"Spiral-up": Review of *The Capital and Loss Assessment under Stress Scenarios* (CLASS) Model

Presentation to the Federal Reserve Bank of Cleveland

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Disclaimer: The views expressed in this presentation are those of the presenter and do not necessarily reflect those of the Federal Reserve Bank, the Federal Reserve System, or any other entities. The tables, figures, and facts about the CLASS model are sourced from the FRB NY Staff Report No. 663, revised in July 2015.

Abstract

This presentation describes the CLASS Model, a top-down capital stress testing framework that projects the effect of macroeconomic scenarios on U.S. banking firms. We overview the results and summarize key strengths and limitations of the model. We discuss possible enhancements and interesting tests. We hypothesize a circular causality that can lead to a credit bubble.

Contents

Preface – Quiz

Quiz: There is an investor. This investor believes that the likelihood for imminent crisis is low, while other things are uncertain. This investor wants to construct a portfolio that would lose severely in an imminent crisis scenario, but would have stable returns for all other scenarios. So this investor buys a security that provides good carry and has diversified specific risk. What could this security be?

Preface – Answer to Quiz

Answer: CLO/CDO/ABS equity or mezzanine tranche. This investor effectively sells a put option on systemic risks by buying diversified leveraged debt. This investor expects a risk neutral spread, exceeding actual loss.

If other market participants agree that the chance for imminent crisis is low, they would bring more inflows to systemic risk securities, which would further lower the risk neutral probability for imminent crisis.

Preface – “Spiral-Up”

Circular causality can drive asset prices up into a hyper-bubble state.

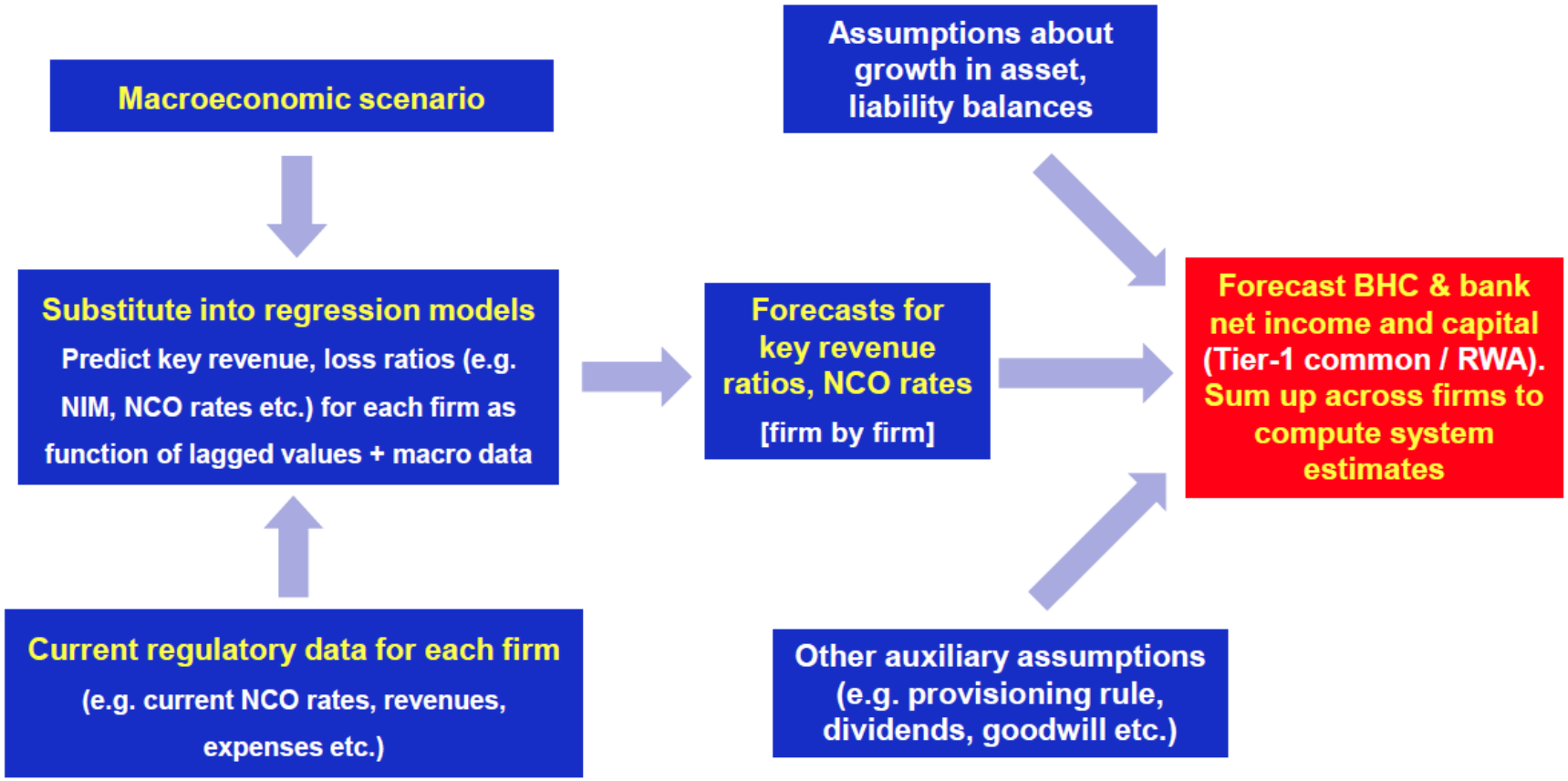
The expectation of a low probability of an imminent crisis is self-fulfilled up. Then, leveraged debt becomes an even more lucrative choice of investment.

Model Description

Model Description

- Simple top-down econometric model to project the effect of macroeconomic stress on US banking firms
- CLASS model has low model risk
- Model uses public data
- CLASS model is inexpensive
- Flexible & transparent for 'What-if' analyses
- Can be further optimized for regional and local/community banks

Model Description - Structure



Source: FRB NY SR 663

Model Description - Structure

- A parsimonious set of macroeconomic variables are regressed to financial ratios
- Macro stresses are geared into the equations
- Current firm data are scaled by the stressed financial ratios for each firm
- Model sums up the projections of individual firms to estimate the capital shortfall of the U.S. banking system

Model Description – Stress

Macro scenarios: Selected variables

	Historical	Baseline			Crisis Redux		
	2013 Q3	First 3Q	Middle 3Q	Last 3Q	First 3Q	Middle 3Q	Last 3Q
Unemployment rate (end)	7.30	7.00	6.70	6.30	7.80	9.70	12.40
GDP growth (%, ann)	1.86	2.59	2.89	2.89	0.47	(2.87)	(1.54)
Equity prices (% ch)	19.44	(0.70)	4.00	4.08	(12.39)	(31.82)	19.39
Home price growth (% ch, ann)	10.90	2.52	2.64	3.07	(15.40)	(21.73)	(11.74)

Note: The historical data and baseline scenario reported here are based on the supervisory scenarios data posted by the Federal Reserve on November 1 2013 (see http://www.federalreserve.gov/bankinforeg/stress-tests-capital-planning.htm). They do not reflect any subsequent data revisions.

Source: FRB NY SR 663

- Macro stresses are sufficiently conservative
- Stressed unemployment rate: up to 12.40%
- Stressed equity prices: down to -31.82%

Model Description – Coverage

- CLASS model covers 200 BHCs and independent banks
- CLASS model creates a hypothetical 201st firm representing the aggregate of the rest of the U.S. banking system

Model Description – Comparison

	CLASS Model	***DFAST/CCAR***
Modeling Approach	Top-down models based on aggregated outcomes (e.g., net charge-offs) for broad income categories and loan and securities securities portfolios	Bottom-up models focused on the risk characteristics of individual loans, securities, and trading positions
Data	Publicly available balance sheet and income statement regulatory report data from Call and Y-9C filings	Detailed supervisory information from individual BHCs, often at the level of individual loans or securities
Coverage	The 200 largest BHCs and independent banks, plus the rest of the industry. Results reported at the aggregate industry level	30 BHCs with assets exceeding $50 billion (starting in 2014). Results reported in the aggregate and at the individual BHC level
Trading and Counterparty	Trading revenue modeled based on the macroeconomic scenario	Separate instantaneous global market shock on the trading and counterparty positions of the 6 largest BHCs

Source: FRB NY SR 663

Methodologies & Assumptions

"the overall margin of conservatism should adequately account for all uncertainties and weaknesses in the quantification process" (Basel Coordination Committee Bulletin 13-5, Federal Reserve System)

Methodologies - Regression

- Each regression equation models a key income or expense ratio as a function of an autoregressive term and nine macroeconomic variables
- Some equation models are estimated using pooled quarterly data on individual firms
- Other equation models are estimated as time-series models summed up across all BHCs and banks (General form)

Methodologies – Time Series

- General form, across firms

$$ratio_t = \alpha + \beta_1 ratio_{t-1} + \beta_2 macro_t + \varepsilon_t$$

- Individual firm

$$ratio_{t,i} = \alpha + \beta_1 ratio_{t-1,i} + \beta_2 macro_{t,i} + \beta_3 X_{t,i} + \varepsilon_t$$

  - Ratios(t,i): Revenue, Loss Rate, etc.
  - X(t,i): Firm-specific characteristics (e.g. balance sheet ratios of RE loans, CRE, Consumer and firm size). These are important controls.

Source: FRB NY SR 663

Methodologies – PPNR

- 5 of the 6 PPNR equations are estimated by weighted least squares using the pooled regression approach
- These PPNR equations reflect individual firm characteristics.
- For example, net interest margin and non-interest expense categories vary with the banks' business focus.

