

Discrete time modeling of subprime mortgage credit

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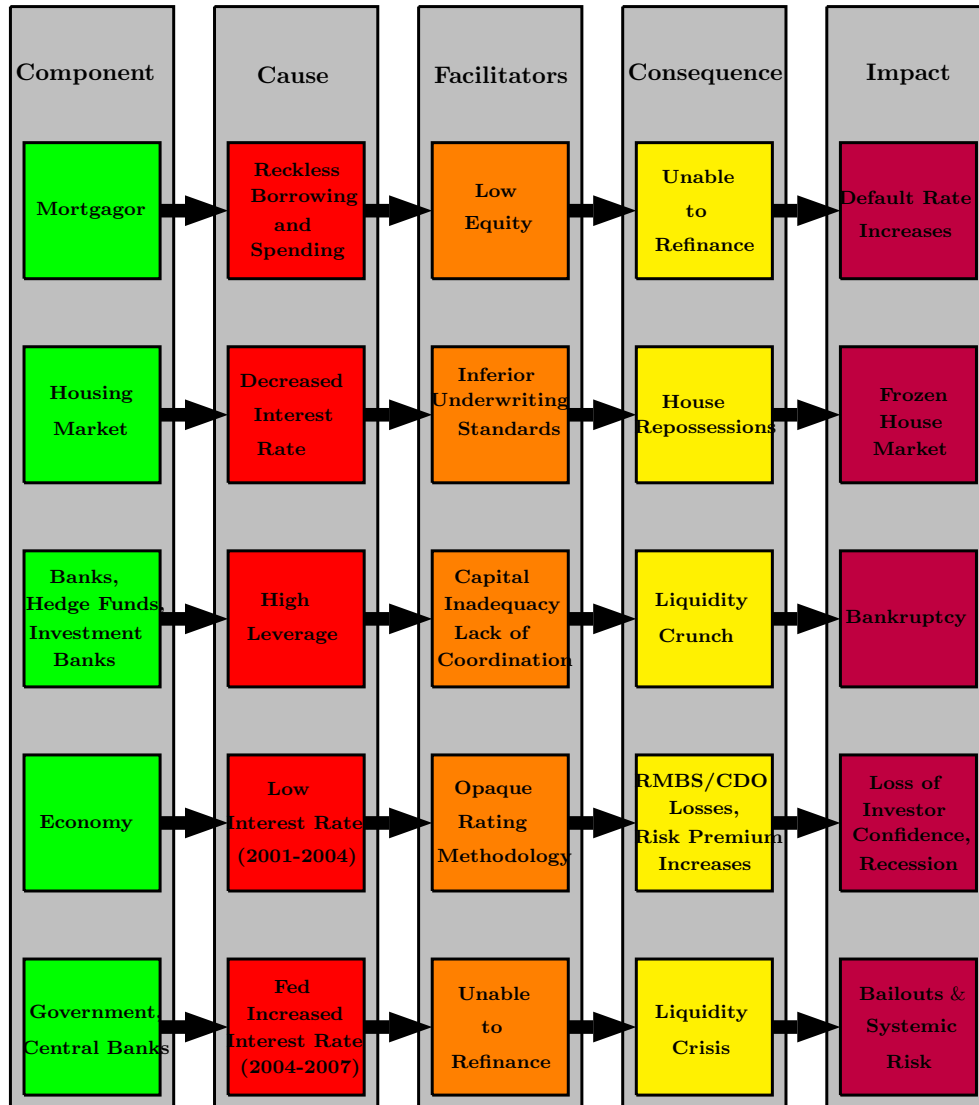


Figure 1: Components, Causes and Consequences of the Subprime Mortgage Crisis

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 Co-Advisor: Dr. Janine Mukuddem-Petersen
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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 Cyclicity
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 and Interbank Lending
MSc	B De Waal	May 2011 Cum Laude	Stochastic Optimization of Subprime Residential Mortgage Loan Funding and its Risks
PhD	MC Senosi	Under Examination	Discrete-Time Modeling of Subprime Mortgage Credit
PhD	S Thomas	Under Examination	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 United States housing market initiated the 2007-2009 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 mortgage origination, data as well as bank bailouts. 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 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 sequel, 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). Furthermore, the primary subprime agents that we consider are house appraisers (HAs), mortgage brokers (MBs), mortgagors (MRs), servicers (SRs), trustees, underwriters and credit enhancement providers (CEPs). Also, the insurers involved in the subprime market are originator mortgage insurers (OMIs) and monoline insurers (MLIs). 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, bailout or policymaking role. Most of the aforementioned banks and agents are assumed to be risk neutral with SOR being the exception since it can be risk (and regret) averse on occasion. The three main aspects of the SMC – subprime mortgage origination, data and bailouts – 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 SORs' capital, information, ratings, risk and 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 loan losses. Furthermore, a constrained optimal valuation problem for SORs under mortgage origination is solved. In addition, we show how high loan-to-value ratios curtailed the refinancing of subprime mortgages, while low ratios imply favorable house equity for subprime MRs. Chapter 2 also explores the relationship between Basel capital regulation and the SMC. This involves studying bank credit and capital under Basel regulation. Further issues dealt with are the quantity and pricing of subprime mortgages as well

as credit ratings under Basel capital regulation. A key problem is whether Basel capital regulation exacerbated the SMC. Very importantly, the thesis answers this question in the affirmative.

Chapter 3 contains subprime data not presented in Chapters 2. We present other mortgage data that also have connections with the main subprime issues raised.

In Chapter 4, a troubled SOR's recapitalization by G via subprime bank bailouts is discussed. Our research supports the view that if SOR is about to fail, it will have an incentive not to extend low risk mortgages but rather high risk mortgages thus shifting risk onto its creditors. Here, for instance, we analyze the efficiency of purchasing toxic structured mortgage products from troubled SORs as opposed to buying preferred and common equity. In this regard, we compare the cases where SORs' on-balance sheet mortgages are fully amortizing, voluntarily prepaying (refinancing and equity extraction) and involuntarily prepaying (defaulting). If bailing out SORs considered to be too big to fail involves buying assets at above fair market values, then these SORs are encouraged ex-ante to invest in high risk mortgages and toxic structured mortgage products. Contrary to the policy employed by G, purchasing common (preferred) equity is always the most (least) ex-ante- and ex-post-efficient type of capital injection. Our research confirms that this is true irrespective of whether SOR volunteers for recapitalization or not.

In order to understand the key results in Chapters 2 to 4, a working knowledge of discrete-time stochastic modeling and optimization is required.

The work presented in this thesis is based on a book (see [103]), 2 peer-reviewed international journal articles (see [51] and [105]), 2 peer-reviewed chapters in books (see [104] and [110]) and 4 peer-reviewed conference proceedings paper (see [23], [106], [107] and [109]).

Key Words: Discrete-Time Modeling; Basel II; Subprime Mortgage Crisis (SMC); Bank Bailouts; Credit Risk; House Prices; Loan-to-Value Ratio (LTVR); Subprime Residential Mortgage Loans (RMLs); Mortgage Interest Rates; Liquidity;

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Key Definitions

In this section, we provide definitions of some of the key concepts discussed in the book. 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 United States 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. Mortgage 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 loanholder¹, 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

¹In 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 judgment.

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 an 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 hybrid² – 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

²A 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.

³Alternatively, 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 is 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 mortgages 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 welfare⁴.

⁴Social 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
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 - United States 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 - United States Department of Housing and Urban Development
IDS - Insured Depository Institution
IMF - International Monetary Fund
IO - Interest-Only
ISOR - Investing Subprime Originator
IRB - Internal Ratings Based
LCR - Loss Coverage Ratio
LGD - Loan Loss Given Default
LIBOR - London InterBank Offered Rate
LLP - Loan Loss Provision
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
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
PPIP - Legacy Securities Public-Private Investment Program
PV - Present Value
RBS - Royal Bank of Scotland
RMBS - Residential Mortgage-Backed Security
RML - Residential Mortgage Loan
RMP - Residential Mortgage Product
ROA - Return-on-Assets
ROE - Return-on-Equity
RPMF - United States Federal Reserve Primary Money Fund
RWA - Risk-Weighted Asset
SBA - Small Business Administration
SCAP - Supervisory Capital Assessment Program
SDB - Subprime Dealer Bank
SEC - United States 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
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 - United States 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
WTIC - Willingness-to-Incur-Costs
XS - Excess Spread

Index of Symbols

M - Face Value of mortgages
 C^s - Claims by the Sen Tranche
 C^m - Claims by the Mezz Tranche
 C^e - Claims by the Jun Tranche
 N - Value at which RMBS Tranches Detach
 B - Face Value of RMBSs
 T - Treasuries
 r^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
 \tilde{O}^c - Over-collateralization Target
 r^c - CDS Rate
 \mathbb{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^e - 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
 L - Loan-to-Value Ratio

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
 E - Expected Value
 δ - Discount Rate
 l - Low mortgage Demand
 h - High mortgage Demand
 S - Subsidies
 β - Deadweight Loss to Society
 r^S - Default Rate
 x_t - Exogenous Stochastic Variable
 σ - Zero-mean Stochastic Shock
 N - Cash Reserves
 τ - Tax
 \mathbf{N} - Nett Cash Flow
 c_t^{dw} - Deadweight Cost
 \tilde{B} - Social Benefits
 \tilde{S} - Social Costs
 r_t^p - Penalty Rate
 \mathbf{O} - Subordinated Debt.

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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 United States 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, United States), 2009.

When United States 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 United States government sponsored enterprises (GSEs) with major consequences for credit and financial markets around the globe.

Subprime mortgage 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. Addressing their risk required a particular design feature linked to house price appreciation (see, for instance, [55]). The primary financing method of subprime mortgage was 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, [55]). 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 prime² 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.

Our next area of interest is subprime data (see Chapter 3 for more information), where we explore issues related to subprime data. In particular, we present mortgage level data and forge connections with the results presented in Chapters 2. As far as subprime bank bailouts are concerned, in Chapter 4, Treasuries shifted directions several times and ultimately invested most of the first \$ 350 billion of TARP funds directly into the banking industry. It did so by buying preferred equity, which is a little like equity and a little like debt. Preferred equity earn dividends like common equity but can be redeemed at the full issue price like a bond at maturity. The government (G) also bought warrants, which give the holder the right to buy common equity at a fixed price at a later date. If the value of the common equity goes up, so do the warrants.

¹Approximately 80 % of United States mortgages issued in recent years to subprime MRs were ARMs (see, for instance, [40]).

²From 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.

In short, this thesis will demonstrate that the SMC was caused by procyclicality in the housing market, MR speculation, origination of high-risk mortgages and lending/borrowing 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. These can be summarized as intricacy and design of subprime mortgage as well as systemic agents led to information (loss, asymmetry and contagion) problems, valuation opaqueness and ineffective risk mitigation. 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. Most importantly, we will conduct an in-depth study of the value to crisis recovery of subprime bank bailouts.

1.1 Literature Review

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

1.1.1 Literature Review of the SMC

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 [34] examines the different factors that have contributed to the SMC (see, also, [6] and [55] and Sections 2.2, 2.3 and 2.4 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 in common with our contribution. Furthermore, this article discusses the aforementioned issues and offers recommendations to help avoid future crises (compare with [52] and [120]).

1.1.2 Literature Review of Subprime Mortgages and Bank Capital

The research conducted on subprime mortgage in this article has connections with several strands of existing literature. In [7], 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 [39] firstly quantifies how different determinants contributed to high delinquency and foreclosure rates for vintage 2006 mortgages (see, also, [21]). By contrast, we investigate what impact the decline in house prices had on SORs' profits (see Subsection 2.3.1 for more details). 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, [55]). Their analysis suggests that different loan-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. The numerical example presented in Subsection 2.5.2 touches on issues related to such deterioration. Thirdly, Demyanyk and Van Hemert show that mortgage quality deterioration could have been detected before the SMC³ (see, also, [52] and [120]). The recent paper [25] 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, [29] shows that the mortgage structure has important implications for tenure decisions, house prices and mortgage pricing.

The article [36] 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 Subsection 2.2.1 for our take on this issue). We concur with these conclusions in Subsection 2.2.2 and subsequent discussions in Subsection 2.6.1.2.

The paper [31] 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, [94] and [95]). 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, [31] 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. In Subsection 2.2.3 (see Subsection 2.6.1.3 for a more comprehensive discussion) and Subsection 2.3.3 (see, also, Subsection 2.6.2.3) we add to the debate on this matter.

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 originations in 2007 (see, for instance, [66]). Also, this period was typified by accelerated market expansion, deteriorating underwriting standards, declining mortgage performance and decreasing risk premiums. As far as the latter is concerned, in Subsections 2.2.1 and 2.6.1.1, 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. Before the SMC,

³We consider "before the SMC" to be the period prior to July-August 2007 and "during the SMC" to be the period thereafter.

the average difference between prime and subprime mortgage interest rates (the *subprime markup*) declined quite dramatically. The paper [44] claims that, compared with other countries, during the boom, the United States 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 United States housing boom was always more likely to end badly than the booms elsewhere. The credit ratings that accompanied booms and busts are discussed in [123] (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 [46], [62] and [96]. In our research, we find a time-independent solution for a SOR's optimal valuation problem (compare with our discussion in Subsection 2.3.2).

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 2.4 together with our discussion on Subsection 2.6.4). Since the release of the Second Consultative Paper [10], many studies have assessed empirically the magnitude of procyclicality in the IRB capital formula (see, for instance, [70]). 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 2.3 and our discussion in Subsection 2.6.2). While not providing an in-depth discussion of the first of the aforementioned problems, Chapter 3 focusses strongly on issues related to subprime data (see, for instance, [10] 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 [27] 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 [27] 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 2.6.4).

1.1.3 Literature Review of Subprime Data

In the article [6], 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 3.1.2 and 3.2.2).

The paper [111] 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). He 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 3.1.3 and 3.2.3).

This paper [113], studies loss given default using a large set of historical loan-level default and recovery data of high loan-to-value residential mortgages from several private mortgage insurance companies. Authors show that loss given default can largely be explained by various characteristics associated with the mortgage, the underlying property, and the default, foreclosure, and settlement process. They find that the current loan-to-value ratio (CLTVR) is the single most important determinant. More importantly, mortgage loss severity in distressed housing markets is significantly higher than under normal housing market conditions. These findings have important policy implications for several key issues in Basel II implementation (see Subsection 2.5.3 and the discussion on Subsection 2.6.3.3).

1.1.4 Literature Review of Subprime Bank Bailouts

The working paper [127] claims that if a bank faces potential failure, it will be tempted to reject safe mortgages and accept risky mortgages in order to shift risk onto its creditors. In this paper, the authors analyze the effectiveness of buying troubled mortgages, preferred stock as well as common stock from problematic banks. If bailouts for banks that are deemed "too-big-to-fail" involve buying assets at above fair market values, then these banks are encouraged *ex ante* to gamble on risky assets. The authors of [127] assert that buying up common (preferred) stock is always the most (least) *ex ante*- and *ex post*-efficient type of capital infusion whether or not the bank volunteers for the recapitalization. Also, [126] adds that efficient lending and voluntary participation can be

best achieved without subsidy by purchasing either toxic RMBSs or common stock. Nevertheless, troubled banks must be subsidized if they will voluntarily participate in any recapitalization. Our analysis is consistent with the findings of these two papers by providing a theoretical model that analyzes the relative merit of purchasing toxic RMBSs, purchasing preferred equity and common stock recapitalizations (see Subsections 4.2.2, 4.3.2 and 4.4.2).

The paper [69] analyzes United States bank closures during 1992-1997 and finds that only banks performing significantly worse than the industry are closed. [24] discusses failures among large banks in 21 major emerging markets in the 1990s and show that the government decision to close or take over a failing bank depends on the financial health of other banks in that country. [14] and [128] assert that common stock is the best way to recapitalize banks (see Subsections 4.6.1, 4.6.2 and 4.6.3 in Section 4.6). The former advocates mandatory rights offerings to force banks to increase the common stock component of their capital structure. The latter advocates a mandatory debt-for-equity swap in the financial sector to achieve a higher equity-to-assets ratio for banks. [13] argues that the Treasury should not overpay for troubled assets and should not mix the buying of distressed assets with direct bank capital injections. Chapter 4 has G buying toxic RMBSs in the troubled SOR only. We find that common equity recapitalizations weakly dominate purchases of such RMBSs. [59] proposes that Troubled Asset Relief Program (TARP) should not pay hold-to-maturity prices for the troubled assets but rather a lower price aiming at providing liquidity for a 3-5 year window. He also suggests that direct capital injection through equity investment is more effective than purchasing troubled assets. Chapter 4 supports these papers' intuition that forced common equity recapitalizations are first-best efficient. In contrast, we consider the case where the regulator lacks the credibility or the political will to force recapitalizations. In that case, our research still finds common stock cash infusions are weakly the most efficient (see Subsections 4.6.1, 4.6.2 and 4.6.3 in Section 4.6).

1.2 Preliminaries about Subprime Mortgage Models

In this section, we provide preliminaries about the SMC, subprime mortgages, subprime risk, the connection between Basel capital regulation and the SMC, subprime bank bailouts 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 SMC

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

1.2.1.1 Diagrammatic Overview of the SMC

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

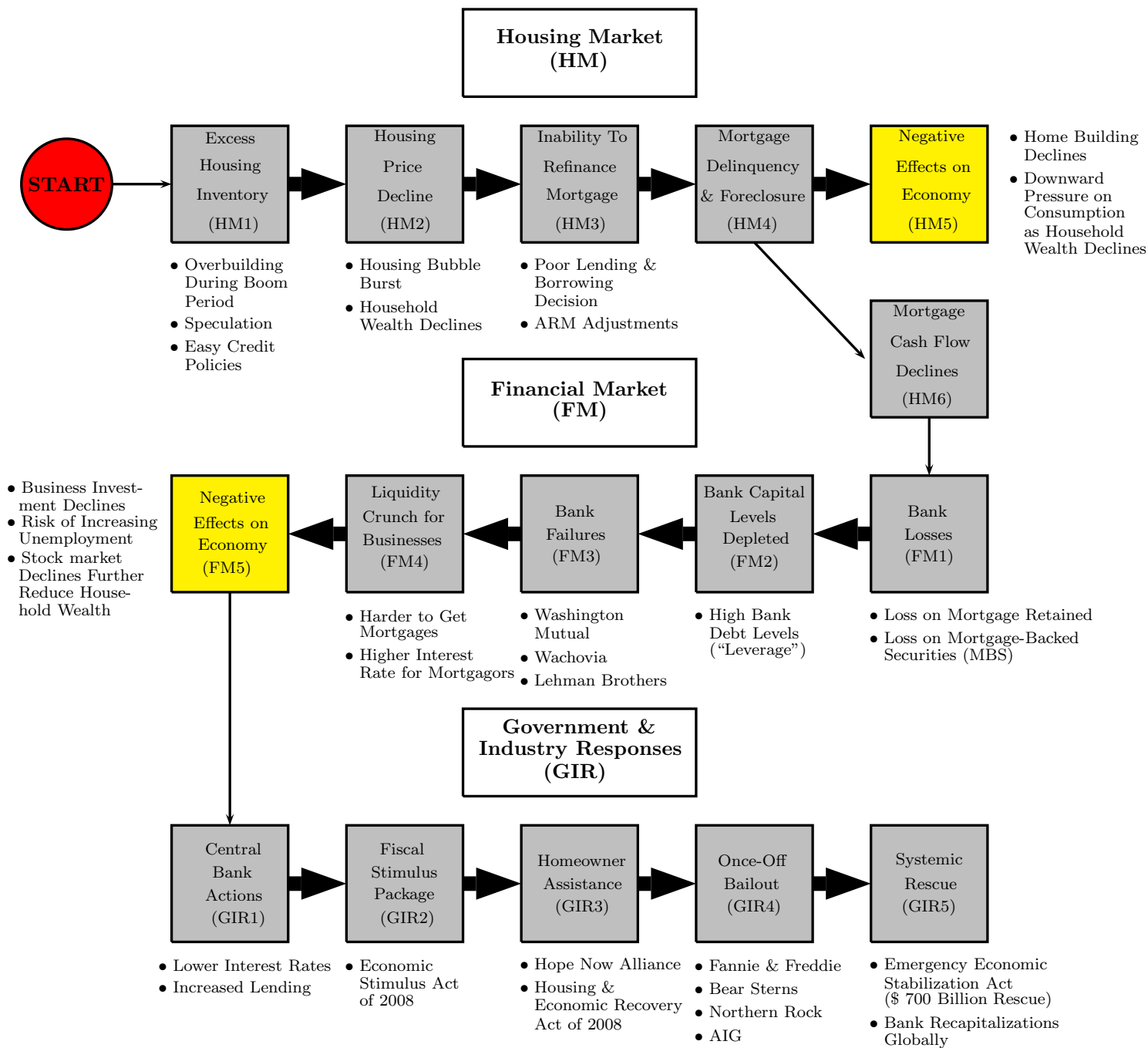


Figure 1.1: Diagrammatic Overview of the SMC

1.2.1.2 Description of the SMC

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 1.1 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 United States housing prices started to fall moderately in 2006-2007, refinancing became more difficult (see HM2 and HM3 in Figure 1.1 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 Chapters 2 to 3 for timeline of SMC events). During 2007, nearly 1.3 million United States housing properties were subject to foreclosure activity, up 79 % from 2006 (see [115] for more details; also HM4 in Figure 1.1 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 1.1) and Chapter 2).

Major SORs around the world reported losses (see [48] and [97]; also FM1 in Figure 1.1 and Chapter 2). Also, capital adequacy ratios declined as capital levels became depleted while banks were highly leveraged (see FM2 in Figure 1.1 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 1.1). 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 1.1). 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 1.1).

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 1.1 and Chapter 4). With interest rates on a large number of subprime and other ARMs due to adjust upward during the 2008 period, United States legislators, the United States 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 United States Federal Reserve to cut interest rates and the passing of the Economic Stimulus Act (ESA) in February 2008 (see, for instance, [8] and [47]; also GIR2 in Figure 1.1 and Chapter 4). 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 United States government and private industry to help some subprime MRs called the Hope Now Alliance (see GIR3 in Figure 1.1). The United States government also offered bail outs to key financial institutions, thus raising additional financial commitments (see GIR4 in Figure 1.1 and Chapter 4). Following a series of ad-hoc market interventions to bailout particular firms, a \$ 700 billion systemic rescue plan was accepted by the United States 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 1.1 and Chapter 4). By October 2008, banks in Europe, Asia, Australia and South America had followed the example of the United States 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, credit ratings. In particular, we specify the components of total capital and risk-weighted assets that we use in our study. We follow [51] 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 Subsection 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, [93]). 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 cyclicity 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

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

where Λ , \widehat{B} , \widehat{R} , \widehat{T} , \widehat{D} , \widehat{B} , n , \widehat{E} , \widehat{O} , \widehat{E}_t^c and \widehat{E}_t^p 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

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

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

$$\Lambda_t = \lambda_0 - \lambda_1 r_t^\Lambda + \lambda_2 C_t + \sigma_t^\Lambda. \quad (1.2)$$

where r_t^Λ is the loan rate, 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.

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_t^B . 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{T}_t , and the Treasury rate by r^T . SOR takes deposits, \widehat{D}_t , at a constant *marginal cost*, c_t^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 $r^D < r^T$.*

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 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 $[0, \overline{D}]$.*

This assumption implies that the *cost of liquidation*, c^l , or additional external funding is a quadratic function of T . In addition, for any t , if we have that $u > \widehat{T}_t$, then SOR assets are liquidated at some *penalty rate*, r_t^p . In this case, the *cost of Treasuries* is $P^{\widehat{T}_t}(\widehat{T}_t) = r_t^p \int_{\widehat{T}_t}^{\infty} [u - \widehat{T}_t] f(u) du = \frac{r_t^p}{2\overline{D}} [\overline{D} - \widehat{T}_t]^2$, with $P^{\widehat{T}_t}(\widehat{T}_t)$ 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{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^B and c^B , respectively. Of course, when SOR borrows from the Central Bank, we have $r^B = r^L$.

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 $f_t \in \mathfrak{R}_0^+$ 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, SOR's 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 [51] (see, also, [30]), SOR's *total capital constraint* is given by

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

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

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

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

$$\begin{aligned} \widehat{J}_t = & \widehat{\Pi}_t + l_t \left[\widehat{K}_t - \rho \left(\omega(\mathcal{C}_t) \Lambda_t + \omega^B \widehat{B}_t + 12.5(mVaR + 0) \right) \right] \\ & - c_t^{dw} \left[\widehat{K}_{t+1} \right] + \mathbf{E}_t \left[\delta_{t,1} \widehat{V} \left(\widehat{K}_{t+1}, x_{t+1} \right) \right], \end{aligned} \quad (1.5)$$

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

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

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

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

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

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

and

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

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, $\bar{c}^{\Lambda\omega}$ 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 [51] 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

$$\Lambda_t^* = \frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^{\mathbb{B}}\widehat{B}_t + 12.5(mVaR + 0)}{\omega(\mathcal{C}_t)} \quad (1.11)$$

and

$$r_t^{\Lambda*} = \frac{1}{\lambda_1} \left(\lambda_0 + \lambda_2 \mathcal{C}_t + \sigma_t^\Lambda - \frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} + \frac{\omega^{\mathbb{B}}\widehat{B}_t + 12.5(mVaR + 0)}{\omega(\mathcal{C}_t)} \right), \quad (1.12)$$

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

$$\begin{aligned}\widehat{D}_t^* &= \frac{1}{(1-\gamma)} \left(\overline{D} + \frac{\overline{D}}{r_t^P} \left[r_t^T + (r_t^B - c_t^B) + (r_t^B + c_t^B) - \frac{1}{1-\gamma} (r_t^D + c_t^D) \right] + \frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B \widehat{B}_t + 12.5(mVaR + 0)}{\omega(\mathcal{C}_t)} \right. \\ &\quad \left. + \widehat{B}_t - \widehat{K}_t - \widehat{B}_t \right),\end{aligned}$$

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

and

$$\begin{aligned}\widehat{\Pi}_t^* &= \left(\frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B \widehat{B}_t + 12.5(mVaR + 0)}{\omega(\mathcal{C}_t)} \right) \\ &\quad \left\{ \frac{1}{\lambda_1} \left(\lambda_0 - \frac{\widehat{K}_t}{\rho\omega(\mathcal{C}_t)} + \frac{\omega^B \widehat{B}_t + 12.5(mVaR + 0)}{\omega(\mathcal{C}_t)} + \lambda_2 \mathcal{C}_t + \sigma_t^\Lambda \right) \right. \\ &\quad \left. - \left(\overline{c}_t^{\Lambda\omega} + (r_t^D + c_t^D) \frac{1}{1-\gamma} \right) \right\} - \left((r_t^D + c_t^D) \frac{1}{1-\gamma} \right) \left(\widehat{B}_t - \widehat{K}_t - \widehat{B}_t \right) \\ &\quad + \left(\overline{D} + \frac{\overline{D}}{r_t^P} \left[r_t^T + (r_t^B - c_t^B) + (r_t^B + c_t^B) - \frac{1}{1-\gamma} (r_t^D + c_t^D) \right] \right) \left(r_t^T - (r_t^D + c_t^D) \frac{1}{1-\gamma} \right) \\ &\quad + \left(r_t^B - c_t^B \right) \widehat{B}_t - \left(r_t^B + c_t^B \right) \widehat{B}_t - P^{\widehat{T}}(\widehat{T}_t),\end{aligned}$$

respectively.

1.2.3 Preliminaries about Subprime Mortgage Models

Next, we introduce a subprime mortgage model with default to explain aspects of the SMC.

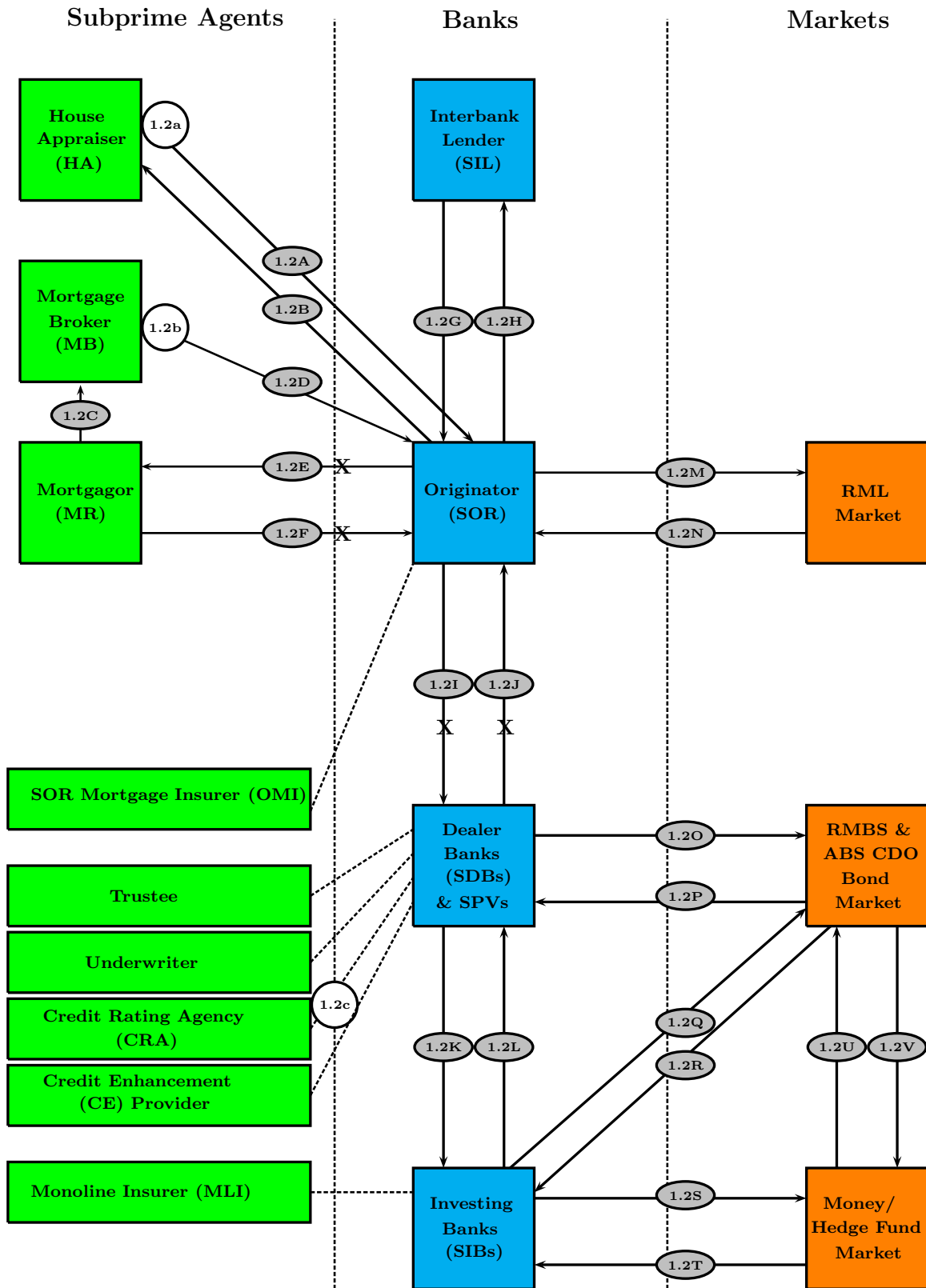


Figure 1.2: Diagrammatic Overview of a Subprime Mortgage Model With Default

Figure 1.2 presents a subprime mortgage model involving ten subprime agents, four banks and three

types of markets. As far as subprime agents are concerned, we note that circles **1.2a**, **1.2b** and **1.2c** represent flawed independent checks by house appraisers (HAs), mortgage brokers (MBs) and credit rating agencies (CRAs), respectively. Regarding the former agent, the process of subprime mortgage is flawed with house appraisers not performing their duties with integrity and independence. According to [26] 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 **1.2D**, independent MBs arrange mortgage deals and perform checks of their own while SOR originates mortgages to MRs in **1.2E**. Subprime MRs generally pay high mortgage interest rates to compensate for their increased risk from poor credit histories (compare with **1.2F**).

SOR mortgage insurers (OMIs) compensate SORs for losses due to mortgage defaults. Several subprime agents interact with the SDB and SPV. For instance, the trustee holds or manages and invests mortgages and RMBSs for the benefit of another. Also, the underwriter is a banking agent who assists the SPV in underwriting new RMBSs. CRAs rate the RMBSs and CE providers devise a method of reducing the risk of securitizing mortgages. Monoline insurers (MLIs) guarantee the repayments of bonds such as, for instance, the senior tranches of RMBSs and ABS CDOs.

In monoline insurance⁴, default risk is transferred from the bondholders - in our case SIBs - to the MLIs. SIBs are only left with the residual risk that the MLI will default. Given the low perceived risk of these products, MLIs generally have very high leverage, with outstanding guarantees often amounting to 150 times capital. MLIs carry enough capital to earn AAA ratings and as a result often do not have to post collateral. As a consequence, MLIs make bond issues 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.

SOR has access to subprime mortgage investments that may be financed by borrowing from SIL, represented by **1.2G**. 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 **1.2H**. Next, the SOR deals with the mortgage market represented by **1.2M** and **1.2N**, respectively. Also, the SOR pools its mortgages and sells them to dealer banks (SDBs) and SPVs (see **1.2I**). The SDB or SPV pays the SOR an amount which is slightly greater than the value of the pool of mortgages as in **1.2J**. A SDB or SPV is an organization formed for a limited purpose that holds the legal rights over mortgages transferred by SORs during securitization. In addition, the SDB or SPV divides this pool into sen, mezz and jun tranches which are exposed to different levels of credit risk. Moreover, the SDB or SPV sells these tranches as securities backed by subprime mortgages to subprime investing banks (SIBs) (see **1.2L**) that is paid out at an interest rate determined by the mortgage default rate, prepayment and foreclosure (see **1.2K**). Also, SDBs and SPVs deal with the RMBS and asset-backed security (ABS) collateral debt obligation (CDO) bond market for their own investment purposes (compare with **1.2O** and **1.2P**). Furthermore, SORs have securitized mortgages on their balance sheets, that have connections with

⁴The 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. However, the SDB has to pay a price for this as the MLI must be paid. In a perfect efficient, MLIs would be superfluous as the cost of insuring bonds would have a value equal to the savings from the lower risk premium. 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.

the RMBS and ABS CDO bond market. SIBs invest in this bond market, represented by **1.2Q** and receive returns on securities in **1.2R**. The money market and hedge fund market are secondary markets where previously issued marketable securities such as RMBSs and ABS CDOs are bought and sold (compare with **1.2U** and **1.2V**). In return, SIBs invest in these short-term securities (see, **1.2S**) to receive profit, represented by **1.2T**. During the SMC, the model represented in Figure 1.2 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. Additional agents such as G and deposits belong in the sketch but not included.

We note that the traditional mortgage model is embedded in Figure 1.2 and consists of the agents, MR, SIL and SOR as well as the mortgage market. In this model, SIL lends funds to SOR to fund mortgages (see, **1.2G** and **1.2H**). Home valuation as well as income and credit checks were done by the SOR before issuing the mortgage. The SOR then extends mortgages to MRs and receives mortgage payments in return, which are represented by **1.2E** and **1.2F**, respectively. The SOR also deals with the mortgage market in **1.2M** and **1.2N**. When a MR defaults on repayments, the SOR repossesses the house.

1.2.3.1 Subprime Mortgages and Their Financing

Securitization is the main method for financing mortgage by subprime SORs⁵. The following table illustrates the extent to which SORs relied on securitization for the financing of subprime mortgages.

Mortgages 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: Subprime Mortgages and Subprime Securitization; Source: [65]

Table 1.2 provides an indication of the quantitative importance of subprime mortgage securitizations. The said table shows that subprime mortgage in 2005 and 2006 was about \$ 1.2 trillion of which 80 % was securitized.

⁵Prominent subprime SORs are Ameriquest, Countrywide Financial, New Century and Option One.

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*. The most fundamental of the above risks is *credit* and *market risk*. In Figure 1.3 below, we provide a diagrammatic overview of the aforementioned subprime risks.

1.2.4.1 Diagrammatic Overview of Subprime Risks

In Figure 1.3 below, we provide a diagrammatic overview of the aforementioned subprime risks.

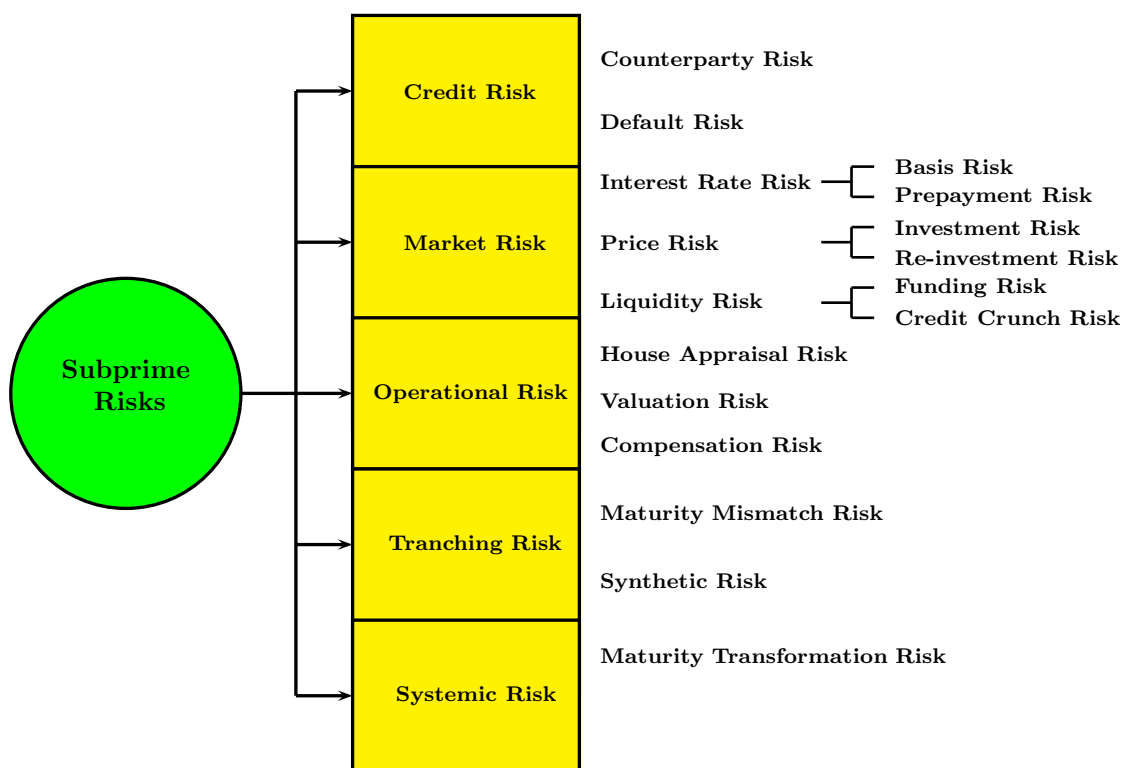


Figure 1.3: Diagrammatic Overview of Subprime Risks

1.2.4.2 Credit Risk

In Figure 1.4 below, we provide a diagrammatic overview of credit risks and its relationship with investor returns.

From Figure 1.4 it is clear that top-level tranches contain the highest quality but lowest paying RMBS bonds. Even though a RMBS may be funded from a reference mortgage portfolio contain-

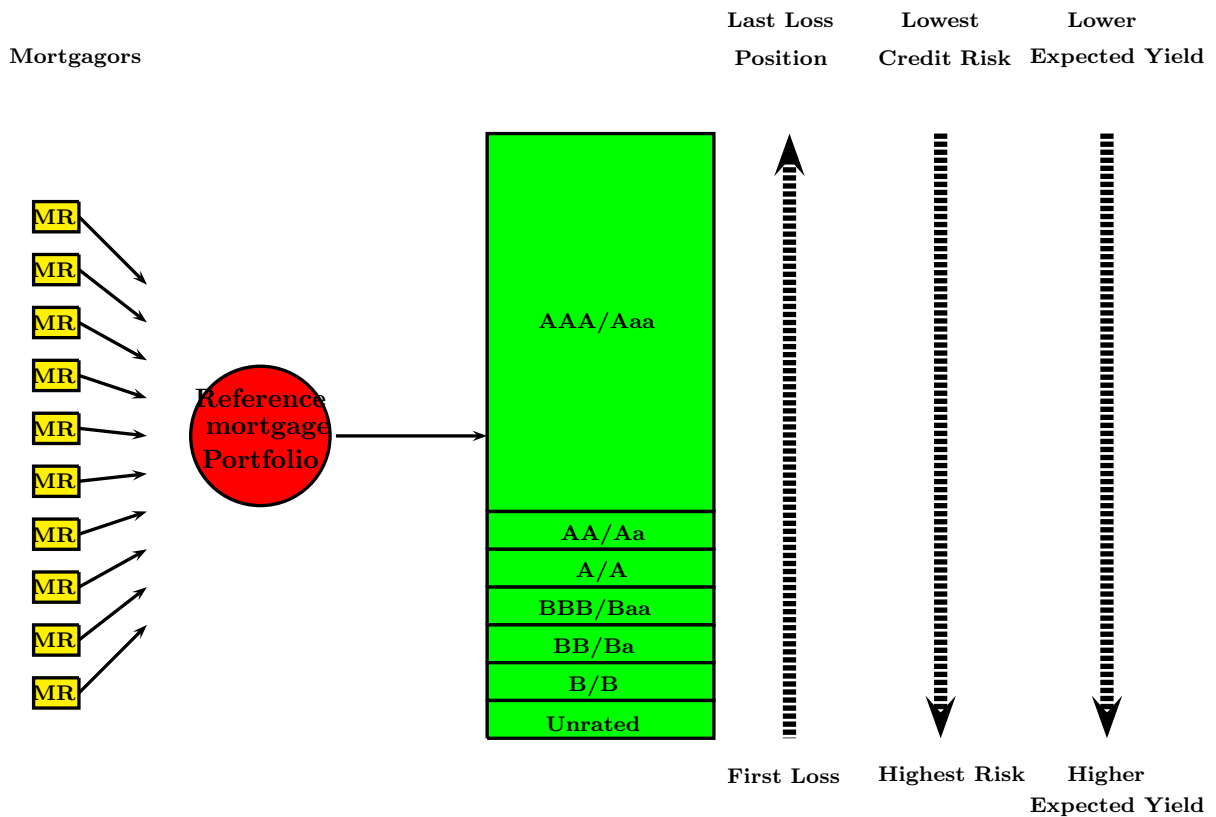


Figure 1.4: Diagrammatic Overview of Risk and Return for Investors

ing subprime mortgages, the top tranches can have investment grade status of AAA-rated bonds because they are paid first from the portfolio. On the other hand, low-level tranches contain the riskiest but highest paying RMBS bonds. They receive a low rating from CRAs and are paid off after the AA- and AAA-rated RMBS bonds are paid.

