An Multi-Agent Model of RMBS, Credit Risk Transfer in Banks and Financial Stability: Implications of the Subprime Crisis

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Extended Abstract

In this paper, we apply the agent-based modelling (ABM) simulation technique for the study of RMBS within banking and the implications for financial stability from the process of credit risk transfer. We design and develop a two-sector computational agent model using an insolvency risk constrained multi-period horizon model of profit maximisation with mortgage origination and securitization by banks on the one hand and the asset liability management activities of institutional investors who seek returns from equity and credit assets. The RMBS model for banks includes regulatory arbitrage from Basel capital adequacy, asset quality deterioration and default risk of loans. Our approach shows how the RMBS activity and the credit risk involved is incorporated into the portfolios of institutional investors and hedge funds who sought high return from the high risk tranche of credit assets. On this basis, we discuss the financial stability implications arising from the calibrations of two sectors where banking data relies on the FDIC data set and the default and coupon rates for credit assets come from the 2007 Citibank Report. Critical to issues such as whether there is an over supply of RMBS with an excessive high proportion of assets being securitized (typical rates of about 40%-49% being the case in the 2001-2002 for subprime originators) is found to lie in inappropriate coupon rates being paid on credit products based on high default RMBS and hence the costs of RMBS were not correctly factored. The implications of the passage of time for insolvencies to kick in can be observed in the agent based model. For instance, institutional investors with large portfolios of up to 38% or more of credit assets with default rates in excess of 10% could be insolvent by year 2. In such a case, the high Dutch Insurance Supervisory Board solvency margin of 30% for institutional investors did not appear to fare any better than a lower one showing that the collapse of market value for RMBS backed credit assets from high default by mortgagees is the dominant determinant of systemic risk. In its fully developed form, it is possible for the agent based model to articulate various components of the financial sector as shown in Figure 1. Future research aims to incorporate the CDO structures fully, add features like

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marking to market accounting, the short term market for commercial paper and an explicit role for regulatory authorities such as Central Banks.

Keywords: Agent-based Modelling; Residential Mortgage Backed Securitization; Default Rates on Loans; Coupon Payments on Credit Assets; Credit Risk Transfer; Systemic risk; Insolvency Margin

JEL Classification: G20; G21; G23; E44; C88

Section 1: Introduction

1.1 Background to the Credit Crunch

As we enter a period of global economic crisis that many regard to be potentially as bad as the Great Depression, this project is concerned about developing a modelling framework that can articulate and demonstrate the interrelationships of the financial contagion with a view to aid policy analysis. The origins of the financial contagion from the sub-prime crisis in the US can be traced back to the development of financial products such as Residential Mortgage Backed Securities (RMBS)[2], Collateralized Mortgage/Debt Obligations (CM/DOs) and Credit Default Swaps (CDS) which were subjected to little or no regulatory scrutiny. These products have been dubbed 'weapons of mass destruction' (by Warren Buffet) as they led to multiple levels of debt/leverage with little contribution to returns from investment in the real economy.[3] They worked to bring about a system wide Ponzi scheme which collapsed, serially engulfing the Wall Street investment banks starting with Bear Sterns in March 2008 and culminating with Lehman Brothers the following September 2008. The collapse of Freddie Mac and Fanny Mae and the severe mark downs on a global scale of the market value of retail banks, institutional investors and hedge funds which harboured sub-prime assets, has placed the financial system under unprecedented stress. The interbank and short term markets for liquidity have seized up resulting in the credit crunch. As we enter a period of a 'liquidity trap' where even at low interest rates of 1% or under, a loss of investor and consumer confidence has resulted in very little lending to the private sector even for real investment. With little traction left in interest rate policy to stimulate the economy, governments are looking to reflate by printing money, euphemistically called 'quantitative easing'. The limited success to date of tax payer bail out of the banking system on both sides of the Atlantic, has brought more radical options to the forefront such as a 'toxic' bank and the full nationalization of banks.

Over the period of the last 15 years or so when financial innovations were progressing at a rapid rate, there has been a marked underdevelopment of a modelling framework to articulate the massive interrelationships in the financial system implied by the workings of these new financial products. Academic economists, policy makers and regulators were and continue to be restricted in their analysis of the crisis by a woefully inadequate set of modelling tools. The current clean up operations are impeded by the lack of a quantitative and dynamic model of the financial contagion. Efficacy of the proposed policies has no way of being quantitatively assessed for their impacts to prevent a slide into another 'Great Depression'. It will be argued that without a multi-agent simulation framework capable of digitally recording fine grained data bases of the different financial players involved and also mapping the links between sectors, we are condemned to sector by sector analysis or a simplistic modelling of interrelations between sectors often assumed for analytical tractability.

The main drawback of extant financial models for credit risk is that pricing is done on a stand alone basis of a single asset rather than in the context of system wide repercussions. Likewise, regulatory oversight of capital adequacy and risk

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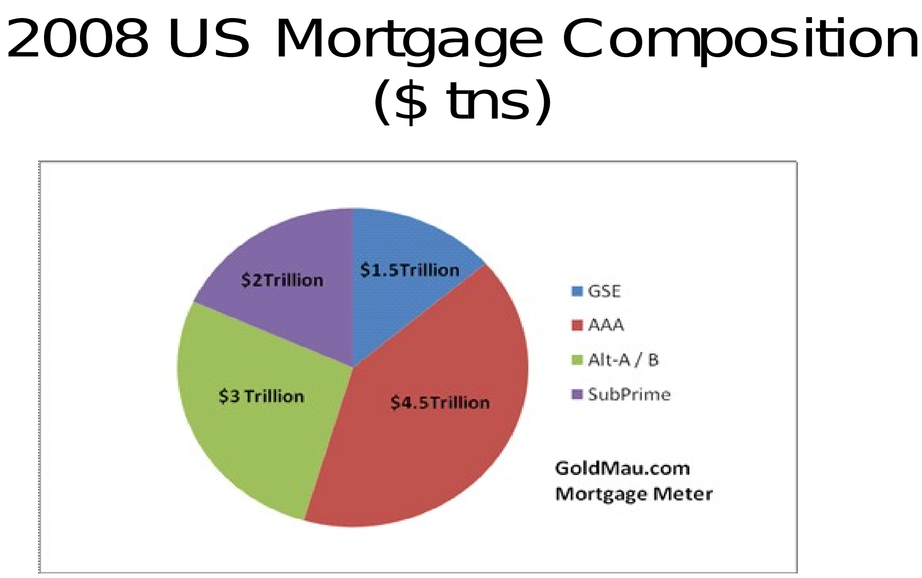
[2] Asset backed Securities , ABS, refers to the wider class of receivables from credit cards, car loans and other credit. If not specified, ABS can include MBS as well.

[3] See, Brunnermeir (2008), Duffie (2007), Ashcroft and Schuermann (2008). They respectively cover the unfolding phases of the crisis, the specific characteristics of the credit derivatives and the specific aspects of subprime securitization.

management is assumed in terms of a single financial entity rather than the implications of its failure for the rest of the system. The case of environmental externalities where over use and degradation of resources result from the underpricing of a resource or asset, with no consideration of the clean up costs, is increasingly being seen as salutary for pricing credit risk which has systemic risk consequences. Economic activities as with financial products that transfer risk should not be valued solely on the principle of marginal costs because it will trigger the well understood problem of the Tragedy of the Commons[4] or as with firm level constraints such as the Basel I capital adequacy requirement will result in regulatory arbitrage. Over supply/ production occurs at the level of the individual economic entity as there is a missing market to price the risk of negative spill overs analogous to the case of environmental externalities. The main implication of such a position is that the ABS type financial innovations were inherently good but the overproduction of inside money [5] due to the critical underpricing of credit risk at the individual level resulted in an over supply of liquidity at a macro level. In particular, a multi-period framework is needed to analyse how mortgage originators managed to securitize a high fraction of their mortgage book and also the extend this to subprime categories with no explicit consideration of additional costs. Figure 1.1 below gives the 2008 composition of the $10 tn value of US mortgages. The US subprime mortgage share is 20% and valued at $2 tn.

Figure 1.1



The multiplier effect of the securitization process that enabled banks to expand loans can be shown to be without limit if appropriate costs of credit risk are not factored in.

[4] Markose et. al. (2007) discuss this in the context of extending cap and trade models to road transport congestion so that the problem of over use or over supply associated with the Tragedy of the Commons is mitigated.

[5] Inside money refers to private sector credit creation which though in principle is self-liquidating, the unconstrained growth in the outstanding quantities of inside money can only fuel a asset price bubble. The bursting of this has huge redistributive consequences as in a Ponzi scheme.

This fuelled a house and asset price bubble that set in motion positive feedback loops to keep default risk on mortgages initially low, but eventually experienced the only natural equilibrating phenomena in the form of a bust. Due to limited growth in deposit base as the source of bank lending, the latter has primarily relied on ABS. The total outstanding value of US ABS peaked in 2007 see Figure 1.2. The close to zero growth in US ABS in early 2008 and the growing marked to market losses of ABS underpins the credit crunch which has impaired the capacity of banks to lend. The ABX index[6] of subprime equity tranche records a 80% haircut in January 2008 implying marked to market losses of the $2tn subprime mortgage pool to bein the order of $1.6 tn. Various sources including the IMF (2008) and First American Loan Performance estimated a default rate of 15%, which would translate to $300 billion of non-collectable principal and interest on the subprime mortgage pool. Current modelling tools simply do not allow a fully dynamic interplay of defaults of borrowers and bank foreclosures that drive the shrinking balance sheet of banks. It is hard to assess the effectiveness of policy interventions for bank bail outs involving direct recapitalization, insurance of impaired loans or removal of these to a 'recovery bank'. Longer term banking and financial market reform which retains the beneficial aspects of ABS must investigate whether supply of ABS can be capped at an aggregate level and traded to avoid the Tragedy of the Commons which arises from its supply being determined by financial entities in the absence of an explicit social cost of credit risk.

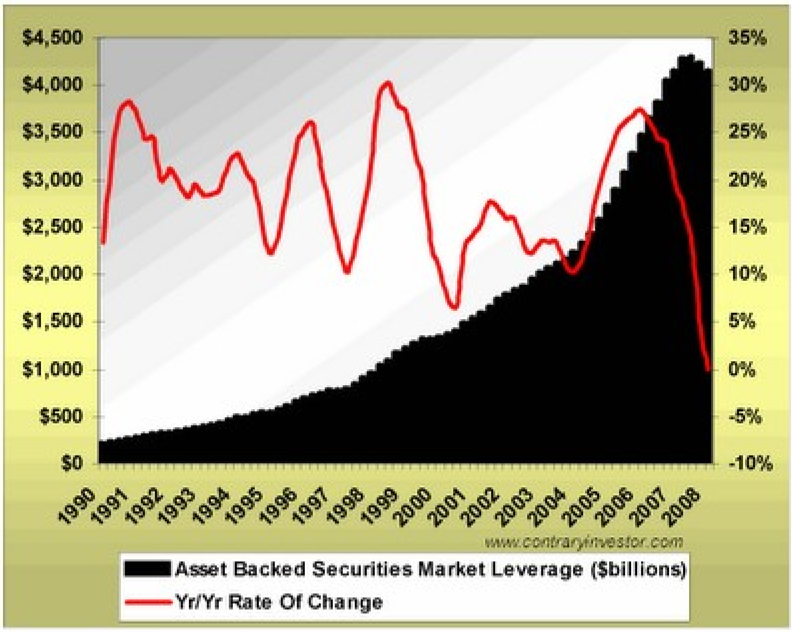


Figure 1.2 Close to Zero growth of US ABS in 2008

1.2 Multi-Agent Modelling of the Financial Contagion: Overview

[6] See Fender and Scheicher (2008) for a discussion on the construction and determinants of the ABX index.

The main objective of this project is to use multi agent-based modelling (ABM) simulation technique for the study of RMBS within banking sector and the implications for financial stability from the process of credit risk transfer. In the ABM modelling technique, systems are represented as a collection of autonomous decision making entities known as agents. Each agent individually assesses its situation often with network based local interactivity and makes decisions on the basis of a set of rules. Agents can execute a diverse array of behaviours appropriate to the system being modelled—for instance the production/supply and consumption/demand of some good or asset. Varying degrees of computational intelligence can be brought to the decision making processes of agents. The power of ABM is that fine grained detail and behaviour of agents can be modelled to the extent of full digitization of factual information on them that have a spatial and dynamic content. Markose et. al. (2007) call this aspect of ABM, model verité . Epstein and Axtell (1996), Axelrod (1997) and Gilbert and Troitzsch (1999) emphasise the importance and merits of the use of agent modelling in the representation of systems where the exploration of the underpinning dynamics are beyond the scope of mathematical techniques. Thus, non linear feedback loops from a global signal or from one sector of the system can be made to bear upon evaluations of agents in other parts of the system. As Markose (2006) has succinctly stated ABM can represent complex economic realities in a manner far beyond what extant analytical/ mathematical or econometric models can do.