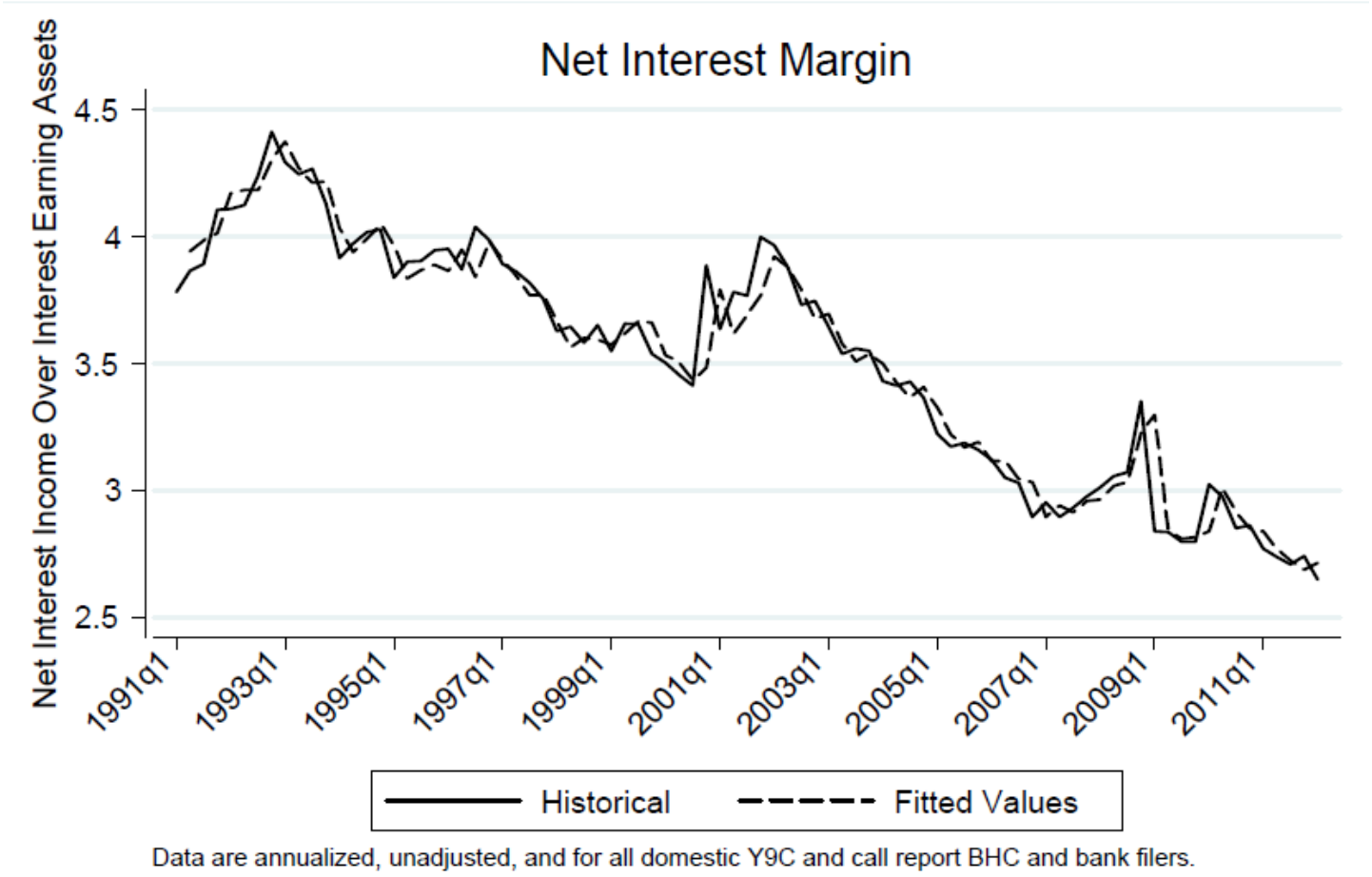
Methodologies – PPNR

Appendix Table 1: PPNR Components and Securities Specifications

	Net Interest Margin	Noninterest Nontrading Income Ratio	Return on Trading Assets	Compensation Nonint. Exp. Ratio	Fixed Asset Nonint. Exp. Ratio
Macroeconomic variables					
Annualized Real GDP growth (%)					0.000552
					(0.000665)
Term Spread (10 year minus 3 months, pct. pt)	0.0426***				
	(0.0139)				
3 Month Treasury Yield (%)	0.0220**				
	(0.0106)				
Quarterly change in 10 year Treasury yield (pct. pt)					
Stock Market returns (quarterly, %)		0.00407*		0.00345***	
		(0.00245)		(0.000886)	
Quarterly change in BBB bond spread (pct. pt)			-0.671		
			(0.452)		
Quarterly change in BBB Spread if change is positive (else zero)			-2.559***		
			(0.588)		
Quarterly change in BBB Spread if change is positive x Risky AFS Ratio					

Source: FRB NY SR 663

Methodology – Fitted NIM



Source: FRB NY SR 663

Methodologies – NCO

- Each of 15 equations of Net Charge Off rates are based on loan categories (e.g. first-lien, junior-lien, construction, consumer, etc.)
- The equation models for residential mortgage loans include a dummy variable for whether the change in the home price growth rate is negative. It captures non-linear behaviors.

Methodologies – NCO of RE Loans

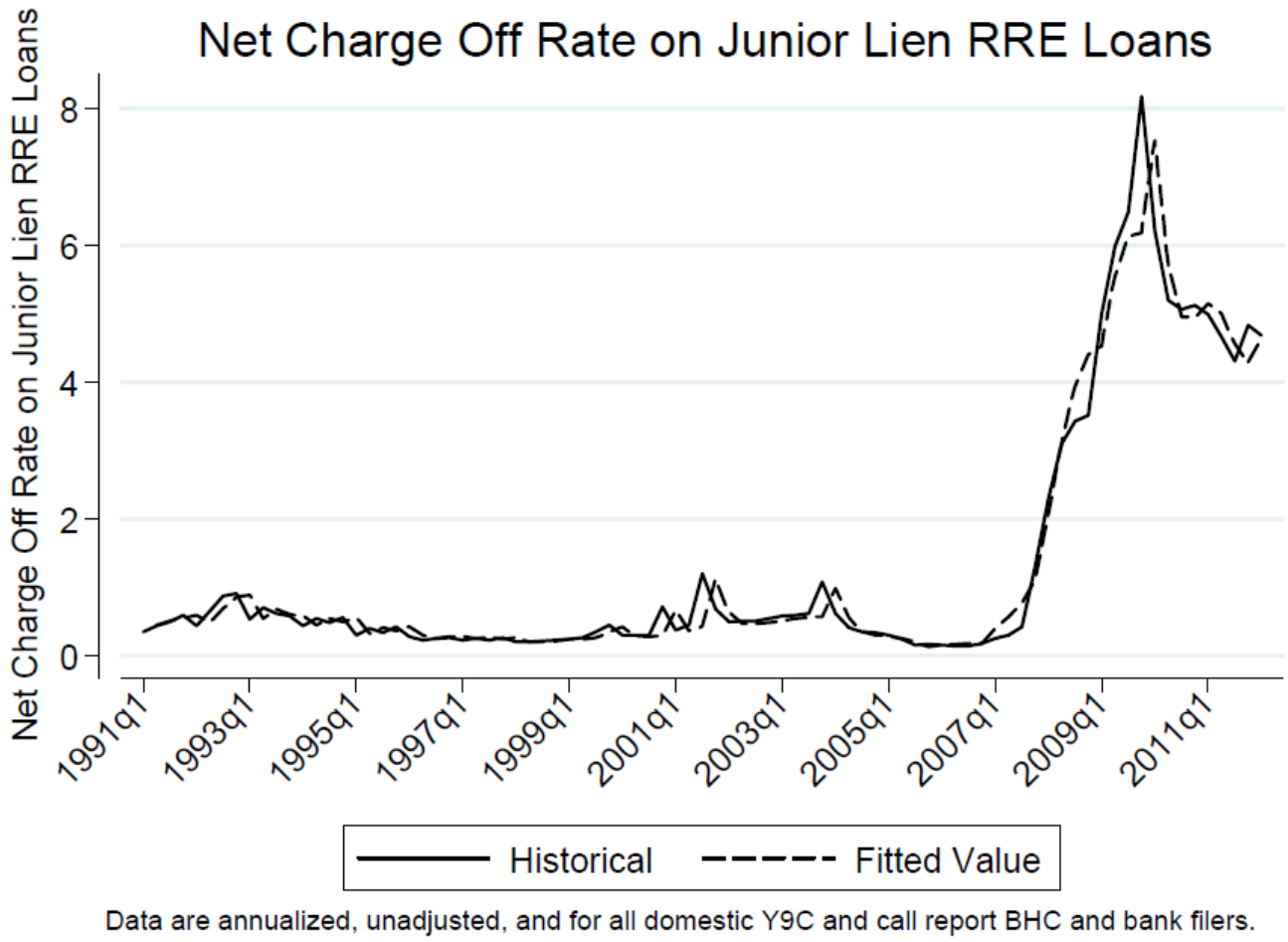
Panel A. Real Estate and Commercial Loans

	Residential real estate			Commercial real estate		
	First Lien Residential	Junior Lien Residential	HELOC	Construction	Multifamily	Nonfarm Nonresidential
Lagged dependent variable	0.884***	0.867***	0.893***	0.801***	0.776***	0.823***
	(0.0776)	(0.0847)	(0.0501)	(0.0887)	(0.105)	(0.0990)
Home price growth (%, year-over-year)	-0.00147	-0.0153	-0.00492			
	(0.00200)	(0.0109)	(0.00330)			
Home price growth if growth is negative (else zero)	-0.0192**	-0.0671***	-0.0284***			
	(0.00756)	(0.0212)	(0.00831)			
Commercial Property Price Growth if negative (else zero)				-0.0473**	-0.0114**	-0.00928***
				(0.0222)	(0.00467)	(0.00343)
Annualized change in Unemployment (%)						

Source: FRB NY SR 663

- Note the differences in coefficients:
  - HELOC, Junior Liens vs First Liens
  - Construction loans vs Multifamily