Credit risk 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. 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. During the SMC, even banking agents who thought they had hedged their bets by buying insurance – via credit default swap contracts or MLI insurance – still faced the risk that the insurer will be unable to pay.

1.2.4.3 Market Risk

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. *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. 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 loan 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. 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.

In the early '80s, in many European countries and the United States, house financing changed from fixed-rate (FRMs) to adjustable-rate mortgages (ARMs) with the interest rate risk shifting 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 lost perhaps forgotten, perhaps also neglected because, after all, the credit risk would affect the RMBS bondholders rather than the SORs (see, for instance, [61]). 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 United States 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.

1.2.4.4 Operational Risk

Operational risk is the risk of incurring losses resulting from insufficient or inadequate procedures, processes, systems or improper actions taken (see [68]). As we have commented before, for subprime mortgage, operational risk involves documentation, background checks and the integrity of loan process. Also, mortgage securitization embeds operational risk via mis-selling, valuation and SIB issues. Operational risk related to mortgage and securitization results directly from the design and intricacy of loans and 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, [26]).

BBB-Rated Subprime RMBS Issuance & Exposure in Mezzanine ABS CDOs Issued in 2005-2007 to BBB-Rated Subprime RMBS (\$ Billions)					
	2004	2005	2006	2007	2008
BBB-Rated Subprime RMBS Issuance	12.3	15.8	15.7	6.2	4.9
Exposure of Mezzanine ABS CDOs Issued In 2005-2007	8.0	25.3	30.3	2.9	2.5
Exposure as a Percent of Issuance	65	160	193	48	31

Table 1.3: BBB-Rated Subprime RMBS Issuance & Exposure in Mezzanine ABS CDOs Issued in 2005-2007 to BBB-rated Subprime RMBS (\$ Billions); Source: Federal Reserve Calculations, cited by Basel Committee on Banking Supervision (April 2008)

1.2.4.5 Tranching Risk

Tranching risk is the risk that arises from the intricacy associated with the slicing of securitized mortgages into tranches in securitization deals. Subcategories of tranching risk are maturity mismatch and synthetic risks. In particular, *maturity mismatch risk* results from the discrepancy between the economic lifetimes of RMBSs and the investment horizons of SORs. *Synthetic risk* can be traded via credit derivatives (mainly CDSs) referencing individual subprime RMBS bonds, or via an index linked to a basket of such bonds. In this regard, dealer banks launched the ABX.HE⁶ (ABX) index in January 2006. For our purposes, the main point is that risk can be traded synthetically via credit derivatives. Such risk cannot be created on nett because these are derivatives, but the identities of the longs and shorts are not known as this market is over-the-counter (OTC). Table 1.3 show approximations of the amount of BBB-rated subprime RMBS issuance over 2004-07 and the exposures of mezz CDOs issued in 2005-07 to those vintages of BBB-rated subprime RMBS.

Clearly, mezz CDOs issued in 2005-07 used CDSs to take on significantly greater exposure to the 2005 and 2006 vintages of subprime BBB-rated RMBS than were actually issued. This suggests that the demand for exposure to riskier tranches of subprime RMBS by far exceeded supply. The additional risk exposure was created synthetically although, on nett, there is no new risk. In addition, synthetic CDOs, relying completely on derivatives became increasingly important. Prior to 2005, the portfolios of ABS CDOs were mainly made up of cash securities. After 2005, CDO managers and underwriters began using CDS referencing individual ABSs, creating synthetic exposures. *Synthetic CDOs* are CDOs with entirely synthetic portfolios while the portfolio of a *hybrid CDO* consists of a mix of cash positions and CDSs. CDO managers and underwriters used synthetic exposures to meet the growing investor demand for ABS CDOs and to cater to investors' preferences to have particular exposures in the portfolio that may not have been available in the cash market. CDO managers and underwriters were able to use CDS to fill out an ABS CDO's portfolio when cash ABS, particularly mezz ABS CDO tranches, were difficult to obtain.

Besides the problems posed by estimation of reference mortgage portfolio loss distribution, tranch-

⁶The ABX Index is a credit derivative that references 20 equally-weighted RMBS tranches. There are also indices comprising sub-index references 20 subprime RMBS bonds with the rating level of the subindex. Every six months the indices are reconstituted based on a pre-identified set of rules. The index is overseen by Markit Partners. The dealers provide Markit Partners with daily and monthly marks.

ing requires in-depth, deal-specific documentation to ensure that desired characteristics, such as the seniority ordering of tranches, will prevail in all situations. In addition, this intricacy may be amplified by the involvement of regret-averse asset managers and other parties, whose own incentives to act in the interest of some investor classes at the expense of others may need to be curtailed. With increased complexity, less sophisticated SORs have more difficulty understanding RMBS tranching and thus a diminished capacity to make informed investment decisions about related structured notes. For instance, tranches from the same deal may have different risk, reward and/or maturity characteristics. Modeling the performance of tranching transactions based on historical performance may have led to the over-rating (by CRAs) and underestimation of risks (by SORs) of asset-backed securities with high-yield debt as their underlying assets. These factors have contributed towards the SMC.

1.2.4.6 Systemic Risk

In banking, *systemic risk* is the risk that problems at one bank will endanger the rest of the banking system. 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.

1.2.4.7 Chain of Subprime Risk

In Table 1.4 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 mortgage 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	Subprime 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 1.4: Chain of Subprime Risk and Securitization; Compare with [55]

Table 1.4 implies that SIBs 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 SIBs likely relied on repeated relationships, bankers and on credit ratings. Essentially, SIBs 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 section we discuss the different statistical techniques which are used analyze data. The techniques include time series analysis, linear regression, logit regression, hazard regression, t -statistics as well as F -test. In this thesis, we consider data from LoanPerformance, ABSNET, Bloomberg 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, [6], [36], [49], [55] and [111]. Some brief preliminaries about time series analysis, linear and logit regression, the Cox-Proportional Hazard Model, t -distributions as well as F -tests are considered in the rest of this subsection.

1.2.5.1 Time Series Analysis

Time series is a chain of processes which show a discrepancy over time. The chain of processes can either be a continuous or discrete movements. Most importantly time series can be used to smooth, forecast, control as well as modeling events. It differs from other analysis techniques by having a natural temporal ordering.

1.2.5.2 Linear Regression

Linear regression is used to model the relationship between a scalar variable and one or more variables. Under this technique, if parameters of the models are not known, they can be estimated from the data using linear models. The objectives of the linear regression are either prediction or forecasting as well as measuring the strength between the scalar variable and other one or more variables. The most common method to fit a linear regression is by using a least square-method.

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 an event happening by fitting data into a logit function logistic curve. It can be used to predict variables that may be either numerical or categorical. Logit function can be defined as

$$f(z) = \frac{\exp^z}{\exp^z + 1} = \frac{1}{1 + \exp^{-z}},$$

where z represents the exposure to some set of independent variables and $f(z)$ represents the probability of a particular outcome, given that set of explanatory variables. z is defined as

$$z = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_kX_k,$$

where b_0 is the intercept and $b_1, b_2, b_3 \dots b_k$ are the regression coefficients.

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.

1.2.5.5 t -Distribution

A t -distribution is a continuous probability distribution is used to approximate the the mean of a normally distributed population when the sample size is small. It has a probability density function

$$f(t) = \frac{\Gamma\left(\frac{\nu+1}{2}\right)}{\sqrt{\nu\pi} \Gamma\left(\frac{\nu}{2}\right)} \left(1 + \frac{t^2}{\nu}\right)^{-(\nu+1)/2},$$

where ν is the number of degrees of freedom and Γ is the Gamma function. A t -distribution differs from the normal distribution by its degrees of freedom. The higher the degrees of freedom, the closer that distribution will resemble a standard normal distribution with a mean of 0, and a standard deviation of 1. t -distribution can be applied on (a) testing differences between means of two samples; (b) testing differences from zero of estimated parameters in regression analysis and experimental design; and (c) evaluation of confidence intervals for means and other estimated quantities.

1.2.5.6 F -Test

A 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. The 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. In this case, the formula for F is simply

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

The variances are arranged so that $F > 1$ with $s_1^2 > s_2^2$. The 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 the 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 3.11 and 3.15.

1.2.6 Preliminaries about Subprime Bank Bailouts

In this subsection, we discuss bank bailouts and their dynamics, provide diagrammatic overviews of United States bank bailouts as well as comment on the economic equilibrium appearing in this thesis chapter. In the sequel, the superscripts "v" and "nv" denote present value (PV) and nett present value (NPV), respectively.

1.2.6.1 Subprime Bank Bailout Agents

Throughout Chapter 4, we consider an economy with periods, $t - 1$, t and $t + 1$, and four main agents, viz., SOR, SIL, G – which is the bailout agency – as well as (subprime) MRs. In the aforementioned chapter, all economic agents are considered to be risk-neutral. Subprime risks are important for loan agreements such as those for subprime mortgages and the risky marketable securities associated with them such as RMBSs. In Chapter 4, we consider SOR's investment in period $t - 1$ to be exclusively in toxic RMBSs rather than mortgages. The arguments, however, are equally applicable to both. The following assumption can be made about the SOR and G as well as their relationship.

Assumption 1.2.6 (Subprime Originators's RMBSs Investment Decision, Insolvency, Liquidity, Equity and Lending Policy): *Suppose that the subprime RMBSs on SOR's balance sheet are at PV⁷ and denoted by B_t^v . In period $t - 1$, we assume that SOR will undertake RMBS investment only if its expected returns strictly exceed the returns in the Treasuries, so that*

$$\mathbf{E}[r_t^{Bv} B_t^v] > r_t^T T_t.$$

We suppose that SORs have not failed in their present states but may become insolvent in future and that they do not have liquidity problems. Furthermore, we assume that in period t , SOR's

⁷In our case, the present value of a subprime RMBSs is the value on a given date of a future RMBS payment or series of future RMBS payments, discounted to reflect the time value of money and other factors such as investment risk.

equity capital at PV is less than the total deposits at PV, so that

$$E_t^v < D_t^v.$$

Lastly, we suppose that G cannot override SOR 's lending policy.

In part, the above assumptions suggest that SOR s could sell RMBSs to G , while they have sufficient funds to invest in new RMBSs.

Assumption 1.2.7 (Government's Ex-Post Social Returns and Dividends Regulation):

We assume that G acts in the public interest and maximizes ex-post social returns in period t . Furthermore, we suppose that G will provide capital to SOR in period t if this strictly increases ex-post social surplus⁸. Furthermore, we assume that G has the power to regulate the payment of dividends, share buybacks, or cash acquisitions for SOR accepting funds from G . Thus, we will assume that any leverage decreasing capital injection cannot be undone by capital structure adjustments by SOR . SOR will be bailed out by G if its subprime RMBS portfolio investment fails.

In period $t - 1$, SOR and SIL make their investments. The risk-free discount rate, δ , between periods is normalized to $\delta = 0$.

⁸Social surplus is made up of surpluses from SOR , SIL and G . It is the primary measure used in welfare to evaluate the efficiency of a policy.

1.2.6.2 Subprime Bank Bailout Agents Interactions

A diagrammatic overview of subprime bank bailout agent interactions may be represented as follows.

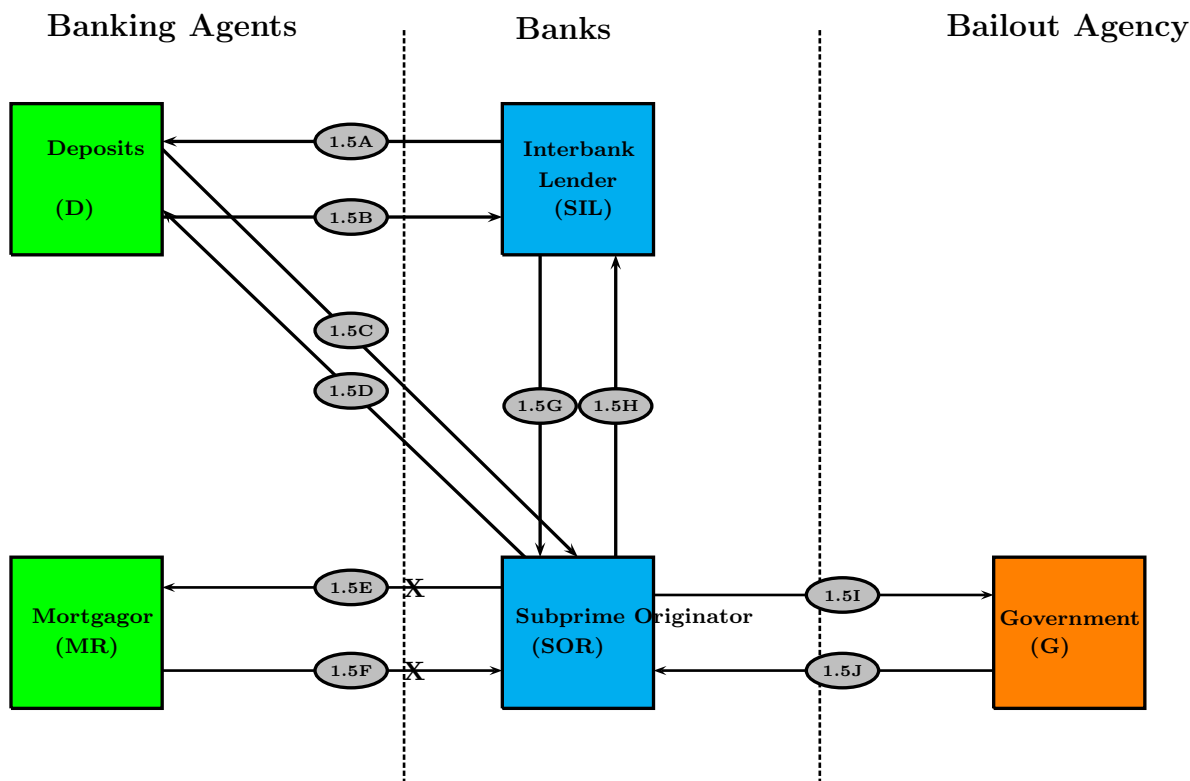


Figure 1.5: Diagrammatic Overview of Bailout Agent Interactions

In Figure 1.5, we have that depositors may choose to either invest their funds in a risk-free asset offering a gross rate of return $\mu^s \geq 1$ or deposit in SIL (see **1.5A** and **1.5B**). SIL's deposits, D^L , are fully protected by comprehensive deposit insurance, so that depositors have an incentive to invest in SIL at a deposit rate $r^{Dnv} \geq \mu^s$. In period $t - 1$, SOR and SIL decide to make their investments. As in [127], in period $t - 1$, SOR has access to subprime mortgage investments that may be financed by borrowing from SIL. SOR also collects deposits, D^v , and may invest them in subprime mortgage projects (see **1.5C** and **1.5D**). SIL, acting in the interest of risk-neutral shareholders, either invests D^L in Treasuries, T, or in SOR's subprime mortgage projects with stochastic returns (compare **1.5G** and **1.5H**).

SOR is a risky subprime originator because it is tempted to make high risk mortgage⁹ investments in period $t - 1$. SOR will only invest in such mortgages if its expected returns are more than the returns from other investments. Both SOR and SIL maximize expected returns to shareholders, therefore, if they fail to pay their depositors back, then their shareholders will not be left with anything. If SOR's project fails, then it will be bailed out by a G via **1.5I** and **1.5J**. G partially finances bailouts by raising lump sum taxes after bank failures have occurred. In addition, SOR securitizes its subprime mortgages and earn a return on the securitization. MR is not aware of the agreement between SIL and SOR and will continue to make mortgage payments at the rate, r^M , which is represented by **1.5E** and **1.5F**. If MR fails to make such payments, SOR and SIL will face default losses.

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, supprime data as well as subprime bank bailouts and Basel capital regulation and their relationship with the SMC.

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, OMI and profits as well as mortgage losses ? (see Subsection 2.3.1 of Section 2.3 in Chapter 2).*

Problem 1.3.3 (Intricacy and Design Leading to Information Problems, Valuation Opaqueness and Ineffective Risk Mitigation): *Was the SMC partly caused by intricacy and design of subprime mortgage that led to information (loss, asymmetry and contagion, systemic risk) problems, valuation opaqueness and ineffective risk mitigation ? (see Sections 2.2, 2.3, 2.4 in Chapter 2).*

Problem 1.3.4 (Optimal Valuation Problem Under Subprime Mortgage): *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 in Subsection 2.3.2 of Section 2.3 in Chapter 2).*

⁹High risk mortgages are defined as mortgages that have a high credit risk associated with it. These mortgages cannot easily be sold or exchanged for cash without a significant loss in value.

Problem 1.3.5 (Mortgages and Capital Under Basel Regulation (Unsecuritized Case)): *What is the effect of changes in credit ratings on SOR's subprime mortgages and capital when the mortgages are unsecuritized ? (see Section 2.4 of Chapter 2).*

Problem 1.3.6 (Examples Involving Subprime Mortgages): *Can we provide appropriate examples to illustrate the main results about subprime mortgages? (see Section 2.5 in Chapter 2).*

Problem 1.3.7 (Examples Involving Subprime Data and the SMC): *Can we rig a numerical example to illustrate the connection between data and the SMC ? (see Subsections 2.5.3 and 2.6.3.3 of Chapter 2).*

Problem 1.3.8 (Defaulting Mortgages): *In the defaulting mortgage case, can we characterize SOR's choices of mortgage, compare preferred equity, common equity and toxic RMBS minimum subsidies and their recapitalizations as well as describe SOR's voluntary participation in bailouts ? (see Propositions 4.2.6, 4.2.7, 4.2.8 and 4.2.9 in Section 4.2 from Chapter 4).*

Problem 1.3.9 (Refinancing Mortgages): *In the refinancing mortgage case, can we characterize SOR's choices of mortgage, compare preferred equity, common equity and toxic RMBS minimum subsidies and their recapitalizations as well as describe SOR's voluntary participation in bailouts ? (see Propositions 4.3.5, 4.3.6, 4.3.7 and 4.3.8 in Section 4.3 from Chapter 4).*

Problem 1.3.10 (Fully Amortizing Mortgages): *In the fully amortizing mortgage case, can we characterize SOR's choices of mortgage, compare preferred equity, common equity and toxic RMBS minimum subsidies and their recapitalizations as well as describe SOR's voluntary participation in bailouts ? (see Propositions 4.4.5, 4.4.6, 4.4.7 and 4.4.8 in Section 4.4 from Chapter 4).*

Problem 1.3.11 (Defaulting vs Refinancing vs Fully Amortizing Mortgages): *How do the defaulting, refinancing and fully amortizing mortgage cases compare with each other in terms of bailouts ? (see Sections 4.2, 4.3 and 4.4 from Chapter 4).*

Problem 1.3.12 (Connections with the SMC): *How do the subprime Mortgages/RMBSs and bank bailout models developed in this thesis chapter relate to the SMC ? (see Section 3.3 and Section 4.6 from Chapter 4).*

1.3.2 General Questions

This thesis specifically seeks to answer the questions posed in Problems 1.3.1 to 1.3.12 and a few more general ones such as

Question 1.3.13 (Basel Capital Regulation and the SMC): *Did Basel capital regulation exacerbate the SMC ?*

Question 1.3.14 (Risk Management Techniques): *Why did contemporary risk management techniques not contribute towards the mitigation of the SMC and its severity ?*

Question 1.3.15 (Market Discipline and Regulation): *Why didn't market discipline and regulation prevent the SMC ?*

Question 1.3.16 (Causes and Consequences of the SMC): *What were the root causes of the SMC and what is its consequences for the real economy ?*

Question 1.3.17 (Cures for the SMC): *What short- and long-term policies will ultimately cure the SMC ?*

Question 1.3.18 (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, information, risk, valuation and bailouts. Furthermore, we review relevant literature on the SMC and Basel capital regulation. 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. This is followed by subprime mortgage and capital under basel regulation (see Section 2.4). In addition we look at numerical examples involving subprime lending, capital, information, risk and valuation (see Section 2.5), discussions on the relationships between the aforementioned issues and the SMC (see Section 2.6), time-line of the SMC (see Section 2.7) and appendices (see Section 2.8).

1.3.3.2 Outline of Chapter 3: Subprime Data

In Chapter 3, Section 3.1 presents the data from the papers [6], [25] and [111]. The data presented relate to subprime mortgage (see Subsection 3.1.1), subprime mortgage securitization (see Subsection 3.1.2) as well securitized and portfolio mortgages (see Subsection 3.1.3). Furthermore we analyze the data on each subsection presented in Section 3.1. The analysis can be found in Subsection 3.2.1, 3.2.2 and 3.2.3 of Section 3.2. We then conclude by investigating the connection the presented data has with our models (see Sections 3.3).

1.3.3.3 Outline of Chapter 4: Subprime Bank Bailouts

Chapter 4 commences with a discussion on defaulting mortgages and subprime bank bailouts in Section 4.2. This involves a background to bank bailouts in the defaulting mortgage case, SOR's mortgages in period t when it purchases toxic RMBSs in period $t - 1$ and a comparison between subsidy and recapitalization strategies. This is followed by Sections 4.3 and 4.4 that provide an analogous treatise to Section 4.2 in the cases where the mortgages are refinancing and fully amortizing, respectively.

In addition, in Section 4.5, we provide examples to illustrate aspects of our subprime bank bailouts while Section 4.6 discusses the main issues emanating from such bailouts. The chapter concludes with a timeline of SMC-related events pertaining to subprime bank bailouts in Section 4.7 and an appendix in Section 4.8.

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 United States 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, subprime originators are offering a temporary fix by granting mortgagors an extension on loan maturities. On paper, that looks like a plus for the subprime originator because the mortgagor pays a fee or agrees to pay a higher interest rate, or both. This allows subprime 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 mortgages 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); Mortgage Interest Rates; Credit Risk; Credit Ratings Agency (CRA); Subprime Originator Mortgage Insurance (OMI); Subprime Mortgage Crisis (SMC); Basel Capital Regulation; Slack Constraints; Holding Constraints; Mortgage Quantity and Pricing.

As was mentioned in Chapter 1, subprime residential mortgage lending involves mortgages 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 loan 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 [55], [89], [90] and [91].

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 United States, 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]).

This chapter supports the view that the SMC was partly caused by the design and intricacy of subprime mortgages that led to the loss of information, opaqueness and ineffective risk mitigation. In the sequel this will be known as the IDIOM hypothesis.

2.1 Background to Subprime Mortgages

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

2.1.1 Originator Mortgage Insurance

Originator 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.

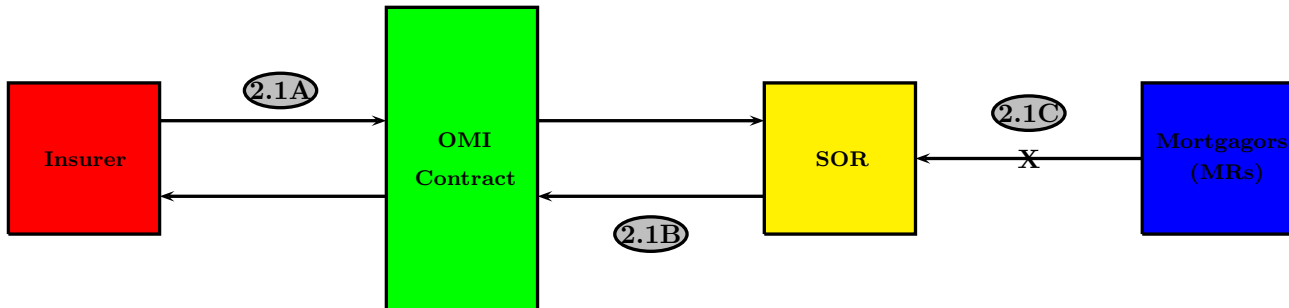


Figure 2.1: Overview of Originator Mortgage Insurance for Subprime Mortgages

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

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

where Γ is given as above, 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 [125]).

2.1.2 Subprime Mortgages 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-United States financial institutions. The write-downs that British, European and Asian institutions had to make on United States 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 United States, 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 United States and abroad 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 [51], we extend aspects of the literature mentioned in Subsection 1.1 in several important directions. Firstly, in a Basel I framework, we investigate the dynamics of bank capital and credit and their sensitivity to changes in the level of credit ratings. Here asset risk-weights are kept constant and we only consider credit and market risk. Next, we repeat the above in a Basel II paradigm where mortgage risk-weights vary while risk-weights for and RMBSs remain constant. Also, as expected, we consider credit and market risk as well as operational risk. Thirdly, we include a discussion of subprime mortgages and their reduced risk premiums. Finally, we consider the effect that Basel capital regulation has had on the SMC.

2.1.3 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) mortgage (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 Mortgage Design

In the United States, 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 Subprime 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 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

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

is the recovery amount. S increases when credit ratings, \mathcal{C} , deteriorate according to $\frac{\partial S_t}{\partial \mathcal{C}_t} < 0$. 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, [51]).

¹Approximately 80 % of United States 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 mortgages since they incorporate the features of both FRMs and ARMs. Another aspect is mortgage payment 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 mortgage but also on the 6-month LIBOR interest rate), and of course conditions in the labor market.

From (1.2), we have that

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

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.

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*

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

where $\bar{c}_t^{M\omega}$ 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 $0 \leq p^i(\mathcal{C}_t) \leq 1$, $\frac{\partial p^i(\mathcal{C}_t)}{\partial \mathcal{C}_t} < 0$. Empirical data supports the claim that p^i is correlated with credit ratings (see, for instance, [22] and [75]).

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

$$L_t = \frac{M_t}{H_t}, \quad (2.6)$$

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 Mortgages 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

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

where $M = f^M \Lambda$, $B = f^M \widehat{B}$, $\mathbf{T} = f^M \widehat{\mathbf{T}}$, $D = f^M \widehat{D}$, $\mathbf{B} = f^M \widehat{\mathbf{B}}$ 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 $\frac{\partial \Pi_t}{\partial \mathcal{C}_t} > 0$. 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

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

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

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

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

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

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, $r_t^T T_t$, 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 , $\bar{c}_t^{M\omega} M_t$, 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, $r_t^B B_t$, the cost of borrowing, $c_t^B B_t$, provisions against deposit withdrawals, $P^T(T_t)$, 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^B and c^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

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

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 $r_t^M M_t$ embeds credit and market risk (in particular, interest rate risk) while $c_t^D r_t^f M_t$ 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 $\bar{c}_t^{M\omega} M_t$ 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, $P^T(T_t)$, carries systemic and market risk. Finally, the term $(r_t^B + c_t^B)B_t$ 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

$$\text{Bank Value for a Shareholder} = \text{Nett Cash Flow} + \text{Ex-Dividend Bank Value.}$$

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

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

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 [51], we have that SOR's total capital constraint for subprime mortgages at face value is given by

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

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*

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

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*

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

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*

$$M_t^* = \frac{K_t}{\rho \omega(\mathcal{C}_t)} - \frac{\omega^B B_t + 12.5 f^M (mVaR + 0)}{\omega(\mathcal{C}_t)} \tag{2.16}$$

and

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

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

$$\begin{aligned}
D_t^* &= \frac{1}{1-\gamma} \left(\overline{D} + \frac{\overline{D}}{r_t^p} \left[r_t^T + (r_t^B - c_t^B) + (r_t^B + c_t^B) - \frac{1}{1-\gamma} (r_t^D + c_t^D) \right] \right. \\
&\quad \left. + \frac{K_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B B_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t)} + B_t - K_t - \mathbf{B}_t \right), \tag{2.18}
\end{aligned}$$

$$\mathbf{T}_t^* = \overline{D} + \frac{\overline{D}}{r_t^p} \left[r_t^T + (r_t^B - c_t^B) + (r_t^B + c_t^B) - \frac{1}{1-\gamma} (r_t^D + c_t^D) \right] \tag{2.19}$$

and

$$\begin{aligned}
\Pi_t^* &= \left(\frac{K_t}{\rho\omega(\mathcal{C}_t)} - \frac{\omega^B B_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t)} \right) \\
&\quad \left\{ \frac{1}{m_1} \left(m_0 - \frac{K_t}{\rho\omega(\mathcal{C}_t)} + \frac{\omega^B B_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t)} + m_2 \mathcal{C}_t + \sigma_t^M \right) \right. \\
&\quad \left. - \left(\overline{c}_t^{M\omega} - c_t^p r_t^f + p_t^i + (1 - r_t^R) r_t^S + (r_t^D + c_t^D) \frac{1}{(1-\gamma)} \right) \right\} \\
&\quad - \left((r_t^D + c_t^D) \frac{1}{(1-\gamma)} \right) (B_t - K_t - \mathbf{B}_t) \\
&\quad + \left(\overline{D} + \frac{\overline{D}}{r_t^p} \left[r_t^T + (r_t^B - c_t^B) + (r_t^B + c_t^B) - \frac{1}{1-\gamma} (r_t^D + c_t^D) \right] \right) \left(r_t^T - (r_t^D + c_t^D) \frac{1}{(1-\gamma)} \right) \\
&\quad + \left(r_t^B - c_t^B \right) B_t - \left(r_t^B + c_t^B \right) \mathbf{B}_t + C(\mathbf{E}[S(\mathcal{C}_t)]) - P^T(\mathbf{T}_t) + \Pi_t^p, \tag{2.20}
\end{aligned}$$

respectively.

Proof. A complete proof is provided in Subsection 2.8.1 of Section 2.8. □

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*

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

and

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

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

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

$$D_t^{n*} = \frac{1}{1-\gamma}\left(\bar{D} + \frac{\bar{D}}{r_t^p}\left[r_t^T + (r_t^B - c_t^B) + (r_t^B + c_t^B) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\right] + M_t^{n*} + B_t - K_t - \mathbf{B}_t\right). \quad (2.24)$$

and

$$\begin{aligned} \Pi_t^{n*} = & \left(\frac{1}{2}(m_0 + m_2\mathcal{C}_t + \sigma_t^M) - \frac{m_1}{2}\left[\bar{c}_t^{M\omega} + p_t^i + (1 - r_t^R)r_t^S + \frac{1}{1-\gamma}(r_t^D + c_t^D) - c_t^p r_t^f\right]\right) \\ & \left\{\frac{1}{2m_1}(m_0 + m_2\mathcal{C}_t + \sigma_t^M) - \frac{1}{2}\left[\bar{c}_t^{M\omega} + p_t^i + (1 - r_t^R)r_t^S + \frac{1}{1-\gamma}(r_t^D + c_t^D) - c_t^p r_t^f\right]\right\} \\ & - \left((r_t^D + c_t^D)\frac{1}{1-\gamma}\right)(B_t - K_t - \mathbf{B}_t) + \left(\bar{D} + \frac{\bar{D}}{r_t^p}\left[r_t^T + (r_t^B - c_t^B) + (r_t^B + c_t^B) - \frac{1}{1-\gamma}(r_t^D + c_t^D)\right]\right) \\ & \left(r_t^T - (r_t^D + c_t^D)\frac{1}{1-\gamma}\right) + \left(r_t^B - c_t^B\right)B_t - \left(r_t^B + c_t^B\right)\mathbf{B}_t \\ & + C(\mathbf{E}[S(\mathcal{C}_t)]) - P^T(\mathbb{T}_t) + \Pi_t^p, \end{aligned} \quad (2.25)$$

respectively.

Proof. A complete proof is provided in Subsection 2.8.2 of Section 2.8. □

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*

$$L_t^* = \frac{K_t}{\rho\omega(\mathcal{C}_t)H_t} - \frac{\omega^B B_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t)H_t}. \quad (2.26)$$

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

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

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

The paper [43] 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

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

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 [43], 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. [43] 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*

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

and

$$\begin{aligned} c_t^{p*} = & \frac{\gamma^1}{2m_1}(m_0 + m_2\mathcal{C}_t + \sigma_t^M) + \frac{1}{2} \left[(1 - r_t^R)r_t^S + \frac{1}{1 - \gamma}(r_t^D + c_t^D) \right. \\ & \left. + (\bar{c}_t^{M\omega} + p_t^i - c_t^p r_t^f) \right] + \gamma^2 X_t + \gamma^3 Z_t^{c^p} + w_t, \end{aligned} \quad (2.30)$$

respectively.

2.4 Subprime Mortgages and Capital Under Basel Regulation (Unsecuritized Case)

We derive results for a model where both subprime mortgage losses and mortgage risk-weights are a function of the current level of credit rating, \mathcal{C}_t . The capital constraint is described by the expression in (2.13), where the risk-weights on short-and long-term marketable securities, $\omega^B \neq 0$, are considered. Also, in this situation, the risk-weight on SOR's mortgages, $\omega(\mathcal{C}_t)$, is a decreasing function of the current level of credit rating, i.e., $\frac{\partial \omega(\mathcal{C}_t)}{\partial \mathcal{C}_t} < 0$. In particular, we keep the risk-weights for short-and long-term marketable securities constant, i.e., $\omega^B = 1$. In this case, the capital constraint (2.13) becomes

$$K_t \geq \rho \left[\omega(\mathcal{C}_t)M_t + \omega^B B_t + 12.5f^M(mVaR + 0) \right]. \quad (2.31)$$

2.4.1 Subprime Mortgage Quantity and Pricing and Basel Capital Regulation (Unsecuritized Case)

In this subsection, we examine how SOR capital, K , and the quantity and price of mortgages, M , are affected by changes in the level of credit rating, \mathcal{C} , when risk-weights on SOR's mortgages, $\omega(\mathcal{C}_t)$, are allowed to vary.

Theorem 2.4.1 (Subprime Originator's Mortgages and Capital under Basel II (Unsecuritized)): *Suppose that $B(\mathcal{C}_t) > 0$ and the mortgage risk-weights, $\omega(\mathcal{C}_t)$, are allowed to vary. In this case, we have that*

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

Proof. The full proof of Theorem 2.4.1 is contained in Subsection 2.8.4. □

2.4.2 Subprime Mortgages and Their Rates Under Basel Capital Regulation (Slack Constraint; Unsecuritized Case)

Next, we consider the effect of a shock to the current level of credit rating, \mathcal{C}_t on SOR's mortgages, M , and the SOR's subprime mortgage rate, r^M . In particular, we analyze the case where the capital constraint (2.31) is slack.

Proposition 2.4.2 (Subprime Mortgages under Basel II (Slack Constraint)): *Under the same hypothesis as Theorem 2.4.1 when $l_t = 0$ we have that*

$$\frac{\partial M_{t+j}^{n*}}{\partial \mathcal{C}_t} = \frac{1}{2} \mu_j^{\mathcal{C}} \left(m_2 - m_1 \frac{\partial p^i(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} - m_1 \frac{\partial r_t^S(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} \right) \quad (2.32)$$

and

$$\frac{\partial r_{t+j}^{Mn*}}{\partial \mathcal{C}_t} = \frac{1}{2} \mu_j^{\mathcal{C}} \left(\frac{m_2}{m_1} + \frac{\partial p^i(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} + \frac{\partial r_t^S(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} \right). \quad (2.33)$$

Proof. The full proof of Proposition 2.4.2 is contained in Subsection 2.8.5. □

2.4.3 Subprime Mortgages and Their Rates Under Basel Capital Regulation (Holding Constraint; Unsecuritized Case)

Next, we present results about the effect of changes in the level of credit rating, \mathcal{C} , on mortgages when the capital constraint (2.31) holds.

Proposition 2.4.3 (Subprime Mortgages under Basel II (Holding Constraint)): *Assume that the same hypothesis as in Theorem 2.4.1 holds. If $l_t > 0$ then by taking the first derivatives of equation (2.16) with respect to C_t and using the fact that the risk-weights for short- and long-term marketable securities, ω^B , are constant we obtain*

$$\frac{\partial M_t^*}{\partial C_t} = - \frac{K_t - \rho \left(\omega^B B_t + 12.5 f^M (mVaR + 0) \right)}{[\omega(C_t)]^2 \rho} \frac{\partial \omega(C_t)}{\partial C_t}. \quad (2.34)$$

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

$$\frac{\partial r_t^{M^*}}{\partial C_t} = \frac{m_2}{m_1} + \frac{K_t - \rho \left(\omega^B B_t + 12.5 f^M (mVaR + 0) \right)}{[\omega(C_t)]^2 \rho m_1} \frac{\partial \omega(C_t)}{\partial C_t}. \quad (2.35)$$

Proof. The full proof of Proposition 2.4.3 is contained in Subsection 2.8.6. □

2.4.4 Subprime Mortgages and Their Rates Under Basel Capital Regulation (Future Time Periods; Unsecuritized Case)

In the sequel, we examine the effect of a current credit rating shock in future periods on subprime mortgages, M , and mortgage rates, r^M .

2.4.4.1 Capital Constraint Slack (Unsecuritized Case)

If the capital constraint is slack, the response of subprime mortgages and mortgage rates in period $j \geq 1$ to current fluctuations in the level of credit rating is described by Theorem 2.4.1. Nevertheless, as time goes by, the impact of the credit rating shock is minimized since $\mu_j^C < 1$.

2.4.4.2 Capital Constraint Holding (Unsecuritized Case)

In future, if the capital constraint holds, the response of subprime mortgages and mortgage rates to a change in the level of credit rating, C_t , is described by

$$\begin{aligned} \frac{\partial M_{t+j}^*}{\partial C_t} &= \frac{\mu_{j-1}^C}{\omega(C_{t+j})\rho} \left[\frac{\partial (K_{t+j} - \rho(\omega^B B_{t+j} + 12.5 f^M (mVaR + 0)))}{\partial C_{t-1+j}} \right] \\ &- \frac{\mu_{j-1}^C}{\omega(C_{t+j})\rho} \left[\frac{\mu^C}{\omega(C_{t+j})} (K_{t+j} - \rho(\omega^B B_{t+j} + 12.5 f^M (mVaR + 0))) \frac{\partial \omega(C_{t+j})}{\partial C_{t+j}} \right] \end{aligned} \quad (2.36)$$

and

$$\begin{aligned} \frac{\partial r_{t+j}^{M*}}{\partial \mathcal{C}_t} &= \frac{m_2}{m_1} \mu_j^{\mathcal{C}} - \frac{\mu_{j-1}^{\mathcal{C}}}{\omega(\mathcal{C}_{t+j}) \rho m_1} \frac{\partial (K_{t+j} - \rho(\omega^B B_{t+j} + 12.5 f^M(mVaR + 0)))}{\partial \mathcal{C}_{t-1+j}} \\ &+ \frac{\mu_j^{\mathcal{C}}}{[\omega(\mathcal{C}_{t+j})]^2 \rho} (K_{t+j} - \rho(\omega^B B_{t+j} + 12.5 f^M(mVaR + 0))) \frac{\partial \omega(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}}. \end{aligned}$$

From the equation (2.36), it can be seen that future subprime mortgages can either rise or fall in response to positive credit rating shocks. This process depends on the relative magnitudes of the terms in equation (2.36). If capital rises in response to positive credit rating shocks, subprime mortgages can fall provided that the effect of the shock on capital is greater than the effect of the shock on subprime mortgage risk-weights.

2.5 Examples Involving Subprime Mortgages

In this section, we present a numerical example to highlight some issues in Sections 2.2 and 2.3. The choice of the value of the economic variables are justified by considering data from the LoanPerformance (LP), Bloomberg, 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 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, [6] and [55]. These provide enough information to support the choices for prices, rates and costs while the parameter amounts are arbitrary.

2.5.1 Illustrative Example Involving Subprime Mortgages

The stylized illustration below is based on [55] (see, also, [91]). The main objective of the illustration is to demonstrate the effect of LTVRs on subprime mortgage and that a subprime mortgage contains an implicit embedded option on H as well as to determine SOR's expected profit from mortgages.

2.5.1.1 Setting the Scene

In the case where the MR is subprime and may not have any collateral, SOR may be reluctant to extend a traditional two period – consisting of period t and period $t + 1$ – mortgage. During period t , H will either increase or decrease. If H increases and MRs build equity in their houses, the origination of mortgages to MRs by SOR may become a viable option. However, SORs may not be willing to wager on H and MR repayment behavior for long periods and, because delinquency and foreclosure is costly, may reserve the right to terminate the subprime mortgage before the end of period $t + 1$. If MRs extract equity via refinancing, subsequent to an increase in H , then SOR's aforementioned plans may be thwarted. In order to stop MR from doing this, SORs usually incorporate high prepayment costs, c^p , in the mortgage contract. For setting the scene, we make the following assumption.

Assumption 2.5.1 (Mortgage Refinancing): *Suppose that r^ψ and c^p for period $t+1$ is restrictively high so that MR must refinance the mortgage or involuntarily prepay at the end of period t . Moreover, suppose that during periods t and $t+1$ there is a π probability of a $\Phi \in [0, 1]$ increase in H .*

In period t , the probability of default is $p(r_t^\epsilon M_t, L_t)$, where L_t denotes the LTVR. Here, p is increasing in $r^\epsilon M$ – implicitly relative to MR’s income – and in L that measures MR’s house equity. For simplicity, we assume the following.

Assumption 2.5.2 (Changes in House Prices): *Assume that H changes occur an instant before the end of period t , so that it does not affect L_0 or $p(r_t^\epsilon M_t, L_t)$ during period t .*

For sake of illustration, in formula (2.3) for the recovery amount, R_t , we set $a = 0.5$. Also, as in [55], we make the following assumption.

Assumption 2.5.3 (Constant Loan-to-Value Ratio): *Assume that the subprime MR applies for a mortgage with face value M for a house worth H with $L = 1$.*

2.5.1.2 Details of the Stylized Illustration

We note that under the conditions set in Subsection 2.5.1.1, on a one-period mortgage, SOR breaks even if r^ϵ is such that

$$(1 + r_1^\epsilon) \left(1 - p(r_t^\epsilon M_t, L_1) \right) M + R_1 p(r_t^\epsilon M_t, L_1) - (1 + \bar{c}^{M\omega}) M_t = 0. \quad (2.37)$$

During period t , if H has fallen then L will have increased to L^h , where the subscript h refers to *higher* with MR having negative house equity. In this case, SOR will be prepared to refinance the mortgage. By contrast, at the beginning of period $t+1$, if H has risen then L will have fallen to L^l , where the subscript l refers to *lower*. In this case, the subprime MR has positive house equity. Here, we assume that the initial or any other SOR will not refinance the mortgage. In this regard, a diagrammatic overview of the evolution of L may be represented as follows.

