MORTGAGE PREPAYMENTS AS PRECURSOR TO THE FINANCIAL CRISIS

Xanthopoulos, Apostolos, Illinois Institute of Technology, Chicago, Illinois, USA

ABSTRACT

Mortgage-backed security prices have depended on interest rates, while idiosyncrasies of prepayments had obscured the effect of rates on portfolio value before the financial crisis. The principal components of balance sheet accounts identified managerial dimensions that could help clarify the portfolio sensitivity to interest rates. The real impact of prepayments and default on the value of equity had appeared negligible since the first two components were correlated, as was required by hedge-accounting rules at that time.

Keywords: *Mortgage-Backed Securities, Prepayments, Default, Principal Component Analysis, Hedging.*

1. INTRODUCTION

Movements in interest rates affect fixed-income portfolios but issuer default severely impacts financial institutions that hold interest-sensitive securities. In addition, institutions risk losses from human error and managerial failure, as well as from inadequate systems, controls and planning. Industry idiosyncrasies beyond the control of any institution blur the boundary between these market, credit and operational risks. For example, the inclusion of liquidation proceeds from default into mortgage prepayments affects models of portfolio values and interest rates that are customarily used to estimate market risk. Traditional risk management methods may have failed to recognize systemic default in case it was mistakenly identified as part of prepayments. That is because the changes in the balance sheet may have been negligible since asset or liability values would have been balanced by hedging items, as required by current accounting standards. This analysis examines a particular prepayment processing event which exemplifies these characteristics. Its timing falls a few years before the financial crisis of 2008 and its existence has been observed in data from a confidential source. The objective is to gauge its effect on the balance sheet of the equivalent portfolio of mortgage-backed securities. Arguably, studies that measured the impact of prepayments on portfolio equity could have pointed to early defaults. In hindsight, this analysis could have lead to a reduction in mortgage-backed security holdings before the financial crisis.

1.1 Mortgage-Backed Security Valuation, Prepayments and Default

Investors in mortgage-backed securities receive cash flows backed by principal and interest payments of mortgages. The estimated MBS price is the expected cash flow discounted at an appropriate interest rate. Cash flows have consisted of scheduled monthly mortgage interest and principal payments, and imprecise prepayments which are hard to predict. Conventional prepayment benchmarks are fraught with arbitrary assumptions. In addition, the discount rate is marred by embedded options to terminate held by borrowers whose mortgages are in an MBS pool. Mortgages are terminated either in default, which is influenced by property values, or in prepayment which depends on the level of interest-rates. But interaction effects between property values and interest rates complicate the theoretical modeling of instantaneous probabilities of default and prepayment. There is also lack of distinction between ‘genuine’ prepayments and actual defaults. Prepayments passed-through to investors include amounts prepaid voluntarily, liquidation amounts from foreclosure and the subsequent sale of properties, and disqualified loan amounts. The Public Security Administration (PSA) prepayment benchmark includes a provision for liquidations of foreclosed properties. However, without information from mortgage-servicing companies it would be difficult to forecast amounts prepaid versus those liquidated. Worse, default and prepayment had become extremely close substitutes as financially distressed borrowers avoided the former through the latter while property values rose. Therefore, high prepayment rates from the period before 2005 simply transferred to high default rates when house prices unexpectedly started falling. The resulting prepayments, though, did not affect portfolio equity values. Equity value ratios did not warn management about the potential of default in conjunction with interest-rate risk.

1.2 Portfolio Balance Sheet and Swap Rate Data

A fixed-income portfolio has market and book values of assets and liabilities and an off-balance-sheet account that holds derivative instrument positions as a risk hedge (mostly interest-rate swaps). This balance sheet resembles a child's swimming pool toy in which owner's equity is the ballast that holds it upright while the durations and convexities of the upper asset and liability compartments are roughly matched. Liabilities are adjusted downward when asset values go down, while assets are sold when liabilities are called or allowed to mature. These practices are partly encapsulated in the spectral decomposition of the correlation matrix between the five main balance sheet accounts in Table 1.

Table 1: Correlation and Eigenvectors of Balance Sheet Accounts in 127 Business Days

Correlation Matrix

	AMV	LMV	HMV	ABV	LBV
AMV	1.0000	0.9995	0.3397	0.9954	0.9954
LMV	0.9995	1.0000	0.3440	0.9965	0.9965
HMV	0.3397	0.3440	1.0000	0.3707	0.3674
ABV	0.9954	0.9965	0.3707	1.0000	0.9999
LBV	0.9954	0.9965	0.3674	0.9999	1.0000

Eigenvectors

	Increase in All Accounts	Market Speculation	Market Value Decline	Market Value Separation	Book Value Separation
AMV	0.4868	0.1282	-0.5718	0.6476	-0.0160
LMV	0.4872	0.1235	-0.4160	-0.7578	0.0072
HMV	0.2200	-0.9750	-0.0314	-0.0002	-0.0030
ABV	0.4886	0.0922	0.4915	0.0661	0.7119
LBV	0.4884	0.0961	0.5073	0.0445	-0.7020
Variance:					
Explained	83.0%	16.8%	0.1%	0.0%	0.0%
Cumulative	83.0%	99.8%	100.0%	100.0%	100.0%

AMV: Asset Market Value
LMV: Liability Market Value
HMV: Hedge Market Value
ABV: Asset Book Value
LBV: Liability Book Value

Principal component analysis (PCA) reveals the internal structure of the data in a way that explains its variance and reduces the dimensionality of variables by transforming them into linear combinations. For the balance sheet accounts in this analysis, PCA eigenvectors reveal the five components listed in Table 1. Each component of the balance sheet appears to measure a distinct managerial characteristic. The cross-multiplication of balance sheet account values with eigenvectors produces component values. The component values are transformed into ranges between zero and one to allow for a comparison to the ratio of equity market to equity book values. This ratio should range between zero and around one by definition. The value of equity ratio is related to the five components of the balance sheet in a forecasting model that includes lagged ratio values. Balance sheet component values are consequently regressed against the level, slope, and curvature of swap rates, and the prepayment indicator variable. Substitution of the second relation into the first leads to the ultimate interest-rate effect on the value of equity.

