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Where is the Option?
Prepayment Modeling of MBS

April 30, 2007

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The Size of the U.S. Mortgage Market

Home mortgages

- $10 trillion outstanding
- $2.5 trillion originated in 2006

Mortgage-backed Securities (MBS)

- $6 trillion total outstanding
- Of which $4 trillion are Fannie Mae, Freddie Mac, and Ginnie Mae ("Agency" MBS)

$4.5 trillion Treasury securities outstanding

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Conventional U.S. Mortgages

Offered in standardized structures

- Maturity: 30-year or 15-year
- Rate: Fixed, ARM, or hybrid ARM
- Principal payment: amortizing or interest-only
- Borrower can reduce rate by paying points, or avoid closing costs by accepting a higher rate

Prepayable at any time, without penalty

- Refinancing entails transaction cost

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What Is an Agency MBS?

- Lender/owner of mortgages wants to securitize pool
  - Say 6% FRMs into a 5 ½% MBS
- Agency overlays its guarantee and creates MBS
  - Principal and specified interest passes through to MBS investors
- Residual interest covers servicing cost and guarantee fee

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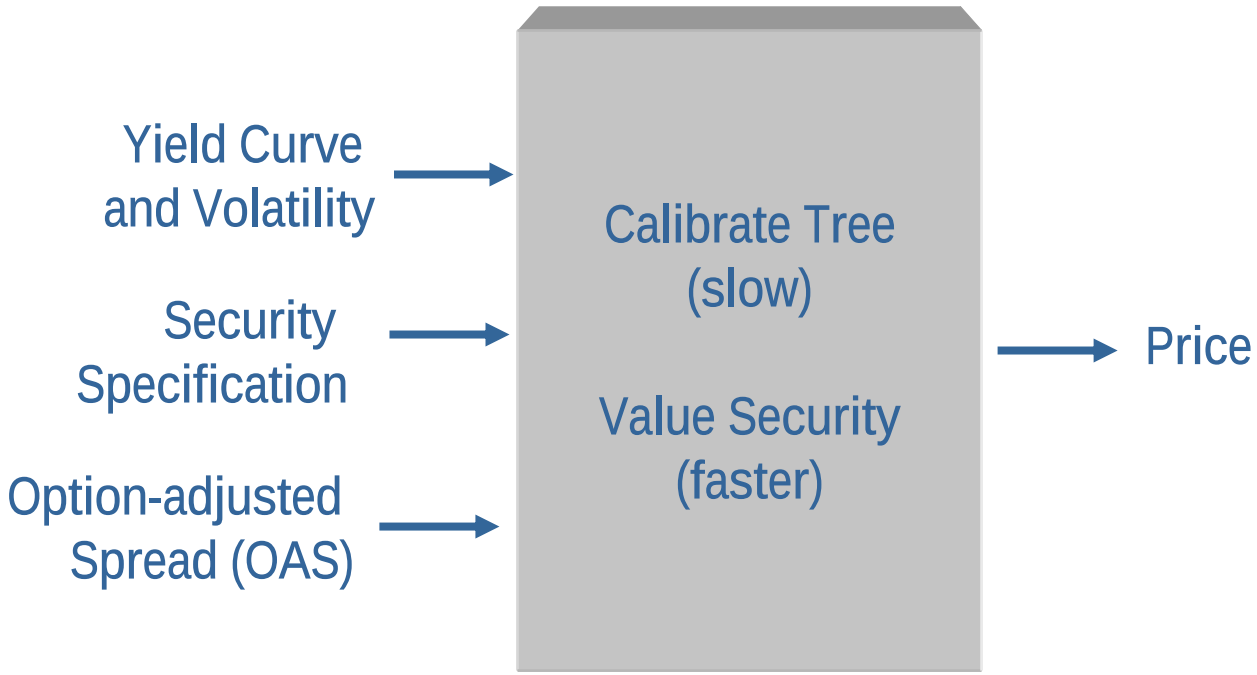
OAS-Based Valuation of Bonds and MBS Since1986



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Bond Valuation Speed Has Improved Dramatically

	1990	2007
Processor	386	3.0 GHz Pentium
Calibrate tree	Up to 4 hours	500 per minute
Compute fair value recursively	Several seconds	80,000 per minute

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MBS Analysis Lags By a Mile

Slow

- At most a few 100 of valuations per minute

Imprecise

- Monte Carlo simulation, rather than recursion

Prepayment models are derived by statistical analysis, rather than financial principles

- Ongoing release of “new and improved” models is a predictable consequence

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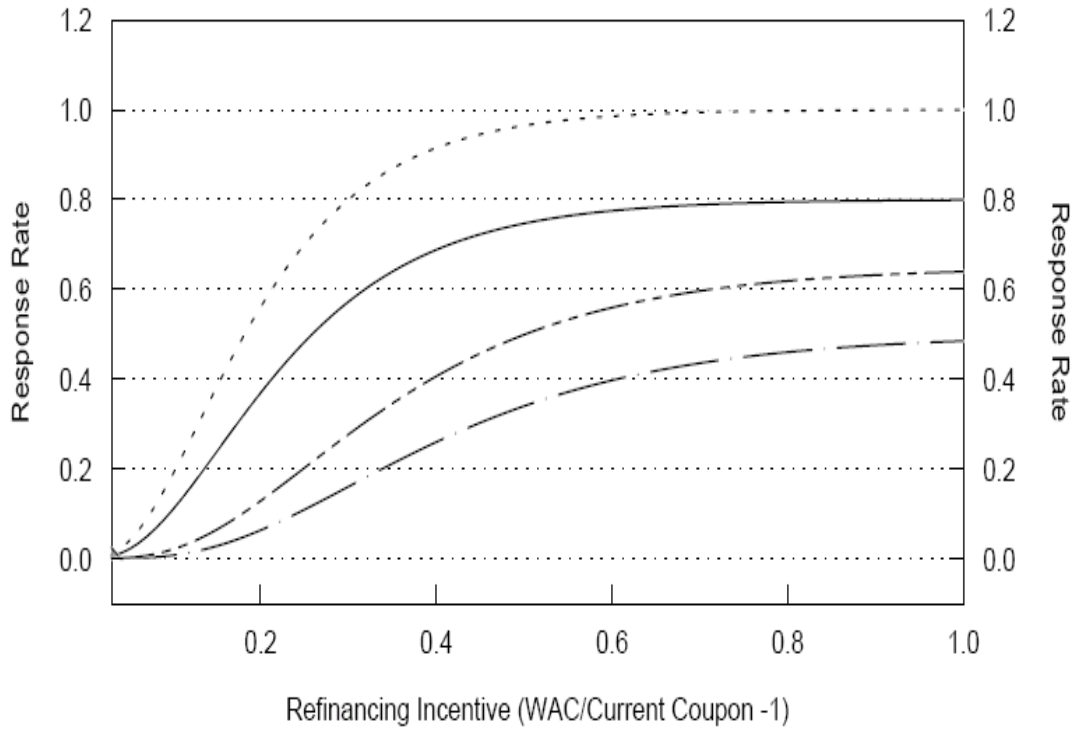
Typical S-shaped Prepayment Model: Rate Depends on Refinancing Incentive