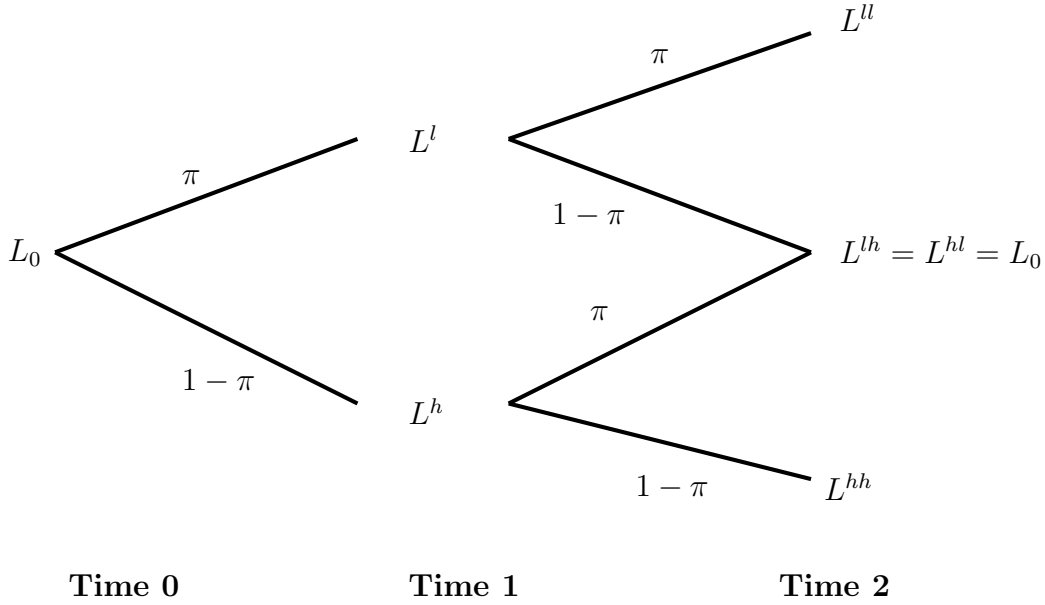


Figure 2.2: Evolution of House Prices and the Loan-to-Value Ratio

The dynamics of H affects MR's choice to either involuntarily prepay or refinance at the end of period t . By assumption, this price dynamics does not affect $p(r_t^\varepsilon M_t, L_t)$, but rather impacts the recovery amount, R . If involuntary prepayment occurs at the end of period t , then M depends on whether H appreciated or not. In this case, by considering monitoring, transaction, funding and OMI costs, the expected value of mortgages in period t is given by

$$\begin{aligned}
 \mathbf{E}(M_t) = & \left(1 - p(r_t^\varepsilon M_t, L_0)\right) (1 + r_t^\varepsilon) M_t + p(r_t^\varepsilon M_t, L_0) \pi R_t^l \\
 & + p(r_t^\varepsilon M_t, L_0) (1 - \pi) R_t^h - \left(1 + \bar{c}_t^{M\omega}\right) M_t,
 \end{aligned} \tag{2.38}$$

where $R_t^l = \min[0.5(1 + \Phi)H_t, M_t]$, in the case where H increases and L decreases. Similarly, we have that $R_t^h = \min[0.5(1 + \Phi)H_t, M_t]$ in the case where H decreases and L increases. Also, the superscripts l and h of R refer to L going down (since H increased) and up (since H decreased), respectively. In the sequel, we assume the following to ensure that the MR has negative house equity when H decrease, and *vice versa*.

Assumption 2.5.4 (To Refinance or Not): *Suppose that if H decreases at the end of period t , the initial or any other SOR will not refinance the mortgage. On the other hand, if H increases at the end of period t , we assume that the initial SOR will be prepared to refinance the mortgage.*

The first part of this assumption ensures that MR has negative house equity and, by assumption, $p(r_t^\varepsilon M_t, L_t)$, is too high for any SOR. An increase in H during period t has the following two effects. MR has positive house equity, which is collateral from SOR's point of view – this makes SOR's recovery amount, R , higher. With all else being equal, with a lower future L , the probability of default is lower, so the step-up rate, r_{t+1}^ψ , may be lower, making the payment lower, which also reduces the probability of default. Throughout this process, MR may extract equity for consumption.

As for period t , house prices may increase or decrease during period $t + 1$. As before, we assume that H changes an instant before the end of period $t + 1$ and so the change does not affect the probability of default of mortgages during the period but does influence R at the end of period $t + 1$. The expected value of the period $t + 1$ mortgage is given by

$$\begin{aligned} \mathbf{E}(M_{t+1}) &= \left(1 - p(r_{t+1}^\psi M_{t+1}, L_t^l)\right) (1 + r_{t+1}^\psi) M_t \\ &+ p(r_{t+1}^\psi M_{t+1}, L_t^l) \pi R_{t+1}^{ll} + p(r_{t+1}^M M_{t+1}, L_t^l) (1 - \pi) R_{t+1}^{lh} - \left(1 + \bar{c}_t^{M\omega}\right) M_t. \end{aligned} \quad (2.39)$$

It is clear that at the start of period $t + 1$, L is now L^h as H has increased. At the end of period $t + 1$, if H decreases, and MR involuntarily prepays, SOR will recover R_{t+1}^{hl} . On the other hand, SOR will recover R_{t+1}^{hh} if H increases. The above discussion leads to the following proposition about SOR's expected profit from mortgages.

Proposition 2.5.5 (Subprime Originator's Expected Profit from Mortgages): *If we neglect to consider discounting and L , SOR's expected profit from mortgage during periods t and $t + 1$ is $\mathbf{E}(M_t) + \pi \mathbf{E}(M_{t+1})$.*

Note that the mortgage in period $t + 1$ is only extended with probability π if prices have increased during period t . At the end of period t , MR has to either involuntarily prepay or refinance. Similarly, SOR faces a choice, which depends on H and leads to optionality in the mortgage. If H increases and L decreases, SOR decides to refinance and opts for $\mathbf{E}(M_{t+1}) = \max[R_t^l, \mathbf{E}(M_{t+1})]$. If H decreases and L increases, SOR decides to opt for the recovery amount and chooses $R_t^h = \max[R_t^h, \mathbf{E}(M_{t+1})]$. It is clear that this optionality is implicit as the strike price is R , that depends on how H performed during period $t + 1$. SOR does not take into account costs to MR from involuntarily prepaying, if there are such costs (see [55] for more details).

The main deduction that we can make is that the SMC was exacerbated by subprime mortgage design that led to the loss of information and opaqueness. As a consequence, subprime originators could not implement effective risk management policies. This matter is discussed in greater detail in Subsection 2.6.3.1.

2.5.2 Numerical Example Involving Subprime Mortgages I

In this subsection, we make choices for subprime mortgages, capital, information, risk and valuation parameters by considering data from LoanPerformance, Bloomberg 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, [6], [36], [49], [55] and [111].

2.5.2.1 Choices of Subprime Mortgage Parameters

In Table 2.1 below, we make choices for subprime mortgages, profit and valuation parameters.

Parameter	Period t	Period $t + 1$	Parameter	Period t	Period $t + 1$
M	\$ 10 000	\$ 12 000	m^0	\$ 5 000	\$ 5 000
ω^M	0.5	0.5	m^1	\$ 5 000	\$ 5 000
r^M	0.051	0.082	m^2	\$ 5 000	\$ 5 000
$\bar{c}^{M\omega}$	0.0414	0.0414	\mathcal{C}	0.5	0.5
p^i	0.01	0.01	a	0.05	0.05
c^p	0.05	0.05	$C(\mathbf{E}[S(\mathcal{C}_t)])$	400	400
r^f	0.01	0.01	r^p	0.1	0.1
r^R	0.5	0.5	K	\$ 500	\$ 650
r^S	0.15	0.25	0	\$ 150	\$ 150
H	\$ 11 000	\$ 11 500	r^0	0.101	0.101
Λ	\$ 50 000	\$ 63 157.89	E	\$ 250	\$ 250
ρ	0.08	0.08	E^p	\$ 150	\$ 150
C	\$ 1 000	\$ 1 000	E^c	\$ 100	\$ 100
r^B	0.105	0.105	r^B	0.1	0.1
c^B	0.101	0.101	c^B	0.09	0.09
B	\$ 1 300	\$ 1 500	B	\$ 5 200	\$ 6 200
ω^B	0.5	0.5	Π^p	\$ 6 000	\$ 6 000
r^T	0.036	0.04	D	\$ 9 300	\$ 11 100
T	\$ 2 000	\$ 2 000	r^D	0.105	0.105
O	150	150	r^O	0.101	0.101
n	1.75	2	r^L	0.02	0.05
d	5.4	5.4	f^M	0.08	0.19
$mVar$	400	400	$\omega(\mathcal{C})$	0.5	0.5
P^T	\$ 800	\$ 1 200	c^D	0.101	0.101

Table 2.1: Choices of Subprime Mortgage Parameters

2.5.2.2 Computation of Subprime Mortgage Parameters

We compute important equations by using the values from Table 2.1. For $\widehat{R}_t = \gamma \widehat{D}_t$, we use equation (2.7) to compute $\gamma_t = 0.1828$. Also, the equity in (1.1) in period $t - 1$ is $\widehat{E}_{t-1} = (500 - 150)/1.75 = 200$. In this case, we calculate the risk premium from equation (2.2) as $\varrho_t = 0.031$.

Nett subprime mortgage losses in equation (2.3) becomes $S_t = 750$, where $R_t = \min[550, 750] = 550$. In period t , the random shock to M , denoted by σ_t^M , in equation (2.4) is given by $\sigma_t^M = 2755$.

The random shock σ_{t+1}^M , in period $t+1$ is given by $\sigma_{t+1}^M = 4910$, so that μ_t^M in equation (2.5) is $\mu_t^M = 0.709$. We confirm that the left-hand side of (2.7) is $M_t + B_t + T_t = 10000 + 1300 + 2000 = 13300$, and also the right-hand side $(1 - \gamma)D_t + B_t + K_t = (1 - 0.1828) \times 9300 + 5200 + 500 = 13300$. A traditional mortgage model with subprime elements for SOR's profit with all SOR's mortgages at face value given by equation (2.11) is computed by $\Pi_t = 2024.4$. Now, we can calculate the retained earnings in equation (2.8) as follows $E_t^r = 1849.8$. Also, the depreciation of fixed assets, ΔF_t , in equation (2.9) is $\Delta F_t = 2062.3$. From equation (2.10), we have that $K_{t+1} = n_t(d_t + E_t) + (1 + r_t^O)O_t - \Pi_t + \Delta F_t = 650$. SOR's total capital constraint for subprime mortgages at face value is given by (2.13)

$$K_t = 500 \geq 0.08[0.5 \times 10000 + 0.5 \times 1300 + 12.5 \times 0.08 \times (400 + 150)] = 496.$$

Furthermore, SOR's optimal M from (2.16) is computed as $M_t^* = 10100$ with the optimal mortgage rate in equation (2.17) being given by $r_t^{M^*} = 0.031$. SOR's corresponding optimal deposits (2.18), provisions for deposit withdrawals (2.19) and profits (2.20) in period t are given by $D_t^* = 15842.6$, $T_t^* = 7246.53$, and

$$\begin{aligned} \Pi_t^* &= 10100 \times \left[\frac{1}{5000} (5000 - 10100 + 5000 \times 0.5 + 2755) - \right. \\ &\quad \left. (0.0414 - 0.05 \times 0.01 + 0.01 + (1 - 0.5) \times 0.15 + (0.105 + 0.101) \frac{1}{1 - 0.1828}) \right] - \\ &\quad \left((0.105 + 0.101) \frac{1}{1 - 0.1828} \right) (1300 - 500 - 5200) + 7246.53 \times \\ &\quad \left(0.036 - (0.105 + 0.101) \frac{1}{1 - 0.1828} \right) + (0.105 - 0.101) \times 1300 - (0.1 + 0.09) \times 5200 + \\ &\quad 400 - 800 + 6000 = 656.02, \end{aligned}$$

respectively.

When the capital constraint (2.13) does not hold, then the solutions for SOR's optimal mortgages (2.21) and mortgage rate (2.22) are given by $M_t^{n^*} = 4182.55$ and $r_t^{M^{n^*}} = 1.21449$, respectively. In this case, corresponding optimal deposits (2.24), provisions for deposit withdrawals (2.23) and profits (2.25) are given by $D_t^{n^*} = 8601.42$, $T_t^{n^*} = 7246.53$ and $\Pi_t^{n^*} = 7659.26$, respectively. The LTVR given by equation (2.6) in period t is given by $L_t = 0.909$. However, the optimal LTVR (2.26) is $L_t^{1^*} = 0.9182$. On the other hand, when $l_t = 0$, then (2.27) becomes $L_t^{n^*} = 0.3802$. When we choose $X_t = 0.5$, $Z_t^{r^M} = Z_t^L = Z_t^{c^p} = 0.02$ and $\alpha^0 = \alpha^1 = \alpha^2 = \alpha^3 = \beta^1 = \beta^2 = \beta^3 = \gamma^1 = \gamma^2 = \gamma^3 = 0.01$, the values from the simultaneous equations model (2.28) are $u_t = 0.03621$, $v_t = 0.90329$ and $w_t = 0.04429$. Therefore, $L_t^{2^*}$ in (2.29) and $c_t^{p^*}$ in (2.30) are given by $L_t^{2^*} = 0.9206$ and $c_t^{p^*} = 0.2487$, respectively.

The following values are obtained in period $t+1$. The factor $\gamma_{t+1} = 0.2207$, while the equity in (1.1) in period t is $\hat{E}_t = (650 - 150)/2 = 250$. The risk premium in period $t+1$ is $\varrho_{t+1} = 0.082 - 0.05 = 0.032$. Nett subprime mortgage losses in equation (2.3) becomes $S_{t+1} = 1500$, where $R_{t+1} = 575$. In period $t+1$, $\sigma_{t+1}^M = 4910$. We confirm that the left- and right-hand sided of (2.7) corresponds to 15500. A traditional mortgage model with subprime elements for SOR's profit given by equation

(2.11) is computed as $\Pi_{t+1} = 694.6$ with $E_{t+1}^r = 518.65$. SOR's total capital constraint for subprime mortgages at face value in period $t + 1$ given by (2.13) is $K_{t+1} = 644.5$. SOR's optimal M (2.16) and optimal mortgage rate (2.17) are $M_{t+1}^* = 12137.5$ and $r_{t+1}^{M^*} = 0.0545$, respectively.

Furthermore, SOR's corresponding optimal deposits (2.18), provisions for deposit withdrawals (2.19) and profits (2.20) are given by $D_{t+1}^* = 18631.83$, $T_{t+1}^* = 7732.28$, and $\Pi_{t+1}^* = -974.36$, respectively. When the capital constraint (2.13) does not hold, then $M_{t+1}^{n^*} = 5104.4$ and $r_{t+1}^{M^{n^*}} = 1.46112$, respectively. In this case, corresponding optimal deposits (2.24), provisions for deposit withdrawals (2.23) and profits (2.25) are given by $D_{t+1}^{n^*} = 9606.93$, $T_{t+1}^{n^*} = 7732.28$ and $\Pi_{t+1}^{n^*} = 8918.54$, respectively.

The LTVR given by equation (2.6) in period $t + 1$ is calculated as $L_{t+1} = 1.043$. However, the optimal LTVR (2.26) is $L_{t+1}^{1^*} = 1.0554$. On the other hand, when $l_{t+1} = 0$, then (2.27) becomes $L_{t+1}^{n^*} = 0.4439$. When we choose $X_{t+1} = 0.5$, $Z_{t+1}^{r^M} = Z_{t+1}^L = Z_{t+1}^{c^p} = 0.02$ and $\alpha^0 = \alpha^1 = \alpha^2 = \alpha^3 = \beta^1 = \beta^2 = \beta^3 = \gamma^1 = \gamma^2 = \gamma^3 = 0.01$, we obtain $u_{t+1} = 0.06587$, $v_{t+1} = 1.03698$ and $w_{t+1} = 0.04398$. Therefore, $L_{t+1}^{2^*}$ in (2.29) and $c_t^{p^*}$ in (2.30) are $L_{t+1}^{2^*} = 1.0568$ and $c_{t+1}^{p^*} = 0.2817$, respectively.

We provide a summary of computed subprime mortgage parameters in Table 2.2 below to give a better understanding of what happened before and during the SMC.

Parameter	Value	Parameter	Value	Parameter	Value
γ_t	0.1828	γ_{t+1}	0.2207	μ_t^M	0.709
\widehat{E}_{t-1}	\$ 200	\widehat{E}_t	\$ 250	u_t	0.03621
ϱ_t	0.031	ϱ_{t+1}	0.032	u_{t+1}	0.06587
S_t	750	S_{t+1}	1 500	v_t	0.90329
R_t	550	R_{t+1}	575	v_{t+1}	1.03698
σ_t^M	2 755	σ_{t+1}^M	4 910	w_t	0.04429
Π_t	\$ 2 024.4	Π_{t+1}	\$ 694.6	ΔF_t	2 062.3
E_t^r	\$ 1 849.8	E_{t+1}^r	\$ 518.65	w_{t+1}	0.04398
M_t^*	\$ 10 100	M_{t+1}^*	\$ 12 137.5	$r_t^{M^*}$	0.031
D_t^*	\$ 15 842.6	D_{t+1}^*	\$ 18 631.83	$r_{t+1}^{M^*}$	0.0545
T_t^*	\$ 7 246.53	T_{t+1}^*	\$ 7 732.28	Π_t^*	\$ 656.02
$M_t^{n^*}$	\$ 4 182.55	$M_{t+1}^{n^*}$	\$ 5 104.4	Π_{t+1}^*	- \$ 974.36
$r_t^{M^{n^*}}$	1.21449	$r_{t+1}^{M^{n^*}}$	1.46112	$T_t^{n^*}$	\$ 7 246.53
$D_t^{n^*}$	\$ 8 601.42	$D_{t+1}^{n^*}$	\$ 9 606.93	$T_{t+1}^{n^*}$	\$ 7 732.28
$\Pi_t^{n^*}$	\$ 7 659.22	$\Pi_{t+1}^{n^*}$	\$ 8 918.54	L_t	0.909
L_{t+1}	1.043	$L_t^{1^*}$	0.9182	$L_{t+1}^{1^*}$	1.0554
$L_t^{n^*}$	0.3802	$L_{t+1}^{n^*}$	0.4439	$L_t^{2^*}$	0.9206
$L_{t+1}^{2^*}$	1.0568	$c_t^{p^*}$	0.2487	$c_{t+1}^{p^*}$	0.2817

Table 2.2: Computed Subprime Mortgage Parameters

The main conclusion that can be drawn from the above example is that the SMC was partly caused by subprime mortgage complexity that led to the loss of information and opaqueness. As a consequence, subprime originators could not implement effective risk management policies. This

matter is discussed in greater detail in Subsection 2.6.3.2.

2.5.3 Numerical Example Involving Subprime Mortgages II

The sample presented in Table 2.3 below, represent the mean and standard error of loss given default (LGD) for different current loan-to-value ratio (CLTVR) segments (≤ 80 , ≤ 90 , ≤ 95 , ≤ 100 , ≤ 110 , ≤ 120), three geographic regions (New England, Pacific and National) and the United States, during three sub-periods and the entire sample period. The three sub-periods are 1990-1994, 1995-1999 and 2000-2003, while the entire period include the data from 1990-2003. The motivation of dividing the data into these periods is to compare (see Subsection 2.6.3.3) the loss severity amongst them. The data used to construct the sample given in Table 2.3 comes from numerous major private mortgage insurance companies, collected by the Mortgage Insurance Companies of America (MICA), trade association of the private mortgage insurance industry. The raw data set consists of 241,293 mortgage insurance claims between 1990 and 2003.

The information considered about the mortgage include the original amount of the mortgage and type of mortgage. The type of mortgage can either be purchasing or refinancing mortgage, conforming or jumbo. Refinancing is when a person or business revises a payment schedule for repaying debt or replacing an older mortgage with a new mortgage offering better terms. Conforming is when a person or business meets the requirements of a mortgage while jumbo is when looking for huge mortgage insurance. The data set also includes the insurance coverage effective date, which is the same as the original mortgage month and year. Furthermore it contains the information about the location of the property, what kind of property it is as well as whether the property is to be occupied by the owner or it is for the investment purposes. In addition, the data includes information about the property's original value, details about default such as month, year, unpaid principal amount at default, and the broker's opinion about the value of the property at default. Moreover the data includes information about the foreclosure such as month and year, was the property sold before foreclosure, salvage value of net of sales costs and repairs. Salvage value is the same as the sale price if it is known. The last information assessed about the data set is the settlement date (month and year).

Default Period	Region	CLTVR													
		≤ 80		≤ 90		≤ 95		≤ 100		≤ 110		≤ 120		> 120	
		Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1990-1994	USA Remainder	20.1	18.4	27.4	14.3	30.6	12.0	32.7	11.9	37.6	11.4	44.0	10.5	56.8	11.9
	New England	23.2	19.4	27.5	14.8	30.9	15.0	29.1	10.1	34.7	9.2	38.8	9.5	51.7	9.5
	Pacific	11.0	13.7	17.6	8.9	22.5	7.6	25.7	8.2	30.5	8.0	35.3	7.3	44.4	9.1
	National	18.7	18.1	25.5	14.0	29.1	11.8	30.6	11.3	35.0	10.7	40.3	10.2	51.7	12.1
1995-1999	USA Remainder	17.9	19.0	20.6	12.5	23.4	10.6	25.9	9.7	31.1	10.5	39.1	10.9	53.4	12.5
	New England	13.6	16.9	17.9	11.8	21.5	9.8	23.6	7.0	29.0	8.9	35.6	8.4	48.6	9.3
	Pacific	5.4	14.9	11.7	8.5	16.4	8.3	20.2	7.8	25.5	7.3	31.8	7.0	42.6	8.6
	National	16.2	19.0	18.3	12.2	21.5	10.5	24.0	9.4	28.7	9.7	35.1	9.6	47.2	11.5
2000-2003	USA Remainder	7.8	16.7	16.3	11.6	21.0	10.2	24.5	9.8	30.1	10.4	37.8	10.5	50.6	10.9
	New England	4.9	20.6	11.5	10.9	16.9	9.7	19.8	8.8	27.8	10.5	34.4	9.6	45.5	10.5
	Pacific	1.6	11.8	9.8	8.4	15.8	7.8	18.4	8.8	24.5	8.6	31.8	8.5	43.9	9.6
	National	7.1	16.5	15.2	11.5	20.2	10.0	23.6	9.9	29.4	10.4	37.0	10.4	49.8	10.9
1990-2003	USA Remainder	15.1	18.9	21.2	13.5	24.8	11.6	26.9	10.8	32.3	11.1	39.9	10.9	53.4	12.0
	New England	16.0	20.2	21.4	14.4	23.5	12.6	24.6	8.9	31.0	9.6	36.9	9.1	50.0	9.7
	Pacific	6.9	14.2	13.0	9.1	17.9	8.5	21.4	8.5	26.8	8.0	32.7	7.4	43.2	8.9
	National	14.0	18.6	19.6	13.2	23.3	11.4	25.5	10.5	30.5	10.5	37.0	10.2	49.2	11.7

Table 2.3: Mean and Standard Error (Std) of Loss Given Default (%) by Year, Region and Current Loan-to-Value Ratio; Source: Mortgage Insurance Companies of America (MICA)

Table 2.3 does not includes other factors that may have effect on loss severity. Those key factors include the mortgage age (AGE) and amount (LNSZN) relative to area median home price at origination, property type (PROPTYPE), mortgage purpose (LNPURP), information about the location of the property and whether there is a statutory right or redemption (SRR), has judicial foreclosure (JUDICIAL), deficiency judgements are not allowed (NODJ), the property is to be occupied by the owner or it is for the investment purposes (OCCUP) and whether the property was sold prior to foreclosure (PRESALE). In Table 2.5, the mean and standard error of loss given default by these key factors are provided. The three kind of properties are single-family (SFD), CONDO (Bigger-family) and DUP (2-4 units).

Table 2.4 provides descriptive data calculate from Table 2.3.

Parameters	Values	Total Values
Original Loan Amount(LOANAMT)	\$109,000	\$109,000
Unpaid Amount at Default(CUPB)	\$106,000	\$106,000
Original Property Value(ORIGVAL)	\$124,000	\$124,000
Net Salvage Value(NETSALVAGE)	73% of ORIGVAL	\$90,520
Broker's Opinion of Value(BOVVAL)	\$100,000	\$100,000
Purchasing(P)	78% of 241,293	188,208.54
Refinancing(R)	19% of 241,293	45,845.67
Conforming	91% of 241,293	219,576.63
Single Family House(SFD)	81% of 241,293	195,447.30
Owner Occupancy	97.5% of 241,293	235,260.68
LOCATION		
Pacific	27% of 241,293	65,149.11
South Atlantic	19% of 241,293	45,845.67
West South Central Region	13% of 241,293	31,368.09

Table 2.4: Descriptive Statistics Generated from Table 2.3; Source: [113]

Regarding the mortgage insurance claims, California has the most claims of 22.5% of all claims, which is $241,293 * 22.5\% = 54,290.925$. The raw data set in Table 2.3 contained some errors. The authors of [113] cleaned the data with some help from MICA. The new sample resulted to 106,857 observations.

This number is almost half of the original data set and it is the one which is used for all the analysis in the rest of Subsection 2.5.3. With regard to the information above, Table 2.6 contains descriptive statistics of the key variable from the cleaned data. LGD, HPR, STRESS stands for loss given default, house price ratio and economic indicator, respectively.

	Mean	Std		Mean	Std		Mean	Std
CLTVR			LTVR			LNPURP		
CLTVR080	14.0	18.6	LTVR080	29.2	17.4	Purchase	30.7	16.6
CLTVR090	19.6	13.2	LTVR090	29.7	15.8	Refinance	29.7	15.5
CLTVR095	23.3	11.4	LTVR090+	31.7	16.7	Other	34.4	16.4
CLTVR100	25.5	10.5						
CLTVR110	30.5	10.5	PROPTYPE			PRESALE		
CLTVR120	37.0	10.2	SFD	29.8	16.2	Yes	25.2	12.2
CLTVR120+	49.2	11.7	CONDO	34.3	16.5	No	29.4	16.0
			DUP	38.0	17.8	Unknown	34.4	17.5
LNSZN			AGE			SRR		
LNSZN060	37.9	19.2	24	28.7	15.5	No	30.4	16.2
LNSZN080	31.2	15.8	48	28.4	14.5	Yes	31.6	18.0
LNSZN110	27.9	14.3	84	30.0	15.6			
LNSZN110+	25.6	13.2	>84	35.9	19.3			
OCCUP			JUDICIAL			NODJ		
Owner Occup	30.4	16.3	No	29.4	15.7	No	31.1	17.1
Investment	34.6	18.7	Yes	32.5	17.3	Yes	29.1	14.4

Table 2.5: Mean and Standard Error (Std) of Loss Given Default (%) by Key Factors; Source: Mortgage Insurance Companies of America (MICA)

Variable	Mean	Std	Min	Max	Variable	Mean	Std	Min	Max
LGD	30.53	16.40	-31.96	99.97	LTVR	90.11	5.42	70.86	108.15
CLTVR	104.42	20.30	38.73	170.89	LTVR080	0.11	0.31	0	1
CLTVR080	0.07	0.26	0	1	LTVR090	0.45	0.50	0	1
CLTVR090	0.16	0.37	0	1	LTVR090+	0.44	0.50	0	1
CLTVR095	0.12	0.33	0	1	PROPTYPE1SFD	0.85	0.36	0	1
CLTVR100	0.12	0.33	0	1	PROPTYPE2CON	0.12	0.32	0	1
CLTVR110	0.19	0.39	0	1	PROPTYPE3DUP	0.02	0.13	0	1
CLTVR120	0.13	0.33	0	1	LNPURP1P	0.76	0.43	0	1
CLTVR120+	0.20	0.40	0	1	LNPURP2R	0.24	0.42	0	1
HPR	104.34	5.43	78.32	135.56	OCCUP1O	0.98	0.16	0	1
HPR100	0.21	0.40	0	1	PRESALE1Y	0.11	0.31	0	1
HPR105	0.30	0.46	0	1	PRESALE2N	0.57	0.49	0	1
HPR110	0.39	0.49	0	1	AGE	58.90	39.30	0	290
STRESS	0.21	0.40	0	1	AGE24	0.18	0.38	0	1
LNSZN	0.92	0.48	0.10	9.94	AGE48	0.32	0.47	0	1
LNSZN060	0.24	0.42	0	1	AGE84	0.29	0.45	0	1
LNSZN080	0.25	0.44	0	1	JUDICIAL	0.37	0.48	0	1
LNSZN110	0.26	0.44	0	1	SRR	0.10	0.30	0	1
LNSZN110+	0.25	0.43	0	1	NODJ	0.28	0.45	0	1

Table 2.6: Descriptive Statistics; Source: [113]

Table 2.7 represent the correlation matrix for the following variables: loss given default (LGD), current loan-to-value ratio (CLTVR), loan-to-value ratio (LTVR), house price ratio (HPR), mortgage size (LNSZN), number of months from origination to foreclosure (AGE) as well as number of months from default to foreclosure (FCTIME). This is to see how the key variables are related. The bold values are significant at 0.01% level.

	LGD	CLTVR	LTVR	HPR	LNSZN	AGE	FCTIME
LGD	1.000	0.699	0.065	-0.172	-0.220	0.178	0.173
CLTVR		1.000	0.002	-0.184	0.003	-0.059	-0.013
LTVR			1.000	0.061	-0.082	0.166	-0.021
HPR				1.000	-0.065	-0.118	-0.104
LNSZN					1.000	-0.099	0.008
AGE						1.000	0.240
FCTIME							1.000

Table 2.7: Pearson Correlation Coefficient; Source: [113]

Table 2.8 represent the LGD regression with CLTVR. The table provides the parameter (key factors) estimates, p-values along with the goodness of the fit (R^2). The values of CLTVR, LTVR and LNSZN are dummies.

Variable	Coefficient	p-value	Variable	Coefficient	p-value
Intercept	12.744	< .0001			
CLTVR090	8.925	< .0001	PROPTYPE1SFD	-0.403	0.0279
CLTVR095	13.925	< .0001	PROPTYPE2CON	-2.134	< .0001
CLTVR100	17.037	< .0001	LNPURP1P	0.347	< .0001
CLTVR110	22.179	< .0001	OCCUP1O	-1.703	< .0001
CLTVR120	28.333	< .0001	PRESALE1Y	-6.069	< .0001
CLTVR120+	38.871	< .0001	PRESALE2N	-2.009	< .0001
STRESS	2.867	< .0001	AGE24	-7.561	< .0001
LTVR090	0.695	< .0001	AGE48	-6.383	< .0001
LTVR095	1.705	< .0001	AGE84	-5.426	< .0001
LNSZN060	10.969	< .0001	JUDICIAL	1.924	< .0001
LNSZN080	4.363	< .0001	SRR	3.029	< .0001
LNSZN110	1.958	< .0001	NODJ	-4.081	< .0001
Adj. R^2	0.610		Observation	106,857	
F	6956.75	< .0001			

Table 2.8: Loss Given Default Regression with Current Loan-to-Value Ratio; Source: [113]

Table 2.9 shows the results of the evaluation done in accordance with LTVR. As in Table 2.8, Table 2.9 provides the parameter (key factors) estimates, p-values along with the goodness of the fit (R^2), however, in this model the CLTVR dummies are not included.

Variable	Coefficient	p-value	Variable	Coefficient	p-value
Intercept	35.812	< .0001			
STRESS	7.433	< .0001	OCCUP1O	-3.339	< .0001
LTVR090	2.489	< .0001	PRESALE1Y	-6.898	< .0001
LTVR090+	5.022	< .0001	PRESALE2N	-3.094	< .0001
LNSZN06	10.542	< .0001	AGE24	-4.511	< .0001
LNSZN08	4.287	< .0001	AGE48	-5.393	< .0001
LNSZN11	1.469	< .0001	AGE84	-4.211	< .0001
PROPTYPE1SFD	-3.206	< .0001	JUDICIAL	1.754	< .0001
PROPTYPE2CON	-1.867	< .0001	SRR	1.330	< .0001
LNPURP1P	-2.389	< .0001	NODJ	-2.172	< .0001
Adj. R^2	0.145		Observation	106,857	
F	1008.29	< .0001			

Table 2.9: Alternative Loss Given Default Regression with Loan-to-Value Ratio; Source: [113]

Using the above information, we now compute the following.

The mortgage risk factor of LTVR (Loan-to-Value Ratio) and CLTVR are calculated as

$$risk\ factor_{LTVR} = MORTGAGEAMT/ORIGVAL = \$109,000/\$124,000 = 0.879$$

and

$$risk\ factor_{CLTVR} = CUPB/BOVVAL = \$106000/\$100000 = 1.06$$

From [113] LGD is defined as

$$LGD = 100 * \frac{CUPB + ACRINT + FCLEXP + PROEXP - NETREC}{CUPB} \quad (2.40)$$

where, CUPB is unpaid balance at default; ACRINT is the interest accrued on CUPB for 3 months at a monthly average of the 30-year fixed conventional commitment rates based on the Freddie Mac weekly survey; FCLEXP is foreclosure expense. FCLEXP includes servicing and legal costs incurred from default to foreclosure, which is = \$6,000. PROEXP is the property maintenance expense, which is = $0.03 * NETREC$. NETREC is the net recovery and it can be calculated as

$$= \min(NETSALVAGE, 1.5 * ORIGVAL) = \min(\$90,520, \$186,000) = \$90,520.$$

The values for the following variables, FCLEXP, PROEXP, ACRINT, mortgage rate and discount rate, are not taken from the MICA data but chosen based on the expert's knowledge. NETSAL-

VAGE is salvage value net of sales costs and repairs; ORIGVAL is the original property value. The LGD equation (2.40) is before the mortgage insurance claim.

The house price index (HPI) reported by the Office of Federal Housing Enterprise and Oversight (OFHEO) can be represented as the proxy for the housing market conditions and the corresponding House Price Ratio(HPR) can be defined as

$$HPR = 100 * (HPI/HPI(t - 18months)).$$

2.5.4 Numerical Example Involving Subprime Mortgages and Basel Capital Regulation

In Table 2.10, we consider a numerical example to illustrate important features of subprime mortgages and Basel capital regulation.

Parameter	Period t	Period $t + 1$	Parameter	Period t	Period $t + 1$
M	\$ 10 000	\$ 12 000	m_0	\$ 5 000	\$ 5 000
ω^M	0.05	0.05	m_1	\$ 5 000	\$ 5 000
r^M	0.051	0.082	m_2	\$ 5 000	\$ 5 000
$\bar{c}^M\omega$	0.0414	0.0414	\mathcal{C}	0.5	0.5
p^i	0.01	0.01	$mVar$	400	400
c^p	0.05	0.05	$\mu_j^{\mathcal{C}}$	0.25	0.25
r^f	0.01	0.01	$\frac{\partial p^i(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}}$	0.1	0.1
r^R	0.5	0.5	K	\$ 500	\$ 650
r^S	0.15	0.25	$\mathbf{0}$	\$ 150	\$ 150
ρ	0.08	0.08	r^0	0.101	0.101
$\omega(\mathcal{C}_t)$	0.5	0.5	$\frac{\partial r_t^S(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}}$	0.2	0.2
$\frac{\partial \omega(\mathcal{C}_t)}{\partial \mathcal{C}_t}$	0.02	0.02	f_t^Σ	0.65	0.5
C	\$ 1 000	\$ 1 000	\hat{f}_t^Σ	0.3	0.2
r^B	0.105	0.105	r^B	0.1	0.1
c^B	0.101	0.101	c^B	0.09	0.09
B	\$ 1 300	\$ 1 500	B	\$ 5 200	\$ 6 200
ω^B	0.5	0.5	f^M	0.08	0.19
r^T	0.036	0.04	D	\$ 9 300	\$ 11 100
T	\$ 2 000	\$ 2 000	r^D	0.105	0.105
P^T	\$ 800	\$ 1 200	c^D	0.101	0.101

Table 2.10: Numerical Example Involving Subprime Mortgages and Basel Capital Regulation

By using the values from Table 2.10, equation (2.31) becomes

$$K_t = 500 \geq 0.08 \times [0.5 \times 10000 + 0.5 \times 1300 + 12.5 \times 0.08 \times (400 + 150)] = 496.$$

Under the same hypothesis of Theorem 2.4.1 in the unsecuritized case when $l_t = 0$, (2.32) is given

by

$$\frac{\partial M_{t+j}^{n*}}{\partial \mathcal{C}_t} = \frac{1}{2} \times 0.25 \times \left(5000 - 5000 \times 0.1 - 5000 \times 0.2 \right) = 437.5$$

and (2.33) is

$$\frac{\partial r_{t+j}^{M^{n*}}}{\partial \mathcal{C}_t} = \frac{1}{2} \times 0.25 \times \left(\frac{5000}{5000} + 0.1 + 0.2 \right) = 0.1625.$$

The partial derivative (2.34) may be computed as

$$\frac{\partial M_t^*}{\partial \mathcal{C}_t} = - \frac{500 - 0.08 \times \left(0.5 \times 1300 + 12.5 \times 0.08 \times (400 + 150) \right)}{[0.5]^2 \times 0.08} \times 0.02 = -404.$$

One can compare this value with (2.34).

In this situation, the subprime mortgage rate response to changes in the level of credit rating, (2.35) is given by

$$\frac{\partial r_t^{M^*}}{\partial \mathcal{C}_t} = \frac{5000}{5000} + \frac{500 - 0.08 \times \left(0.5 \times 1300 + 12.5 \times 0.08 \times (400 + 150) \right)}{[0.5]^2 \times 0.08 \times 5000} \times 0.02 = 1.0808,$$

which is comparable to (2.35)

2.6 Discussions About Subprime Mortgages and the SMC

In this section, we discuss SOR's subprime mortgages and its relation with capital, information, risk and valuation, data on subprime mortgages as well as a numerical example involving the aforementioned issues and their relationship with the SMC.

2.6.1 Subprime Mortgage Design and the SMC

In this subsection, we discuss SOR's own interest rates, subprime mortgages, LTVRs as well as a stylized illustration of SOR's subprime mortgages and their relationship with the SMC.

2.6.1.1 Subprime Mortgage Rates and the SMC

Before and during the SMC, interest rate cuts were made in order to lower subprime mortgage rates and stimulate the economy, respectively. As we have noted in Subsection 2.2.1, low r^e were charged for a while before a higher, market-based, step-up rate, r^ψ , kicked in (compare with the

mortgage rate for profit maximizing SORs given by (2.2) in Subsection 2.2.1). An estimated one-third of subprime mortgages originated between 2004 and 2006 had $r^\varepsilon < 4\%$, which then increased significantly after some initial period. During the SMC, many new MRs eventually had trouble making their monthly repayments when H started to decline and r^ε increased to r^ψ . Teaser rate mortgage products artificially inflated the United States home-ownership market. Subprime ARMs are updated every six months for the life of the mortgage, and is subject to limits called *adjustment caps* on the amount that it can increase: the cap on the first adjustment is called the *initial cap*; the cap on each subsequent adjustment is called the *period cap*; the cap on the interest rate over the life of the mortgage is called the *lifetime cap*; and the floor on the interest rate is called the *floor*.

The hypothesis that interest rate resets were central to causing the SMC may be explained as follows (see, for instance, [36]). SORs found subprime mortgages attractive because of high r^ψ . MRs found them attractive because of r_t^ε , but subsequently regretted their decisions when they were obligated to pay r^ψ . The article [49], argues against this hypothesis. Backed by numerical proof, their reasons are, firstly, that there was never something like a low teaser rate on the typical subprime mortgage. Secondly, the interest-rate adjustments at reset, while not trivial, were not explosive. In support of this view, the risk premium was found to be relatively low. Thirdly, [49] claims that subprime SORs anticipated that most MRs would refinance their mortgages before or shortly after their interest-rate resets.

The risk premium, ϱ , that is key to mortgage pricing (see equation (2.2)), had an important role to play in the SMC. The size of ϱ is an indication of SOR's perceived credit risk. Before the SMC, the average difference between prime and subprime mortgage interest rates (the *subprime markup*) declined quite dramatically. In other words, the ϱ required by SOR to offer a subprime mortgage declined – should have resulted in an increase in ϱ . This trend continued to occur during the SMC even though the credit ratings of subprime MRs and the quality of subprime mortgages, both declined. Another observation is that if ϱ is very high then SORs are not likely to engage in mortgage securitization. Before the SMC, low risk premiums lead to increased mortgage securitization.

2.6.1.2 Subprime Mortgages and the SMC

The penalty, c^p extends the duration of subprime mortgages, while MR documentation status is associated with higher delinquency status. 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. [21] finds that predatory lending is associated with highly collateralized mortgages, inefficient refinancing of subprime mortgages, lending without due regard to ability to pay, prepayment penalties, balloon payments and poorly informed MRs. Under most circumstances competition among SORs attenuates predatory lending. Furthermore, literature (see, for instance, [95]) supports the view that either mortgage amount or cash extracted does not depend on the degree of the incentive to refinance. Nevertheless, it's a determinant of whether to refinance or not prior to MR deciding how much to be extracted.

Formula (2.3) in Subsection 2.2.2 represents the recovery amount, R . 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. During the SMC, the main cause of systemic contagion was the interconnectedness of the financial system. Asset managers relied on large financial institutions for their funding, asset protection and derivative transactions resulting in significant counterparty exposure to those institutions. Simultaneously, these institutions had complex balance sheets that lead to significant counterparty risk to one another. For instance, when Lehman Brothers and AIG failed, the market was unable to ascertain whether the same fate would befall other large financial institutions thereby hastening the collapse of the entire financial system. As a consequence, investors decided to move their assets away from institutions perceived to be risky. The SMC was deepened by investors that chose to discontinue their funding of such institutions. Counterparty risk became a system wide problem and ceased only when the United States government intervened with capital injections and credit guarantees via, for instance, the Troubled Assets Relief Program (TARP).

Subprime mortgages are important underlying assets in the process of securitization. Before the SMC, investors sought higher yields than those offered by United States Treasury bonds. The supply of relatively safe, income generating investments had not grown as fast as the risky ones. Investment banks answered this demand with financial innovation such as subprime residential mortgage-backed securities (RMBSs) and collateralized debt obligations (CDOs), which were assigned safe ratings by the credit rating agencies. By 2003, the supply of mortgages originated at traditional lending standards had been exhausted. However, continued strong demand for RMBSs and CDOs began to drive down lending standards, as long as mortgages could still be sold along the supply chain. Thus mortgage increased dramatically in order to satisfy this demand. Eventually, this speculative bubble proved unsustainable.