Methodology – NCO Junior Mortgage



Source: FRB NY SR 663

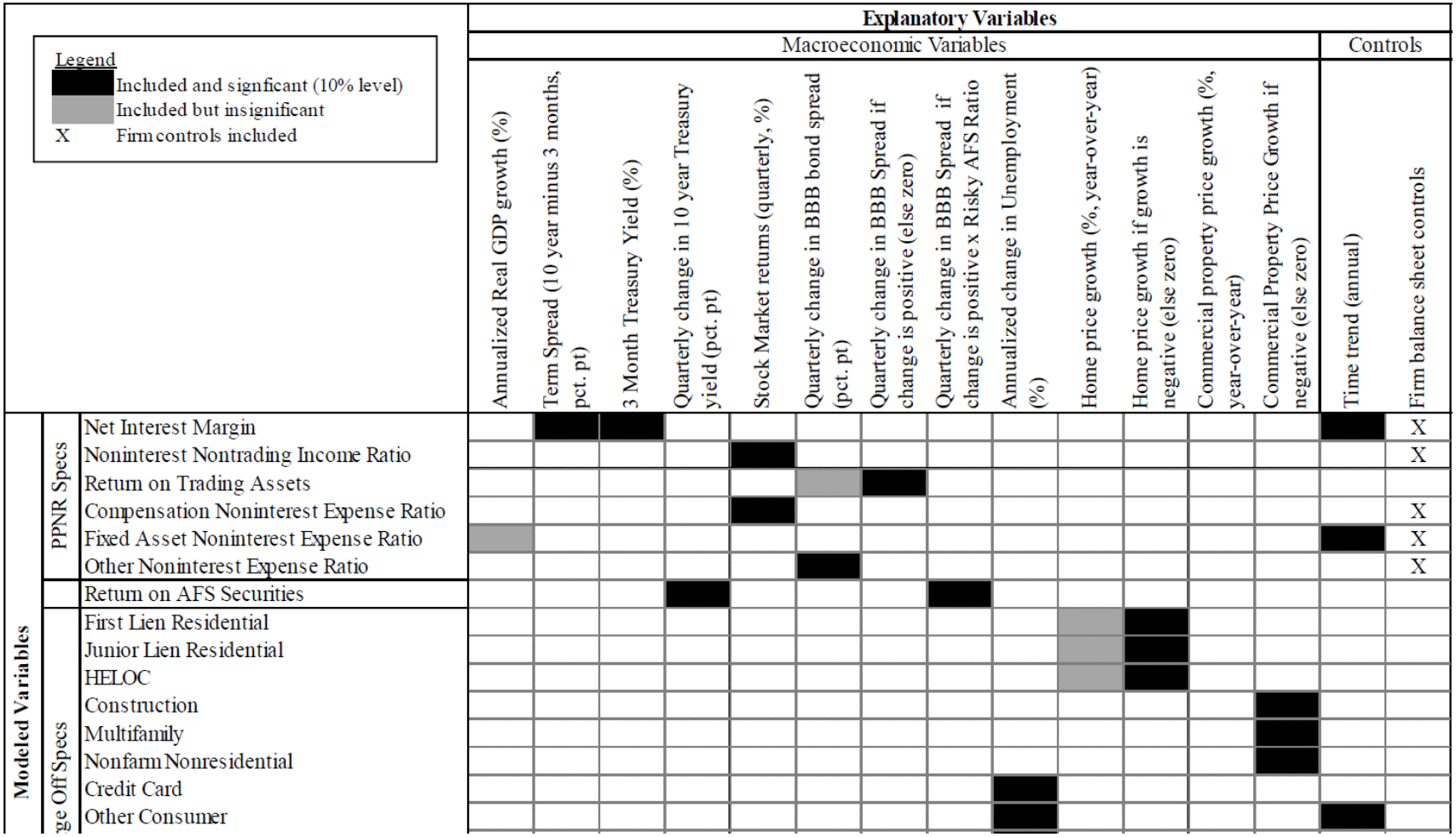
Methodologies – AFS

- 1 equation for gain/loss
- There is significant variation in the riskiness of AFS portfolios across firms and over time.
- Model includes an interaction term between the shares of risky assets and increases in BBB bond spreads

Methodologies – AFS

- AFS assets are classified as either agency assets (i.e. “safe” assets) or other assets (i.e. “risky” assets)
- AFS returns are negatively correlated with the change in Treasury Yield

Methodologies – Factors



Source: FRB NY SR 663

Methodologies – Intuitions

- Net interest margin revenue is explained using the Treasury term spread
- The NCO rates of commercial real estate loans are explained by the commercial property price growth rate
- The unemployment rate is generally most correlated with losses of other loans
- The NCO rates are highly auto-regressive

Methodologies – Auto-regression

- Projected financial ratios for each firm will converge slowly from its most recent historical value towards a long-run steady state value
- The paths will be significantly influenced by the assumed macroeconomic scenarios

Assumptions – Balance Sheet

- Fixed rate growth of balance sheet
- Balance sheet composition does not evolve with macroeconomic conditions. This reduces complexity
- Model uses the more conservative sensitivities where there are heterogeneous sensitivities between smaller and larger banks

Assumptions - Others

- Projected taxes are calculated in a simplified form
- Dividends and other distributions: model assumes that firms do not issue new share or make re-purchases during the test horizon
- Allowance for Loan and Lease Losses are bounded in a range

Model Strength

"Model risk increases with greater model complexity" (SR11-7, Office of the Comptroller of the Currency, Federal Reserve System)

Strength – Low Model Risk

- Macroeconomic variables are parsimonious and have minimal multicollinearity risk
- Over-fitting risk was minimized using linear regression.
- No bias from regularization (e.g. LASSO)
- Conservative parameters were selected
- Simple design is transparent for validation

Strength – Transparency

- Results are intuitive
- Model behaviors can be explained and can be used to analyze macroeconomic phenomena
- Not a “black-box”
- CLASS model can be used as a benchmark

Strength – Comparison to Actual

Table 8: Comparing CLASS projections to performance during the financial crisis

CLASS projections are compared to the actual evolution of capital over the six quarters between 2007:Q3 and 2008:Q4, and the actual evolution of net income over the nine quarters from 2007:Q3 to 2009:Q4.

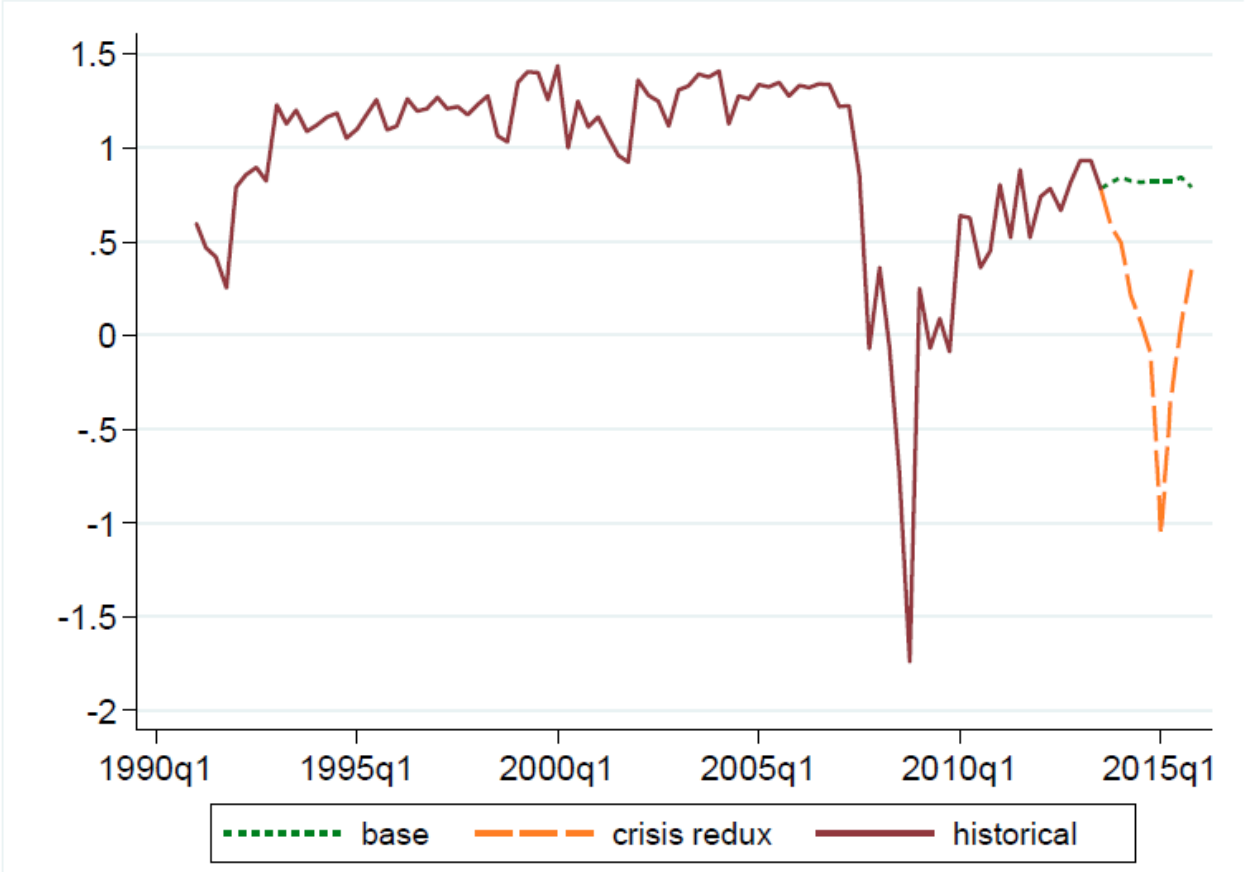
	Industry values			Actual vs predicted: across firms (actual = α + β. predicted + ε)[1]			
				Weighted		Unweighted	
	Model	Actual	Difference	Slope coefficient (β)	R^2	Slope coefficient (β)	R^2
Income and loan performance (9 quarter cumulative, annualized):							
PPNR / total assets	1.54	1.47	0.07	0.552***	0.223	0.194***	0.068
Net chargeoff rate	1.93	1.99	-0.05	1.284***	0.674	0.609***	0.120
Return on assets	0.13	-0.05	0.18	0.558***	0.094	0.229**	0.025
Change in T1C / RWA (6 qtr)	-1.12	-1.77	0.65	0.593***	0.079	0.288***	0.086