In the first component the weight for the market and book values of assets and liabilities is 0.49 and for the hedge account it is 0.22. Through cross-multiplication with account values this eigenvector captures a general increase in the balance sheet. The weight for the hedge account in the second component is negative and large (-0.97), signifying potential speculation in an attempt to enhance returns. Hedge accounting is generally required through Financial Accounting Standard (FAS) 133 of June 2000 with respect to fixed-income balance sheets. However, this accounting standard has not successfully imposed strict hedging in every risk management practice. Therefore, in this analysis both hedging and speculation activities may be initially presumed to affect the market value of the hedge account (HMV). In the third

component the market values move in a direction opposite to book values for both assets and liabilities. This third component captures the pure sensitivity of the balance sheet to interest rates which largely excludes the effect of hedging/speculation. Components five and six capture the separation between assets and liabilities in the market values, and book values respectively. These relatively volatile components collectively explain a very small amount of the total variance in the balance sheet.

Figure 1: First Portfolio Balance Sheet Component and Swap Rate Level over Time

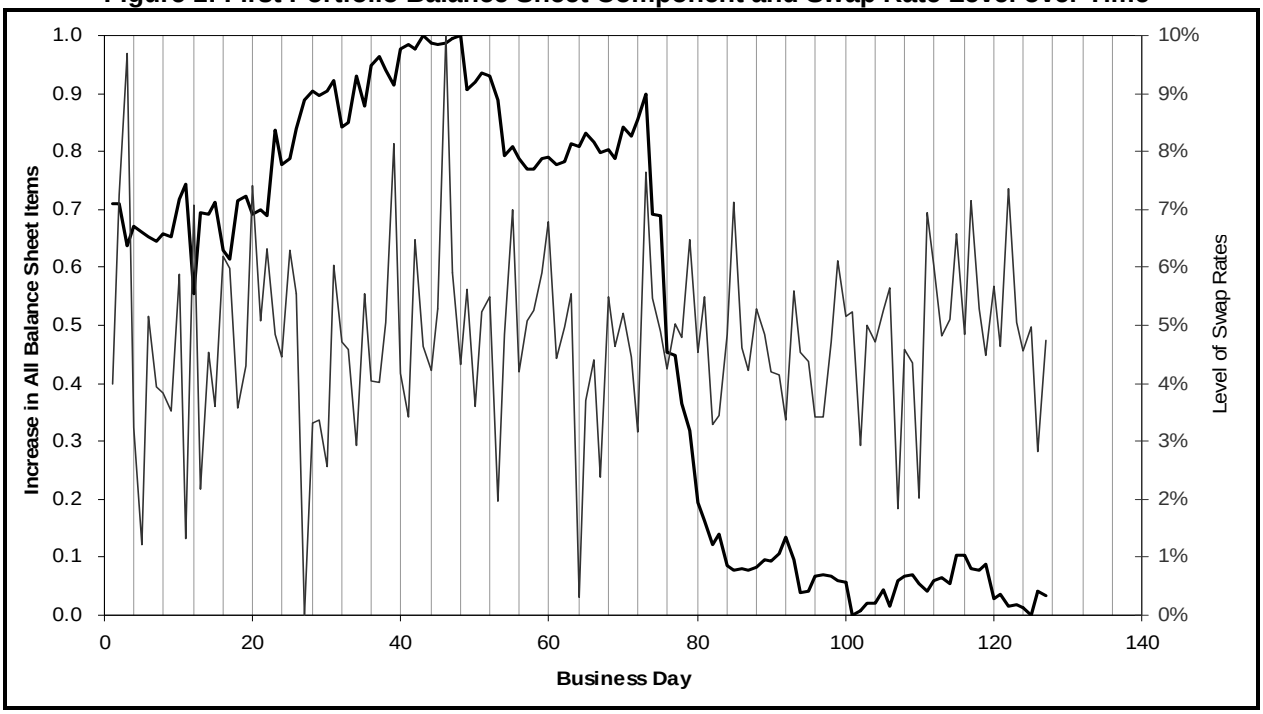


Figure 2: Second Portfolio Balance Sheet Component and Swap Rate Level over Time

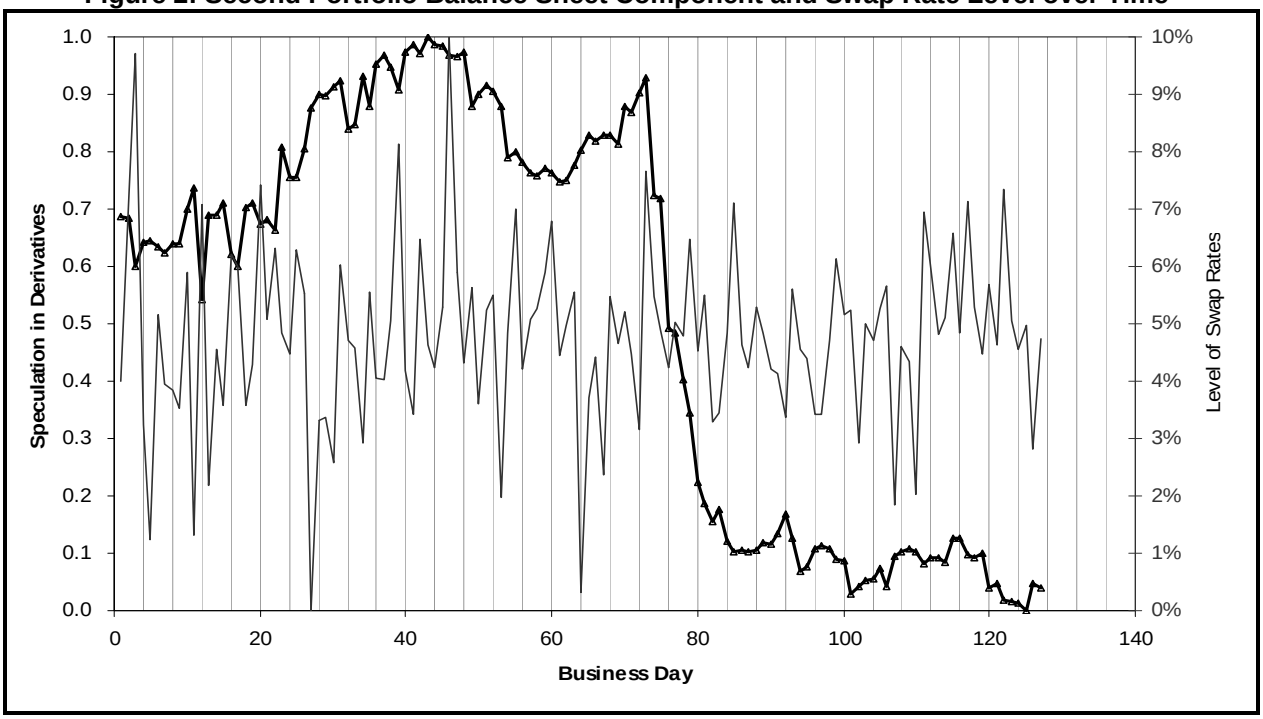
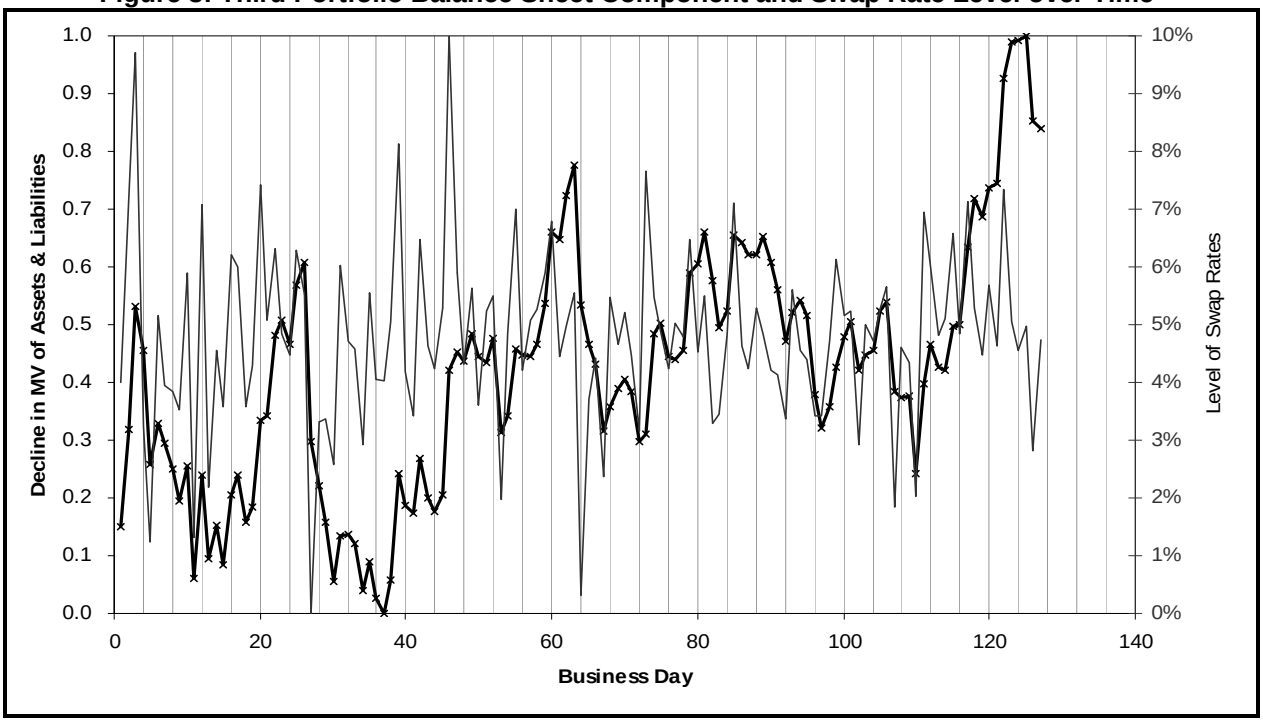


