time and fluctuates depending on the customers' behavior. SOR needs a pool of such receivables to replenish its reference mortgage portfolio. Thirdly, increasing securitization would result in significant changes in operations and might change SORs' perception by, for instance, modifying its cost of funds. This may or may not be true depending on how K^{es} is utilized.

3.6.4.3 Example of a Subprime RMBS Bond Deal and the SMC

From Table 3.8 in Subsection 3.5.3, for the structure of SAIL 2005-6, we can deduce that there are four reference mortgage portfolios with limited cross-collateralization. This deal took place immediately prior to the onset of the SMC in mid-2007. Furthermore, it is obvious that principal payments on the sen certificates will largely depend on collections on the reference mortgage portfolios. Thus, even if the loss rate per reference portfolio related to any sen certificates class is low, losses in unrelated mortgages may reduce the loss protection for those certificates. This is so because the sen certificates will have the benefit of CE in the form of OC and subordination from each mortgage pool. This is typically what happened during the SMC with toxic mortgages reducing protection for sen certificates.

Initially, the mezz tranches are thin and small with respect to defaults. This makes the investment-grade rating BBB- of these tranches somewhat surprising. This may be offset by a significant amount of prepayment, $\varpi^2 f^p f^\Sigma M$, coming into the SAIL 2005-6 deal at the onset. Despite the fact that the underlying supposition is that the deal's cash flow dynamics has a high probability of success, the accuracy of these ratings are being questioned in the light of the SMC. The procedure by which $\varpi^2 f^p f^\Sigma M$ from $f^\Sigma M$ are allocated will differ depending on the occurrence of several different triggers[10] given in Subsection 3.5.3. As noted in [53] and described in the SAIL 2005-6 prospectus supplement, the triggers have the following specifications.

• whether a distribution date occurs before or on or after the *step-down date*, which is the latter of the (1) distribution date in July 2008 and (2) first distribution date on which the ratio

$$\frac{\text{Total Principal Balance of the Subordinate Certificates Plus Any OC Amount}}{\text{Total Principal Balance of the mortgages in the Trust Fund}}$$

equals or exceeds the percentage specified in this prospectus supplement;

• a *cumulative loss trigger event* occurs when cumulative losses on the mortgages are higher than certain levels specified in this prospectus supplement;

[10]Some of these triggers were simply ignored before and during the SMC.

• a *delinquency event* occurs when the rate of delinquencies of the mortgages over any 3-month period is higher than certain levels set forth in this prospectus supplement and

• in the case of reference mortgage portfolio 1, a *sequential trigger event* occurs if (a) before the distribution date in July 2008, a cumulative loss trigger event occurs or (b) on or after the distribution date in July 2008, a cumulative loss trigger event or a delinquency event occurs.

3.6.4.4 Comparisons Between Two Subprime RMBS Deals and the SMC

From the example involving the deals AMSI 2005-R2 and SAIL 2006-2 in Subsection 3.5.4, it is clear that the thin tranches and low subordination levels at inception are acceptable provided that the reference mortgages refinance in the anticipated way. In this situation, the RMBS bond deals shrink as amortization occurs. Also, depending on house prices, CE will build up and after the step down date, SIBs will consider investing in the BBB tranches.

The features of AMSI 2005-R2 and SAIL 2006-2 illustrate the differences between subprime and standard securitizations with their fixed tranche sizes and use of XS to create CE through reserve fund build-up. However, this is not the primary form of CE. In the subprime case, Subsection 3.5.4 illustrates how the *option* on house prices implicitly embedded in subprime reference mortgage portfolios resulted in the behavior of subprime RMBSs being sensitive to house prices. By contrast to standard securitization, the tranche thickness and extent of CE – depend on cash flow coming into the deal from $\varpi^2 f^p f^\Sigma M$ on $f^\Sigma M$ via refinancing that is also house price dependent.

The deals AMSI 2005-R2 and SAIL 2006-2 illustrate this link to house price very effectively. The former passed its triggers and achieved the CE and subordination levels hoped for at inception – largely due to reference mortgage refinancing and prepayments. By contrast, the SAIL 2006-2 deal deteriorated. In 2006, subprime MRs did not accumulate enough house equity to refinance with the result that they defaulted on their repayments. Consequently, SAIL 2006-2 was not able to pass its triggers.

3.7 2007-2010 Timeline of SMC-Related Events Involving Subprime Mortgage Securitization

In this subsection,we give a timeline of SMC-related events involving subprime mortgage securitization in the period 2007-2010.

Tuesday, 27 February 2007: Freddie Mac announces that it will no longer buy the most risky subprime RMLs and securities backed by them.

Friday, 1 June 2007: S&P and Moody's Investor Services downgrade over 100 bonds backed by second-lien subprime RMLs.

Thursday, 7 June 2007: Bear Stearns informs investors that it is suspending redemptions from its High-Grade Structured Credit Strategies Enhanced Leverage Fund.

Monday, 11 July 2007: S&P places 612 securities backed by subprime RMLs on a credit watch.

Tuesday, 31 July 2007: Bear Stearns liquidates two hedge funds that invested in various types of MBSs.

Monday, 15 October 2007: Citigroup, Bank of America, and JPMorgan Chase announce plans for an $ 80 billion MLEC to purchase highly rated assets from existing SPVs.

Wednesday, 12 December 2007: FOMC authorizes temporary reciprocal currency arrangements (swap lines) with ECB and SNB. Fed states that it will provide up to $ 20 billion and $ 4 billion to the ECB and SNB, respectively, for up to 6 months.

Friday, 21 December 2007: Citigroup, JPMorgan Chase, and Bank of America abandon plans for the MLEC announcing that the fund "is not needed at this time."

Friday, 2 May 2008: FOMC expands the list of eligible collateral for Schedule 2 TSLF auctions to include AAA/Aaa-rated asset-backed securities, in addition to already eligible residential and commercial MBSs and agency collateralized mortgage obligations. FOMC also increases existing swap lines with ECB by $ 20 billion and SNB by $ 6 billion. FRB expands TAF auctions from $ 50 billion to $ 75 billion.

Tuesday, 15 July 2008: SEC issues an emergency order temporarily prohibiting naked short selling in the securities of Fannie Mae, Freddie Mac, and primary dealers at commercial and investment banks.

Wednesday, 30 July 2008: FOMC increases its swap line with the ECB to $ 55 billion.

Sunday, 14 September 2008: FRB expands the list of eligible collateral for the PDCF to include any collateral that can be pledged in the tri-party repo system of the two major clearing banks. Previously PDCF collateral had been limited to investment-grade debt securities.

Tuesday, 16 September 2008: The net asset value of shares in the RPMF falls below $ 1, primarily due to losses on Lehman Brothers commercial paper and medium-term notes.

Thursday, 18 September 2008: FOMC expands existing swap lines by $ 180 billion and authorizes new swap lines with the Bank of Japan, BOE, and Bank of Canada.

Friday, 19 September 2008: FRB announces the creation of the AMLF to extend non-recourse loans at the primary credit rate to U.S. depository institutions and bank holding companies to finance their purchase of high-quality asset-backed commercial paper from money market mutual funds. The Federal Reserve Board also announces plans to purchase federal agency discount notes (short-term debt obligations issued by Fannie Mae, Freddie Mac, and Federal Home Loan Banks) from primary dealers.

Wednesday, 24 September 2008: FOMC establishes new swap lines with the Reserve Bank of Australia and the Sveriges Riksbank for up to $ 10 billion each and with the Danmarks National bank and the Norges Bank for up to $ 5 billion each.

Friday, 26 September 2008: FOMC increases existing swap lines with the ECB by \$ 10 billion and the Swiss National Bank by \$ 3 billion.

Monday, 29 September 2008: FOMC authorizes a \$ 330 billion expansion of swap lines with Bank of Canada, BOE, Bank of Japan, Danmarks Nationalbank, ECB, Norges Bank, Reserve Bank of Australia, Sveriges Riksbank, and SNB swap lines outstanding now total \$ 620 billion.

Tuesday, 7 October 2008: FRB announces the creation of CPFF, which will provide a liquidity backstop to U.S. issuers of commercial paper through a SPV that will purchase three-month unsecured and asset-backed CP directly from eligible issuers.

Monday, 13 October 2008: FOMC increases existing swap lines with foreign central banks. BOE, ECB and SNB announce that they will conduct tenders of U.S. dollar funding at 7-, 28-, and 84-day maturities at fixed interest rates.

Tuesday, 14 October 2008: Fed announces additional details of CPFF. FOMC increases its swap line with the Bank of Japan.

Tuesday, 28 October 2008: FOMC and Reserve Bank of New Zealand establish a \$ 15 billion swap line.

Thursday, 29 October 2008: FOMC establishes swap lines with the Banco Central do Brasil, Banco de Mexico, Bank of Korea, and the Monetary Authority of Singapore for up to \$ 30 billion each.

Friday, 21 November 2008: Treasury announces that it will help liquidate the Fed Fund's U.S. Government Fund. Treasury agrees to serve as a buyer of last resort for the fund's securities to ensure the orderly liquidation of the fund.

Tuesday, 25 November 2008: Treasury and FRB announce the launch of TALF. Under the program, the Federal Reserve Bank of New York will lend up to \$ 200 billion to eligible owners of certain AAA-rated ABSs backed by newly and recently originated auto loans, credit card loans, student loans and small business loans that are guaranteed by SBA.

Wednesday, 2 December 2008: FRB announces that it will extend three liquidity facilities – PDCF, AMLF and TSLF – until Thursday, 30 April 2009.

Friday, 19 December 2008: FRB announces revised terms and conditions of TALF. Among the revisions are an extension of TALF loans from maturities of one year to three years and an expansion of eligible ABS collateral.

Tuesday, 30 December 2008: SEC releases a report that recommends against the suspension of fair value accounting standards and was mandated by EESA.

Saturday, 5 January 2009: FRBNY begins purchasing fixed-rate MBSs guaranteed by Fannie Mae, Freddie Mac and Ginnie Mae under a program first announced on Tuesday, 25 November 2008.

Tuesday, 3 February 2009: Swap lines between the Fed and other central banks are also extended to day, 30 October 2009. The expiration date for the TALF remains Thursday, 31 December 2009, and the TAF does not have an expiration date.

Friday, 6 February 2009: FRB releases additional terms and conditions of TALF. Under TALF, the FRBNY will lend up to $ 200 billion to eligible owners of certain AAA-rated ABSs backed by newly and recently originated auto loans, credit card loans, student loans and SBA-guaranteed small business loans.

Tuesday, 3 March 2009: Fed and Treasury expect to include ABSs backed by other types of loans in future monthly TALF fundings.

Thursday, 19 March 2009: FRB announces an expansion of the eligible collateral for loans extended by TALF to include ABSs backed by mortgage servicing advances, loans or leases related to business equipment, leases of vehicle fleets, and floorplan loans.

Wednesday, 1 April 2009: Fed chairman, Bernanke, and FRBNY president, Dudley, respond to questions from the COP about TALF, explaining in detail the rationale and operation of it.

Monday, 6 April 2009: Fed announces new reciprocal currency agreements (swap lines) with the BOE, ECB, the Bank of Japan and SNB that would enable the provision of foreign currency liquidity by the Fed to U.S. financial institutions.

Thursday, 9 April 2009: FASB issues three final Staff Positions intended to provide additional application guidance and enhance disclosures regarding fair value measurements and impairments of securities.

Friday, 1 May 2009: FRB announces that, starting in June 2009, CMBSs and securities backed by insurance premium finance loans will be eligible collateral under TALF. FRB also authorizes TALF loans with maturities of five years.

Wednesday, 13 May 2009: Treasury proposes amendments to the CEA and securities laws to enhance government regulation of OTC derivatives markets. The proposed changes include requirements that all standardized OTC derivatives be cleared through regulated central counterparties, and that all OTC derivatives dealers and all other firms whose activities in those markets create large exposures to counterparties be subject to prudential supervision and regulation.

Tuesday, 19 May 2009: FRB announces that, starting in July 2009, certain high-quality CMBSs issued before Thursday, 1 January 2009 – known as legacy CMBSs – will become eligible collateral under TALF. The objective of the expansion is to restart the market for legacy securities and, by doing so, stimulate the extension of new credit by helping to ease balance sheet pressures on banks and other financial institutions. Eligible CMBSs must have a AAA rating from at least two major rating services.

Wednesday, 24 June 2009: The Fed announces extensions of and modifications to a number of its liquidity programs. The expiration date AMLF, CPFF, PDCF and TSLF is extended until Monday, 1 February 2010. The expiration date of TALF remains set at Thursday, 31 December 2009. In addition, the temporary reciprocal currency arrangements (swap lines) between the Fed and other central banks have been extended to Monday, 1 February 2010.

Wednesday, 8 July 2009: Treasury, Fed and FDIC announce the details of PPIP. Under this program, Treasury will invest up to $ 30 billion with private sector fund managers and private investors for the purpose of purchasing legacy securities. PPIP will participate in the market for CMBSs and non-agency RMBSs. To qualify for purchase, these securities must have been issued prior to 2009 and have originally been rated AAA (or an equivalent rating by two or more nationally recognized statistical rating organizations) without ratings enhancement and must be secured directly by the actual MLs, leases, or other assets known as *eligible assets*.

Monday, 17 August 2009: FRB and Treasury announce an extension to TALF. Eligible loans against newly issued ABSs and legacy CMBSs can now be made until Wednesday, 31 March 2010. Because new CMBS deals can take a significant amount of time to arrange, TALF lending against newly issued CMBS was approved until Wednesday, 30 June 2010. The previously-announced deadline for TALF loans was Thursday, 31 December 2009. Fed and Treasury do not anticipate any further additions to the types of collateral that are eligible for the TALF.

Thursday, 21 January 2010: FRB and thrift regulatory agencies announce the final risk-based capital rule related to the Financial Accounting Standards Board's adoption of Statements of Financial Accounting Standards Nos. 166 and 167. These new accounting standards make substantive changes to how banking organizations account for many items, including securitized assets, that had been previously excluded from these organizations' balance sheets. Banking organizations affected by the new accounting standards generally will be subject to higher risk-based regulatory capital requirements. The rule better aligns risk-based capital requirements with the actual risks of certain exposures. It also provides an optional phase-in for four quarters of the impact on risk-weighted assets and tier 2 capital resulting from a banking organization's implementation of the new accounting standards

Tuesday, 16 March 2010: To provide support to mortgage lending and housing markets and to improve overall conditions in private credit markets, the Federal Reserve has been purchasing $1.25 trillion of agency mortgage-backed securities and about $175 billion of agency debt; those purchases are nearing completion, and the remaining transactions will be executed by the end of this month. The Committee will continue to monitor the economic outlook and financial developments and will employ its policy tools as necessary to promote economic recovery and price stability. In light of improved functioning of financial markets, the Federal Reserve has been closing the special liquidity facilities that it created to support markets during the crisis. The only remaining such program, the Term Asset-Backed Securities Loan Facility, is scheduled to close on June 30 for loans backed by new-issue commercial mortgage-backed securities and on March 31 for loans backed by all other types of collateral.

Wednesday, 17 March 2010: The federal banking agencies, in conjunction with the Conference of State Bank Supervisors (CSBS), released a policy statement on their expectations for sound funding and liquidity risk management practices. This policy statement, adopted by each of the agencies, summarizes the principles of sound liquidity risk management issued previously and, when appropriate, supplements them with the "Principles for Sound Liquidity Risk Management and Supervision" issued in September 2008 by the Basel Committee on Banking Supervision.

Friday, 30 April 2010: The federal financial regulatory agencies issued final guidance to address the risks associated with funding and credit concentrations arising from correspondent relationships. A correspondent relationship occurs when a financial organization provides another financial organization with services related to deposits, lending, or other activities. The guidance highlights the need for institutions to identify, monitor, and manage correspondent concentration risk on a standalone and organization-wide basis. The guidance also reinforces the supervisory view that financial institutions should perform appropriate due diligence on all credit exposures to, and funding transactions with, other financial institutions as part of their risk management policies and procedures. The guidance does not supplant or amend applicable regulations such as Limitations on Interbank Liabilities.

Sunday, 9 May 2010: FOMC has authorized temporary reciprocal currency arrangements (swap lines) with the Bank of Canada, the Bank of England, the European Central Bank (ECB), and the Swiss National Bank. The arrangements with the Bank of England, the ECB, and the Swiss National Bank will provide these central banks with the capacity to conduct tenders of U.S. dollars in their local markets at fixed rates for full allotment, similar to arrangements that had been in place previously. The arrangement with the Bank of Canada would support drawings of up to $30 billion, as was the case previously.

Tuesday, 20 June 2010: FRB announced that it had agreed with the Treasury Department that it was appropriate for Treasury to reduce from $20 billion to $4.3 billion the credit protection provided for the Term Asset-Backed Securities Loan Facility (TALF) under the Troubled Asset Relief Program (TARP). The Board had authorized up to $200 billion in TALF loans, but when the program closed on June 30, 2010, there were $43 billion in loans outstanding.

Wednesday, 30 June 2010: FRB published its annual adjustment of the dollar amount of fees that triggers additional disclosure requirements under the Truth in Lending Act and the Home Ownership and Equity Protection Act of 1994 for home mortgage loans that bear rates or fees above a certain amount. The Home Ownership and Equity Protection Act restricts credit terms such as balloon payments and requires additional disclosures when total points and fees payable by the consumer exceed the fee-based trigger (initially set at $400 and adjusted annually) or 8 percent of the total loan amount, whichever is larger.

Wednesday, 10 August 2010: The federal banking agencies agreed to publish an advance notice of proposed rule making regarding alternatives to the use of credit ratings in their risk-based capital rules for banking organizations. The advance notice is issued in response to section 939A of the Dodd-Frank Wall Street Reform and Consumer Protection Act (Act), enacted on July 21, 2010, which requires the agencies to review regulations that (1) require an assessment of the credit-worthiness of a security or money market instrument and (2) contain references to or requirements regarding credit ratings. In addition, the agencies are required to remove such references and requirements and substitute in their place uniform standards of credit-worthiness, where feasible. This advance notice describes the areas in these capital rules where the agencies rely on credit ratings, as well as the Basel Committee on Banking Supervision's recent amendments to the Basel Accord.

Monday, 16 August 2010: FRB announced final rules to protect mortgage borrowers from unfair, abusive, or deceptive lending practices that can arise from loan originator compensation practices. The new rules apply to mortgage brokers and the companies that employ them, as well as mortgage loan officers employed by depository institutions and other lenders. Lenders commonly pay loan originators more compensation if the borrower accepts an interest rate higher than the rate required by the lender (commonly referred to as a "yield spread premium"). Under the final rule, however, a loan originator may not receive compensation that is based on the interest rate or other loan terms. This will prevent loan originators from increasing their own compensation by raising the consumers' loan costs, such as by increasing the interest rate or points. Loan originators can continue to receive compensation that is based on a percentage of the loan amount, which is a common practice. The final rule also prohibits a loan originator that receives compensation directly from the consumer from also receiving compensation from the lender or another party.

Sunday, 12 September 2010: The U.S. federal banking agencies actively supported the efforts of the GHOS and the Basel Committee on Banking Supervision (Basel Committee) to increase the quality, quantity, and international consistency of capital, to strengthen liquidity standards, to discourage excessive leverage and risk taking, and to reduce procyclicality in regulatory requirements. The agreement represents a significant step forward in reducing the incidence and severity of future financial crises, providing for a more stable banking system that is less prone to excessive risk-taking, and better able to absorb losses while continuing to perform its essential function of providing credit to creditworthy households and businesses.