2.6.1.3 Subprime Loan-to-Value Ratios and the SMC

The LTVR denoted by L is one of the most important determinants of the riskiness of a mortgage. 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 (see, for instance, [55] and [74]). 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.

The paper, [31] shows that in the subprime market, lower incomes and rising H – decreasing L – increase the likelihood of extracting equity while refinancing. The aforementioned contribution produces evidence from individual loan-level data that subprime MRs are substituting mortgage debt for credit card debt and car loans. In particular, subprime MRs are more likely to extract house equity when the prevailing interest rates on this debt rises. These findings indicate that, in the subprime market, despite being liquidity- and credit-constrained, MRs do respond to the

relative cost of borrowing and attempt to finance consumption in the cheapest manner possible. In addition, the proportional increase in the probability of default is over 75 % higher for cash-outs than non-cash-outs in response to a 10 % reduction in L .

During the SMC, the positive expectation of house prices enhanced all mortgages, especially subprime mortgages accompanied with high credit risk. Therefore, risks, especially credit risk, increased on an SOR's balance sheet. Credit risk was shifted to investors around the world via securitization. Higher LTVRs increased the default risk of MRs. The collapse of the house market caused MRs to default as risk grew in the subprime market.

2.6.2 Subprime Capital, Information, Risk and Valuation and the SMC

In Section 2.3, a traditional mortgage model with subprime elements for SOR's profit as well as its optimal valuation was discussed.

2.6.2.1 Risk and Profit Under Subprime Mortgages and the SMC

In Subsection 2.3.1, the equations for retained earnings, depreciation and capital are given by (2.8), (2.9) and (2.10), respectively, led to a traditional mortgage model with subprime elements for SOR's profits. Furthermore, during the SMC, a decrease in H contributed to a decline in SOR profits (related to the traditional mortgage model with subprime elements given by (2.11)). SORs that retained credit risk were the first to be affected, as MRs became unable or unwilling to make payments and the value of mortgage portfolios declined. In this regard, profits at the 8 533 United States banks insured by the Federal Deposit Insurance Corporation (FDIC) fell from \$ 35.2 billion to \$ 646 million (effectively by 89 %) during Quarter 4 of 2007 when compared with the previous year. This was largely due to escalating mortgage losses and provisions for such losses. This decline in profits contributed to the worst bank and thrift quarterly performance since 1990. In 2007, these banks earned approximately \$ 100 billion, which represented a decline of 31 % from the record profit of \$ 145 billion in 2006. Profits decreased from \$ 35.6 billion to \$ 19.3 billion during the first quarter of 2008 versus the previous year, a decline of 46 %. FDIC quarterly reports intimated that profits decreased from \$ 35.6 billion to \$ 19.3 billion during the first quarter of 2008 versus the previous year, a decline of 46 %.

2.6.2.2 Valuation Under Subprime Mortgages and the SMC

Equation (2.12) in Subsection 2.3.2 provides a formula for SOR's valuation with mortgages at face value. As far as the valuation of subprime mortgages and their derivatives are concerned, in January 2006, Markit launched the ABX which is a series of indices that track the price of OMI on a standardized basket of home equity ABS obligations. The ABX actually has five indices, differentiated by credit rating: AAA, AA, A, BBB and BBB-. Each of these indices is an equally-weighted average of the price of OMI at a maturity of 30-years across similarly-rated tranches from 20 different home equity ABS deals. For example, the BBB index tracks the average price of OMI on the BBB-rated tranche. In addition, SOR valuation declined quite considerably during the SMC due to increased defaults and decreased profitability.

Before the SMC, high credit ratings were given by CRAs, thereby financing and exacerbating the housing boom. The issuing of these ratings were believed justified because of risk reducing practices, such as CDI 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 financial role players, increasing the counterparty risk which caused interest rates to increase. Refinancing became almost impossible and default rates exploded. All this operations embed systemic risk which finally caused the whole financial system to collapse.

In Subsection 2.3.2, SOR's total capital constraint for subprime mortgages at face value and the performance criterion at time t are given by (2.13) and (2.14), respectively, with the optimal valuation problem being stated in (2.15). In this regard, Theorem 2.3.4 addresses the issue of an optimal M under regulatory constraint. In order for SOR to fulfill its primary role as a subprime lender, (2.16) should satisfy the condition

$$\frac{K_t}{\rho\omega(C_t)} > \frac{\omega^B B_t + 12.5f^M(mVaR + 0)}{\omega(C_t)}.$$

In other words, M^* should have a positive value. A similar comment can be made about the optimal mortgage rate, r^{M^*} in (2.17). SOR's corresponding optimal deposits, provisions for deposit withdrawals and profits are given by (2.18), (2.19) and (2.20), respectively, when the capital constraint (2.13) holds. As far as the proof of Theorem 2.3.4 in Subsection 2.8.1 is concerned, if we substitute (2.45) into the optimal decisions for the mortgage rate and deposits represented by (2.42) and (2.43), respectively, we obtain a time-independent solution for SOR's optimal valuation problem. This leads to a significant reduction in the technical difficulty of the procedure. We use equations (2.11) and (2.46) in order to obtain SOR's profit given in (2.47). It is ironic that the SMC occurred despite the fact that most SOR's complied with the capital adequacy standards prescribed in Theorem 2.3.4.

On the other hand, when the capital constraint (2.13) does not hold, then M^* , r^{M^*} , T , D^* and Π^* are given by (2.21), (2.22), (2.23), (2.24) and (2.25), respectively. In terms of the SMC, this scenario is not very interesting unless capital constraints have been violated.

2.6.2.3 Optimal Valuation Problem and Loan-to-Value Ratios and the SMC

In Corollary 2.3.6 from Subsection 2.3.3, when $l_t > 0$, the LTVR corresponding to optimal M is given by (2.26). From this formula it is clear that, *ceteris parabis*, L^* will be favorable when ρ , H and ω is high and K is low. Before the SMC, conditions conducive to high H and low K prevailed while ρ was also relatively high. During the SMC, ω increased steadily although its influence on L is questionable. On the other hand, when $l_t = 0$, then the L corresponding to M^* is given by (2.27). This formula for L^* has a more complicated relationship with its constituting components than was the case in (2.26).

The simultaneous equations model (2.28) provides a relationship between r^M , L and c^p while (2.29) and (2.30) represents the L and c^p corresponding to M^* , respectively. For the first equation in (2.28), we may use r^M to explain ϱ that is primarily used to price mortgages and reflects an

opportunity cost of production of such mortgages. The prime rate is not widely used as an index rate for ARMs or hybrid ARMs. The prime rate is an administered rate that changes relatively infrequently and is influenced by many considerations other than the cost of funds (see [43] and the references contained therein). As such, the prime rate is not very responsive to changes in market rates and is largely uncorrelated with MRs' decisions to choose a mortgage with or without a c^p . For the second equation in (2.28) explaining L , [43] uses MR age and H in MR's zip-code area as instruments. Use of these variables as instruments is motivated by observations that older households tend to have higher wealth than younger households, which may make them less likely to seek a large mortgage relative to H , and that wealthier MRs tend to choose higher value properties than less wealthy MRs (once again, see [43]). These values would not be expected to be correlated with MR choices for ρ or c^p . For the last equation in (2.28) explaining the choice of c^p , the share of MRs that recently moved into MR's residential area and a dummy variable indicating whether MR's state passed a law restricting c^p is utilized. A high share of MRs that recently moved is an indication of high turnover in the local real estate market, which may lessen demand for mortgages with c^p . This indicator would be uncorrelated with r^M or L . State laws restricting c^p directly affect the supply of mortgages with c^p .

2.6.3 Examples Involving Subprime Mortgages and the SMC

In this subsection, we discuss an illustrative and numerical examples involving subprime mortgages and its relationship with capital, information, risk and valuation and its connections with the SMC.

2.6.3.1 Illustrative Example Involving Subprime Mortgages and the SMC

As far as the stylized illustration of subprime mortgages presented in Subsection 2.5.1 is concerned, between 1998 and 2006 subprime mortgages functioned in the intended way. During this period, the majority of the originations in the subprime market were refinancings of existing mortgages. Such mortgages contain an implicit embedded option on house prices, H . The question that arises in this case is who benefited from the option on house prices. The answer to this question is that if SOR is willing to refinance the house even with equity extraction, there is a split of the capital benefit between SOR and subprime MR. Depending on the value of H , SOR may be enticed to extend mortgages to riskier (subprime) MRs. In this regard, SORs only face a possibly safer MR if equity accumulates (compare with [55]).

Note that from Subsection 2.5.1.2, if $\mathbf{E}(M_t) < 0$, then SOR will not want to allow equity extraction at the end of period t unless there is a large fee to compensate SOR for the lost $\pi\mathbf{E}(M_{t+1})$. MRs refinanced their mortgages to avoid the higher step-up rate in the second period of their mortgage, but high prepayment penalty rates had to be paid. Thus, MRs started to default as risk grew in the subprime market. In reality, a mortgage rate that satisfies (2.37) in Subsection 2.5.1 may not exist. SOR cannot simply increase r^M since this action increases p and it becomes less likely that MR can make the higher repayment. Because period t is either two or three years long, MR would have to refinance at the end of period t or face imminent default. The expected value of mortgages in period t is (2.38), considered monitoring-, transaction-, funding- and OMI costs. In period $t+1$, the expected value of mortgages is given by (2.39) as in [55].

2.6.3.2 Numerical Example Involving Subprime Mortgages I and the SMC

The example in Subsection 2.5.2 shows that under favorable economic conditions (for instance, where mortgage default rates are low and \mathcal{C} is high) huge profits can be made from extending subprime mortgages as was the case before the SMC. On the other hand, during the SMC, when conditions are less favorable (for instance, where mortgage default rates are high and \mathcal{C} is low), SORs suffer large mortgage losses. In this regard, [35] demonstrates that low r^M discourage MRs from defaulting. However, when r^M is high as in the case of subprime MRs with M larger than H , the number of subprime mortgage defaults increase significantly. Daghli's main findings state that subprime MRs' credit quality is very sensitive to mortgage interest rate fluctuations.

We observe from the numerical example that costs of funds and capital constraints from Basel capital regulation have important roles to play in subprime mortgages and its relationship with capital, information, risk and valuation. We see that the profit in period $t + 1$ is less than the profit in period t . This is mainly due to higher mortgage default as a result of higher mortgage rates in period $t + 1$. This was a major cause of the SMC. Furthermore, the numerical example illustrates that L was much larger in period $t + 1$ as a consequence of the dramatic decrease in H . In other words, house equity in period $t + 1$ decreased in value when compared to period t .

2.6.3.3 Numerical Example Involving Subprime Mortgages II and the SMC

Using equation (2.40), the following observations were noted from Table 2.3: (1) the mean and standard error of LGD changes as CLTVR changes; (2) For the same region and during the same period, the highest mean loss severity is always associated with the highest CLTVR, e.g CLTVR >120 has a mean of 56.8 which is the highest; (3) For mortgages with CLTVR less than 80, LGD is insignificant at 5% level across all regions and time periods, however for mortgages with CLTVR between 80 and 90, LGD is trivial at 5% level in almost all but stress period. On the other hand, for mortgages with CLTVR greater than 90, LGD is significant for each and every region and time period. (4) LGD is usually higher for the duration of the economic downturn period of 1990-1994 compared to other periods.

The observations noted from Table 2.5 include the following: (1) There is a positive correlation between CLTVR and LGD. The highest CLTVR bucket has LGD mean of 49.2% which is the highest for all means and is three times as large as that of the lowest CLTVR bucket which is about 14%; (2) The initial LTVR appears to be positively related to LGD, even though with a small amount compared to CLTVR. The highest LTVR bucket has mean LGD of about 31.7% and is only 2.5 percentage points higher than the mean LGD of the lowest LTVR bucket of about 29.2%. (3) LGD and normalized mortgage size are negatively related. (4) As the mortgage ages increase so is the LGD. (6) LGD also seems to vary with property type, mortgage purpose, whether the owner intends to live in the property at origination, and whether the property was sold prior to foreclosure. (7) There are some differences between LGD and the state foreclosure laws.

In Table 2.6, descriptive statistics of the key variables from the cleaned data are presented, and the following observations were noted: LGD illustrate considerable amount of variation ranging from around -32.0% to 100.0%, with a mean of 30.5% and standard deviation of 16.4%. CLTVR varies wildly from 38.8% to 170.9% with an average of 104.4%. The average initial LTVR is 90.1%,

and only 11% of the mortgages have an LTVR below 80%. Also from Table 2.6, HPR ranges from 78.3% to 135.6% with a mean of 104.3% and a small standard deviation of 5.4%. The economic downturn indicator has a mean of 0.206, suggesting that 20.6% of the defaults happened in states where house prices depreciated in the past 18 months. Only 10.9% of the properties were sold prior to foreclosure for sure and for 57.2 of the properties were not pre-sold. The average time from mortgage to foreclosure (or settlement if the foreclosure date is missing) is around five years. About 18% of defaulted properties in the sample were foreclosed (settled) within two years, and 50% within four years. To get more insight into how the key variables are related, Table 2.7 reports the correlation matrix for the following variables: LGD, CLTVR, LTVR, HPR, mortgage size (LNSZN), and the number of months from origination to foreclosure (AGE) and from default to foreclosure (FCTIME). As can be seen from Table 2.7, the only variables that are positively correlated are CLTVR and LGD. Most of the variables have a modest negative correlation amongst each other.

Equation 2.41 denotes a general regression equation relating LGD to mortgage and property characteristics and housing market conditions.

$$LGD_{it} = \alpha + \sum_{j=1}^J \beta_j X_{ijt} + \sum_{k=1}^K \lambda_k Z_{ik} + \varepsilon_{it}, \quad (2.41)$$

where LGD_{it} is the loss given default of the i th defaulted mortgage measured at time of default t , calculated as in equation (2.40); X_{ijt} is the value of the j th time-varying explanatory variable for the i th defaulted mortgage at time t , such as CLTVR dummies, economic downturn indicator, whether the property was sold prior to foreclosure, and mortgage age indicators; Z_{ik} is the value of the k th non-time-varying explanatory variable for the i th defaulted mortgage, such as LTVR dummies, mortgage size dummies, mortgage purpose, property type, owner occupancy, and state foreclosure law dummies, that are observed at mortgage. Since CLTVR, LTVR, and mortgage size may have nonlinear effect on LGD, dummy values of CLTVR, LTVR, and mortgage size are used instead of the continuous variables.

With regard to regression with CLTVR, the regression parameter estimates, corresponding p-values, and goodness of fit measures are shown in Table 2.8. The model shows relatively high explanatory power ($\bar{R}^2 = 0.610$).

To assess the relevance of LTVR in determining loss severity, CLTVR dummies are dropped from CLTVR regression. The resulting model is shown in Table 2.9. On the other hand, in this model explanatory power is very low. The overall observations made from Table 2.8 and Table 2.9 are that: the key factors mentioned in Table 2.3 and Table 2.5 can explain about 61% ($= \bar{R}^2$) of variation in the loss severity (LGD) in the data from MICA; CLTVR is the single most important determinant of LGD (see Tables 2.7, 2.8 and 2.9). During the housing market downturn, LGD is statistically significantly higher. The stress factor is more important in the absence of CLTVR because LGD increased from 2.867 (see Table 2.8) to 7.344 (see Table 2.9). CLTVR is a much better predictor of LGD than LTVR.

2.6.3.4 Connections Between Subsection 2.5.3 and our Models

From Chapter 2, Subsection 2.2.3 of Section 2.2, we define loan-to-value ratio (LTVR) by the formula in equation (2.6), which is calculated the same as in Subsection 2.5.3. As explained before, it is clear that high L from equation (2.6), results from declining house prices that ultimately curtail the refinancing of mortgages. This is consistent with the analysis made in Subsection 2.6.3.3 that loss severity is generally higher during economic downturn (see also, Tables 2.3, 2.8 and 2.9) and the notion that loss severity should vary with the housing market condition. On the other hand, low ratios imply favorable house equity for subprime MRs. In Corollary 2.3.6 from Subsection 2.3.3, the LTVR corresponding to optimal M is given by (2.26). From this formula it is clear that L^* will be favorable when ρ , H and ω are high and K is low, this corresponds with Table 2.9 that LTVR is statistically and economically significantly related to LGD. Higher LTVR is associated with higher LGD. Since regulatory capital, K is linearly related to LGD, the result from Table 2.9 support the use of LTVR to segment risk and the notion that the higher the LTVR, the higher the risk-weights. The results in Table 2.6 proves the statement that says the rational borrower will default only when the value of the collateral falls below the mortgage value by an amount equal to the net transaction costs.

The view that house price appreciation reduces credit risk in a mortgage contract leads to an overoptimistic assessment of default risks if the property appreciation itself is overestimated. Moreover, if one fails to take account of the common factors that are driving house prices, this view also leads to an overoptimistic assessment of correlations between the different MRs' default risks (see, for instance, [61]);

2.6.4 Subprime Mortgages and Basel Capital Regulation (Unsecuritized Case)

In this subsection, we discuss the connections between Basel capital regulation and the SMC.

The capital constraint in Section 2.4 for the unsecuritized case is described by the expression in (2.13). In particular, we keep the risk-weights for short-and long-term marketable securities constant, i.e., $\omega^B = 1$. In this case, the capital constraint (2.13) becomes (2.31).

2.6.4.1 Subprime Mortgage Quantity and Pricing and Basel Capital Regulation (Unsecuritized Case) and the SMC

From the statement of Theorem 2.4.1 and the equivalence of \mathcal{C} and \mathbf{M} , we can deduce that

$$\text{if } \frac{\partial \sigma_{t+1}^{M^*}}{\partial \mathcal{C}_t} < 0 \text{ then } \frac{\partial K_{t+1}}{\partial \mathcal{C}_t} > 0 \text{ and if } \frac{\partial \sigma_{t+1}^{M^*}}{\partial \mathcal{C}_t} > 0 \text{ then } \frac{\partial K_{t+1}}{\partial \mathcal{C}_t} < 0.$$

This amended form of Theorem 2.4.1 suggests that an interesting relationship exists between mortgage quantity and price and bank capital. Under the assumptions of positive mortgage losses and a risk-sensitive capital constraint, banks can either raise or lower their capital holdings in response to an increase in the credit rating. Their choice depends on the effect that the changes in \mathcal{C}_t has on the likelihood of the capital constraint holding in the next time period.

During the 2004-2008 period, several so-called "quantitative impact studies" (QISs) were conducted under the auspices of the Basel Committee on Banking Supervision (BCBS) to explore the consequences of shifting from Basel I to Basel II for large banks. These studies show that bank capital requirements will fall further for many banks when Basel II is fully implemented. For instance, in the United States, the QIS results indicate potential reductions in required capital of more than 50 % for some major banks. The need to recapitalize banks reveals that the internal risk models of many banks performed poorly and greatly under-estimated risk exposure, forcing banks to reassess and reprice credit risk. To some extent, this reflects the difficulties of accounting for low-probability but large events (see, for instance, [121]). This situation does not comply with Theorem 2.4.1 where higher credit ratings imply that banks hold more capital. Furthermore, in the period during the SMC, credit ratings decreased while the banks attempted to hoard cash in order to boost their capital. In this regard, it is clear that the relationship between the banks and the CRAs during the real estate bubble has had and will have a long-lasting impact on banks' ability to recover from the current crisis. More specifically, the CRAs, who are remunerated by the mortgage issuers, gave high ratings to securities backed by subprime mortgages. In order to compensate for this situation, the pace of downgrades by credit agencies on MBSs has accelerated considerably in recent times. This has created additional problems since every time their portfolios are hit by significant credit downgrades, banks are compelled to raise their capital adequacy ratios. Often this results in the issuance of new equity which leads to dilution as shareholders at Citigroup, Merrill Lynch and Washington Mutual have experienced.

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

From the statement of Proposition 2.4.2 and the equivalence of \mathcal{C} and \mathcal{M} , in Subsection 2.4.2, we can deduce that if $l_t = 0$, then (2.32) and (2.33) is true.

Firstly, we deduce that when the capital constraint (2.31) is slack, the models with constant and varying mortgage risk-weights (while keeping the risk-weights for and RMBSs constant) yield the same results. Under the same hypothesis as Theorem 2.4.1, when the capital constraint (2.31) is slack, subprime mortgages, M , increase as a result of an increase in the credit rating, \mathcal{C} . Furthermore, the bank's own mortgage rate, r^M , can either increase or decrease depending on the parameters characterizing the mortgage default rate and the mortgage demand function.

In the period prior to the SMC, higher credit ratings of mortgages generally meant that less capital was held by banks in order to cover unexpected losses. This is contrary to what is suggested by Theorem 2.4.1 where higher credit ratings imply that banks hold more capital. Furthermore, in the period during the SMC, credit ratings decreased while the banks attempted to hoard cash in order to boost their capital.

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

From the statement of Proposition 2.4.3 and the equivalence of \mathcal{C} and \mathcal{M} , we can deduce that if $l_t > 0$ then by taking the first derivatives of equation (2.16) with respect to \mathcal{C}_t and using the fact

that the risk-weights for short- and long-term RMBSs, ω^B , are constant we obtain (2.34). In this situation, the mortgage rate response to changes in the credit rating is given by (2.35).

Under the same hypothesis as Theorem 2.4.1, when the capital constraint (2.31) holds, bank lending rises in response to an increase in the credit rating. The mortgage rate, r^M , can either rise or fall depending on the parameters characterizing the mortgage demand, M , and mortgage risk-weights, $\omega(\mathcal{C}_t)$. In the Basel II Capital Accord, a change in the credit rating does not only affect the mortgage demand but also the risk-weights in the bank's capital adequacy ratios (CARs). If the capital constraint (2.31) is slack, subprime mortgages rise as in Basel I. On the other hand, if the capital constraint holds, banks can still expand their credit supply, but to a lesser degree compared to the case where the capital constraint is slack. Banks are able to do so because an increase in the credit rating cause lower risk-weights and ultimately lead to a more relaxed capital requirement. The lower rate can either rise or fall, depending on the relative size of the change in mortgage demand and the capital adequacy ratio. Similarly, a decrease in the credit rating results in a possibly greater reduction of credit extension than in the Basel I model because of both a decrease in mortgage demand as well as a tightening of the capital constraint. Furthermore, under Basel II, an indication of the change in bank capital held is undetermined because credit rating increases have two counteracting effects on the equilibrium values of bank capital. On the one hand, increased credit ratings have a continual positive effect on mortgage demand and so raises the probability of the capital constraint (2.31) holding in future. At the same time, the CAR increases so that the chance of the capital constraint being lower exists.

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

If the capital constraint holds, the response of subprime mortgages and mortgage rates to a change in the level of credit rating, \mathcal{C}_t , is described by (2.36) in Subsection 2.4.4.

In the unsecuritized case, the rate of change of subprime mortgage value with respect to credit ratings when $l_t = 0$ has the value 437.5 while the same rate when $l_t > 0$ is 1 416.7. This means that, in an unsecuritized context, when the constraint is holding, the rate of change of subprime mortgage value is much greater than when it is not. In addition, in the unsecuritized case, the rate of change of the subprime mortgage rate with respect to credit ratings when $l_t = 0$ has the value 0.1625 while the same rate when $l_t > 0$ is 0.717. This means that, in an unsecuritized context, when the constraint is holding, the rate of change the subprime mortgage rate is much greater than when it is not.

2.7 2007-2010 Timeline of the SMC-Related Events Involving Subprime Mortgages

In this subsection, we give a timeline of events related to mortgages and their connection with the SMC.

Tuesday, 27 February 2007: Freddie Mac announces that it discontinue buying the most risky subprime mortgages and securities backed by them.

Monday, 2 April 2007: Subprime SOR, New Century Financial Corporation, files for Chapter 11 bankruptcy protection.

Thursday, 28 June 2007: FOMC votes to maintain its target for the federal funds rate at 5.25 %.

Monday, 6 August 2007: AHMIC files for Chapter 11 bankruptcy protection.

Tuesday, 7 August 2007: FOMC votes to maintain its target for the federal funds rate at 5.25 %.

Thursday, 9 August 2007: France's largest bank, BNP Paribas, halts redemptions on three investment funds.

Friday, 10 August 2007: Central banks coordinate efforts to increase liquidity for first time since the aftermath of the Tuesday, 11 September 2001 terrorist attacks. The Fed injected a combined \$ 43 billion, ECB 156 billion Euros (\$ 214.6 billion) and the Bank of Japan 1 trillion Yen (\$ 8.4 billion). Smaller amounts have come from the central banks of Australia and Canada. In particular, FRB announces that it "will provide reserves as necessary . . . to promote trading in the federal funds market at rates close to OMC's target rate of 5.25 %. In current circumstances, depository institutions may experience unusual funding needs because of dislocations in money and credit markets. As always, the discount window is available as a source of funding."

Friday, 17 August 2007: Fed cuts the discount rate by 0.5 % to 5.75 % from 6.25 % – only 50 basis points (bps) above FOMC's federal funds rate target – while leaving the federal funds rate unchanged in an attempt to stabilize financial markets. It also warns that the credit crunch could be a risk to economic growth. FRB also increases the maximum primary credit borrowing term to 30 days, renewable by MRs.

Tuesday, 4 September 2007: The rate at which banks lend to each other rises to its highest level since December 1998. The so-called LIBOR was 6.7975 %, way above the Bank of England's 5.75 % base rate. This means that banks either worry whether other banks will survive or urgently need the money themselves.

Tuesday, 18 September 2007: Fed via FOMC cuts its main federal funds (base) rate by 50 bps, i.e., half a point (0.5 %) to 4.75 %. FRB votes to reduce the primary credit (prime) rate by 50 bps to 5.25 % in order to limit damage to the economy from the SMC.

Wednesday, 10 October 2007: Treasury secretary, Paulson, announces the HOPE NOW initiative, an alliance of investors, servicers, mortgage market participants, and credit and homeowners' counselors encouraged by the Treasury Department and HUD.

Wednesday, 31 October 2007: Fed lowers the federal funds rate by 25 bps to 4.5 %, while FRB votes to reduce the primary credit rate 25 bps to 5.00 %. Also, the S&P500, Nasdaq and Dow tops.

Tuesday, 11 December 2007: The FOMC votes to reduce its target for the federal funds rate 25 bps to 4.25 %. The FRB votes to reduce the primary credit rate 25 bps to 4.75 %.

Wednesday, 12 December 2007: FRB announces the creation of TAF in which fixed amounts of term funds will be auctioned to depository institutions against a wide variety of collateral.

Thursday, 13 December 2007: Fed co-ordinates an unprecedented action by five leading central banks around the world to offer billions of dollars in loans to banks. The Bank of England calls it an attempt to "forestall any prospective sharp tightening of credit conditions." The move succeeds in temporarily lowering the rate at which banks lend to each other, i.e., the LIBOR decreased.

Friday, 21 December 2007: FRB announces that TAF auctions will be conducted every two weeks as long as financial market conditions warrant.

Tuesday, 22 January 2008: FOMC votes to reduce its target for the federal funds rate by 75 bps to 3.5 %, while the FRB votes to reduce the primary credit rate 75 bps to 4 %.

Wednesday, 30 January 2008: FOMC votes to reduce its target for the federal funds rate 50 bps to 3 %, while the FRB votes to reduce the primary credit rate 50 bps to 3.5 %.

Tuesday, 11 March 2008: FRB announces the creation of the TSLF, which will lend up to \$ 200 billion of Treasury securities for 28-day terms against federal agency debt, federal agency RMBS, non-agency AAA/Aaa private label RMBSs, and other securities. FOMC increases its swap lines with the ECB by \$ 10 billion and the Swiss National Bank by \$ 2 billion and also extends these lines until Tuesday, 30 September 2008.

Sunday, 16 March 2008: FRB establishes the PDCF, extending credit to primary dealers at the primary credit rate against a broad range of investment grade securities. FRB votes to reduce the primary credit rate 25 bps to 3.25 %, lowering the spread between the primary credit rate and FOMC target for the federal funds rate to 25 bps. FRB also votes to increase the maximum maturity of primary credit loans to 90 days.

Tuesday, 18 March 2008: FOMC votes to reduce its target for the federal funds rate 75 bps to 2.25 %, while the FRB votes to reduce the primary credit rate 75 bps to 2.50 %.

Wednesday, 30 April 2008: FOMC votes to reduce its target for the federal funds rate 25 bps to 2 %, while the FRB votes to reduce the primary credit rate 25 bps to 2.25 %.

Wednesday, 25 June 2008: FOMC votes to maintain its target for the federal funds rate at 2.00 %.

Wednesday, 30 July 2008: FRB extends the TSLF and PDCF until Friday, 30 January 2009, introduces auctions of options on \$ 50 billion of draws on the TSLF and introduces 84-day TAF loans.

Tuesday, 5 August 2008: FOMC votes to maintain its target for the federal funds rate at 2.00 %.

Tuesday, 16 September 2008: FOMC votes to maintain its target for the federal funds rate at 2.00 %.

Wednesday, 17 September 2008: SEC announces a temporary emergency ban on short selling of stocks of all companies in the financial sector.

Friday, 19 September 2008: Treasury announces a temporary guarantee program that will make available up to \$ 50 billion from ESF to guarantee investments in participating money market mutual funds.

Sunday, 21 September 2008: FRB approves applications of investment banking companies Goldman Sachs and Morgan Stanley to become bank holding companies.

Monday, 29 September 2008: FRB expands TAF, announcing an increase in the size of the 84-day maturity auction to \$ 75 billion and two forward TAF auctions totaling \$ 150 billion to provide short-term (one- to two-week) TAF credit over year-end.

The Treasury opens its TMMFGP – see Friday, 19 September 2008. The temporary guarantee program provides coverage to shareholders for amounts that they held in participating money market funds as of the close of business on Friday, 19 September 2008.

Monday, 6 October 2008: FRB announces that Fed will pay interest on depository institutions' required and excess reserve balances at an average of the federal funds target rate less 10 bps on required reserves and less 75 bps on excess reserves.

Wednesday, 8 October 2008: The U.K. government offers up to GBP 200 billion (\$ 350 billion) in short-term lending support. The Treasury freezes assets of Landsbanki in the U.K. while threatening legal action. Central banks in the United States (i.e., the United States Federal Reserve), England, China, Canada, Sweden, Switzerland and the European Central Bank cut rates in a coordinated effort to aid world economy. The base rate cuts on this day can be summarized as follows in the table below.

The Fed also reduced its emergency lending rate to banks by half a percentage point, to 1.75 %. The IMF, in its bleakest forecast in years, foresees major global downturn. Japan's Nikkei plunged more than 9 % and Indonesia's Jakarta composite dropped 10 % as Asia markets responded to the Dow's lowest close in five years and fears of a global recession. Europe's financial markets suffered more heavy losses despite the world's leading economies slashing interest rates to tackle the global financial crisis. The NYSE opened nervously following the interest rate cuts. Markets in Britain, France and Germany closed well down despite the coordinated rate cuts led by the United States

Tuesday, 14 October 2008: FDIC creates a new TLGP to guarantee the senior debt of all FDIC-insured institutions and their holding companies, as well as deposits in non-interest-bearing deposit transactions until Tuesday, 30 June 2009.

8/10/2008 Interest Rate Changes	
Country	Changes
United States:	2 % to 1.5 %
Canada:	3 % to 2.5 %
European Central Bank:	5 % to 4.5 %
England:	5 % to 4.5 %
Switzerland:	2.75 % to 2.25 %
Sweden:	5 % to 4.25 %
China:	7.24 % to 6.93 %
Hong Kong:	3.5 % to 2.5 %
Japan:	Holding at 0.5 %

Table 2.11: Base Rate Cuts on Wednesday, 8 October 2008

Wednesday, 22 October 2008: FRB announces that it will alter the formula used to determine the interest rate paid to depository institutions on excess reserve balances. The new rate will be set equal to the lowest FOMC target rate in effect during the reserve maintenance period less 35 bps.

Wednesday, 29 October 2008: FOMC votes to reduce its target for the federal funds rate 50 bps to 1.00 %, while FRB reduces the primary credit rate 50 bps to 1.25 %. IMF announces the creation of a short-term liquidity facility for market-access countries.

Wednesday, 5 November 2008: FRB announces that it will alter the formula used to determine the interest rate paid to depository institutions on required and excess reserve balances. The rate on required reserves will be set equal to the average target federal funds rate over the reserve maintenance period. The rate on excess balances will be set equal to the lowest FOMC target rate in effect during the reserve maintenance period.

Thursday, 6 November 2008: BOE cuts its interest (base) rate from 4.5 % to 3.0 %, the lowest rate in 50 years. ECB cut by 0.5 % down to 3.25 %. Fed and Central Banks in China, Japan and Australia had already cut rates several days earlier. According to a prognosis of the IMF in Washington, D.C., a worldwide recession of the developed economies, -0.3 % on average, will happen in 2009. There has not been four consecutive negative growth quarters since WWII. United States futures, which offer an indication of how NYSE markets, were higher, possibly signaling a rebounded after two days of selling. European markets are having a rough time as well. London, Paris and Frankfurt all lost 6 % to 7 %. The International Monetary Fund (IMF) approves \$ 16.4 billion Ukraine loan to bolster its economy, shaken by global financial turmoil. The Bank of England slashes interest rates unexpectedly from 4.5 % to 3 % - the lowest level since 1955. The European Central Bank lowers eurozone rates to 3.25 % from 3.75 % in an attempt to prevent a recession.

Tuesday, 11 November 2008: Treasury announces a new streamlined loan modification program

with cooperation from FHFA, HUD and the HOPE NOW alliance.

Thursday, 20 November 2008: Fannie Mae and Freddie Mac announce that they will suspend mortgage foreclosures until January 2009.

Tuesday, 16 December 2008: FOMC votes to establish a target range for the effective federal funds rate of 0 to 0.25 %, while FRB votes to reduce the primary credit rate 75 bps to 0.50 %. FRB also establishes the interest rates on required reserve balances and excess balances at 0.25 % for reserve maintenance periods beginning Thursday, 18 December 2008.

Friday, 30 January 2009: The Board of Governors announces a policy to avoid preventable foreclosures on certain mortgages held, controlled or owned by a Federal Reserve Bank. The policy was developed pursuant to section 110 of the Emergency Economic Stabilization Act.

Tuesday, 3 February 2009: Fed announces the extension, until Friday, 30 October 2009, of the existing liquidity programs scheduled to expire on Thursday, 30 April 2009. The Board of Governors and the FOMC note "continuing substantial strains in many financial markets."

Tuesday, 17 February 2009: The Treasury releases its first monthly survey of bank lending by the top 20 recipients of government investment through CPP. The survey found that banks continued to originate, refinance and renew mortgages from the beginning of the program in October until December 2008.

Wednesday, 18 February 2009: President Obama announces HASP that includes a program to permit the refinancing of conforming mortgages owned or guaranteed by Fannie Mae or Freddie Mac that currently exceed 80 % of the value of the underlying house. The plan also creates a \$ 75 billion HSI to modify the terms of eligible mortgages to reduce monthly repayments. In addition, the Treasury will increase its preferred stock purchase agreements with Fannie Mae and Freddie Mac to \$ 200 billion, and increase the limits on the size of Fannie Mae and Freddie Mac's portfolios to \$ 900 billion.

Thursday, 26 February 2009: FDIC announces that the number of "problem banks" increased from 171 institutions with \$ 116 billion of assets at the end of the third quarter of 2008, to 252 insured institutions with \$ 159 billion in assets at the end of fourth quarter of 2008. FDIC also announces that there were 25 bank failures and five assistance transactions in 2008, which was the largest annual number since 1993.

Fannie Mae reports a loss of \$ 25.2 billion in the fourth quarter of 2008, and a full year 2008 loss of \$ 58.7 billion. Fannie Mae also reports that on 25 February 2009, the FHFA submitted a request for \$ 15.2 billion from the Treasury under the terms of the SPSPA in order to eliminate Fannie Mae's net worth deficit as of 31 December 2008.

Wednesday, 4 March 2009: The Treasury announces guidelines to enable servicers to begin modifications of eligible mortgages under the HASP.

Thursday, 5 March 2009: Carlyle Capital Corporation receives a default notice after failing to meet margin calls on its mortgage fund.

Wednesday, 11 March 2009: Fed releases the minutes of its meetings from Sunday, 13 July 2008 through Tuesday, 16 December 2008 concerning Fed liquidity facilities and other issues related to the financial turmoil.

Tuesday, 17 March 2009: FDIC decides to extend the debt guarantee portion of the TLGP from 30 June 2009 through 31 October 2009, and to impose a surcharge on debt issued with a maturity of one-year or more beginning in the second quarter of 2009 to gradually phase-out the program.

Wednesday, 18 March 2009: FOMC votes to maintain the target range for the effective federal funds at 0 to 0.25 % and decides to increase the size of Fed's balance sheet by purchasing up to an additional \$ 750 billion of agency MBSs, bringing its total purchases of these securities to up to \$ 1.25 trillion this year, and to increase its purchases of agency debt this year by up to \$ 100 billion to a total of up to \$ 200 billion. FOMC also decides to purchase up to \$ 300 billion of longer-term Treasuries over the next six months to help improve conditions in private credit markets. Finally, FOMC announces that it anticipates expanding the range of eligible collateral for TALF.

The FRBNY releases more information on Fed's plan to purchase Treasuries. The Desk will concentrate its purchases in nominal maturities ranging from 2 to 10 years. The purchases will be conducted with Fed's primary dealers through a series of competitive auctions and will occur two to three times a week. The Desk plans to hold the first purchase operation the next week.

Thursday, 2 April 2009: FASB approves new guidance to ease the accounting of toxic assets held by banks and other financial companies. In particular, FASB provides new guidance on how to determine the fair value of assets for which there is no active market.

Thursday, 23 April 2009: Fed publishes the annual financial statements for the combined Federal Reserve Banks, the 12 individual Federal Reserve Banks, the limited liability companies that were created in 2008 to respond to strains in the financial markets, and the Board of Governors for the years ended 31 December 2008 and 2007.

Thursday, 7 May 2009: Fed releases the results of SCAP – stress test – of the 19 largest United States bank holding companies. The assessment finds that the 19 firms could lose \$ 600 billion during 2009 and 2010 if the economy were to track the more adverse scenario considered in the program. The assessment also finds that 9 of the 19 firms already have adequate capital to maintain Tier 1 capital in excess of 6 percent of total assets and common equity capital in excess of 4 percent under the more adverse scenario. Ten firms would need to add \$ 185 billion to their capital to maintain adequate buffers under the more adverse scenario. However, transactions and revenues since the end of 2008 have reduced to \$ 75 billion the additional capital that these firms must raise in order to establish the capital buffer required under the program. A bank holding company needing to augment its capital buffers will be required to develop a detailed plan to be approved by its primary supervisor within 30 days and to implement its plan to raise additional capital by early November 2009.

Thursday, 21 May 2009: S&P's Ratings Services lowers its outlook on U.K. government debt from stable to negative because of the estimated fiscal cost of supporting the nation's banking system. S&P estimates that this cost could double the government's debt burden to about 100 % of GDP by 2013.

Friday, 22 May 2009: FRB announces the adoption of a final rule that will allow bank holding companies to include in their Tier 1 capital without restriction senior perpetual preferred equity issued to the United States Treasury Department under TARP.

Wednesday, 27 May 2009: FDIC announces that the number of "problem banks" increased from 252 insured institutions with \$ 159 billion in assets at the end of fourth quarter of 2008, to 305 institutions with \$ 220 billion of assets at the end of the first quarter of 2009. FDIC also announces that there were 21 bank failures in the first quarter of 2009, which is the largest number of failed institutions in a quarter since the first quarter of 1992.

Sunday, 31 May 2009: Treasury announces an extension of its TMMFGP through Friday, 18 September 2009 that provides coverage to shareholders up to the amount held in participating money market funds as of the close of business on Thursday, 18 September 2008. The Program currently covers over \$ 3 trillion of combined fund assets and was scheduled to end on Thursday, 30 April 2009.

Monday, 1 June 2009: FRB announces the criteria it will use to evaluate redemption applications from the 19 bank holding companies that received Treasury capital as part of the SCAP. An initial set of redemption approvals are expected to be announced during the week of Monday, 8 June 2009.

Wednesday, 10 June 2009: Fed issues the first of an ongoing series of monthly reports on its credit and lending facilities. The report provides information on borrowing patterns and collateral for many of Fed's credit and liquidity programs, including the number of borrowers and borrowing amounts by type of institution, collateral by type and credit rating, and data on the concentration of borrowing. The report also includes information on liquidity swap usage by country, quarterly income for important classes of Fed assets, and asset distribution and other information on the limited liability companies created to avert the disorderly failures of Bear Stearns and AIG.

Friday, 12 June 2009: Fed announces that it is reviewing regulatory capital requirements for banking organizations in response to a decision by FASB to address weaknesses in accounting and disclosure standards for off-balance sheet vehicles.

Thursday, 28 June 2007: FOMC votes to maintain its target for the federal funds rate at 5.25 %.

Tuesday, 30 June 2009: Treasury proposes a bill to Congress that would create a new CFPA. The bill would transfer all current consumer protection functions of FRB, Comptroller of the Currency, Office of Thrift Supervision, FDIC, FTC, and the National Credit Union Administration to the new agency. In addition, Treasury proposes amendments to the Federal Trade Commission Act with regards to coordination with the proposed CFPA.

Thursday, 23 July 2009: FRB proposes significant changes to Regulation Z (Truth in Lending) intended to improve the disclosures consumers receive in connection with closed-end mortgages and home-equity lines of credit. Among other changes, FRB's proposal would improve the disclosure of the annual percentage rate on closed-end mortgages and require lenders to show SORs how much their monthly payments might increase for ARMs. The proposal would also prohibit payments to a mortgage broker or officer that are based on a mortgage's interest rate or other terms and prohibit SORs from steering consumers to transactions that are not in their interest in order to increase SOR's compensation.

Friday, 24 July 2009: Fed announces that the amounts of TAF credit offered at each of the two auctions in August will be reduced to \$ 100 billion from \$ 125 billion in July. The reduction is consistent with the expectation that TAF auction amounts would be reduced gradually further in coming months if market conditions continue to improve.

Sunday, 26 July 2009: Citigroup announces the preliminary results of its offers to exchange its publicly held convertible and non-convertible preferred and trust preferred securities for newly issued shares of its common stock.