Figure 14. Refinancing Curves for Different Borrower Types



WAC Weighted-Average Coupon
Source: Salomon Brothers Inc.

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MBS Models Can't Cope with Pertinent "What if" Questions

What if refis were optimal?

(MBS yields would increase by 10 to 15 bps)

What if borrowers gave up the right to refi?

(MBS yields would decline by 45 to 50 bps)

How sensitive are MBS prices to closing costs?

Can prepayments be sensibly modeled without a command of refis?

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The right approach to MBS valuation:
Understand mortgages; the rest will follow

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Analytical Model of Refinancing Decision

Mortgage: a callable amortizing bond

Represent call prices as remaining principal plus anticipated refinancing cost

e.g. 1% of remaining principal

Mortgage rates: OAS to a benchmark curve

Use a volatility consistent with swaption vols

Optimum: act only if value received is adequate

Provides a benchmark for sub-optimal behavior

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The Right Decision Tool Is Generalized Refunding Efficiency

$$Efficiency_{gen} = \frac{PV\ Savings}{\Delta\ Option\ Value}$$

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Refinance or Wait? Decide Like a Professional!

Should I Refinance?

CURRENT MORTGAGE

Years left:	26
Interest rate (%):	6.000
Remaining principal ($):	100,000

Refinance Now?

patent pending

NEW MORTGAGE

Term (in years):	30
Interest rate (%):	5.600
Discount points (%):	1.000
Upfront costs (legal fees, etc.) ($):	1,500
New principal ($):	102,525

Use Custom Inputs

And The Answer Is...

CASH FLOWS

Current monthly payment ($):	634
New monthly payment ($):	588
Savings per month ($):	46
Principal remaining after 26 years ($):	25,259

Analysis as of 09/07/2005 11:02:14 10-Yr Treasury at 4.131%

RECOMMENDATION

Total savings (in today's $):	1,498
÷	
Loss of option value (in today's $):	2,029
=	
Kalotay Refi Score 100% best. Refinancing not recommended below 90%.	72.3%

Not Yet!

See www.kalotay.com/calculators

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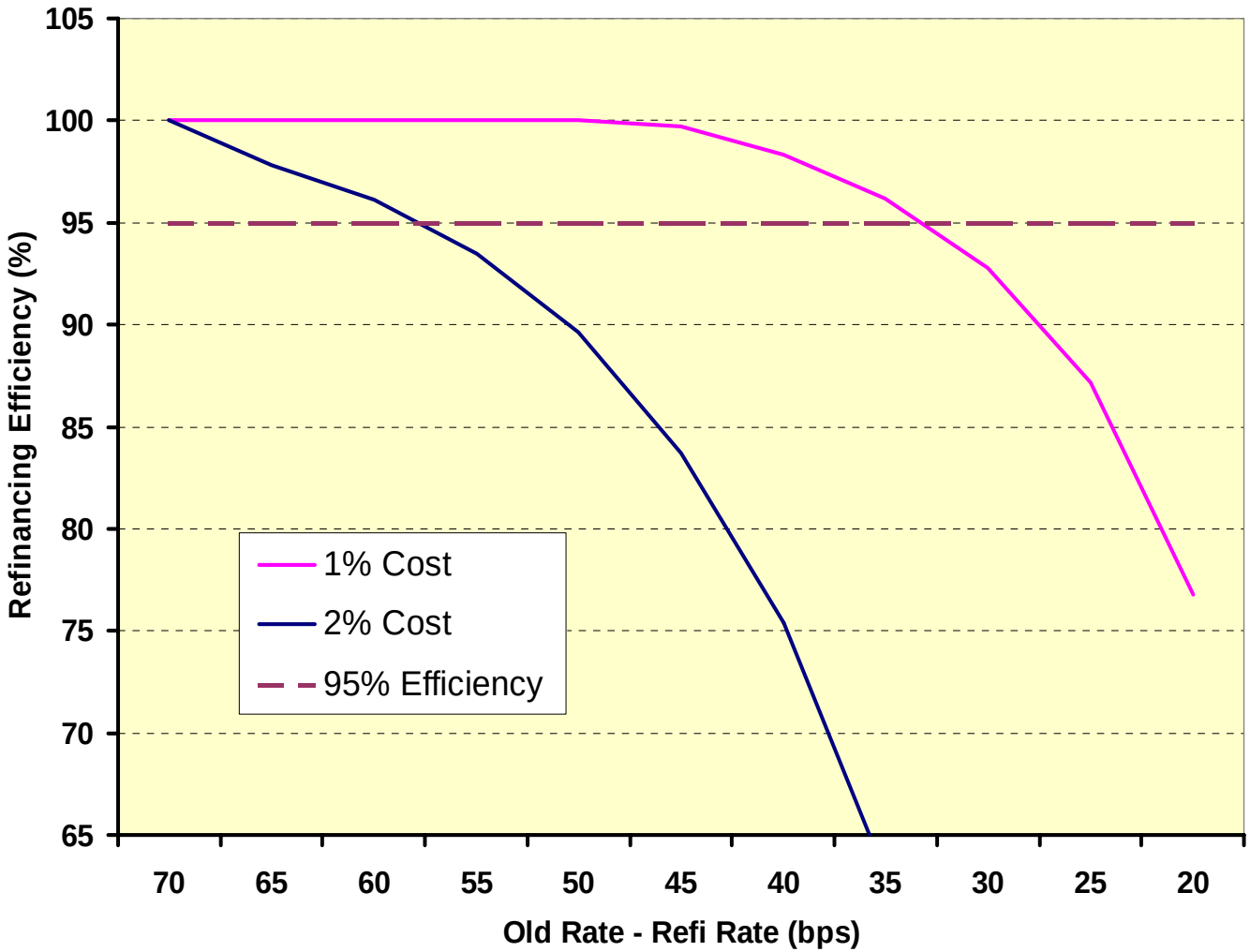
Transaction Costs Impede Refinancing (And Increase MBS Value)