The so called reduced form and structural form analytical models for credit risk pricing are restricted by what is analytically tractable and the role of multi agent behaviour for dynamics of the system has to be proxied by single parameters which are often produced by statistical techniques such as Monte Carlo simulations. The large scale ABM model of the financial contagion resembles large scale macro-econometric models in its structural composition. However, as will be seen the micro-foundations of the ABM model do not require explicit estimation of equations based on optimization by representative agents. In ABM outputs of decisions rules of agents where the endogeniety of variables that represent outputs of decisions of other agents can be nested without the need for explicit reestimations which are needed in an equation based macro- econometric model. Further, for purposes of policy analysis, econometric models run into Lucas Critique as structural equations cannot be assumed to be invariant to policy or for that matter to the strategic behaviour of other agents. Large scale macro-econometric models are also not very good at tracking fast moving financial crisis as reestimation of parameters is often needed. ABM models can have live feeds from real time data from markets and automation of updates is part of the design of such systems.

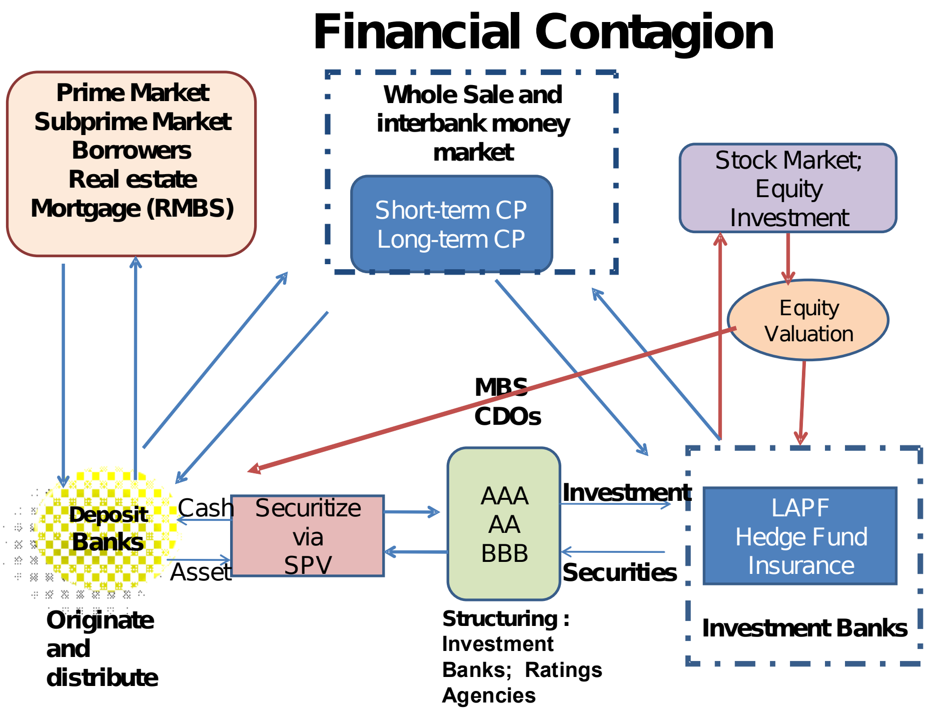
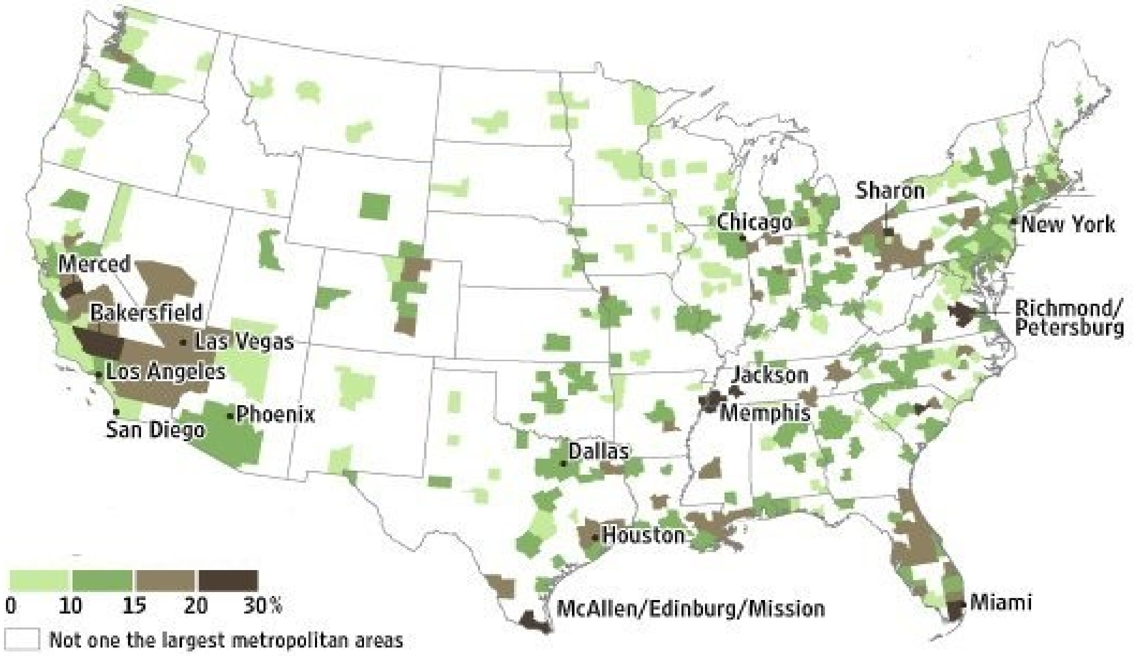


Figure 1.3: Financial Contagion from Sub- Prime RMBS

The first overview of the issues involved for the ABM model of the current financial contagion is presented in Figure 3.1. Following Figure 3.1, these agents belong to classes of different economic sectors with complex interrelations among them. Starting from the top left of Figure 1, we have the housing market and the prime and subprime mortgagees. This is followed by the deposit based banking sector and then the so called 'shadow' banking sector that was involved in the production of structured products and the facilitation of the credit risk transfer from the balance sheet of banks to other financial institutions. Agents here include the Special Purpose Vehicles, investment banks and ratings agencies. The products involved are the RMBS, CMO and CDS. Institutional investors such as Life Assurance and Pension Funds (LAPFs), insurance companies and other financial entities such as hedge funds and investment banks globally acquired the above products and their portfolios included equity and credit products. All financial entities are connected to the whole sale and interbank and repo markets which facilitate their short term liquidity requirements. The RMBS, CMO and CDS products which represent high degree of leverage have great capacity for the non-linear propagation of financial contagion. Likewise, many of these financial entities are listed on the stock exchange which in unison with the defaults propagated from the subprime mortgagees via the RMBS, CMO and CDS cause vicious 'bear raids' that effectively destroyed many of the Wall Street investment banks and deposit banks.

To illustrate the power of multi-agent modelling to incorporate fine grained detail on the different sectors we will consider the class of agents representing the US households that constitute the prime and subprime mortgagees. They have spatial and economic characteristics which will characterize their default behaviour. The two following graphs give the regional distribution of subprime mortgagees in the US and data on the growth in defaults from 2005-2006. The ABM model is able to digitally map these in a spatial dimension and historically track the collateral characteristics, repayment flows and default behaviour of these mortgagees (see, Fabozzi et, al, (2005) and Frankel (2006)).[7] This is important to get good quantitative outputs for the ABM simulations for the systemic risk emanating from sub prime lending.

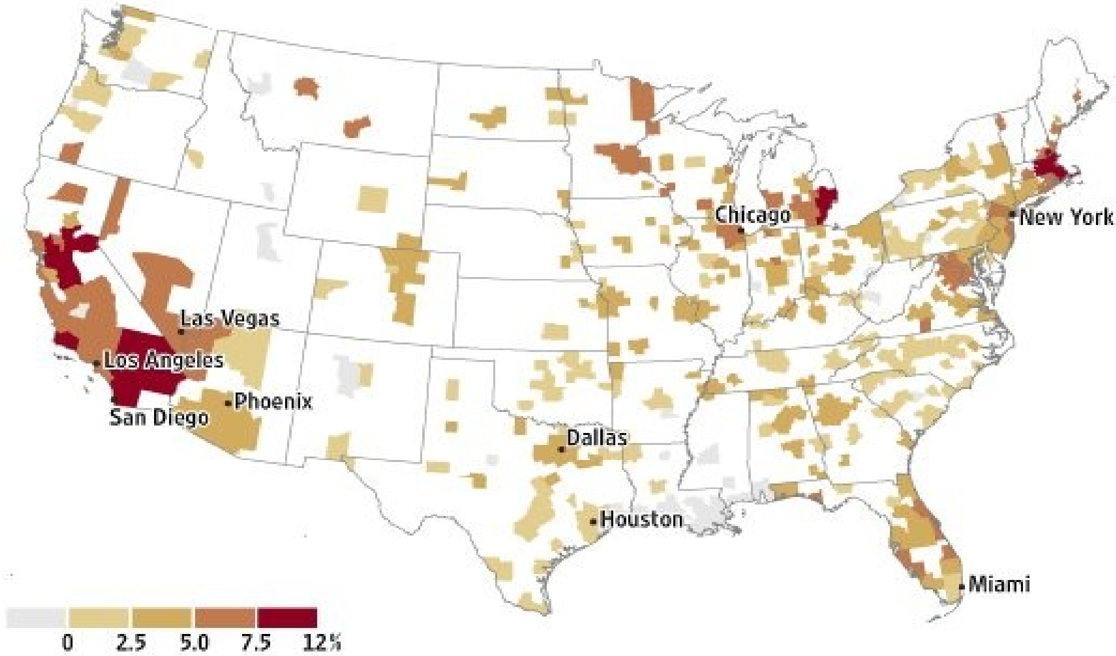
Figure 1.4: Subprime as Percentage of Loans Dec 2006 Map



Source: First American Loan Performance; Census Bureau , and Wall Street Journal Online

[7] Collateral characteristics are two fold : the credit risk of individual borrowers and the price of the house. FICO (Fair Isaac Corporation) scores measure the credit risk of individual borrowers based on the statistical analysis of their credit files. FICO scores range between 300 and 850 and subprime borrowers are often defined as those who have a FICO score of 650 or 650 and/or have limited income. Cash flow projections, delinquencies, defaults and losses are oft modelled on the basis of FICO scores, loan to value ratios, loan size, house price paths and loan rates.

Figure 1.5: Increase in Subprime Delinquency 2005 to 2006 Map



Source: First American LoanPerformance; Census Bureau , and Wall Street Journal Online

1.3 Overview of the Sectors and Stages Involved in Credit Risk Transfer and Financial Contagion fro m RMBS

This draft only reports on the development of the RMBS of subprime loans from the perspective of banks and the credit risk transfer implications for institutional investors such as life assurance and pension funds (LAPFs). The ABM model of the CDO structures and the impact of bear raids via the stock market and the role of regulatory authorities to implement different clean up strategies of the recent crisis awaits development in the near future. Section 2 below begins with a brief overview of the so called 'originate and distribute' model of bank lending which began to supersede bank lending behaviour which is constrained by the deposit base and the retention of long maturity loans such as mortgages on a bank balance sheet. We design and develop a two-sector computational agent model. We use an insolvency risk constrained multi-period horizon model of profit maximisation with mortgage origination and securitization by banks on the one hand and the asset liability management activities of institutional investors who seek returns from equity and credit assets. The RMBS model for banks includes regulatory arbitrage from Basel capital adequacy, asset quality deterioration and default risk of loans. Section 3 shows how the RMBS activity and the credit risk involved is incorporated into the portfolios of institutional investors and hedge funds who sought high return from the high risk tranche of credit assets. On this basis, we discuss the financial stability implications arising from the calibrations of two sectors where banking data relies on the FDIC data set and the default and coupon rates for credit assets come from the 2007 Citibank Report. Critical to issues such as whether there is an over supply of RMBS with an excessive high proportion of assets being securitized (typical rates of about 40%-49% being the case in the 2001-2002 for subprime originators) is found to lie in inappropriate coupon rates being paid on credit products based on high default

RMBS and hence the costs of RMBS were not correctly factored. The implications of the passage of time for insolvencies to kick in can be observed in the agent based model. For instance, institutional investors with large portfolios of up to 38% or more of credit assets with default rates in excess of 10% could be insolvent by year 2. In such a case, the high Dutch Insurance Supervisory Board solvency margin of 30% for institutional investors did not appear to fare any better than a lower one showing that the collapse of market value for RMBS backed credit assets from high default by mortgagees is the dominant determinant of systemic risk. In its fully developed form, it is possible for the agent based model to articulate various components of the financial sector as shown in Figure 1.1. Future research aims to incorporate the CDO structures fully, add features like mark to market accounting, the impact of bear raids via the stock market and CDS, the role of short term market for commercial paper and an explicit role for regulatory authorities such as Central Banks.