Thursday, 27 August 2009: FDIC announces that the number of "problem banks" increased from 305 insured institutions with \$ 220 billion in assets at the end of first quarter of 2009, to 416 institutions with \$ 299.8 billion of assets at the end of the second quarter of 2009.

Friday, 28 August 2009: Fed announces that the amounts of Term Auction Facility (TAF) credit offered at each of the two auctions in September will be reduced to \$ 75 billion from \$ 100 billion in August. This follows on a reduction from \$ 125 billion in July. The reduction is consistent with expectations that the TAF auction amounts will continue to decrease as market conditions improve.

Wednesday, 14 October 2009: The DJIA closes above 10,000 for the first time since Friday, 3 October 2008.

Monday, 9 November 2009: FRB announces that 9 of the 10 bank holding companies that were determined in SCAP earlier this year to need to raise capital or improve the quality of their capital now have increased their capital sufficiently to meet or exceed their required capital buffers. GMAC was the one firm that to date has not raised enough capital to meet its required capital buffer.

Tuesday, 17 November 2009: Citing continued improvement in financial market conditions, the FRB approves a reduction in the maximum maturity of primary credit loans at the discount window for depository institutions to 28 days from 90 days effective Thursday, 14 January 2010. Fed had lengthened the maximum maturity of primary credit loans first to 30 days on Friday, 17 August 2007 and then to 90 days on Sunday, 16 March 2008.

Monday, 28 December 2009: FRB proposes amendments to Regulation D (Reserve Requirements of Depository Institutions) that would enable the establishment of a term deposit facility.

Under the proposal, the Federal Reserve Banks would offer interest-bearing term deposits to eligible institutions through an auction mechanism.

Saturday, 28 December 2009: FRB proposes amendments to Regulation D (Reserve Requirements of Depository Institutions) that would enable the establishment of a term deposit facility. Under the proposal, the Federal Reserve Banks would offer interest-bearing term deposits to eligible institutions through an auction mechanism.

Thursday, 7 January 2010: The Federal Reserve releases an advisory reminding depository institutions of supervisory expectations for sound practices in managing interest rate risk. This advisory, adopted along with the other financial regulators, reiterates the importance of effective corporate governance, policies and procedures, risk measuring and monitoring systems, stress testing, and internal controls related to the interest rate risk exposures of depository institutions.

Tuesday, 12 January 2010: The Federal Reserve Board announces preliminary unaudited results indicating that the Reserve Banks transferred approximately \$46.1 billion of their estimated 2009 net income of \$52.1 billion to the United States Treasury. This represents a \$14.4 billion increase over the 2008 results. The increase was primarily due to increased earnings on securities holdings during 2009.

Thursday, 21 January 2010: President Obama proposes new restrictions on the trading activities and market shares of commercial banks. Specifically, he calls for prohibiting banks from owning, investing in or sponsoring hedge funds, private equity funds, or proprietary trading operations for their own profit. He also calls for broader market share limits on commercial banks.

Thursday, 18 February 2010: The Federal Reserve Board announces an increase in the primary credit rate (generally referred to as the discount rate) from 1/2 percent to 3/4 percent, effective February 19, 2010. The Board also announces that, effective on March 18, the typical maximum maturity for primary credit loans will be shortened to overnight. In addition, the Board announces that it has raised the minimum bid rate for the Term Auction Facility (TAF) by 1/4 percentage point to 1/2 percent. The final TAF auction will be on March 8, 2010. The Board cites continued improvement in financial market conditions for the changes to the terms of its discount window lending programs.

Wednesday, 24 February 2010: Freddie Mac reports a net loss of \$6.5 billion in the fourth quarter of 2009 and a full-year 2009 net loss of \$21.6 billion, compared with a \$50.1 billion net loss in 2008.

Sunday, 9 May 2010: The Federal Reserve re-establishes temporary reciprocal currency arrangements (swap lines) with the Bank of Canada, the Bank of England, the European Central Bank and the Swiss National Bank in response to the re-emergence of strains in United States dollar short-term funding markets in Europe.

Tuesday, 11 May 2010: The Federal Reserve publicly releases the text of three agreements with foreign central banks to reestablish temporary dollar swap facilities and announces that it would disclose information weekly on use of the swap lines by each of the counterparty central banks.

Friday, 28 May 2010: The Congressional Budget Office releases a study describing the various actions by the Federal Reserve to stabilize financial markets since 2007 and how those actions are likely to affect the federal budget in coming years. The report also presents estimates of the risk-adjusted (or fair value) subsidies that the Federal Reserve provided to financial institutions through its emergency programs.

2.8 Appendix to Chapter 2

In this section, we provide the proofs of the main results in Chapter 2.

2.8.1 Appendix to Chapter 2: Proof of Theorem 2.3.4

An immediate consequence of the prerequisite that the capital constraint (2.13) holds, is that M is closely related to the capital adequacy constraint and is given by (2.16). Also, the dependence of changes in r^M on credit ratings may be fixed as $\frac{\partial r_t^{M*}}{\partial \mathcal{C}_t} = \frac{m_2}{m_1}$. Equation (2.16) follows from (2.13) and the fact that the capital constraint holds. This also leads to equality in (2.13). In (2.17) we substituted SOR's optimal value for M_t into the subprime mortgage constraint (2.4) to get SOR's optimal default rate. We obtain optimal \mathbb{T}_t using the following steps. Firstly, we rewrite (2.7) in terms of deposits so that $D_t = \frac{\mathbb{T}_t + M_t + B_t - K_t - \mathbb{B}_t}{1 - \gamma}$. Next, we note that the first-order conditions (for verification of these conditions see the appendix in Subsection 2.8.3) are given by

$$\frac{\partial \Pi_t}{\partial r_t^M} \left[1 + c_t^{dw} - \mathbf{E}_t \left\{ \int_{\underline{M}}^{\overline{M}} \delta_{t,1} \frac{\partial V}{\partial K_{t+1}} dF(\sigma_{t+1}^M) \right\} \right] + l_t \rho m_1 \omega(\mathcal{C}_t) = 0; \quad (2.42)$$

$$\frac{\partial \Pi_t}{\partial D_t} \left[1 + c_t^{dw} - \mathbf{E}_t \left\{ \int_{\underline{M}}^{\overline{M}} \delta_{t,1} \frac{\partial V}{\partial K_{t+1}} dF(\sigma_{t+1}^M) \right\} \right] = 0; \quad (2.43)$$

$$\rho \left[\omega(\mathcal{C}_t) M_t + \omega^B B_t + 12.5 f^M(mVaR + 0) \right] \leq K_t; \quad (2.44)$$

$$-c_t^{dw} + \mathbf{E}_t \left\{ \int_{\underline{M}}^{\overline{M}} \delta_{t,1} \frac{\partial V}{\partial K_{t+1}} dF(\sigma_{t+1}^M) \right\} = 0. \quad (2.45)$$

Here $F(\cdot)$ is the cumulative distribution of the shock to M . Using (2.45) we can see that (2.43) becomes $\frac{\partial \Pi_t}{\partial D_t} = 0$. Looking at the form of Π_t given in (2.11) and the equation

$$P^{\mathbb{T}_t}(\mathbb{T}_t) = \frac{r_t^p}{2D} [\overline{D} - \mathbb{T}_t]^2 \quad (2.46)$$

it follows that

$$\begin{aligned}\Pi_t = & \left(r_t^M - \bar{c}_t^{M\omega} - p_t^i + c_t^p r_t^f - (1 - r_t^R) r_t^S \right) M_t + C(\mathbf{E}[S(\mathcal{C}_t)]) + \left(r_t^B - c_t^B \right) B_t \\ & + r_t^T \mathbf{T}_t - \frac{r_t^p}{2\bar{D}} [\bar{D} - \mathbf{T}_t]^2 - (r_t^D + c_t^D) D_t - \left(r_t^B + c_t^B \right) B_t + \Pi_t^p.\end{aligned}\quad (2.47)$$

Finding the partial derivatives of profit, Π_t , with respect to deposits, D_t , we have that

$$\frac{\partial \Pi_t}{\partial D_t} = (1 - \gamma) \left[r_t^T + \left(r_t^B + c_t^B \right) + \frac{r_t^p}{\bar{D}} (\bar{D} - \mathbf{T}_t) + (r_t^B - c_t^B) \right] - (r_t^D + c_t^D). \quad (2.48)$$

This would then give us the optimal value for D_t . Using (2.7) and all SOR's optimal values calculated to date, we can find optimal deposits, and the same goes for optimal profits. \square

2.8.2 Appendix to Chapter 2: Proof of Corollary 2.3.5

For the situation where capital constraint (2.13) does not hold (i.e., $l_t = 0$), using equation (2.45) and the fact that $l_t = 0$, we can see that (2.43) becomes $\frac{\partial \Pi_t}{\partial r_t^M} = 0$. As in the proof of Theorem 2.3.4, looking at the form of Π_t given in (2.11) and (2.46), we have equation (2.47). Therefore

$$\begin{aligned}\frac{\partial \Pi_t}{\partial r_t^M} = & M_t - m_1 \left(r_t^M - \bar{c}_t^{M\omega} - p_t^i + c_t^p r_t^f - (1 - r_t^R) r_t^S \right) \\ & + m_1 (r_t^T + (r_t^B + c_t^B) + (r_t^B - c_t^B)) + \frac{r_t^p}{\bar{D}} (\bar{D} - \mathbf{T}_t) m_1 = 0.\end{aligned}\quad (2.49)$$

Substituting (2.48) into (2.49) and using (2.4) would give us optimal mortgages and mortgage rate given by (2.21) and (2.22), respectively. Furthermore we can find SOR's optimal deposit, deposit withdrawals and profits. \square

To derive equations (2.42) to (2.45), we rewrite equation (2.15) to become

$$\begin{aligned}V(K_t, x_t) = & \max_{r_t^M, D_t, \Pi_t} \left\{ \Pi_t + l_t \left[K_t - \rho \left(\omega(\mathcal{C}_t) M_t + \omega^B B_t + 12.5 f^M (mVaR + 0) \right) \right] \right. \\ & \left. - c_t^{dw} \left[K_{t+1} \right] + \mathbf{E}_t \left[\delta_{t,1} V \left(K_{t+1}, x_{t+1} \right) \right] \right\},\end{aligned}\quad (2.50)$$

but

$$\Pi_t = n_t (d_t + E_t) + (1 + r_t^O) O_t - K_{t+1} + \Delta F_t. \quad (2.51)$$

By substituting the subprime mortgage constraint (2.4) and equation (2.51), equation (2.50) be-

comes

$$\begin{aligned}
V(K_t, x_t) = & \max_{r_t^M, D_t, \Pi_t} \left\{ \left(n_t(d_t + E_t) + (1 + r_t^O)O_t - K_{t+1} + \Delta F_t \right) \right. \\
& + l_t \left[K_t - \rho \left[\omega(C_t) \left(m_0 - m_1 r_t^M + m_2 C_t + \sigma_t^M \right) + \omega^B B_t + 12.5 f^M(mVaR + 0) \right] \right] \\
& \left. - c_t^{dw} \left[K_{t+1} \right] + \mathbf{E}_t \left[\delta_{t,1} V \left(K_{t+1}, x_{t+1} \right) \right] \right\}. \tag{2.52}
\end{aligned}$$

Finding the partial derivative of SOR value in (2.52), with respect to the capital constraint, K_{t+1} , we have

$$\frac{\partial V}{\partial K_{t+1}} = -1 - c_t^{dw} + \mathbf{E}_t \left[\int_{\underline{M}}^{\overline{M}} \delta_{t,1} \frac{\partial V}{\partial K_{t+1}} dF \left(\sigma_{t+1}^M \right) \right]. \tag{2.53}$$

2.8.3 Appendix to Chapter 2: Derivation of First Order Conditions (2.42) to (2.45)

Next, we discuss the formal derivation of the first order conditions (2.42) to (2.45).

2.8.3.1 First Order Condition (2.42)

Choosing r_t^M from equation (2.52) and using equation (2.53) above, the first order condition (2.42) for Problem 2.3.3 is $\frac{\partial \Pi_t}{\partial r_t^M} \left[1 + c_t^{dw} - \mathbf{E}_t \left\{ \int_{\underline{M}}^{\overline{M}} \delta_{t,1} \frac{\partial V}{\partial K_{t+1}} dF(\sigma_{t+1}^M) \right\} \right] + l_t \rho m_1 \omega(C_t) = 0$.

2.8.3.2 First Order Condition (2.43)

Choosing the deposits, D_t , from equation (2.52) and using equation (2.53) above, the first order condition (2.43) for Problem 2.3.3 is $\frac{\partial \Pi_t}{\partial D_t} \left[1 + c_t^{dw} - \mathbf{E}_t \left\{ \int_{\underline{M}}^{\overline{M}} \delta_{t,1} \frac{\partial V}{\partial K_{t+1}} dF(\sigma_{t+1}^M) \right\} \right] = 0$.

2.8.3.3 First Order Condition (2.44)

Finding the partial derivative of SOR value in (2.52) with respect to the Lagrangian multiplier, l_t , yields $\frac{\partial V}{\partial l_t} = K_t - \rho \left[\omega(C_t) M_t + \omega^B B_t + 12.5 f^M(mVaR + 0) \right]$. Therefore the first order condition (2.44) for Problem 2.3.3 is $\rho \left[\omega(C_t) M_t + \omega^B B_t + 12.5 f^M(mVaR + 0) \right] \leq K_t$.

2.8.3.4 First Order Condition (2.45)

Choosing the regulatory capital, Π_t , from equation (2.52) and using equation (2.53) above, the first order condition (2.45) for Problem 2.3.3 is $-1 - c_t^{dw} + \mathbf{E}_t \left\{ \int_{\underline{M}}^{\overline{M}} \delta_{t,1} \frac{\partial V}{\partial K_{t+1}} dF(\sigma_{t+1}^M) \right\} + 1 = 0$, which is the same as $-c_t^{dw} + \mathbf{E}_t \left\{ \int_{\underline{M}}^{\overline{M}} \delta_{t,1} \frac{\partial V}{\partial K_{t+1}} dF(\sigma_{t+1}^M) \right\} = 0$.

2.8.4 Appendix to Chapter 2: Proof of Theorem 2.4.1

We equate SOR's optimal mortgages for the problems with $l_t = 0$ and $l_t > 0$ in order to obtain

$$\begin{aligned} & \frac{1}{2}(m_0 + m_2 \mathcal{C}_t + \sigma_t^M) - \frac{m_1}{2} \left[\bar{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) + (1 - r_t^R) r_t^S(\mathcal{C}_t) + \frac{1}{1 - \gamma} (r_t^D + c_t^D) - c_t^p r_t^f \right] \\ &= \frac{K_t}{\omega(\mathcal{C}_t)\rho} - \frac{B_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t)}. \end{aligned}$$

Solving for σ_t^M , we obtain

$$\begin{aligned} \sigma_t^{M*} &= 2 \left(\frac{K_t}{\omega(\mathcal{C}_t)\rho} - \frac{B_t + 12.5f^M(mVaR + 0)}{\omega(\mathcal{C}_t)} \right) - (m_0 + m_2 \mathcal{C}_t) + m_1 \left[\bar{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) + (1 - r_t^R) r_t^S(\mathcal{C}_t) \right. \\ & \quad \left. + \frac{1}{1 - \gamma} (r_t^D + c_t^D) - c_t^p r_t^f \right] \end{aligned}$$

Using equation (2.42) and substituting equation (2.19), we obtain

$$m_1 \rho \omega(\mathcal{C}_t) l_t = m_1 \left(r_t^M - \bar{c}_t^{M\omega} - p_t^i(\mathcal{C}_t) + c_t^p r_t^f - (1 - r_t^R) r_t^S(\mathcal{C}_t) - \frac{1}{1 - \gamma} (r_t^D + c_t^D) \right) - M_t.$$

Substitute r_t^{M*} and M_t^* into the expression above to obtain

$$l_t^* = \frac{\sigma_t^M - \sigma_t^{M*}}{\omega(\mathcal{C}_t)\rho m_1}.$$

Using equation (2.15) to find the partial derivative of the value function with respect to SOR capital we obtain

$$\frac{\partial V}{\partial K_t} = \begin{cases} l_t + \frac{1}{1-\gamma}(r_t^D + c_t^D), & \text{for } \underline{M} \leq \sigma_t^M \leq \sigma_t^{M*}, \\ \frac{1}{1-\gamma}(r_t^D + c_t^D), & \text{for } \underline{M} \leq \sigma_t^M \leq \sigma_t^{M*}, \\ \frac{1}{1-\gamma}(r_t^D + c_t^D) + \frac{\sigma_t^M - \sigma_t^{M*}}{\omega(\mathcal{C}_t)\rho m_1}, & \text{for } \sigma_t^{M*} \leq \sigma_t^M \leq \overline{M}. \end{cases}$$

By substituting the above expression into the optimal condition for total capital (2.45), we obtain

$$c_t^{dw} - \mathbf{E}_t \left[\delta_{t,1} \frac{1}{1-\gamma} (r_t^D + c_t^D) \right] - \frac{1}{\omega(\mathcal{C}_{t+1})\rho m_1} \mathbf{E}_t \left[\int_{\sigma_{t+1}^{M*}}^{\overline{M}} \delta_{t,1} (\sigma_{t+1}^M - \sigma_{t+1}^{M*}) dF(\sigma_{t+1}^M) \right] = 0.$$

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

$$Y = \frac{1}{\omega(\mathcal{C}_{t+1})\rho m_1} \mathbf{E}_t \left[\int_{\sigma_{t+1}^{M*}}^{\overline{M}} \delta_{t,1} (\sigma_{t+1}^M - \sigma_{t+1}^{M*}) dF(\sigma_{t+1}^M) \right]. \quad (2.54)$$

From the Implicit Function Theorem, we can calculate $\frac{\partial Y}{\partial \mathcal{C}_t}$ by using equation (2.54) in order to obtain

$$\begin{aligned} \frac{\partial Y}{\partial \mathcal{C}_t} &= -\frac{1}{\rho m_1} \frac{(-\mu^{\mathcal{C}_t}) \frac{\partial \omega}{\partial \mathcal{C}_{t+1}}}{[\omega(\mathcal{C}_{t+1})]^2} \mathbf{E}_t \left[\int_{\sigma_{t+1}^{M*}}^{\overline{M}} \delta_{t,1} (\sigma_{t+1}^M - \sigma_{t+1}^{M*}) dF(\sigma_{t+1}^M) \right] \\ &\quad - \frac{1}{\rho m_1 \omega(\mathcal{C}_{t+1})} \frac{\partial \sigma_{t+1}^{M*}}{\partial \mathcal{C}_t} \mathbf{E}_t \left[\int_{\sigma_{t+1}^{M*}}^{\overline{M}} \delta_{t,1} dF(\sigma_{t+1}^M) \right], \end{aligned}$$

where

$$\begin{aligned} \frac{\partial \sigma_{t+1}^{M*}}{\partial \mathcal{C}_t} &= -\frac{2}{\rho} \left(\frac{K_t - \rho(B_t + 12.5f^M(mVaR + 0))}{[\omega(\mathcal{C}_{t+1})]^2} \right) \mu^{\mathcal{C}_t} \frac{\partial \omega}{\partial \mathcal{C}_{t+1}} - m_2 \mu^{\mathcal{C}_t} \\ &\quad + m_1 \mu^{\mathcal{C}_t} \frac{\partial p^i}{\partial \mathcal{C}_{t+1}} + m_1 \mu^{\mathcal{C}_t} \frac{\partial r_t^S}{\partial \mathcal{C}_{t+1}} \end{aligned} \quad (2.55)$$

and

$$\frac{\partial Y}{\partial K_{t+1}} = \frac{2}{m_1 [\omega(\mathcal{C}_{t+1})\rho]^2} \mathbf{E}_t \left[\int_{\sigma_{t+1}^{M*}}^{\overline{M}} \delta_{t,1} dF(\sigma_{t+1}^M) \right].$$

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

2.8.5 Appendix to Chapter 2: Proof of Proposition 2.4.2

In order to prove Proposition 2.4.2, we find the partial derivatives of SOR's mortgage supply, M^* , and the SOR's subprime mortgage rate, r^{M^*} , with respect to the current credit rating, \mathcal{C}_t . Here, we consider (2.21), (2.22) and the conditions $\frac{\partial r_t^S(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} < 0$, and $r_t^R = 0$. We are now able to calculate

$$\begin{aligned} & \frac{\partial M_{t+j}^{n^*}}{\partial \mathcal{C}_t} \left[\frac{1}{2}(m_0 + m_2 \mathcal{C}_t + \sigma_t^M) - \frac{m_1}{2} \left[\bar{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) + (1 - r_t^R)r_t^S(\mathcal{C}_t) + \frac{1}{1-\gamma}(r_t^D + c_t^D) - c_t^p r_t^f \right] \right] \\ &= \frac{1}{2} \mu_j^{\mathcal{C}} \left(m_2 - m_1 \frac{\partial p^i(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} - m_1 \frac{\partial r_t^S(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} \right) \end{aligned}$$

and

$$\begin{aligned} & \frac{\partial r_{t+j}^{M^*}}{\partial \mathcal{C}_t} \left[\frac{1}{2m_1}(m_0 + m_2 \mathcal{C}_t + \sigma_t^M) + \frac{1}{2} \left[\bar{c}_t^{M\omega} + p_t^i(\mathcal{C}_t) + (1 - r_t^R)r_t^S(\mathcal{C}_t) + \frac{1}{1-\gamma}(r_t^D + c_t^D) - c_t^p r_t^f \right] \right] \\ &= \frac{1}{2} \mu_j^{\mathcal{C}} \left(\frac{m_2}{m_1} + \frac{\partial p^i(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} + \frac{\partial r_t^S(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} \right). \end{aligned}$$

2.8.6 Appendix to Chapter 2: Proof of Proposition 2.4.3

In order to prove Proposition 2.4.3, we find the partial derivatives of the optimal bank mortgage supply, M^* , and SOR's subprime mortgage rate, r^M , with respect to \mathcal{C}_t . This involves using the equations (2.16) and (2.17) and the condition $\frac{\partial \omega(\mathcal{C}_{t+j})}{\partial \mathcal{C}_{t+j}} < 0$ in order to find $\frac{\partial M_t^*}{\partial \mathcal{C}_t}$ and $\frac{\partial r_t^{M^*}}{\partial \mathcal{C}_t}$, respectively. We are now able to determine that

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

and

$$\begin{aligned} & \frac{\partial r_t^{M^*}}{\partial \mathcal{C}_t} \left(\frac{1}{m_1} \left(m_0 + m_2 \mathcal{C}_t + \sigma_t^M - \frac{K_t}{\rho \omega(\mathcal{C}_t)} + \frac{\omega^B B_t + 12.5 f^M (mVaR + 0)}{\omega(\mathcal{C}_t)} \right) \right) \\ &= \frac{m_2}{m_1} + \frac{K_t - \rho(12.5 f^M (mVaR + 0) + \omega^B B_t)}{[\omega(\mathcal{C}_t)]^2 \rho m_1} \frac{\partial \omega(\mathcal{C}_t)}{\partial \mathcal{C}_t} \end{aligned}$$

as required to complete the proof of Proposition 2.4.3.

Chapter 3

More Subprime Data

”On Wednesday, 1 October 2008, the United States Senate approved an amended version of the plan which was ratified by the House on Friday, 3 October 2008 and immediately signed into law by President Bush. After the law was passed, the United States Treasury instead primarily used the first \$ 350 billion of bailout funds to buy preferred stock in banks instead of troubled mortgage assets.”

– Wikipedia, 2008.

”As the United States is going through one of the worst financial crises of the last decades, it seems important to recall that the current crisis is not unique in its features. During the last few decades, the world has seen several financial crises (Asian crisis, Russian crisis, etc.) that all shared a common theme: Periods of increased risk appetites, as typically evidenced by high leverage ratios, led financial institutions to the brink of bankruptcy. Bailouts and restructuring followed.”

– Prof. Panageas, NBER, United States, 2010.

KEYWORDS: Loss-Given Default; Residential Mortgage; Recovery; Downturn; Basel II; Renegotiation ; Mortgage-Backed Security; Credit Rating Agency; Subordination; Default Rate; Bond Insurance; Coupon Rate; Geographic Concentration of Mortgages; Securitization; Current Loan-to-Value Ratio (CLTV); FICO (Fair Isaac Corporation) Score; 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 [6], [25] and [111]. Furthermore we analyze the data and investigate the connection the presented data has with our models.

3.1 Data Representation

In this section we present all the data used for the analysis presented in Section 3.2.

3.1.1 Subprime Mortgage Data

In this section, we present the data from [25], where two large databases from Ft. Lauderdale, Florida office of First American CoreLogic and San Francisco subsidiary LoanPerformance are used to study the issue and its impact of the mortgage payment reset.

Table 3.1 presents the cumulative equity groups according to the year of first mortgages.

Equity Group	1990	1995	2002	2003	2004	2005	2006
< -35	0.5%	0.6%	1.0%	0.7%	1.0%	1.0%	1.2%
< -30	0.5%	0.8%	1.2%	0.9%	1.2%	1.2%	1.5%
< -25	0.7%	0.9%	1.4%	1.1%	1.5%	1.5%	2.0%
< -20	0.8%	1.1%	1.8%	1.3%	1.9%	1.9%	2.6%
< -15	1.0%	1.4%	2.2%	1.7%	2.4%	2.6%	3.5%
< -10	1.3%	1.7%	2.8%	2.3%	3.2%	3.6%	5.2%
< -5	1.6%	2.1%	3.7%	3.2%	4.4%	5.4%	9.1%
< 0	2.0%	2.6%	4.9%	4.5%	6.3%	9.0%	17.6%
< 5	2.5%	3.3%	6.8%	6.7%	9.9%	16.2%	28.8%
< 10	3.2%	4.1%	9.6%	9.9%	15.0%	25.4%	38.6%
< 15	4.1%	5.2%	13.5%	14.1%	21.5%	35.2%	47.3%
< 20	5.1%	6.5%	18.1%	19.1%	28.7%	44.8%	56.4%
< 25	6.3%	8.2%	23.3%	24.7%	37.0%	55.3%	67.1%
< 30	7.9%	10.6%	29.3%	31.4%	46.4%	65.7%	75.2%
< 35	9.8%	13.8%	36.1%	38.9%	56.0%	74.2%	80.8%
< 40	12.6%	17.8%	43.5%	46.9%	64.8%	80.4%	84.8%
< 45	16.5%	22.8%	51.2%	55.1%	72.4%	85.0%	88.0%
< 50	21.5%	28.4%	59.0%	63.0%	78.4%	88.4%	90.4%

Table 3.1: Cumulative Equity Percentages for Different Years of First Mortgage Origination; Source: Ft. Lauderdale, Florida Office of First American CoreLogic

Table 3.2 presents the differences in equity distributions for properties with fixed and adjustable first mortgages.

	2004		2005		2006	
Percent Equity	Fixed	Adjustable	Fixed	Adjustable	Fixed	Adjustable
< -15	2.2%	2.7%	2.3%	2.9%	2.8%	4.1%
< -10	2.8%	3.7%	3.2%	4.1%	3.9%	6.3%
< -5	3.9%	5.2%	4.6%	6.4%	5.9%	12.1%
< 0	5.5%	7.6%	7.3%	11.1%	10.3%	23.9%
< 5	8.5%	12.1%	12.9%	20.7%	18.3%	37.5%
< 10	12.9%	18.6%	19.9%	32.4%	26.8%	48.9%
< 15	18.7%	26.5%	27.9%	44.5%	35.1%	58.8%
< 20	25.1%	35.4%	36.2%	55.9%	43.7%	68.6%
< 25	32.5%	45.6%	46.0%	67.2%	54.1%	78.4%
< 30	41.3%	56.8%	56.8%	77.4%	63.6%	85.2%

Table 3.2: Cumulative Equity Percentages: Fixed and Adjustable First Mortgages Originated 2004-2006; Source: Ft. Lauderdale, Florida Office of First American CoreLogic

Table 3.3 presents a set of monthly payments appropriate to different interest rates and looks at the impact of possible resets.

Rate Group	Initial Interest Rate	Monthly Payment, \$300,000 Loan 30-Year Fixed Rate	Possible Reset	Ratio of Payment After Reset to Payment Before Reset
Red	1.0%	964.92	1.0% - 6.5%	1.97
Red	1.5%	1,035.36		
Red	2.0%	1,108.86		
Red	2.5%	1,185.36		
Red	3.0%	1,264.81		
Red	3.5%	1,347.13		
Yellow	4.0%	1,432.25	4.5% - 7.0%	1.31
Yellow	4.5%	1,520.06		
Yellow	5.0%	1,610.46		
Yellow	5.5%	1,703.37		
Yellow	6.0%	1,798.65		
Orange	6.5%	1,896.20	7.0% - 9.5%	1.26
Orange	7.0%	1,995.91		
Orange	7.5%	2,097.64		
Orange	8.0%	2,201.29		
Orange	8.5%	2,306.74		
Orange	9.0%	2,413.87		
Orange	9.5%	2,522.56		
Orange	10.0%	2,632.71		
Orange	10.5%	2,744.22		
Orange	11.0%	2,856.97		
Orange	11.5%	2,970.87		
Orange	12.0%	3,085.84		

Table 3.3: Mortgage Payments; Source: San Francisco Subsidiary LoanPerformance

Table 3.4 presents a current balance of \$5.4 trillion in debt of active first mortgages originated in 2004 to 2006 through purchase or refinance.

Initial Interest Rate	Number of Mortgages	Balance in Millions
below 2.0%	1,123,595	\$431,018
from 2% to 3%	123,427	\$41,267
from 3.0% to 4%	174,651	\$48,705
from 4.0% to 4.5%	293,195	\$88,339
from 4.5% to 5.0%	607,090	\$176,104
from 5.0% to 5.5%	897,065	\$269,387
from 5.5% to 6.0%	1,056,880	\$317,401
from 6.0% to 6.5%	932,623	\$273,313
from 6.5% to 7.0%	896,898	\$225,146
from 7.0% to 7.5%	553,895	\$117,762
from 7.5% to 8.0%	589,086	\$113,518
from 8.0% to 8.5%	345,431	\$60,660
from 8.5% to 9.0%	335,176	\$54,160
from 9.0% to 9.5%	164,074	\$24,339
from 9.5% to 10.0%	139,373	\$19,500
from 10.0% to 10.5%	57,543	\$7,367
from 10.5% to 11.0%	42,834	\$5,165
from 11.0% to 11.5%	17,761	\$1,932
from 11.5% to 12.0%	12,926	\$1,297
Total adjustable	8,372,523	\$2,276,380
percent adjustable	32.3%	
Total fixed	17,562,609	\$3,100,882
percent fixed	67.7%	
Total 2004-2006	25,935,132	\$5,377,262

Table 3.4: Active First Mortgages Originated in 2004 to 2006; Source: San Francisco Subsidiary LoanPerformance

The following Table 3.5, shows the distributions of initial interest rates for the three years separately.

Initial Interest Rate	No. of Mortgages	Balance (Millions)	No. of Mortgages	Balance (Millions)	No. of Mortgages	Balance (Millions)
	2004	2004	2005	2005	2006	2006
below 2.0%	223,122	\$71,837	550,911	\$211,647	349,562	\$147,534
from 2% to 3%	23,963	\$7,938	43,145	\$12,349	65,319	\$20,980
from 3.0% to 4%	137,455	\$38,588	22,292	\$5,841	14,904	\$4,276
from 4.0% to 4.5%	259,095	\$78,573	30,457	\$8,715	3,643	\$1,051
from 4.5% to 5.0%	442,707	\$122,576	156,233	\$50,470	8,150	\$3,058
from 5.0% to 5.5%	379,496	\$97,963	473,993	\$155,947	43,576	\$15,477
from 5.5% to 6.0%	246,188	\$57,837	591,473	\$180,058	219,219	\$79,506
from 6.0% to 6.5%	146,388	\$29,759	387,717	\$102,094	398,518	\$141,460
from 6.5% to 7.0%	158,334	\$28,128	390,943	\$88,657	347,621	\$108,361
from 7.0% to 7.5%	109,147	\$16,903	264,803	\$53,275	179,945	\$47,584
from 7.5% to 8.0%	116,542	\$16,058	273,982	\$49,699	198,562	\$47,761
from 8.0% to 8.5%	66,059	\$8,029	152,724	\$24,773	126,648	\$27,858
from 8.5% to 9.0%	56,629	\$6,341	138,555	\$20,287	139,992	\$27,532
from 9.0% to 9.5%	24,103	\$2,400	62,748	\$8,154	77,223	\$13,785
from 9.5% to 10.0%	17,272	\$1,619	48,412	\$5,862	73,689	\$12,019
from 10.0% to 10.5%	6,290	\$530	18,243	\$1,991	33,010	\$4,846
from 10.5% to 11.0%	4,491	\$363	12,037	\$1,258	26,306	\$3,544
from 11.0% to 11.5%	1,775	\$132	4,586	\$439	11,400	\$1,361
from 11.5% to 12.0%	1,264	\$92	3,135	\$293	8,527	\$912
Total adjustable percent adjustable	2,420,320 29.3%	\$585,666	3,626,389 35.6%	\$981,809	2,325,814 31.1%	\$708,905
Total fixed percent fixed	5,831,594 70.7%	\$899,185	6,570,399 64.4%	\$1,203,748	5,160,616 68.9%	\$997,949
Total 2004-2006	8,251,914	\$1,484,851	10,196,788	\$2,185,557	7,486,430	\$1,706,854

Table 3.5: Active First Mortgages Originated in 2004 to 2006, Interest Rates; Source: San Francisco Subsidiary LoanPerformance

Table 3.6 displays the percentage distribution of adjustable mortgages by initial interest rate for the three years studied (2004-2006).

Initial Interest Rate	2004	2005	2006
below 2.0%	9.2%	15.2%	15.0%
from 2% to 3%	1.0%	1.2%	2.8%
from 3.0% to 4%	5.7%	0.6%	0.6%
from 4.0% to 4.5%	10.7%	0.8%	0.2%
from 4.5% to 5.0%	18.3%	4.3%	0.4%
from 5.0% to 5.5%	15.7%	13.1%	1.9%
from 5.5% to 6.0%	10.2%	16.3%	9.4%
from 6.0% to 6.5%	6.0%	10.7%	17.1%
from 6.5% to 7.0%	6.5%	10.8%	14.9%
from 7.0% to 7.5%	4.5%	7.3%	7.7%
from 7.5% to 8.0%	4.8%	7.6%	8.5%
from 8.0% to 8.5%	2.7%	4.2%	5.4%
from 8.5% to 9.0%	2.3%	3.8%	6.0%
from 9.0% to 9.5%	1.0%	1.7%	3.3%
from 9.5% to 10.0%	0.7%	1.3%	3.2%
from 10.0% to 10.5%	0.3%	0.5%	1.4%
from 10.5% to 11.0%	0.2%	0.3%	1.1%
from 11.0% to 11.5%	0.1%	0.1%	0.5%
from 11.5% to 12.0%	0.1%	0.1%	0.4%

Table 3.6: Distribution of Initial Interest Rate: Adjustable First Mortgages Originated in 2004 to 2006; Source: San Francisco Subsidiary LoanPerformance

3.1.2 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 3.7 to 3.15 present the data from [6]. The two types of deals are classified as subprime or Alt-A based on their assignment in LP (LoanPerformance), and analyzed separately.

Table 3.7 presents summary statistics for sample of 3,144 subprime and Alt-A deals issued between 2001 and 2007.

Table 3.8 presents summary statistics for the 12.1*m* individual mortgages underlying the 3,144 deals contained in Table 3.7.

As for Table 3.9, it displays time-series trends in key variables for subprime and Alt-A deals.

Regression coefficients from baseline loan-level default model is presented in Table 3.10. The dependent variable is set equal to one if the mortgage is 90+ days delinquent, real-estate owned (REO) or prepaid with loss 12 months after origination, and zero otherwise. *** denote statistical significance at 1% level.

	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 3.7: Deal Characteristics; Source: LoanPerformance, Bloomberg and ABSNET

	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
Current loan-to-value 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 3.8: Mortgage Characteristics; Source: LoanPerformance

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								
CLTVR (% , 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								
CLTVR (% , 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 3.9: Time Series Patterns for Key Variables; Source: [6]

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	
CLTVR (%)	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 3.10: Loan-Level Default Model; Source: [6]

Table 3.11 displays Deal-level regression of the determinants of AAA subordination, based on full sample of 3,144 deals. Dependent variable is $\ln(1 + \% \text{ subordination below AAA})$. ***, ** and * denote significance at the 1%, 5% and 10% levels.

Dependent variable: $\ln(1 + \% \text{ subordination below AAA class})$.				
	Subprime		Alt-A	
Mortgage credit risk				
$\ln(1 + \text{projected } \% \text{ default rate})$	0.751*** (0.231)	0.680** (0.254)	0.727*** (0.231)	0.651*** (0.186)
$\ln(1 + \text{projected } \% \text{ default rate})^2$	0.0551 (0.0676)	0.0723 (0.0705)	-0.130 (0.0870)	-0.153** (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*** (0.100)	-0.478*** (0.100)	-0.0250 (0.0395)	0.00370 (0.0376)
Percentage of deal with bond insurance	-0.0104** (0.00432)	-0.0104** (0.00426)	-0.00331 (0.00245)	-0.00414* (0.00223)
Weighted average coupon rate (%)	0.00811 (0.0408)	0.0201 (0.0405)	-0.0634*** (0.0145)	-0.0231 (0.0148)
Weighted mortgage interest rate (%)	0.0468* (0.0231)	0.0498** (0.0233)	0.0681* (0.0368)	0.0263 (0.0341)
Geographic concentration of loans	1.897*** (0.212)	1.677*** (0.263)	0.406*** (0.134)	0.399*** (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 3.11: Determinants of AAA Subordination; Source: [6]

Relationship between subordination and early payment defaults for subprime and Alt-A deals is presented in Table 3.12. Dependent variable is a weighted fraction of mortgages in the deal that are +90 days delinquent, prepaid with loss or REO 12 months after deal is issued. ***, ** and * denote significance at the 1%, 5% and 10% levels.

Dependent variable: $\ln(1 + \% \text{ deal in default 12 months after deal is issued})$.

	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						
$\ln(1 + \% \text{ subordination below AAA})$	0.112*** (0.0340)	0.112*** (0.0305)	0.118*** (0.0325)	0.198*** (0.0378)	0.0505 (0.0344)	0.0553* (0.0317)
$\ln(1 + \% \text{ subordination below BBB-})$	0.0955*** (0.0157)	0.0645*** (0.0144)	0.0552*** (0.0134)	-0.144*** (0.0423)	-0.0960*** (0.0241)	-0.0794*** (0.0234)
Model-projected mortgage default rate						
$\ln(1 + \text{projected default rate})$	0.941*** (0.0622)	1.004*** (0.0567)	0.837*** (0.0522)	1.470*** (0.102)	1.523*** (0.0422)	1.503*** (0.0610)
$\ln(1 + \text{default rate}) * \text{"boom" dummy}$			0.317*** (0.0939)			0.0724 (0.115)
Fraction of low documentation mortgages						
% of low/no-doc mortgages		0.00681*** (0.000656)	0.00327*** (0.000852)		0.00290*** (0.000792)	0.00267*** (0.000839)
%low/no doc * "boom" dummy			0.00568*** (0.00115)			0.000607 (0.00128)
Other deal characteristics						
Bond insurance (1=yes)	3.35e - 05 (0.0438)	0.000129 (0.0334)	0.00554 (0.0323)	-0.0120 (0.0358)	0.0237 (0.0329)	0.0261 (0.0320)
% of deal with bond insurance	0.00177* (0.000872)	0.00131* (0.000664)	0.00133** (0.000623)	-0.00112 (0.00117)	-0.00221** (0.00104)	-0.00192* (0.000992)
Weighted average coupon rate (%)	-0.0243 (0.0222)	-0.0112 (0.0221)	-0.0500** (0.0190)	-0.0264** (0.0124)	0.0105 (0.00964)	0.00340 (0.0106)
Weighted mortgage interest rate (%)	-0.0762*** (0.0105)	-0.130*** (0.0152)	-0.122*** (0.0154)	0.0613 (0.0428)	0.0184 (0.0265)	0.00422 (0.0280)
Geographic concentration of mortgages	0.475** (0.194)	0.0635 (0.203)	0.0540 (0.196)	-0.133 (0.107)	-0.239** (0.101)	-0.241** (0.0953)
Dummies for number of credit ratings (omitted category: three ratings)						
One Rating		0.213*** (0.0343)	0.305*** (0.0392)		-0.0161 (0.0343)	-0.0581 (0.0392)
Two Ratings		0.0108 (0.0149)	0.0505* (0.0268)		0.0366* (0.0149)	0.00127 (0.0268)
Four Ratings		0.113*** (0.0290)	0.106*** (0.0275)		0.0620 (0.0290)	0.0976 (0.0275)
Other loan-level covariates						
Average CLTVR (%)		0.00889*** (0.00188)	0.00715*** (0.00169)		0.0188*** (0.00130)	0.0182*** (0.00160)
FICO		0.000279 (0.000469)	0.000302 (0.000486)		0.00143*** (0.000230)	0.00145*** (0.000219)
12 month trailing HPA (%)		-0.00279 (0.00815)	-0.00245 (0.00753)		0.00857 (0.00539)	0.00751 (0.00550)
% of interest only mortgages		-0.000429 (0.000515)	-0.000990 (0.000765)		0.00155** (0.000608)	-0.000256 (0.000649)
% of investor mortgages		0.00430* (0.00230)	0.0212*** (0.00454)		0.00190** (0.000814)	-0.000272 (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 3.12: Credit Ratings and Early-Payment Mortgage Defaults; Source: [6]

Table 3.13 presents year by year regression of early-payment defaults on subordination below AAA and BBB-, the model-projected default rate, the fraction of low documentation mortgages, and the same set of deal controls used in Table 3.12 (insurance, excess spread, etc.). Dependent variable is a weighted fraction of mortgages in the deal that are +90 days delinquent, prepaid with loss or REO 12 months after deal is issued.

Table 3.14 shows the determinants of post-issuance credit rating downgrades, as an alternative measure of deal performance. ***, ** and * represent significance at the 1%, 5% and 10% levels.