Tuesday, 19 October 2010: FRB issued a report on the potential impact of credit risk retention requirements on securitization markets. The report was required by the Dodd-Frank Wall Street Reform and Consumer Protection Act. The Dodd-Frank Act also requires the Federal Reserve and other agencies to jointly implement risk retention requirements for securitizers or originators of assets securitized through the issuance of asset-backed securities. The report highlights the significant differences in market practices and performance across securitizations backed by different types of assets. The report recommends that the agencies take these differences into account when developing risk retention requirements in order to achieve the objectives of the Dodd-Frank Act without unnecessarily impeding the availability of credit.

3.8 Appendix

This section provides some of the main results of this chapter.

3.8.1 Appendix A: Derivation of First Order Conditions (3.19) to (3.22)

To derive equations (3.19) to (3.22), we rewrite equation (3.11) to become

$$\begin{aligned} V^{\Sigma}(K_t^{\Sigma}, x_t) &= \max_{r_t^B,\ D_t,\ \Pi_t^{\Sigma}} \Bigg\{ \Pi_t^{\Sigma} + l_t^b \Bigg[K_t^{\Sigma} - \rho \Bigg(\omega(\mathcal{C}_t^B) B_t + \omega^M M_t \\ &\quad + 12.5 f^M (mVaR + \mathtt{0}) \Bigg) \Bigg] - c_t^{dw} \Bigg[K_{t+1}^{\Sigma} \Bigg] + \mathbf{E}_t \Bigg[\delta_{t,1} V \Bigg(K_{t+1}^{\Sigma},\ x_{t+1} \Bigg) \Bigg] \Bigg\}. \end{aligned} \tag{3.58}$$

By substituting equations (3.12) and (3.5), equation (3.58) becomes

$$\begin{aligned} V^{\Sigma}(K_t^{\Sigma}, x_t) &= \max_{r_t^B,\ D_t,\ \Pi_t^{\Sigma}} \{ n_t(d_t + E_t) - K_{t+1}^{\Sigma} + \Delta F_t + (1 + r_t^O) O_t + \Big(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma} \\ &\quad - r_t^M + c_t^t + c_t^{t\Sigma} \Big) f_t^{\Sigma} \widehat{f}_t^{\Sigma} \Big(m_0 - m_1 r_t^M + m_2 \mathcal{C}_t + \sigma_t^M \Big) + \Big(\overline{c}_t^{M\omega} + p_t^i + (1 - r_t^R) r_t^S \\ &\quad - c_t^t - c_t^{t\Sigma} - c_t^p r_t^f - a \Big) f_t^{\Sigma} \Big(m_0 - m_1 r_t^M + m_2 \mathcal{C}_t + \sigma_t^M \Big) - \mathtt{E}_t - \mathtt{F}_t + \widetilde{\Pi}_t^{\Sigma} \\ &\quad + l_t^b \Big[K_t^{\Sigma} - \rho \Big[\omega(\mathcal{C}_t^B) \Big(b_0 + b_1 r_t^B + b_2 \mathcal{C}_t^B + \sigma_t^B \Big) + \omega^M \Big(m_0 - m_1 r_t^M + m_2 \mathcal{C}_t + \sigma_t^M \Big) \\ &\quad + 12.5 f^M (mVaR + \mathtt{0}) \Big] \Big] - c_t^{dw} \Big[K_{t+1}^{\Sigma} \Big] + \mathbf{E}_t \Big[\delta_{t,1} V \Big(K_{t+1}^{\Sigma},\ x_{t+1} \Big) \Big] \Big\}. \end{aligned} \tag{3.59}$$

Finding the partial derivative of SIB's value in (3.59), with respect to the capital constraint, K_{t+1}^{Σ}, we have

$$\frac{\partial V^{\Sigma}}{\partial K_{t+1}^{\Sigma}} = -1 - c_t^{dw} + E_t \Bigg[\int_{\underline{B}}^{\overline{B}} \delta_{t,1} \frac{\partial V^{\Sigma}}{\partial K_{t+1}^{\Sigma}} dF \Big(\sigma_{t+1}^B \Big) \Bigg]. \tag{3.60}$$

Next, we discuss the formal derivation of the first order conditions (3.19) to (3.22).

3.8.1.1 First Order Condition (3.19)

Choosing the RMBS rate, r_t^B, from equation (3.59) and using equation (3.60) above, the first order condition (3.19) for Problem 3.2.3 is

$$\frac{\partial \Pi_t^{\Sigma}}{\partial r_t^B} \Bigg[1 + c_t^{dw} - \mathbf{E}_t \Bigg\{ \int_{\underline{B}}^{\overline{B}} \delta_{t,1} \frac{\partial V^{\Sigma}}{\partial (K_{t+1}^{\Sigma})} dF(\sigma_{t+1}^B) \Bigg\} \Bigg] - l_t^b \rho b_1 \omega(\mathcal{C}_t^B) = 0.$$

3.8.1.2 First Order Condition (3.20)

Choosing the deposits, D_t, from equation (3.59) and using equation (3.60) above, the first order condition (3.20) for Problem 3.2.3 is

$$\frac{\partial \Pi_t^{\Sigma}}{\partial D_t}\Bigg[1 + c_t^{dw} - \mathbf{E}_t\Bigg\{\int_{\underline{B}}^{\overline{B}} \delta_{t,1}\frac{\partial V^{\Sigma}}{\partial (K_{t+1}^{\Sigma})}dF(\sigma_{t+1}^{B})\Bigg\}\Bigg] = 0$$

3.8.1.3 First Order Condition (3.21)

We now find the partial derivative of SIB's value in (3.59) with respect to the Lagrangian multiplier, l_t^b.

$$\frac{\partial V^{\Sigma}}{\partial l_t^b} = K_t^{\Sigma} - \rho\Bigg[\omega(\mathcal{C}_t^B)B_t + \omega^M M_t + 12.5 f^M(mVaR + 0)\Bigg].$$

In this case, the first order condition (3.21) for Problem 3.2.3 is given by

$$\rho\Bigg[\omega(\mathcal{C}_t^B)B_t + \omega^M M_t + 12.5 f^M(mVaR + 0)\Bigg] \leq K_t^{\Sigma}.$$

3.8.1.4 First Order Condition (3.22)

Choosing the regulatory capital, Π_t^{Σ}, from equation (3.59) and using equation (3.60) above, the first order condition (3.22) for Problem 3.2.3 is

$$-1 - c_t^{dw} + \mathbf{E}_t\Bigg\{\int_{\underline{B}}^{\overline{B}} \delta_{t,1}\frac{\partial V^{\Sigma}}{\partial (K_{t+1}^{\Sigma})}dF(\sigma_{t+1}^{B})\Bigg\} + 1 = 0,$$

which is the same as

$$-c_t^{dw} + \mathbf{E}_t\Bigg\{\int_{\underline{B}}^{\overline{B}} \delta_{t,1}\frac{\partial V^{\Sigma}}{\partial (K_{t+1}^{\Sigma})}dF(\sigma_{t+1}^{B})\Bigg\} = 0.$$

3.8.2 Appendix B: Proof of Theorem 3.3.3

An immediate consequence of the prerequisite that the capital constraint (3.9) holds, is that RMBS supply is closely related to the capital adequacy constraint and is given by (3.14). Also, the dependence of changes in the RMBS rate on credit rating may be fixed as

$$\frac{\partial r_t^B}{\partial \mathcal{C}_t^B} = \frac{b_2}{b_1}.$$

Equation (3.14) follows from (3.9) and the fact that the capital constraint holds. This also leads to equality in (3.9). In (3.15) we substituted the optimal value for B_t into control law (3.12) to get the optimal default rate. We obtain the optimal T_t using the following steps. Firstly, we rewrite (2.7) to make deposits the dependent variable so that

$$D_t = \frac{M_t + B_t + \mathtt{T}_t - \mathtt{B}_t - K_t}{1-\gamma}.$$

Next, we note that the first-order conditions are given by

$$\frac{\partial \Pi_t^{\Sigma b}}{\partial r_t^B}\left[1 + c_t^{dw} - \mathbf{E}_t\left\{\int_{\underline{B}}^{\overline{B}} \delta_{t,1}\frac{\partial V^{\Sigma b}}{\partial (K_{t+1}^{\Sigma b})}dF(\sigma_{t+1}^B)\right\}\right] + b_1\left[\left(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b}\right.\right. \tag{3.61}$$

$$\left. -r_t^{S\Sigma b} - c_t^{i\Sigma b} - r_t^B + c_t^{tb} + c_t^{t\Sigma b}\right) f_t^{\Sigma b}\widehat{f}_t^{\Sigma b} + \left(\overline{c}_t^{M\omega b} + p_t^{ib} + (1 - r_t^{Rb})r_t^{Sb}\right.$$

$$\left.\left. -c_t^{tb} - c_t^{t\Sigma b} - c_t^{pb}r_t^{fb} - a^b\right) f^{\Sigma b} + \left(r_t^B - \overline{c}_t^{M\omega b} - p_t^{ib} + c_t^{pb}r_t^{fb} - (1 - r_t^{Rb})r_t^{Sb}\right)\right]$$

$$+(1 - f_t^{\Sigma b}\widehat{f}_t^{\Sigma b})B_t - l_t^b\rho b_1\omega(\mathcal{C}_t^B) = 0;$$

$$\frac{\partial \Pi_t^{\Sigma b}}{\partial D_t}\left[1 + c_t^{dw} - \mathbf{E}_t\left\{\int_{\underline{B}}^{\overline{B}} \delta_{t,1}\frac{\partial V^{\Sigma b}}{\partial (K_{t+1}^{\Sigma b})}dF(\sigma_{t+1}^B)\right\}\right] = 0; \tag{3.62}$$

$$\rho\left[\omega(\mathcal{C}_t^B)B_t + \omega^M M_t + 12.5 f^M(mVaR + \mathtt{O})\right] \leq K_t^{\Sigma b}; \tag{3.63}$$

$$-c_t^{dw} + \mathbf{E}_t\left\{\int_{\underline{B}}^{\overline{B}} \delta_{t,1}\frac{\partial V^{\Sigma b}}{\partial (K_{t+1}^{\Sigma b})}dF(\sigma_{t+1}^B)\right\} = 0. \tag{3.64}$$

Here $F(\cdot)$ is the cumulative distribution of the shock to the RMBS CDOs. Using (3.64) we can see that (3.62) becomes

$$\frac{\partial \Pi_t^{\Sigma b}}{\partial D_t} = 0.$$

Looking at the form of $\Pi_t^{\Sigma b}$ given in (3.32)and the equation

$$P^{\mathtt{T}}(\mathtt{T}_t) = \frac{r_t^p}{2\overline{D}}[\overline{D} - T_t]^2 \tag{3.65}$$

it follows that

$$
\begin{aligned}
\Pi_t^{\Sigma b} &= \left(r_t^r - \overline{c}_t^{M\Sigma\omega} - r_t^{S\Sigma} - c_t^{i\Sigma}\right)\widehat{f}_t^{\Sigma} f_t^{\Sigma} M_t + \left(r_t^M - c_t^t - c_t^{t\Sigma}\right)(1-\widehat{f}_t^{\Sigma}) f_t^{\Sigma} M_t \qquad (3.66)\\
&+\left(r_t^M - \overline{c}_t^{M\omega} - p_t^i + c_t^p r_t^f - (1-r_t^R) r_t^S\right)(1-f_t^{\Sigma})M_t - a f_t^{\Sigma} M_t\\
&+\left(r_t^{rb} - \overline{c}_t^{M\Sigma\omega b} - r_t^{S\Sigma b} - c_t^{i\Sigma b}\right)\widehat{f}_t^{\Sigma b} f_t^{\Sigma b} B_t + \left(r_t^B - c_t^{tb} - c_t^{t\Sigma b}\right)(1-\widehat{f}_t^{\Sigma b}) f_t^{\Sigma b} B_t\\
&+\left(r_t^B - \overline{c}_t^{M\omega b} - p_t^{ib} + c_t^{bp} r_t^{fb} - (1-r_t^{Rb}) r_t^{Sb}\right)(1-f_t^{\Sigma b})B_t - a^b f_t^{\Sigma b} B_t + r_t^{\mathtt{T}} \mathtt{T}_t\\
&-\left(r_t^{\mathtt{B}} + c_t^{\mathtt{B}}\right)\mathtt{B}_t - \left(r_t^D + c_t^D\right) D_t + C(\mathbf{E}[S(\mathcal{C}_t)]) - \frac{r_t^p}{2\overline{\overline{D}}}[\overline{D} - T_t]^2 + \Pi_t^{\Sigma p} - \mathtt{E}_t - \mathtt{F}_t.
\end{aligned}
$$

Finding the partial derivatives of SIB's profit under RMBS CDOs, $\Pi_t^{\Sigma b}$, with respect to deposit, D_t, we have that

$$
\frac{\partial \Pi_t^{\Sigma b}}{\partial D_t} = (1-\gamma)\left(r_t^{\mathtt{T}} + (r_t^{\mathtt{B}} + c_t^{\mathtt{B}}) + \frac{r_t^p}{\overline{\overline{D}}}(\overline{D} - \mathtt{T}_t)\right) - (r_t^D + c_t^D) \qquad (3.67)
$$

This would then give us the optimal value for D_t. Using (2.7) and all the optimal values calculated to date, we can find optimal deposits as well as optimal profits. □

Chapter 4

More Subprime Data

"The subprime and Alt-A mortgage markets, which relied heavily on the securitization process, dried up. Of course, this just reinforced the downward pressure on housing prices, which, in turn, led to increased delinquencies and foreclosures. This deterioration undermined the value of the securities further. It was a vicious feedback loop in action. The poor performance of highly-rated mortgage secretaries caused investors to begin to shun securitizations more generally."

– William C. Dudley, 2009.

"The subprime crisis exposed problems with the securitization of mortgages. In particular, it became painfully clear how poor the underwriting and credit-risk analysis were for a wide range of products. Some appraisers, brokers, and investment banks were motivated by transaction fees and had little stake in the ultimate performance of the loans they helped to arrange. Many securitized products were complex, and the ownership structure of the underlying assets was opaque. Investors relied heavily on credit ratings instead of conducting due diligence themselves, and credit rating agencies failed to fulfill their raison d'etre. The result has been rising defaults, particularly in the subprime mortgage markets, with losses to both investors and financial institutions."

– Prof. Frederic S. Mishkin, 2008.

KEYWORDS: Mortgage Backed Security (MBS); Credit Rating Agencies; Subordination; Default Rate; Bond Insurance; Coupon Rate; Geographic Concentration of Mortgages; Securitization; Renegotiation; FICO (Fair Isaac Corporation) Score; Current Loan-to-value Ratio (CLTV); Credit Score; Full Documentation; Limited Documentation; Metropolitan Statistical Areas (MSAs); Securitized Mortgages; Portfolio (Bank-held) Mortgages; Treatment Group; Control Group; Cure Rate; Foreclosure Rate; Delinquency.

In this chapter, we present the data from the papers [7] and [105]. Furthermore we analyze the data and investigate the connection the presented data has with our models.

4.1 Data Representation

In this section we present data used for analysis, concerning credit ratings of subprime and Alt-A mortgage backed security deals and foreclosure rates of bank-held and securitized mortgages.

4.1.1 Subprime Mortgage Security Data

Subprime mortgages are considered to be of the lowest credit quality, and have the poorest supporting characteristics, such as low FICO (borrower credit score) scores, high LTVR (loan-to-value ratio) and DTI (Debt-to-income)ratios. Alt-A mortgages have stronger average underwriting characteristics, and are made to borrowers with stronger credit histories. They also include risky contract features or limited documentation (i.e. a higher fraction of low- and no-documentation, interest-only, and negative amortization mortgages). The Tables 4.1 to 4.9 present the data from [7]. The authors classify deals as subprime or Alt-A based on their assignment in LP (LoanPerformance), and analyze these two deal types separately.

Table 4.1 presents summary statistics for sample of 3,144 subprime and Alt-A deals issued between 2001 and 2007. The average deal is backed by $749m in mortgages. Alt-A deals are backed by higher-quality mortgages than subprime deals on average, and consistently have lower subordination levels. Every deal is rated by either two or three CRAs, each agency's rating methodology involve number of key areas such as structure of the models used, decisions about the distribution of home price changes and other macroeconomic variables.

	Subprime	**Alt-A**	**All**
Number of deals	1607	1537	3144
Total number of securities	26430	33525	59955
Securities per deal, median	17	19	18
AAA securities per deal, median	5	10	6
Credit enhancement			
Percent of deals with bond insurance	14.0	8.8	11.5
Average value of insurance (%FV)	5.0	1.9	3.5
Excess spread at origination (%), median	3.8	1.2	2.6
Excess spread at origination (%), average	4.1	1.4	2.8
Deal size ($m):			
Mean	896	595	749
25^{th} percentile	509	313	391
50^{th} percentile	790	487	631
75^{th} percentile	1120	756	960
Fraction of AAA (%)			
Mean	82.4	93.1	87.6
25^{th} percentile	79.1	92.4	81.4
50^{th} percentile	81.7	93.9	89.3
75^{th} percentile	84.5	95.0	94.1
Fraction of non-AAA securities (mean, %)			
AA rating	7.9	3.4	5.7
A rating	4.9	1.5	3.2
BBB rating	3.5	1.0	2.3
BB rating	0.8	0.4	0.6
unrated or OC	1.3	2.0	1.7
Number of CRAs that rated the deal (%)			
Rated by one rating agency	0.3	0.4	0.3
Rated by two rating agencies	48.1	83.0	65.1
Rated by three rating agencies	45.1	16.5	31.1
Rated by four rating agencies	6.5	0.2	3.4

Table 4.1: Deal Characteristics; Source: LoanPerformance, ABSNET and Bloomberg.

Table 4.2 presents summary statistics for the 12.1m individual mortgages underlying the 3,144 deals contained in Table 4.1. There are extensively more mortgages on average in subprime deals than in Alt-A deals, average concentration of junior-lien mortgages is also higher for subprime deals. Mortgages in Alt-A deals have higher FICO scores, lower LTV and DTI ratios. Interest only mortgages involve no initial payments of the principal by the borrower.

	Subprime	**Alt-A**	**All**
Mortgage amounts			
Number of mortgages, total	8,810,111	3,263,992	12,074,103
Number of mortgages per deal, average	5,506	2,114	3,840
Mortgage size (average)	256,652	435,641	325,517
Combined loan-to-valuation ratio (%)			
Average (%, value-weighted)	85.3	80.8	83.6
10^{th} percentile	68.0	59.3	64.3
50^{th} percentile	87.3	80.0	85.0
90^{th} percentile	100.0	100.0	100.0
% missing	0.0	0.0	0.0
junior-lien mortgages (% of deal size, avg)	6.8	0.4	4.3
FICO scores			
Average (value-weighted)	625	706	656
10^{th} percentile	545	646	563
50^{th} percentile	626	708	660
90^{th} percentile	708	776	754
% missing	0.4	0.7	0.5
Debt-to-income ratio			
Average (value-weighted)	41.1	37.2	40.0
10^{th} percentile	28.3	25.0	27.3
50^{th} percentile	43.0	38.4	41.7
90^{th} percentile	50.0	47.4	50.0
% missing	28.5	56.3	39.2
Interest only mortgages			
%IO mortgages	17.4	54.0	31.5
Number of deals with IO $>$ 1%	1,136	1,215	2,351
Number of deals with IO $>$ 75%	32	485	517
Documentation (%):			
Full	59.1	28.4	47.3
Low	40.3	65.0	49.8
No	0.4	5.8	2.5
Missing	0.2	0.8	0.4

Table 4.2: Mortgage Characteristics; Source: LoanPerformance.