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CLEAN™
*C*oupled *L*attice *E*fficiency *AN*alysis

- Mortgage rates and MBS rates are modeled as a coupled lattice
  - Each lattice has its own OAS spread relative to benchmark term structure
- Mortgage rates determine refis
  - Using notion of refunding efficiency
- MBS cashflows (coupon and principal) discounted on MBS lattice

See "An Option-Theoretic Prepayment Model for Mortgages and Mortgage-Backed Securities" in References

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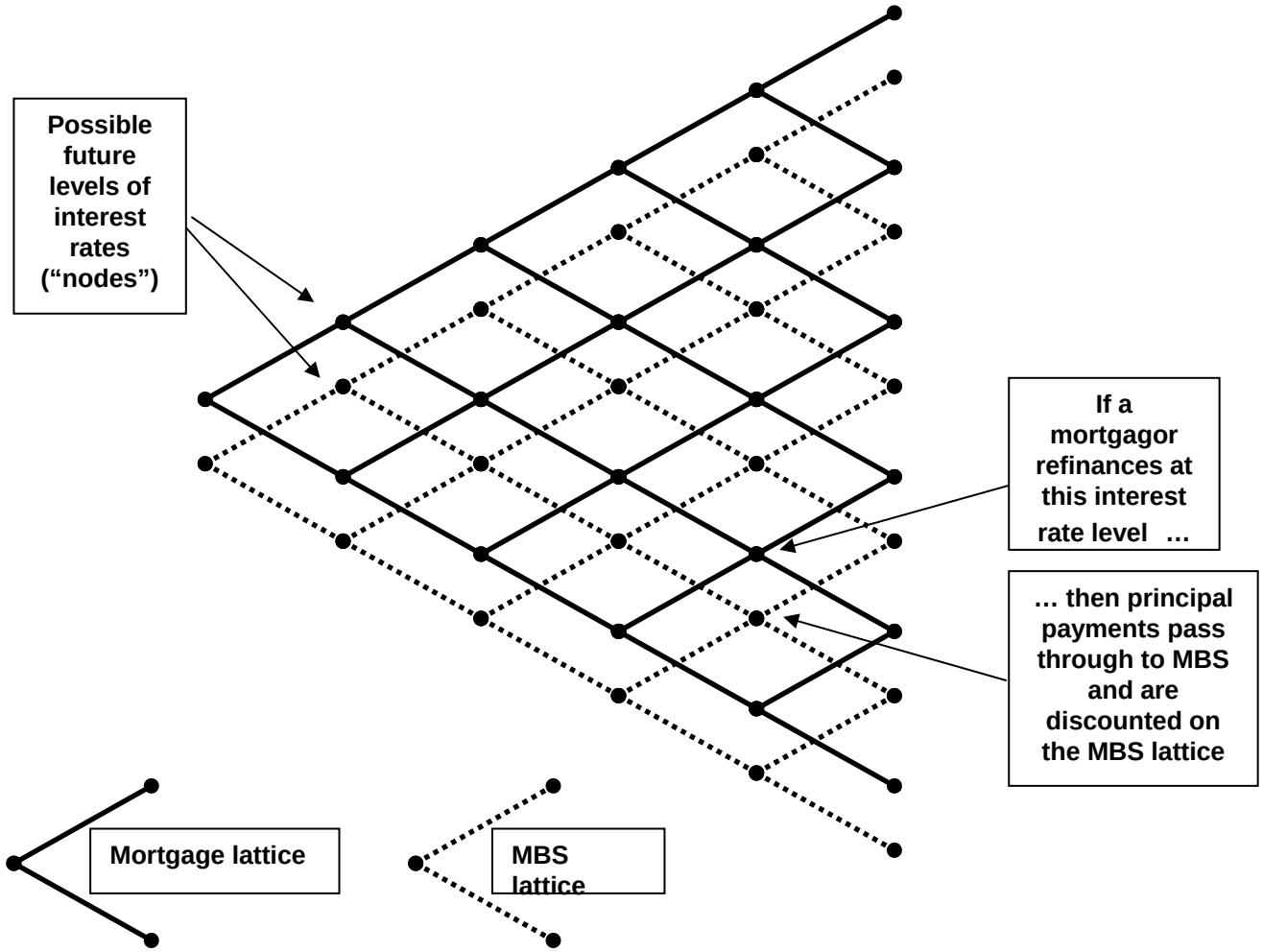
Mortgage-MBS Coupled Lattice



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CLEAN™ Framework for Prepayments

A deterministic model of turnover

- Say a specified annual rate

A simple but complete parametrization of interest rate driven refinancings

- A wide spectrum of refinancing behavior
- Pool is divided into several buckets
  - Financial engineers, leapers, and laggards
- For a given behavior, prediction is straightforward

Burnout is a natural consequence of the model

- As “leapers” refinance, pool becomes weighted towards “laggards”

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Modeling Laggards

Each mortgagor is assigned an "imputed" coupon representing refinancing behavior

- Refinancing is triggered when a Financial Engineer would refinance a mortgage with the imputed coupon
- A 7% mortgagor whose imputed coupon is 6% is a 1% Laggard