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 (0.0781)	-0.0328 (0.0281)	0.0387 (0.0749)	0.119** (0.0288)	0.129* (0.0479)	0.310* (0.122)	0.188* (0.0628)
ln(1+% subordination below BBB-)	0.107** (0.0291)	0.0116 (0.109)	0.152* (0.0518)	0.0694** (0.0161)	0.0386** (0.0116)	-0.0298 (0.0204)	0.0245 (0.0533)
ln(1+ projected default rate)	0.969*** (0.160)	0.616** (0.153)	0.642*** (0.104)	0.716*** (0.0940)	1.314*** (0.0330)	0.794** (0.243)	1.039*** (0.0238)
% of low/no-doc mortgages	0.00917 (0.00443)	0.0146** (0.00321)	0.00457** (0.00102)	0.00556*** (0.000315)	0.00810*** (0.00119)	0.00664*** (0.00102)	0.00789** (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
B. Alt-A deals							
Baseline specification: including credit ratings, model default and low doc							
ln(1+% subordination below AAA)	-0.0473 (0.159)	-0.0221 (0.0381)	0.0481 (0.0335)	0.0969* (0.0379)	0.380** (0.0708)	0.303*** (0.0482)	0.0274 (0.0972)
ln(1+% subordination below BBB-)	-0.00240 (0.0593)	-0.150 (0.172)	-0.0746 (0.0676)	-0.0771 (0.0446)	-0.111 (0.0488)	-0.124 (0.0880)	-0.206 (0.108)
ln(1+ projected default rate)	0.198 (0.375)	1.106** (0.253)	1.186*** (0.114)	0.833*** (0.136)	1.089** (0.326)	1.463*** (0.177)	1.869*** (0.0477)
% of low/no-doc mortgages	0.00560 (0.00389)	0.00420** (0.00121)	0.00356* (0.00143)	0.00117 (0.000820)	0.00258 (0.00119)	0.00509** (0.00131)	0.00815 (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 3.13: Subordination and Early-Payment Defaults, Cohort Regressions; Source: [6]

Dependent variable: Credit rating downgrades (value-weighted average).

	Subprime		Alt-A	
Dependent variable: Rating downgrades				
ln(1+% subordination below AAA)	-0.923*** (0.246)	-0.902*** (0.258)	-0.0465 (0.227)	-0.566* (0.282)
ln(1+% subordination below BBB-)	0.630*** (0.206)	0.442** (0.178)	1.489*** (0.420)	1.640*** (0.440)
Projected default and concentration of low documentation mortgages				
ln(1+projected default rate)	0.817* (0.472)	0.748 (0.597)	2.595*** (0.909)	3.066*** (0.948)
% of low/no-documentation mortgages		0.0444*** (0.0133)		0.0151*** (0.00521)
Other deal characteristics				
Bond insurance (1=yes)	-0.379 (0.226)	-0.309* (0.160)	-0.707** (0.342)	-0.621* (0.345)
% of deal with bond insurance	0.00798 (0.00557)	0.00488 (0.00592)	0.0243*** (0.00634)	0.0210*** (0.00588)
Weighted average coupon rate (%)	-0.421 (0.314)	-0.471* (0.256)	0.0734 (0.111)	0.154 (0.102)
Weighted mortgage interest rate (%)	1.234*** (0.331)	0.986*** (0.339)	-0.270 (0.360)	-0.318 (0.387)
Geographic concentration of mortgages	6.441*** (2.015)	5.566*** (1.871)	-0.415 (1.077)	-1.354 (1.109)
Dummies for number of credit ratings (omitted category: three ratings)				
One Rating		5.130 (3.599)		-0.723* (0.367)
Two Ratings		-0.294** (0.130)		-0.391 (0.259)
Four Ratings		0.158 (0.248)		0.833 (1.332)
Other loan-level covariates				
Average CLTVR (%)		0.0377 (0.0237)		0.0290* (0.0162)
FICO		0.000947 (0.00208)		0.00499*** (0.00163)
12 month trailing HPA (%)		-0.166** (0.0713)		0.109** (0.0500)
% of interest only mortgages		0.00183 (0.00550)		0.00780 (0.00600)
% of investor mortgages		0.0443*** (0.0151)		0.0115 (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 3.14: Determinants of Credit Rating Downgrades; Source: [6]

Table 3.15 presents results for two cumulative measures of ex-post mortgage performance for subprime and Alt-A deals. ***, ** and * denote significance at the 1%, 5% and 10% levels.

Dependent variable:	ln(1 + % cumulative losses)		ln(1 + % cumulative defaults)	
	Subprime	Alt-A	Subprime	Alt-A
Market segment:				
ln(1+% subordination below AAA)	0.0397 (0.0263)	0.0689 (0.0502)	0.0525* (0.0303)	0.104*** (0.0312)
ln(1+% subordination below BBB-)	0.124*** (0.0191)	-0.0402** (0.0189)	0.0374** (0.0163)	-0.0412 (0.0290)
Projected default and concentration of low documentation mortgages				
ln(1+projected default rate)	0.369*** (0.0668)	0.684*** (0.0726)	0.653*** (0.0834)	0.731*** (0.0713)
% of low/no-doc mortgages	0.00779*** (0.00141)	0.00187*** (0.000629)	0.00489*** (0.000874)	0.00394*** (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 3.15: Additional Measures of Ex-Post Performance; Source: [6]

3.1.3 Securitized and Portfolio Mortgage Data

Table 3.16 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
LTVR	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
LTVR	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
LTVR	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 3.16: Summary Statistics of All Mortgages; Source: [111].

As Table 3.16, Table 3.17 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, however only delinquent mortgages of high-quality at time of origination are represented in Table 3.17. High-quality delinquent mortgages refer to the mortgages which are fully documented with FICO > 680.

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
LTVR	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
LTVR	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
LTVR	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 3.17: Summary Statistics of High-Quality Mortgages; Source: [111].

Table 3.18 accounts for the marginal effects of a logit regression for the mortgages represented in Table 3.16. ***, ** 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*** (-8.12)	-0.048*** (-8.86)	-0.046*** (-8.21)	-0.070*** (-10.91)	-0.059*** (-8.21)	-0.060*** (-12.99)	-0.066*** (-12.97)	-0.038*** (-14.25)
FICO < 620 (d)	-0.109*** (-11.15)	-0.133*** (-18.42)	-0.127*** (-17.92)	-0.145*** (-23.61)	-0.155*** (-19.81)	-0.124*** (-15.24)	-0.108*** (-16.43)	-0.069*** (-12.51)
620 <= FICO < 680 (d)	-0.025*** (-3.57)	-0.037*** (-8.01)	-0.034*** (-6.36)	-0.038*** (-8.01)	-0.042*** (-7.82)	-0.030*** (-6.41)	-0.028*** (-4.97)	-0.017*** (-4.37)
LTVR	0.579*** (6.47)	0.280*** (4.50)	0.501*** (7.10)	0.535*** (6.68)	0.553*** (7.37)	0.401*** (5.14)	0.100*** (3.56)	0.055*** (3.18)
LTVR squared	-0.405*** (-5.73)	-0.163*** (-3.24)	-0.342*** (-6.20)	-0.361*** (-5.53)	-0.373*** (-6.16)	-0.265*** (-4.17)	-0.035 (-1.45)	-0.015 (-1.04)
Origination amount	-0.003 (-0.47)	0.000 (0.08)	-0.001 (-0.19)	-0.003 (-0.84)	0.001 (0.09)	0.007 (1.08)	0.003 (0.62)	0.009** (2.21)
Origination amount squared	0.009 (1.64)	0.001 (0.26)	-0.002 (-0.28)	-0.001 (-0.16)	0.001 (0.19)	-0.011 (-1.52)	-0.008 (-1.42)	-0.016** (-2.12)
Original interest rate	0.015*** (6.71)	0.012*** (5.40)	0.020*** (9.89)	0.018*** (8.89)	0.021*** (8.44)	0.015*** (9.01)	0.013*** (9.04)	0.010*** (8.13)
FIX (d)	-0.081*** (-15.34)	-0.070*** (-12.52)	-0.058*** (-13.62)	-0.060*** (-13.93)	-0.053*** (-7.24)	-0.046*** (-10.27)	-0.036*** (-7.55)	-0.026*** (-6.97)
15-Year term (d)	0.013 (0.48)	-0.047** (-2.21)	-0.074*** (-3.12)	-0.060*** (-2.69)	-0.108*** (-5.50)	-0.028 (-1.06)	-0.114*** (3.59)	-0.072* (1.94)
20-Year term (d)	0.022 (0.35)	-0.053 (-1.27)	-0.073* (-1.88)	-0.074 (-1.47)	-0.086 (-1.32)	-0.104*** (-3.31)	-0.046 (-0.87)	-0.050*** (-2.91)
No insurance (d)	-0.018*** (-3.53)	-0.016*** (-2.81)	-0.002 (-0.37)	0.004 (0.64)	0.013** (2.32)	0.024*** (4.42)	0.014** (2.23)	-0.002 (-0.59)
Insurance (d)	-0.019 (-1.55)	-0.011 (-0.98)	-0.015 (-1.40)	0.009 (0.64)	-0.005 (-0.27)	-0.019 (-1.06)	-0.013 (-0.99)	-0.004 (-0.38)
Age at delinquency	-0.085*** (-13.51)	-0.096*** (-17.02)	-0.109*** (-26.89)	-0.135*** (-32.76)	-0.163*** (-44.74)	-0.136*** (-51.75)	-0.127*** (-60.27)	-0.097*** (-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 3.18: Logit Regression of Default Conditional on 60+ Days Delinquency for All Mortgages; Source: [111].

Table 3.19 accounts for the marginal effects of a logit regression for the mortgages represented in Table 3.17. ***, ** 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 (-1.29)	-0.057*** (-3.04)	-0.041*** (-1.98)	-0.066*** (-3.85)	-0.079*** (-2.88)	-0.096*** (-4.81)	-0.089*** (-7.20)	-0.045*** (-3.25)
680 <= FICO < 720 (d)	-0.028 (-0.87)	0.002 (0.06)	0.050* (1.89)	0.027 (1.20)	-0.023 (-0.59)	0.037 (1.27)	-0.028 (-1.15)	0.010 (0.35)
720 <= FICO < 760 (d)	-0.005 (-0.15)	0.024 (0.76)	0.113** (2.49)	0.026 (1.05)	-0.013 (-0.32)	0.046 (1.25)	-0.028 (-1.25)	0.010 (0.33)
LTVR	0.529** (2.37)	0.007 (0.10)	0.448*** (4.71)	0.213** (2.07)	0.236** (2.04)	0.351** (2.00)	0.112* (1.85)	-0.045 (-1.48)
LTVR squared	-0.439** (-2.19)	0.034 (0.55)	-0.355*** (-4.14)	-0.143 (-1.56)	-0.157 (-1.48)	-0.281* (-1.74)	-0.067 (-1.07)	0.058** (1.98)
Origination amount	-0.055 (-1.48)	0.008 (0.65)	0.003 (0.18)	0.057 (1.51)	0.006 (0.33)	0.025 (1.18)	0.009 (0.54)	0.059** (2.14)
Origination amount squared	0.164*** (2.63)	-0.012 (-1.48)	0.001 (0.09)	-0.162* (-1.73)	0.002 (0.10)	-0.025 (-1.23)	-0.010 (-0.64)	-0.070* (-1.80)
Original interest rate	0.022 (1.45)	0.036*** (3.53)	0.026*** (2.57)	0.034*** (3.53)	0.007 (0.74)	0.040*** (3.58)	0.015* (1.96)	0.015** (2.37)
FIX (d)	-0.085*** (-3.71)	-0.108*** (-6.34)	-0.049** (-2.35)	-0.053*** (-2.83)	-0.078*** (-3.15)	-0.006 (-0.38)	-0.036** (-2.32)	0.001 (0.08)
15-Year term (d)	-0.040 (-0.28)	-0.145*** (-3.03)	-0.018 (-0.16)	-0.103** (-2.31)	-0.067 (-0.55)	-0.086 (-1.23)	0.489** (2.12)	0.040 (0.43)
20-Year term (d)		0.041 (0.32)	-0.074 (-0.85)	-0.032 (-0.31)				
No insurance (d)	-0.014 (-0.58)	-0.055** (-2.30)	-0.022 (-1.22)	-0.041** (-2.27)	-0.006 (-0.25)	0.011 (0.39)	-0.001 (-0.09)	0.000 (-0.01)
Insurance (d)	-0.040 (-0.62)	-0.017 (-0.45)	-0.024 (-0.59)	-0.072*** (-2.89)	0.091 (0.93)	-0.003 (-0.06)	-0.028 (-0.62)	-0.048** (-2.24)
Age at delinquency	-0.100*** (-6.40)	-0.104*** (-9.09)	-0.109*** (-18.96)	-0.121*** (-16.17)	-0.183*** (-23.29)	-0.139*** (-23.59)	-0.130*** (-35.71)	-0.089*** (-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 3.19: Logit Regression of Default Conditional on 60+ days Delinquency for High-Quality Mortgages; Source: [111] .

Table 3.20 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.

Dependent variable: Mean securitized	<i>Panel A: All mortgages</i>		<i>Panel B: High-quality mortgages</i>	
	Foreclosure 0.25	Transfer 0.02	Foreclosure 0.25	Transfer 0.01
Portfolio (d)	0.759*** (-21.34)	5.76*** (79.86)	0.662*** (-8.28)	4.797*** (12.17)
FICO	1.006*** (91.77)	1.000*** (-2.80)	1.000 (0.82)	1.006*** (3.62)
LTVR	1.162*** (18.23)	1.011* (1.79)	1.113*** (3.37)	0.973 (-1.27)
LTVR squared	0.999*** (-16.18)	1.000 (-1.15)	0.999*** (-2.80)	1.000 (1.48)
Origination amount	1.000*** (7.19)	1.000 (-0.09)	1.000 (-0.15)	1.001* (1.70)
Origination amount squared	1.000*** (-4.41)	1.000*** (-3.46)	1.000 (0.18)	1.000* (-1.74)
Original interest rate	1.162*** (50.75)	1.196*** (23.44)	1.110*** (7.62)	1.040 (1.12)
Fix(d)	0.68*** (-39.57)	0.82*** (-7.79)	0.627*** (-11.53)	1.66*** (4.09)
15-Year term (d)	0.778*** (-4.17)	0.837 (-1.60)	0.576* (-1.87)	1.318 (0.66)
20-Year term (d)	0.507*** (-4.48)	0.485*** (-2.74)	0.788 (-0.58)	0.000*** (-143.93)
No insurance (d)	0.999 (-0.16)	1.89*** (28.49)	0.852*** (-4.10)	0.614*** (-3.48)
Insurance (d)	0.903*** (-5.01)	1.292*** (5.25)	0.734*** (-3.26)	0.534** (-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 3.20: Hazard Regression of Default Conditional on 60+ Days Delinquency for All Mortgages and High-Quality Mortgages; Source: [111].

The values reported in Table 3.21 are the estimates (marginals) on portfolio dummy using the same specification as in Table 3.18. ***, ** and * denote significance at the 1%, 5% and 10% levels.

Mean securitized	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 loans	High-quality	All mortgages	High-quality	All mortgages	High-quality	All mortgages	High-quality	All mortgages	High-quality
	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 3.21: Additional Robustness Tests; Source: [111].

The values reported in Table 3.22 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.

	<i>Panel A: All mortgages</i>		<i>Panel B: High-quality mortgages</i>	
Dependent variable:	Cure	Transfer	Cure	Transfer
Mean securitized	0.47	0.02	0.4	0.01
Portfolio (d)	1.129*** (17.15)	6.226*** (71.91)	1.205*** (6.69)	8.261*** (14.31)
FICO	0.996*** (-98.15)	1.00*** (-2.08)	1.000 (-0.22)	1.006*** (3.44)
LTVR	0.991*** (-8.67)	0.996 (-0.57)	0.992 (-1.64)	0.965* (-1.71)
LTVR squared	1.000*** (-7.01)	1.000 (0.54)	1.000* (-1.78)	1.000 (1.55)
Original amount	1.000*** (-20.62)	1.000** (-2.18)	1.000*** (-3.19)	1.002** (2.13)
Original amount squared	1.000*** (8.08)	1.000* (-1.81)	1.000 (1.28)	1.000** (-2.13)
Original interest rate	0.892*** (-73.59)	1.166*** (16.78)	0.907*** (-12.52)	1.046 (1.23)
FIX (d)	1.227*** (39.79)	0.999 (-0.02)	1.416*** (14.44)	2.655*** (6.92)
15-year term (d)	1.125*** (6.10)	0.812 (-1.39)	1.178** (2.25)	1.828 (1.33)
20-year term (d)	1.177*** (4.22)	0.458** (-2.18)	1.159 (1.41)	0.000*** (-127.51)
No insurance (d)	1.011*** (2.03)	2.114*** (28.05)	1.071*** (2.82)	0.406*** (-5.49)
Insurance (d)	1.196*** (13.56)	1.259*** (3.78)	1.258*** (4.11)	0.259*** (-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 3.22: Hazard Regression of Cure Rate Conditional on 60+ Days Delinquency for All Mortgages and High-Quality Mortgages; Source: [111].

The values reported in Table 3.23 are the estimated hazard ratios from a Cox-proportional hazard model of the transition. The change takes place from delinquency to foreclosure/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* (1.95)	9.859*** (76.57)	0.734*** (-14.24)	5.39*** (44.33)	0.67*** (-18.32)	1.915*** (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*** (-3.01)	9.462*** (61.16)	1.171*** (12.53)	6.35*** (4.79)	1.349*** (22.53)	2.829*** (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 3.23: Hazard Regression of Default and Cure Conditional on 60+ Days Delinquency; Source: [111].

Table 3.24 gives the summary statistics of a sample of mortgages used to conduct the test that exploits the repurchase clauses.

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
LTVR	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
LTVR	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 3.24: Summary Statistics of Sample of Mortgages Using the Repurchase Clauses; Source: [111].

The values reported in Table 3.25 are the estimates(marginals) using the same specification and controls as in Table 3.18.

	(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* (-1.80)	-0.065* (-2.49)	0.011 (1.39)	-0.069** (-2.44)	-0.041** (-2.32)	-0.033** (-1.97)	-0.031* (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 3.25: Regression Estimates Using Logit Specification; Source: [111].

3.2 Data Analysis

In this section we analyze the data from [25]. The Data is supplied by Ft. Lauderdale, Florida office of First American CoreLogic and San Francisco subsidiary LoanPerformance.

3.2.1 Analysis of Subprime Mortgage Data

Table 3.1 shows that 4.5% and 17.6% of those who purchased or most recently refinanced their first mortgage in 2003 and 2006, respectively, have negative equity. As it can be seen from Table 3.1, the percentages at different levels for mortgages in 2003 and earlier are very low, however the values start to become large from 2004 onwards, which is the period leading to the subprime mortgage crisis. As for Table 3.2, the properties purchased or most recently refinanced with adjustable-rate first mortgages and fixed-rate mortgages in 2005, 11.1% and 7.3% are in negative equity, respectively. While for the year 2006, for those whose purchases or last refinances, 23.9 percent of properties with adjustable-rate first mortgages have negative equity and only 10.3% of properties with fixed-rate mortgages are in the same situation.

From Table 3.3, there are three groups in the table classified as red, yellow and orange. Red loans are “teaser”, yellow loans are “market-rate” and orange loans are “sub-prime adjustable loans”. The initial interest rates for teaser loans are less than 4%. These loans are likely to face substantial reset impact. Market-rate adjustable loans have initial interest rate between 4% and 6.5%. These loans will face some reset impact, but not nearly so much as the teaser loans. The last group, sub-prime adjustable loans, start at the initial interest rate of 7%. Their resets may actually be less proportionately than those of the market-rate loans, but the borrowers are likely to have fewer financial resources and will find payment reset more difficult to bear.

From Table 3.4, the data set included 17.56 and 8.37 million fixed-rate and adjustable-rate first mortgages originated in 2004 through 2006, respectively. The mortgages represent the total active balances of \$3.1 and \$2.276 trillion in debt, respectively. While default is still possible due to job loss, divorce, serious illness, or death, such events represent only the normal background rate of default and lender loss. The first row of Table 3.4 shows 1.1 million adjustable teaser mortgages with initial interest rates less than 2 percent (1.4 million starting under 4 percent); these mortgages are likely to experience strong reset sensitivity.

Table 3.5 shows that the strongest year for lending and for adjustable mortgages in particular was 2005. Whereas from Table 3.6, we see that there has been a general shift towards higher initial interest rates from 2004 to 2006, as the high-frequency cells appear at higher rate levels. During this period, the spread between adjustable rates and fixed rates has decreased, as a result leading many to refinance from adjustable into fixed mortgages. Table 3.6 also shows that the teaser mortgages starting below 2 percent became more common during 2005 and 2006.

3.2.2 Annalysis of Subprime Mortgage Security Data

In this subsection, we analyze the paper [6], where credit ratings on subprime and Alt-A mortgage-backed-securities (MBS) deals are studied. 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 loan-level data, sourced from Bloomberg, ABSNet and LoanPerformance (See Tables 3.7, 3.8 and 3.9).

3.2.2.1 Non-Agency Mortgage-Backed Security Deals

Non-agency MBS are deals without guarantee. They are combined into one or more pools and seized in a bankruptcy-remote trust. In addition, non-agency MBS 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. Non-agency MBS deals are structured with credit enhancement features used to protect MBS deal investors from credit losses. These features includes subordination, excess spread, insurance, etc.

3.2.2.2 Primer on Credit Ratings

Credit rating can be defined as an estimation of the credit risk of a fixed income security. This is summarized as a discrete alphanumeric grade. For an MBS deal, credit ratings are more often modified based on the level of subordination below a given letter rating. Subordination is calculated as

$$SUBORDINATION \text{ below rating } i = 1 - \frac{\sum \text{Face value of securities with rating } i \text{ or above}}{\sum \text{Face value of all mortgages underlying deal}}, \quad (3.1)$$

3.2.2.3 Rating Process for Non-Agency Mortgage-Backed Security Deals

The rating process for MBS 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 economic models to calculate a path of default and losses, which then the projected losses are aggregated across the defaults path and losses to generate a distribution of losses. The 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 3.2.2.1.

3.2.2.4 Measuring Credit Enhancement

In this subsection, credit ratings for each deal through levels of subordination are summarized. This is a set off of the division of highly-rated securities in the contract. For example, if 85% of the deal receives a triple-A rating, then triple-A subordination is 15% (see Subsection 3.2.2.2). From the above mentioned paper, focus is on subordination at two points: below triple-A, and below the investment grade boundary (BBB-). When deals are rated by more than one CRAs, subordination is computed based on the most traditional 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. Mortgage defaults and losses

are correlated because of common shocks to home prices and economic conditions. In addition, a measure of geographic diversification of the mortgage collateral underlying each deal is estimated by the sum of the squared value-weighted share of mortgages. That is,

$$geographic\ concentration = \sum_{j \in states} \left(\frac{total\ mortgage\ principal\ in\ state\ j}{total\ mortgage\ principal\ balance} \right)^2. \quad (3.2)$$

3.2.2.5 Loan-Level Default Model and Determinants of Subordination

Mortgage-level default model is used to approximate an average projected mortgage default rate for every MBS contract. The estimated default rate is planned to be an ex-ante measure of risk, produced by means of information accessible to CRAs at the time every deal was originally 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 substituted into the regression model valued up to 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 delivered. The variables used in the models are mortgage characteristics at origination like the borrower FICO Score, combined LTV, debt-payments-to-income (DTI), dummies for income and asset documentation (full-, partial-, low- and no-document). Time dummies at 6-months period are included to reflect any time-series trends in mortgage default rates not captured by the model variables. The logit estimates for the regression model above are presented in Table 3.10. It can be observed from Table 3.10, 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:

$$AAA\ subordination = f(mortgage\ credit\ risk, credit\ enhancement, diversification, time\ dummies). \quad (3.3)$$

Equation (3.3) narrates subordination to the credit risk of the mortgages underlying the agreement, the potency of credit enhancement features (see Subsection 3.2.2.1) that supply additional support to bondholders and a measure of the geographical diversification of the mortgage collateral. Time dummies included will take into account any time-series changes in ratings calculating the measures of risk. The estimates are shown in Table 3.11, where the subprime and Alt-A deals are estimated separately (see Columns 1 and 2 and Columns 3 and 4, respectively). From equation (3.3), the

dependent variable is given by $\ln(1 + \% \text{ of subordination below AAA})$.

3.2.2.6 Credit Ratings and Deal Performance

Subsection 3.2.2.6 evaluate the connection between credit ratings and ex-post deal performance. The three different temporary 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 the following:

$$\text{deal performance} = f(\text{subordination, model-projected default, share of low-doc mortgages, deal controls, other covariates, time dummies}). \quad (3.4)$$

From above subordination is considered below both AAA and BBB- ratings. Mortgage default and loss rates are anticipated to be rising in subordination, since agreements with greater risk should have a small portion of highly-rated securities. Deal controls are defined the same way as the measures of credit enhancement and geographic concentration from Table 3.11. The results for equation (3.4) are presented in Tables 3.12, 3.13, 3.14 as well as 3.15.

3.2.3 Analysis of Securitized and Portfolio Mortgage Data

In this subsection, we look at the data from paper [111]. The Data is supplied by Lender Processing Servicer (LPS) and include loan-level data from mortgage servicing firms. Information included in the data set is about the mortgage at the time of origination, such as the mortgage amount, term, loan-to-value ratio (LTVR), credit score (FICO), and interest rate type of a securitized or a portfolio (bank-held) mortgage (see Table 3.16 and Table 3.17). Table 3.17 represents mortgages with $FICO \geq 680$ and full documentation. The sample used in this paper is for first lien mortgages originated in 2005 and 2006.

3.2.3.1 Comparing Foreclosure Rates of Securitized and Portfolio Mortgages

In this subsection the foreclosure rates of securitized and portfolio mortgages are assessed. In order to approximate the shock securitization or portfolio mortgages has on foreclosing the delinquent mortgages the following equation is used:

$$Pr(Y_i = 1 | Delinquency) = \phi(\alpha + \beta \times Portfolio_i + \gamma \cdot X_i + \delta_m + \epsilon_i), \quad (3.5)$$

where the reliant variable 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, LTVR, and origination amount, and γ is a vector of coefficients. Portfolio is a dummy variable that correspond to 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.

By approximating equation (3.5), the trivial consequences of a logit regression executed for the whole test are observed in Table 3.18. The dependent variable is whether or not the mortgage is foreclosed provisional on the mortgage becoming delinquent. Regressions are reviewed specifically for every quarter of initiation to lessen fears that macroeconomic conditions might have altered considerably throughout the sample phase. In columns 1-8, the coefficient on (Portfolio) dummy is always negative and considerable for all quarters. This signifies that a mortgage on a lender's balance sheet is less likely to be foreclosed than a mortgage that is securitized. Mortgages with higher LTVRs are more likely to foreclose. The coefficient on FICO implies that, conditional on being delinquent, mortgages with lower FICO default less.

Table 3.19 presents the estimates using the condition (3.5) for a subsample of higher quality mortgages (fully documented mortgages with FICO > 680). As can be observed from columns 1 to 8, the coefficient on the portfolio dummy is negative and significant for all quarters except one (2005 Q1).

3.2.3.2 Additional Robustness Tests Using Hazard Model

Table 3.20 presents the projected hazard ratios from a Cox-proportional hazard model for the mortgages prior their move. Hazard model consider three states depending on whether the mortgage is: foreclosed, not foreclosed, or transferred to a servicer outside the data. Panel A presents the outcomes for all the mortgages in the sample whereas panel B represents the outcomes using the high-quality mortgages. All the regressions are calculated using time and MSA fixed effects. The coefficients in the table illustrate the hazard ratio of portfolio mortgages weighed against securitized mortgages for the foreclosure and the transfer states.

Table 3.21 presents the approximations on portfolio dummy using a requirement similar to Table 3.18. The dependent variable is a foreclosure. Regressions are projected by means of other descriptions of delinquency (30+ and 90+). High-quality mortgages entail mortgages with FICO greater than or equal to 680 and full documentation. There may possibly be worries that the house price index changed considerably for the duration of the sample phase, which may not be revealed in the MSA fixed effects, so the baseline regressions calculating house price actions at the MSA level and for zip-code level fixed effects are re-calculated. From columns 1 and 2 of Table 3.21, it can be observed that delinquent bank-held mortgages are more likely to be foreclosed by about 5.7% in complete terms as weighed against 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 starting along with foreclosure post-sale, and REO, and re-estimating regressions using this definition, the results are presented in columns 3 and 4 . We can see a negative and significant effect (at 1% level) on the portfolio estimate: the delinquent bank-held mortgages are foreclosed at 10% lower in absolute terms (18% lower in relative terms) compared to similar securitized mortgages.

If delinquent securitized mortgages had additional current loan-to-value ratio (CLTVR) than equivalent portfolio mortgages, then delinquent securitized mortgages would be extremely risky and for that reason prone to be foreclosed. This can only be deal t with by re-calculating the results includ-

ing a dummy that takes a value 1 if the mortgage has an LTVR of 80%. This dummy variable ought to decrease the magnitude and significance of the portfolio variable in the foreclosure regression and the results are shown in columns 5 and 6. Also the logit and hazard stipulations in charge of the quarter for delinquency of the mortgage are determined and the results are reported in columns 7 to 10 of Table 3.21. Results from logit condition propose that portfolio mortgages are 3% less likely to be foreclosed than securitized mortgages (13% in relative terms) after taking charge for noticeable 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).

Based on the initial creditworthiness of the borrower, we divide the mortgages 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 3.23 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. From table we can observe that, for medium credit quality mortgages, the foreclosure rate for bank-held mortgages is lower in absolute terms by 7.4% (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 bank-held 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.

3.2.3.3 Treatment and Control Groups

In this Subsection, the characteristics of the treatment and control groups are described. Treatment group include 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 3.24 presents summary statistics of a sample of mortgages using the repurchase clauses. The table shows that treatment and control groups have similar contracted terms such as the LTVR and FICO score. From the last four columns of Panel B LTVRs for the treatment and control groups are 82.1 and 80.7, however FICO scores are 617 and 611 for the treatment and control groups, respectively. The interest rate is also identical for the treatment and control groups (8.2% and 8.3% , respectively). Mortgages in the treatment group are less likely to be foreclosed relative to mortgages in the control group (compare 32% of the delinquent mortgages in the treatment group to 39% in the control group).

By estimating equation (3.5) using a logit specification, the results of the estimation is presented in Table 3.25. The dependent variable is a foreclosure while the coefficient on portfolio, (β), takes a value 1 for mortgages in the treatment group and 0 for mortgages in the control group.

3.3 Connections With Chapter 2

The topics that the papers [6], [25], [111] and [113] 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 opacity, extant valuation model limitations and structured product intricacy (see Chapter 2 for more details and [103]).

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 (see Subsection 2.2.1 and its discussion on Subsection 2.6.1.1). This environment encouraged investors (including 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, which was the primary financing method for mortgages. 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, [55]). Subprime mortgage and securitization are very risky and intricate. This is shown in Tables 3.15 to 3.25, where securitized mortgages are likely to be foreclosed more than portfolio mortgages. This is consistent with our IDIOM hypothesis which says that during the SMC, intricacy and design of subprime mortgage and securitization as well as systemic agents led to information (loss, asymmetry and contagion) problems, valuation opacity and ineffective risk mitigation.

MR documentation status is associated with higher delinquency status (see [21] and Tables 3.7 to 3.15). 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, [55]). 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 3.2.2.3 and 3.2.2.5 of Chapter 3).

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 and subsequent discussions in Subsection 2.6.1.2 (see Tables 3.7 to 3.15).

When United States house prices declined in 2006 and 2007, refinancing became more difficult and adjustable-rate mortgages (ARMs) began to reset at higher rates. This resulted in a dramatic increase in residential mortgage loan (RML) delinquencies (see (2.6) and Tables 3.7 to 3.15) 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 (see Section 2.2). In the early '80s, in many European countries and the United States, house financing changed from fixed-rate (FRMs) to adjustable-rate mortgages (ARMs) with the interest rate risk shifting to MRs. However, when market interest rates rose again in the late '80s, SORs found that many of their 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 lost – perhaps forgotten, perhaps also neglected because, after all, the credit risk would affect the RMBS bondholders rather than the SORs (see, for instance, [61]);

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.

Those in favor of the expansion of subprime mortgage might also argue that there is nothing intrinsically bad about higher credit risks, provided SORs are aware of these risks and price them properly. The development in such origination was said to have been made possible by improvements in credit scoring techniques, transferring such techniques from automobile loans to mortgage loans. Interest rates on subprime mortgages were said to properly reflect the higher credit risks, providing for risk premia where risks were higher. Couldn't it be the case that the government-sponsored entities (GSEs), Fannie Mae and Freddie Mac, had simply not been sufficiently innovative? We do not actually share this view. We merely present it in order to show how difficult it is to assess a development that has gone astray. Once things have gone wrong, hindsight suggests that these mortgages should not have been made. However, hindsight is not a useful guide. The question must be whether we have evidence that, beforehand, it was, or should have been, clear that these mortgages should not be made (see, for instance, [61]);

From Panel A of Tables 3.16 and 3.17, 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 3.8 and 3.9. Panels B of Tables 3.16 and 3.17 show that portfolio mortgages have higher FICO scores, lower interest rate as well as slightly higher LTVR and origination amounts.

By estimating equation (2.41), the marginal effects of a logit regression performed for all mortgages is reported in Table 3.18. It can be seen that the coefficients on dummy portfolio mortgages are negative and significant at all times for the entire period (see also, Tables 3.19 and 3.22). 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 3.18 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 the result, if high FICO mortgage becomes delinquent, then high FICO may be act as a proxy for the size of credit shock in regression.

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 an OMI 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 3.7 to 3.15 in Section 3.1). 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, [61]);

The example in Subsection 2.5.2 shows that under favorable economic conditions (for instance, where mortgage default rates are low and \mathcal{C} is high) huge profits can be made from extending subprime mortgages as was the case before the SMC. On the other hand, during the SMC, when conditions are less favorable (for instance, where mortgage default rates are high and \mathcal{C} is low), SORs suffer large mortgage losses. In this regard, [35] demonstrates that low r^M discourage MRs from defaulting. However, when r^M is high as in the case of subprime MRs with M larger than H , the number of subprime mortgage defaults increase significantly. Daghli's main findings state that subprime MRs' credit quality is very sensitive to mortgage interest rate fluctuations.

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 Subsection 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.

$$\frac{\partial \omega(C_t)}{\partial C_t} < 0.$$

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.

Putting the different pieces of puzzle together, one obtain the following picture: In the years since 2000, with low interest rates, low intermediation margins, and depressed stock markets, many private investors were eagerly looking for securities offering better yields and many financial institutions were looking for better margins and better 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 the rating agencies assessments of credit risks, without appreciating that these assessments might have some errors. Given the hunger of investment banks for the business of securitization and the hunger of investors for high-yielding securities, there was little to contain moral hazard in mortgage, which, indeed, seems to have risen steadily from 2001 to 2007. For a while, the flaws in the system were hidden because real-estate prices were rising, partly in response to the inflow of funds generated by this very system. However, after real-estate prices began to fall in the summer of 2006, the credit risk in the reference mortgage portfolios became apparent (see, for instance, [61]);

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, [100]). 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, [51]). The increased distance between SORs and the ultimate bearers of risk potentially reduced SORs' incentives to screen and monitor MRs (see [108]). 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, [51] and [55]).

Chapter 4

Subprime Bank Bailouts

”Quite frankly, this amounts to robbery of the American people. I don’t think it’s going to work because I think there’ll be a lot of anger about putting the losses so much on the shoulders of the American taxpayers.”

– Prof. Josef Stiglitz (2001 Nobel Prize Laureate for Economics, Columbia University, United States), 2009.

”Don’t subsidize inefficiency.... let these businesses go bankrupt. They gambled, they lost. That’s part of life.”

– Prof. Ed Prescott (2004 Nobel Prize Laureate for Economics, University of Minnesota, United States), 2009.

KEYWORDS: Bank Bailouts; Subprime Interbank Lenders (SILs); Subprime Originators (SORs); Mortgagors (MRs); Government (G); Subprime Residential Mortgage Loans (mortgages); Residential Mortgage-Backed Securities (RMBSs); Risk-Taking, Risk-Shifting; Toxic RMBSs; Efficient Lending Constraints (ELCs); Liquidity; Preferred Equity; Common Equity; Capital Injections; Deposits; Liquidation; Audits; Tax; Dividends; Subsidies; Voluntary Participation Constraints (VPCs); Deadweight Costs and Losses; Welfare; Subprime Mortgage Crisis (SMC); Troubled Assets Relief Program (TARP); Discrete-Time Modeling.

During the SMC, several major SORs either failed, were bailed out by Gs, or merged (voluntarily or otherwise). While the specific circumstances varied, in general the decline in the value of MBSs resulted in either their insolvency – the equivalent of bank runs as investors withdrew funds – or inability to secure new funding in the credit markets. These SORs had typically borrowed and invested large sums of money relative to their cash or equity capital, meaning they were highly leveraged and vulnerable to unanticipated credit market disruptions. The five largest United States investment banks, with combined liabilities or debts of \$ 4 trillion, either went bankrupt (Lehman Brothers), were taken over by other companies (Bear Stearns and Merrill Lynch), or were bailed-out by the United States government (Goldman Sachs and Morgan Stanley) during 2008. Fannie Mae and Freddie Mac either directly owed or guaranteed nearly \$ 5 trillion in mortgage obligations, with a similarly weak capital base, when they were placed into receivership in September 2008. For scale, this \$ 9 trillion in obligations concentrated in seven highly leveraged institutions can be compared to the \$ 14 trillion size of the United States GDP or to the total national debt of \$ 10 trillion in September 2008.

4.1 Background for Chapter 4

In this chapter, we discuss bailouts and their dynamics as well as comment on the economic equilibrium appearing in this thesis chapter. We investigate the validity of the results by [127] by considering the special cases of fully amortizing, refinancing and defaulting mortgages. In the sequel, the superscripts "v" and "nv" denote present value (PV) and nett present value (NPV), respectively (refer to the definitions in the Preface).

4.1.1 Subprime Bank Bailout Events

In the following table, we sequence the subprime bailout events discussed in Chapter 4.

Subperiod	Period $t - 1$	Period t	Period $t + 1$
, 1	SOR decides whether or not to buy toxic RMBSs and SIL decides whether to extend credit to SOR to buy RMBSs	G decides whether or not to bail out SOR	mortgage returns as well as returns from high risk mortgages are realized as high or low
, 2		SOR make a choice between high and low risk mortgages	SOR pays SIL back

Table 4.1: Sequence of Bailout Events

4.1.2 Subprime Bank Bailout Equilibrium

A subgame Nash perfect equilibrium (SPE¹) is an equilibrium that can be found by using backward induction, an iterative process for solving finite extensive form or sequential games. In other words, the last player is the first one to find the optimal strategy. Then the rest, next-to-last optimal actions will be determined based on the last player's action. The procedure continues in this manner backwards until all the solutions for each player have been determined. In this thesis chapter, we consider a SPE which is formulated in a manner that depends on whether SOR does or does not voluntarily participate in a bailout.

4.1.3 Subprime Bank Bailout Assumptions

In this subsection, we look at the assumptions assumed for the chapter in bank bailouts.

4.1.3.1 Investment in Subprime Mortgages

During period $t - 1$, SOR can decide to invest its deposits worth D^v in Treasuries and earn a return, $r_{t+1}^T T_{t+1} = 0$ in period $t + 1$, where r_t^T is the rate of return on Treasuries or invest in RMBSs with a PV denoted by B_t^v . The price of this RMBS investment is $B_t^v + c_t^{Bv} B_t^v > B_t^v$, where $c_t^{Bv} B_t^v$ is the transaction costs of this purchase. The expected nett present value (NPV) of this RMBS investment is given by $\mathbf{E}[B_t^{nv}] = -c_t^{Bv} B_t^v$, where $c_t^{Bv} B_t^v > 0$ can be considered to be a deadweight loss to society. In this regard, B_t^v is a function of a Bernoulli random variable that has a probability of high returns of q and a probability of low returns of $1 - q$ in period $t + 1, 1$. The superscripts $h(l)$ denotes a high (low) RMBS return in period $t + 1, 1$. The expected value of these RMBSs is

$$\mathbf{E}[B_{t-1}^v] = qB_{t+1,1}^{hv} + (1 - q)B_{t+1,1}^{lv}, \text{ where } B_{t+1,1}^{hv} > B_{t-1}^v > B_{t+1,1}^{lv}. \quad (4.1)$$

The evolution of the securitization of a reference mortgage portfolio is illustrated by Figure 4.1 below.

To incorporate the impact of counterparty risk (subcategory of credit risk) which is important to RMBSs as well as mortgages, we will present a stylized story of lending between banks. SIL is potentially the counterparty to SOR. If SOR decides against investing in RMBSs, then SIL can invest only in Treasuries, T_t^{nv} , that generate a nett return, $r_t^T T_t^{nv} = 0$. However, we assume that SIL has two choices in period $t - 1$ if SOR does invest in RMBSs. SIL has deposits of magnitude $D_t^v = B_t^v$, that it can invest in Treasuries, T_t^{nv} , that earn a return, $r_t^T T_t^{nv} = 0$, or it can lend them to SOR in return for repayment of

$$B_{t+1}^v + r_{t+1}^B B_{t+1}^v > B_{t+1}^v$$

¹A Nash equilibrium, named after John Nash, is a set of strategies, one for each player, such that no player has incentive to unilaterally change her action. Players are in equilibrium if a change in strategies by any one of them would lead that player to earn less than if she remained with her current strategy. For games in which players randomize (mixed strategies), the expected or average payoff must be at least as large as that obtainable by any other strategy.