As for Table 4.3, it displays time-series trends in key variables for subprime and Alt-A deals. The fraction of interest only and low- or no-documentation mortgages rises considerably over the sample period, at the same time fraction of deals supported by external bond insurance declines over time.

Panel A: Subprime deals

	2001	2002	2003	2004	2005	2006	2007	All
Deal characteristics								
Number of deals	63	90	166	286	370	422	210	1,607
Deal size, average ($m)	448	633	767	971	1,040	908	874	896
Fraction of AAA securities (%)								
Average	90.1	88.2	86.1	83.5	80.5	80.4	80.3	82.4
Median	90.2	86.5	84.6	83.0	80.6	80.1	79.6	81.7
Excess spread (median, %)	5.5	6.3	5.8	5.1	3.5	2.8	2.7	3.8
Fraction deals with bond insurance	39.7	35.6	18.7	19.2	9.2	5.9	11.4	14.0
Percent deals rated by all three CRAs	42.9	48.9	63.9	61.2	60.5	43.1	33.8	0.3
Mortgage characteristics, value weighted								
CLTV (%, average)	81.9	82.6	83.0	84.0	85.6	86.8	86.5	85.3
Junior-lien mortgages (average % of deal)	13.4	9.0	4.4	3.1	5.3	9.5	10.3	6.8
FICO, average	611	614	622	623	631	630	631	625
Debt-to-income (%), average	35.8	35.2	38.0	38.7	40.0	41.3	41.3	41.1
Interest-only mortgages (avg % of deal)	0.0	0.3	2.4	11.4	28.0	21.4	16.4	17.4
Low/no-doc mortgages (% of deal, avg)	24.8	30.2	33.6	36.8	42.4	46.0	45.1	40.7
12-month-ended HPA (FHFA)	9.0	8.3	8.8	15.6	17.7	12.5	3.0	12.0

Panel B: Alt-A deals

	2001	2002	2003	2004	2005	2006	2007	All
Deal characteristics								
Number of deals	49	95	148	259	359	348	279	1,537
Deal size, average ($m)	300	377	398	554	631	723	661	595
Fraction of AAA securities (%)								
Average	93.7	94.6	93.7	93.3	92.6	92.8	92.9	93.1
Median	94.3	95.0	95.0	94.3	93.4	93.5	93.7	93.9
Excess spread (median, %)	2.4	2.4	1.7	1.4	1.0	1.0	1.0	1.2
Fraction deals with bond insurance	28.6	15.8	11.5	8.1	7.8	4.6	8.6	8.8
Percent deals rated by all three CRAs	32.7	10.5	4.1	4.2	12.0	25.3	29.4	0.4
Mortgage characteristics, value weighted								
CLTV (%, average)	79	79	76	80	80	82	81	81
Junior-lien mortgages (average % of deal)	0.1	0.1	0.0	0.2	0.1	0.1	0.7	0.4
FICO, average	698	699	706	708	712	708	711	706
Debt-to-income (%), average	18.6	21.4	22.6	26.6	29.0	29.0	29.7	37.2
Interest-only mortgages (avg % of deal)	0.4	2.4	12.2	45.9	58.4	60.7	62.3	54.0
Low/no-doc mortgages (% of deal, avg)	66.3	63.1	64.5	63.2	65.8	77.4	79.3	70.9
12-month-ended HPA (%, FHFA)	10.3	9.1	9.1	16.7	18.4	12.7	1.8	12.0

Table 4.3: Time Series Patterns for Key Variables; Source: [7].

Table 4.4 presents regression coefficients from baseline mortgage-level default model. *** denote statistical significance at 1% level.

Dependent variable:	=	**1** if mortgage is in default (defined as +90 delinquent, foreclosure, prepaid with loss or REO) 12 months after origination.
	=	**0** otherwise.

Underwriting variables	
CLTV (%)	0.0286***
	(0.00334)
FICO	−0.0105***
	(0.000265)
12-month trailing HPA (%)	−0.000535***
	(0.0000619)
Balloon loan (1=yes)	0.00119***
	(0.000150)
Low Doc (1=yes)	0.00532***
	(0.000324)
No Doc (1=yes)	0.00743***
	(0.000504)
Investor (1=yes)	0.00406***
	(0.000287)
Debt-payments-to-income (DTI)	0.00990***
	(0.000489)
DTI Missing	0.00254***
	(0.000290)
Cashout Refinance (1=yes)	−0.00356***
	(0.000235)
ln (mortgage amount)	0.500***
	(0.0456)
Prepayment Penalty (1=yes)	0.00364***
	(0.000140)
Local unemployment rate (%)	0.00543
	(0.00827)
Spread at Origination (SATO, %)	0.121***
	(0.0304)
Other covariates	
Dummies for missing values of other variables	yes
Year-half dummies	yes
N(10% LP sample)	1309495
Unconditional mean of dependent variable	0.0602
Pseudo R-Squared	0.1497

Table 4.4: Mortgage-Level Default Model; Source: [7].

Table 4.5 reports deal-level regression of the determinants of AAA subordination, based on full sample of 3,144 deals. Dependent variable is ln(1+ % subordination below AAA). ***, ** and * denote significance at the 1%, 5% and 10% levels.

Dependent variable: $\ln(1 + \%$ subordination below AAA class).

	Subprime		Alt-A	
Mortgage credit risk				
ln(1+ projected % default rate)	0.751***	0.680**	0.727***	0.651***
	(0.231)	(0.254)	(0.231)	(0.186)
ln(1+ projected % default rate)^2	0.0551	0.0723	-0.130	−0.153**
	(0.0676)	(0.0705)	(0.0870)	(0.0707)
joint significance: F-Test(p-value)	0.0000***	0.0000***	0.0000***	0.0006***
Include aggregated loan-level variables	No	Yes	No	Yes
Joint significance: F-Test(p-value)		0.1440		0.0000***
Other deal characteristics				
Bond insurance (1=yes, 0=no)	−0.473***	−0.478***	−0.0250	0.00370
	(0.100)	(0.100)	(0.0395)	(0.0376)
Percentage of deal with bond insurance	−0.0104**	−0.0104**	-0.00331	−0.00414*
	(0.00432)	(0.00426)	(0.00245)	(0.00223)
Weighted average coupon rate (%)	0.00811	0.0201	−0.0634***	-0.0231
	(0.0408)	(0.0405)	(0.0145)	(0.0148)
Weighted mortgage interest rate (%)	0.0468*	0.0498**	0.0681*	0.0263
	(0.0231)	(0.0233)	(0.0368)	(0.0341)
Geographic concentration of mortgages	1.897***	1.677***	0.406***	0.399***
	(0.212)	(0.263)	(0.134)	(0.117)
Time-series variation in subordination				
Year x quarter dummies	yes	yes	yes	yes
F-test: ratings decline over 2005-07? (p-value)	0.0000***	0.0000***	0.0000***	0.0388**
Number of observations	1607	1607	1537	1537
R^2	0.529	0.531	0.193	0.281

Table 4.5: Determinants of AAA Subordination; Source: [7].

Relationship between subordination and early payment defaults for subprime and Alt-A deals is presented in Table 4.6. Table 4.7 reports year by year regression of subordination and early-payment defaults. Dependent variable is weighted fraction of mortgages in the deal that are +90 days delinquent, prepaid with loss or REO 12 months after deal is issued.

Deal level regression of exopost rating downgrades on initial credit ratings, projected default rate from mortgage level model and other deal controls are described in Table 4.8. ***, ** and * denote significance at the 1%, 5% and 10% levels.

Dependent variable: ln(1 + % deal in default 12 months after deal is issued)

	Subprime deals			Alt-A deals		
Include covariates	No	Yes	Yes	No	Yes	Yes
Credit boom (Q1:05-Q2:07) interactions	No	No	Yes	No	No	Yes
Credit ratings						
ln(1+% subordination below AAA)	0.112^{***}	0.112^{***}	0.118^{***}	0.198^{***}	0.0505	0.0553^{*}
	(0.0340)	(0.0305)	(0.0325)	(0.0378)	(0.0344)	(0.0317)
ln(1+% subordination below BBB)	0.0955^{***}	0.0645^{***}	0.0552^{***}	-0.144^{***}	-0.0960^{***}	-0.0794^{***}
	(0.0157)	(0.0144)	(0.0134)	(0.0423)	(0.0241)	(0.0234)
Model-projected mortgage default rate						
ln(1+projected default rate)	0.941^{***}	1.004^{***}	0.837^{***}	1.470^{***}	1.523^{***}	1.503^{***}
	(0.0622)	(0.0567)	(0.0522)	(0.102)	(0.0422)	(0.0610)
ln(1+default rate)* "boom" dummy			0.317^{***}			0.0724
			(0.0939)			(0.115)
Fraction of low documentation mortgages						
% of low/no-doc mortgages		0.00681^{***}	0.00327^{***}		0.00290^{***}	0.00267^{***}
		(0.000656)	(0.000852)		(0.000792)	(0.000839)
%low/no doc * "boom"dummy			0.00568^{***}			0.000607
			(0.00115)			(0.00128)
Other deal characteristics						
Bond insurance (1=yes)	$3.35e-05$	0.000129	0.00554	-0.0120	0.0237	0.0261
	(0.0438)	(0.0334)	(0.0323)	(0.0358)	(0.0329)	(0.0320)
% of deal with bond insurance	0.00177^{*}	0.00131^{*}	0.00133^{**}	-0.00112	-0.00221^{**}	-0.00192^{*}
	(0.000872)	(0.000664)	(0.000623)	(0.00117)	(0.00104)	(0.000992)
Weighted average coupon rate (%)	-0.0243	-0.0112	-0.0500^{**}	-0.0264^{**}	0.0105	0.00340
	(0.0222)	(0.0221)	(0.0190)	(0.0124)	(0.00964)	(0.0106)
Weighted mortgage interest rate (%)	-0.0762^{***}	-0.130^{***}	-0.122^{***}	0.0613	0.0184	0.00422
	(0.0105)	(0.0152)	(0.0154)	(0.0428)	(0.0265)	(0.0280)
Geographic concentration of mortgages	0.475^{**}	0.0635	0.0540	-0.133	-0.239^{**}	-0.241^{**}
	(0.194)	(0.203)	(0.196)	(0.107)	(0.101)	(0.0953)
Dummies for number of credit ratings (omitted category: three ratings)						
One Rating		0.213^{***}	0.305^{***}		-0.0161	-0.0581
		(0.0343)	(0.0392)		(0.0343)	(0.0392)
Two Ratings		0.0108	0.0505^{*}		0.0366^{*}	0.00127
		(0.0149)	(0.0268)		(0.0149)	(0.0268)
Four Ratings		0.113^{***}	0.106^{***}		0.0620	0.0976
		(0.0290)	(0.0275)		(0.0290)	(0.0275)
Other mortgage-level covariates						
Average CLTV (%)		0.00889^{***}	0.00715^{***}		0.0188^{***}	0.0182^{***}
		(0.00188)	(0.00169)		(0.00130)	(0.00160)
FICO		0.000279	0.000302		0.00143^{***}	0.00145^{***}
		(0.000469)	(0.000486)		(0.000230)	(0.000219)
12 month trailing HPA (%)		-0.00279	-0.00245		0.00857	0.00751
		(0.00815)	(0.00753)		(0.00539)	(0.00550)
% of interest only mortgages		-0.000429	-0.000990		0.00155^{**}	-0.000256
		(0.000515)	(0.000765)		(0.000608)	(0.000649)
% of investor mortgages		0.00430^{*}	0.0212^{***}		0.00190^{**}	-0.000272
		(0.00230)	(0.00454)		(0.000814)	(0.00111)
Boom x IO, investor, num ratings	no	no	yes	no	no	yes
Year x quarter dummies	yes	yes	yes	yes	yes	yes
N	1607	1607	1607	1537	1537	1537
R^2	0.521	0.594	0.613	0.640	0.741	0.747

Table 4.6: Credit Ratings and Early-Payment Mortgage Defaults; Source: [7].

Dependent variable: Fraction of deal in default 12 months after deal is issued

	Vintage						
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
A. Subprime deals							
Baseline specification: including credit ratings, model default and low doc							
ln(1+% subordination below AAA)	0.00256	-0.0328	0.0387	0.119^{**}	0.129^{*}	0.310^{*}	0.188^{*}
	(0.0781)	(0.0281)	(0.0749)	(0.0288)	(0.0479)	(0.122)	(0.0628)
ln(1+% subordination below BBB)	0.107^{**}	0.0116	0.152^{*}	0.0694^{**}	0.0386^{**}	-0.0298	0.0245
	(0.0291)	(0.109)	(0.0518)	(0.0161)	(0.0116)	(0.0204)	(0.0533)
ln(1+ projected default rate)	0.969^{***}	0.616^{**}	0.642^{***}	0.716^{***}	1.314^{***}	0.794^{**}	1.039^{***}
	(0.160)	(0.153)	(0.104)	(0.0940)	(0.0330)	(0.243)	(0.0238)
% of low/no-doc mortgages	0.00917	0.0146^{**}	0.00457^{**}	0.00556^{***}	0.00810^{***}	0.00664^{***}	0.00789^{**}
	(0.00443)	(0.00321)	(0.00102)	(0.000315)	(0.00119)	(0.00102)	(0.00180)
R^2	0.875	0.806	0.564	0.542	0.564	0.628	0.756
N	63	90	166	286	370	422	210
Explanatory power of different specifications (measured by R^2)							
Just deal controls	0.341	0.409	0.309	0.195	0.026	0.402	0.260
Deal controls and subordination	0.520	0.424	0.359	0.365	0.154	0.487	0.559
Deal controls and projected default	0.856	0.716	0.516	0.413	0.449	0.550	0.674

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
B. Alt-A deals							
Baseline specification: including credit ratings, model default and low doc							
ln(1+% subordination below AAA)	-0.0473	-0.0221	0.0481	0.0969^{*}	0.380^{**}	0.303^{***}	0.0274
	(0.159)	(0.0381)	(0.0335)	(0.0379)	(0.0708)	(0.0482)	(0.0972)
ln(1+% subordination below BBB)	-0.00240	-0.150	-0.0746	-0.0771	-0.111	-0.124	-0.206
	(0.0593)	(0.172)	(0.0676)	(0.0446)	(0.0488)	(0.0880)	(0.108)
ln(1+ projected default rate)	0.198	1.106^{**}	1.186^{***}	0.833^{***}	1.089^{**}	1.463^{***}	1.869^{***}
	(0.375)	(0.253)	(0.114)	(0.136)	(0.326)	(0.177)	(0.0477)
% of low/no-doc mortgages	0.00560	0.00420^{**}	0.00356^{*}	0.00117	0.00258	0.00509^{**}	0.00815
	(0.00389)	(0.00121)	(0.00143)	(0.000820)	(0.00119)	(0.00131)	(0.00466)
R^2	0.843	0.830	0.798	0.632	0.655	0.650	0.739
N	49	95	148	259	359	348	279
Explanatory power of different specifications (measured by R^2)							
Just deal controls	0.779	0.696	0.598	0.450	0.338	0.368	0.273
Deal controls and credit ratings	0.786	0.699	0.603	0.496	0.547	0.451	0.343
Deal controls and projected default	0.818	0.809	0.775	0.612	0.534	0.622	0.706

Table 4.7: Subordination and Early-Payment Defaults, Cohort Regressions; Source: [7]

.

Dependent variable: Credit rating downgrades (value-weighted average)

	Subprime		Alt-A	
Dependent variable: Rating downgrades				
ln(1+% subordination below AAA)	-0.923^{***}	-0.902^{***}	-0.0465	-0.566^{*}
	(0.246)	(0.258)	(0.227)	(0.282)
ln(1+% subordination below BBB)	0.630^{***}	0.442^{**}	1.489^{***}	1.640^{***}
	(0.206)	(0.178)	(0.420)	(0.440)
Projected default and concentration of low documentation mortgages				
ln(1+projected default rate)	0.817^{*}	0.748	2.595^{***}	3.066^{***}
	(0.472)	(0.597)	(0.909)	(0.948)
% of low/no-documentation mortgages		0.0444^{***}		0.0151^{***}
		(0.0133)		(0.00521)
Other deal characteristics				
Bond insurance (1=yes)	-0.379	-0.309^{*}	-0.707^{**}	-0.621^{*}
	(0.226)	(0.160)	(0.342)	(0.345)
% of deal with bond insurance	0.00798	0.00488	0.0243^{***}	0.0210^{***}
	(0.00557)	(0.00592)	(0.00634)	(0.00588)
Weighted average coupon rate (%)	-0.421	-0.471^{*}	0.0734	0.154
	(0.314)	(0.256)	(0.111)	(0.102)
Weighted mortgage interest rate (%)	1.234^{***}	0.986^{***}	-0.270	-0.318
	(0.331)	(0.339)	(0.360)	(0.387)
Geographic concentration of mortgages	6.441^{***}	5.566^{***}	-0.415	-1.354
	(2.015)	(1.871)	(1.077)	(1.109)
Dummies for number of credit ratings (omitted category: three ratings)				
One Rating		5.130		-0.723^{*}
		(3.599)		(0.367)
Two Ratings		-0.294^{**}		-0.391
		(0.130)		(0.259)
Four Ratings		0.158		0.833
		(0.248)		(1.332)
Other mortgage-level covariates				
Average CLTV (%)		0.0377		0.0290^{*}
		(0.0237)		(0.0162)
FICO		0.000947		0.00499^{***}
		(0.00208)		(0.00163)
12 month trailing HPA (%)		-0.166^{**}		0.109^{**}
		(0.0713)		(0.0500)
% of interest only mortgages		0.00183		0.00780
		(0.00550)		(0.00600)
% of investor mortgages		0.0443^{***}		0.0115
		(0.0151)		(0.00740)
Year x quarter dummies	yes	yes	yes	yes
N	1607	1607	1537	1537
R^2	0.612	0.654	0.674	0.685

Table 4.8: Determinants of Credit Rating Downgrades; Source: [7].

Regressions of realized losses and mortgage defaults on credit ratings, projected default rate from mortgage level model and other deal controls are presented in Table 4.9. Two cumulative measures of ex-post mortgage performance are considered, cumulative losses and cumulative defaults. ***, ** and * denote significance at the 1%, 5% and 10% levels.

Dependent variable:	**ln(1 + % cumulative losses)**		**ln(1 + % cumulative defaults)**	
Market segment:	Subprime	Alt-A	Subprime	Alt-A
ln(1+% subordination below AAA)	0.0397	0.0689	0.0525*	0.104***
	(0.0263)	(0.0502)	(0.0303)	(0.0312)
ln(1+% subordination below BBB)	0.124***	−0.0402**	0.0374**	-0.0412
	(0.0191)	(0.0189)	(0.0163)	(0.0290)
Projected default and concentration of low documentation mortgages				
ln(1+projected default rate)	0.369***	0.684***	0.653***	0.731***
	(0.0668)	(0.0726)	(0.0834)	(0.0713)
% of low/no-doc mortgages	0.00779***	0.00187***	0.00489***	0.00394***
	(0.00141)	(0.000629)	(0.000874)	(0.000735)
Controls and other covariates				
Deal characteristics	Yes	Yes	Yes	Yes
Mortgage summary covariates	Yes	Yes	Yes	Yes
F-test: [p-value]	0.0000***	0.0000***	0.0000***	0.0000***
Year x quarter dummies	Yes	Yes	Yes	Yes
N	1567	1461	1567	1461
R^2	0.516	0.611	0.282	0.674

Table 4.9: Additional Measures of Ex-Post Performance; Source: LoanPerformance.