Section 2: Originate and Distribute Credit Risk Transfer Model for Banks

2.1 Literature Survey

Traditionally banks retained loans on their balance sheet till they reached maturity or they were defaulted on. Increase in loan portfolios was strongly restricted by the size of a bank's deposit base. Securitisation is the process of converting cash flows arising from underlying assets or debts/receivables (typically illiquid such as corporate loans, mortgages, car loans and credit cards receivables) due to the originator into a smoothed liquid marketable repayment stream. This enables the originator to raise asset-backed finance through a loan or an issue of debt securities. Many have noted (see, Tomas and Wang (2004), Martelline et. al. (2003)) that securitization dramatically alters the liquidity of the asset originator. Loans, with expected future cash inflows, are exchanged for immediate cash. In a securitization transaction, the credit risks associated with a defined pool of receivables are isolated from the originator of the receivables, then structured and passed on to one or more investors. By transferring risk in a securitization transaction, a bank can restructure its credit portfolio and to rectify mismatches in the maturity structure of their financial assets and liabilities. By moving longer duration assets off their balance sheets and securitizing them, financial institutions are able to decrease their interest rate risk exposure by reducing the duration gap between assets and liabilities. This assumes the financial institutions use the proceeds to purchase assets of shorter duration or hold it as cash on the balance sheet. Calomiris and Mason (2003)[8] explore the degree to which securitization results in the transfer of risk out of the originating bank, and the extent to which securitization permits the bank to economize on capital by avoiding regulatory minimum capital requirements and whether banks' avoidance of minimum capital regulation through securitization with implicit recourse has been undesirable from a regulatory standpoint.

The benefits to the bank that our bank balance sheet model of asset liability management demonstrates is that securitization can be used to reduce the regulatory capital requirement stipulated by the Bank of International Settlement (BIS) capital adequacy accord (from here on in Basel I) and the European Union Capital Adequacy Directive (CAD). Aggressive growth of loan portfolios and reductions in capital has

[8] Ambrose et. al (2005) investigate whether it is regulatory arbitrage, reputation or asymmetric information which drives securitization.

been found to be greater in banks which pursue loan securitization activities (Brewer et. al (2000), Cebenoyan and Strahan (2004), Froot et al (1998))[9] Secondly, as first discussed in Wolfe (2000), securitization could help the bank to increase return on equity (ROE), by reissuing the capital released from securitization into new mortgages/loans. However, the long run viability of this is found to be critically dependent on the costs of securitization. Indeed, linear cost structure generates a veritable money pump scenario of ABS. Likewise, we find that an underestimation of the credit risk arising from the default of the mortgagees, even if costs increase at an increasing rate with the size of the loan portfolio, is essential in order to get the high fractions of RMBS found among the top US subprime providers. However, the retention of poor quality assets on the bank balance sheet is a consequence of the increased costs of securitizing these and so also the tendency to accumulate more subprime loans as loan growth from securitization continues to fuel the house price boom which kept the demand for mortgages buoyant. Despite a consensus that banks retained toxic components of loans, and that the major driver of securitization was the need to maintain or increase market share in loans[10] by the deliberate reduction in risk capital, few appeared to conclude that the credit risk transfer from the bank was in fact illusory.

The pros and cons of credit risk transference from banks to insurance companies and pension funds (LAPFs), hedge funds and other financial entities has been discussed. While this phenomenon has seen to increase the interdependence between these entities, few have related the CRT activity especially in RMBS to the fuelling of a house price bubble. Persuad (2002) stated that CRT may cause problems for the stability of the financial system either by increasing the fragility of the risk buyer or through increased risk-taking by banks. Having noted that non-performing loans increased significantly (by 20% in 2002) while balance sheets continued to look healthy, Persaud (2002) asks “where have all the credit risk gone?” He ascribes this phenomenon to the proliferation of credit derivatives (a ten-fold increase to $2 trillion in only five years), and warns “The more risks are valued, traded and hedged in the same way, in the same markets, the greater are systematic risks”.

The issue of welfare benefits of credit risk transfer, Wagner and Marsh (2004) find that risk transfer out of a relatively fragile banking sector leads to an improvement in system wide stability. More specifically they stipulate that by enabling diversification, CRT ensures banks are better able to diversify their risk, thus enhancing financial stability and reduces the cost of financing. Furthermore, whilst it is argued the transferring of risk from banks to other less fragile financial players, such as insurance companies, may induce the former to take up new risks through an increase in their lending activities making loans more risky, this increase in lending may, on

[9] See for instance, Donahoo and Shaffer (1991), Hoenig (1996), Llewellyn (1999), Berger and Mester (2001), Sinkey (2004) and Molyneux (2004) for reviews.

[10] Goderis et. al (2007) find that the banks’ use of advanced products like CLOs enabled them to achieve a permanent increase in the target level of loans. Their Table 1 shows that the equity capital ratio of banks that used CRT techniques was 5.4% while those banks that did not was close to 9.8%.

the other hand, lead to a more efficient allocation of capital in the economy.

Morrison (2003) by contrast argues that markets for credit derivatives can destroy the signalling role of bank debt and lead to an overall reduction in welfare by reducing banks' alignment with firms' interests. Chiesa (2004) considers a situation where banks have a comparative advantage in evaluating and monitoring risks but limited risk bearing capacity. Credit risk transfer is found to improve efficiency by allowing the monitored debt of larger firms to be transferred to the market while banks can use their limited risk bearing capacity for loans to small businesses. Arping (2004) in considering changes in lender and borrower incentives following credit risk transfer argues that lenders will be more willing to call loans but less willing to provide monitoring effort. Allen and Gale (2005a) develop a model with two sectors suggesting that securitisation and the resulting credit risk transfer can be beneficial in certain circumstances but also produce in welfare deterioration due to the creation of contagion in others. Allen and Carletti (2005), also using a two sector model with banking and insurance posit that ABS can be beneficial when banks face uniform demand for liquidity. However, when they face idiosyncratic liquidity risk and hedge this risk in an interbank market, ABS and credit risk transfer in general can be detrimental to welfare, leading to contagion between both sectors and increase the risk of financial crises.

Wagner (2005a), however, suggests the chances of crises arising from credit risk transfer stems only from banks' willingness to take greater risk as asset liquidity increases. Wagner (2005b) extends this by showing that the increased portfolio diversification possibilities introduced by credit risk transfer can greatly increase the probability of liquidity-based crises. In particular, where increased diversification leads to banks reducing the amount of liquid assets held for more risky assets.

We will note that many of the above studies failed to model a multi-period setting and often did not depict the balance sheet constraints on banks that is posed by capital requirements on loan portfolio growth. The unique elements of subprime mortgages need to be spelt out and modelled. Also the demand for credit assets in the portfolios of non-bank financial entities was not modelled in any detail.

Our study will look to overcome the shortcomings of many of the above models and also to test some of these claims in a constructive way in a multi-agent setting. We proceed with our analysis using a two sector model similar in spirit to Allen and Gale (2005) using the Markose and Dong (2004) multi period model of optimal securitisation in banking with insolvency analysis forms the basis of our banking sector in Section 2.2. In Section 3, we capture the LAPF sector using a simplified model of Sherris (2003) for the asset and liability valuation processes undertaking by such institutional investors. LAPFs provide the insured entities protection against premature death and the loss of income from retirement. Funds available to the insurance sector are exclusively those raised from premiums or contributions made to the sponsored scheme by the sponsoring entity. The LAPF sector is subject to an aggregate risk, in that the may not be able to meet their liability commitments on the basis of investment risk, and so go bankrupt. The role of the credit assets in propagating the default risk from the mortgages or loans originated by banks is studied.

2.2 *Banking Sector Model*

Banks face the constraint of insolvency in their profit maximisation. The main forces driving the risk of insolvency within banking are credit and interest rate risks. Interest rate risk, typically modelled by the well-known asymmetry in the duration between assets and liabilities, is a product of the sensitivity of capital and income—and more generally the balance sheet and income statement—to changes in interest rates. Credit risk represents the most potent source of financial risk in terms of potential losses within banking. This risk stems from credit events, namely default of borrowers and deterioration in their credit quality[11]. This sort of risk is captured by the default probability from one period to the next.

As an attempt to mitigate the systemic risk implications of these risks, due to the special role banks play in the payments system, regulations are set to control the risk, particularly credit risk, exposure of banks. Banks are therefore required to maintain a certain amount of capital as a buffer against unexpected losses. The cost and amount of this required capital will, however, adversely impact on the bank's profit taking and the size of its loan portfolio. In other words, idle capital is wasted capital. Securitisation therefore plays a key role in enabling banks to reduce their regulatory capital holdings, through the transformation of risk assets into liquid assets subject to significantly lower capital requirements. Capital saved can be used for loan portfolio growth. Bernanke and Lowe (1992) were amongst the first to show how capital requirements influenced loan portfolio growth. We explicitly build on this and show how capital injections needed for banks if capital adequacy is not met can result in contraction of its loan stock and there is a critical trade off between asset accumulation via securitization and the costs of this. The credit risk is captured by the default probability with which some assets are destroyed from one period to the next.

[11] Note that default does not necessarily imply a failure of the bank to recover the full amount of the loan but rather the failure of the borrower to meet successive interest and principle payment obligations at any point over the during the course of the loan's life time.

While initially we use the stylized facts of the FDIC insured banks[12] in section 2.4 the asset growth model of banks is extended to incorporate the unique features of subprime mortgages. Banks are assumed to be risk neutral.

2.2.1 Bank asset and liability management

In order to analyze the effect of securitization on the asset value, in terms of the balance sheet variables, we assume that the bank's liabilities are composed of a fixed value of deposits at time t. Hence, the liability at t+1 is given by adding on the interest rate payment $L_t r^L$.

$$L_{t+1} = L_t(1+r^L) \quad (1)$$

With $L_0 = D_0$

D_0 is the initial value of deposit of the bank. Depositor behaviour is therefore not modelled here.

The face value of assets is A_t and it is composed of loans and cash. As for assets, traditionally, the growth in the value of assets is influenced by the following two factors:

(i) Return on the asset: $r^A A_t$

(ii) Default on assets denoted by ($1-\gamma$) which is the proportion of defaulted loans. (1- γ) A_t can be considered to be loss given default. Hence, $\gamma_t A_t$ is the survival value of assets from t .

We have $A_{t+1} = \gamma_t A_t + r^A \gamma_t A_t$ (2)

To consider the impact of capital adequacy requirement on the bank's balance sheet, let ε denote the capital adequacy requirement ratio, and the amount of εA_t capital is the minimum capital required to be held in the capital account.

2.2.2 Insolvency analysis

We analyze the condition of capital injection, insolvency and bankruptcy by using the following formulation. Defining the bank's equity as $A_t - L_t = E_t$, if

$$\begin{cases} \{A_t \geq L_t, and, E_t \geq \varepsilon A_t\} & \text{Bank is solvent and meets the capital adequacy requirement (3a)} \\ \{A_t \geq L_t, and, E_t < \varepsilon A_t\} & \text{=>Bank is still solvent, but capital injection is required (3b)} \\ \{A_t \leq L_t \Rightarrow E_t < \varepsilon A_t\} & \text{Bank is bankrupt (3c)} \end{cases}$$

Hence, when the value of total assets in the bank is greater than total liabilities, and the equity capital of the bank is greater than the capital requirement, the bank is solvent. It is the state described by equation (3a). However, in equation (3b), if the value of the total assets is greater than the value of total liabilities, but the capital requirement is not fulfilled, then the bank needs to sell some assets to increase equity capital. The bankruptcy scenario is represented by equation (3c), where capital adequacy requirement is also violated. Since the bank can not raise more capital, it will be bankrupt.

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[12] The measurement on default risk is based on the 30 banks, which have securitization activity among FDIC top 100 banks in US.