Figure 3: Third Portfolio Balance Sheet Component and Swap Rate Level over Time



The market benchmarks used as independent variables are the fixed rates on interest-rate swaps against floating London Inter-bank Offer rates (LIBOR) for maturities of 3 and 6 months and 1, 2, 3, 5, 10 and 30 years. Principal component analysis finds the level, slope and curvature of changes in the US LIBOR swap curve. Most of the variation is captured by the three eigenvectors in Table 2. The cross-multiplication of changes in daily swap rates with eigenvectors in Table 2 produces the variables 'Level', 'Slope' and 'Curvature' which are then adjusted to range between zero and ten percent. An increase in the variable 'Level' captures higher swap rates across all maturities. An increase in 'Slope' describes higher long maturities and lower short maturities. 'Curvature' increases take place when the volatility of interest rates generally goes up, raising long and short rates and lowering intermediate maturity rates.

The data used are six months of daily balance sheets and swap rate values which amount to 127 business days. The prepayment event occurs around day 77 and corresponds to an abrupt reduction in assets and proportional adjustment in liabilities. The balance sheet response to the prepayment event is mostly captured by the first component (an increase in all accounts describes 83% of the balance sheet variation in Table 1) and the level of swap rates (an increase in swap rates of all maturities describes 75.1% of rate variation in Table 2). An abrupt decline around the day of prepayments obstructs the relation between the level of swap rates and the balance sheet in Figure 1. This first component of the balance sheet is primarily affected by this event which due to its size may have been substituting for a large amount of postponed mortgage defaults. In Figure 2 the second component (hedging/speculation) captures 16.8% of the variation in the balance sheet and responds to the prepayment event more than any movement in the level of interest rates. This component should not respond to prepayments at all, unless it compensates for them through an increase in the market value of the hedge account. Such increase would move the second component value down (please refer to the eigenvectors in Table 1 and the coefficient values in Table 5). A total 99.8% of the variation in the balance sheet is thus affected by this prepayment event, but the net effect on equity becomes relatively small (please refer to Figure 4). The third component (decline in market values and increase in book values) describes a mere 0.1% of the balance sheet variation and seems unaffected by the prepayment event. As a result market value declines track the level of swap rates closer than in other components, in Figure 3. An increase in swap rates lowers the present value of cash flows for assets and liabilities and moves the third-component value up. The effect of this increase should be a small decline in portfolio equity since the asset weight (-0.57) is larger that the liability weight (-0.42) in the third eigenvector in Table 1.

Table 2: Eigenvectors of Swap Rate Changes in 127 Business Days

Swap Rates	Level	Slope	Curvature
3 Month	0.1070	-0.8658	0.3033
6 Month	0.3429	-0.4012	-0.2881
1 Year	0.3805	-0.0332	-0.4017
2 Year	0.3882	0.0661	-0.3189
3 Year	0.3974	0.1130	-0.1486
5 Year	0.3974	0.1540	0.1006
10 Year	0.3754	0.1559	0.4177
30 Year	0.3444	0.1526	0.5960
Variance Explained:	75.1%	14.2%	8.5%
Cumulative:	75.1%	89.3%	97.9%

2. STATISTICAL ESTIMATION

In the analogy of the balance sheet and the pool toy the water waves describe the level, slope and curvature of the swap curve. Asset-liability practices may have primarily gauged the effect of interest-rate waves on the portfolio equity value while this pool was being emptied. The ratio of market to book value of equity is a widely used measure of balance sheet stability. A ratio less than 1 indicates a decline of market value below book value. Changes in the value of equity ratio are linked to market forces after the impact of managerial responses. Principal components of the balance sheet help discern dimensions along which portfolio managers respond to changes in interest rates. Empirically, each of these portfolio management dimensions relates linearly to the level, slope and curvature of interest rates after considering the disruption introduced by the prepayments process. Final market and prepayment effects on the value of equity ratio are estimated in three stages. In the first stage the ratio of market to book value of equity (*VER*) is regressed against components of the balance sheet in model *(1)*. In the second stage, each balance sheet component is regressed against swap components in *(2)*. In the third state the substitution of equations *(2)* into *(1)* yields the final effect of swap rate components and the prepayment event on the value of equity ratio for relations *(3)* and *(4)*.

$$VER(t) = \beta_0 + \sum_{j=1}^{5} \beta_j BSC_j(t) + \delta\, VER(t-1) + u_t \qquad (1)$$

$VER(t)$: Value of Equity Ratio (Market Value/Book Value)