4.1.2 Securitized and Portfolio Mortgage Data

Table 4.10 includes first lien mortgages. All mortgages in the sample are originated between 2005 and 2006. The investor is either private (securitized) or portfolio (bank balance sheet) at the time of the first observed month of 60+ days delinquency.

Panel A: Delinquent mortgages

Origination quarter	2005 Q1	2005 Q2	2005 Q3	2005 Q4	2006 Q1	2006 Q2	2006 Q3	2006 Q4
% Portfolio	13.8%	12.5%	13.5%	10.7%	8.9%	8.6%	10.4%	11.7%
Original credit score	628.0	630.9	639.8	638.0	637.6	636.6	634.4	632.8
LTV	80.1	80.3	79.8	79.1	79.6	80.0	79.9	80.5
Original interest rate	7.02%	7.13%	7.13%	7.56%	8.08%	8.26%	8.45%	8.29%
Original mortgage amount	217,526	231,752	252,690	254,366	251,435	256,711	261,184	272,667
Age at delinquency	17.5	16.9	16.9	15.4	13.4	12.0	10.6	9.17
% Default/Foreclosure	24.19%	23.52%	22.73%	24.70%	26.27%	22.29%	19.93%	16.18%
N	35,585	46,521	46,907	45,133	42,978	42,354	37,386	30,574

Panel B: Delinquent mortgages by investor status

Portfolio	2005 Q1	2005 Q2	2005 Q3	2005 Q4	2006 Q1	2006 Q2	2006 Q3	2006 Q4
Original credit score	639.2	656.2	656.3	662.9	664.7	660.1	634.0	641.6
LTV	78.9	79.2	79.4	79.1	80.3	81.3	82.2	83.2
Original interest rate	6.16%	6.29%	6.50%	6.67%	6.97%	7.54%	7.97%	7.64%
Original mortgage amount	248,033	282,570	271,062	305,099	297,276	286,659	249,147	264,680
Age at delinquency	17.4	16.9	14.9	14.2	12.8	11.0	9.0	8.0
% Default/Foreclosure	19.22%	19.26%	18.80%	20.00%	22.63%	19.18%	16.01%	15.35%
N	4,921	5,837	6,313	4,811	3,822	3,654	3,892	3,570

Securitized	2005 Q1	2005 Q2	2005 Q3	2005 Q4	2006 Q1	2006 Q2	2006 Q3	2006 Q4
Original credit score	626.2	627.2	637.2	635.0	634.9	634.4	634.4	631.6
LTV	80.3	80.5	79.9	79.1	79.5	79.9	79.7	80.2
Original interest rate	7.15%	7.26%	7.23%	7.67%	8.19%	8.32%	8.50%	8.37%
Original mortgage amount	212,631	224,461	249,833	248,313	246,960	253,884	262,583	273,723
Age at delinquency	17.5	16.9	17.2	15.6	13.5	12.1	10.8	9.3
% Default/Foreclosure	24.99%	24.14%	23.35%	25.27%	26.62%	22.58%	20.38%	16.29%
N	30,664	40,684	40,594	40,322	39,156	38,700	33,494	27,004

Table 4.10: Summary Statistics of All Mortgages; Source: LPS.

Delinquent mortgages of high-quality at the time of origination (fully documented with FICO > 680) are represented in Table 4.11. The investor is either private (securitized) or portfolio (bank balance sheet) at the time of the first observed month of 60+ days delinquency. All mortgages in the sample are originated between 2005 and 2006.

Panel A: Delinquent mortgages

Origination quarter	2005 Q1	2005 Q2	2005 Q3	2005 Q4	2006 Q1	2006 Q2	2006 Q3	2006 Q4
% Portfolio	17.6%	20.8%	21.5%	19.3%	20.7%	21.2%	17.8%	24.2%
Original credit score	716.5	718.3	718.8	718.5	717.6	716.2	715.6	717.8
LTV	79.9	80.2	79.6	78.7	78.4	79.1	79.0	79.4
Original interest rate	6.09%	6.29%	6.12%	6.53%	6.86%	7.16%	7.31%	7.19%
Original mortgage amount	250,483	256,730	280,300	276,557	276,597	297,623	311,906	320,919
Age at delinquency	21.2	20.0	19.4	17.8	15.8	13.5	11.7	9.8
% Default/Foreclosure	25.45%	25.08%	20.02%	21.01%	23.48%	20.44%	16.95%	13.67%
N	2,008	2,911	2,452	2,228	1,793	2,099	1,793	1,207

Panel B: Delinquent mortgages by investor status

Portfolio	2005 Q1	2005 Q2	2005 Q3	2005 Q4	2006 Q1	2006 Q2	2006 Q3	2006 Q4
Original credit score	723.2	726.0	727.6	728.2	721.9	722.4	719.9	722.0
LTV	80.5	80.5	80.5	79.4	78.5	80.1	81.8	79.5
Original interest rate	5.13%	5.66%	5.44%	6.18%	6.54%	6.76%	6.89%	6.65%
Original mortgage amount	257,893	266,009	292,939	290,574	273,631	294,194	305,043	342,780
Age at delinquency	21.1	20.6	18.5	15.9	14.7	12.3	10.7	9.4
% Default/Foreclosure	19.26%	19.64%	14.61%	14.22%	18.28%	13.03%	8.44%	10.96%
N	353	606	527	429	372	445	320	292

Securitized	2005 Q1	2005 Q2	2005 Q3	2005 Q4	2006 Q1	2006 Q2	2006 Q3	2006 Q4
Original credit score	715.1	716.3	716.4	716.2	716.4	714.6	714.7	716.5
LTV	79.8	80.2	79.4	78.5	78.4	78.9	78.3	79.4
Original interest rate	6.29%	6.46%	6.31%	6.62%	6.94%	7.27%	7.40%	7.36%
Original mortgage amount	248,903	254,290	276,839	273,214	277,374	298,546	313,397	313,942
Age at delinquency	21.2	19.8	19.6	18.3	16.2	13.8	11.9	10.0
% Default/Foreclosure	26.77%	26.51%	21.51%	22.62%	24.84%	22.43%	18.81%	14.54%
N	1,655	2,305	1,925	1,799	1,421	1,654	1,473	915

Table 4.11: Summary Statistics of High-Quality Mortgages; Source: LPS.

Table 4.12 accounts for the marginal effects of a logit regression for the mortgages represented in Table 4.10. Standard errors are clustered at MSA level and resulting t-statistics are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels.

Origination quarter	2005 Q1	2005 Q2	2005 Q3	2005 Q4	2006 Q1	2006 Q2	2006 Q3	2006 Q4
Dependent variable:Foreclosure								
Mean securitized	0.2499	0.2414	0.2335	0.2527	0.2662	0.2258	0.2038	0.1629
Portfolio (d)	−0.046***	−0.048***	−0.046***	−0.070***	−0.059***	−0.060***	−0.066***	−0.038***
	(-8.12)	(-8.86)	(-8.21)	(-10.91)	(-8.21)	(-12.99)	(-12.97)	(-14.25)
FICO < 620 (d)	−0.109***	−0.133***	−0.127***	−0.145***	−0.155***	−0.124***	−0.108***	−0.069***
	(-11.15)	(-18.42)	(-17.92)	(-23.61)	(-19.81)	(-15.24)	(-16.43)	(-12.51)
620 <= FICO < 680 (d)	−0.025***	−0.037***	−0.034***	−0.038***	−0.042***	−0.030***	−0.028***	−0.017***
	(-3.57)	(-8.01)	(-6.36)	(-8.01)	(-7.82)	(-6.41)	(-4.97)	(-4.37)
LTV	0.579***	0.280***	0.501***	0.535***	0.553***	0.401***	0.100***	0.055***
	(6.47)	(4.50)	(7.10)	(6.68)	(7.37)	(5.14)	(3.56)	(3.18)
LTV squared	−0.405***	−0.163***	−0.342***	−0.361***	−0.373***	−0.265***	-0.035	-0.015
	(-5.73)	(-3.24)	(-6.20)	(-5.53)	(-6.16)	(-4.17)	(-1.45)	(-1.04)
Origination amount	-0.003	0.000	-0.001	-0.003	0.001	0.007	0.003	0.009**
	(-0.47)	(0.08)	(-0.19)	(-0.84)	(0.09)	(1.08)	(0.62)	(2.21)
Origination amount squared	0.009	0.001	-0.002	-0.001	0.001	-0.011	-0.008	−0.016**
	(1.64)	(0.26)	(-0.28)	(-0.16)	(0.19)	(-1.52)	(-1.42)	(-2.12)
Original interest rate	0.015***	0.012***	0.020***	0.018***	0.021***	0.015***	0.013***	0.010***
	(6.71)	(5.40)	(9.89)	(8.89)	(8.44)	(9.01)	(9.04)	(8.13)
FIX (d)	−0.081***	−0.070***	−0.058***	−0.060***	−0.053***	−0.046***	−0.036***	−0.026***
	(-15.34)	(-12.52)	(-13.62)	(-13.93)	(-7.24)	(-10.27)	(-7.55)	(-6.97)
15-Year term (d)	0.013	−0.047**	−0.074***	−0.060***	−0.108***	-0.028	0.114***	0.072*
	(0.48)	(-2.21)	(-3.12)	(-2.69)	(-5.50)	(-1.06)	(3.59)	(1.94)
20-Year term (d)	0.022	-0.053	−0.073*	-0.074	-0.086	−0.104***	-0.046	−0.050***
	(0.35)	(-1.27)	(-1.88)	(-1.47)	(-1.32)	(-3.31)	(-0.87)	(-2.91)
No insurance (d)	−0.018***	−0.016***	-0.002	0.004	0.013**	0.024***	0.014**	-0.002
	(-3.53)	(-2.81)	(-0.37)	(0.64)	(2.32)	(4.42)	(2.23)	(-0.59)
Insurance (d)	-0.019	-0.011	-0.015	0.009	-0.005	-0.019	-0.013	-0.004
	(-1.55)	(-0.98)	(-1.40)	(0.64)	(-0.27)	(-1.06)	(-0.99)	(-0.38)
Age at delinquency	−0.085***	−0.096***	−0.109***	−0.135***	−0.163***	−0.136***	−0.127***	−0.097***
	(-13.51)	(-17.02)	(-26.89)	(-32.76)	(-44.74)	(-51.75)	(-60.27)	(-126.99)
MSA fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	35,365	46,279	46,636	44,904	42,789	42,050	37,008	29,939

Table 4.12: Logit Regression of Default Conditional on 60+ Days Delinquency for All Mortgages; Source: LPS.

Table 4.13 accounts for the marginal effects of a logit regression for the mortgages represented in Table 4.11. ***, ** and * denote significance at the 1%, 5% and 10% levels.

Origination quarter	2005 Q1	2005 Q2	2005 Q3	2005 Q4	2006 Q1	2006 Q2	2006 Q3	2006 Q4
Dependent variable:Foreclosure								
Mean securitized	0.2677	0.2651	0.2151	0.2262	0.2484	0.2243	0.1881	0.1454
Portfolio (d)	-0.039	−0.057***	−0.041***	−0.066***	−0.079***	−0.096***	−0.089***	−0.045***
	(-1.29)	(-3.04)	(-1.98)	(-3.85)	(-2.88)	(-4.81)	(-7.20)	(-3.25)
680 <= FICO < 720 (d)	-0.028	0.002	0.050*	0.027	-0.023	0.037	-0.028	0.010
	(-0.87)	(0.06)	(1.89)	(1.20)	(-0.59)	(1.27)	(-1.15)	(0.35)
720 <= FICO < 760 (d)	-0.005	0.024	0.113**	0.026	-0.013	0.046	-0.028	0.010
	(-0.15)	(0.76)	(2.49)	(1.05)	(-0.32)	(1.25)	(-1.25)	(0.33)
LTV	0.529**	0.007	0.448***	0.213**	0.236**	0.351**	0.112*	-0.045
	(2.37)	(0.10)	(4.71)	(2.07)	(2.04)	(2.00)	(1.85)	(-1.48)
LTV squared	−0.439**	0.034	−0.355***	-0.143	-0.157	−0.281*	-0.067	0.058**
	(-2.19)	(0.55)	(-4.14)	(-1.56)	(-1.48)	(-1.74)	(-1.07)	(1.98)
Origination amount	-0.055	0.008	0.003	0.057	0.006	0.025	0.009	0.059**
	(-1.48)	(0.65)	(0.18)	(1.51)	(0.33)	(1.18)	(0.54)	(2.14)
Origination amount squared	0.164***	-0.012	0.001	−0.162*	0.002	-0.025	-0.010	−0.070*
	(2.63)	(-1.48)	(0.09)	(-1.73)	(0.10)	(-1.23)	(-0.64)	(-1.80)
Original interest rate	0.022	0.036***	0.026***	0.034***	0.007	0.040***	0.015*	0.015**
	(1.45)	(3.53)	(2.57)	(3.53)	(0.74)	(3.58)	(1.96)	(2.37)
FIX (d)	−0.085***	−0.108***	−0.049**	−0.053***	−0.078***	-0.006	−0.036**	0.001
	(-3.71)	(-6.34)	(-2.35)	(-2.83)	(-3.15)	(-0.38)	(-2.32)	(0.08)
15-Year term (d)	-0.040	−0.145***	-0.018	−0.103**	-0.067	-0.086	0.489**	0.040
	(-0.28)	(-3.03)	(-0.16)	(-2.31)	(-0.55)	(-1.23)	(2.12)	(0.43)
20-Year term (d)		0.041	-0.074	-0.032				
		(0.32)	(-0.85)	(-0.31)				
No insurance (d)	-0.014	−0.055**	-0.022	−0.041**	-0.006	0.011	-0.001	0.000
	(-0.58)	(-2.30)	(-1.22)	(-2.27)	(-0.25)	(0.39)	(-0.09)	(-0.01)
Insurance (d)	-0.040	-0.017	-0.024	−0.072***	0.091	-0.003	-0.028	−0.048**
	(-0.62)	(-0.45)	(-0.59)	(-2.89)	(0.93)	(-0.06)	(-0.62)	(-2.24)
Age at delinquency	−0.100***	−0.104***	−0.109***	−0.121***	−0.183***	−0.139***	−0.130***	−0.089***
	(-6.40)	(-9.09)	(-18.96)	(-16.17)	(-23.29)	(-23.59)	(-35.71)	(-30.00)
MSA fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,758	2,631	2,123	1,978	1,555	1,826	1,518	905

Table 4.13: Logit Regression of Default Conditional on 60+ Days Delinquency for High-Quality Mortgages; Source: LPS.

Table 4.14 provides the result when using Cox-proportional hazard model to integrate the mortgage's payment history that is existing prior their transfer. Panel A is for all delinquent mortgages and Panel B gives only the results for high-quality mortgages. ***, ** and * denote significance at the 1%, 5% and 10% levels.

	Panel A: All mortgages		*Panel B: High-quality mortgages*	
Dependent variable:	Foreclosure	Transfer	Foreclosure	Transfer
Mean securitized	0.25	0.02	0.25	0.01
Portfolio (d)	0.759***	5.76***	0.662***	4.797***
	(-21.34)	(79.86)	(-8.28)	(12.17)
FICO	1.006***	1.000***	1.000	1.006***
	(91.77)	(-2.80)	(0.82)	(3.62)
LTV	1.162***	1.011*	1.113***	0.973
	(18.23)	(1.79)	(3.37)	(-1.27)
LTV squared	0.999***	1.000	0.999***	1.000
	(-16.18)	(-1.15)	(-2.80)	(1.48)
Origination amount	1.000***	1.000	1.000	1.001*
	(7.19)	(-0.09)	(-0.15)	(1.70)
Origination amount squared	1.000***	1.000***	1.000	1.000*
	(-4.41)	(-3.46)	(0.18)	(-1.74)
Original interest rate	1.162***	1.196***	1.110***	1.040
	(50.75)	(23.44)	(7.62)	(1.12)
Fix(d)	0.68***	0.82***	0.627***	1.66***
	(-39.57)	(-7.79)	(-11.53)	(4.09)
15-Year term (d)	0.778***	0.837	0.576*	1.318
	(-4.17)	(-1.60)	(-1.87)	(0.66)
20-Year term (d)	0.507***	0.485***	0.788	0.000***
	(-4.48)	(-2.74)	(-0.58)	(-143.93)
No insurance (d)	0.999	1.89***	0.852***	0.614***
	(-0.16)	(28.49)	(-4.10)	(-3.48)
Insurance (d)	0.903***	1.292***	0.734***	0.534**
	(-5.01)	(5.25)	(-3.26)	(-2.20)
Time fixed effects	Yes	Yes	Yes	Yes
MSA fixed effects	Yes	Yes	Yes	Yes
N	316,772	316,772	15,203	15,203

Table 4.14: Hazard Regression of Default Conditional on 60+ Days Delinquency for All Mortgages and High-Quality Mortgages; Source: LPS.

The values reported in Table 4.15 are the estimates (marginals) on portfolio dummy using the same specification as in Table 4.12. The dependent variable is foreclosure. Time and MSA (or zip-code) fixed effects are included in all specifications. Standard errors are clustered at MSA level and resulting t-statistics are reported in parentheses. ***, ** and * denote significance at the 1%, 5%, and 10% levels.

	Zip-code Fixed Effects		Alternative foreclosure definition		LTV = 80 Dummy		Quarter of Delinquency Fixed Effects			
							Logit regressions		Hazard regressions	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	All mortgages	High-quality mortgages	All mortgages	High-quality mortgages	All mortgages	High-quality mortgages	All mortgages	High-quality mortgages	All mortgages	High-quality mortgages
Mean securitized	0.23	0.23	0.56	0.54	0.23	0.23	0.23	0.23	0.25	0.25
Portfolio (d)	-0.057^{***} -24.73	-0.063^{***} -4.03	-0.101^{***} -19.69	-0.124^{***} -9.96	-0.051^{***} -15.04	-0.057^{***} -6.57	-0.030^{***} (-14.13)	-0.053^{***} (-14.03)	0.772^{***} (-19.55)	0.715^{***} (-6.40)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter of origination fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter of delinquency fixed effects	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Clustering unit	MSA	MSA	MSA	MSA	MSA	MSA	MSA	MSA	MSA	MSA
Other fixed effects	Zip	Zip	MSA	MSA	MSA	MSA	MSA	MSA	MSA	MSA
N	327,438	16,491	327,372	16,272	327,401	16,106	327,438	13,822	316,772	15,203

Table 4.15: Additional Robustness Tests; Source: LPS.

The values reported in Table 4.16 are the estimated hazard ratios from a Cox-proportional hazard model of the transition. The change takes place from delinquency to cure/transfer. ***, ** and * denote significance at the 1%, 5% and 10% levels.