[1] Based on winsorized OLS (winsorized at 2% and 98%)

Source: FRB NY SR 663

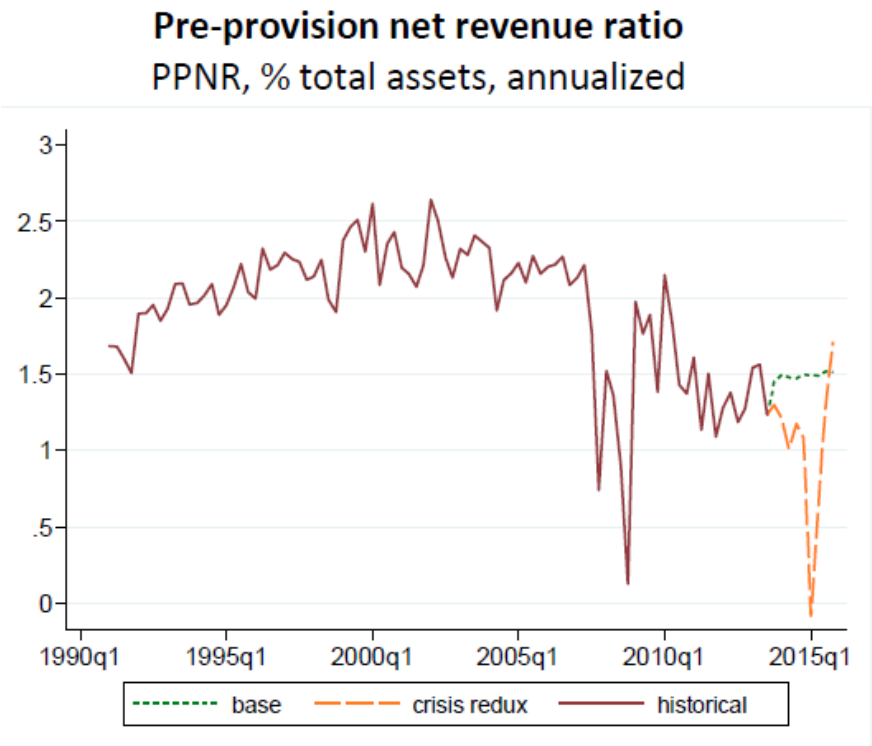
Strength – Comparison to Actual

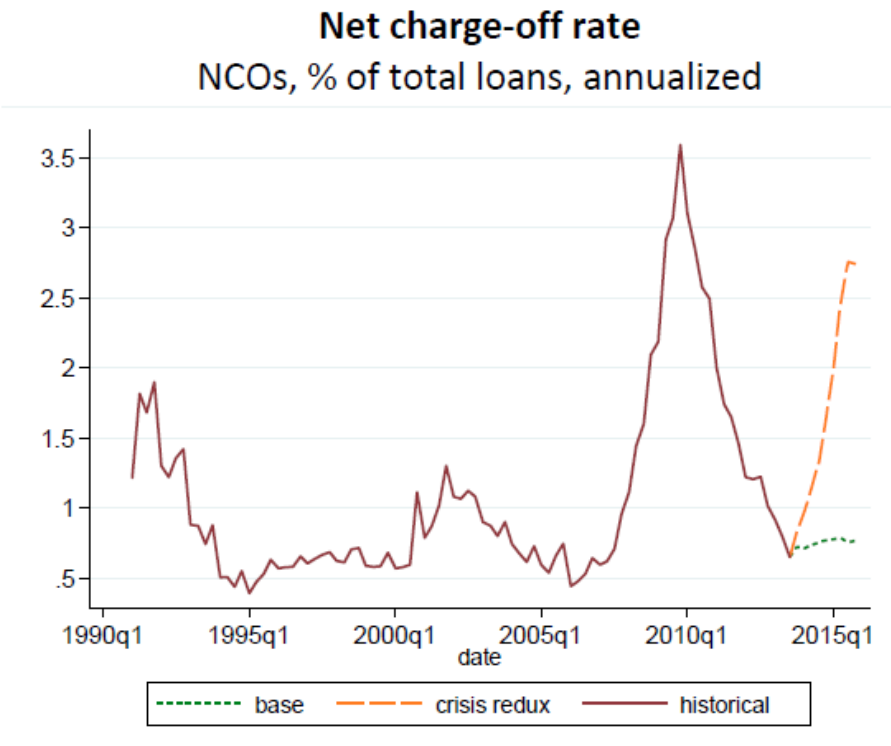
Figure 3: Return on assets (Annualized after-tax net income, % of total assets)



Source: FRB NY SR 663

Strength – Comparison to Actual





Source: FRB NY SR 663

Strength – Comparison to DFAST

Table 7: Comparison between CLASS and DFAST projections

Projections under the DFAST severely adverse macroeconomic scenario based on data as of 2013:Q3 for the 30 firms subject to the 2014 CCAR and DFAST supervisory stress tests.

				CLASS vs DFAST: across firms (CLASS = α + β. DFAST + ε)	
Income Category	CLASS	DFAST	Difference	Slope coefficient (β)	R^2
PPNR/Assets	1.97	1.57	0.39	0.845***	0.869
Provision Expense/Assets	1.99	2.88	-0.89	0.729***	0.658[a]
Other/Assets	-0.02	-0.26	0.24	-0.044	0.008
Net Income Before Tax / Assets	-0.05	-1.57	1.52	0.533***	0.338
Change in T1C / RWA	-1.77	-3.63	1.87	0.145	0.091

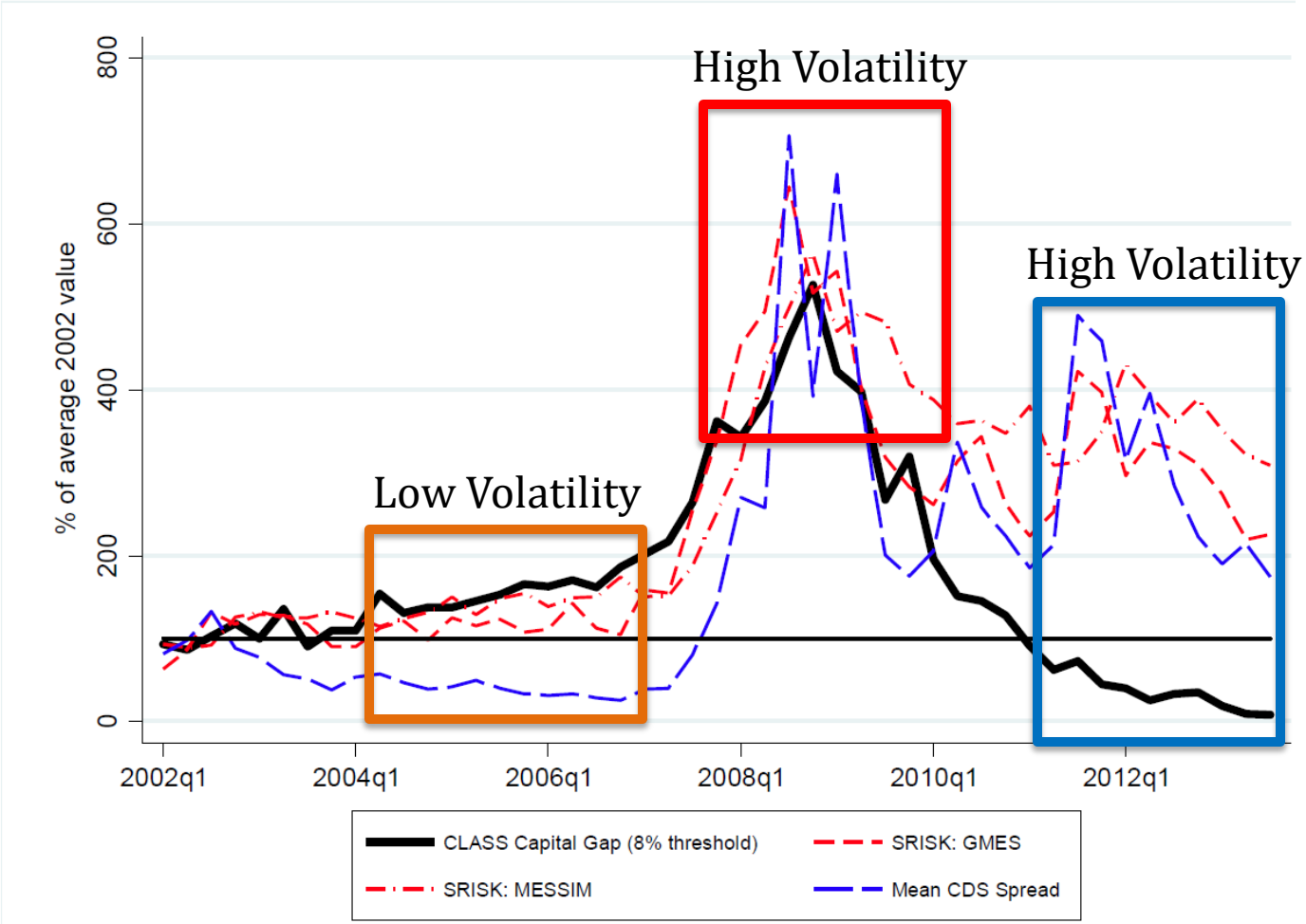
a) Provision Expense R^2 is calculated from projections of Provision Expense / Total Loans

Note: PPNR is reported inclusive of trading and counterparty losses. DFAST projected trading loss is 0.86% of total assets. "Other" includes realized losses/gains on securities (AFS/HTM), as well as the projected change in fair value of loans held for sale and loans held for investment measured under the fair value option, and goodwill impairment losses.