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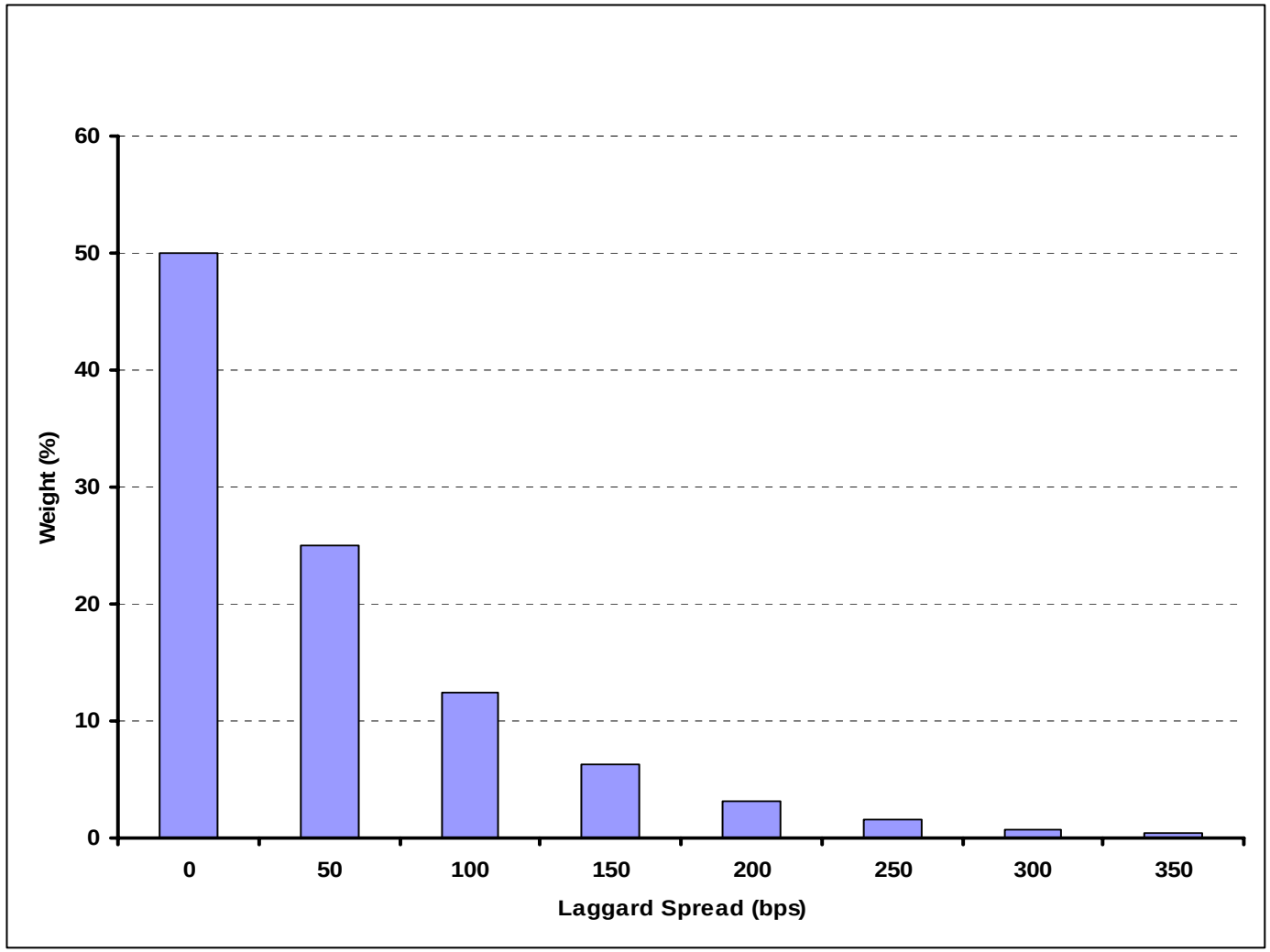
Laggard Distribution Used In Analysis Below (Same as in Paper)



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Baseline Inputs for Market Testing
September 5, 2006

Environment:		
	Reference yield curve	Swap curve
	Interest rate volatility	14%
Mortgagors:		
	Turnover rate	8%/year
	Mortgagor OAS	70 bps
	Refinancing cost (% principal)	1%
	Laggard distribution	Original*
MBS:	OAS	5 bps

**As in paper*

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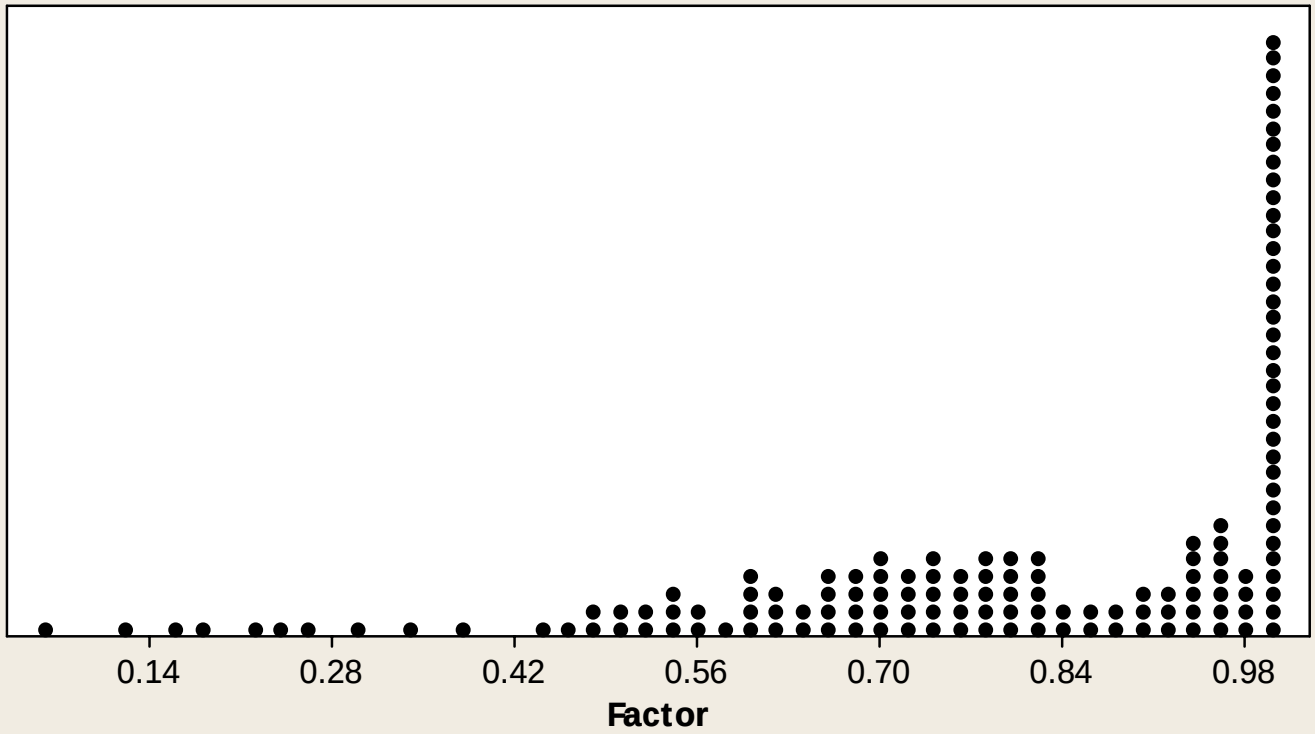
Distribution of Factors in Sample (363 Fannie and Freddie MBS)



Each symbol represents up to 3 observations.