	Panel A: All mortgages		*Panel B: High-quality mortgages*	
Dependent variable:	Cure	Transfer	Cure	Transfer
Mean securitized	0.47	0.02	0.4	0.01
Portfolio (d)	1.129***	6.226***	1.205***	8.261***
	(17.15)	(71.91)	(6.69)	(14.31)
FICO	0.996***	1.00***	1.000	1.006***
	(-98.15)	(-2.08)	(-0.22)	(3.44)
LTV	0.991***	0.996	0.992	0.965*
	(-8.67)	(-0.57)	(-1.64)	(-1.71)
LTV squared	1.000***	1.000	1.000*	1.000
	(-7.01)	(0.54)	(-1.78)	(1.55)
Original amount	1.000***	1.000**	1.000***	1.002**
	(-20.62)	(-2.18)	(-3.19)	(2.13)
Original amount squared	1.000***	1.000*	1.000	1.000**
	(8.08)	(-1.81)	(1.28)	(-2.13)
Original interest rate	0.892***	1.166***	0.907***	1.046
	(-73.59)	(16.78)	(-12.52)	(1.23)
FIX (d)	1.227***	0.999	1.416***	2.655***
	(39.79)	(-0.02)	(14.44)	(6.92)
15-year term (d)	1.125***	0.812	1.178**	1.828
	(6.10)	(-1.39)	(2.25)	(1.33)
20-year term (d)	1.177***	0.458**	1.159	0.000***
	(4.22)	(-2.18)	(1.41)	(-127.51)
No insurance (d)	1.011***	2.114***	1.071***	0.406***
	(2.03)	(28.05)	(2.82)	(-5.49)
Insurance (d)	1.196***	1.259***	1.258***	0.259***
	(13.56)	(3.78)	(4.11)	(-3.51)
Time fixed effects	Yes	Yes	Yes	Yes
MSA fixed effects	Yes	Yes	Yes	Yes
N	316,772	316,772	15,203	15,203

Table 4.16: Hazard Regression of Cure Rate Conditional on 60+ Days Delinquency for All Mortgages and High-Quality Mortgages; Source: LPS.

The values reported in Table 4.17 are the estimated hazard ratios from a Cox-proportional hazard model of the transition. The change takes place from delinquency to foclosure/transfer and from delinquency to cure/transfer. In this table different FICO segments are considered. ***, ** and * denote significance at the 1%, 5% and 10% levels.

	FICO < 620		620 < FICO < 680		FICO > 680	
Dependent variable:	Foreclosure	Transfer	Foreclosure	Transfer	Foreclosure	Transfer
Mean securitized	0.21	0.02	0.28	0.02	0.28	0.02
Portfolio (d)	1.044*	9.859***	0.734***	5.39***	0.67***	1.915***
	(1.95)	(76.57)	(-14.24)	(44.33)	(-18.32)	(12.46)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
MSA fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	131,466	131,466	111,638	111,638	73,668	73,668

	FICO < 620		620 < FICO < 680		FICO > 680	
Dependent variable:	Cure	Transfer	Cure	Transfer	Cure	Transfer
Mean securitized	0.58	0.02	0.41	0.02	0.34	0.02
Portfolio (d)	0.967***	9.462***	1.171***	6.35***	1.349***	2.829***
	(-3.01)	(61.16)	(12.53)	(4.79)	(22.53)	(17.76)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
MSA fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	131,466	131,466	111,638	111,638	73,668	73,668

Table 4.17: Hazard Regression of Default and Cure Conditional on 60+ Days Delinquency; Source: LPS.

Table 4.18 gives the summary statistics of a sample of mortgages used to conduct the test that exploits the repurchase clauses. The treatment group consists of securitized mortgages that return to portfolio either in the month of 60+ days delinquency or within the corresponding time horizon. The control group consists of mortgages that remain securitized throughout the corresponding time horizon.

Panel A: One-month tracking horizon

Months after securitization delinquent	One month				Two months				Three months				Three vs. Four months			
	Treatment		Control		Treatment		Control		Treatment		Control		Treatment		Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
FICO	615.3	63.3	613.6	65.5	618.7	63.3	613.3	65.6	614.7	60	612.7	63.8	614.7	60	610.8	62.2
LTV	82.2	11.6	80.5	12.3	82.2	11.8	80.3	11.2	81.7	12.2	80.4	11.1	81.7	12.2	80.5	11.4
Interest rate	0.089	0.016	0.083	0.015	0.086	0.015	0.084	0.016	0.082	0.014	0.083	0.015	0.082	0.014	0.083	0.015
Foreclosure	0.46	0.5	0.36	0.48	0.41	0.49	0.39	0.49	0.31	0.46	0.37	0.48	0.31	0.46	0.35	0.48
N	390	390	7,610	7,610	1,041	1,041	10,849	10,849	394	394	12,345	12,345	394	394	12,824	12,824

Panel B: Three-month tracking horizon

Months after securitization delinquent	One month				Two months				Three months				Three vs. Four months			
	Treatment		Control		Treatment		Control		Treatment		Control		Treatment		Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
FICO	616.1	60.4	611.1	65.1	618.2	61.6	613.4	65.6	617.6	61.1	613.1	63.5	617.6	61.1	611.2	62.0
LTV	82.7	12.2	80.4	11.8	81.7	11.8	80.5	11.1	82.1	11.5	80.5	11.1	82.1	11.5	80.7	11.2
Interest rate	0.087	0.014	0.084	0.015	0.085	0.015	0.084	0.016	0.082	0.015	0.083	0.015	0.082	0.015	0.083	0.015
Foreclosure	0.41	0.49	0.4	0.49	0.4	0.49	0.41	0.49	0.32	0.47	0.39	0.49	0.32	0.47	0.36	0.48
N	1,044	1,044	6,240	6,240	1,489	1,489	9,934	9,934	526	526	11,636	11,636	526	526	12,157	12,157

Table 4.18: Summary Statistics of Sample of Mortgages Using the Repurchase clauses; Source: LPS.

The values reported in Table 4.19 are the regression estimates (marginals) using the same logit specification and controls as in Table 4.12. The dependent variable is foreclosure. Standard errors are clustered at MSA level and resulting t-statistics are reported in parentheses. ***, ** and * represent significance at the 1%, 5%, and 10% respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Test(3-month tracking horizon)	3:4 (Main)	3:4 (Main)	3:4 (Placebo)	3:3 (Main)	1:1+2:2+3:3 (Pooled)	123:456 (Pooled)	1:1+2:2+3:3 (Pooled)
Mean control	0.364	0.364	0.364	0.391	0.401	0.367	0.401
Portfolio (d)	-0.049^{*}	-0.065^{*}	0.011	-0.069^{**}	-0.041^{**}	-0.033^{**}	-0.031^{*}
	(-1.80)	(-2.49)	(1.39)	(-2.44)	(-2.32)	(-1.97)	(1.93)
Portfolio (d)* High-quality (d)							-0.115^{***}
							(-2.63)
High-quality (d)							-0.028^{**}
							(-2.30)
Time fixed effects	Yes	yes	Yes	yes	Yes	yes	Yes
MSA fixed effects	Yes	yes	Yes	yes	Yes	yes	Yes
Mortgage age	No	yes	Yes	yes	Yes	yes	Yes
Mortgage origination period	05Q1-06Q4	05Q1-06Q4	05Q1-06Q4	05Q1-06Q4	05Q1-06Q4	05Q1-06Q4	05Q1-06Q4
Other controls	Yes	yes	Yes	yes	Yes	yes	Yes
Clustering unit	MSA	MSA	MSA	MSA	MSA	MSA	MSA
Treatment / Control	481 / 11,196	481 / 11,196	10,816 / 11,313	474 / 10,672	2,880 / 25,913	2,887 / 59,211	2,880 / 25,913

Table 4.19: Regression Estimates Using Logit Specification; Source: LPS.

4.2 Data Analysis

In this section we analyze the data presented in Section 4.1.

4.2.1 Analysis of Subprime Mortgage Security Data

We analyze paper [7] in this subsection, where the authors study credit ratings on subprime and Alt-A mortgage-backed-securities (MBS) deals. These deals were issued between 2001 and 2007, which is the period leading up to the subprime crisis. The analysis is based on a novel dataset of 3,144 MBS deals matched by the authors with security- and mortgage-level data, sourced from Bloomberg, ABSNet and LoanPerformance (see, Tables 4.1, 4.2 and 4.9).

4.2.1.1 Mortgage-Backed-Security (MBS) deals

MBS deal is a set of structured bonds linked to a common pool (or pools) of mortgages. Non-agency MBS deals are deals without credit guarantee. In addition, non-agency MBS investors are more riskier because of borrower not paying their mortgages that leads to realized losses. These losses may include foreclosure sale whose net proceeds are less than the mortgage face value. MBS deals are structured with credit enhancement features used to protect investors from credit losses.

4.2.1.2 Credit Enhancement Features for MBS Deals

Credit enhancement features such as subordination, excess spread, bond insurance and geographic concentration for MBS deals are discussed below.

Credit Ratings for an MBS Deal: Credit rating is an opinion of the credit risk of a fixed income security, summarized as a discrete alphanumeric grade. Credit ratings for an MBS deal are normally represented in terms of the level of subordination below a given letter rating. Subordination is calculated as:

$$\textit{Subordination below rating } i = 1 - \frac{\sum \textit{Face value of securities with rating i or above}}{\sum \textit{Face value of all mortgages underlying deal}}, \qquad (4.1)$$

In [7], authors focus on subordination at two points: below triple-A, and below the investment grade boundary (BBB). For example, if 85% of the deal receives a triple-A rating, then triple-A subordination is 15%. subordination below BBB of 5% means 95% of the bonds in the deal receive a rating of BBB or higher. Even if the rating on each bond takes a discrete letter value, subordination is a continuous variable between 0% and 100%. When deals are rated by more than one CRAs, subordination is calculated based on the most conservative rating, double counting of mortgage strips and exchangeable tranches are avoided, variables measuring different types of credit enhancement, and a proxy for the correlation of mortgage losses are constructed.

Excess Spread and Insurance: Interest payments from the mortgages underlying the deal usually exceed the sum of servicer fees, net payments to the interest rate swap counterparty and coupon payments to MBS issued by the trust. Difference between average mortgage interest rate for the deal and the average interest rate paid to bondholders is referred to as the excess spread of the deal at origination and it provides additional credit protection to MBS bondholders.

MBS deals are insured by an external bond insurer, who promises to compensate investors for any principal losses on the bond. Fraction of deal with bond insurance is the percentage of the face value of the bonds in the MBS deal that are insured.

Geographic Concentration: A measure of geographic diversification of the mortgage collateral underlying each deal is constructed. This measure is estimated using the sum of the squared value-weighted share of mortgages from each state. That is

$$\textit{geographic concentration} = \sum_{j \,\epsilon\, states} \left(\frac{\textit{total mortgage principal in state } j}{\textit{total mortgage principal balance}} \right)^2 \tag{4.2}$$

This measure is bounded between 0.02 and 1. Higher value indicates greater geographic concentration of mortgages in the deal.

4.2.1.3 Rating Process for MBS Deals

The rating process for MBS deal is a combination of formal statistical modeling and subjective judgement. As for statistical analysis, econometric prepayment and default models are maintained by CRAs. The models use macroeconomic variable, especially home prices and interest rates as well as mortgage characteristics as their inputs. The paths of these macroeconomic variables are simulated by CRA. The simulated paths are then substituted into econometric models to calculate a path of default and losses, these projected losses are then aggregated across paths to generate a distribution of losses. This distribution of losses are then used to set subordination level below each rating class, however, after taking into account credit enhancement features mentioned in Subsection 4.2.1.2.

4.2.1.4 Mortgage-level Default Model and Determinants of Subordination

Mortgage-level default model is used to estimate an average expected mortgage default rate for each MBS deal. The projected default rate is proposed to be an ex-ante measure of risk, created using information available to CRAs at the time each deal was initially rated and issued. The model is based on a set of logit default regressions. These regressions are assessed using a random 10% LoanPerformance sample, and estimate the probability that a mortgage will be seriously 90+ days delinquent one year after origination. These regressions are valued on a rolling basis, where the end of the sample period is 9/2000, 3/2001, 9/2001, and so on, up to 3/2007 (a regression calculated using sample up to time T includes mortgages originated only up to T minus one year). Moreover, each mortgage is substitued into the regression model valued up to the six-month period prior to the issuance of the deal. For example, if a mortgage is part of a deal issued between January and June 2005, projected default rate for the mortgage using the regression model is estimated based on the sample up to September 2004. The projected default rate for each mortgage is concentrated only on historical data available at the time the deal is issued.

Logit regression estimates for the mortgage default model is presented in Table 4.4. Variables used in the model are mortgage characteristics at origination like the FICO score, combined LTV, debt payments-to-income (DTI), dummies for income and asset documentation (full-, partial-, low- and no-document). Time dummies at six-months periods are included to display any time-series trends in mortgage default rates not captured by the model variables . Trailing HPA (%) represent percentage of house price appreciation over the previous 12 months. It can be observed from Table 4.4, that past home price appreciation is significantly negatively correlated with future mortgage default rates, indicating the high autocorrelation in house price growth.

The following equation is a simple regression model that connects MBS subordination to proxies for the level of credit risk facing the investors. The model is defined as:

$$\begin{aligned}\text{AAA subordination} &= \text{f(mortgage credit risk, credit enhancement,} \\ &\quad \text{diversification, time dummies)}\end{aligned} \tag{4.3}$$

Equation (4.3) relates subordination to the credit risk of the mortgages underlying the deal. Subordination below AAA is the fraction of the MBS deal that does not attract a triple-A rating. Credit enhancement measures (See, Subsection 4.2.1.2) provide additional support to bondholders. Time dummies represent time-series changes in subordination unexplained by the risk and credit enhancement variables..

Deal-level regression of the determinants of AAA subordination for subprime and Alt-A deals are estimated separately (see Columns 1 and 2 and Columns 3 and 4) in Table 4.5. Subordination is enumerated in logs so that the time dummies shift subordination respectively to each deals baseline risk level. The model is estimated using least squares, with standard errors clustered by year x quarter. Projected default rate is the primary measure mortgage credit risk, estimated using historical data available prior to the six month calendar period in which the deal was issued. The aggregated loan-level variables are jointly significant for Alt-A deals but not for subprime deals. Bond insurance dummy (1=yes, 0=no) variable indicates whether at least one tranche in the deal was insured by a bond insurer.

4.2.1.5 Credit Ratings and Deal Performance

This subsection analyze the relationship between credit ratings and ex-post deal performance. Three different measures of deal performance are (i) early payment mortgage defaults; (ii) realized mortgage loss rates; and (iii) ex-post credit rating downgrades.

For each performance measure, variations are calculated as follows:

$$\begin{aligned}\text{deal performance} &= \text{f (subordination, model-projected default, share of low-doc} \\ &\quad \text{mortgages, deal controls, other covariates, time dummies)}\end{aligned} \tag{4.4}$$

From above subordination is considered below both AAA and BBB- ratings. Mortgage default and loss rates are expected to be increasing in subordination, since deals with greater risk should have a small fraction of highly-rated securities. Deal controls includes the same credit enhancement measures such as bond insurance, excess spread and a measure of geographic concentration (see Table 4.5). Mortgage-level covariates are LTV, FICO and trailing HPA (House Price Appreciation). Year x quarter dummies represent time-series changes in subordination.

Linear regression between credit rating and early payment mortgage defaults are presented in Table 4.6. Early payment mortgage defaults is defined as the weighted fraction of mortgages seriously delinquent after 12 months or at longer horizons. For subprime deals, higher subordination is statistically correlated with higher ex-post default rates. MBS deals represented by the model-projected default rate experience worse performance than deals based on subordination levels. MBS deal with a high share of low-doc mortgages will have a higher predicted default rate. Credit boom interactions between model-projected default rate and low-doc share with a credit boom dummy is represented in columns 3 and 6 of Table 4.6. These interactions take value one between Q1:05 and Q2:07, the period of peak MBS deal flow. These relations are positive and statistically significant for subprime deals, and positive but insignificant for Alt-A deals. Risky deals measured by the model-projected default rate and deals with a high concentration of low-doc mortgages face higher early-payment defaults in every cohort. These performance differences are statistically significant, in spite of the much smaller sample sizes compared to the aggregate pooled regression.

Year by year regression of early-payment defaults on subordination below AAA and BBB, model-projected default rate, the fraction of low documentation mortgages, and the set of deal controls are represented in Table 4.7. Explanatory power measured by the regression R^2 in this table is obtained by just including deal controls, and the new R^2 is obtained after including either the two subordination variables, or the projected default rate. The increase in explanatory power is higher for projected mortgage default rate (For subprime deals explanatory power for projected default rate is 0.856 in 2001 and for deal controls and subordination is 0.341 and 0.520 respectively). This shows that deal-level model in Table 4.7 focus on early-payment defaults, rather than final losses.

Table 4.8 studies the deal-level regression of ex-post rating downgrades on initial credit ratings, projected default rate from mortgage level model and other deal controls. Credit rating downgrades provides a useful robustness check for the analysis of defaults and losses on underlying mortgage collateral. Deals with a high share of low-documentation mortgages experience significantly larger credit rating downgrades both in the Alt-A and subprime sectors (0.0444 for subprime and 0.0151 for Alt-A deals), significant at the 1% level. Deals with a high model-projected default rate also undergo larger ex-post rating downgrades, significant at the 1% level in the Alt-A market (2.595 and 3.066), and statistically significant for subprime deals. Relation between credit rating and realized mortgage loss rate is explained in Table 4.9. Table presents results for two cumulative measures of ex-post mortgage performance, cumulative losses and cumulative defaults. Realized losses represent final losses of mortgage principal, which in turn determines how far up the capital structure bond investors will suffer losses of principal. Table 4.9 shows that deals with high projected default rate, experience significantly higher cumulative losses and cumulative default rates. A 10% increase in the projected default rate is associated with higher cumulative losses and cumulative defaults of 4-7%. Also deals with higher low-doc share increases cumulative losses and cumulative defaults by an additional 2-7%, depending on the specification. Coefficients on these variables are statistically significant at the 1% level for subprime and Alt-A deals.

4.2.2 Analysis of Securitized and Portfolio Mortgage Data

In this subsection, we look at the data from paper [105]. The data is supplied by Lender Processing Servicer (LPS) and include mortgage-level data from mortgage servicing firms. This data set contain information about the mortgage at the time of origination, such as the mortgage amount, term, loan-to-value ratio (LTV), borrower's credit score (FICO), and interest rate type of the mortgage (see Tables 4.10 and 4.11).

A mortgage is 60+ days delinquent if the borrower is behind by two mortgage payments, the missed payments do not necessarily have to be consecutive. In the case of delinquent mortgages the ownership status is documented, that is whether they are securitized to private investors or bank-held (portfolio) at the time of the first observed month of 60+ days delinquency. Portfolio mortgages are seriously delinquent mortgages held by the bank. Age at delinquency is the number of months since origination when a mortgage becomes 60+ days delinquent. Default is defined as a mortgage that enters into foreclosure post-sale or REO (real estate owned) status during the course of the mortgage payment history. Higher quality mortgages are fully documented and have good initial credit quality represented by a FICO credit score of at least 680 (summary statistics of high-quality mortgages are considered in Table 4.11). The sample used in paper [105] is for first lien mortgages originated between 2005 and 2006.

4.2.2.1 Foreclosure Rates of Securitized and Portfolio Mortgages

In this subsection the foreclosure rates of securitized and portfolio mortgages are assessed. In order to estimate the impact of securitization on foreclosing a delinquent mortgage the following equation is used:

$$Pr(Yi = 1|Delinquency) = \phi(\alpha + \beta \times Portfolio_i + \gamma.Xi + \delta_m + \epsilon_i), \tag{4.5}$$

where the dependent variable (Y) is an indicator variable for a delinquent mortgage i that takes a value of 1 if the mortgage is foreclosed, and 0 otherwise. X_i is a vector of a mortgage and borrower characteristics that includes variables such as FICO scores, interest rate, LTV, and origination amount, and γ is a vector of coefficients. Portfolio is a dummy variable that represents the investor status at the time of delinquency, it takes the value 1 if the delinquent mortgage was held on the lender's balance sheet, and 0 if the mortgage was securitized. β would evaluate the effect of securitization on a servicer's decision to foreclose the delinquent property. To account for regional factors MSA (Metropolitan Statistical Areas) fixed effects (δ_m) are included.