Now we will discuss the role of securitization and its benefit on asset-liability management. Denoting α as the proportion of securitized assets, we assume the securitized assets αA_t are held as liquid assets or cash. Consequently, this part of total assets will not be subjected to the capital adequacy requirement (Milne 2002). Hence, the capital required can be reduced to $\varepsilon(1-\alpha)A_t$. If the capital adequacy requirement is greater than the equity capital of the bank, then a capital injection is needed. Otherwise, the capital accumulation can be realized. M in equation (4) defines the condition for capital injection/accumulation.

$$M_t = \varepsilon(1-\alpha)A_t - (A_t - L_t)$$

$$= \varepsilon(1-\alpha)A_t - E_t \qquad (4.a)$$

Hence, if M > 0 Capital injection is needed
M < 0 Capital accumulation.

Indeed, banks are modelled as maximize equity capital accumulation over a fixed horizon, $-M_t$ which can be viewed as increases in shareholder value of the bank.

The asset accumulation process with securitization can be expressed as:

$$A_{t+1} = \gamma_t(1-\alpha)A_t + \alpha A_t + r^A\gamma_t A_t - M_t - C(\alpha)A_t \qquad (5)$$

At time t, the non-securitized assets are $(1-\alpha)A_t$, and these assets are subject to a survival rate, which is γ. As a result $\gamma_t(1-\alpha)A_t$ is the amount of assets that will survive from period t to period t+1. Then at the same time, the bank keeps αA_t as liquid assets that have been raised from securitization. Moreover, bank will get the investment return from the total surviving assets, irrespective of the assets securitized[13]. This is the receivable $r^A A_t$ in equation (5). In addition, if the equity capital falls below the capital requirement, the bank needs to sell M amount of assets to replenish the capital account, hence, "M" has to be subtracted from equation (5) $C(\alpha)A_t$ is the cost of securitization, which is also needed to be subtracted from the total benefit. We will discuss the cost of securitization in detail in what follows.

Substituting equation (4) in equation (5), we have:

$$A_{t+1} = \gamma_t(1-\alpha)A_t + \alpha A_t + r^A\gamma_t A_t - \varepsilon(1-\alpha)A_t + (A_t - L_t) - C(\alpha)A_t$$

$$= \left[(\gamma_t - \varepsilon)(1-\alpha) + \alpha + r^A\gamma_t - C(\alpha)\right]A_t + E_t$$

$$= qA_t + E_t \qquad (6)$$

where $q = \left[(\gamma_t - \varepsilon)(1-\alpha) + \alpha + r^A\gamma_t - C(\alpha)\right]$

$$= \left[\Omega_1 + \alpha\Omega_2\right] \qquad (7.a)$$

And

$$\Omega_1 = (\gamma_t - \varepsilon) + \gamma_t r^A$$

$$\Omega_2 = [1 - (\gamma_t - \varepsilon)] - \theta$$

From equation (6), q can be treated as the asset accumulation factor, which cause asset to grow at the rate of q. Typically Ω_2 is usually greater than 0; q is a positive function of α. If α increases, q will increase, and assets will start accumulating. Clearly, if ε is too high, it can put a brake on the asset accumulation. Solving equation (6) recursively, we have

$$A_t = q^t A_0 + \sum_{i=1}^{t} q^{i-1} E_{t-i} \qquad (8)$$

[13] Technically the liquid assets from securitization only receive the short term rates rather than the long term loan rate r^A.

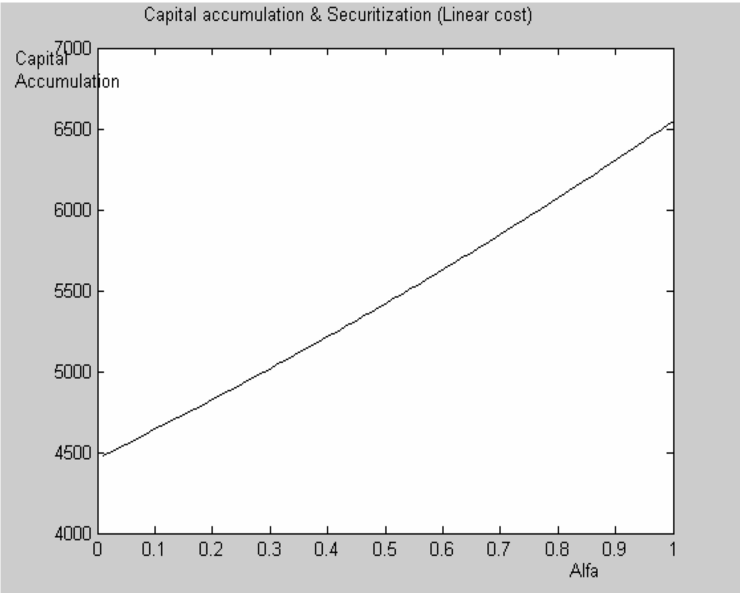
Since $A_t = L_t + E_t$, we can rewrite our equation as:

$$A_t = (1+q)^t A_0 - \sum_{i=1}^{t} (1+q)^{i-1} L_{t-i} \quad (9)$$

It is clearly shown from equation (7) that if q is a positive function of α. When α increases, the asset value grows. However, to make the conclusion on the relationship between α and A, we need to have a further study on the cost function of securitization C(α). As first pointed out in Wolfe (2000) a linear cost of securitization ie. C(α)= θ α A is a constant proportion θ of α A, produces a corner solution with a 100% securitization of its assets in each time period, a veritable money pump. A simulation for this assuming fixed survival rates (γ=0.93) [14], interest rates $r^A = 0.1$, $r^L = 0.0565$, for a 5 period model where the capital accumulation equation in (4) set as $-M_t$ is solved for having substituted (11) of A_t there.

Figure 6 : Linear Cost of Securitization and the Money Pump Model

Figure I.5 Capital accumulation and α analysis I (T=5) (linear Cost)



2.2.3 Non-linear cost of Securitization

In the financial market, it has been found that the quality of bank's assets is not homogenous. Hence, the cost of securitization would vary as well. A number of studies discussed in Section 2.1 have uncovered the tendency of banks to securitize their high quality assets first. We assume a nonlinear cost of securitization or loan expansion on assets because banks have costs that increase increasing rate as quantities increase. This could be seen as a proxy for loan quality deterioration as loan expansion grows via securitization. Also larger credit enhancements or coupon rates have to be paid for securitization or retention of lower quality assets.

As shown in the Table 4.1, we can divide the costs of securitization into two groups: flexible cost and fixed cost (see Giddy (2000)).

Table 1 Costs of Securitization and/or

Flexible cost	Fixed cost

[14] The default rates (1-γ) in the sensitivity analysis are based on the data on 30 banks, which have securitization activities among FDIC top 100 banks in the period 2001-2004. From the data analysis, the worst default scenario case in the data is 0.07.

-Coupon rate or credit spread (if retained on balance sheet) -Credit enhancement (if securitized)	-Structuring fees payable to bankers -Legal fee -Accounting fee -Tax -Rating agencies fee -Management time

Hence, the non-linear cost function can be written as:

$C = (\alpha + \alpha^2)\theta$

Hence, equation (7) can be rewritten as:

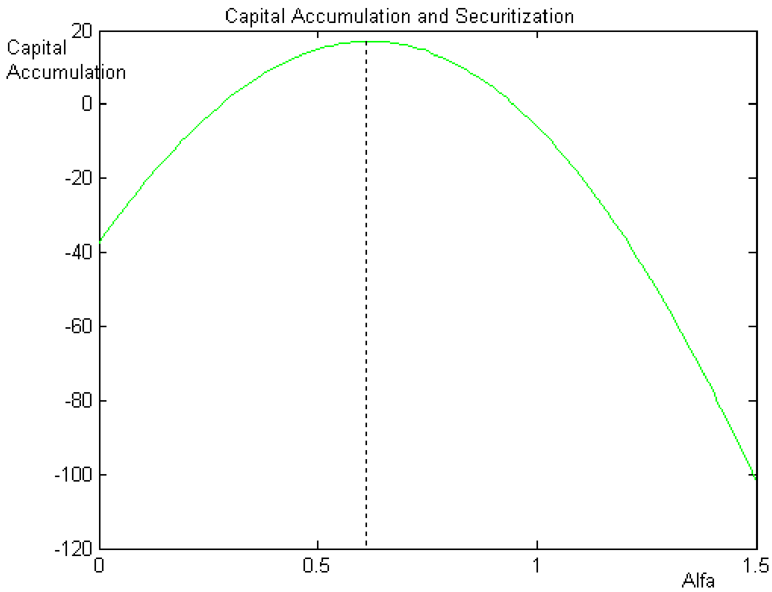
$$q = \left[\Omega_1 + \alpha\Omega_2 - \theta \alpha^2\right] \qquad (7.b)$$

On substituting equation (19) into (4), we can get:

$$M_t = \varepsilon(1-\alpha)(qA_{t-1} + E_{t-1}) - E_t \qquad (4.b)$$

To understand implication of the non-linear cost function we will in the first instance simply assume θ=0.05 as in the linear case. For the multi-period optimization, the optimal values for have been solved numerically in MATLAB constant value for α to be applied in each time period.. By setting the value range of α from 0 to 1 with 0.01 intervals, program generates values for $-M_t$. The optimal α is the one that maximizes $-M_t$. In the simulation, other variables are calibrated as $A_0 = 100$, $L_0 = 92$, $E_0 = 8$, $\varepsilon = 0.08$, $r^A = 0.1$, $r^L = 0.0565$, Figure 6 plots the relationship between the capital accumulation and α when cost coefficient θ=0.05, t=5 and the survival rate on assets γ=0.93.

Figure 7 Capital accumulation and α analysis for homogenous assets for the worse default scenario (t=5) (non-linear cost, γ=93%, θ=0.05)



In the Figure 7, it is shown that in our simulation result, the optimal value for α is around 0.6 a strict interior solution as compared to the linear cost case. Moreover, note that there is only 20% growth in capital over the 5 year period as compared to the with the increase of the flexible cost, the optimal ratios of securitization will be reduced.

2.2.4 Cost of securitization in practice: Asset Quality and Coupon Rate

In practice, the cost of securitization can be expressed as follows:

$$C(\alpha) = \left(\alpha + \alpha^2\right)\sum_{i=1}^{T}(Coupon_i + enhancement_i)$$

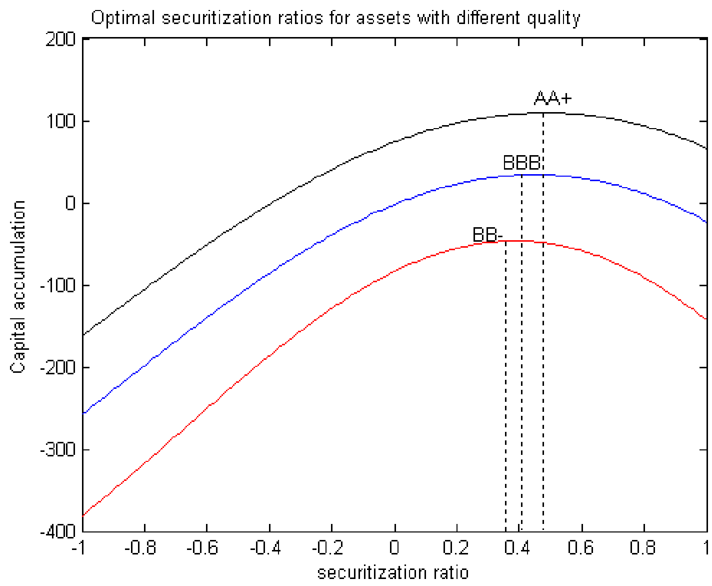
Where i denotes each tranche of assets in asset pool, T denotes the number of total tranches in the asset pool. Now the cost is negatively related to the quality of tranche in the asset pool. Moreover, if we assume there is no credit enhancement available, the cost could be proxied by the coupon payment, which is highly related to the default rate. We can use $\sum R^c$ to denote the total coupon payment. From the information provided by Citi Bank, we have calculated the relation between of coupon payment in the cost function C(α) and default rate as shown in Table below.

	Default Rate (1-γ)	Coupon Rate on MBS 2007	Coupon Rate [1] 88-04
CCC-	0.33	0.16	
CCC	0.16	0.16	
BB-	0.15	0.15	
	0.16	0.14	
	0.13	0.13	
	0.12	0.12	
	0.11	0.11	
BB	0.1	0.1	0.0987
	0.07	0.07	
BBB	0.05	0.06	0.0642
A			0.0517
AA	0.001	0.04	0.0503
AAA	1	0.03	0.044

Source Citi Bank 2007

Above shows how asset quality will affect the cost of securitization, assets with higher quality will subject to lower cost. Therefore, the optimal securitization ratios will vary as the quality of assets vary as well. By simulating the securitization activity for each tranche of assets, we can calculate the optimal securitization ratios for AAA, AA, BBB, BB, BB- rated assets. It is shown in Figure 7.