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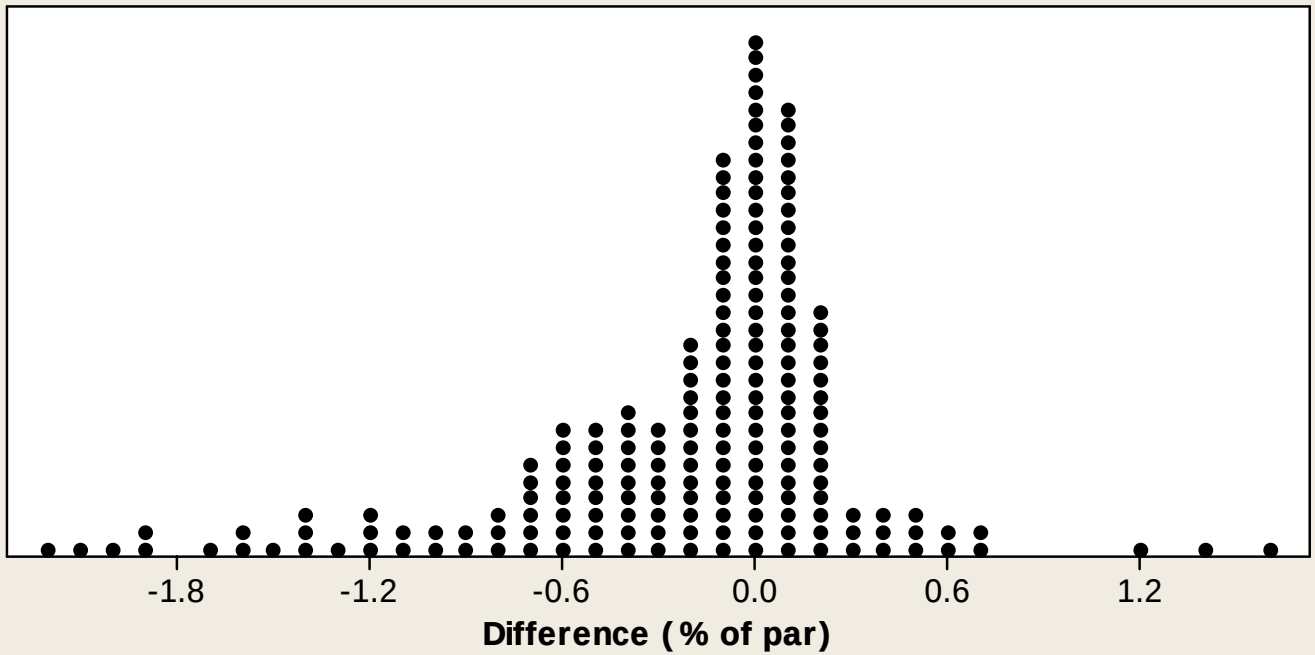
Distribution of "Model – Quote"



Each symbol represents up to 2 observations.

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Baseline Inputs Undervalue Recent High-Coupon MBS

Above-market WAC reflects weaker credit, which impedes refis

- Flat 70 bps OAS overestimates mortgagor's ability to refi and thus undervalues MBS

The cause suggests a cure

- Increase mortgagor OAS to reflect weaker credit
- Slows down refis and increases MBS value

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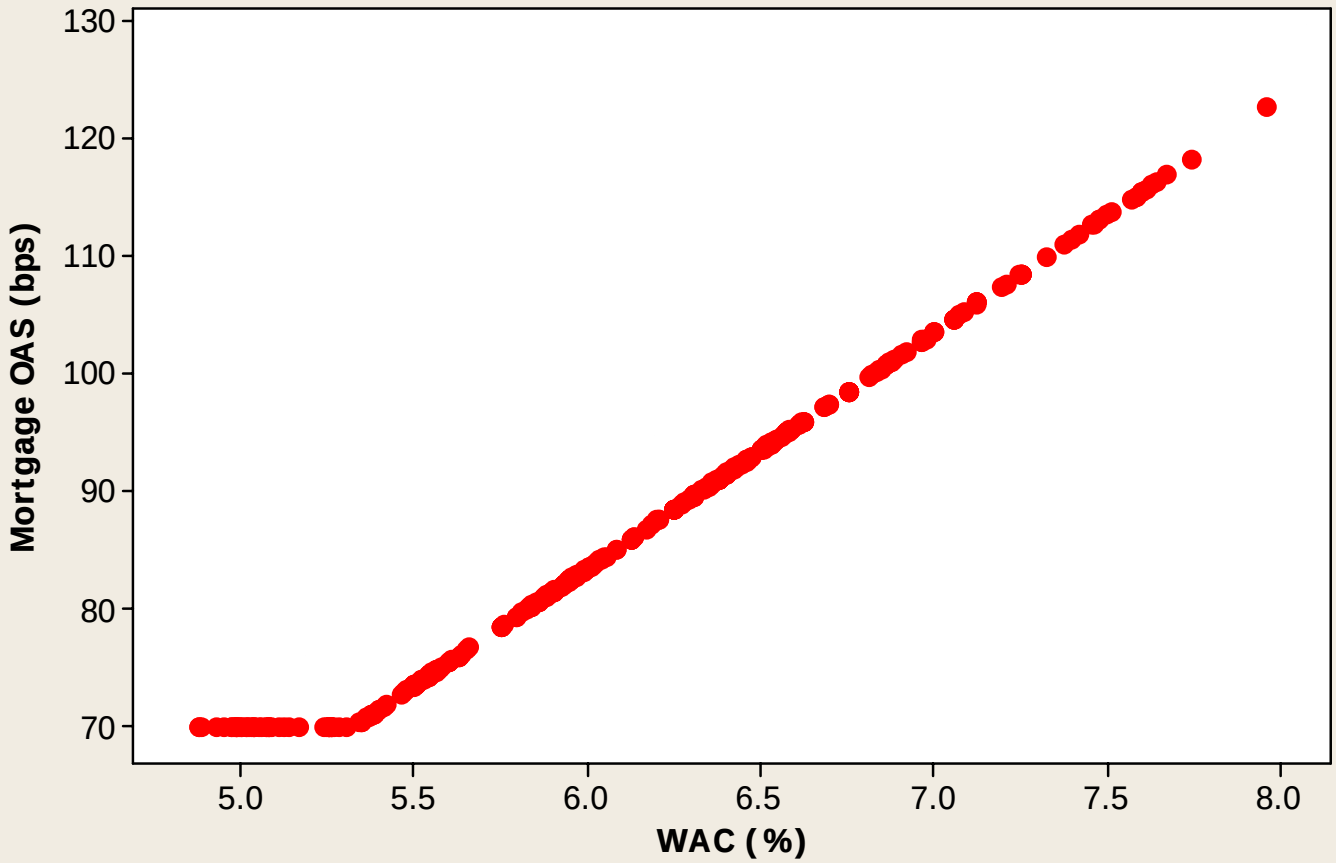
"Hockey-stick" Adjustment to Mortgagor OAS