Source: FRB NY SR 663

Strength – Comparison to SRISK

Each measure is normalized by its average value in 2002.



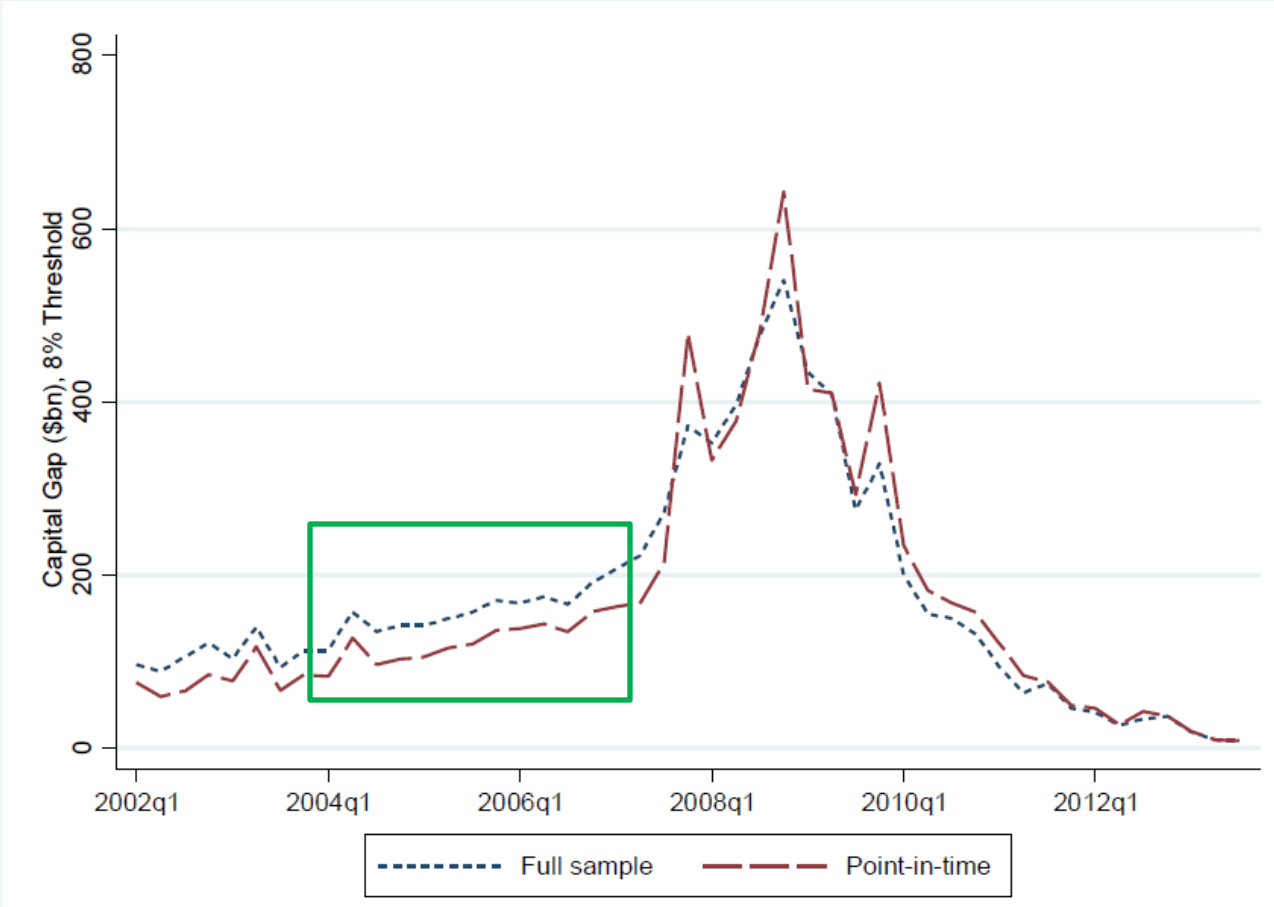
Source: FRB NY SR 663

Strength – Reliability

- Model is influenced less by market risk premiums. Market risk premiums during a "spiral-up" may underestimate the vulnerability of the U.S. banking system
- CLASS model takes inputs from both statistics and economic intuitions
- Model effectively measures the leverage of the U.S. banking system

Strength – Point-in-time test

Figure 6: Point-in-time and full sample industry capital "gap"



Source: FRB NY SR 663

Strength – Practicality

- CLASS is a practical model
- Model is flexible and can be optimized for specific purpose and new ‘What-if’ scenario analyses

Model Limitation

"Limitations are also a consequence of assumptions underlying a model that may restrict the scope to a limited set of specific circumstances and situations" (SR 11-7)

Limitation – Use cases

- Not necessarily for measuring the absolute level of risk
- The scope is the U.S. banking system, excluding non-financial firms, and not necessarily the systemic risk of the U.S. economy

Limitation – Smaller banks

- CLASS model is more effective for firms engaged in a range of activities, rather than small firms concentrated in particular types of lending. The model can be optimized further.

Limitation – “Risky” assets

- “Risky” assets of AFS is modeled together, which can include all vintages and ratings of private-label residential mortgages, municipal bonds, ABS (e.g. subprime auto, unsecured personal loans, student loans, etc.), corporate loans, and other low grade loans.

Limitation – Projection

- Regression specification was not purely statistically set. Intuition was used. This can be a strength (reliability) or a weakness (an element of subjectivity)
- Equations are from historical dynamics which may not necessarily repeat under new economic normals for new asset types
- Balance composition is static (no evolution)

Limitation – ‘Stressed Baseline’

- Capital market can (and often does) ‘price in’ stress scenarios. The baseline prices of instruments can already imply certain future stressed environments for certain securities. For example, CRE price can be discounted and can imply future change in CPPI.
- It is inconsistent to apply the same stress to ‘full price debt’ and ‘discounted debt’. This is a common problem for many models.

Limitation - Misspecification

- "[The CLASS Model] is clearly a simplification and surely (unavoidably) misspecified in known and unknown dimensions"

  Source: FRB Working Paper 2016-26, Bidder, Giacomini, McKenna, "Stress Testing with Misspecified Models"

- "the most aggregated top-down risk models may suffer from aggregation bias"

  Source: FRB Working Paper 2015-14, Hale, Krainer, "Aggregation Level in Stress Testing Models"

Possible Enhancement & Tests

"Models are employed in real-world markets and events and therefore should be tailored for specific applications and informed by business uses" (SR 11-7)

Possible Enhancement & Tests

- Further optimization for regional and smaller banks
- Analysis of model performance of smaller, local, community banks

Possible Enhancement & Tests

- NCO rates and AFS projections further tailored to granular asset subtypes (e.g. mortgage vintages, subprime auto, student loans, unsecured personal loans, corporate debt)
- Test for over-fitting and multicollinearity with additional characteristic variables

Possible Enhancement & Tests

- Enhancement in non-linear behaviors of market dynamics
- Incorporate more market-based variables, relevant to "risky" assets, such as:
    1. Swaption volatility (2-3Y)
    2. Mortgage spread (30Y fixed – 10Y Tresury)
    3. Various series and ratings of CMBX indices
    4. CDX HY spreads
    5. Oil prices

Possible Enhancement & Tests

- Analyze the marginal impact on capital shortfalls from each macroeconomic variable and newly examined variable (e.g. mortgage spread, swaption volatility, CMBX).
- Analyze the historical changes in marginal impact

Possible Enhancement & Tests

- Model risk control
- Automation of data process, analytics, estimation of losses, and aggregation
- Automated model validation: comparisons of interim parameters and outputs across model versions. Check over-fitting, multicolinearity, and intuitive behaviors

Spiral-Up - Low Volatility Market

Assume that all market participants *believe* that the (risk neutral) probability for imminent crisis is minimal

Assume that each investor believes that the other market participants have the same view and logical preference for investing in diversified debt.

Spiral-Up - Nash Equilibrium

Buying (or holding) diversified debt can become a Nash equilibrium strategy, because each investor believes no one would decide to bet against others, when observing low risk neutral probability for imminent crisis.

Gradually, rational choice of risk can evolve to confirmation bias, hoping for ‘one more year before crash’.

Conclusions

- CLASS model is a simple and flexible 'what-if' analysis tool with low model risk
- A stable market can enter a state of circular causality together with decreasing risk premium
- CLASS model is a reliable and intuitive benchmark tool, which can be optimized further

Conclusions

"What's the likelihood of another financial crisis? And I begin by saying it's a certainty" (Hank Paulson)

When a stable market begins to spiral up, central banks can intervene and avoid a credit crisis.

Appendix

"Vulnerabilities that originate overseas could spill into global and U.S. markets and institutions" (2016 Financial Stability Report, Office of Financial Research)

Appendix – Spiral-Up Logics

Q. The expected timing of the next crisis is an important factor for investment decisions. The question is, is the next crisis imminent?