$BSC_j(t)$: Principal Component j of Portfolio Balance Sheet $(j = 1,...,5)$

$$BSC_j(t) = a_{j,0} + a_{j,1} I_{[Day_t \geq 77]}(t) + b_{j,1} Level(t) + b_{j,2} Slope(t) + b_{j,3} Curvature(t) + c_j Day(t) + \varepsilon_j(t) \qquad (2)$$

$$VER(t) = \underbrace{\beta_0 + \boldsymbol{\beta}^{\mathsf{T}}\boldsymbol{\alpha}_0 + \boldsymbol{\beta}^{\mathsf{T}}\boldsymbol{\alpha}_1 I_{[Day_t \geq 77]}(t) + \boldsymbol{\beta}^{\mathsf{T}}\mathbf{c}\, Day(t)}_{\gamma_0} + \underbrace{\boldsymbol{\beta}^{\mathsf{T}}\mathbf{b}_1}_{\gamma_1} Level(t) + \underbrace{\boldsymbol{\beta}^{\mathsf{T}}\mathbf{b}_2}_{\gamma_2} Slope(t) +$$

$$+ \underbrace{\boldsymbol{\beta}^{\mathsf{T}}\mathbf{b}_3}_{\gamma_3} Curvature(t) + \delta\, VER(t-1) + \underbrace{\boldsymbol{\beta}^{\mathsf{T}}\boldsymbol{\varepsilon}(t) + u(t)}_{error} \qquad (3)$$

$$\boldsymbol{\beta}^{\mathsf{T}} = [\beta_1 \quad \beta_2 \quad \ldots \quad \beta_5]; \quad \boldsymbol{\alpha}_0 = \begin{bmatrix} \alpha_{1,0} \\ \alpha_{2,0} \\ \ldots \\ \alpha_{5,0} \end{bmatrix}; \quad \boldsymbol{\alpha}_1 = \begin{bmatrix} \alpha_{1,1} \\ \alpha_{2,1} \\ \ldots \\ \alpha_{5,1} \end{bmatrix}; \quad \underset{i=1,2,3}{\mathbf{b}_i} = \begin{bmatrix} b_{1,i} \\ b_{2,i} \\ \ldots \\ b_{5,i} \end{bmatrix}; \quad \mathbf{c} = \begin{bmatrix} c_1 \\ c_2 \\ \ldots \\ c_5 \end{bmatrix}; \quad \boldsymbol{\varepsilon}(t) = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \ldots \\ \varepsilon_5 \end{bmatrix}$$

$$VER(t) \equiv \frac{MVE(t)}{BVE(t)} = \frac{AMV(t) - LMV(t) + HMV(t)}{ABV(t) - LBV(t)} = \gamma_0 + \gamma_1 Level(t) + \gamma_2 Slope(t) + \gamma_3 Curvature(t) + \delta\, VER(t-1)$$

$$\gamma_0 = \beta_0 + \boldsymbol{\beta}^{\mathbf{T}}\boldsymbol{\alpha}_{\mathbf{0}} + \boldsymbol{\beta}^{\mathbf{T}}\boldsymbol{\alpha}_{\mathbf{1}} I_{[Day_t \geq 77]}(t) + \boldsymbol{\beta}^{\mathbf{T}}\mathbf{c} Day(t);\ \ \gamma_1 = \boldsymbol{\beta}^{\mathbf{T}}\mathbf{b}_{\mathbf{1}};\ \ \gamma_2 = \boldsymbol{\beta}^{\mathbf{T}}\mathbf{b}_{\mathbf{2}};\ \ \gamma_3 = \boldsymbol{\beta}^{\mathbf{T}}\mathbf{b}_{\mathbf{3}} \qquad (4)$$

2.1 Balance Sheet Components

In the first stage portfolio managers are presumed to make decisions along dimensions in Table 1. Almost all of the variance in the portfolio accounts is explained by an increase in the overall balance sheet (*BSC*$_1$), a decrease in the market value of hedging/speculation (*BSC*$_2$), and a relative market value decline (*BSC*$_3$). These decisions affect *VER*(*t*) while the lagged variable *VER*(*t-1*) captures first-order autoregressive effects (*R*-square is 0.9999, *F*-significance is 0.0000, and the significance of coefficient t-statistics is less than 0.0200 in equation *1a*). The average value of equity ratio is 85.75 cents on the dollar. If components 1 and 2 both went up by a maximum of 1 the ratio would go down by 47.96 – 49.03 = -1.07 which is not entirely risk-neutral. Table 3 summarizes the effect of components 1 and 2. In the absence of hedge-accounting the portfolio manager could have raised the value of equity ratio by increasing all balance sheet accounts including hedging/speculation. These actions would have increased portfolio market risk which the 0.9987 correlation between components 1 and 2 in Table 4 is preventing. The balance sheet cannot be improved by raising all accounts and also increasing the market value of hedging/speculation (I and IV). Instead, the value of equity ratio *VER*(*t-1*) remains largely constrained according to the requirements for hedge accounting as balance sheet accounts decline and the market value of speculation increases (III and IV). An increase in the value of the third component by 1 (market value of assets and liabilities declines relative to book value) subtracts 3.78 cents from the ratio. Book values go up and market values down when securities are acquired and obligations issued in a declining market with high interest rates. Acquiring securities at low prices has a negative effect on the value of equity ratio as assets decline more than liabilities. Also, component 3 is negatively correlated with 1 and 2 in Table 4. Therefore, an increase in 'buying low' presupposes operating in quadrants III and IV which constrain the effect of prepayments on *VER*(*t*). Only 0.1% of the variation in the balance sheet is attributed to the third component. Finally, an increase in the market value of assets relative to liabilities (component 4) raises the value of equity ratio by 10.00 cents, while an increase in the book value of assets relative to liabilities (component 5) lowers it by 6.24 cents. Despite their substantial effect on *VER*(*t*) these components explain a very small portion of the balance sheet variance.

$$VER(t) = 0.8575 + 0.4796 BSC_1(t) - 0.4903 BSC_2(t) - 0.0378 BSC_3(t) + 0.1000 BSC_4(t) - 0.0624 BSC_5(t) + \\ + 0.0038\, VER(t-1) + u(t) \qquad (1a)$$