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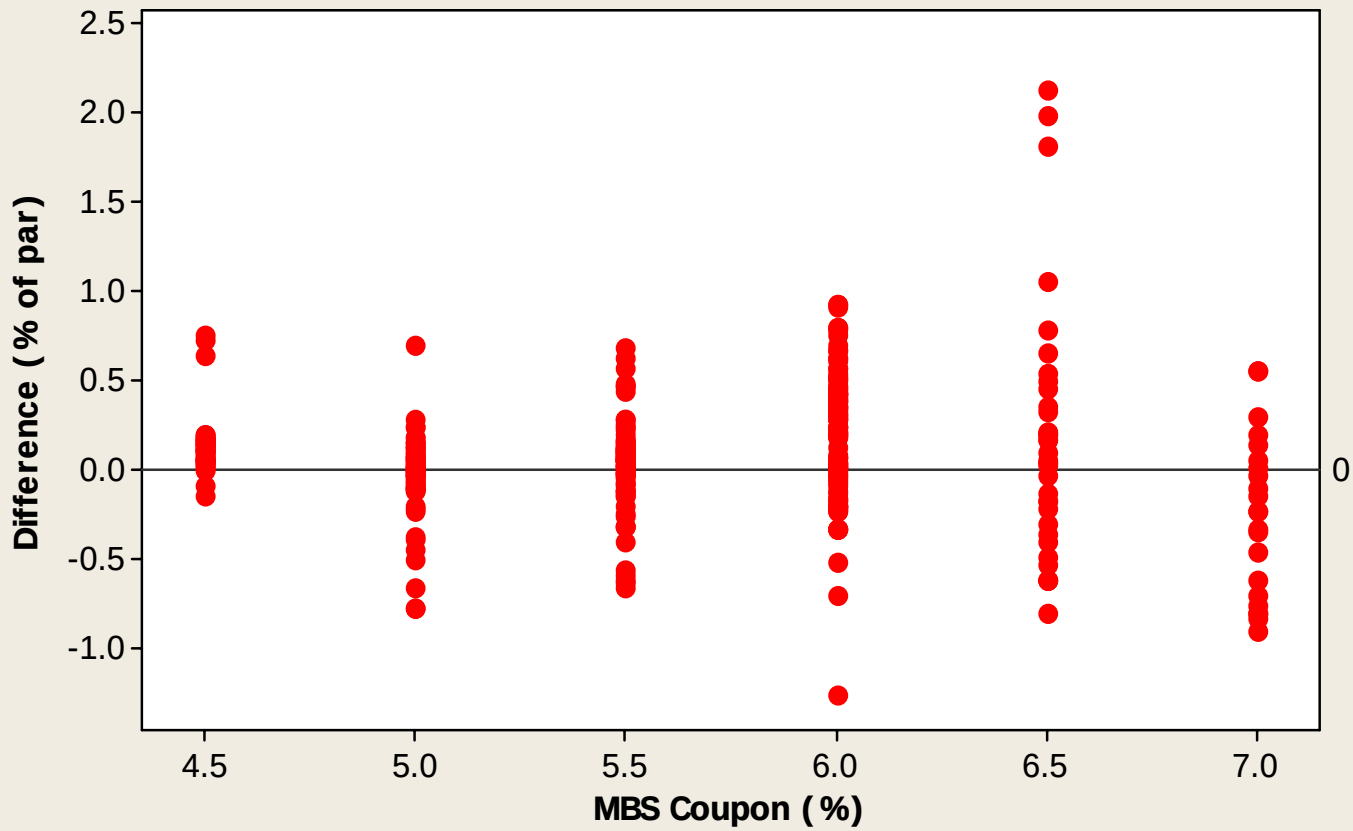
Model Values of High-Coupon MBS Improve