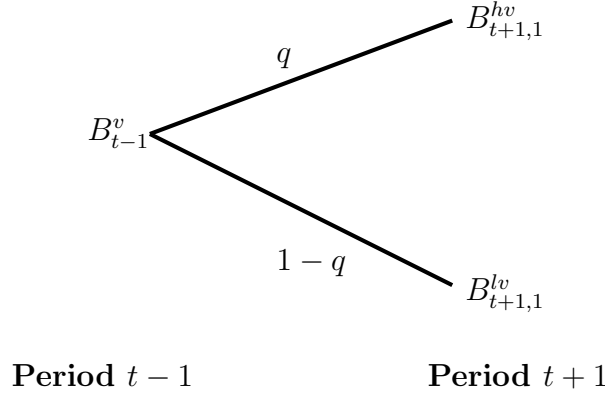


Figure 4.1: Diagrammatic Overview of the Chain of Mortgages, RMBSs and CDOs

for these borrowings in period $t + 1$. If SIL lends to SOR, SIL is a junior creditor to SOR's depositors but a senior creditor to SOR's shareholders. If SOR invests only in Treasuries, \mathbf{T} , that have expected nett present value² (NPV) given by

$$\mathbf{E}[\mathbf{T}_{t+1}^{nv}] = 0,$$

when they mature in period $t + 1$. SOR has equity capital in the form of cash of

$$E_t^v = E_t^r + c_t^{B^v} B_t^v + r_t^{\mathbf{B}} \mathbf{B}_t^v,$$

where E_t^r is SOR's cash reserve and $c_t^{B^v} B_t^v, r_t^{\mathbf{B}} \mathbf{B}_t^v > 0$. The assumption that SOR has a reserve of E_t^r is not necessary to obtain the risk shifting result. Instead, all that is necessary is that SOR has available liquid assets to make its investment in risky RMBSs because it will be unable to profitably convince new investors to fund it. From [105], we have that

$$E_t^v = n_t E_{t-1}^{cv} + n_t E_{t-1}^{pv} = E_t^r + c_t^{B^v} B_t^v + r_t^{\mathbf{B}} \mathbf{B}_t^v < D_t^v,$$

where n_t, E_t^{cv} and E_t^{pv} denote the number of shares, common equity and preferred equity, respectively. In period t , SOR's balance sheet with RMBSs, B^v , considered at PV is given by

$$M_t^v + B_t^v + \mathbf{T}_t^v = D_t^v + \mathbf{B}_t^v + E_t^v.$$

²In our case, nett present value is the nominal amount outstanding minus the sum of all future debt-service obligations (interest and principal) on existing debt discounted at an interest rate different from the contracted rate.

On the other hand, SIL has equity normalized to be worth 0 at the beginning of period $t - 1$ in the base case where it does not grant credit to SOR, i.e., SIL's balance sheet can be written as

$$M_{t-1}^{Lv} + B_{t-1}^{Lv} + T_{t-1}^{Lv} = D_{t-1}^{Lv} + B_{t-1}^{Lv},$$

where M_t^{Lv} , B_t^{Lv} , T_t^{Lv} , D_t^{Lv} , and B_t^{Lv} denote the PVs of SIL's subprime mortgages, RMBSs, Treasuries, deposits and borrowings, respectively.

4.1.3.2 Riskless and Risky Subprime Mortgages

In period t , SOR has access to a riskless, positive NPV mortgage denoted by M_t^{+nv} , which we will call the *riskless mortgage* with PV denoted by M_t^{+v} . This mortgage is extended by SOR in period $t, 2$ and will receive the proceeds in period $t + 1, 1$. The NPV of the social benefits from extending this riskless mortgage, which do not accrue to SIL, are $\tilde{B}_t^+ > 0$. The expected value of the riskless mortgage, M_t^{+v} , is the size of the cash reserve, E_t^r , so that

$$\mathbf{E}[M_t^{+v}] = E_t^r.$$

In period t , it is not only possible for SOR to extend riskless mortgages but, instead, can extend risky mortgages with the same timing as the former lending opportunity. This second type of mortgage, the *risky mortgage*, has a negative NPV of magnitude $-M_t^{-nv} < 0$, where M_t^{-nv} represents the expected loss from investing in the risky mortgage, $\mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}]$, where r_t^{-Rnv} and r_t^{-Snv} denote the recovery rate and the default rate of the nett present value of the risky mortgage, respectively. Thus, total investor wealth which includes shareholder plus creditor wealth, is destroyed by investing in the risky mortgage. For the marginal cost of the risky mortgage, M_t^{-v} , being denoted by c_t^{-v} , we suppose the cost of M_t^{-v} coincides with the cash reserve, E_t^r , and $\mathbf{E}[M_t^{-v}]$ is such that

$$\mathbf{E}[M_t^{-v}] = E_t^r - M_t^{-nv}, \quad E_t^r = c_t^{-v} M_t^{-v}.$$

The NPV of the risky mortgage is $-\mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}] < 0$, and the NPV of social benefits from the risky mortgage that do not accrue to SIL are normalized to zero, i.e., $\tilde{B}_t^{-nv} = 0$. Therefore, the difference in aggregate social benefits from the risky and riskless mortgage

$$\tilde{B}_t = (M_t^{+nv} + \tilde{B}_t^{+nv}) - (-M_t^{-nv} + \tilde{B}_t^{-nv}) = M_t^{+nv} + \tilde{B}_t^{+nv} + M_t^{-nv} > 0.$$

This means that if the riskless rather than the risky mortgage is extended, society gains the NPV of the riskless mortgage to investors, M_t^{+nv} , and the additional social benefits of the riskless mortgage, \tilde{B}_t^+ . Further, when SOR does not extend the risky mortgage, it does not obliterate wealth of magnitude M_t^{-nv} . The following assumptions about risky mortgages are also important.

Assumption 4.1.1 (Subprime Originator's Repayment of Subprime Interbank Lender's Loan): *If SOR fails to pay back SIL, we assume that there is an exogenous social cost of*

$$\tilde{C}_t > 0.$$

Also, we assume that the following holds.

Assumption 4.1.2 (Subprime Originator Insolvency in the Low Demand State): *We assume that*

$$B_{t+1,1}^{lv} + E_t^r - D_t^v - B_t^v + M_t^{+nv} < 0,$$

so that SOR is insolvent with a low demand realization even with the increase in the NPV, M_t^{+nv} , which comes from extending a riskless mortgage.

Next, we decompose the NPV of subprime mortgages denoted by M into three components, viz., a fully amortizing, refinancing and defaulting components. In period t , we consider the decomposition

$$M_t^{nv} = (1 - r^{fnv} - r^{Snv})M_t^{nv} + r^{fnv}M_t^{nv} + r^{Snv}M_t^{nv}. \quad (4.2)$$

where r^{Snv} and r^{fnv} are the rates of defaulting and refinancing, respectively, of SOR's mortgages at NPV, M^{nv} . An analogue of (4.2) can be written for the PV of subprime mortgages, M^v . We assume that refinancing excludes default so that $r^{Snv} = 0$. Fully amortizing subprime mortgages are considered to be full-term loans so that $r^{fnv} = r^{Snv} = 0$. Suppose that the above preliminaries and assumptions hold. In this case, because

$$B_t^v = 2D_t^v = D_t^v + B_t^v,$$

and

$$E_t^r > \mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}] + \left(\frac{q}{1-q}\right)\mu_t^{-Hv}M^{-Hv},$$

where $\mu_t^{-Hv} = r_t^{-Hv} - \bar{c}_t^{-H\omega v} - p_t^{-Hiv} + c_t^{-pHv}r_t^{-Hfv} - (1 - r_t^{-HRv})r_t^{-HSv}$. Here $\bar{c}_t^{-H\omega v}$ and p_t^{-Hiv} are the cost of funds and default premium, respectively, for SOR's risky mortgages in the high state. It follows that

$$B_t^v + E_t^r - D_t^v - B_t^v - \mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}] - \left(\frac{q}{1-q}\right)\mu_t^{-Hv}M^{-Hv} > 0.$$

4.1.3.3 Government Subsidy and Its Losses

Both SOR and SIL aim to maximize expected returns to shareholders who enjoy limited liability. If either bank defaults on a mortgage commitment or fails to pay back depositors, their shareholders will be ruined. Any expected losses, for G from the capital injection, which may take the form of a direct or indirect subsidy, leads to deadweight losses from taxation (see, for instance, [54]). These losses are proportional to the size of any subsidy, S_t , so that

$$\tau|S_t|, S_t, \text{ where } S_t \in (-\infty, \infty) \text{ and } 1 > \tau > 0,$$

where τ is a proportionality constant and $|S_t|$ is the size of the subsidy. Therefore, all else being equal, G strictly prefers to offer a subsidy of zero. It seems reasonable that the deadweight losses of any subsidy are substantial, but far less than unity.

4.2 Defaulting Mortgages and Subprime Bank Bailouts

In this section, we study the case involving defaulting subprime mortgages and their relation with bank bailouts.

4.2.1 Assumptions about Bank Bailouts in the Defaulting Mortgage Case

In this section, we assume that Assumptions 4.1.1 to 4.1.2 from Subsection 4.1.3.1 hold. In addition, the following assumptions are important.

Assumption 4.2.1 (Defaulting Mortgages: Return in Excess): *We assume that*

$$\mu_t^{-Hnv} M_t^{-Hnv} - \mathbf{E}[(1 - r_t^{-Rnv}) r_t^{-Snv} M_t^{-nv}] > 0,$$

is the return in excess (return rate - risk free rate) of the amount invested in the risky mortgage in the high state, where

$$\begin{aligned} \mu_t^{-Hnv} &= r_t^{-Hnv} - \bar{c}_t^{-H\omega nv} - p_t^{Hinv} + c_t^{-Hpnv} r_t^{-Hfnv} \\ &\quad - (1 - r_t^{-HRnv}) r_t^{-HSnv}. \end{aligned}$$

Here r^{-Hnv} , $\bar{c}^{-H\omega nv}$, p^{Hinv} , c^{-Hpnv} , r^{-Hfnv} , r^{-HRnv} and r^{-HSnv} , are the marginal rate of return, cost of funds, default premium, cost of prepayment accruing to SOR, rate of refinancing, rate of recovery, and default rate, respectively, for SOR's risky mortgages in the high state.

Assumption 4.2.2 (Defaulting Mortgages: Nett Loss From Low Demand State for Risky Mortgages): *We assume that*

$$S_t^{-Lnv} = -\left(\frac{1-q}{q}\right)\mu_t^{-Lnv}M_t^{-Lnv}$$

is the nett loss from the risky mortgage in the low demand state, where

$$\begin{aligned}\mu_t^{-Lnv} &= r_t^{-Lnv} - \bar{c}_t^{-L\omega v} - p_t^{Liv} + c_t^{-Lp nv} r_t^{-Lfv} - \\ &(1 - r_t^{-LRnv})r_t^{-LSnv}.\end{aligned}$$

Here r^{-Lnv} , $\bar{c}^{-L\omega v}$, p^{Liv} , $c^{-Lp nv}$, r^{-Lfv} , r^{-LRnv} and r^{-LSnv} , are the marginal rate of return, cost of funds, default premium, cost of prepayment accruing to SOR, rate of refinancing, rate of recovery, and default rate, respectively, for SOR's risky mortgages in the low state.

In the high demand state, the risky mortgage investment returns

$$\mu_t^{-Hv}M_t^{-Hv} = E_t^r + \mu_t^{-Hnv}M_t^{-Hnv} - \mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}] > E_t^r.$$

In the low demand state, the risky mortgage return is a positive amount, which is less than the principal

$$\mu_t^{-Lv}M_t^{-Lv} = E_t^r - \left(\frac{q}{1-q}\right)\mu_t^{-Hnv}M_t^{-Hnv} - \mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}]$$

where $\mu_t^{-Lv} = r_t^{-Lv} - \bar{c}_t^{-L\omega v} - p_t^{Liv} + c_t^{-Lp nv} r_t^{-Lfv} - (1 - r_t^{-LRv})r_t^{-LSv}$. The PV of these returns is

$$\begin{aligned}\mu_t^{-v}M_t^{-v} &= q\left(E_t^r + \mu_t^{-Hnv}M_t^{-Hnv} - \mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}]\right) \\ &+ (1-q)\left(E_t^r - \left(\frac{q}{1-q}\right)\mu_t^{-Hnv}M_t^{-Hnv} - \mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}]\right) \\ &= E_t^r - \mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}] < E_t^r.\end{aligned}$$

where $\mu_t^{-v} = r_t^{-v} - \bar{c}_t^{-\omega v} - p_t^{iv} + c_t^{-pv} r_t^{-fv} - (1 - r_t^{-Rv})r_t^{-Sv}$.

The following assumptions about risky mortgages are crucial to our subsequent analysis.

Assumption 4.2.3 (Defaulting Mortgages: Nett Returns from Risky Mortgages at Net Present Value): *We assume that high nett returns for mortgages with negative NPV exceed such returns for positive NPV mortgages. Symbolically, we have that*

$$\mu_t^{-Hnv}M_t^{-Hnv} - \mathbf{E}[(1 - r_t^{-Rnv})r_t^{-Snv}M_t^{-nv}] > \mu_t^{+nv}M_t^{+nv},$$

where $\mu_t^{+nv} = r_t^{+nv} - \bar{c}_t^{+\omega nv} - p_t^{+inv} + c_t^{+p nv} r_t^{+fnv} - (1 - r_t^{+Rnv}) r_t^{+S nv}$.

Assumption 4.2.4 (Defaulting Mortgages: Costs and Expected Value of Risky Mortgages): *Suppose the risky mortgage at PV, M_t^{-v} , costs, E_t^r , with expected value of*

$$\mathbf{E}[M_t^{-v}] = E_t^r - \mathbf{E}[(1 - r_t^{-Rnv}) r_t^{-S nv} M_t^{-nv}] > 0,$$

where $\mathbf{E}[(1 - r_t^{-Rnv}) r_t^{-S nv} M_t^{-nv}] > 0$.

Assumption 4.2.5 (Defaulting Mortgages: Risky Mortgage Returns in the Low State): *We assume that*

$$E_t^r > E_t^r - \left(\frac{q}{1-q} \right) \mu_t^{-Lv} M_t^{-Lv} - \mathbf{E}[(1 - r_t^{-Rnv}) r_t^{-S nv} M_t^{-nv}] > 0.$$

4.2.2 Defaulting Mortgages: Subprime Originator's Mortgages in Period t When It Purchases Toxic RMBSs in Period $t - 1$

In the next proposition, we look at SOR's defaulting mortgage behavior in period t when it purchased toxic RMBSs in period $t - 1$.

Proposition 4.2.6 (Defaulting Mortgages: Mortgage Choices): *Suppose that Assumptions 4.2.1, 4.2.3, 4.2.4 and 4.2.5 hold. SOR will choose the risky instead of the riskless mortgage if it buys toxic RMBSs in period $t - 1$.*

Proof. The Proof is similar to the one of Proposition 1 in [127]. □

4.2.3 Defaulting Mortgages: Comparing Subsidy and Recapitalization Strategies

Next, we consider G's recapitalization problem in period $t, 1$. Firstly, we compare the costs incurred during the purchase of B_t^v and E_t^{pv} as well as E_t^{cv} , in the recapitalization of a troubled SOR. The following proposition considers voluntary participation constraints (VPCs) for SORs for all mortgages.

Proposition 4.2.7 (Defaulting Mortgages: Comparing Minimum Subsidies): *Suppose that Assumptions 4.2.1, 4.2.2, 4.2.3, 4.2.4 and 4.2.5 hold. The minimum subsidies for which a troubled SOR's participation constraints are satisfied are identical regardless of whether G buys toxic RMBSs, B_t^v , preferred equity, E_t^{vp} , or common equity, E_t^{cv} , in that SOR, so that*

$$\widehat{S}_t^{B^v} = \widehat{S}_t^{E^{pv}} = \widehat{S}_t^{E^{cv}}. \tag{4.3}$$

Proof. The Proof is similar to the one of Proposition 2 in [127]. \square

The next proposition compares the efficient lending constraints (ELCs) for B_t^v , E_t^{pv} and E_t^{cv} used to recapitalize a troubled SOR.

Proposition 4.2.8 (Defaulting Mortgages: Preferred Equity vs Common Equity vs Toxic RMBSs): *Suppose that Assumptions 4.2.1, 4.2.2, 4.2.3, 4.2.4 and 4.2.5 hold. Regardless of whether voluntary participation is necessary or not (see Proposition 4.2.7), E_t^{pv} capital injections are strictly dominated by both E_t^{cv} capital injections and G 's purchase of B_t^v .*

Proof. The Proof is similar to the one of Proposition 3 in [127]. \square

4.2.4 Defaulting Mortgages: Voluntary Participation in Bank Bailouts

Next, we look at the nature of the Subgame Perfect Nash Equilibrium (SPE) that results from SOR deciding to voluntarily participate in the bailout.

Proposition 4.2.9 (Defaulting Mortgages: SOR's Voluntary Participation in Bailout): *Suppose that Assumptions 4.2.1, 4.2.2, 4.2.3, 4.2.4 and 4.2.5 hold.*

(a) *If SORs must voluntarily participate in a bailout, then G will be indifferent between a strategy of buying a common equity, E_t^{cv} , or buying toxic RMBSs, B_t^v . If G buys common equity, E_t^{cv} , the common equity stake will be $E_t^{cv} \in [\hat{E}_t^{cv}, +\infty)$, and G will pay as subsidy $\hat{S}_t^{E^{cv}} = \hat{S}_t^{B^v}$*

(b) *If SOR decides to voluntarily participate in a bailout, then the SPE may be described as follows.*

1. *If both*

$$\hat{S}_t^{E^{cv}} > c_t^{Bv} B_t^v + r_t^{Bv} \mathbf{B}_t^v \text{ and } M_t^{+nv} + \tilde{B}_t^+ + \mathbf{E}[r_t^{-Sv}(1 - r_t^{-Rv})M_t^{-v}] + (1 - q)\tilde{C}_t > \tau\hat{S}_t^{E^{cv}},$$

then SOR will lend from SIL to buy B_t^v . SOR will be bailed out with E_t^{cv} if mortgage returns are low and receive a subsidy $\hat{S}_t^{E^{cv}}$, where $E_t^{cv} \in [\hat{E}_t^{cv}, +\infty)$. Notwithstanding the mortgage returns in period t , SOR will extend the low risk mortgage in period $t - 1$ and SIL's repayment by SOR, in period $t + 1$, will be ensured.

2. *If either*

$$\hat{S}_t^{E^{cv}} \leq c_t^{Bv} B_t^v + r_t^{Bv} \mathbf{B}_t^v \text{ or } M_t^{+nv} + \tilde{B}_t^+ + \mathbf{E}[r_t^{-Sv}(1 - r_t^{-Rv})M_t^{-v}] + (1 - q)\tilde{C}_t \leq \tau\hat{S}_t^{E^{cv}},$$

then SOR will invest in Treasuries and there will be no bailout.

(c) *If voluntary participation in the bailout is not needed, then this means that*

$$\hat{S}_t^{E^{cv}} \leq c_t^{Bv} B_t^v + r_t^{Bv} \mathbf{B}_t^v \text{ or } M_t^{+nv} + \tilde{B}_t^+ + \mathbf{E}[r_t^{-Sv}(1 - r_t^{-Rv})M_t^{-v}] + (1 - q)\tilde{C}_t \leq \tau\hat{S}_t^{E^{cv}},$$

so that SOR will purchase Treasuries and no bailout will take place.

Proof. The Proof is similar to the one of Proposition 4 in [127]. □

4.3 Refinancing Mortgages and Subprime Bank Bailouts

In this section, we study the case involving refinancing subprime mortgages and their relation with bank bailouts.

4.3.1 Assumptions about Bank Bailouts in the Refinancing Mortgage Case

The following assumptions are important.

Assumption 4.3.1 (Refinancing Mortgages: Return in Excess): *We assume that*

$$\mu_t^{-Hrnv} M_t^{-Hrnv} > 0,$$

where $\mu_t^{-Hrnv} = r_t^{-Hrnv} - \bar{c}_t^{-H\omega rnv} - p_t^{Hirnv} + c_t^{-Hprnv} r_t^{-Hfrnv}$. Here r^{-Hrnv} , $\bar{c}^{-H\omega rnv}$, p^{Hirnv} , c^{-Hprnv} and r^{-Hfrnv} are the marginal rate of return, cost of funds, default premium, cost of prepayment accruing to SOR and rate of refinancing for SOR's risky mortgages in the high state in the refinancing case.

In the high demand state, the risky mortgage investment returns

$$\mu_t^{-Hrv} M_t^{-Hrv} = E_t^{rr} + \mu_t^{-Hrnv} M_t^{-Hrnv} > E_t^{rr}.$$

where $\mu_t^{-Hrv} = r_t^{-Hrv} - \bar{c}_t^{-H\omega rv} - p_t^{Hirv} + c_t^{-Hprv} r_t^{-Hfrv}$. In the low demand state, the risky mortgage returns a positive amount, which is less than the principal

$$\mu_t^{-Lrv} M_t^{-Lrv} = E_t^{rr} - \left(\frac{q}{1-q} \right) \mu_t^{-Hrnv} M_t^{-Hrnv},$$

where $\mu_t^{-Lrv} = r_t^{-Lrv} - \bar{c}_t^{-L\omega rv} - p_t^{Lirv} + c_t^{-Lprv} r_t^{-Lfrv}$. The PV of these returns is

$$\mu_t^{-rv} M_t^{-rv} = q \left(E_t^{rr} + \mu_t^{-Hrnv} M_t^{-Hrnv} \right) + (1-q) \left(E_t^{rr} - \left(\frac{q}{1-q} \right) \mu_t^{-Hrnv} M_t^{-Hrnv} \right).$$

The following assumptions about risky mortgages in the refinancing case are crucial to our subsequent analysis.

Assumption 4.3.2 (Refinancing Mortgages: Nett Returns from Risky Mortgages at Net Present Value): *We assume that high nett returns for mortgages with negative NPV exceed such returns for positive NPV mortgages. Symbolically, we have that*

$$\mu_t^{-Hrnv} M_t^{-Hrnv} > \mu_t^{+rnv} M_t^{+rnv},$$

where $\mu_t^{+rnv} = r_t^{+rnv} - \bar{c}_t^{+wrnv} - p_t^{+irnv} + c_t^{+prnv} r_t^{+frnv}$.

Assumption 4.3.3 (Refinancing Mortgages: Costs and Expected Value of Risky Mortgages): *Suppose the risky mortgage at PV, M_t^{-rv} , costs, E_t^{rr} , with expected value of*

$$\mathbf{E}[M_t^{-rv}] = E_t^{rr} > 0.$$

Assumption 4.3.4 (Refinancing Mortgages: Risky Mortgage Returns in the Low State): *We assume that*

$$E_t^{rr} > E_t^{rr} - \left(\frac{q}{1-q} \right) \mu_t^{-Lrv} M_t^{-Lrv} > 0.$$

4.3.2 Refinancing Mortgages: Subprime Originator's Mortgages in Period t When It Purchases Toxic RMBSs in Period $t - 1$

In the next proposition, we look at a refinancing SOR's mortgage behavior in period t when it purchased toxic RMBSs in period $t - 1$.

Proposition 4.3.5 (Refinancing Mortgages: Mortgage Choices): *Suppose that Assumptions 4.3.1, 4.3.2, 4.3.3 and 4.3.4 are satisfied and that the subprime mortgages are refinancing and non-defaulting. In this case, SOR will choose the risky mortgage above the riskless mortgage if it buys toxic RMBSs in period $t - 1$.*

Proof. A full proof of this result can be found in Appendix 4.8.1. □

4.3.3 Refinancing Mortgages: Comparing Subsidy and Recapitalization Strategies

Next, we consider G's recapitalization problem in period $t, 1$. Firstly, we compare the costs incurred during the purchase of B_t^{rv} and E_t^{prv} as well as E_t^{crv} , in a recapitalization of a troubled SOR. The following proposition considers VPCs for SORs for all mortgages.

Proposition 4.3.6 (Refinancing Mortgages: Comparing Minimum Subsidies): *Suppose that Assumptions 4.3.1, 4.3.2, 4.3.3 and 4.3.4 hold and that the subprime mortgages are refinancing and non-defaulting. The minimum subsidies for which the troubled SOR's participation constraints*

are satisfied are the same without regard for whether G buys toxic RMBSs, B_t^{rv} , preferred equity, E_t^{prv} , or common equity, E_t^{crv} , in that SOR. Thus

$$\widehat{\mathbf{S}}_t^{B^{rv}} = \widehat{\mathbf{S}}_t^{E^{prv}} = \widehat{\mathbf{S}}_t^{E^{crv}}. \quad (4.4)$$

Proof. A full proof of this result can be found in Appendix 4.8.2. \square

The next proposition compares the ELCs for B_t^{rv} , E_t^{prv} and E_t^{crv} used to recapitalize a troubled SOR.

Proposition 4.3.7 (Refinancing Mortgages: Preferred Equity vs Common Equity vs Toxic RMBSs): *Suppose that Assumptions 4.3.1, 4.3.2, 4.3.3 and 4.3.4 hold and that the subprime mortgages are refinancing and non-defaulting. Regardless of whether voluntary participation is necessary or not (see Proposition 4.3.6), E_t^{prv} capital injections are strictly dominated by both E_t^{crv} capital injections and G 's purchase of B_t^{rv} .*

Proof. A full proof of this result can be found in Appendix 4.8.3. \square

4.3.4 Refinancing Mortgages: Voluntary Participation in Bank Bailouts

Next, we look at the nature of the SPE that results from SOR deciding to voluntarily participate in the bailout in the refinancing case.

Proposition 4.3.8 (Refinancing Mortgages: Subprime Originator's Voluntary Participation in Bailout): *Suppose that Assumptions 4.3.1, 4.3.2, 4.3.3 and 4.3.4 hold and that the subprime mortgages are refinancing and non-defaulting. Then the following statements are true.*

(a) *If SORs must voluntarily participate in the program, then G , acting in the public interest, will be indifferent between a strategy of purchasing common equity, E_t^{crv} , or buying toxic RMBSs, B_t^{rv} . If G buys common equity, E_t^{crv} , the common equity stake will be $E_t^{crv} \in [\widehat{E}_t^{crv}, +\infty)$, and G will pay as subsidy $\widehat{\mathbf{S}}_t^{E^{crv}} = \widehat{\mathbf{S}}_t^{B^{rv}}$*

(b) *If SOR decides to voluntarily participate in a bailout, then the SPE is given as follows.*

1. *If both*

$$\widehat{\mathbf{S}}_t^{E^{crv}} > c_t^{B^{rv}} B_t^{rv} + r_t^{B^{rv}} \mathbf{B}_t^{rv} \quad \text{and} \quad M_t^{+r_{nv}} + \widetilde{B}_t^{+r} + (1-q)\widetilde{C}_t^r > \tau \widehat{\mathbf{S}}_t^{E^{crv}},$$

then SOR will lend from SIL to buy B_t^{rv} . SOR will be bailed out with E_t^{crv} if mortgage returns are low and receive a subsidy $\widehat{\mathbf{S}}_t^{E^{crv}}$, where $E_t^{crv} \in [\widehat{E}_t^{crv}, +\infty)$. Notwithstanding the mortgage returns in period t , SOR will extend the low risk mortgage in period $t-1$ and SIL's repayment by SOR, in period $t+1$, will be ensured.

2. *If either*

$$\widehat{\mathbf{S}}_t^{E^{crv}} \leq c_t^{Brv} B_t^{rv} + r_t^{Brv} \mathbf{B}_t^{rv} \text{ or } M_t^{+rnv} + \widetilde{B}_t^{+r} + (1-q)\widetilde{C}_t^r \leq \tau \widehat{\mathbf{S}}_t^{E^{crv}},$$

then SOR will invest in Treasuries and there will be no bailout.

(c) If voluntary participation in the bailout is not needed, then this means that

$$\widehat{\mathbf{S}}_t^{E^{crv}} \leq c_t^{Brv} B_t^{rv} + r_t^{Brv} \mathbf{B}_t^{rv} \text{ or } M_t^{+rnv} + \widetilde{B}_t^{+r} + (1-q)\widetilde{C}_t^r < \tau \widehat{\mathbf{S}}_t^{E^{crv}},$$

so that SOR will purchase Treasuries and no bailout will take place.

Proof. A full proof of this result can be found in Appendix 4.8.4. □

4.4 Fully Amortizing Mortgages and Subprime Bank Bailouts

In this section, we study the case involving fully amortizing subprime mortgages and their relation with bank bailouts.

4.4.1 Assumptions about Bank Bailouts in the Fully Amortizing Mortgage Case

In this section, we assume that Assumptions 4.1.1 to 4.1.2 from Subsection 4.1.3.1 hold. In addition, the following assumptions are important.

Assumption 4.4.1 (Fully Amortizing Mortgages: Return in Excess): *We assume that*

$$\mu_t^{-Hanv} M_t^{-Hanv} > 0,$$

where $\mu_t^{-Hanv} = r_t^{-Hanv} - \bar{c}_t^{-H\omega av} - p_t^{Hianv}$. Here r^{-Hanv} , $\bar{c}^{-H\omega av}$ and p^{Hianv} are the marginal rate of return, cost of funds and default premium for SOR's risky mortgages in the high state in the fully amortizing case.

In this case, in the high demand state, risky fully amortizing mortgage investment returns

$$\mu_t^{-Hav} M_t^{-Hav} = E_t^{ra} + \mu_t^{-Hanv} M_t^{-Hanv} > E_t^{ra}.$$

where $\mu_t^{-Hav} = r_t^{-Hav} - \bar{c}_t^{-H\omega av} - p_t^{Hia v}$. In the low demand state, the risky mortgage returns a positive amount, which is less than the principal

$$\mu_t^{-Lav} M_t^{-Lav} = E_t^{ar} - \left(\frac{q}{1-q} \right) \mu_t^{-Hanv} M_t^{-Hanv},$$

where $\mu_t^{-Lav} = r_t^{-Lav} - \bar{c}_t^{-L\omega av} - p_t^{Lia v}$. The PV of these returns is

$$\mu_t^{-av} M_t^{-av} = q \left(E_t^{ar} + \mu_t^{-Hanv} M_t^{-Hanv} \right) + (1 - q) \left(E_t^{ar} - \left(\frac{q}{1 - q} \right) \mu_t^{-Hanv} M_t^{-Hanv} \right),$$

where $\mu_t^{-av} = r_t^{-av} - \bar{c}_t^{-\omega av} - p_t^{-ia v}$.

The following assumptions about risky mortgages in the fully amortizing case are crucial to our subsequent analysis.

Assumption 4.4.2 (Fully Amortizing Mortgages: Nett Returns from Risky Mortgages at Net Present Value): *We assume that high nett returns for mortgages with negative NPV exceed such returns for positive NPV mortgages. Symbolically, we have that*

$$\mu_t^{-Hanv} M_t^{-Hanv} > \mu_t^{+anv} M_t^{+anv},$$

where $\mu_t^{+anv} = r_t^{+anv} - \bar{c}_t^{+\omega anv} - p_t^{+ia nv}$.

Assumption 4.4.3 (Fully Amortizing Mortgages: Costs and Expected Value of Risky Mortgages): *Suppose the risky mortgage at PV, M_t^{-av} , costs, E_t^{ar} , with expected value of*

$$\mathbf{E}[M_t^{-av}] = E_t^{ar} > 0.$$

Assumption 4.4.4 (Fully Amortizing Mortgages: Risky Mortgage Returns in the Low State): *We assume that*

$$E_t^{ar} > E_t^{ar} - \left(\frac{q}{1 - q} \right) \mu_t^{-Lav} M_t^{-Lav} > 0.$$

4.4.2 Fully Amortizing Mortgages: Subprime Originator's Mortgages in Period t When It Purchases Toxic RMBSs in Period $t - 1$

In this subsection, for fully amortizing mortgages, we discuss SOR's mortgages in period t when it purchases toxic RMBSs in period $t - 1$.

Proposition 4.4.5 (Fully Amortizing Mortgages: Mortgage Choices): *Suppose that Assumptions 4.4.1, 4.4.2, 4.4.3 and 4.4.4 hold and that the subprime mortgages are fully amortizing. In this case, SOR will choose the risky instead of the riskless mortgage if it buys toxic RMBSs in period $t - 1$.*

Proof. The Proof is similar to the one of Proposition 4.3.5 in Section 4.3. □

4.4.3 Fully Amortizing Mortgages: Comparing Subsidy and Recapitalization Strategies

Next, we compare the costs incurred during the purchase of all B_t^{av} and E_t^{pav} as well as E_t^{cav} , in a recapitalization of a troubled SOR. The following proposition considers SOR's VPCs for all RMBSs.

Proposition 4.4.6 (Fully Amortizing Mortgages: Comparing Minimum Subsidies): *Suppose that Assumptions 4.4.1, 4.4.2, 4.4.3 and 4.4.4 hold and that the subprime mortgages are fully amortizing. The minimum subsidies for which troubled SORs VPCs are satisfied are identical regardless of whether G buys toxic RMBSs, B_t^{av} , preferred equity, E_t^{pav} , or common equity, E_t^{cav} , in that SOR. Thus*

$$\widehat{S}_t^{B^{av}} = \widehat{S}_t^{E^{pav}} = \widehat{S}_t^{E^{cav}}. \quad (4.5)$$

Proof. The Proof is similar to the one of Proposition 4.3.6 in Section 4.3. □

The next proposition compares the ELCs for B_t^{av} , E_t^{pav} and E_t^{cav} used to recapitalize a troubled SOR.

Proposition 4.4.7 (Fully Amortizing Mortgages: Preferred Equity vs Common Equity vs Toxic RMBSs): *Suppose that Assumptions 4.4.1, 4.4.2, 4.4.3 and 4.4.4 hold and that the subprime mortgages are fully amortizing. Regardless of whether voluntary participation is necessary or not (see Proposition 4.4.6), E_t^{pav} capital injections are strictly dominated by both E_t^{cav} capital injections and G 's purchase of B_t^{av} .*

Proof. The Proof is similar to the one of Proposition in 4.3.7 in Section 4.3. □

4.4.4 Fully Amortizing Mortgages: Voluntary Participation in Bank Bailouts

Next, we look at the nature of the SPE that results from SOR deciding to voluntarily participate in the bailout.

Proposition 4.4.8 (Fully Amortizing Mortgages: Subprime Originator's Voluntary Participation in Bailout): *Suppose that Assumptions 4.4.1, 4.4.2, 4.4.3 and 4.4.4 hold and that the subprime mortgages are fully amortizing.*

(a) *If SORs must voluntarily participate in the program, then G will be indifferent between a strategy of buying common equity, E_t^{cav} , or buying toxic RMBSs, B_t^{av} . If G buys common equity, E_t^{cav} , the common equity stake will be $E_t^{cav} \in [\widehat{E}_t^{cav}, +\infty)$, and G will pay as subsidy $\widehat{S}_t^{E^{cav}} = \widehat{S}_t^{B^{av}}$*

(b) *If SOR decides to voluntarily participate in a bailout, then the SPE may be described as follows.*

1. If both

$$\widehat{\mathbf{S}}_t^{E^{cav}} > c_t^{Bav} B_t^{av} + r_t^{Bav} \mathbf{B}_t^{av} \text{ and } M_t^{+anv} + \widetilde{B}_t^{+a} + (1 - q)\widetilde{C}_t^a > \tau \widehat{\mathbf{S}}_t^{E^{cav}},$$

then SOR will lend from SIL to buy B_t^{av} . SOR will be bailed out with E_t^{cav} if mortgage returns are low and receive a subsidy $\widehat{\mathbf{S}}_t^{E^{cav}}$, where $E_t^{cav} \in [\widehat{E}_t^{cav}, +\infty)$. Notwithstanding the mortgage returns in period t , SOR will extend the low risk mortgage in period $t - 1$ and SIL's repayment by SOR, in period $t + 1$, will be ensured.

2. If either

$$\widehat{\mathbf{S}}_t^{E^{cav}} \leq c_t^{Bav} B_t^{av} + r_t^{Bav} \mathbf{B}_t^{av} \text{ or } M_t^{+anv} + \widetilde{B}_t^{+a} + (1 - q)\widetilde{C}_t^a \leq \tau \widehat{\mathbf{S}}_t^{E^{cav}},$$

then SOR will invest in Treasuries and there will be no bailout.

(c) If voluntary participation in the bailout is not needed, then this means that

$$\widehat{\mathbf{S}}_t^{E^{cav}} \leq c_t^{Bav} B_t^{av} + r_t^{Bav} \mathbf{B}_t^{av} \text{ or } M_t^{+anv} + \widetilde{B}_t^{+a} + (1 - q)\widetilde{C}_t^a < \tau \widehat{\mathbf{S}}_t^{E^{cav}},$$

so that SOR will purchase Treasuries and no bailout will take place.

Proof. The Proof is similar to the one of Proposition 4.3.8 in Section 4.3. □

4.5 Examples Involving Subprime Bank Bailouts

In Table 4.2, we provide parameter values for a numerical example to illustrate important features of subprime bank bailouts.

For this example, we concentrate on Proposition 4.2.9, 4.3.8 and 4.4.8 in Subsections 4.2.4, 4.3.4 and 4.4.4, respectively, by looking at the nature of the SPE that results from SOR deciding to voluntarily participate in the bailout.

Firstly, we look at defaulting mortgages. We calculate the two conditions

$$\widehat{\mathbf{S}}_t^{E^{cv}} > c_t^{Bv} B_t^v + r_t^{Bv} \mathbf{B}_t^v \text{ and } M_t^{+nv} + \widetilde{B}_t^+ + \mathbf{E}[r_t^{-Sv}(1 - r_t^{-Rv})M_t^{-v}] + (1 - q)\widetilde{C}_t > \tau \widehat{\mathbf{S}}_t^{E^{cv}}.$$

Condition A: $c_t^{Bv} B_t^v + r_t^{Bv} \mathbf{B}_t^v = 0.101 \times 1300 + 0.1 \times 5200 = 651.3$ and

Condition B: $M_t^{+nv} + \widetilde{B}_t^+ + \mathbf{E}[r_t^{-Sv}(1 - r_t^{-Rv})M_t^{-v}] + (1 - q) \times \widetilde{C}_t = 10000 + 800 + 1200 + (1 - 0.4) \times 1000 = 12600$

The SPE may be described as follows: If SOR decides to voluntarily participate in a bailout, both $\widehat{\mathbf{S}}_t^{E^{cv}} > A$ and $B > \tau \widehat{\mathbf{S}}_t^{E^{cv}}$ then SOR will lend from SIL to buy B_t^v . SOR will be bailed out with E_t^{cv} if mortgage returns are low and receive a subsidy $\widehat{\mathbf{S}}_t^{E^{cv}}$.

Parameter	Period t	Parameter	Period t
M_t^{+nv}	\$ 10 000	m_0	\$ 5 000
ω^M	0.05	m_1	\$ 5 000
r^M	0.051	m_2	\$ 5 000
$\bar{c}^{M\omega}$	0.0414	\tilde{C}_t	1 000
p^i	0.01	q	0.4
c^p	0.05	$\mathbf{E}[r_t^{-Sv}(1 - r_t^{-Rv})M_t^{-v}]$	1 200
r^f	0.01	\tilde{B}_t^+	800
r^R	0.5	K	\$ 500
r^S	0.15	$\mathbf{0}$	\$ 150
H	\$ 11 000	r^0	0.101
L	0.909	E	\$ 250
τ	0.05	E^p	\$ 150
C	\$ 1 000	E^c	\$ 100
r_t^{Bv}	0.105	r_t^{Bv}	0.1
c_t^{Bv}	0.101	c_t^{Bv}	0.09
B_t^v	\$ 1 300	\mathbf{B}_t^v	\$ 5 200
ω^B	0.5	Π^p	\$ 6 000
r^T	0.036	D	\$ 9 300
T	\$ 2 000	r^D	0.105
P^T	\$ 800	c^D	0.101

Table 4.2: Numerical Example Involving Subprime Bank Bailouts

If either $\widehat{\mathbf{S}}_t^{Ecv} \leq A$ or $B \leq \tau \widehat{\mathbf{S}}_t^{Ecv}$, then SOR will invest in Treasuries and there will be no bailout. If voluntary participation in the bailout is not needed, then this means that $\widehat{\mathbf{S}}_t^{Ecv} \leq A$ or $B \leq \tau \widehat{\mathbf{S}}_t^{Ecv}$, so that SOR will purchase Treasuries and no bailout will take place.

Secondly, we look at refinancing mortgages. We calculate the two conditions

$$\widehat{\mathbf{S}}_t^{Ecrv} > c_t^{Brv} B_t^{rv} + r_t^{Brv} \mathbf{B}_t^{rv} \text{ and } M_t^{+rnv} + \tilde{B}_t^{+r} + (1 - q)\tilde{C}_t^r > \tau \widehat{\mathbf{S}}_t^{Ecrv}.$$

Condition A: $c_t^{Brv} B_t^{rv} + r_t^{Brv} \mathbf{B}_t^{rv} = 0.101 \times 1300 + 0.1 \times 5200 = 651.3$ and

Condition B: $M_t^{+rnv} + \tilde{B}_t^{+r} + (1 - q) \times \tilde{C}_t^r = 10000 + 800 + (1 - 0.4) \times 1000 = 11400$

The SPE may be described as follows: If SOR decides to voluntarily participate in a bailout, both $\widehat{\mathbf{S}}_t^{Ecrv} > A$ and $B > \tau \widehat{\mathbf{S}}_t^{Ecrv}$ then SOR will lend from SIL to buy B_t^{rv} . SOR will be bailed out with E_t^{crv} if mortgage returns are low and receive a subsidy $\widehat{\mathbf{S}}_t^{Ecrv}$.

If either $\widehat{\mathbf{S}}_t^{Ecrv} \leq A$ or $B \leq \tau \widehat{\mathbf{S}}_t^{Ecrv}$, then SOR will invest in Treasuries and there will be no bailout.

If voluntary participation in the bailout is not needed, then this means that $\widehat{\mathbf{S}}_t^{Ecrv} \leq A$ or $B \leq \tau \widehat{\mathbf{S}}_t^{Ecrv}$, so that SOR will purchase Treasuries and no bailout will take place.

The fully amortizing case follows exactly the same as the refinancing case above.

4.6 Discussions on Subprime Bank Bailouts

In this section, we discuss subprime bank bailouts in the cases where SOR's mortgage default, refinance and fully amortize.

4.6.1 Defaulting Mortgages and Subprime Bank Bailouts

In the defaulting mortgage case in Section 4.2, we characterize SOR's choices of mortgage (see Proposition 4.2.6), compare preferred equity, common equity and toxic RMBS minimum subsidies, (4.3) (see Proposition 4.2.7) and their recapitalizations (see Proposition 4.2.8) as well as describe SOR's voluntary participation in bailouts (see Proposition 4.2.9).

The immediate cause or trigger of the crisis was the bursting of the United States housing bubble which peaked in approximately 2005/2006. High default rates on "subprime" and adjustable rate mortgages (ARM), began to increase quickly thereafter. Defaults and foreclosure activity increased dramatically as easy initial terms expired, home prices failed to go up as anticipated, and ARM interest rates reset higher.