Table 3: Change in First Two Components of the Balance Sheet and Effect on Value of Equity Ratio

$\rho_{BSC_1,BSC_2} = 0.9987$	**All Balance Sheet Accounts: *BSC*$_1$** $w_k \approx 0.49, k \in \{AMV, LMV, ABV, LBV\}$ $\beta_1 = 0.4796$	**Market Hedging/Speculation: *BSC*$_2$** $w_{HMV} = -0.9750$ $\beta_2 = -0.4903$
Component Value Goes Up	(I) $AMV \uparrow\ LMV \uparrow\ HMV \uparrow\ ABV \uparrow\ LBV \uparrow$ $VER \uparrow$	(II) $HMV \downarrow\downarrow$ $VER \downarrow$
Component Value Goes Down	(III) $AMV \downarrow\ LMV \downarrow\ HMV \downarrow\ ABV \downarrow\ LBV \downarrow$ $VER \downarrow$	(IV) $HMV \uparrow\uparrow$ $VER \uparrow$

Figure 4: Value of Equity Ratio against Balance Sheet Components over Time

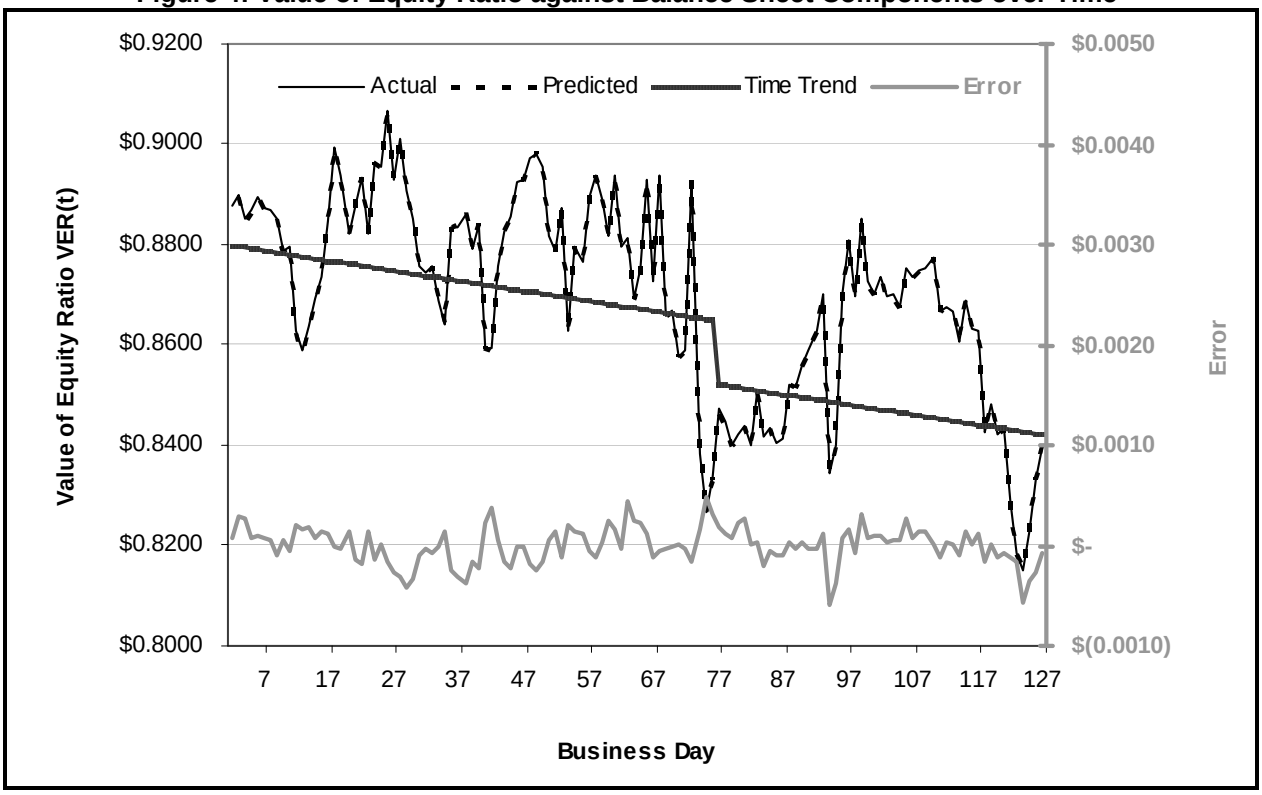


Table 4: Correlation between Components of the Balance Sheet

	Increase in All Accounts	Market Speculation	Market Value Decline	Market Value Separation	Book Value Separation
	$BSC_1(t)$	$BSC_2(t)$	$BSC_3(t)$	$BSC_4(t)$	$BSC_5(t)$
$BSC_1(t)$	1.0000				
$BSC_2(t)$	0.9987	1.0000			
$BSC_3(t)$	-0.5700	-0.5875	1.0000		
$BSC_4(t)$	0.8045	0.8045	-0.5020	1.0000	
$BSC_5(t)$	0.9295	0.9223	-0.4658	0.7441	1.0000

2.2 Interest Rate Effects

The second stage of this analysis associates the components of the balance sheet to changes in interest rates. The effect of rate levels on the first three components of the balance sheet was illustrated in Figure 1, 2 and 3. Additional variables in this estimation include the prepayment indicator variable, the slope and curvature of the swap rate curve, and a day count. The indicator variable captures the change in balance sheet components due to prepayments. Each of the five balance sheet components is therefore regressed against five independent variables: the Prepayment Indicator variable $I_{[\,]}$, the Level, Slope, and Curvature of the swap rate maturity curve, and the Day count. Estimated models correspond to equation (2) above. The results in Table 5 and 6 confirm that prepayments affect all balance sheet components except 'Market Value Decline' which only goes up with the level of interest rates and has a positive trend.