Figure 8 Optimal Securitization Ratios for Assets with different Rating (Same interst rate assumptions as before)

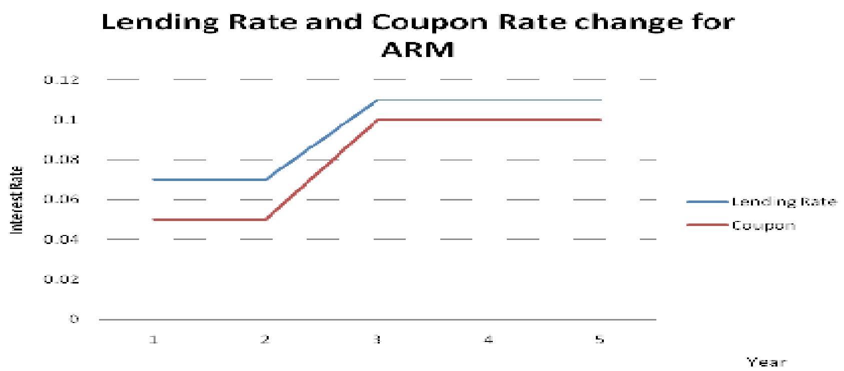


It is found that when the asset quality is lower, which implicate a higher default rate and higher coupon payment, the optimal value for α will not only be reduced, we see that there are no benefits for capital growth when assets below a BBB rating is securitized.

2..2.4 The application of multi period optimal securitization model to subprime assets

In this section we will see how the securitization model has to be extended in a multi period setting so that both future interest rates, default rates and coupon rates can be adjusted according to contractual covenants in the loans and the resulting projections for loan interest rates and default behaviour. Without going into the full expose of the subprime phenomena the important features to be modelled involve the dominance of the so called exploding arms or adjustable rate mortgages which accounted for 80% of the subprime market. These subprime mortgages have low fixed-interest payments in their first couple of years, then they usually adjust to higher interest payment. Subprime lenders charge higher interest rates, which could be around four percentage points more than on loans to more credit-worthy borrowers and it is well known that defaults increase at points of reset. What is notable is the fact that assets that are possibly AA+ should be downgraded to BB at points of reset. These ARM mortgages have commensurate costs of securitization either as credit enhancement if taken off balance sheet or imply coupon payments for insurance if retained on balance sheet. The dynamics of the ARMs and their costs structure for securitization have been simulated below while taken on board the .

Figure 9. Adjustable Rate Mortgage (ARM)



Source: simulated by authors

In order to incorporate time varying interest rates and parameters over the future course of the mortgage, we need to rewrite our model (equation 6.a) as follows:

$$A_{t+1} = \gamma_t(1-\alpha)A_t + \alpha A_t + r^A\gamma_t A_t - \varepsilon(1-\alpha)A_t + (A_t - L_t) - C(\alpha)A_t$$

In the case of securitization of subprime assets, the borrowing and lending rates, as well as the coupon rates will vary after 2 years. In this case, r^A and r^L are variable at different period. Hence, we replace them by $r^A{}_t$ and $r^L{}_t$. So we can rewrite the equation as follows:

$$A_{t+1} = \gamma_t(1-\alpha)A_t + \alpha A_t + r^A{}_t\gamma_t A_t - \varepsilon(1-\alpha)A_t + (A_t - L_t) - C(\alpha)A_t$$

Where $L_t = L.\prod_{i=0}^{t-1}(1+r_t^L)$

Therefore:

$$A_T = A_0\prod_{i=0}^{T}X_i - L_0\prod_{i=1}^{T}X_i - L_1\prod_{i=2}^{T}X_i \ldots - L_{T-1}\prod_{i=T}^{T}X_i - L_T$$

And

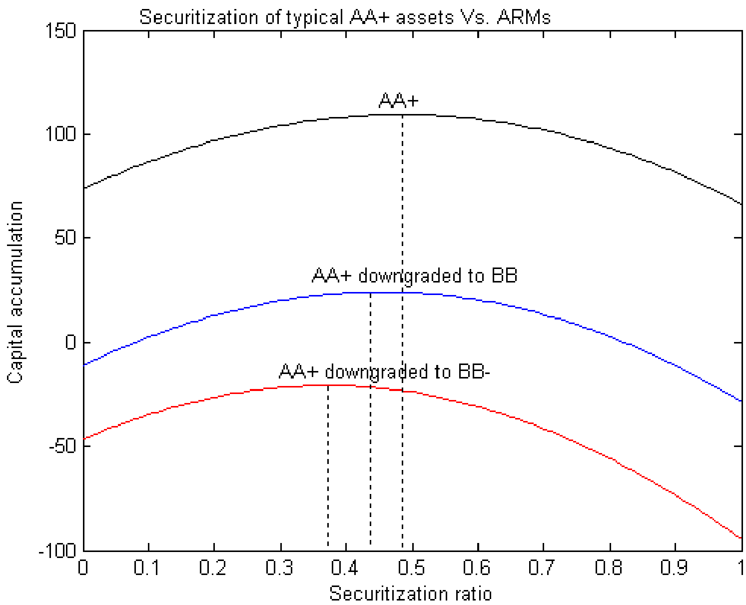
$$X_i = [1 + (\gamma_i - \varepsilon)(1-\alpha) + \alpha + r_i^A\gamma_t - C(\alpha)]$$

Therefore, by maximizing the capital growth in a 5 year horizon, we have:

$$-M_5 = [1-\varepsilon(1-\alpha)]A_5 - L_5$$

The multi-period optimization problem, T=5, is numerically solved with a constant value for α to be applied in each time period[15]. Following figure plots the relationship between the capital accumulation and α when the securitized assets are BB- rated assets and subprime CDOs respectively.

Figure 5. Optimal securitization rate for subprime assets



In the figure, the black curve shows the case of securitization of AA+ assets in normal circumstances. The blue curve denotes the case that ARMs that has been downgraded from AA to BB as is fully anticipated from the structure of the ARM itself, The red curve denotes the case that ARMs that has been downgraded from AA to BB- to reflect falling house prices. What is important to note is the substantial negative growth of equity capital and sure bankruptcy that is implied by year 5 from the supply of ARM mortgages and their securitization (and or retention of the remainder) is clear from this simulation. What this simulation indicates is that top subprime providers like Washington

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[15] For the multi-period optimization, the optimal values for have been solved numerically using MATLAB. By setting the value range of α from 0 to 1 with 0.01 intervals, program generates values for. The optimal α is the one that maximizes.

Mutual in the early part of 2001 securitized close to 50% of their mortgages and this is feasible only if the asset was treated as a AA+ one through out the 5 year period. The answer to the question of excessive securitization arising from underestimation of credit risk costs is borne out here. The propagation of credit risk to other institutional investors is investigated in the next section.

Section 3: Life Assurance and Pension Fund Model

3.1 The Economic Problem Facing Life Assurance and Pension Funds.

Though the economic problems facing LAPFs is complex, we will give a three step analysis [16]. Firstly LAPFs must determine how to value their assets and liabilities when the assets are liquid and subject to market value while liabilities are not (or more strictly are less liquid and potentially less volatile). Secondly, they must be able to ensure that there are always sufficient cash flows from the assets to meet the promised liability payment when they fall due. Finally, LAPFs should be capable of delivering these pensions at the lowest economic cost to the sponsor.

For simplicity and as we are only interested in modelling LAPFs as a proxy to the welfare impacts of credit risk transfer, we utilise a highly stylised framework of asset-liability management undertaken by such funds. In line with Wise (1984a, 1984b, 1987a, 1987b), Wilkie (1985) and Sherris (2003) we are looking purely at a liability driven discrete time model. This is both for simplicity and because, in practice most asset allocation decisions and insolvency tests are undertaken at discrete moments in time. We also assume that there are legal protections for fund members such that in the case of insolvency claimants receive an amount of the fund liabilities less the deficit. As a liability driven process our model incorporates assets held specifically to meet the value of the expected liabilities as derived by the appointed actuary. As such we treat our solvency determination process purely in terms of liabilities. We are therefore solving the optimal asset allocation problem backwards.

3.2 The Basic ALM Solvency analysis Model.

We start by assuming our LAPFs have a fairly certain liability (L) for future payment which is stochastic in nature. Note that in practice, the nature of this liability will differ between life assurance and pension funds due to the unique idiosyncrasies that underpin the benefit schemes. We also assume each fund has an initial endowment of assets (A^{LAPF}) to meet liabilities such that,

---

[16] It should be noted that when referring to Pension Funds in this model we are only considering as relevant the defined benefit (DB) or final salary schemes and not defined contribution (DC) or market value schemes. This is because only DB schemes provide any guarantees as to the market value of the annuity to be purchased upon retirement. That is DB schemes guarantee a minimum value of the annuity at retirement linked to salary at the retirement date.

$$A^{LAPF} \equiv C + K \tag{10}$$

where C is the fixed component to fund the expected value of the liabilities. In its simplest form C can be treated as the net present value of future liabilities based upon a given set of actuarial and economic assumptions determined by the scheme actuary at valuation[17]. With respect to life assurance schemes C can be seen as the expected market value of the liabilities where as in pension schemes it is the expected value of claim payments under the scheme rules. For life assurance policies K can be regarded as the provision for adverse deviations which is provided as risk capital or equity. In the case of pension funds K refers to the margin added to the expected value of future claim payments by the actuary, explicitly or implicitly through fund valuation assumptions, in establishing the scheme sponsor's contribution to the fund.

Initial assets as defined by equation 10 can thus be re-expressed as

$$A^{LAPF} \equiv (1+\rho) \times C \tag{11}$$

where ρ = K/C which, can be thought of as the solvency margin[18]. De Gelder, and. Valkenberg (1999), Elliott (2003), Patel (2005) and FSA (2006) have indicated that this across the European Union typically ranges between 4%-25%. If actual assets is greater than A^{LAPF} we have an initial surplus. Otherwise the fund is insolvent and closes and the assets as defined by equations 10 and 11 are distributed amongst the pension scheme members or the policy holders in the case of life assurance.

We further assume the end of period cash flow for asset i is denoted by

$$R^i \equiv (\text{١} + r^i) \quad for\ i = \{\text{١}, \text{٢}, ..., n\} \tag{12}$$

We specifically use a two asset framework as our agent modelling exercise consists solely of two main asset classes; traditional assets and credit assets (securitised assets and credit derivatives). However this does not result in a loss of generality.

Now since two of the threefold objectives of LAPFs is to ensure there are always sufficient cash flows form assets to meet promised liability payments when they fall due and to deliver these liabilities at the lowest economic cost to the sponsor, we have the following end of period solvency condition:

[17] Whilst scheme valuations generally tend to occur over four to five year intervals based on the scheme rules we assume valuations occur on an annual basis. We do not believe however that this is detrimental to our model, primarily because recent regulatory and accounting standards developments such as FRS17 and the revisions to The Pensions Act 2004 expected for full implementation in April 2006 have and will bring about an increase in the frequency of scheme valuations albeit not on the scale and detail required in a full actuarial valuation. FRS17, for instance, requires that scheme sponsors provide a full financial overview of their sponsored schemes within their balance sheets at least on an annual basis.

[18] This is the minimum amount of extra capital that insurance providers are required to hold as a buffer against unforeseen events such as higher than expected claim levels or unfavourable investment results. It is calculated according to a set formula as defined by the regulatory authority.

$$S_t = A^{LAPF}\left[(1-x)R_t^E + xR_t^C - f(x)\Phi\right] - L_t \qquad (13)$$

Equation 10 stipulates that solvency at time t is equal to the difference between the combined cash flows from the proportions of initial wealth invested in both traditional (R_t^E) and credit (R_t^C) assets less the cost of any particular investment strategy ($f(x)\Phi$)—as represented by the proportions invested in each asset class—and actual liabilities at time t. Assuming $S_{t-1} = 0$ we can substitute for A^{LAPF} in equation (13) to rewrite the solvency condition as follows:

$$S_t = C(1+\rho)\left[(1-x)R_t^E + xR_t^C - f(x)\Phi - (1/1+\rho)\Delta_t^L\right] \qquad (14)$$

where Δ_t^L = L/C. Since, by definition we know C is the initial period expectation of future liabilities, we can regard Δ_t^L simply as one plus the stochastic growth rate of liabilities from their expected value. Furthermore given that C will tend to be the lagged value of actual liabilities, we can simply that Δ_t^L to be the log of actual liabilities.