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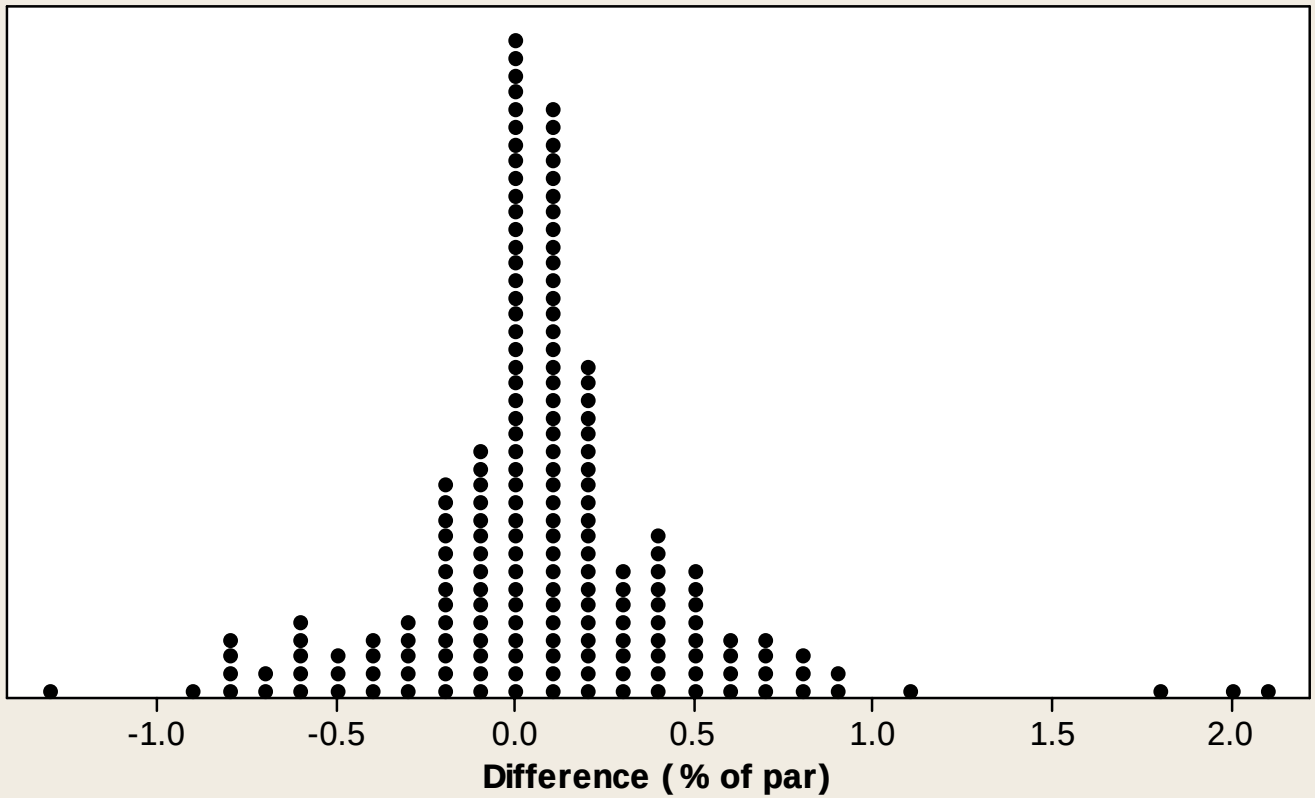
Resulting in a Much Better Fit



Each symbol represents up to 2 observations.

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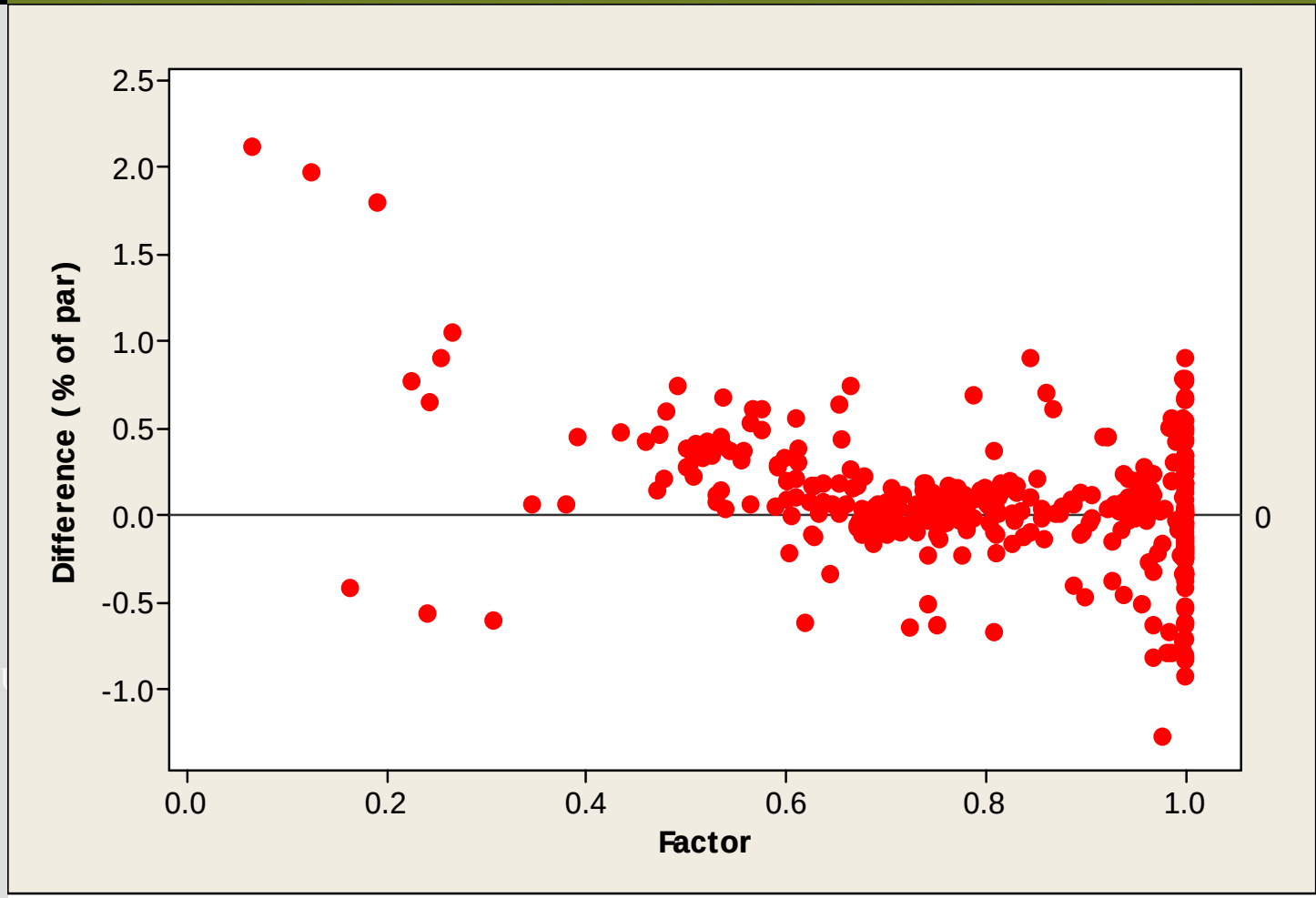
But Low-Factor Pools Remain Problematic