Based on Table 1 above the effect of prepayments on the first component is direct. Prepayments reduce the value of assets which are duration-matched to lower liabilities. This is in contrast to the second component which tracks hedging items primarily for assets and may be absorbing the impact of prepayments due to FAS 133. The counteracting effect between the first two components constrains the impact of prepayments on the market value of equity. Recent findings point to the substitution of default

with large prepayments in a rising home-price environment. General knowledge of portfolio management practices should help attribute the correlation between assets/liabilities and hedging/speculation to hedge accounting which requires regression/correlation studies between hedged assets/liabilities and hedging items. Therefore, this accounting standard may have effectively mitigated early signals of default in the underlying mortgages.

The decline in the market value relative to book value of assets and liabilities (third component) is affected by the level of swap rates and has a positive time trend. This negative impact of rising interest rates becomes stronger over time. The decline in the market value of assets and liabilities as interest rates rise can only be discerned after the first two components are explicitly accounted for. Still, declining market values explain only 0.1% of the variability in the balance sheet. The curvature in swap rates affects the last two components which describe the apparent separation between assets and liabilities for market values and book values. The volatility in swap rates and the prepayment event affect swaption contract prices, the consequence of which is most likely accounted for in the last two components.

Table 5: Estimated Coefficients of Balance Sheet Component Equations

	Increase in All	Market	Market Value	Market Value	Book Value
Equation:	**Items**	**Speculation**	**Decline**	**Separation**	**Separation**
Variable:	$BSC_1(t)$	$BSC_2(t)$	$BSC_3(t)$	$BSC_4(t)$	$BSC_5(t)$
Intercept	0.7756	0.7743	0.0379	0.6609	0.5502
Prepayment	-0.7604	-0.7443	0.0035	-0.3455	-0.3509
Level	0.3421	-0.0072	3.0096	-0.6626	-0.4175
Slope	-0.7589	-0.5990	-0.4936	-0.2111	0.4392
Curvature	0.7002	0.5423	0.6574	2.1550	0.9584
Day	0.0006	0.0009	0.0037	0.0002	-0.0008
R Square	0.9186	0.9072	0.4778	0.6009	0.8160

Table 6: Significance of t-statistics for Balance Sheet Component Equations

	Increase in All	Market	Market Value	Market Value	Book Value
Equation:	**Items**	**Speculation**	**Decline**	**Separation**	**Separation**
Variable:	$BSC_1(t)$	$BSC_2(t)$	$BSC_3(t)$	$BSC_4(t)$	$BSC_5(t)$
Intercept	0.0000	0.0000	0.4906	0.0000	0.0000
Prepayment	0.0000	0.0000	0.9489	0.0000	0.0000
Level	0.7702	0.9952	0.0758	0.6612	0.6912
Slope	0.4424	0.5545	0.7281	0.8684	0.6201
Curvature	0.2391	0.3738	0.4415	0.0056	0.0737
Day	0.2268	0.0925	0.0000	0.7423	0.0646
Significance F	0.0000	0.0000	0.0000	0.0000	0.0000

2.3 The Value of Equity Ratio

The third stage of this analysis reveals the ultimate effect of swap rates and prepayments on the value of equity ratio in relation *(3a)*. The intercept value $\gamma_0 = 0.8674$ is higher than $\beta_0 = 0.8575$ because of the non-zero intercepts in interest-rate effects, prepayments that affect all balance sheet components except 'Market Value Decline' and the time trend which significantly impacts *VER*(*t*) as shown in Figure 4. The additional (γ_0 - β_0) = 0.99 cents toward the average value of equity ratio is attributed to interest rates (0.0227) prepayments (-0.0126) and the time trend (-0.0002). For a maximum 10% increase in the level of swap rates there is a 0.137 cent increase in the value of equity ratio (swap rate components range between 0 and 10%). Therefore, rate increases have a small positive impact on the ratio through the coefficient γ_1 = [0.4796 -0.4903 -0.0378 0.1000 -0.0624] x [0.3421 -0.0072 3.0096 -0.6626 -0.4174]^T = 0.0137. For a 10% increase in the slope of rates there is a 1.002 cent increase in the value of equity ratio. Slope has a negative coefficient γ_2 = [0.4796 -0.4903 -0.0378 0.1000 -0.0624] x [-0.7589 -0.5590 -0.4936 -0.2111 -0.4392]^T = -0.1002. This slope in swap rates of different maturities is not statistically significant in any balance sheet component of Table 6. For a 10% increase in the curvature of rates there

is a 2.009 cent increase in the value of equity ratio. Convex rates have a positive impact γ_3 = [0.4796 -0.4903 -0.0378 0.1000 -0.0624] x [0.7002 0.5423 0.6574 2.1550 0.9584]^T = 02009. The curvature in swap rates raises the values of the last two components in Table 5 and 6. However, the separation between the book values of assets and liabilities partly counteracts the separation between market values of the same (please refer to coefficients -0.0624 and 0.1000 in *1a*). The second and third components primarily produce the negative trend in $\boldsymbol{\beta}^T\mathbf{c}$ = [0.4796 -0.4903 -0.0378 0.1000 -0.0624] x [0.0006 0.0009 0.0037 0.0002 -0.0008]^T = -0.0002.