3.3 Impact of Solvency Analysis on Fund Capital Reserves.

As noted above, we assume a legal protection for scheme sponsors in the event of insolvency. Therefore, there will exist an initial capital reserve K such that $k \in K$ and is defined by the condition,

$$K_t = (1 + r^{global})* \max(0, K_{t-1} + S_t) \qquad (15)$$

Theoretically we can have any starting value for K. Nevertheless, the maximum condition sets the legal floor on K, as we require by assumption. In reality K can be negative however, by providing legal protection to scheme sponsors, we assuming that if K fall below zero the sponsor underwriting the fund goes bankrupt and as such the LAPF is closed. We also assume that the scheme sponsor does not pay any surpluses to its shareholders but rather adds these onto the capital reserves of the fund which is placed in a bank account and grows at the risk free rate r^{global}[19].

3.4 LAPF Optimal Asset Allocation and Market Clearing.

Solving for x in equation (14) given a quadratic cost function $f(x)\Phi$ = $x^2\Phi$, where Φ is some constant between 0 and 0.99, we get the optimal demand for credit assets by the life assurance and pension fund sector:

$$x* = \left(\frac{1}{2\Phi}\right)\left(R_t^C - R_t^E\right) \qquad (16)$$

[19] It is perfectly within reason to also link K to the profit distribution processes of the company providing the employee benefit scheme as would be the case in reality.

and the market clearing condition for credit asset cash flow in the calibrated model with both banking and LAPF sectors is given by,

$$\overset{*}{R}{}_t^{C} = R_t^E + 2\Phi\left[\frac{\alpha * A^{Banking}}{C(1+\rho)}\right]$$

(17.a)

$R_t^C > 0$ if and only $A_t > L_t$ for banks. (17.b)

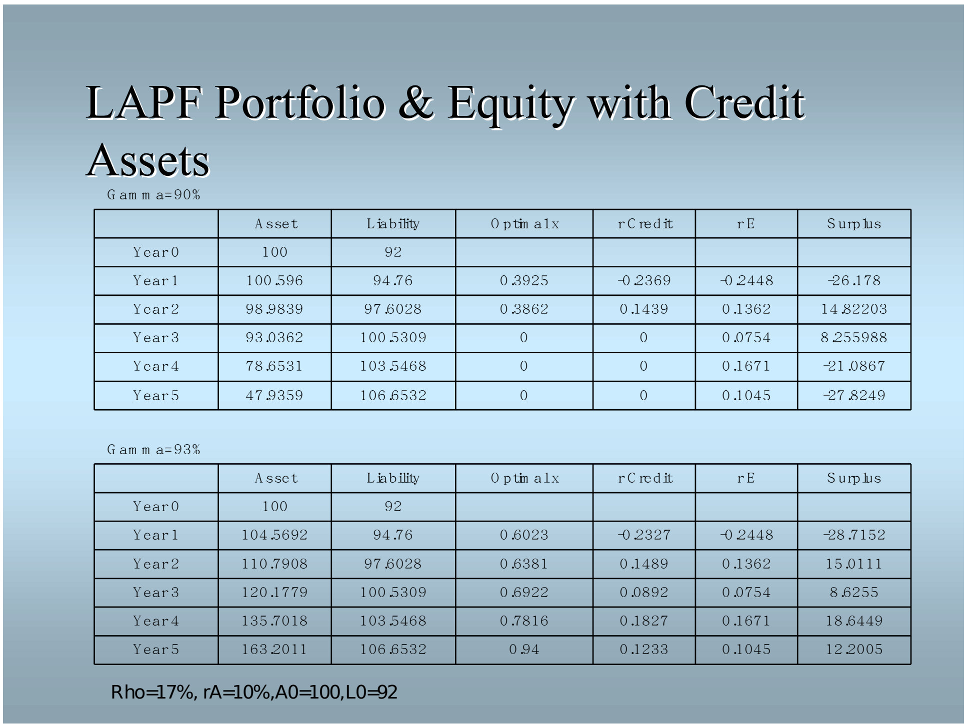
We impose the condition that for R^C to be positive, ie. the coupon on insurance on credit products paid by banks must continue. Banks themselves have to be solvent and not renege on their coupon payments.

From equations (16) and (17), we see that the primary influence on the optimal asset allocation of LAPFs is the spread between returns on credit assets and traditional equity assets. Moreover, as the securitisation rate in the banking sector increases, as discussed earlier, then coupon rate credit assets increase in (17) and hence so does demand for such assets by LAPFs. We can also observe the theoretical justification for regulation in the insurance sector vis-à-vis investment risk. That is, the more stringent regulatory pressures on LAPFs through an increase in ρ will ultimately reduce the demand for more risky assets and ultimately maintain a smoothing of surpluses. However this tempering impact will be countered by events in the banking sector through the contagion effect.

3.5 Securitisation, Contagion and Systemic Risk

As stated previously, one of our main objectives in this project is to understand the broader system wide implications of the evolution of credit risk transfer instruments. As a benchmark model, we assume that all supply is exhausted by the LAPFs. That is, LAPFs do not restrict demand and buy all available credit assets. We therefore implicitly clear the market such that our surpluses are derived in terms of own known optimal securitisation rate for the banking sector as a whole and the average value of assets within that sector. Mathematically, this is done by taking the average banking sector securitisation rates and asset values and substituting for $x*$ and $\overset{*}{R}{}_t^{C}$ in equation (14).

To measure the system wide contagion or systemic risk impact of securitisation in our two sector model, we assume all variables fixed and gradually increase the default rate on banking sector assets. The historical returns on the equity asset is given in Table below. The period of 2000-2001 shows the massive the negative 24% returns on equity and a similar picture but somewhat better return for credit. However, in the case of survival of banks assets at the rate of 90% (hence a default rate of 10%) implies insolvency for the bank at period 2. This triggers an immediate invocation of condition (17.b) That is, bank assets A_t begin to fall below L_t, and discontinued coupon payments can reduce demand for credit assets by LAPFS to zero and LAPF surpluses also soon become negative by the 4th year after an early boost, as we saw in the recent crisis. A higher solvency ratio for LAPFs at ρ = 30% rather than ρ = 17% does not alter the evolution of the surpluses of LAPFs.



LAPF Portfolio & Equity with Credit Assets

Gamma=90%

	Asset	Liability	Optimal x	rCredit	rE	Surplus
Year 0	100	92				
Year 1	100.596	94.76	0.3925	-0.2369	-0.2448	-26.178
Year 2	98.9839	97.6028	0.3862	0.1439	0.1362	14.82203
Year 3	93.0362	100.5309	0	0	0.0754	8.255988
Year 4	78.6531	103.5468	0	0	0.1671	-21.0867
Year 5	47.9359	106.6532	0	0	0.1045	-27.8249

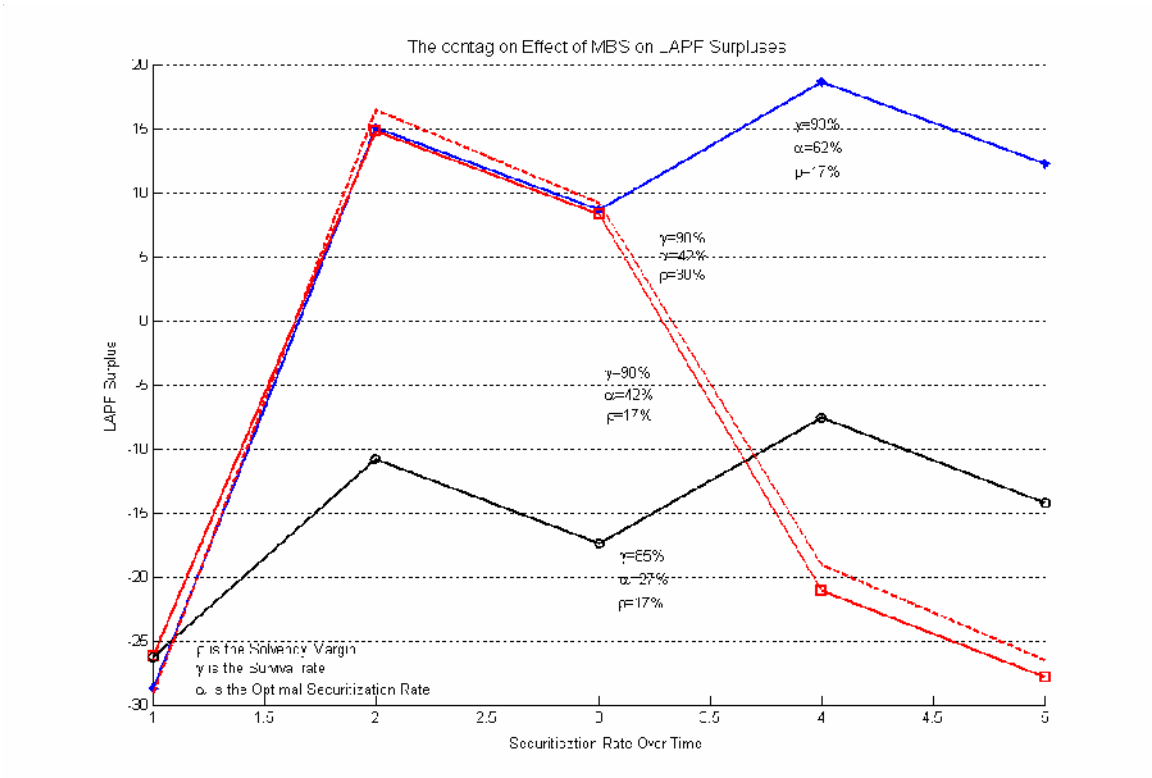
Gamma=93%

	Asset	Liability	Optimal x	rCredit	rE	Surplus
Year 0	100	92				
Year 1	104.5692	94.76	0.6023	-0.2327	-0.2448	-28.7152
Year 2	110.7908	97.6028	0.6381	0.1489	0.1362	15.0111
Year 3	120.1779	100.5309	0.6922	0.0892	0.0754	8.6255
Year 4	135.7018	103.5468	0.7816	0.1827	0.1671	18.6449
Year 5	163.2011	106.6532	0.94	0.1233	0.1045	12.2005

Rho=17%, rA=10%,A0=100,L0=92

Figure 5: *The Contagion Effect of Securitisation on LAPF Surpluses*

Survival rates of assets at gamma = 93%, shows a very rosy picture in the table and graph, there appears to be a sustainable impact on LAPF surplus.



which ultimately leads to bank failures; hence the sharp drop in LAPF surpluses. Conversely, during an economic recovery or boom, we observe banks' asset quality to be significantly high and as such the industry optimal rate of securitisation falls significantly as does the market return on credit assets. LAPF demand for such assets and surpluses therefore do not rise as sharply as was the case where banking sector asset quality was low. LAPF surplus are smoothened over time and slowly drop of into deficits. The reason for these observed deficits is that, as we are looking at an industry average, we do have banks with poor quality assets which fail over time. This

Securitisation can thus be regarded as double edged sword in relation to the effective well being of economic stability. On the one hand too high a level of securitisation will result in system wide shocks to financial stability when lao. Too low a level of securitisation on the other hand, may hinder economic welfare and put increased pressure on investor portfolios and their ability to cover their liabilities.

4. Concluding Remarks

In this paper, we have sought to develop an agent-based simulation of securitisation within the banking sector using the insolvency risk constrained model of profit maximisation. We analyse the role of securitisation within banking and develop a computational banking model for optimal securitisation, with special emphasis on the issues of regulatory arbitrage and asset quality deterioration and default risk. We then extended this to include a model of market clearing by developing a computational model of how credit assets and their associated credit risks are incorporated into the portfolios of life assurance and pension funds and institutional investors more generally. On this footing we discussed the financial stability implications arising from the calibrated two sector model.

Our results show that quantities securitized by banks are critically affected by the cost/price of credit risk. There are inbuilt incentives for managers to boost size of loan portfolios growth via securitization under condition of competitive narrow interest rate spreads on assets and deposits and limited deposit growth. Short term equity capital growth of banks achieved by the expansion into subprime mortgages required a systematic underpricing of the risk to the bank for retaining the toxic elements of the RMBS. The fact that the coupon rate on securitization drives the size of their holdings on LAPF portfolios which is skewed in the direction of higher default assets with larger coupon rates. On the demand side, we observe that the inclusion of credit assets in the portfolios of LAPFs is highly beneficial under low credit risk environments as it relieves pressure on their surpluses given their liabilities and thereby enabling more of them to remain solvent over time.

Conversely, we also observe that by separating physical ownership of assets from the ownership of cash flows from those assets, securitisation significantly increases the risk of contagion between both sectors. We observe that with the active use of securitisation as a solvency maintaining tool, LAPF surpluses are significantly dependant on events within the banking sector and thus subject to high levels of volatility. In particular we observe that LAPF portfolios are significantly subject to the systemic risk/contagion effect in times of economic recession when bank asset survivability is substantially reduced compared to other times in the economic business cycle.