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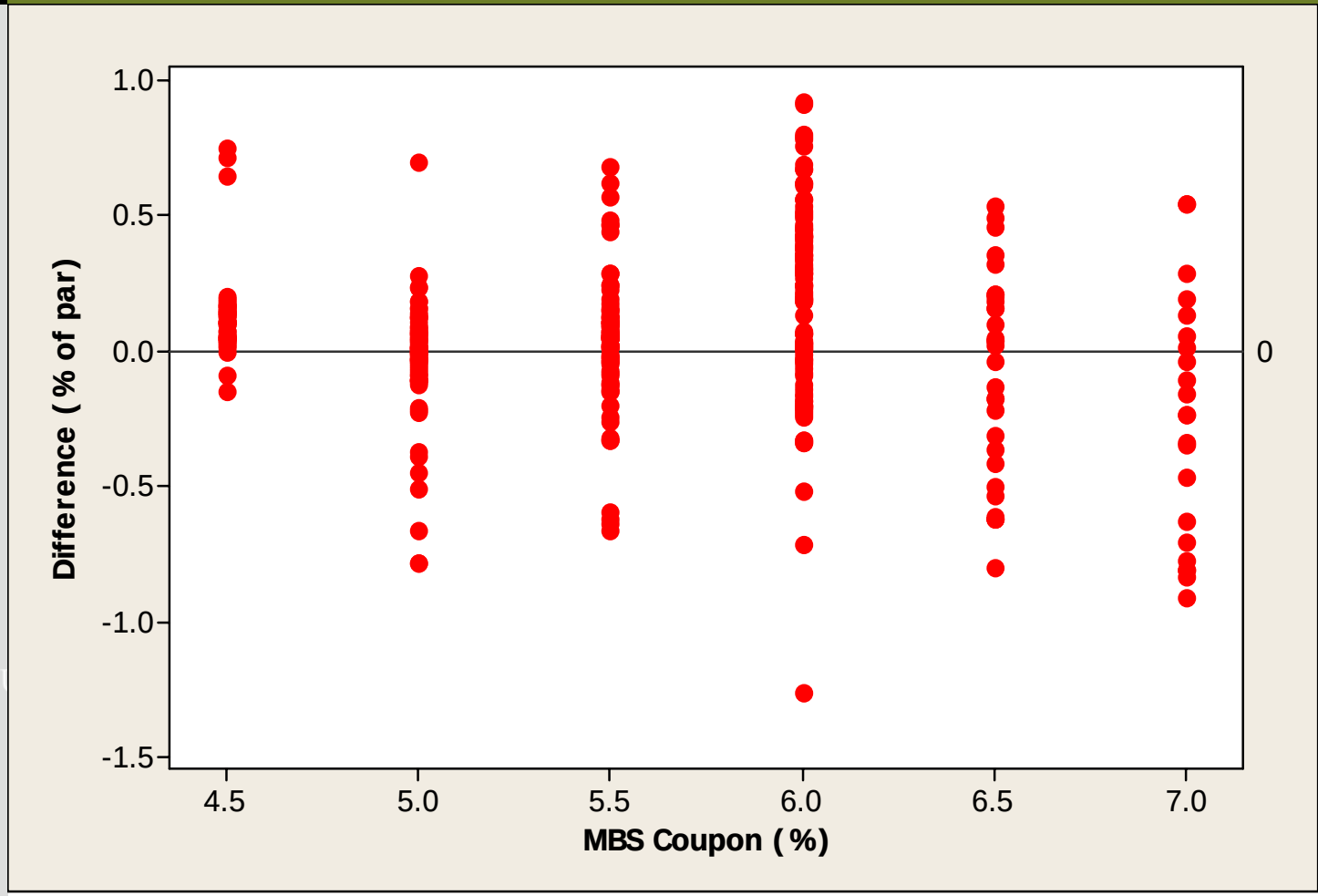
After Removing 9 Low-Factor 6.5% MBS



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Summary Statistics of "Model-Quote" (363 MBS)

Model Inputs	Mean	Median	Std Dev	1st Quartile	3rd Quartile
Baseline	0.21	-0.07	0.53	-0.40	0.10
Hockey-stick adjustment	0.07	0.06	0.37	-0.09	0.21
Hockey-stick, without 9 low-factor MBS	0.05	0.05	0.32	-0.09	0.19

All units % par

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Calibration of CLEAN™

Mortgagor OAS should reflect borrower's credit

- For Fannie and Freddie pools, 70 bps over swap curve (strong BBB credit)
- For Ginnie pools, 100bps (weak BBB credit)

Keep other inputs as in example above

- Including laggard distribution and hockey stick adjustment

Estimate MBS OAS from TBA prices

- OAS of whole loans should be roughly 30 bps higher

Refine inputs, depending on precision required

- Low factor pools require special handling
- Turnover can be customized

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Applications of CLEAN™

End-of-day pricing

850,000 fixed-rate Agency MBS by NYSE/Sector

Electronic trading

Indicative pricing for buy-side platform

Risk management

High-speed stress testing

Real-time portfolio analysis

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Why is CLEAN™ a Good Model?

Fully consistent with analysis of swaps and bonds

- Including volatility-dependent option exercise and interpretation of OAS

Expected prepayment behavior is inferred from the market, rather than history

- Just as options trade on implied volatility

User has full control of model

- Including parameterization of refinancing behavior

Quick and accurate calculation of prices and sensitivities

- 10,000 recursive valuations per minute

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References

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"An Option-Theoretic Prepayment Model for Mortgages and Mortgage-Backed Securities", Andrew Kalotay, Deane Yang, and Frank Fabozzi, *International Journal of Theoretical and Applied Finance* (December 2004)

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"Refunding Efficiency: A Generalized Approach", Andrew Kalotay, Deane Yang, and Frank Fabozzi, forthcoming in *Applied Financial Economics*

"Optimum Refinancing: Bringing Professional Discipline to Household Finance", Andrew Kalotay, Deane Yang, and Frank Fabozzi, working paper

"A Pointer on Points," Andrew Kalotay and Jinghua Qian, forthcoming in *OR/MS Today*

For Calculators, see www.kalotay.com/calculators

CLEAN™ available at www.kalotay.com/downloads/clean