Borrower Behavior, Mortgage Terminations, and The Pricing of Residential Mortgages

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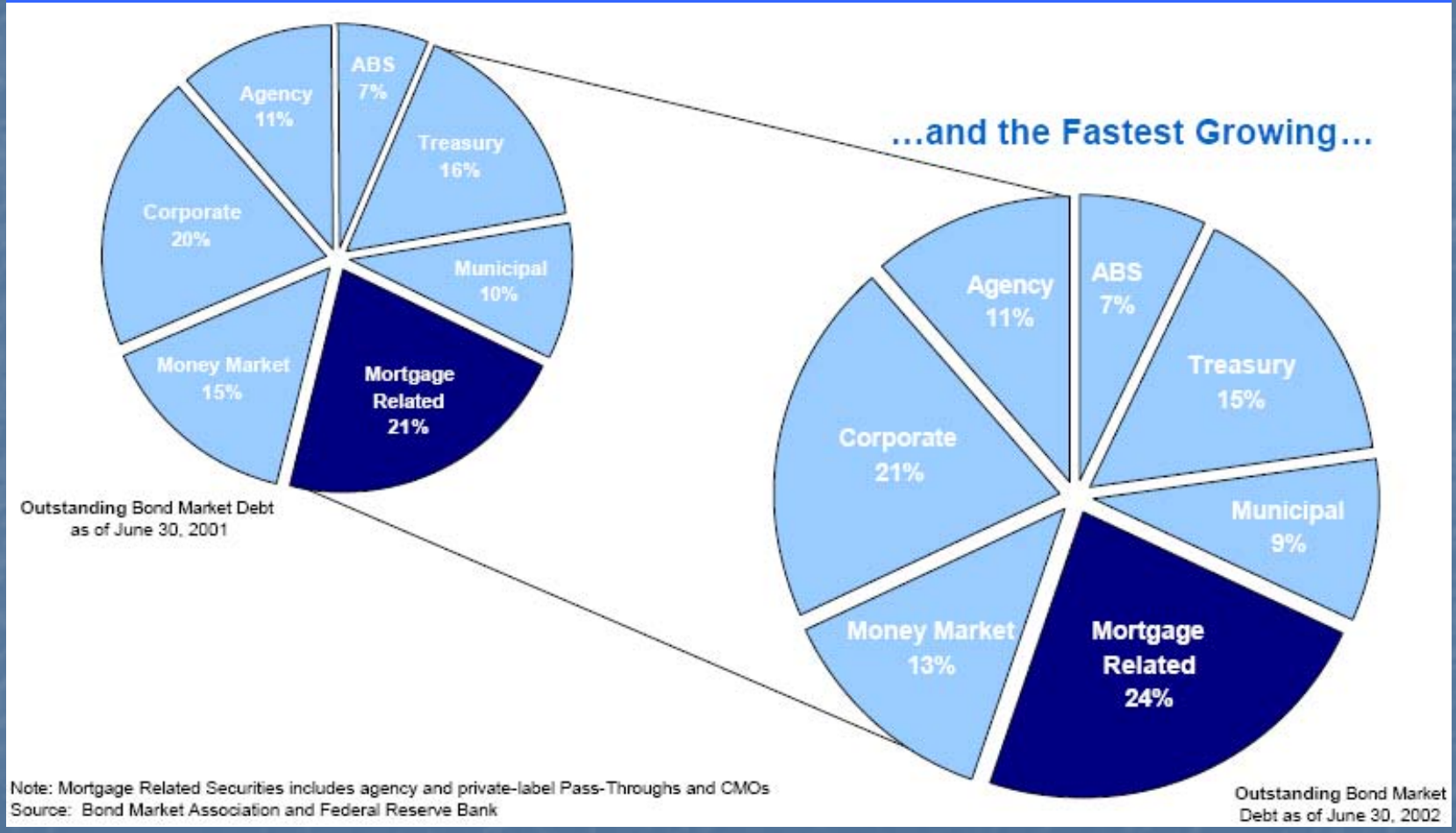
Reserve Bank of New Zealand, Wellington, September 2006