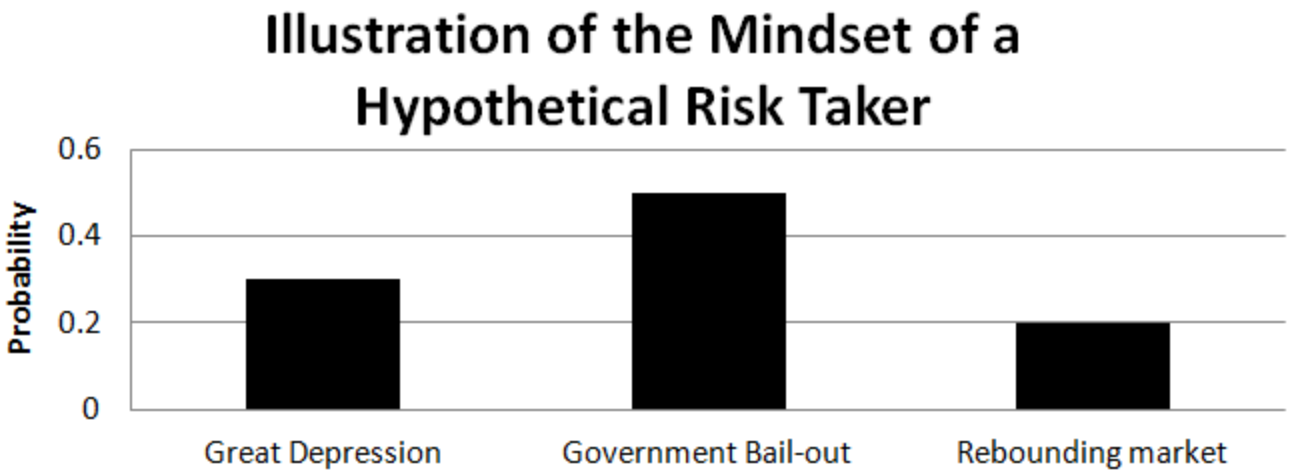
If not, the market participants can take long systemic risk using leveraged debt instruments, which would lose severely for imminent crisis scenario.

Then, the risk neutral probability for imminent crisis becomes even lower. This choice of strategy becomes an even better one.

Appendix – Delay in Crisis

- All of the above 4 vintages of mortgages have the same subprime pool quality. However, the older deals had a seasoning period prior to market deterioration. Longer seasoning periods prior to a crisis significantly benefit structured debt.

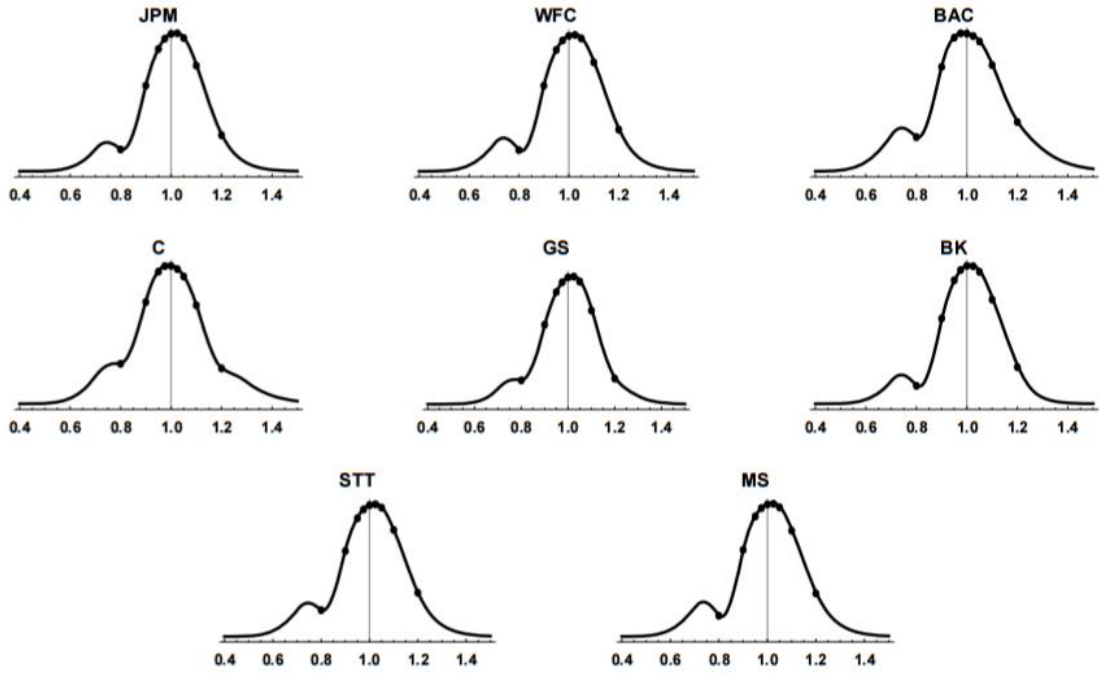
Appendix – Market Deterioration



- The risk neutral density of a credit asset could have a tri-modal distribution during market deterioration.

Appendix – Systemic Risk

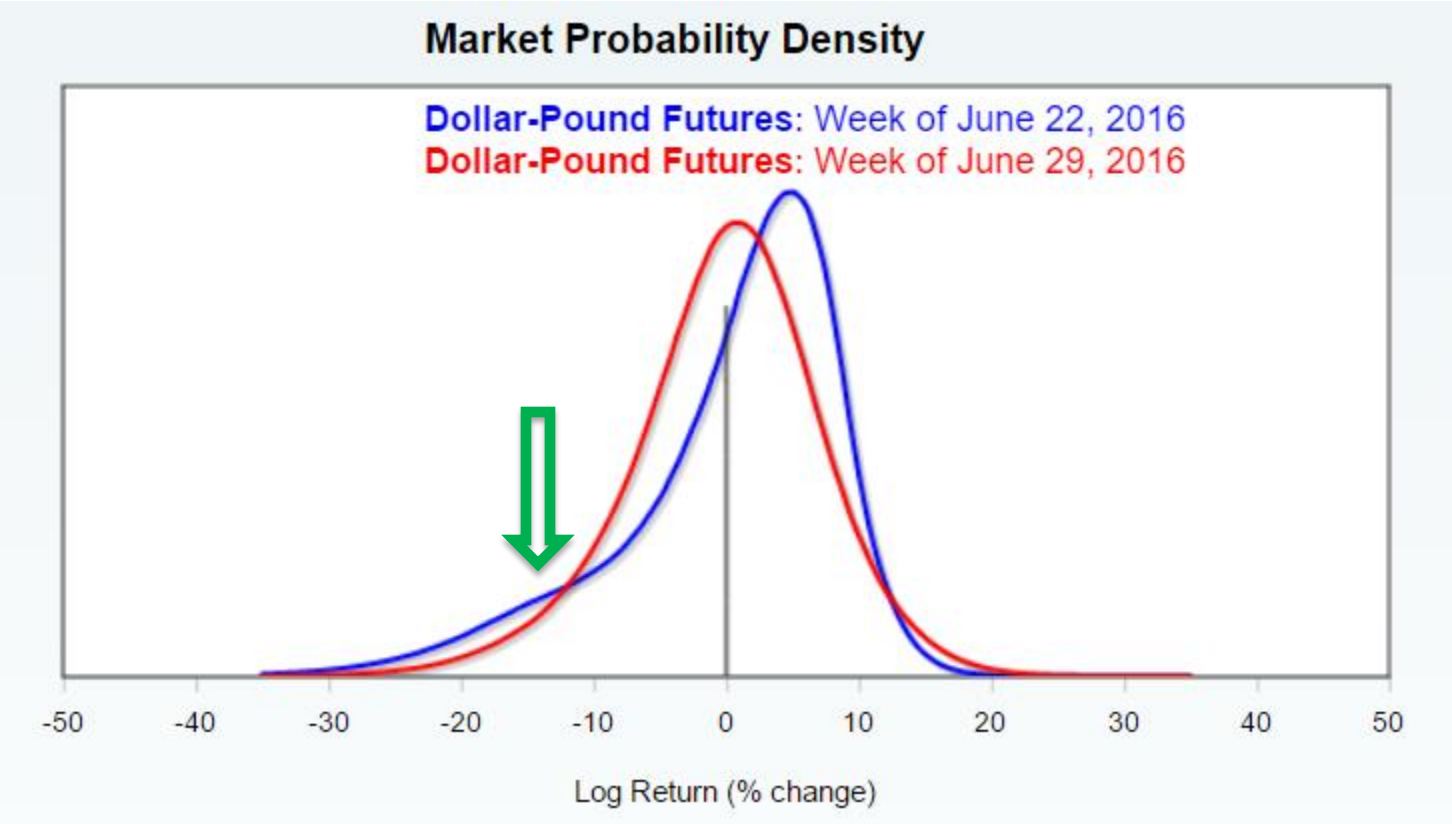
Figure 1: Risk-neutral densities of major U.S. financial firms



- Systemic risk implied in equity market

Source: A. Malz, "Risk Neutral Systemic Risk Indicator", NY FRB SR 607 (2013)