By estimating equation (4.5), the trivial consequences of a logit regression executed for the whole test are described in Table 4.12. The dependent variable is whether or not the mortgage is foreclosed conditional on the mortgage becoming delinquent. Regressions are calculated separately for each quarter of origination. Portfolio is a dummy which denotes that the loan was bank-held at the time of first 60+ days of delinquency. In columns 1-8, the coefficient on portfolio dummy is constantly negative and significant for all quarters. This indicate that a portfolio mortgage is less likely to be foreclosed than a securitized mortgage. Mortgages with higher LTV ratios are more likely to foreclose and mortgages with lower FICO default less. Higher FICO score denote the size of the credit shock borrower have because of the delinquency of portfolio mortgages.

Table 4.13 presents the estimates using equation (4.5) for a subsample of higher quality mortgages (fully documented mortgages with FICO > 680). Similar to Table 4.12, the coefficient on the portfolio dummy is negative and significant for all quarters except one (2005 Q1). Foreclosure rates of higher quality mortgages are depending on their securitization status. Table shows that, in 2006 Q4, portfolio mortgages decrease the probability of foreclosure in absolute terms by about 4.5%, nearly a 31% decrease relative to the mean foreclosure rate of 14.5% among securitized mortgages. Also in 2006 Q3, the probability of foreclosure for portfolio mortgages is lower by about 47% in relative terms. The difference between foreclosure rates of portfolio and securitized mortgages is about 14.5% and 21.5% in relative terms in 2005 Q1 and 2005 Q2, considerably a smaller number when compared to 47% and 31% in 2006 Q3 and 2006 Q4. This indicate that the magnitude of results from Table 4.13 is stronger in the periods of house price declines, this declining house prices eroded borrowers ability to renegotiate their contract through refinancing, thereby intensifying the foreclosure bias.

4.2.2.2 Tests Using Hazard Model

Cox-proportional hazard model incorporate the payment history available for the mortgages before they are transferred. Hazard model consider three states depending on whether the mortgage is: foreclosed, not foreclosed, or transferred to a servicer outside the data. Table 4.14 reports the estimated hazard ratios from a Cox-proportional hazard model for the mortgages before they are transferred. Panel A presents the results for all the mortgages in the sample whereas panel B represents the results using the high-quality mortgages. Hazard regressions are estimated using time and MSA fixed effects. Coefficients in the table describe the hazard ratio of portfolio mortgages corresponding to securitized mortgages for the foreclosure and the transfer states. Panel A shows that portfolio mortgages are about 24% less likely to be foreclosed than securitized mortgages. Obviously from Panel B, the high-quality portfolio mortgages are about 34% less likely to be foreclosed relative to the comparable high-quality securitized mortgages.

Table 4.15 presents the estimates on portfolio dummy using a specification similar to Table 4.12. The dependent variable is foreclosure. Regressions are estimated using another definitions of delinquency (30+ and 90+). To represent variations in house price index, regressions are estimated at MSA level and for zip-code level fixed effects. From columns 1 and 2 of Table 4.15, it can be observed that delinquent bank-held mortgages are less likely to be foreclosed by about 5.7% in absolute terms as compared to delinquent securitized mortgages (24.5% in relative terms) and these effects are larger for higher-quality mortgages. By extending the definition of foreclosure to include foreclosure starts along with foreclosure post-sale, and REO, and re-estimating regressions using this definition and the results are presented in columns 3 and 4 . There is a negative and significant effect at 1% level on the portfolio estimate; portfolio mortgages are foreclosed at 10% lower in absolute terms (18% lower in relative terms) compared to similar securitized mortgages.

If delinquent securitized mortgages had more current loan-to-value (CLTV) than corresponding portfolio mortgages, then delinquent securitized mortgages would be more risky and more ready foreclose. So by re-calculating the results including a dummy that takes a value 1 if the mortgage has an LTVR of 80%. Addition of this dummy variable should reduce the magnitude and significance of the portfolio variable in the foreclosure regression (see,columns 5 and 6). Also the logit and hazard specifications controlling for the quarter of delinquency of the mortgage are calculated and the results are reported in columns 7 to 10 of Table 4.15. Results from logit specification propose that portfolio mortgages are 3% less likely to be foreclosed than securitized mortgages (13% in relative terms) after controlling for observable risk characteristics, MSA, quarter of origination and quarter of delinquency fixed effects. Similarly, results from hazard specification indicate that portfolio mortgages are foreclosed at 5.7% lower rate in absolute terms (23% in relative terms).

In Table 4.16, the authors of [105] discuss the payment behavior of the borrowers of seriously delinquent mortgages concentrating on the rate at which borrowers of portfolio mortgages making payments relative to borrowers of securitized mortgages. Table reports the estimated hazard ratios from a Cox-proportional hazard model of the transition from delinquency to cure and transfer states similar to Table 4.14. Specifically, the mortgage is assigned to one of three states: it is cured, not cured, or it is transferred. A mortgage is considered cured [1] if it makes another payment following delinquency. Panel A of Table 4.16 presents the results for all the mortgages in the sample while panel B exhibits the results using high-quality mortgages. Coefficients in the table present the hazard ratio of portfolio mortgages relative to securitized mortgages for cured and transfer states. In the entire sample of mortgages, the 60+ delinquent portfolio mortgages are more possible to making payments compared to borrowers of securitized mortgages. These mortgages are cured at a rate 6% higher in absolute terms compared to securitized mortgages within a year after delinquency (12.9% higher in relative terms). Panel B shows that, differences in cure rate between bank-held mortgages and securitized mortgages are higher for better quality mortgages: 60+ delinquent bank-held mortgages continue making payments a year after delinquency at a rate 8.2% higher in absolute terms compared to equivalent securitized mortgages (20.5% higher in relative terms). Results show that portfolio mortgages are not only foreclosed at a lower rate but also making payments at a comparably higher rate (higher cure rates) compared to securitized mortgages.

Table 4.17 analyze the difference between cure and foreclosure rates of portfolio and securitized mortgages. Based on the initial creditworthiness of the borrower, mortgages can be divided into three groups: lowest credit quality (with FICO credit score less than 620), medium credit quality (with FICO credit score between 620 and 680), and highest credit quality (with FICO credit score greater than 680). Table 4.17 presents the estimated hazard ratios from Cox-proportional hazard models of the transition from delinquency to foreclosure/transfer and of the transition from delinquency to cure/transfer for different FICO divisions. For mortgages of the lowest credit quality (FICO score less than 620) there is an economically very small difference in foreclosure and cure rates. Instead for mortgages with medium and highest credit quality these differences are large. Table shows that, for medium credit quality mortgages, the foreclosure rate for portfolio mortgages is lower in absolute terms by 73.4% (26.6% in relative terms) and the cure rate is higher by 7% (17.1% in relative terms). For mortgages with highest credit quality foreclosure rate for portfolio

[1] The mortgage is assigned a cured state if a 60+ delinquent mortgage's payment history becomes better than 60+ during the period we trace the mortgages, it takes value one if a 60+ delinquent mortgage's payment history improves in delinquency status at the end of a prespecified window; otherwise value is zero.

mortgages is lower in absolute terms by 9.2% (33% in relative terms) and the cure rate is higher by 12.1% (35% in relative terms) within a year after delinquency.

4.2.2.3 Treatment and Control groups

This subsection describes the characteristics of the treatment and control groups. Treatment group includes securitized mortgages that become delinquent just before 90 days and return to the balance sheet either in the month of 60+ days delinquency or within the corresponding time horizon. The control group consists of securitized mortgages that become delinquent just after 90 days and remain securitized during the corresponding time horizon. Table 4.18 presents summary statistics of a sample of mortgages using the repurchase clauses. Table shows that treatment and control groups have similar prescribed terms such as the LTV ratio, FICO score and interest rate. From Panel B, it can be observed that LTV ratio is 82.1 for the treatment group and 80.7 for the control group, FICO scores are 617 for the treatment group and 611 for the control group. The interest rate is also identical for the treatment and control groups (8.2% for the treatment as compared to 8.3% for the control group). Mortgages in the treatment group are less likely to be foreclosed compared to mortgages in the control group, for example, 32% of the delinquent mortgages in the treatment group are foreclosed compared to 39% in the control group (see, last four columns of Panel B).

By estimating equation (4.5) using a logit specification, the results of the estimation is presented in Table 4.19. The dependent variable is foreclosure while the coefficient on portfolio (β), takes value 1 for mortgages in the treatment group and 0 for mortgages in the control group. In Table 4.19, authors use 3:4 test (see, columns 1, 2 and 3), placebo test (column 3), 3:3 test (column 4), 1:1+2:2+3:3 test (columns 5 and 7) and 123:456 test (column 6). In 3:4 test foreclosure rates of mortgages that became delinquent in the third month of securitization is compared with mortgages that were delinquent in the fourth month but stayed securitized. In columns (1) and (2), the treatment group consist of securitized mortgages which became 30+ days delinquent three months after securitization, transitioned to 60+ in the next month, and were repurchased by the originator in the following three months, while the control group consist of securitized mortgages which became 30+ days delinquent four months after securitization, transitioned to 60+ in the next month, and remained securitized in the next three months. The estimate of column 2 indicates that delinquent securitized mortgages that are taken back on the banks balance sheet foreclose at a rate that is 6.5% lower in absolute terms compared to delinquent securitized mortgages that remain securitized.

In placebo test mortgages in the treatment group of main test (3:4 test) is replaced by mortgages that did not receive the treatment. 3:3 test compares foreclosure rates of mortgages that were delinquent in the third month and came back on the bank balance sheet with mortgages that were delinquent in the third month but stayed securitized. In 1:1+2:2+3:3 test, treatment group consists of securitized mortgages that were delinquent in the first three months and came back on the bank balance sheet. The control group includes securitized mortgages that were delinquent in the first three months of being securitized and stayed securitized. In 123:456 test, treatment group consists of mortgages same as in the previous case, but the control group consists of securitized mortgages that were delinquent in fourth, fifth, and sixth months of being securitized and stayed securitized. Table 4.19 shows that cure rate is higher for mortgages in the treatment group than mortgages in the control group in 3:3 and 3:4 tests.

4.3 Connections with Our Work

The topics that the papers [7] and [105] have in common with our contribution are yield enhancement, investment management, agency problems, lax underwriting standards, credit rating agency (CRA) incentive problems, ineffective risk mitigation, market opaqueness, extant valuation model limitations and structured product intricacy (see Chapters 2 and 3 for more details and [99]).

4.3.1 Connection with Chapter 2

Mortgage delinquency involves mortgages of short duration extended to low credit score MRs with low or no documentation. This takes place in housing markets with moderately volatile and flat or declining nominal house prices. These mortgages are typically more risky than prime mortgages and are characterized by higher rates of prepayment, delinquency and default (see Subsection 2.2.1 for our take on this issue). We concur with these conclusions in Subsection 2.2.2 (see Tables 4.1 to 4.9). From Subsection 2.2.2, the decomposition $M_t = (1 - r^f - r^S)M_t + r^f M_t + r^S M_t$, with high r^S values has connections with predatory mortgages – mortgages that MRs should not take. Predatory lending is associated with poorly informed MRs. Formula (2.3) in Subsection 2.2.2 represents the recovery amount, R. Subprime mortgages are designed to providing housing to riskier MRs. Addressing their risk required a particular design feature linked to house price appreciation (see, for instance, [53]).

Before the SMC, mortgage default rates were low and collateral values were high, so that recovery was not problematic. During the SMC, the value of R decreased steadily as H and MR mortgage collateral declined. Also from Subsection 2.2.2, we note that M in (2.4) is an increasing function of $\mathcal{C}$ and a decreasing function of r^M. As a consequence, before the SMC, M was high. During the SMC, the opposite was true as credit ratings of mortgages began to decline significantly. Also, equation (2.5) embeds the fact that mortgage losses, $S(\mathcal{C}_t)$, and OMI premium rates, $p^i(\mathcal{C}_t) \in [0,1]$, (see (2.1)) are correlated with credit rating. Also, $p^i(\mathcal{C}_t)$ and its interplay with $C(S(\mathcal{C}_t))$ is important with respect to counterparty risk – the inability of economic agents to fulfill their obligations towards each other (see Subsections 4.2.1.3, 4.2.1.4 and 4.2.1.5 of Chapter 4).

From equation (2.6), we note that L at origination is positively correlated with delinquency. Also, L is a measure of the incentive for MRs to extract house equity via cash out refinancing. When the house prices declined, subprime MRs with high LTVRs were more likely to have a larger M than H. Therefore, such MRs are more likely to default than prime MRs, thus increasing SOR's exposure to credit risk – the main subprime risk associated with the SMC.

From Panel A of Tables 4.10 and 4.11, fully documented mortgages have higher FICO scores, lower LTVR, larger origination amounts on average and lower interest rate , which means when house prices declined subprime MRs with FICO score greater than 680 will default less than all mortgages. This is consistent with equation (2.6) and Tables 4.2 and 4.3. Panels B of Tables 4.10 and 4.11 show that portfolio mortgages have higher FICO scores, lower interest rate as well as slightly higher LTVR and origination amounts. This concludes by saying that portfolio mortgages will default less often than securitized mortgages.

By estimating equation (4.5), the marginal effects of a logit regression performed for all mortgages is reported in Table 4.12. It can be seen that the coefficients on dummy portfolio mortgages are negative and significant at all times for the entire period (see Tables 4.13 and 4.16). This imply that if a mortgage on a lender's balance sheet is delinquent then it is less likely to be foreclosed than a mortgage that is securitized. This results are also supported in periods where house prices declines. Also mortgages with higher LTVR are more likely to foreclose. However, the coefficients from Table 4.12 suggest that if the mortgages with lower FICO are delinquent, then default will be less. But FICO and delinquency are negatively related, the reason being if high FICO mortgage becomes delinquent, then the borrower has received larger credit shock given initial credit quality. As a result, if high FICO mortgage becomes delinquent, then high FICO may be act as a proxy for the size of credit shock in regression.

4.3.2 Connection with Chapter 3

The 2007-2009 subprime mortgage crisis (SMC) was preceded by a decade of low interest rates that spurred significant increases in both residential mortgage loan (RML) financing and house prices. This environment encouraged investors (including subprime investment banks) to pursue instruments that offer yield enhancement. Subprime mortgages offer higher yields than standard mortgages and consequently have been in demand for securitization. This is important not only because the risk will be spread but also because the structure of the securitization will have special features reflecting the design of the subprime mortgages themselves. The latter point means that there will be additional intricacy (see, for instance, [53]). Subprime mortgages and securitization are very risky and intricate. This is shown in Tables 4.10 to 4.19, where securitized mortgages are more likely to be foreclosed than portfolio mortgages. This is consistent with our IDIOM hypothesis that postulates that the SMC was partly caused by the intricacy and design of subprime mortgage origination, securitization and systemic agents that led to information (loss, asymmetry and contagion) problems, valuation opaqueness and ineffective risk mitigation.

The demand for increasingly intricate structured products such as residential mortgage backed securities (RMBSs) and collateralized debt obligations (CDOs) which embed leverage within their structure exposed subprime investing banks (SIBs) to an elevated risk of default. In the light of relatively low interest rates, rising house prices and investment grade credit ratings (usually AAA) given by the credit rating agencies (CRAs), this risk was not considered to be excessive. A surety wrap – insurance purchased from a monoline insurer (MLI) – may also be used to ensure such credit ratings.

The risks involved in holding these securities were seriously underestimated. To some extent, they were hedged through insurance arrangements, but, because of overoptimism and an excessive reliance on the assessments of CRAs, for most securities, the hedges covered only a fraction of the exposure; moreover, no attention was paid to the possibility that the counterparties to the hedges might themselves be in trouble and that this was most likely to happen at the very time when they would be called upon to step in and replace losses from borrower defaults (see Tables 4.1 to 4.9 in Section 4.1). Also no attention seems to have been paid to correlations of risks on these securities with the risks involved in warehousing securities in the process of securitization. Indeed, once the credit risk of a position was hedged, this risk was deemed to be neutralized and did not appear any more in the quantitative risk analysis of the bank. In the actual course of events, these hedged positions were a major source of losses, partly because hedges were incomplete, partly because counterparties were in trouble (see, for instance, [58]);

The example in Subsection 3.5.1 shows that under favorable economic conditions (for instance, where RMBS default rates are low and $\mathcal{C}^B$ is high) huge profits can be made from securitizing subprime RMBSs as was the case before the SMC. On the other hand, during the SMC, when conditions are less favorable (for instance, where RMBS default rates are high and $\mathcal{C}^B$ is low), SIBs suffer large mortgage securitization losses.

Default rate is proposed to be an ex-ante measure of credit risk, created using information available to CRAs at the time each deal was initially rated and issued. MBS deal with a high share of low-doc mortgages will have a higher predicted default rate. Risky subprime and Alt-A deals measured by the model-projected default rate, and deals with a high concentration of low-doc mortgages, experience higher early-payment defaults in every cohort (see, Tables 4.6, 4.7, 4.8 and 4.9). Deals with a high model-projected default rate experience larger ex-post rating downgrades. Default (foreclosure) rates of delinquent securitized and portfolio mortgages is compared in Tables 4.10 and 4.11. Tables show that delinquent securitized mortgages are foreclosed (defaulted) at a much higher rate as compared to similar delinquent portfolio mortgages.

The assumption made in this thesis is that write-offs are related to the current value of RMBS credit rating, $\mathcal{C}^B$, which can be thought of as a proxy for the level of macroeconomic activity (see Section 3.4 for more details). However, they depend on past macroeconomic conditions as well, given that $\mathcal{C}^B$ is described by an autoregressive process.

$$\frac{\partial \omega(\mathcal{C}_t^B)}{\partial \mathcal{C}_t^B} < 0.$$

This is in line with the procyclical notion that before the SMC, when credit ratings were high, the risk-weights were low. On the other hand, during the SMC, risk-weights increased because of an elevated probability of default and/or loss given default on mortgages.

Subsection 3.4.1 explain how capital, K, and the quantity and price of RMBSs, B, are affected by changes in the level of credit rating $\mathcal{C}^B$ when risk-weight on RMBSs, $\omega(\mathcal{C}_t^B)$, are allowed to vary (see Theorem 3.4.1 and Corollary 3.4.2). Equation (3.53) shows that when the capital constraint is slack, subprime RMBSs, B, increase as a result of an increase in the RMBS credit rating. When the capital constraint holds, the response of subprime RMBSs and RMBS rates to a change in the level of credit rating in future is given by equation (3.57). Subprime RMBSs can either rise or fall in response to positive credit rating shocks in future. This process depends on the relative magnitudes of the terms in equation (3.57). If capital rises in response to positive credit rating shocks, subprime RMBSs can fall provided that the effect of the shock on capital is greater than the effect of the shock on subprime RMBS risk-weights.

Credit rating is measured via levels of subordination below AAA and BBB in Tables 4.6, 4.7, 4.8 and 4.9. Subordination levels give information about the credit risk of mortgages underlying the deal. Deals with a high share of low-documentation mortgages experience significantly larger credit rating downgrades both in the Alt-A and subprime deals. Above mentioned tables indicate that credit rating influence the cost of subprime credit, particularly for low-doc mortgages and mortgages with observably poor underwriting characteristics.

We believe that mortgage standards became slack because securitization gave rise to moral hazard, since each link in the mortgage chain made a profit while transferring associated credit risk to the next link (see, for instance, [95]). At the same time, some financial institutions retained significant amounts of the RMBSs they originated, thereby retaining credit risk and so were less guilty of moral hazard (see, for instance, [48]). The increased distance between SORs and the ultimate bearers of risk potentially reduced SORs' incentives to screen and monitor MRs (see [97]). The increased intricacy of markets related to mortgages and their securitization also reduces SIB's ability to value them correctly where the value depends on the correlation structure of default events (see, for instance, [48] and [53]).