Though the observations of this paper are powerful, this is as yet only in developmental stage, highlighting the role of agent modelling in the analysis of credit risk transfer. More detailed research outlined in Section 1 is required to fully articulate the demand and supply side across the full structure of credit assets such as CDOs and CDS. It will be interesting to see if there is wider applicability of the results from extant simulations that sole suppliers of assets in excess of 10 % default (the main subprime lenders) and demand side portfolios of institutions like LAPFs which have 1/3of their portfolios invested in these high default assets will suffer insolvency.

Appendix Table A.1 US Subprime Regional Distribution

Table 1.Metropolitan areas	State	Portion of all mortgages as of Dec. '06.	Delinquency portion of subprime as of Dec. '06*	Delinquency portion of subprime as of Dec. '05*	Change in delinquencies from '05, in pct. pts.
McAllen-Edinburg-Mission	Texas	25.96	11.55	9.52	2.03
Memphis	Tenn.; Ark.; Miss.	24.00	19.52	15.22	4.30
Sharon	Pa.	23.08	16.91	15.06	1.85
Miami	Fla.	22.96	8.25	6.20	2.05
Richmond-Petersburg	Va.	22.28	10.70	6.48	4.22
Brownsville-Harlingen-San Benito	Texas	21.64	12.36	11.44	0.92
Merced	Calif.	21.56	12.24	2.42	9.82
Sumter	S.C.	20.69	16.52	17.76	-1.24
Bakersfield	Calif.	20.23	9.17	2.19	6.98
Jackson	Tenn.	20.16	16.78	13.36	3.42
Riverside-San Bernardino	Calif.	19.91	11.21	3.60	7.61
Pueblo	Colo.	19.87	16.44	12.03	4.41
Stockton-Lodi	Calif.	19.78	12.74	3.47	9.27

Laredo	Texas	19.69	11.89	11.02	0.87
Lakeland-Winter Haven	Fla.	19.68	8.78	5.38	3.40
Scranton-Wilkes-Barre-Hazleton	Pa.	19.43	13.84	12.58	1.26
Gary	Ind.	19.36	14.67	13.06	1.61
Rocky Mount	N.C.	19.06	15.88	13.78	2.10
Chattanooga	Tenn.; Ga.	18.86	13.81	9.91	3.90
Fort Lauderdale	Fla.	18.36	8.91	7.25	1.66
Modesto	Calif.	18.23	13.18	3.44	9.74
Yuba City	Calif.	17.99	11.44	2.56	8.88
Las Vegas	Nev.; Ariz.	17.76	10.82	4.02	6.80
Terre Haute	Ind.	17.74	15.70	16.66	-0.96
Waterbury	Conn.	17.57	10.70	6.52	4.18
Fort Pierce-Port St. Lucie	Fla.	17.55	10.25	4.77	5.48
South Bend	Ind.	17.54	20.34	14.65	5.69
Ocala	Fla.	17.53	6.58	4.05	2.53
Visalia-Tulare-Porterville	Calif.	17.53	7.69	2.33	5.36
Youngstown-Warren	Ohio	17.53	21.75	19.02	2.73
Steubenville-Weirton	Ohio; W.Va.	17.41	14.15	13.18	0.97
Altoona	Pa.	17.12	12.92	13.09	-0.17
Flint	Mich.	17.04	20.65	15.10	5.55
St. Joseph	Mo.	16.91	11.79	10.35	1.44
Danville	Va.	16.83	11.85	6.39	5.46
Florence	S.C.	16.74	17.30	16.11	1.19
Muncie	Ind.	16.72	18.06	16.02	2.04
Houston	Texas	16.67	15.17	13.99	1.18
Fresno	Calif.	16.62	8.84	2.90	5.94
Pine Bluff	Ark.	16.56	13.15	13.39	-0.24
Jackson	Miss.	16.44	22.68	24.31	-1.63
Johnstown	Pa.	16.31	14.02	12.87	1.15
Beaumont-Port Arthur	Texas	16.27	14.51	23.41	-8.90
Orlando	Fla.	16.16	7.64	3.88	3.76
Jacksonville	Fla.	16.15	10.77	8.21	2.56
Vineland-Millville-Bridgeton	N.J.	16.15	12.92	8.62	4.30
Mansfield	Ohio	16.13	17.12	13.92	3.20
Fort Myers-Cape Coral	Fla.	16.12	9.69	3.52	6.17
Jackson	Mich.	16.09	21.96	14.81	7.15
Greeley	Colo.	15.92	16.62	12.61	4.01
Kokomo	Ind.	15.92	17.84	12.25	5.59
Pittsburgh	Pa.	15.76	16.36	15.07	1.29
Erie	Pa.	15.73	17.28	15.11	2.17
Tampa-St. Petersburg-Clearwater	Fla.	15.67	9.15	5.05	4.10
Elkhart-Goshen	Ind.	15.66	15.80	11.39	4.41
Fayetteville	N.C.	15.65	12.07	10.33	1.74
Benton Harbor	Mich.	15.54	14.48	10.65	3.83
Knoxville	Tenn.	15.50	9.88	7.57	2.31
Biloxi-Gulfport-Pascagoula	Miss.	15.48	15.83	34.41	-18.58
Cleveland-Lorain-Elyria	Ohio	15.48	24.94	20.81	4.13
Alexandria	La.	15.33	13.81	13.58	0.23
Daytona Beach	Fla.	15.33	9.84	4.25	5.59
Baton Rouge	La.	15.32	13.12	18.18	-5.06
New Orleans	La.	15.31	20.07	42.93	-22.86
Providence-Fall River-Warwick	R.I.; Mass.	15.30	13.24	5.90	7.34
Longview-Marshall	Texas	15.22	9.50	8.04	1.46

Springfield	Mass.	15.22	14.14	7.79	6.35
Wheeling	W.Va.; Ohio	15.21	13.67	11.90	1.77
Brockton	Mass.	15.07	19.25	9.53	9.72
Tacoma	Wash.	15.05	8.55	5.79	2.76
Elmira	N.Y.	15.02	11.79	10.53	1.26
Newburgh	N.Y.; Pa.	14.96	11.75	6.91	4.84
Columbus	Ga.; Ala.	14.95	12.92	11.61	1.31
Goldsboro	N.C.	14.90	15.77	14.10	1.67
Jamestown	N.Y.	14.88	15.32	15.47	-0.15
Phoenix-Mesa	Ariz.	14.88	6.56	2.64	3.92
Indianapolis	Ind.	14.78	17.87	14.27	3.60
El Paso	Texas	14.68	7.58	6.88	0.70
Johnson City-Kingsport-Bristol	Tenn.; Va.	14.67	8.75	6.80	1.95
Kankakee	Ill.	14.66	20.12	15.31	4.81
Lansing-East Lansing	Mich.	14.65	18.39	12.74	5.65
Detroit	Mich.	14.56	24.58	16.97	7.61
Shreveport-Bossier City	La.	14.41	12.96	11.88	1.08
Canton-Massillon	Ohio	14.40	19.20	15.12	4.08
Lewiston-Auburn	Maine	14.38	10.23	5.97	4.26
New Bedford	Mass.	14.38	16.64	7.64	9.00
Vallejo-Fairfield-Napa	Calif.	14.38	12.09	3.40	8.69
Brazoria	Texas	14.37	13.78	13.72	0.06
Lima	Ohio	14.36	17.43	14.33	3.10
New Haven-Meriden	Conn.	14.32	11.18	6.92	4.26
Akron	Ohio	14.23	19.65	16.25	3.40
St. Louis	Mo.; Ill.	14.22	13.87	10.64	3.23
Kansas City	Mo.; Kan.	14.14	14.18	11.43	2.75
Cumberland	Md.; W.Va.	14.13	8.79	7.17	1.62
Lake Charles	La.	14.10	12.20	20.62	-8.42
Casper	Wyo.	14.06	6.27	4.94	1.33
Glens Falls	N.Y.	14.00	13.53	8.66	4.87
Odessa-Midland	Texas	13.96	8.65	8.22	0.43
Yuma	Ariz.	13.96	5.32	2.04	3.28
Dover	Del.	13.88	8.46	6.55	1.91
Huntington-Ashland	W.Va.; Ky.; Ohio	13.86	15.19	12.70	2.49
Hickory-Morganton-Lenoir	N.C.	13.83	13.37	12.93	0.44
Evansville-Henderson	Ind.; Ky.	13.78	15.91	14.63	1.28
Fort Wayne	Ind.	13.74	16.52	13.16	3.36
Hamilton-Middletown	Ohio	13.71	16.14	12.71	3.43
Fort Worth-Arlington	Texas	13.69	14.39	11.44	2.95
Galveston-Texas City	Texas	13.68	13.62	14.37	-0.75
New London-Norwich	Conn.; R.I.	13.67	11.49	5.46	6.03
Lawton	Okla.	13.65	11.61	11.14	0.47
Kalamazoo-Battle Creek	Mich.	13.62	16.95	12.29	4.66
Tulsa	Okla.	13.56	14.17	12.76	1.41
Dallas	Texas	13.52	16.11	12.70	3.41
Salem	Ore.	13.49	7.12	6.41	0.71
Birmingham	Ala.	13.45	15.04	12.15	2.89
Denver	Colo.	13.44	17.74	12.77	4.97
West Palm Beach-Boca Raton	Fla.	13.33	9.26	6.23	3.03
Corpus Christi	Texas	13.29	11.87	9.76	2.11

Nashville	Tenn.	13.25	11.82	10.31	1.51
Janesville-Beloit	Wis.	13.19	14.35	10.63	3.72
Houma	La.	13.16	13.43	21.19	-7.76
Clarksville-Hopkinsville	Tenn.; Ky.	13.15	11.45	10.40	1.05
Sherman-Denison	Texas	13.14	12.23	11.53	0.70
Macon	Ga.	13.12	16.84	14.83	2.01
Bridgeport	Conn.	13.10	10.73	6.13	4.60
Dayton-Springfield	Ohio	13.08	19.74	17.24	2.50
Waco	Texas	13.08	12.71	9.01	3.70
Fitchburg-Leominster	Mass.	13.07	16.69	7.76	8.93
San Antonio	Texas	13.00	10.32	8.92	1.40
Williamsport	Pa.	12.98	13.00	10.00	3.00
Toledo	Ohio	12.93	19.06	15.46	3.60
Oklahoma City	Okla.	12.88	12.48	10.67	1.81
Cincinnati	Ohio-Ky.; Ind.	12.85	16.91	13.81	3.10
Salt Lake City-Ogden	UT	12.82	9.07	9.22	-0.15
Colorado Springs	Colo.	12.73	12.35	8.77	3.58
Sacramento	Calif.	12.71	14.12	3.44	10.68
Bangor	Maine	12.64	15.07	8.44	6.63
Jersey City	N.J.	12.63	8.92	4.40	4.52
Hartford	Conn.	12.62	9.83	6.55	3.28
Albany	Ga.	12.56	13.11	10.24	2.87
Savannah	Ga.	12.56	13.13	9.65	3.48
Charlotte-Gastonia-Rock Hill	N.C.; S.C.	12.55	13.50	11.91	1.59
Los Angeles-Long Beach	Calif.	12.43	8.67	3.05	5.62
Columbia	S.C.	12.42	15.21	13.20	2.01
Binghamton	N.Y.	12.41	10.35	9.28	1.07
Anniston	Ala.	12.36	10.16	7.36	2.80
Atlanta	Ga.	12.36	17.81	13.62	4.19
Gadsden	Ala.	12.36	10.63	7.61	3.02
Greensboro-Winston-Salem-High Point	N.C.	12.32	13.84	12.56	1.28
Texarkana	Texas; Ark.	12.32	13.82	9.05	4.77
Salinas	Calif.	12.23	9.45	2.28	7.17
Wilmington-Newark	Del.; Md.	12.22	9.13	6.67	2.46
Milwaukee-Waukesha	Wis.	12.17	12.37	7.68	4.69
Columbus	Ohio	12.15	17.55	14.54	3.01
Pensacola	Fla.	12.12	10.14	5.39	4.75
Victoria	Texas	12.12	10.13	9.89	0.24
Greenville-Spartanburg-Anderson	S.C.	12.06	15.60	13.90	1.70
Joplin	Mo.	11.99	12.63	8.01	4.62
Chicago	Ill.	11.98	14.50	9.26	5.24
Nassau-Suffolk	N.Y.	11.94	11.70	6.61	5.09
Albany-Schenectady-Troy	N.Y.	11.91	11.54	8.40	3.14
Saginaw-Bay City-Midland	Mich.	11.89	18.47	14.37	4.10
Yakima	Wash.	11.89	8.82	9.17	-0.35
Enid	Okla.	11.87	10.17	9.81	0.36
Racine	Wis.	11.87	13.04	8.85	4.19
Hagerstown	Md.	11.82	8.24	3.51	4.73
Kenosha	Wis.	11.82	13.14	7.29	5.85
Lafayette	La.	11.81	12.32	15.38	-3.06
Mobile	Ala.	11.81	15.10	17.2	-2.10
Philadelphia	Pa.; NJ	11.81	11.50	8.84	2.66
Punta Gorda	Fla.	11.80	8.94	3.50	5.44