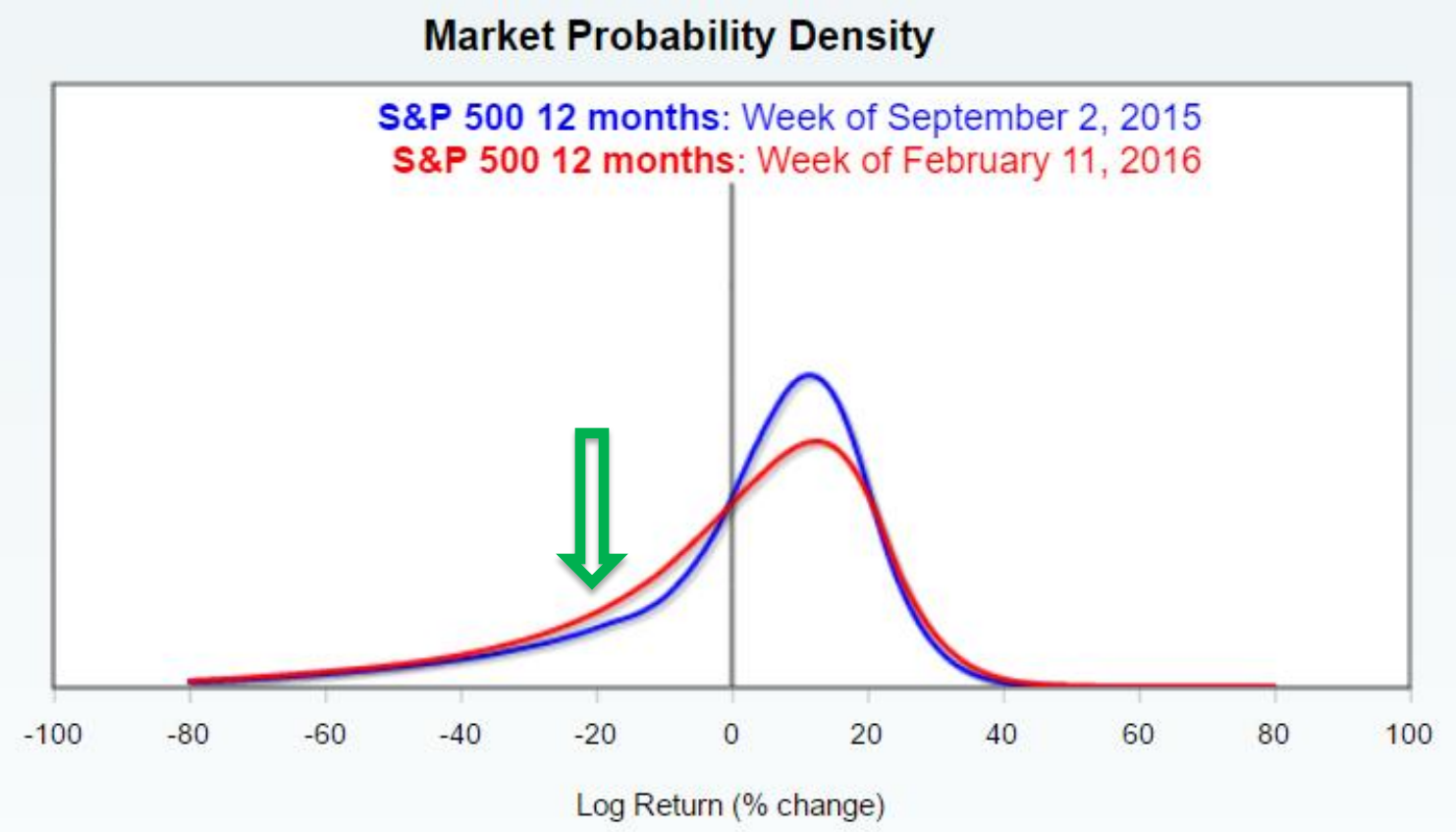
Appendix – Risk Neutral Density



Green arrow: 'Brexit'

Source: FRB of Minneapolis

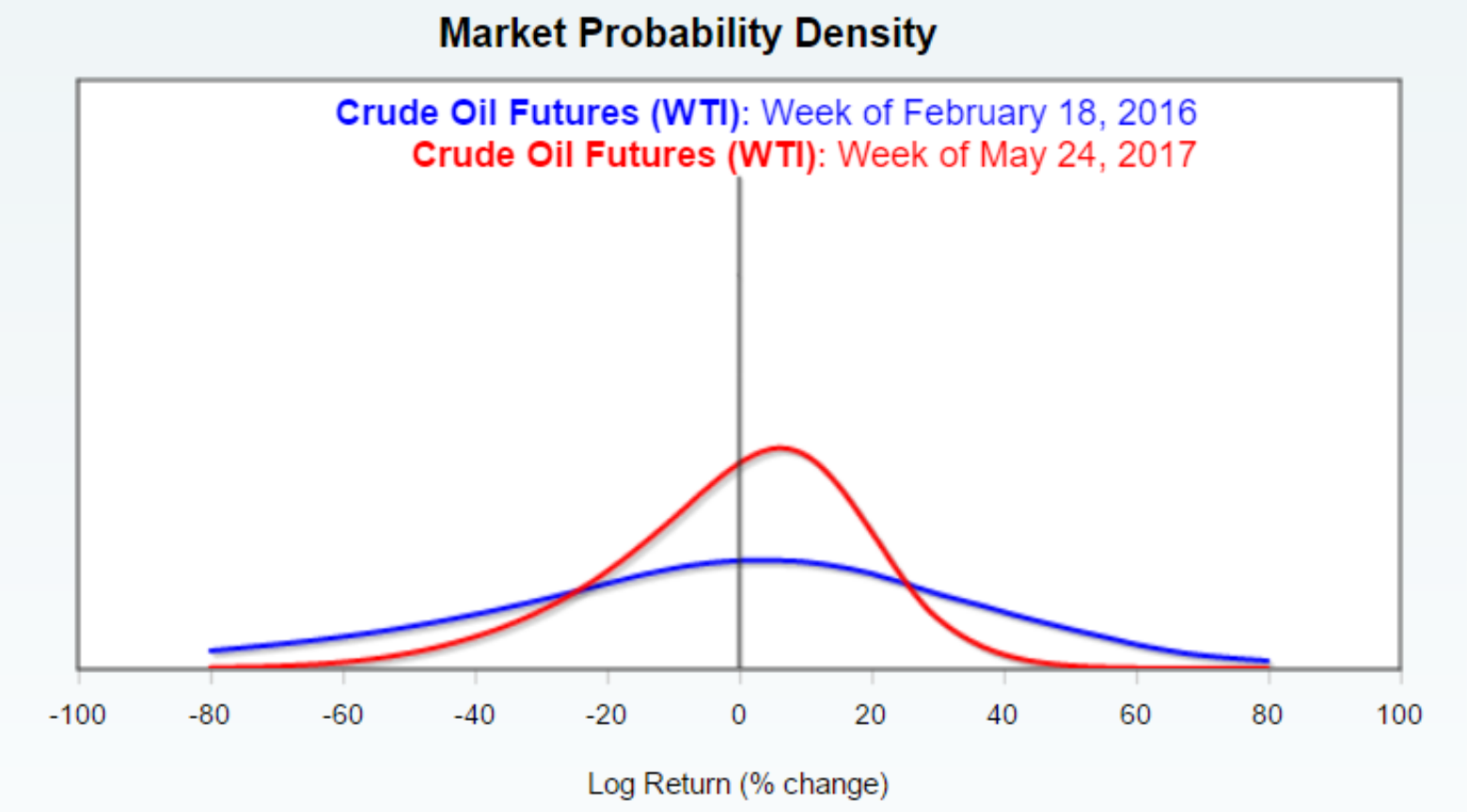
Appendix – Risk Neutral Density



Green arrow: Concern for 'Oil sell-off'

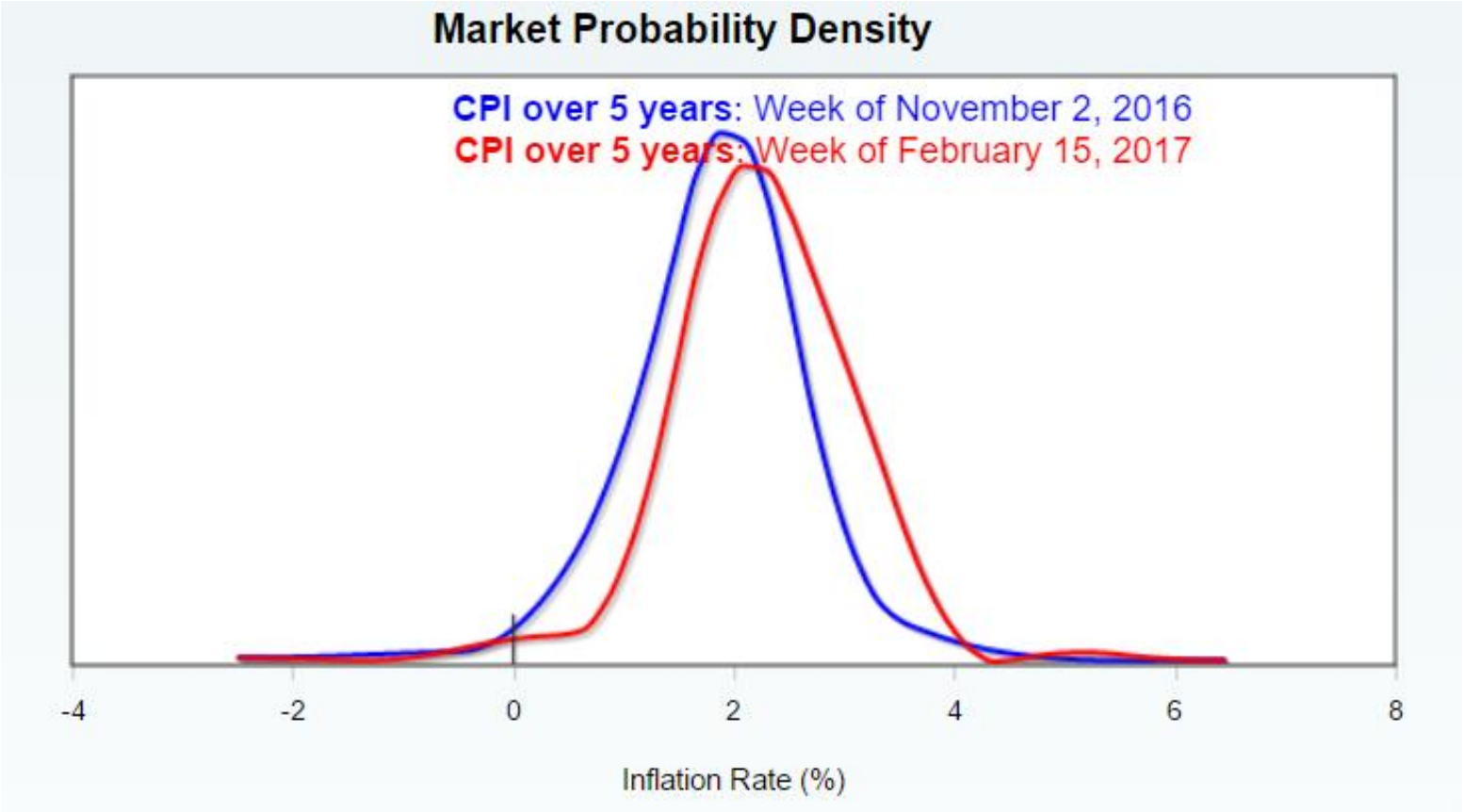
Source: FRB of Minneapolis

Appendix – Risk Neutral Density



Source: FRB of Minneapolis

Appendix – Risk Neutral Density



Source: FRB of Minneapolis

Appendix – Commercial Property

Figure 39. U.S. Commercial Real Estate Prices (index)