In the case where SOR's subprime mortgages default, we investigate how various types of capital injections (purchasing of RMBSs, preferred equity and common equity) affect SOR's incentives to lend efficiently. We address the question of which RMBSs should be used to recapitalize troubled SORs. In particular, this study provides a theoretical model that analyzes recapitalizations when banks have enough liquid assets to participate in risk-shifting. We assume that G cannot contract over SOR's lending policy. Instead, G's primary mechanism for improving the troubled SOR's lending decisions is to recapitalize it. In this chapter, we assume that troubled SORs has a sufficient amount of liquid assets to extend new mortgages. Nevertheless, since SOR is not solvent in all states of the world, it is tempted to shift risk onto its creditors. For defaulting mortgages, in terms of inducing efficient lending, G's purchases of new common equity is always at least or more effective than buying toxic RMBSs or purchasing preferred equity. We find that the subsidies (overpayment for assets) are always necessary to induce SOR to agree to the recapitalization voluntarily. Further, we determine that the purchasing of preferred equity is the least effective form of recapitalization. All the gains from such a recapitalization come from G's implicit subsidy from purchasing that equity. In this case, it is only the G's overpayment for preferred equity that improves lending incentives. Moreover, we prove that just because SOR agrees to a preferred equity recapitalization does not imply that SOR's lending behavior will improve. Indeed, as long as G buys enough common equity or toxic RMBSs, lending incentives improve without a subsidy for potentially, but not yet insolvent, SORs.

The previous paragraph brings into question the effectiveness of the TARP. More specifically, G has mostly used preferred equity to inject capital into SORs. There are concerns about the TARP bailout, which have not been explicitly addressed by this chapter, but probably should be addressed by lawmakers or the incoming administration going forward. It could pose some problems that the recipients of the TARP monies are not prohibited from cash acquisitions. Cash acquisitions increase SOR's leverage or reduce the acquirer's cash cushion and thus increase the risk of its equity, all other things being equal. SOR will often be tempted to undo any leverage decreasing transaction, which includes a taxpayer subsidy, with a leverage increasing transaction. It is somewhat surprising

that so many SORs have received TARP funds. Certainly, many of those banks are not too-big-to-fail. As of Monday, 8 December 2008, there were 156 financial institutions that had received at least preliminary approval for TARP. Many of the banks due to receive TARP funds probably would not pose systematic risk if they were closed down due to insolvency. It is not clear that the closure of all but the handful of giant commercial and formerly investment banks pose any short or long-term damage to the financial system as a whole. For this reason, the banking sector as a whole may be made healthier if the weaker regional banks were closed down and their assets were sold to stronger institutions. It may be more efficient to close down rather than recapitalize insolvent banks. Nevertheless, [1], for example, have more to say about how many, and which banks should be bailed out. In contrast, the present paper primarily answers which mortgages should be used to bail out banks that are deemed too-big-to-fail.

The analysis in Section 4.2 enables us to derive an traditional mortgage model with subprime elements model for SOR's profit with defaulting mortgages at NPV. In period t , in order to derive this model, we take *cash inflow* to be constituted by returns on risky RMBSs, $r_t^{Bnv} B_t^{nv}$, mortgages, $\mu_t^{Mnv} M_t^{nv}$, Treasuries, $r_t^T \mathbf{T}_t^{nv}$, recovery amount, R_t^{nv} , CDS protection leg payments, $C^{nv}(S(\mathcal{C}_t))$ and Π_t^{pnv} is the NPV of future profits from additional mortgages based on current mortgages. Furthermore, we consider the average weighted cost of funds for M_t^{nv} , $\bar{c}_t^{c\omega nv} M_t^{nv}$, NPV of mortgages in default, $\mu_t^S M_t^{nv}$, CDS premium, $p_t^i(\mathcal{C}_t) M_t^{nv}$, the all-in cost of holding securities, $c_t^{Bnv} B_t^{nv}$, interest paid to depositors, $r_t^{Dnv} D_t^{nv}$, cost of taking deposits, $c_t^{Dnv} D_t^{nv}$, interest paid to borrowers, $r_t^B \mathbf{B}_t^{nv}$, the cost of borrowing, $c_t^B \mathbf{B}_t^{nv}$, provisions against deposit withdrawals, $P_t^T(\mathbf{T}_t^{nv})$, and the value of mortgage losses $S^{nv}(\mathcal{C}_t)$, as *cash outflow*. Here r_t^{Dnv} and c_t^{Dnv} are the deposit rate and marginal cost of deposits, respectively, r_t^B and c_t^B are the borrower rate and marginal cost of borrowing, respectively. In this case, we have that an traditional mortgage model with subprime elements model for SOR's profit with subprime mortgages at NPV may be expressed as

$$\begin{aligned} \Pi_t^{nv} &= \mu_t^{nv} M_t^{nv} + C^{nv}(\mathbf{E}[S(\mathcal{C}_t)]) + r_t^{Bnv} B_t^{nv} \\ &\quad + r_t^T \mathbf{T}_t^{nv} - P^T(\mathbf{T}_t^{nv}) - \left(r_t^{Dnv} + c_t^{Dnv} \right) D_t^{nv} - \left(r_t^B + c_t^B \right) \mathbf{B}_t^{nv} + \Pi_t^{pnv} \geq 0, \end{aligned} \quad (4.6)$$

where $\mu_t^{nv} = r_t^{nv} - \bar{c}_t^{c\omega nv} - p_t^{inv} + c_t^{pnv} r_t^{fnv} - (1 - r_t^{Rnv}) r_t^{Snv}$. From equation (4.6), we may have

$$\begin{aligned} r_t^{Bnv} B_t^{nv} &= \Pi_t^{nv} + P^T(\mathbf{T}_t^{nv}) + \left(r_t^{Dnv} + c_t^{Dnv} \right) D_t^{nv} + \left(r_t^{Bnv} + c_t^{Bnv} \right) \mathbf{B}_t^{nv} \\ &\quad - \mu_t^{nv} M_t^{nv} - C^{nv}(\mathbf{E}[S(\mathcal{C}_t)]) - r_t^{Tnv} \mathbf{T}_t^{nv} - \Pi_t^{pnv}. \end{aligned} \quad (4.7)$$

In this case, $r_t^{Bnv} B_t^{nv} \geq 0$ and $r_t^{Bnv} B_t^{nv} < 0$, if

$$\begin{aligned} \mu_t^{nv} M_t^{nv} &\leq \Pi_t^{nv} + P^T(\mathbf{T}_t^{nv}) + \left(r_t^{Dnv} + c_t^{Dnv} \right) D_t^{nv} + \left(r_t^{Bnv} + c_t^{Bnv} \right) \mathbf{B}_t^{nv} \\ &\quad - C^{nv}(\mathbf{E}[S(\mathcal{C}_t)]) - r_t^{Tnv} \mathbf{T}_t^{nv} - \Pi_t^{pnv} \end{aligned} \quad (4.8)$$

and

$$\begin{aligned} \mu_t^{nv} M_t^{nv} &> \Pi_t^{nv} + P^T(\mathbf{T}_t^{nv}) + \left(r_t^{Dnv} + c_t^{Dnv} \right) D_t^{nv} + \left(r_t^{Bnv} + c_t^{Bnv} \right) \mathbf{B}_t^{nv} \\ &\quad - C^{nv}(\mathbf{E}[S(C_t)]) - r_t^{Tnv} \mathbf{T}_t^{nv} - \Pi_t^{pnv}, \end{aligned} \quad (4.9)$$

respectively.

4.6.2 Refinancing Mortgages and Subprime Bank Bailouts

Section 4.3 shows that even if there is not a possibility of mortgages refinancing after their origination in period t , the purchase of toxic RMBSs in period $t - 1$ may lead to SOR having to be bailed out.

The choice of MRs to extract wealth from housing in the subprime mortgage market while refinancing and assesses the prepayment and default performance of these cash-out refinance loans relative to rate refinance mortgages. Consistent with survey evidence the propensity to extract equity while refinancing is sensitive to interest rates on other forms of consumer debt. After mortgage is originated, results indicate 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.

4.6.3 Fully Amortizing Mortgages and Subprime Bank Bailouts

In the fully amortizing mortgage case in Section 4.4, we characterize SOR's choices of mortgage (see Proposition 4.4.5), compare preferred equity, common equity and toxic RMBS minimum subsidies (4.5) (see Proposition 4.4.6) and their recapitalizations (see Proposition 4.4.7) as well as describe SOR's voluntary participation in bailouts (see Proposition 4.4.8).

The conclusions drawn from Section 4.4 are similar to those of Subsection 4.6.2 for refinancing mortgages. For instance, it demonstrates that despite mortgages not defaulting after their origination in period t , the purchase of toxic RMBSs in period $t - 1$ may lead to an SOR bailout.

4.7 2007-2010 Timeline of the SMC-Related Events Involving Subprime Bank Bailouts

In this section, we provide examples of notable events related to subprime bank bailouts in the period 2007 to 2010.

4.7.1 2007-2010 Timeline of Events Related to Subprime Bank Bailouts

In this subsection, we give a timeline of SMC-related events involving subprime bank bailouts.

Monday, 24 December 2007: A consortium of banks officially abandons the United States government-supported "super-SIV" mortgage crisis bailout plan announced in mid-October, citing a lack of demand for the risky mortgage products on which the plan was based, and widespread criticism that the fund was a flawed idea that would have been difficult to execute.

Wednesday, 18 June 2008: As the chairman of the Senate Banking Committee Connecticut's, Christopher Dodd, proposed a housing bailout to the Senate floor that would assist troubled sub-prime mortgage lenders such as Countrywide Bank.

Wednesday, 1 October 2008: The United States Senate passes HR1424, their version of the \$ 700 billion bailout bill. A report says that French Finance Minister, Christine Lagarde, calls for an emergency EU bailout fund for banks threatened with failure.

Monday, 6 October 2008: Proposed Hypo Real Estate bailout collapses. German Chancellor, Angela Merkel, announces new plan for Hypo bailout worth \$ 69 billion. Major markets in Europe, Asia and Latin America sank as traders looked past America's bank bailout bill and focused on Europe's growing financial crisis.

Wednesday, 8 October 2008: The U.K. announces details of a rescue package for the banking system worth at least £50 billion (\$ 88 billion). The deal is considered to amount to semi-nationalization. White House considers taking ownership stakes in private banks as a part of the bailout bill. Warren Buffett and George Soros criticized the original approach of the bailout bill.

Monday, 13 October 2008: EU stock markets bounce back in response to EU leaders' bailout announcements. French president, Nicolas Sarkozy, pledges 360 billion Euros in liquidity to French banks. The plan will include 320 billion Euros in guarantees for new bank debt and a 40 billion Euros fund for recapitalizing lenders. In return for the bailout, the French government will demand conditions on the banks such as changes to pay and bonus structures. The U.K. government starts the nationalization process by injecting £37 billion of taxpayers' money into the nation's three largest banks. The U.K. government will end up owning a majority share in the Royal Bank of Scotland (RBS) and over a 40 % share in Lloyds and HBOS. In return for the bailout, the banks have agreed to cancel dividend payments until the loans are repaid, have board members appointed by the Treasury and limit executive pay.

Monday, 10 November 2008: FRB and Treasury announce a restructuring of the government's financial support of AIG. The Treasury will purchase \$ 40 billion of AIG preferred equity under the TARP program, a portion of which will be used to reduce the Fed's loan to AIG from \$ 85 billion to \$ 60 billion. The terms of the loan are modified to reduce the interest rate to the 3-month LIBOR plus 300 bps and lengthen the term of the loan from two to five years.

Wednesday, 31 December 2008: Treasury purchases a total of \$ 1.91 billion in preferred equity from seven United States banks under CPP.

Friday, 9 January 2009: COP issues its second monthly report on the expenditure of TARP. Official figures show the US jobless rate rose to 7.2 % in December 2008, the highest in 16 years.

The figures also indicate that more US workers lost jobs in 2008 than in any year since World War II.

Monday, 12 January 2009: FDIC issues a letter to FDIC-supervised institutions calling on them to implement a process to monitor their use of (1) capital injections, (2) liquidity support and/or (3) financing guarantees obtained through Treasury, FDIC and Fed financial stability programs. At the request of President-Elect Obama, President Bush submits a request to Congress for the remaining \$ 350 billion in TARP funding for use by the incoming administration.

Friday, 16 January 2009: Treasury announces that it will lend \$ 1.5 billion from TARP to a SPV created by Chrysler Financial to finance the extension of new consumer auto loans. Sony posted \$ 1.1 billion operating loss. The US government reaches an agreement to provide Bank of America with another \$ 20 billion in fresh aid from its \$ 700 billion financial rescue fund. The emergency funding will help the troubled bank absorb the losses it incurred when it bought Merrill Lynch. Struggling US banking giant Citigroup announces plans to split the firm in two, as it reports a quarterly loss of \$ 8.29 billion (£5.6 billion).

Wednesday, 21 January 2009: Britain says its bank bailouts have dealt a major blow to Britain's public finances as the recapitalization of ailing RBS blows out the deficit to £44.2 billion (\$ 62 billion) last month, its highest on record.

Friday, 23 January 2009: Treasury purchases a total of \$ 326 million in preferred equity from 23 United States banks under the CPP.

Wednesday, 28 January 2009: The United States House of Representatives passed President Barack Obama's \$ 819 billion (£572 billion) economic stimulus package. Passed by 244 votes to 188, no Republicans backed the plan, saying it was too expensive and would not work.

Friday, 30 January 2009: Treasury purchases a total of \$ 1.15 billion in preferred equity from 42 United States banks under the CPP.

Tuesday, 3 February 2009: Fed announces the extension until Friday, 30 October 2009, of the existing liquidity programs scheduled to expire on Thursday, 30 April 2009. FRB and FOMC note "continuing substantial strains in many financial markets." In addition, the swap lines between the Fed and other central banks are also extended to Friday, 30 October 2009. The expiration date for TALF remains Thursday, 31 December 2009, while TAF does not have an expiration date.

Wednesday, 4 February 2009: Treasury issues restrictions on executive pay for financial institutions that receive government assistance during the financial crisis. Any bank receiving exceptional assistance from the US government will be required to limit the pay of senior executives to \$ 500 000 a year. The companies will be able to give executives restricted equity above the \$ 500 000 limit but the equity cannot vest until the government has been completely paid back for the assistance given, with interest.

Thursday, 5 February 2009: Russia announces that it will change its approach to combating the global financial crisis. Instead of bailing out individual companies, Russia will attempt to support the economy through the banking sector and limit its deficit through large budget cuts. This news followed a credit downgrade of Russia's debt by the Fitch rating agency.

Friday, 6 February 2009: Treasury purchases a total of \$238.5 million in preferred equity from 28 United States banks under CPP.

Tuesday, 10 February 2009: Treasury Secretary, Timothy Geithner, announces a Financial Stability Plan involving Treasury purchases of convertible preferred equity in eligible banks, the creation of a Public-Private Investment Fund to acquire troubled loans and other assets from financial institutions, expansion of the Federal Reserves TALF, and new initiatives to stem residential mortgage foreclosures and to support small business lending. The \$2 trillion plan includes a financial stability trust to manage the US government's investments, a public-private investment fund to clean up the banks' balance sheets, a consumer and business lending initiative, a small business and community lending initiative, and housing support and foreclosure prevention plan. Commentators have suggested that the Financial Stability Plan is not detailed enough to restore confidence in the financial system. UBS announces that it lost \$17 billion in 2008, the largest corporate loss in Swiss history. UBS intends to keep its investment banking division despite cutting 1500-2000 more investment banking jobs.

Friday, 13 February 2009: Treasury purchases a total of \$429 million in preferred equity from 29 United States banks under CPP.

Tuesday, 17 February 2009: Treasury releases its first monthly survey of bank lending by the top 20 recipients of government investment through CPP. The survey found that banks continued to originate, refinance and renew loans from the beginning of the program in October until December 2008.

Monday, 23 February 2009: Treasury, FDIC, Office of the Comptroller of the Currency, Office of Thrift Supervision and FRB issue a joint statement that the United States government stands firmly behind the banking system, and that the government will ensure that banks have the capital and liquidity they need to provide the credit necessary to restore economic growth. Further, the agencies reiterate their determination to preserve the stability of systemically important financial institutions.

Tuesday, 23 February 2010: The FDIC announces that the number of "problem banks" increased from 552 insured institutions with \$345.9 billion in assets at the end of third quarter of 2009, to 702 institutions with \$402.8 billion of assets at the end of the fourth quarter of 2009.

Tuesday, 24 February 2009: Treasury purchases a total of \$ 365.4 million in preferred equity from 23 United States banks under CPP.

Thursday, 26 February 2009: FDIC announces that the number of "problem banks" increased from 171 institutions with \$116 billion of assets at the end of the third quarter of 2008, to 252

insured institutions with \$159 billion in assets at the end of fourth quarter of 2008. FDIC also announces that there were 25 bank failures and five assistance transactions in 2008, which was the largest annual number since 1993.

Friday, 27 February 2009: Treasury announces its willingness to convert up to \$ 25 billion of Citigroup preferred equity issued under CPP into common equity. The conversion is contingent on the willingness of private investors to convert a similar amount of preferred shares into common equity. Remaining Treasury and FDIC preferred shares issued under the Targeted Investment Program and Asset Guarantee Program would be converted into a trust preferred security of greater structural seniority that would carry the same 8% cash dividend rate as the existing issue. Treasury purchases a total of \$394.9 million in preferred equity from 28 United States banks under the CPP.

Friday, 20 March 2009: Treasury purchases a total of \$80.8 million in preferred equity from 10 United States banks under CPP.

Monday, 23 March 2009: The Fed and Treasury issue a joint statement on the appropriate roles of each during the current financial crisis and into the future, and on the steps necessary to ensure financial and monetary stability. The four points of agreement are (1) Treasury and the Fed will continue to cooperate in improving the functioning of credit markets and fostering financial stability, (2) Fed should avoid credit risk and credit allocation, which are the province of fiscal authorities, (3) The need to preserve monetary stability, and that actions by the Fed in the pursuit of financial stability must not constrain the exercise of monetary policy as needed to foster maximum sustainable employment and price stability and (4) The need for a comprehensive resolution regime for systemically critical financial institutions. In addition, Treasury will seek to remove the Maiden Lane facilities from the Fed's balance sheet.

Thursday, 26 March 2009: Treasury outlines a framework for comprehensive regulatory reform that focuses on containing systemic risks in the financial system. The framework calls for assigning responsibility over all systemically-important firms and critical payment and settlement systems to a single independent regulator. Further, it calls for higher standards on capital and risk management for systemically-important firms; for requiring all hedge funds above a certain size to register with a financial regulator; for a comprehensive framework of oversight, protection and disclosure for the over-the-counter derivatives market; for new requirements for money market funds; and for stronger resolution authority covering all financial institutions that pose systemic risks to the economy.

Friday, 27 March 2009: Treasury purchases a total of \$193 million in preferred equity from 14 United States banks under CPP.

Tuesday, 31 March 2009: GAO releases a report on the status of efforts to address transparency and accountability issues for TARP. The report provides information about the nature and purpose TARP funding until Friday, 27 March 2009, the performance of the Treasury's Office of Financial Stability and TARP performance indicators.

Four bank holding companies announced that they had redeemed all of the preferred shares that they had issued to Treasury under the CPP of TARP. The four banks are Bank of Marin Bancorp

(Novato, CA), Iberiabank Corporation (Lafayette, LA), Old National Bancorp (Evansville, IN), and Signature Bank (New York, NY).

Friday, 3 April 2009: Treasury purchases a total of \$54.8 million in preferred equity from 10 United States banks under CPP.

Tuesday, 7 April 2009: COP releases its monthly report on TARP. This report, entitled "Assessing Treasury's Strategy: Six Months of TARP," provides information about expenditures and commitments to date of TARP funds, evaluates Treasury's strategy for improving the condition and functioning of financial institutions and markets and discusses potential policy alternatives.

Friday, 10 April 2009: Treasury purchases a total of \$ 22.8 million in preferred equity from 5 United States banks under CPP.

Friday, 17 April 2009: Treasury purchases a total of \$ 40.9 million in preferred equity from 6 United States banks under CPP.

Friday, 24 April 2009: Treasury purchases a total of \$ 121.8 million in preferred equity from 12 United States banks under CPP.

Friday, 1 May 2009: Treasury purchases a total of \$ 45.5 million in preferred equity from 7 United States banks under CPP.

Friday, 8 May 2009: Treasury purchases a total of \$ 42 million in preferred equity from 7 United States banks under CPP.

Friday, 15 May 2009: Treasury purchases a total of \$ 107.6 million in preferred equity from 14 United States banks under CPP.

Friday, 22 May 2009: FRB announces the adoption of a final rule that will allow bank holding companies to include in their Tier 1 capital without restriction senior perpetual preferred equity issued to Treasury under TARP. Treasury purchases a total of \$108 million in preferred equity from 12 United States banks under CPP.

Friday, 29 May 2009: Treasury purchases a total of \$ 89 million in preferred equity from 8 United States banks under CPP.

Friday, 5 June 2009: Treasury purchases a total of \$ 40 million in preferred equity from 3 United States bank under CPP.

Tuesday, 9 June 2009: Treasury announces that 10 of the largest United States financial institutions participating in CPP have met the requirements for repayment established by the primary federal banking supervisors. If these firms choose to repay the capital acquired through the program, Treasury will receive up to \$ 68 billion in repayment proceeds.

Friday, 12 June 2009: Treasury purchases a total of \$ 39 million in preferred equity from 7 United States Banks under CPP.

Wednesday, 17 June 2009: Treasury releases a proposal for reforming the financial regulatory system. The proposal calls for the creation of a Financial Services Oversight Council and for new authority for the Fed to supervise all firms that pose a threat to financial stability, including firms that do not own a bank.

Friday, 19 June 2009: Treasury purchases a total of \$ 84.7 million in preferred equity from 10 United States banks under the CPP.

Friday, 26 June 2009: Treasury announces its policy regarding the disposition of warrants acquired under CPP. For publicly traded companies, Treasury received warrants to purchase common shares of equity; these warrants have not been exercised. Treasury's policy allows banks to repurchase warrants following a multi-step process to determine fair market value.

Thursday, 23 July 2009: Citigroup announces that it completed a previously announced exchange offer with private investors of convertible preferred securities and a previously announced matching exchange offer with the United States Government. Citigroup exchanged \$ 12.5 billion in aggregate liquidation value of convertible preferred securities held by private holders for interim securities and warrants, and made a similar exchange of \$ 12.5 billion in aggregate liquidation value of convertible preferred securities held by the United States Government for interim securities and warrants. The interim securities will convert to common equity, subject to shareholder authorization of the increase in Citigroup's authorized common equity.

Sunday, 26 July 2009: Citigroup announces the preliminary results of its offers to exchange its publicly held convertible and non-convertible preferred and trust preferred securities for newly issued shares of its common equity. Citigroup also announces that it expects to complete a further exchange with the United States Government of \$12.5 billion in aggregate liquidation preference of Citigroup preferred equity, and that in aggregate, approximately \$58 billion in aggregate liquidation value of preferred and trust preferred securities will have been exchanged to common equity as a result of the completion of all the exchange offers.

Monday, 14 September 2009: Treasury releases the report "The Next Phase of Government Financial Stabilization and Rehabilitation Policies." This report focuses on winding down those programs that were once deemed necessary to prevent systemic failure in the financial markets and the broader economy.

Thursday, 22 October 2009: The Special Master for TARP Executive Compensation releases determinations on the compensation packages for the top 25 most highly paid executives at the seven firms that received exceptional TARP assistance (AIG, Citigroup, Bank of America, Chrysler, Chrysler Financial, GM, and GMAC).

Sunday, 1 November 2009: CIT Group, Inc., files for bankruptcy protection under Chapter 11 of the bankruptcy code. The United States Government purchased \$2.3 billion of CIT preferred

equity in December 2008 under TARP. The firm's prepackaged bankruptcy is expected to wipe out the equity stakes of CIT's current shareholders, including the United States Government.

Monday, 9 November 2009: FRB announces that 9 of the 10 bank holding companies that were determined in the Supervisory Capital Assessment Program earlier this year to need to raise capital or improve the quality of their capital now have increased their capital sufficiently to meet or exceed their required capital buffers. GMAC was the one firm that to date has not raised enough capital to meet its required capital buffer.

Wednesday, 2 December 2009: Bank of America announces that it will repurchase the entire \$ 45 billion of cumulative preferred equity issued to Treasury under TARP after the completion of a securities offering.

Wednesday, 9 December 2009: Treasury Secretary, Timothy Geithner, sends a letter to Congressional leaders outlining the Administration's exit strategy for TARP. Geithner announces that the program will be extended to Sunday, 3 October 2010, and focus on three areas: (1) foreclosure mitigation, (2) providing capital to small and community banks and (3) possible increases in Treasury's commitment to TALF.

Monday, 14 December 2009: Citigroup announces that it has reached an agreement with the United States Government to repay the remaining \$ 20 billion in TARP trust preferred securities issued to Treasury. Citi will issue \$ 20.5 billion of capital and debt, and Treasury will sell up to \$5 billion of the common equity it holds in a concurrent secondary offering.

4.7.2 Specific Subprime Bank Bailout Events

In this subsection, we highlight specific subprime bank bailout events.

4.7.2.1 Bear Sterns Bailout

On Friday, 14 March 2008, the FRBNY and JP Morgan Chase jointly extended a 28-day emergency loan to Bear Stearns in order to prevent the potential market crash that would result from Bear Stearns failing. In reality, counterparty and trader belief in Bear's ability to repay its obligations quickly receded. Since the emergency loan was not perceived to be enough to keep Bear Stearns solvent and because of the fear of systemic losses if Bear was permitted to open in the markets on Monday, 17 March 2008, Bernanke and Paulson Jr. persuaded Bear's CEO Alan Schwartz to sell the bank before the opening of the Asian market. In this regard, on Sunday 16 March 2008, Bear merged with JP Morgan Chase in an equity swap worth \$ 2 a share – less than 10 % of Bear's market value. This sale price represented a significant loss as its equity had traded at \$ 172 and \$ 93 a share as late as January 2007 and February 2008, respectively. Furthermore, the United States Federal Reserve issued a non-recourse loan of \$ 29 billion to JP Morgan Chase, thereby taking on the risk of Bear Stearns's less liquid assets. This entails the collateralization of the United States Federal Reserve loan by mortgage debt and ensures that the United States government cannot seize J.P. Morgan Chase's assets if the mortgage debt collateral becomes insufficient to repay the loan.

Expert opinions attribute the collapse of Bear Stearns to a lack of confidence rather than a lack of capital.

On Monday, 24 March 2008, a class action lawsuit was filed on behalf of Bear's shareholders, challenging the terms of JP Morgan's acquisition of the bank. As a result, new terms were agreed that raised JP Morgan Chase's offer from \$ 2 to \$ 10 a share – the equivalent of a \$ 1.2 billion agreement. The reconfigured deal was aimed to appease investors and prevent legal action against JP Morgan Chase. Also, it was aimed at preventing employees – whose past compensation consisted of Bear Stearns equity capital – from resigning. The Bear bailout is considered to be an extreme example, and as a consequence continues to raise important questions about United States Federal Reserve intervention. On Friday, 29 May 2008, Bear Stearns shareholders approved the sale to JP Morgan Chase at the \$ 10-per-share price.

4.7.2.2 Goldman Sachs Group Inc. Bailout

Berkshire Hathaway purchased \$ 5 billion in Goldman's preferred equity capital and acquired warrants to buy another \$ 5 billion in Goldman's *E^{cv}*. Under the TARP, in October 2008, Goldman received a \$ 10 billion capital injection from the United States government.

4.7.2.3 Morgan Stanley Bailout

On Sunday, 21 September 2008, the United States Federal Reserve oversaw the change in status of Morgan Stanley from an investment bank to a bank holding company. On Tuesday, 14 October 2008, Mitsubishi UFJ Financial Group – Japan's largest bank – bought a stake of \$ 9 billion (21 %) in Morgan Stanley equity. Equity growth subsequent to the purchase, was preceded by the October 2008 stock market crash during which concerns over the completion of the Mitsubishi deal caused a dramatic decrease in Morgan Stanley's equity price to 14 year lows.

4.7.2.4 2008 United Kingdom Bank Rescue Package

Due to the ongoing global financial crisis, a bank bailout totalling \$ 850 billion was announced by the U.K. government on Wednesday, 8 October 2008. This was in response to major decreases in the stock market in preceding weeks and subsequent concerns about the financial stability of U.K. banks. The main objective of the bailout was to restore confidence in financial markets and help stabilize the U.K. banking sector. The programme also provided for a range of short-term loans and guarantees of interbank lending as well as up to £50 billion of government investment in the banks themselves.

4.7.2.5 2008 Canadian Bank Bailout

By the end of the 2008 fiscal year, the Canadian government purchased an additional \$ 50 billion of insured mortgage pools as part of its ongoing efforts to maintain the availability of longer-term credit in Canada. This purchase brought to \$ 75 billion the maximum value of mortgages purchased through Canada Mortgage and Housing Corporation (CMHC) under this program.

4.7.2.6 Some European Bank Bailouts

Fortis Bank was jointly bailed out by the Dutch, Belgium and Luxemburg governments for Euro 4.7 billion. Eventually Fortis was sold to BNP Paribas. Further European bailouts included the three largest Icelandic banks (Glitnir, Landsbanki, and Kaupthing) and UBS in Switzerland.

4.7.2.7 Bank of America Bailout

Bank of America (BoA) received \$ 25 billion and \$ 20 billion in bailout funds from the United States government through the TARP program in September 2008 and on Friday, 16 January 2009, respectively. An additional \$ 118 billion in potential losses were guaranteed by the government. This extra payment formed part of a deal with the United States government to preserve BoA's merger with the troubled Merrill Lynch. According to a Sunday, 15 March 2009 article in The New York Times, BoA received an additional \$ 5.2 billion in government bailout money via the American International Group (AIG).

4.8 Appendix to Chapter 4

In this section we calculate proofs of Propositions 4.3.5 to 4.3.8

4.8.1 Appendix to Chapter 4: Proof of Proposition 4.3.5

We note that SOR's equity with positive NPV is

$$E_t^{+r} = q \left(B_{t+1,1}^{rhv} + E_t^{rr} - B_t^{rv} - D_t^{rv} + M_t^{+rnv} \right),$$

where

$$\begin{aligned} & B_{t+1,1}^{rhv} + E_t^{rr} - B_t^{rv} - D_t^{rv} + M_t^{+rnv} \\ & > B_{t+1,1}^{rhv} + E_t^{rr} - B_t^{rv} - D_t^{rv} - \left(\frac{q}{1-q} \right) \mu_t^{-rHnv} M_t^{-rHnv} > 0 \\ & \text{but } B_{t+1,1}^{rlv} + E_t^{rr} - B_t^{rv} - D_t^{rv} + M_t^{+rnv} < 0. \end{aligned}$$

This means that SOR's value is raised by the riskless mortgage but its obligations remain risky. Also, the equity with negative NPV is

$$E_t^{-r} = q \left(B_{t+1,1}^{rhv} + E_t^{rr} + \mu_t^{-rHnv} M_t^{-rHnv} - B_t^{rv} - D_t^{rv} \right) \quad (4.10)$$

in period $t + 1$, where

$$\mu_t^{-rHnv} M_t^{-rHnv} > M_t^{+rnv}$$

and $B_{t+1,1}^{rhv} + E_t^{rr} - B_t^{rv} - D_t^{rv} + M_t^{+rnv} > 0$, but $B_{t+1,1}^{rlv} + E_t^{rr} - B_t^{rv} - D_t^{rv} + M_t^{+rnv} < 0$.

Thus $E_t^{-r} > E_t^{+r}$. Subtracting E_t^{+r} from E_t^{-r} , we have

$$E_t^{-r} - E_t^{+r} = q(\mu_t^{-rHnv} M_t^{-rHnv} - M_t^{+rnv}) > 0.$$

4.8.2 Appendix to Chapter 4: Proof of Proposition 4.3.6

In order to deduce (4.4) we note that all VPCs emanate from

$$\begin{aligned} E_t^{**+r} - E_t^{-r} &= (B_t^{rv} + \mathbf{S}_t^{**r} + E_t^{rr} - D_t^{rv} - B_t^{rv} + M_t^{+rnv}) - q(B_{t+1,1}^{rhv} + E_t^{rr} + \mu_t^{-rHnv} M_t^{-rHnv} \\ &\quad - B_t^{rv} - D_t^{rv}) \geq 0, \end{aligned} \quad (4.11)$$

where ** is used to denote toxic RMBSs, B_t^{rv} , preferred equity, E_t^{prv} , or common equity, E_t^{crv} . Solving for \mathbf{S}_t^{**r} from equation (4.11), we get

$$\begin{aligned} \mathbf{S}_t^{**r} &\geq -(1-q) \left(B_{t+1,1}^{rlv} + E_t^{rr} - D_t^{rv} - B_t^{rv} + M_t^{+rnv} \right) \\ &\quad + q(\mu_t^{-rHnv} M_t^{-rHnv} - M_t^{+rnv}) \equiv \widehat{\mathbf{S}}_t^{**r} > 0. \end{aligned}$$

4.8.3 Appendix to Chapter 4: Proof of Proposition 4.3.7

The result follows from subtracting $\widetilde{\mathbf{S}}_t^{M^{rv}}$ from $\widetilde{\mathbf{S}}_t^{E^{prv}}$, where $\widetilde{\mathbf{S}}_t^{E^{prv}} > \widetilde{\mathbf{S}}_t^{M^{rv}}$. In addition to that, we have that $\widetilde{\mathbf{S}}_t^{E^{prv}} > 0$, therefore

$$\widetilde{\mathbf{S}}_t^{E^{prv}} > \widetilde{\mathbf{S}}_t^{M^{rv}}; \quad \widetilde{\mathbf{S}}_t^{E^{prv}} > \widetilde{\mathbf{S}}_t^{E^{crv*}} = 0, \quad (4.12)$$

An important distinguishing feature of these capital injection types is that the minimum efficient lending subsidies used to recapitalize SOR are distinct. These constraints may be calculated from

$$E_t^{**+r} - E_t^{**-r} \geq 0,$$

where ** represent toxic RMBSs, B_t^{rv} , preferred equity, E_t^{prv} , or common equity, E_t^{crv} . By solving \mathbf{S}_t^{**r} , all ELCs may be represented by

$$\begin{aligned}
S_t^{B^{rv}} &\geq \left(\frac{q}{1-q}\right) \left(\mu_t^{-rHnv} M_t^{-rHnv} - M_t^{+rnv}\right), \\
&\quad - \left[B_t^{rv} + E_t^{rr} - D_t^{rv} - B_t^{rv} + M_t^{+rnv}\right] \equiv \tilde{S}_t^{M^{rv}} \\
S_t^{E^{prv}} &\geq \left(\frac{q}{1-q}\right) \left(\mu_t^{-rHnv} M_t^{-rHnv} - M_t^{+rnv}\right) \\
&\quad - \left(B_{t+1,1}^{rlv} + E_t^{rr} - D_t^{rv} - B_t^{rv} + M_t^{+rnv}\right) \equiv \tilde{S}_t^{E^{prv}} > 0 \quad \text{and} \\
S_t^{E^{crv}} &\geq \left(\frac{q}{1-q}\right) \left(\mu_t^{-rHnv} M_t^{-rHnv} - M_t^{+rnv}\right) \\
&\quad - \left(B_{t+1,1}^{rlv} + E_t^{rr} - D_t^{rv} - B_t^{rv} + M_t^{+rnv}\right) - E_t^{crv} \equiv \tilde{S}_t^{E^{crv}}.
\end{aligned}$$

4.8.4 Appendix to Chapter 4: Proof of Proposition 4.3.8

(a) Proposition 4.3.8(a) follows from equation (4.4),

$$\hat{S}_t^{B^{rv}} = \hat{S}_t^{E^{prv}} = \hat{S}_t^{E^{crv}}$$

and

$$\tilde{S}_t^{E^{prv}} > \tilde{S}_t^{M^{rv}}; \quad \tilde{S}_t^{E^{prv}} > \tilde{S}_t^{E^{crv*}} = 0.$$

(see Proposition 4.3.7, equation (4.12)). The minimum equilibrium stakes of common equity are found by

$$\begin{aligned}
E_t^{crv} &\geq \hat{E}_t^{crv} \equiv q \left(\frac{q}{1-q}\right) \left(\mu_t^{-rHnv} M_t^{-rHnv} - M_t^{+rnv}\right) \\
&\quad - \left(B_{t+1,1}^{rlv} + E_t^{rr} - D_t^{rv} - B_t^{rv} + M_t^{+rnv}\right) > 0,
\end{aligned}$$

if SORs must volunteer for the subprime bailout program. First, there is no difference between the three types of subprime bailouts (buying RMBSs, buying preferred equity or common equity) in terms of the VPC, according to equation (4.4). Yet, there is a big difference between the three alternatives in terms of the ELC, according to equation (4.12). The ELC is always slack for B_t^{rv} purchases and common equity subprime bailouts. Yet, it is always the binding constraint for preferred equity subprime bailouts. Thus, the subsidy is minimized given that voluntary participation is required for common equity or toxic RMBS purchases.

- (b) Social welfare is very different under each of the scenarios in Proposition 4.3.8(b). *Ex ante*, period $t - 1$ social welfare in scenario 1 is

$$M_t^{+rnv} + \tilde{B}_t^{rsnv} - c_t^{Brv} B_t^{rv} - \tau \hat{S}_t^{E^{crv}}.$$

This is clearly less than social welfare under scenario 2,

$$M_t^{+rnv} + \tilde{B}_t^{rsnv}.$$

Clearly, social welfare would be benefit if G could commit to not bailout SOR when it must voluntarily participate.

If G can force SOR to participate in the common equity bailout, there is no conflict between *ex post* and *ex ante* welfare maximization for G. According to Proposition 4.3.8(c), G can buy an equity stake at fair market value in the troubled SOR large enough so that no subsidy, $\hat{S}_t^{E^{crv}}$, is necessary to induce efficient lending.

- (c) We know from equation (4.12) that the subsidy, $\hat{S}_t^{E^{crv}}$, required to bail out the troubled SOR is weakly the smallest when E_t^{crv} is used and the troubled SOR's VPC can be ignored.

Suppose that SOR did buy B_t^{rv} in period $t - 1$. G could push the subsidy to zero in period t . In this scenario, G will weakly prefer to buy $E_t^{crv} \in [\tilde{E}_t^{crv}, +\infty)$. Thus, $\hat{S}_t^{E^{crv}}$ will be zero in all possible states of the world if SOR buys toxic RMBSs. SOR's shareholders must sacrifice

$$c_t^{Brv} B_t^{rv} + r_t^{rBlv} B_t^{rlv} > 0$$

to underwrite B_t^{rv} . The cost

$$c_t^{Brv} B_t^{rv} + r_t^{rBlv} B_t^{rlv}$$

exceeds the benefit which is the expected subsidy of zero. Therefore, SOR will purchase Treasuries and no bailout will take place.

Chapter 5

Conclusions and Future Directions

”A basic cause of the current financial crisis was the mandate by the United States 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 United States 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 mortgage, risks, data and bank bailouts in the SMC. Throughout our contribution, we consider maximization problems in order to chart such fundamental mortgage issues such as capital, information, risks and valuation. With regard to the risks, the thesis discusses credit, maturity mismatch, basis, counterparty, liquidity, synthetic, prepayment, interest rate, price, tranching and systemic. The main hypothesis of this paper is that the SMC was largely caused by the intricacy and design of subprime mortgage that led to information (loss and asymmetry) problems, valuation opaqueness and ineffective risk mitigation

(see Problem 1.3.3). This claim is illustrated via the examples presented in Section 2.5 and their discussions in Subsection 2.6.3 of Section 2.6.

In summary, our contribution subscribes to the following SMC-related timeline. In the years since 2000, with low interest rates, low intermediation margins and depressed stock markets, many private investors were eagerly looking for 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 and high-yielding securities, there was little to contain moral hazard in mortgage, 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.

5.1.1 Conclusions About Chapter 2: Subprime Mortgages

Chapter 2 offers several novel insights into the modeling of subprime mortgage 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 traditional mortgage model with subprime elements 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 1.3.4 and Theorem 2.3.4 in Subsection 2.3.2 of Section 2.3). In addition, the discussions on subprime risks may be useful in order to make SOR's risk management more effective.

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: More Subprime Data

The main question that was answered in Chapter 3 was whether or not subprime data supported our intricacy-information dispersion (IID) 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 2, Section 2.6, Subsection 2.6.4). As a consequence, the aforementioned reduction in SOR capital has reduced the credit available to businesses and households.

5.1.3 Conclusions About Chapter 4: Subprime Bank Bailouts

Chapter 4 demonstrated that the mortgages used to bail out SORs, which are perceived as too-big-to-fail, affects welfare. This was done for the cases related to defaulting, refinancing and fully amortizing mortgages. We analyzed capital injections involving buying toxic RMBSs, purchasing preferred equity and buying common equity. In particular, from both an ex post and ex ante perspective the least expensive bailout involves G's buying common equity. Preferred equity is the most expensive in terms of its affects on ex ante and ex post welfare.

We find that common equity capital injections always produce the lowest subsidy to the troubled SOR. Indeed, no subsidy is needed to induce efficient lending if the troubled SOR can be forced to sell common equity at its fair value. Lower subsidies in capital injections are more likely to encourage SOR to buy toxic RMBSs in the first place. Therefore, common equity capital injections always lead to the lowest ex ante distortions. Preferred equity capital injections are the least efficient and lead to the largest subsidy. Indeed, the implicit subsidy in preferred equity capital injections is the only thing that induces efficient lending ex post. Chapter 4 casts doubt on the effectiveness and the efficiency of G's attempts to recapitalize SORs through the TARP. In short, because it primarily uses preferred equity to inject capital into highly leveraged SORs, it is unlikely to curb incentives to extend speculative 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. Haircuts on bond holders and counterparties should be imposed prior to using taxpayer money in bailouts. 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, it would be an ideal 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, a clearer understanding of the dynamics of related banking issues such as subprime mortgages, structured notes, subprime risk, subprime bailouts and Basel capital regulation would be developed. From a numerical point of view, MFRB Research Group plan to validate the aforementioned models by analyzing specific real-world data in an empirically sound manner. More details of 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. In this regard, an investigation could be done in order to show 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 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. 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, the question that should be answered is 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. On the other hand, 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 United States subprime mortgage market (about 16 % of all United States 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, the mechanism involved in causing this knock-on effect could be investigated. 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, the possible financial stability implications of issues mentioned in Subsection 5.2.1 could be identified and determine the effect these have on macroprudential policy and prudential behavior. In addition, the link between cyclicity, financial stability and regulation as it pertains to the GFC could be highlighted.

The main thrust of future mathematically rigorous research should involve models of banking items driven by Lévy processes (see, for instance, Protter in [112, 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 loans, profit, capital and CARs 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, [37], [50], [78] and [117]) 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, [67] and [87]). 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 loan 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.

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