$$VER(t) = \underbrace{0.8575 + 0.0227 - 0.0126 I_{[Day_t \geq 77]}(t) - 0.0002 Day(t)}_{\gamma_0 = 0.8674} + \underbrace{0.0137}_{\gamma_1} Level(t) - \underbrace{0.1002}_{\gamma_2} Slope(t) + \\ + \underbrace{0.2009}_{\gamma_3} Curvature(t) + \underbrace{0.0038}_{\delta} VER(t-1) + \underbrace{\boldsymbol{\beta}^T \boldsymbol{\varepsilon}(t) + u(t)}_{error} \qquad (3a)$$

Prepayments reduce the value of equity ratio by only 1.26 cents on the dollar. This is a small effect in comparison to the -76.04 and -74.43 cent individual reduction in the first two components in Table 5. But the impact of components $BSC_1(t)$ and $BSC_2(t)$ on the value of equity ratio cancels each out and results in this small overall effect of prepayments. The high correlation between these two components effectively cushions the value of equity ratio from default episodes that may have initially manifested themselves as very large prepayments. In this and other instances, the market and book values of mortgage-backed securities on the balance sheet may have declined without any clear indication of balance sheet instability in the value of equity ratio. In the alternative scenario, the value of equity ratio would have fallen initially as the portfolio operated in Quadrant III of Table 3 above. There would be no Quadrant IV consequence as the absence of correlation requirements between assets and the hedge account would have left hedging/speculation unaffected during this large prepayment event. In that case the abrupt decline in the value of equity ratio could have served as a signal toward the desirability of a timely reduction in portfolio holdings for mortgage-backed securities.

3. CONCLUSION

Market, credit and operational risks intermingled in early mortgage defaults that appeared to be only large prepayments. The restatement of assets, liabilities and hedges in terms of principal components would isolate the effect of potential default on equity values of mortgage portfolios. Results from a specific event show that 98% of the variability in the balance sheet would have been affected by large prepayments. However, because the first and second components of the balance sheet generally work in opposite directions their impact on the ratio of market to book values would have been mitigated, while the effect of level, slope and curvature of swap rates would have remained mild. The increase in hedging/speculative market values at the time of prepayment processing can be attributed to accounting rule FAS 133 which imposes a high correlation between hedged positions and hedging items. In reference to the mortgage crisis, any method of assessing performance for fixed-income portfolios should have already taken into consideration counteractive effects between assets and hedged items which could disguise the impact of large prepayments and subsequent default. A methodology that tracks the fluctuation in components of the balance sheet could discern the effect of early default in mortgages within the environment of high correlation between assets and hedging items. On the other hand, the sole use of the value of equity ratio would have most likely promoted the industry-wide march toward a crisis in mortgage-backed securities.

BIBLIOGRAPHY

Archer, Wayne R., David Ling, and Gary McGill. "Prepayment Risk and Lower Income Borrowers," *Joint Center for Housing Studies*, Sep. 2001, 1-41.

Bhardwajy, Geetesh, and Rajdeep Sengupta. "Did Prepayments Sustain the Subprime Market?" *Research Division, Federal Reserve Bank of St. Louis Working Paper 2008-039A,* Oct. 2008, 1-44.

Campbell, John Y., Andrew W. Lo, and A. Craig MacKinlay. The Econometrics of Financial Markets, Princeton: Princeton University Press, 1997.

DeLiban, Nancy and Brian P. Lancaster. "Understanding and Valuing Mortgage Security Credit," The Handbook of Mortgage-Backed Securities, ed. Frank J. Fabozzi, Chicago: Probus Publishing, 1995, 449-487.

Dillon, William R. and Matthew Goldstein. Multivariate Analysis: Methods and Applications, New York: John Wiley & Sons, 1984.

Fabozzi, Frank J., and Franco Modigliani. Mortgage and Mortgage-Backed Securities Markets, Boston: Harvard Business School Press, 1992.

Gangwani, Sunil. "MBS Structuring: Concepts and Techniques." *The Securitization Conduit*, Vol. 1, 1998, 26-37.

Golub, Bennett W. and Leo M. Tilman. "Measuring Yield Curve Risk Using Principal Component Analysis, Value at Risk, and Key Rate Durations." *Journal of Portfolio Management*, Vol. 24, Summer 1997, 72-84.

Report of Survey Results. "The Impact of FAS 133 on the Risk Management Practices of End Users of Derivatives," *Association for Financial Professionals*, Sep 2002, 1-15.

Sharpe, William. "A Simplified Model for Portfolio Analysis." *Management Science*, Vol. 9, Jan. 1963, 277-293.

Sharpe, William. "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk." *The Journal of Finance*, Vol. 19, Sep. 1964, 425-442.

Taleb, Nassim N. The Black Swan: The Impact of the Highly Improbable, New York: Random House, 2007.

Tuckman, Bruce. Fixed Income Securities: Tools for Today's Markets, New York: John Wiley & Sons, 2002.