Commercial real estate prices have risen above pre-crisis levels

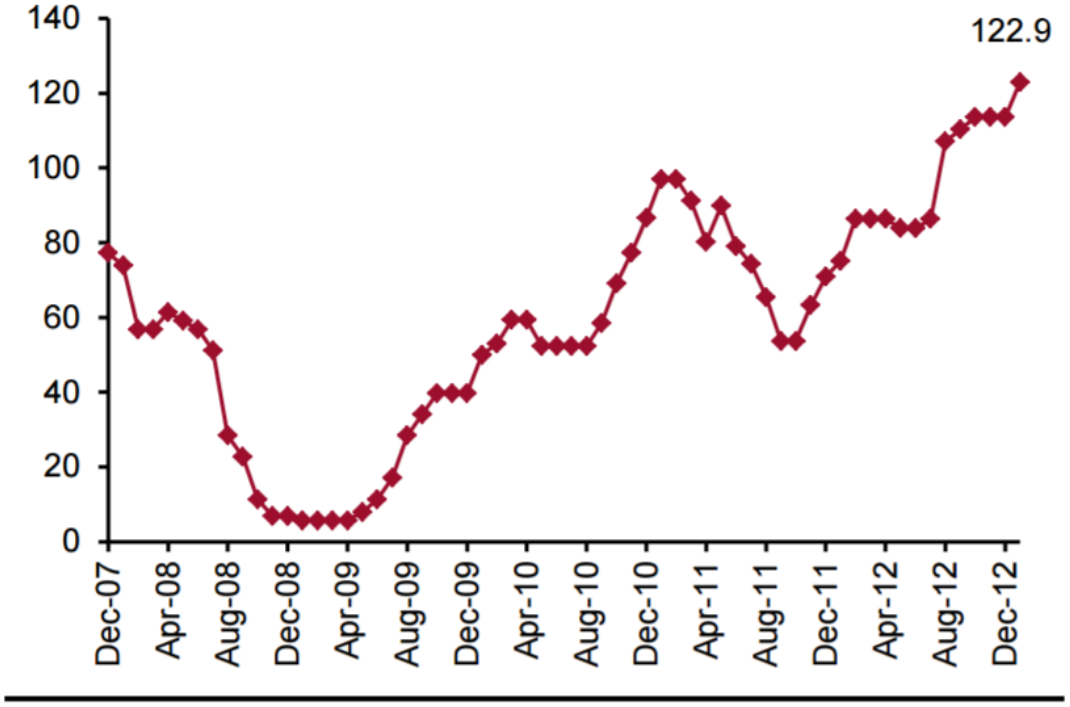
Notes: Data as of June 30, 2016. Index = 100 at first quarter of 1998. The Federal Reserve Board index is most recently based on the CoStar Commercial Repeat Sale Index. The NCREIF All Property index is transaction-based, and the Green Street Advisors index is a value-weighted, appraisal-based index of properties owned by real estate investment trusts.

Sources: Haver Analytics, OFR analysis

Source: Office of Financial Research

Appendix – CLO Equity (07-12)

Exhibit 19: US CLO equity price index



Source: Credit Suisse

Low rate increased excess spread of CLO deals

Appendix – Sovereign Spill-over

TABLE 7—*t*-STATISTICS AND OTHER RESULTS FROM THE REGRESSION OF DEFAULT COMPONENTS ON GLOBAL FACTORS

	Brazil	Bulgaria	Chile	China	Colombia	Croatia	Korea	Malaysia
Stock market	−1.23	−3.24**	−3.49**	−2.25**	−4.68**	−2.43**	−4.57**	−3.43**
Treasury market	0.84	1.57	0.67	−1.11	−0.50	1.90	1.47	−0.44
Investment grade	0.83	1.12	0.39	0.18	0.33	−0.18	−2.13**	−0.50
High yield	0.85	4.57**	1.05	1.85*	0.48	5.97**	0.65	0.60
Equity premium	−0.86	−0.04	2.64**	2.08**	0.21	−0.73	2.20**	2.35**
Volatility premium	−0.30	−3.43**	−2.82**	−0.83	−0.67	−2.85**	−3.48**	−2.17**
Term premium	−0.87	−1.39	−1.20	1.37	1.28	−0.93	−1.38	−0.25
Stock flows	0.95	−0.41	−0.70	0.37	0.43	−0.72	−0.55	0.39
Bond flows	−0.42	−0.84	−0.67	−0.05	0.25	−0.62	−1.51	−0.33
Adjusted R^2	−0.106	0.704	0.715	0.627	0.411	0.787	0.746	0.651

Source: Longstaff, Pedersen, Singleton, "How Sovereign is Sovereign Credit Risk?", American Economic Journal: Macroeconomics 3: 75-103

Appendix – CCAR 2017 CRE

CCAR 2017: Severely Adverse Scenario

Securitized Products

	CMBS					
	CMBS CDS	CMBS CDO	Credit Basket	Index Tranches	Whole Loans	Other / Unspecified
BBB Total						
Pre 2006	-11.2%	-18.7%	-11.2%	-11.2%	-18.7%	-18.7%
2006	-6.0%	-10.0%	-6.0%	-6.0%	-10.0%	-10.0%
2007	-12.0%	-20.1%	-12.0%	-12.0%	-20.1%	-20.1%
Post 2007	-51.7%	-86.2%	-51.7%	-51.7%	-86.2%	-86.2%
Unspecified Vintage	-51.7%	-86.2%	-51.7%	-51.7%	-86.2%	-86.2%

- Note vintage (i.e. issue date) dependencies

Source: FRB

Appendix – CCAR 2017 Agency

CCAR 2017: Severely Adverse Scenario
Agencies

US Residential Agency Products	OAS Widening (bps)
IOs	1,687.0
POs	330.0
Other CMOs	177.0
Pass-Throughs	158.0
Agency Debt/Debentures	149.0
IOS Index	1,687.0
POS Index	330.0
MBX Index	158.0
Other Agency Derivatives	149.0
TBA's	133.0
Reverse Mortgages	177.0
Residential Other / Unspecified	158.0

- Spread scenarios for agency mortgages

Source: FRB

Appendix – CMBX Series 6 BBB-

Source: Bloomberg

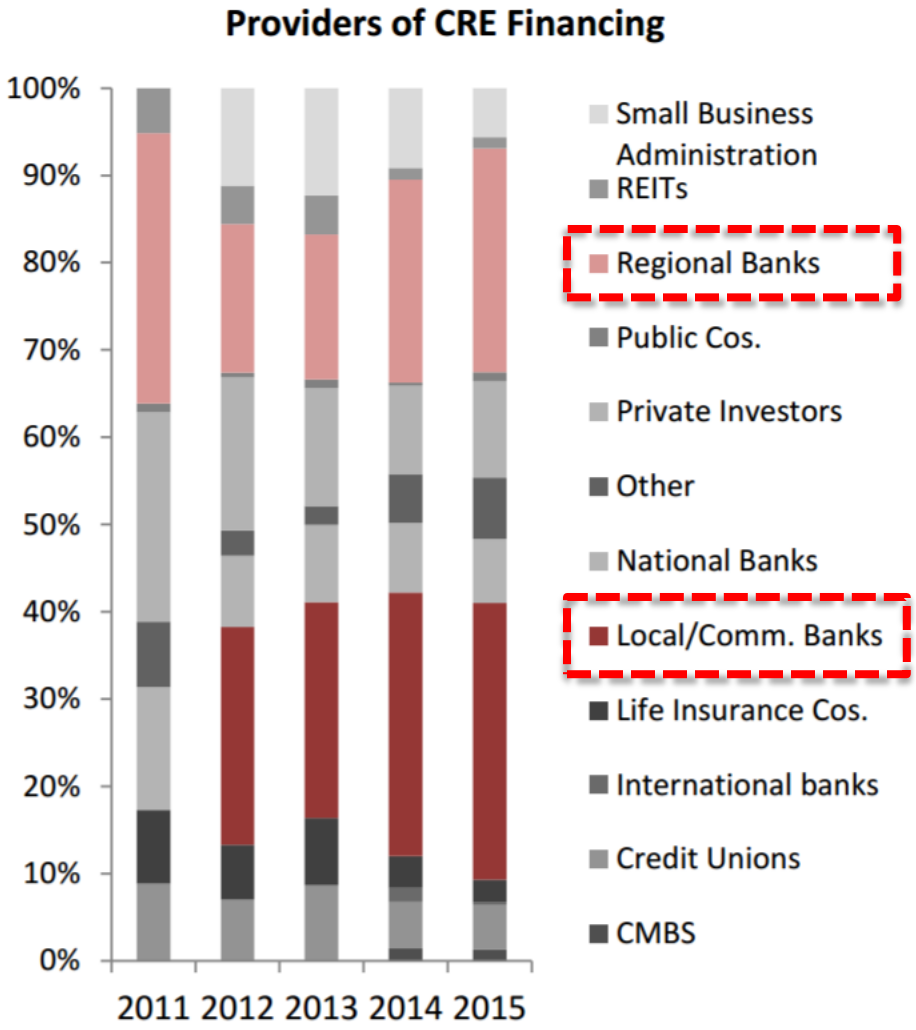
Appendix – CDX HY Spread

Source: Bloomberg

Appendix – IOS FN 3.5% 2014

Source: Bloomberg

Appendix – CRE Financing



- Regional Banks and Local/Community Banks are lenders of CRE financing. International banks reduced exposures

Source: National Association of Realtors