Chapter 5

Conclusions and Future Directions

"A basic cause of the current financial crisis was the mandate by the U.S. Congress for Fannie Mae to vastly increase its support of low-income housing. This mandate required a lowering of lending standards. These lower standards encouraged people with relatively high incomes to buy more expensive houses than they otherwise would have or to buy speculative second homes with the option of walking away from them if house prices fell. The problem was aggravated by novel, obscure, highly leveraged financial instruments that were not well understood by the companies that used them. These instruments caused an information crisis in which parties refused to enter into transactions with each other whenever doing so involved counterparty risk because no one knew who held bad paper. Part of the cure for the current crisis - which would also remove one potential cause of future crises - is for Congress to stop pressuring Fannie Mae to acquire mortgages with insufficient borrowing standards. On the contrary, any mortgages that Fannie Mae purchases should meet solid, traditional down-payment and documentation requirements. Inducing families to buy houses they could not afford did not benefit them, the U.S. and international financial systems, or the world economy."

– Prof. Harry Markowitz, University of California, 2010.

In this chapter, we provide a few brief concluding remarks about Chapters 2, 3, and 4 as well as comment about possible future regulation and research.

5.1 Conclusions

In this thesis, we analyze the role of subprime mortgages and their securitization as well as risks and data in the SMC. Throughout our contribution, we consider maximization problems in order to chart such fundamental mortgage issues such as profit and valuation. The main hypothesis of the thesis is that the SMC was partly caused by the design and intricacy of subprime mortgages and securitization that led to information dispersion, opaqueness and ineffective risk mitigation.

5.1.1 Conclusions About Chapter 2: Subprime Mortgages

Chapter 2 offers several novel insights into the modeling of subprime mortgages in a theoretical-quantitative framework. More specifically, we modeled subprime mortgages that are able to fully amortize, voluntarily prepay or involuntarily prepay (default) (see Problem 1.3.1 and Subsection 2.2.2 of Section 2.2). Furthermore, we constructed a discrete-time OTH model for SOR profit incorporating costs of funds and OMI as well as mortgage losses (see Problem 1.3.2 and Subsection 2.3.1 of Section 2.3). Finally, we made decisions regarding mortgage rates, deposits and Treasuries, in order to obtain an optimal SOR valuation with subprime mortgages at face value (see Problem 1.3.3 and Theorem 2.3.4 in Subsection 2.3.2 of Section 2.3).

Our contention is that the SMC was partly caused by subprime mortgage design and complexity that, in turn, led to the loss of information and subprime risk opaqueness. As a result of the latter, subprime SORs could not implement effective risk management policies. During this process, declining H – inversely related to L – curtailed the refinancing of subprime mortgages. This sensitivity to H has widespread implications. Also, we concur with the literature that suggests that subprime mortgages is the first link of an interwoven chain that includes mortgage backed structured notes. If subprime mortgages are dysfunctional, the quality of the notes in the rest of the chain will be compromised. From our findings, we observe that high LTVRs curtailed refinancing of subprime mortgages due to house price depreciation, while low LTVRs increase the house equity of MRs.

5.1.2 Conclusions About Chapter 3: Subprime Mortgage Securitization

Chapter 3 investigates modeling aspects of mortgages into structured products such as subprime RMBSs and CDOs. In this regard, our discussions in Sections 3.2 and 3.3 focus on risk, profit and valuation as well as the role of capital under RMBSs and RMBS CDOs, respectively. With regard to the former, my thesis discusses credit, maturity mismatch, basis, counterparty, liquidity, synthetic, prepayment, interest rate, price, tranching and systemic risks. The main hypothesis of this thesis is that the SMC was largely caused by the intricacy and design of subprime mortgage securitization that led to information (loss and asymmetry) problems, valuation opaqueness and ineffective risk mitigation (see Problem 1.3.6 in Section 1.3). This claim is illustrated via the examples presented in Section 3.5 and their discussions in Section 3.6.

On the face of it the securitization of housing finance through MBSs appears, in principle, to be an excellent way of shifting risks resulting from the mismatch between the economic lifetimes of housing investments and SIBs' horizons away from SORs and their debtors without impairing SORs' incentives to originate mortgages. Securitization would thus appear to provide a substantial improvement in risk allocation in the global banking system. The question is then what went wrong. In several important respects, the practice was different from the theory. Firstly, moral hazard in origination was not eliminated, but was actually enhanced by several developments (see Subsections 3.6.1.1 and 3.6.2.1 of Section 3.6). Secondly, many of the MBSs did not end up in the portfolios of insurance companies or pension funds, but in the portfolios of highly leveraged SIBs that engaged in substantial maturity transformation and were in constant need of refinancing. Finally, the markets for refinancing these highly leveraged banks broke down during the SMC.

As far as subprime risks are concerned, we identify that SIBs carry credit, market and operational risks involving mark-to-market issues, the worth of mortgage securitizations when sold in volatile markets, uncertainty involved in investment payoffs and the intricacy and design of structured products. Market reactions include market risk, operational risk involving increased volatility leading to behavior that can increase operational risk such as unauthorized trades, dodgy valuations and processing issues and credit risk related to the possibility of bankruptcies if SORs, SDBs and SIBs cannot raise funds. Recent market events, which demonstrate how credit, market and operational risks come together to create volatility and losses, suggest that it is no longer relevant to dissect, delineate and catalogue credit and market risk in distinct categories without considering their interconnection with operational risk. Underlying many of the larger credit events are operational risk practices that have been overlooked such as documentation, due diligence, suitability and compensation (see Subsections 3.6.1, 3.6.2 and 3.6.3 of Section 3.6).

Our contribution also underlies the following SMC-related timeline (see Section 3.7). In the years since 2000, with low interest rates, low intermediation margins and depressed stock markets, many private investors were eagerly looking for structured products offering better yields and many banks were looking for better margins and fees. The focus on yields and on growth blinded them to the risk implications of what they were doing. In particular, they found it convenient to rely on CRA assessments of credit risks, without appreciating that these assessments involved some obvious flaws. Given SIBs' hunger for the business of securitization and high-yielding securities, there was little to contain moral hazard in mortgage origination, which, indeed, seems to have risen steadily from 2001 to 2007. For a while, the flaws in the system were hidden because house prices were rising, partly in response to the inflow of funds generated by this very system. However, after house prices began to fall in the summer of 2006, the credit risk in the reference mortgage portfolios became apparent. Often additional operational risk issues such as model validation, data accuracy and stress testing lie beneath large market risk events. Market events demonstrate that risk cannot always be eliminated and can rarely be completely outsourced. It tends to come back in a different and often more virulent form. For instance, Countrywide Financial had outsourced its credit risk through packaging and selling of subprime mortgages. However, in doing so, the company created sizeable operational risks through its business practices and strategy.

5.1.3 Conclusions About Chapter 4: More Subprime Data

The main question that was answered in Chapter 4 was whether or not subprime data supported the IDIOM hypothesis. Notwithstanding the fact some data had conflicting outcomes, in the main this question was answered in the affirmative.

The IMF estimates that financial institutions around the world will eventually have to write off $ 1.5 trillion of their holdings of subprime MBSs. About $ 750 billion in such losses had been recognized as of November 2008. These losses have obliterated much of the capital of the banking system. SORs operating in countries that have been party to Basel capital regulation have to maintain capital adequacy ratios (refer to the discussion in Chapter 3, Subsection 3.6.3). As a consequence, the aforementioned reduction in SOR capital has reduced the credit available to businesses and households.

Analysis of credit ratings on RMBS deals uncovers systematic performance differences amongst different types of deals from a given cohort. We can observe that default model is based on observable risk characteristics, such as FICO, LTV and DTI. Higher subordination is correlated with worse ex-post mortgage performance (see Subsection 4.2.1 of Section 4.2). Analysis on securitized and portfolio mortgages focuses on establishing that delinquent securitized mortgages are foreclosed at a much higher rate as compared to similar delinquent bank-held mortgages. But in certain subsamples of the data there are no differences between the cure rates of delinquent securitized and portfolio mortgages, this shows that there is no renegotiation rate difference between securitized and portfolio mortgages. Our estimate of foreclosure bias in securitized mortgage servicing is measured relative to foreclosures by banks. As banks are likely to fully internalize the costs and benefits of the decision to foreclose a delinquent mortgage, results suggest that securitization has imposed renegotiation frictions that have resulted in a higher foreclosure rate than would be desired by investors. In addition we find that delinquent portfolio mortgages are not only foreclosed at a lower rate, but also making payments at a higher rate relative to comparable securitized mortgages (see Subsection 4.2.2 of Section 4.2). This suggest that some investors could have benefited if their mortgages were serviced similarly to portfolio mortgages.

5.2 Future Directions

In this section, we look at possible regulatory solutions to problems associated with the SMC as well as future research.

5.2.1 Future Regulation

A variety of regulatory changes have been proposed by role players to minimize the impact of the current crisis and prevent recurrence. However, as of March 2010, many of the proposed solutions have not yet been implemented. These include the following regulation.

One of the first regulatory priorities is to establish resolution procedures for closing troubled financial institutions in the shadow banking system, such as investment banks and hedge funds. Also, the leverage that financial institutions can assume should be restricted. New regulation should require executive compensation to be more related to long-term performance. There has been renewed calls for the re-instatement of the separation of commercial (depository) and investment banking established by the Glass-Steagall Act in 1933 and repealed in 1999 by the Gramm-Leach-Bliley Act. Systemic risk could also be mitigated by splitting institutions that are too-big-to-fail. It would be a good idea to regulate institutions that *act like banks* similarly to banks. Banks should have a stronger capital cushion, with graduated regulatory capital requirements (i.e., capital ratios that increase with bank size), to discourage them from becoming too big and to offset their competitive advantage. Minimum down payments for mortgages of at least 10 % and income verification should be insisted upon by SORs. G should ensure that financial institutions should have the necessary capital to support its financial obligations. Counterparty risk can be mitigated by regulating credit derivatives and ensuring that they are traded on well-capitalized exchanges. Financial institutions should be required to maintain sufficient *contingent capital* that involves paying insurance premiums to G during boom periods, in exchange for payments during a downturn. An early-warning system to assist in detecting systemic risk should be put in place. Another regulatory provision should enable the nationalization of failed banks. Debt for equity swaps should be introduced to reduce debt levels across the financial system. Mortgage balances should be reduced in order to assist MRs, thereby giving SOR a share in any future house appreciation. Counter-cyclical regulatory policy should be introduced to help modulate human nature that tends to operate pro-cyclically meaning that it amplifies the extent of booms and busts. From this viewpoint, humans are momentum investors rather than value investors. Counter-cyclical policies would include increasing capital requirements during boom periods and reducing them during busts.

In addition to the above, Treasury Secretary, Timothy Geithner's, testimony before Congress on Thursday, 29 October 2009 included five elements that are deemed to be critical to effective reform. These are listed below.

• Expand the FDIC bank resolution mechanism to include non-bank financial institutions;

• Ensure that a firm is allowed to fail in an orderly way and not be "rescued";

• Ensure taxpayers are not on the hook for any losses, by applying losses to the firm's investors and creating a monetary pool funded by the largest financial institutions;

• Apply appropriate checks and balances to the FDIC and Federal Reserve in this resolution process;

• Require stronger capital and liquidity positions for financial firms and related regulatory authority.

5.2.2 Future Research

In future, we would like to extend and adapt the existing econometric techniques to produce models that have relevance for financial crises such as the ongoing SMC and GFC. In this regard, we hope to develop a clearer understanding of the dynamics of related banking issues such as subprime mortgages, securitization of subprime mortgages and Basel capital regulation. From a numerical point of view, we plan to validate the aforementioned models by analyzing specific real-world data in an empirically sound manner. More details of our intended research are provided in the sequel.

A first specific activity will be to determine whether subprime mortgages were extended to all classes of MRs, not only to those with impaired credit. A mortgage can be labeled subprime not only because of MR characteristics, but also because of the type of SOR that originated it, features of the mortgage product itself or how it was securitized. In this regard, we would like to investigate whether subprime mortgages were also extended to MRs without impaired credit and the impact of this. A further objective is to ascertain the extent to which subprime mortgages promoted homeownership. Also, we would like to determine the links between declining house prices as well as mortgage underwriting standards and the SMC. Rising house prices and falling mortgage interest rates before 2006 gave many MRs an opportunity to refinance their mortgages and extract cash. In this regard, the question is whether subprime mortgages failed because of this practice. The belief that rate resets caused many subprime defaults has its origin in the statistical analysis of mortgage performance that was done on ARMs and FRMs soon after the problems with subprime mortgages started emerging. Here, we would like to know whether subprime mortgages failed because of mortgage rate resets as is the case for ARMs.

Another area of future research involves the extent to which subprime MRs were offered (low) ARM teaser rates. In this regard, the claim is that the initial rates offered to subprime MRs may have been lower than they most likely would have been for the same MRs had they chose a FRM, but they are not low in absolute terms. Observing the extent of the SMC in the US and the global financial crisis that followed, another important issue is whether this turmoil and its magnitude were anticipated by role players in the financial system. In this regard, data analysis suggests that some market participants were likely aware of an impending market correction. Furthermore, the following viewpoint has to be investigated. The effect of the SMC in the US is unique since it is large and devastating and has led to global financial turmoil. However, neither the origin of this crisis or the way it has played out was unique at all. In fact, it seems to have followed the classic lending boom-and-bust scenario that has been observed historically in many countries. Before the SMC, there was a conventional belief that a market as relatively small as the U.S. subprime mortgage market (about 16 % of all U.S. mortgage debt in 2008) could not cause significant problems in wider markets even if it were to crash completely. However, we are now experiencing a severe ongoing crisis that has affected the real economies of many countries in the world, causing recessions, banking and financial failure and a credit crunch – rippling out from failures in the subprime market. In future, we would like to investigate the mechanism involved in causing this knock-on effect. We anticipate that the solution to this problem lies in the complexity of the market for securities backed by subprime mortgages.

As far as monetary policy and regulation is concerned, we would like to identify the possible financial stability implications of issues mentioned in Subsection 5.2.1 and to determine the effect these have on macroprudential policy and prudential behaviour. In addition, we would like to highlight the link between cyclicality, financial stability and regulation as it pertains to the GFC.

The main thrust of future mathematically rigorous research should involve models of banking items driven by Lévy processes (see, for instance, Protter in [106, Chapter I, Section 4]). Such processes have an advantage over the more traditional modeling tools such as Brownian motion in that they describe the non-continuous evolution of the value of economic and financial items more accurately. For instance, because the behaviour of bank mortgages, profit, capital and CRAs are characterized by jumps, the representation of the dynamics of these items by means of Lévy processes is more realistic. As a result of this, recent research has strived to replace the existing Brownian motion-based bank models (see, for instance, [35], [49], [74] and [109]) by systems driven by more general processes. Also, a study of the optimal capital structure should ideally involve the consideration of taxes and costs of financial distress, transformation costs, asymmetric bank information and the regulatory safety net. Another research area that is of ongoing interest is the (credit, market, operational, liquidity) risk minimization of bank operations within a regulatory framework (see, for instance, [64] and [83]). A further possible field of study arises from the bank capital literature that motivates capital and internal financing as important in bank decisions by invoking specific market imperfections or mispricings such as costly equity-financing frictions, dead-weight costs from insolvency and risk-insensitive deposit provisions for mortgage losses premiums. Furthermore, the assumed asset, equity and liability processes and the bank's objectives and control variates will be dependent on the specific market or pricing conditions being assumed. These effects are not fully recognized in our contribution and requires further attention.

Chapter 6

BIBLIOGRAPHY

Bibliography

[1] Acharya, V. V., & Yorulmazer, T. (2008). Cash-in-the-market pricing and optimal resolution of bank failures. Review of Financial Studies, 21, 2705–2742.

[2] Affinito, M., & Tagliaferri, E. (2010) Why do (or did ?) banks securitize their loans ? Evidence from Italy. Journal of Financial Stability, 6(4), 189–202.

[3] Aguesse, P. (2007). Is rating an efficient response to the challenges of the structured finance markets ? Risk and Trend Mapping No.2, Autorit des Marchs Financiers, Available: http://www.amf-france.org/documents/general/7693_1.pdf.

[4] Altug, S., & Labadie, P. (1994). Dynamic choice and asset markets. California Academic Press. ISBN: 0120554550.

[5] Altunbas, Y., Gambacorta, L., & Marqués, D. (2007). Securitization and the bank lending channel. Banca d'Italia, Temi di discussione, No. 653 and ECB Working Paper Series, No. 838.

[6] Ameriquest Mortgage Securities Inc. (AMSI) 2005-R2. Prospectus dated 22 March 2005. AMSI 2005-R2 closed 24 March 2005. Available: http://www.dbrs.com/research/221070/ameriquest-mortgage-securities-inc-2005-r2/.

[7] Ashcraft, A. B., Goldsmith-Pinkham, P., & Vickery, H. May 2010. MBS ratings and the mortgage credit boom. Federal Reserve Bank of New York. Staff Report # 449.

[8] Ashcraft, A. B., & Schuermann, T. (2008). Understanding the securitization of subprime mortgage credit. SSRN eLibrary, Available: http://ssrn.com/paper=1071189.

[9] Aversa, J. (2008). Rebate checks in the mail by spring. The Huffington Post, Arianna Huffington, Available: http://www.huffingtonpost.com/2008/02/13/rebate-checks-in-the-mail_n_86525.html.

[10] Bangia, A., Diebold, F. X., Kronimus, A., Schagen, C., & Schuermann, T. (2002). Ratings migration and the business cycle, with applications to credit portfolio stress testing. Journal of Banking & Finance, 26(2/3), 445–474.

[11] Basel Committee on Banking Supervision. (2006). International convergence of capital measurement and capital standards; A revised framework. Bank for International Settlements, Available: `http://www.bis.org/publ/bcbs107.pdf`.

[12] Basel Committee on Banking Supervision. (2001). The new Basel Capital Accord. Bank for International Settlements, Available: `http://www.bis.org/publ/bcbsca.htm`.

[13] Bear Sterns. (September 2006). Bear Sterns quick guide to non-agency mortgage-backed securities. Residential Mortgage Criteria Report.

[14] Bebchuck, L. A. (2008). A plan for addressing the financial crisis. The Economists' Voice, 5(5), Article 6. SSRN, Available: `http://ssrn.com/paper=1273241`.

[15] Bebchuck, L. A. (2008). A better plan for addressing the financial crisis. Economists' Voice, 5(5), Article 7.

[16] Bell, D. E. (1982). Regret in decision making under uncertainty. Operations Research, 30, 961-981.

[17] Benmelecht, E., & Dlugosz, J. (2009). The alchemy of CDO credit ratings. Journal of Monetary Economics, 56, 617-634.

[18] Bernanke, B. S. (2009). Four questions about the financial crisis. Available: `http://www.federalreserve.gov/newsevents/speech/bernanke20090414a.htm`.

[19] Blum, J. (1999). Do capital adequacy requirements reduce risks in banking ? Journal of Banking and Finance, 22, 755-771.

[20] Bolton, P., Freixas, X., & Shapiro, J. (February 2009). The credit ratings game. NBER Working Paper Series, Working Paper 14712, Available: `http://www.nber.org/papers/w14712`.

[21] Bond, P., Musto, D. K., & Yilmaz, B. (2009). Predatory mortgage lending. Journal of Financial Economics, 94(3), 412–427.

[22] Borio. C., Furfine, C., & Lowe, P. (2001). Procyclicality of the financial system and financial stability: issues and policy options. Bank for International Settlements, Working Paper, Available: `http://www.bis.org/publ/biospap01a.pdf`.