Tyler	Texas	11.80	12.36	8.84	3.52
Dutchess County	N.Y.	11.79	11.40	6.68	4.72
Melbourne-Titusville-Palm Bay	Fla.	11.71	10.50	3.57	6.93
Baltimore	Md.	11.64	8.10	4.44	3.66
Grand Rapids-Muskegon-Holland	Mich.	11.62	18.23	12.15	6.08
Worcester	Mass.; Conn.	11.54	17.22	8.64	8.58
Louisville	Ky; Ind.	11.48	17.32	13.67	3.65
Allentown-Bethlehem-Easton	Pa.	11.47	9.83	8.10	1.73
Charleston-North Charleston	S.C.	11.45	10.55	8.52	2.03
Sioux City	Iowa; NE	11.45	15.06	13.47	1.59
Provo-Orem	UT	11.44	6.90	7.78	-0.88
Cheyenne	Wyo.	11.43	8.95	4.23	4.72
Lafayette	Ind.	11.42	14.62	10.78	3.84
Redding	Calif.	11.21	9.03	2.80	6.23
Harrisburg-Lebanon-Carlisle	Pa.	11.12	11.22	10.81	0.41
Little Rock-North Little Rock	Ark.	11.08	12.40	10.27	2.13
Newark	N.J.	11.08	12.61	7.32	5.29
York	Pa.	11.00	8.98	7.52	1.46
Wichita	Kan.	10.95	12.64	10.18	2.46
Utica-Rome	N.Y.	10.91	12.37	11.67	0.70
Tallahassee	Fla.	10.90	8.69	7.14	1.55
Olympia	Wash.	10.85	6.96	4.93	2.03
Wichita Falls	Texas	10.83	12.18	9.53	2.65
Grand Junction	Colo.	10.70	5.55	5.23	0.32
Lawrence	Mass.; N.H.	10.70	16.03	7.33	8.70
Pittsfield	Mass.	10.64	15.73	11.19	4.54
Reading	Pa.	10.64	9.22	8.50	0.72
Oakland	Calif.	10.62	12.41	3.61	8.80
New York	N.Y.	10.57	11.63	6.83	4.80
Hattiesburg	Miss.	10.55	17.33	27.75	-10.42
Sarasota-Bradenton	Fla.	10.55	9.35	3.04	6.31
Topeka	Kan.	10.53	13.92	10.57	3.35
Killeen-Temple	Texas	10.51	11.47	9.78	1.69
Parkersburg-Marietta	W.Va.; Ohio	10.49	15.97	16.05	-0.08
Montgomery	Ala.	10.43	11.61	8.97	2.64
Buffalo-Niagara Falls	N.Y.	10.34	13.69	13.21	0.48
Norfolk-Virginia Beach-Newport News	Va.; N.C.	10.33	7.02	4.13	2.89
Tucson	Ariz.	10.33	6.85	4.06	2.79
Omaha	Neb.; Iowa	10.29	13.89	11.73	2.16
Monroe	La.	10.28	12.22	12.32	-0.10
Roanoke	Va.	10.22	10.27	7.24	3.03
Lynchburg	Va.	10.07	9.87	6.46	3.41
Gainesville	Fla.	10.05	6.84	4.71	2.13
Syracuse	N.Y.	9.99	12.71	10.11	2.60
Augusta-Aiken	Ga.; S.C.	9.97	12.63	11.68	0.95
San Angelo	Texas	9.92	12.08	8.09	3.99
Davenport-Moline-Rock Island	Iowa; Ill.	9.86	15.23	11.69	3.54
Portland-Vancouver	Ore.; Wash.	9.77	6.93	5.06	1.87
Manchester	N.H.	9.74	11.91	6.55	5.36
Abilene	Texas	9.73	9.61	9.77	-0.16
Asheville	N.C.	9.73	9.82	7.71	2.11
Bloomington	Ind.	9.67	12.39	11.36	1.03
Decatur	Ill.	9.64	15.35	11.91	3.44

Yolo	Calif.	9.64	10.35	2.91	7.44
San Diego	Calif.	9.57	11.30	3.44	7.86
Greenville	N.C.	9.56	16.22	12.95	3.27
Rockford	Ill.	9.56	14.97	12.16	2.81
Duluth-Superior	Minn.; Wis.	9.54	14.59	9.51	5.08
Naples	Fla.	9.51	8.34	4.06	4.28
Washington	DC; Md.; Va.; W.Va.	9.46	8.76	3.17	5.59
Fort Smith	Ark.; Okla.	9.45	11.64	10.47	1.17
Lexington	Ky.	9.45	12.92	8.85	4.07
Springfield	Mo.	9.19	10.63	7.20	3.43
Des Moines	Iowa	9.17	15.57	11.62	3.95
Raleigh-Durham-Chapel Hill	N.C.	9.15	12.78	10.46	2.32
Danbury	Conn.	9.14	9.25	5.87	3.38
Richland-Kennewick-Pasco	Wash.	9.12	10.37	7.97	2.40
Rochester	N.Y.	9.10	12.86	10.51	2.35
Trenton	N.J.	9.06	11.66	8.01	3.65
Honolulu	HI	9.03	5.17	2.63	2.54
Boise City	Idaho	8.96	6.91	6.10	0.81
Lubbock	Texas	8.96	11.66	8.58	3.08
Reno	Nev.	8.96	8.90	2.68	6.22
Chico-Paradise	Calif.	8.93	8.82	4.10	4.72
Dothan	Ala.	8.90	10.97	7.58	3.39
Spokane	Wash.	8.87	7.21	6.18	1.03
Las Cruces	N.M.	8.86	7.26	7.11	0.15
Pocatello	Idaho	8.84	9.54	9.91	-0.37
Minneapolis-St. Paul	Minn.; Wis.	8.78	16.49	9.88	6.61
Decatur	Ala.	8.75	7.76	7.42	0.34
Lowell	Mass.; N.H.	8.70	16.31	7.48	8.83
Portsmouth-Rochester	N.H.; Maine	8.61	12.39	5.88	6.51
Eugene-Springfield	Ore.	8.60	6.84	5.23	1.61
Fort Collins-Loveland	Colo.	8.58	12.93	9.41	3.52
Austin-San Marcos	Texas	8.56	10.93	10.06	0.87
Peoria-Pekin	Ill.	8.52	15.25	12.98	2.27
Bergen-Passaic	N.J.	8.47	10.95	5.24	5.71
Florence	Ala.	8.47	12.52	9.43	3.09
Charleston	W.Va.	8.40	14.74	18.33	-3.59
Tuscaloosa	Ala.	8.40	12.98	11.96	1.02
Bremerton	Wash.	8.37	6.79	5.32	1.47
Albuquerque	N.M.	8.36	8.33	8.79	-0.46
Auburn-Opelika	Ala.	8.35	10.28	8.80	1.48
Waterloo-Cedar Falls	Iowa	8.31	14.42	10.87	3.55
Atlantic-Cape May	N.J.	8.28	10.28	5.43	4.85
Anchorage	Ark.	8.25	7.36	4.23	3.13
Nashua	N.H.	8.20	12.21	6.03	6.18
St. Cloud	Minn.	8.18	16.64	10.13	6.51
Lancaster	Pa.	8.14	10.34	8.29	2.05
Orange County	Calif.	8.13	8.53	2.65	5.88
Ventura	Calif.	8.06	9.42	3.15	6.27
Owensboro	Ky.	8.00	10.79	10.01	0.78
Myrtle Beach	S.C.	7.94	8.49	7.71	0.78
Medford-Ashland	Ore.	7.93	9.66	3.97	5.69
Santa Rosa	Calif.	7.92	9.70	2.51	7.19
Portland	Maine	7.91	12.83	5.56	7.27
Seattle-Bellevue-Everett	Wash.	7.85	7.55	6.36	1.19
Ann Arbor	Mich.	7.84	18.50	12.02	6.48
Jacksonville	N.C.	7.73	7.68	6.30	1.38
State College	Pa.	7.69	10.87	7.60	3.27
Wausau	Wis.	7.62	12.08	10.00	2.08

Wilmington	N.C.	7.58	6.97	5.99	0.98
Fayetteville-Springdale-Rogers	Ark.	7.44	10.99	6.82	4.17
Jonesboro	Ark.	7.43	14.44	10.04	4.40
Appleton-Oshkosh-Neenah	Wis.	7.39	12.95	7.97	4.98
Boston	Mass.; N.H.	7.39	15.09	7.34	7.75
Barnstable-Yarmouth	Mass.	7.34	16.99	7.75	9.24
Springfield	Ill.	7.33	16.28	14.01	2.27
Huntsville	Ala.	7.29	12.00	9.29	2.71
Panama City	Fla.	7.29	8.83	3.64	5.19
Athens	Ga.	7.27	14.78	10.45	4.33
Rapid City	S.D.	7.27	10.95	6.82	4.13
Amarillo	Texas	7.24	10.50	8.34	2.16
Fort Walton Beach	Fla.	7.22	7.68	4.16	3.52
Cedar Rapids	Iowa	7.19	13.74	11.29	2.45
Sioux Falls	S.D.	7.02	13.49	9.16	4.33
Monmouth-Ocean	N.J.	6.98	12.56	7.43	5.13
Santa Barbara-Santa Maria-Lompoc	Calif.	6.96	10.75	3.20	7.55
Eau Claire	Wis.	6.94	16.47	12.17	4.30
San Jose	Calif.	6.79	8.47	3.23	5.24
Sheboygan	Wis.	6.77	13.26	8.44	4.82
Lincoln	Neb.	6.72	12.38	8.37	4.01
Flagstaff	Ariz.; Utah	6.62	3.61	3.13	0.48
Stamford-Norwalk	Conn.	6.41	8.21	4.93	3.28
Boulder-Longmont	Colo.	6.37	11.53	10.56	0.97
Middlesex-Somerset-Hunterdon	N.J.	6.37	9.88	6.25	3.63
Santa Cruz-Watsonville	Calif.	6.23	8.35	2.25	6.10
Great Falls	Mont.	6.17	14.42	9.26	5.16
Bryan-College Station	Texas	6.15	7.32	6.11	1.21
Grand Forks	N.D.; Minn.	6.15	11.94	9.01	2.93
Columbia	Mo.	6.08	8.58	5.23	3.35
Rochester	Minn.	6.03	14.78	9.84	4.94
Green Bay	Wis.	5.86	13.73	8.23	5.50
Bellingham	Wash.	5.68	7.40	4.41	2.99
Fargo-Moorhead	N.D.; Minn.	5.48	8.65	6.63	2.02
Charlottesville	Va.	5.33	7.57	4.66	2.91
Champaign-Urbana	Ill.	5.30	12.73	8.36	4.37
La Crosse	Wis.; Minn.	5.25	11.71	6.54	5.17
Corvallis	Ore.	5.22	2.95	4.25	-1.30
San Francisco	Calif.	4.96	8.42	3.05	5.37
Lawrence	Kan.	4.91	11.50	9.84	1.66
Billings	Mont.	4.89	12.70	6.49	6.21
Bismarck	N.D.	4.72	7.04	4.27	2.77
Santa Fe	N.M.	4.72	9.63	9.38	0.25
Madison	Wis.	4.71	11.83	6.74	5.09
San Luis Obispo-Atascadero-Paso Robles	Calif.	4.69	10.06	3.32	6.74
Bloomington-Normal	Ill.	4.55	13.51	9.56	3.95
Missoula	Mont.	4.30	8.45	9.31	-0.86
Dubuque	Iowa	4.18	13.38	9.34	4.04
Burlington	Vt.	4.05	11.50	6.47	5.03
Iowa City	Iowa	2.90	13.11	10.15	2.96

**Metropolitan areas where subprime delinquencies of 60 days or more increased from Dec. 31, 2005, to Dec. 31, 2006, in percentage points*

Note: Figures are based on the value of mortgages outstanding as of December 2006. Mortgage percentages are First American LoanPerformance estimates, based on its projections of the value of loans outstanding; projections are based on its coverage of 50% of subprime-mortgage originators and

of 80% of prime originators; 331 metropolitan areas based on 1999 Census Bureau divisions
Sources: First American LoanPerformance; Census Bureau , and Wall Street Journal Online.

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