[23] Cagan, P. (2008). What lies beneath operational risk issues underlying the subprime crisis. The Risk Management Association (RMA) Journal, 96–99.

[24] Cagan, C. (2007). Mortgage payment reset. unpublished mimeo, Available: `http://www.facorelogic.com/landingpages/caganform.jsp?id=8037`.

[25] Cannata, F., & Quagliariello, M. (2009). The role of Basel II in the subprime financial crisis: guilty or not guilty ? Carefin, University of Bocconi, SSRN eLibrary, Available: http://ssrn.com/paper=1330417.

[26] Case, K. E., & Shiller, R. J. (1989). The efficiency of the market for single family homes. American Economic Review, 79(1), 125–137.

[27] Chambers, M. S., Garriga, C., & Schlagenhauf, D. (2009). The loan structure and housing tenure decisions in an equilibrium model of mortgage choice, Review of Economic Dynamics, 12, 444-468.

[28] Chami, R., & Cosimano, T. F. (2001). Monetary policy with a touch of Basel. International Monetary Fund, Working Paper WP/01/151. Available: http://ssrn.com/paper=879965.

[29] Chomsisengphet, S., & Pennington-Cross, A. (2006). Subprime refinancing: Equity extraction and mortgage termination. Working Paper 2006-023A. Available: http://research.stlouisfed.org/wp/2006/2006-023.pdf.

[30] Claessens, S., Demirgüç-Kunt, A., & Moshirian, F. (July 2009). Global financial crisis, risk analysis and risk measurement. Journal of Banking and Finance, 33, 1949-1952.

[31] Cowan, A. M., & Cowan, C. D. (2004). Default correlation: An empirical investigation of a subprime lender. Journal of Banking and Finance, 28, 753-771.

[32] Crouhy, D., Turnbull, P., & Jarrow, H. (2008). The subprime credit crisis of 07'. Working Paper. University of Houston, Natixis and Cornell University.

[33] Daglish, T. (2009). What motivates a subprime borrower to default ? Journal of Banking & Finance, 33, 681–693.

[34] Danis, M. A., & Pennington-Cross, A. (2008). The delinquency of subprime mortgages. Journal of Economics and Business, 60, 67–90.

[35] Decamps, J-P., Rochet, J-C., & Roger, B. (2004). The three pillars of Basel II: Optimizing the mix. Journal of Financial Intermediation, 13, 132–155.

[36] Dell'Ariccia, G., Igan, D., & Laeven, L. (2008). Credit booms and lending standards: Evidence from the subprime mortgage market. IMF Working Paper WP/08/106. Available: http://ssrn.com/paper=1141005.

[37] Demyanyk, Y., & Van Hemert, O. (2008). Understanding the subprime mortgage crisis. Social Science Research Network. Available: http://ssrn.com/abstract=1020396.

[38] Dodd, C. (2007). Create, sustain, preserve, and protect the American dream of home ownership. United States Senator for Connecticutt. Available: http://dodd.senate.gov/?q=node/3731.

[39] Duffie, D. (2008). Innovations in credit risk transfer: implications for financial stability. BIS Working Papers, No. 255.

[40] Dwyer, G. P., & Tkac, P. (2009). The financial crisis of 2008 in fixed-income markets. Journal of International Money and Finance, 28(8), 1293–1316.

[41] Elliehausen, G., Staten, M. E., & Steinbuks J. (2008). The effect of prepayment penalties on the pricing of subprime mortgages. Journal of Economics and Business, 60, 33–46.

[42] Ellis, L. (2008). The housing meltdown: Why did it happen in the United States. Bank for International Settlements, Available: `http://www.bis.org/publ/work259.htm`.

[43] Fabozzi, F. J., Cheng X., & R-R. Chen. (2007) Exploring the components of credit risk in credit default swaps. Finance Research Letters, 4, 10–18.

[44] Financial Services Authority. (July 2010). Mortgage market review: Responsible lending. Consultation Paper 10/16. Available: `http://www.fsa.gov.uk/`.

[45] Financial Stability Forum (7 April 2008). Report of the Financial Stability Forum on Enhancing Market and Institutional Resilience.

[46] Fineman, J., & Keoun, B. (2008). Merrill Lynch posts fourth straight quarterly loss (Update 2). Available: `http://www.bloomberg.com/apps/news`.

[47] Foote, C. L., Gerardi, K., Goette L., & Willen, P. S. (2008) Just the facts: An initial analysis of subprime's role in the housing crisis. Journal of Housing Economics, 17, 291-305.

[48] Fouche, C. H., Mukuddem-Petersen, J., Petersen, M. A., & Senosi, M. C. (2008). Bank valuation and its connections with the subprime mortgage crisis and Basel II Capital Accord. Discrete Dynamics in Nature and Society, vol. 2008, Article ID740845, 44 pages.

[49] Fouche, C. H., Mukuddem-Petersen, J., & Petersen, M. A. (2006). Continuous-time stochastic modeling of capital adequacy ratios for banks. Applied Stochastic Models in Business and Industry, 22, 41–71.

[50] Gollier C., Salanie B. (2006). Individual decisions under risk, risk-sharing and asset prices with regret. Working Paper.

[51] Goolsbee, A. (1998). Taxes, organizational form and the dead weight loss of corporate income tax. Journal of Public Economics, 69, 143–152.

[52] Gorton, G. B. (2009). Information, liquidity, and the (ongoing) panic of 2007. American Economic Review: Papers & Proceedings, 99(2), 567-572.

[53] Gorton, G. B. (2008). The subprime panic. Yale ICF Working Paper, 08, 25, Available: `http://ssrn.com/abstract=1276047`.

[54] Gorton, G., & Souleles, N. S. (2007). Special purpose vehicles and securitization. In R. Stulz, & M. Carey (Eds.), The Risks of Financial Institutions. Chicago, Illinois: University of Chicago Press.

[55] Hanson, S. G., & Schuermann, T. (2006). Confidence intervals for probabilities of default. Journal of Banking and Finance, 30(8), 2281–2301.

[56] Harvey, C. R. (2008). The financial crisis of 2008: What needs to happen after TARP. Duke University, Working Paper. Available: http://ssrn.com/paper=1274327.

[57] Heitfeld, E. (2008) Parameter uncertainty and the credit risk of collateralized debt obligations. Federal Reserve Board, working paper.

[58] Hellwig, M. (2009). Systemic risk in the financial sector: An analysis of the subprime-mortgage financial crisis. De Economist, 157, 129–207.

[59] Hull, J., Predescu, M., & White, A. (2004). The relationship between credit default swap spreads, bond yields and credit rating announcements. Journal of Banking and Finance, 28, 2789–2811.

[60] Hunt, J. (2008). Credit rating agencies and the worldwide credit crisis: The limits of reputation, the insufficiency of reform and a proposal for improvement. Berkeley Law. University of California, Available: http://www.law.berkeley.edu/files/RAShortWhitePaperJH090908KTrev-1.pdf.

[61] Inside Mortgage Finance. (2007). The 2007 Mortgage Market Statistical Annual. Key Data (2006), Joint Economic Committee.

[62] International Monetary Fund. (2008). Containing systemic risks and restoring financial soundness, Global financial stability report. Washington, DC: International Monetary Fund.

[63] Ivashina, V., & Scharfstein, D. (2010). Bank lending during the financial crisis of 2008. Journal of Financial Economics, 97(3), 319–338.

[64] Jackson, P., & Perraudin, W. (2000). Regulatory implications of credit risk modeling. Journal of Banking and Finance, 24, 1–14.

[65] Jorion, P., & Zhang, G. (2009). Credit contagion from counterparty risk. Journal of Finance, 64, 2053-2087.

[66] Kashyap, A. K., & Stein, J. C. (2004). Cyclical implications of the Basel II capital standards. Federal Reserve Bank Chicago, Economic Perspectives, 1, 18–31.

[67] Kendra, K. (February 2007). Tranche ABX and basis risk in subprime RMBS structured portfolios. Bloomberg, Available: http://www.fitchratings.com/web_content/sectors/subprime/Basis_in_ABX_TABX_Bespoke_SF_CDOs.ppt.

[68] Keys, B. J., Mukherjee, T., Seru, A., & Vig, V. (2009). Financial regulation and securitization: Evidence from subprime loans. SSRN eLibrary, Available: http://ssrn.com/paper=1346131.

[69] Klein, M. (2008). SA's credit crunch: Companies battle to cope in tough times. Business Times Supplement, Sunday Times. Available: http://www.thetimes.co.za/PrintEdition/Article.aspx?id=856149.

[70] LaCour-Little, M., & Rosenblatt, E. (2009). Home equity extraction by homeowners: 2000–2006. Journal of Real Estate Research. Available: http://ssrn.com/paper=1336049.

[71] Laeven, L., & Majnoni, G. (2003). Loan loss provisioning and economic slowdowns: too much, too late ? Journal of Financial Intermediation, 12, 178–197.

[72] Lando, D. & Skdeberg, T. (2002). Analyzing ratings transitions and rating drift with continuous observations. Journal of Banking and Finance, 26(2/3), 423–444.

[73] Larrick, R. P., & Boles, T. L. (1995). Avoiding regret in decisions with feedback: A negotiation example. Organization Behavior and Human Decision Processes, 63(1), 87-97.

[74] Leland, H. (1994). Risky debt, bond covenants and optimal capital structure. Journal of Finance, 49, 1213–1252.

[75] Liao, H-H., Chen, T-K., & Lu, C-W. (2009). Bank credit risk and structural credit models: Agency and information asymmetry perspectives. Journal of Banking and Finance, 33, 1520–1530.

[76] Loutskina, E., & Strahan, P. E. (2009). Securitization and the declining impact of bank financial condition on loan supply. Journal of Finance, 64(2), 861889.

[77] Mason, J., & Rosner, J. (2007) Where did the risk go ? How misapplied bond ratings cause mortgage backed securities and collateralized debt obligation market disruptions. SSRN eLibrary, Available: `http://ssrn.com/paper=1027475`.

[78] Mishkin, F. S. (2009). Monetary policy flexibility, risk management, and financial disruptions. Journal of Asian Economics, 21(3), 242–246.

[79] Moody's Investors Service. (February 2006). Moody's cashflow assumptions for RMBS Alt-A transactions. Structured Finance Special Report.

[80] Moody's Investors Services. (May 2003). Impact of predatory lending on RMBS securitizations. Moody's Special Report, New York.

[81] Moody's Investors Services. (January 2002). An introduction to structured investment vehicles. International Structured Finance Special Report.

[82] Mukuddem-Petersen, J., Mulaudzi, M. P., Petersen, M. A., & Schoeman, I. M. (2010). The subprime crisis and monoline insurance: Structured mortgage products with regret. Discrete Dynamics in Nature and Society, vol. 2010, Article ID 950413.

[83] Mukuddem-Petersen, J., & Petersen, M. A. (2006). Bank management via stochastic optimal control. Automatica, 42, 1395–1406.

[84] Mukuddem-Petersen, J., Petersen, M. A., Schoeman, I. M., & Tau, B. A. (2007). An application of stochastic optimization theory to institutional finance. Applied Mathematical Sciences, 1, 1359–1384.

[85] Mukuddem-Petersen, J., Petersen, M. A., Schoeman, I. M., & Tau, B. A. (2007). Maximizing banking profit on a random time interval. Journal of Applied Mathematics, 2, 1–22.

[86] Mukuddem-Petersen, J., Petersen, M. A., Schoeman, I. M., & Tau, B. A. (2008). Dynamic modeling of bank profits. Applied Financial Economic Letters, 4, 151–157.

[87] Nickell, P., Perraudin, W., & Varotto, S. (2000). Stability of rating transitions. Journal of Banking and Finance, 24, 203–227.

[88] Niinimaki, J-P. (2009). Does collateral fuel moral hazard in banking ? Journal of Banking and Finance, 33, 514–521.

[89] Niinimaki, J-P. (2009). Hidden loan losses, moral hazard and financial crises. Journal of Financial Stability, doi:10.1016/j.jfs.2009.08.001. Available: http://www.sciencedirect.com/science/article/B7CRR-4X2DD2D-1/2/2b93fef3d4942883429a62e28b37d454.

[90] O'Kane, D., & Turnbull, S. (April 2003). Valuation of credit default swaps. Fixed Income Quantitative Credit Research.

[91] Onaran, Y. (2008). Subprime losses top $ 379 billion on balance-sheet marks. Bloomberg.com, Available: http://www.bloomberg.com/apps/news.

[92] Parlour, C.A., & Plantin, G. (2008). Loan sales and relationship banking. Journal of Finance, 63(3), 1291-1314.

[93] Petersen, M. A., De Waal, B., Mukuddem-Petersen, J., Bosch, T., & Thomas, S. (2010). The banking crisis and its risks: Commercial mortgage-backed securities. Chapter 16, Progress in Economics Research. Volume 18. Series: Progress in Economics Research. Editor: Albert Tavidze. Nova Science Publishers, New York (Invited Chapter in Book), ISBN: 978-1-61668-547-8 (Hardcover); ISBN: 978-1-61728-625-4 (ebook).

[94] Petersen, M. A., Mulaudzi, M. P., Mukuddem-Petersen, J., & Schoeman, I. M. (2010). The subprime mortgage crisis: Optimal cash flows from the financial leverage profit engine. Chapter 21, Handbook of Optimization Theory: Decision Analysis and Application. Series: Mathematics Research Developments. Editors: Juan Varela and Sergio Acuña. Nova Science Publishers, New York (Invited Chapter in Book), ISBN: 978-1-60876-500-3.

[95] Petersen, M. A., Mulaudzi, M. P., Schoeman, I. M., & Mukuddem-Petersen, J. (2010). A note on the subprime mortgage crisis: Dynamic modeling of bank leverage profit under loan securitization, Applied Economic Letters, 17(15), 1469–1474.

[96] Petersen, M. A., Mulaudzi, M. P., Schoeman, I. M., Mukuddem-Petersen, J., & De Waal, B. (2010). Bank securitization, capital and profitability with applications to the subprime mortgage crisis. Chapter 18, Handbook of Optimization Theory: Decision Analysis and Application. Series: Mathematics Research Developments. Editors: Juan Varela and Sergio Acuña. Nova Science Publishers, New York (Invited Chapter in Book), ISBN: 978-1-60876-500-3.

[97] Petersen, M. A., & Rajan, R. G. (2002). Does disturbance still matter ? The information revolution in small business lending. Journal of Finance, 57(6), 2533-2570.

[98] Petersen, M. A., Senosi, M. C., De Waal, B., Mukuddem-Petersen, J., & Thomas, S. (2010) Funding of subprime residential mortgage loans via marketable securities and deposits. Proceedings of the Third IASTED Africa Conference on Modelling and Simulation (AfricaMS 2010), Gaborone, Botswana, 6-8 September 2010, ISBN: 978-0-88986-848-9, ISSN: 1922-8058, Paper # 685-011.

[99] Petersen, M. A., Senosi, M. C., & Mukuddem-Petersen, J. (2010). Subprime mortgage models. New York: Nova, ISBN: 978-1-61728-694-0.

[100] Petersen, M. A., Senosi, M. C., Mukuddem-Petersen, J., De Waal, B., & Thomas, S. (2010). The subprime mortgage crisis and its connections with bank bailouts. Chapter 13, Finance and Banking Developments. Series: Banking and Banking Developments. Editor: Charles V. Karsone. Nova Science Publishers, New York (Invited Chapter in Book), ISBN: 978-1-60876-329-0.

[101] Petersen, M. A., Senosi, M. C., Mukuddem-Petersen, J., Mulaudzi, M. P., & Schoeman, I. M. (2009). Did bank capital regulation exacerbate the subprime mortgage crisis ? Discrete Dynamics in Nature and Society, vol. 2009, Article ID 742968.

[102] Petersen, M. A., Senosi, M. C., Thomas, S., Mukuddem-Petersen, J., De Waal, B., Bosch, T. (2010) Modeling subprime residential mortgage loans, Proceedings of the Third IASTED Africa Conference on Modelling and Simulation (AfricaMS 2010), Gaborone, Botswana, 6-8 September 2010, ISBN: 978-0-88986-848-9, ISSN: 1922-8058, Paper # 685-017.

[103] Petersen, M. A., Thomas, S., Senosi, M. C., Mukuddem-Petersen, J., De Waal, B., Bosch, T. (2010) An Originate-to-Distribute (OTD) model for subprime lending, Proceedings of the Third IASTED Africa Conference on Modelling and Simulation (AfricaMS 2010), Gaborone, Botswana, 6-8 September 2010, ISBN: 978-0-88986-848-9, ISSN: 1922-8058, Paper # 685-045.

[104] Petersen, M. A., Thomas, S., Senosi, M. C., Mukuddem-Petersen, J., Bosch T., Mulaudzi, M. P., Schoeman I. M., De Waal, B. (2010). Subprime mortgages and their securitization with regard to capital, information, risk and valuation. Chapter 17, Handbook of Optimization Theory: Decision Analysis and Application. Series: Mathematics Research Developments. Editors: Juan Varela and Sergio Acuña. Nova Science Publishers, New York (Invited Chapter in Book), ISBN: 978-1-60876-500-3.

[105] Piskorski, T., Seru, A., Vig, V. (2010). Securitization and distressed loan renegotiation: evidence from the subprime mortgage crisis. Journal of Financial Economics, 97, 369 - 397. Available: `http://ssrn.com/paper=1321646`.

[106] Protter, P. (2004). Stochastic Integration and Differential Equations (2nd Edition). Berlin, Germany: Springer.

[107] Realtytrac Staff. (2008). US foreclosure activity increases 75 percent in 2007. Realytrac.com, Available: `http://www.realtytrac.com/ContentManagement/pressrelease.aspx`.

[108] Roberts, J., & Jones, M. (2009). Accounting for self interest in the credit crisis. Accounting, Organization and Society, 34, 856-867.

[109] Rochet, J-C. (2004). Rebalancing the three pillars of Basel II. Economic Policy Review, 10, 7–25.

[110] Rochet, J.C. (1992). Capital requirements and the behaviour of commercial banks. European Economic Review, 36(5), 1137-1170.

[111] Schuermann, T. 2004. Why were banks better off in the 2001 recession ? In: Federal Reserve Bank of New York Current Issues in Economics and Finance, pp. 1011.

[112] Securities Exchange Commission. (14 January 2010). Testimony by SEC chairman, Mary L. Shapiro, concerning the state of the financial crisis. Before the Financial Crisis Inquiry Commission. Available: http://www.sec.gov/news/testimony/2010/ts011410mls.htm.

[113] Securities Industry and Financial Markets Association. (14 October 2007). SIFMA Research and Statistics. Available: http://www.sifma.org.

[114] Standard & Poor's. (September 2003). Structured investment vehicle criteria: New develpments. Standard & Poor's Credit Ratings, New York.

[115] Stolper, A. (2009). Regulation of credit rating agencies. Journal of Banking and Finance, 33, 1266-1273.

[116] Structured Asset Investment Loan Trust 2006-2 (SAIL 2006-2). Prospectus dated 22 September 2005. AMSI 2005-R2 closed January 2006. Available: http://www.secinfo.com/d12atd.z3e6.html.

[117] UBS. (13 November 2007). Mortgage strategist. Available: http://www.ubs.org.

[118] U.S Federal Reserve. (2008). FRB: Press Release–FOMC statement–22 January 2008. Press release. Available: http://www.federalreserve.gov/newsevents/press/monetory/20080122.htm.

[119] Wikipedia: The Free Encyclopedia. (June 2010). Subprime Mortgage Crisis. Available: http://en.wikipedia.org/wiki/Subprime_mortgage_crisis.