Motivation

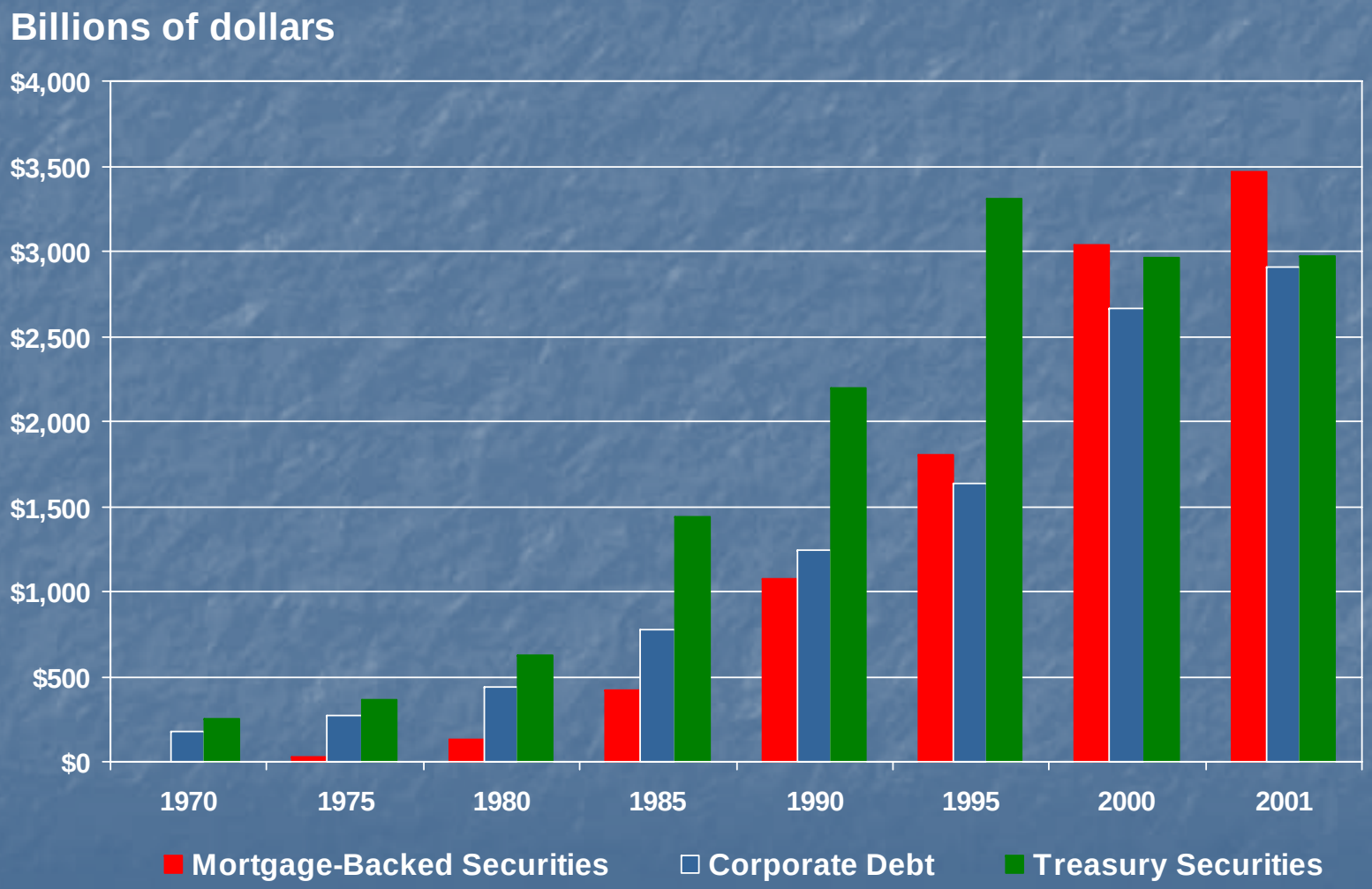
Why do we care about mortgage borrowers' behavior?

Mortgages are the Largest Segment of the Fixed Income Market



Note: Mortgage Related Securities includes agency and private-label Pass-Throughs and CMOs
Source: Bond Market Association and Federal Reserve Bank

MBS: A Major Investment Vehicle



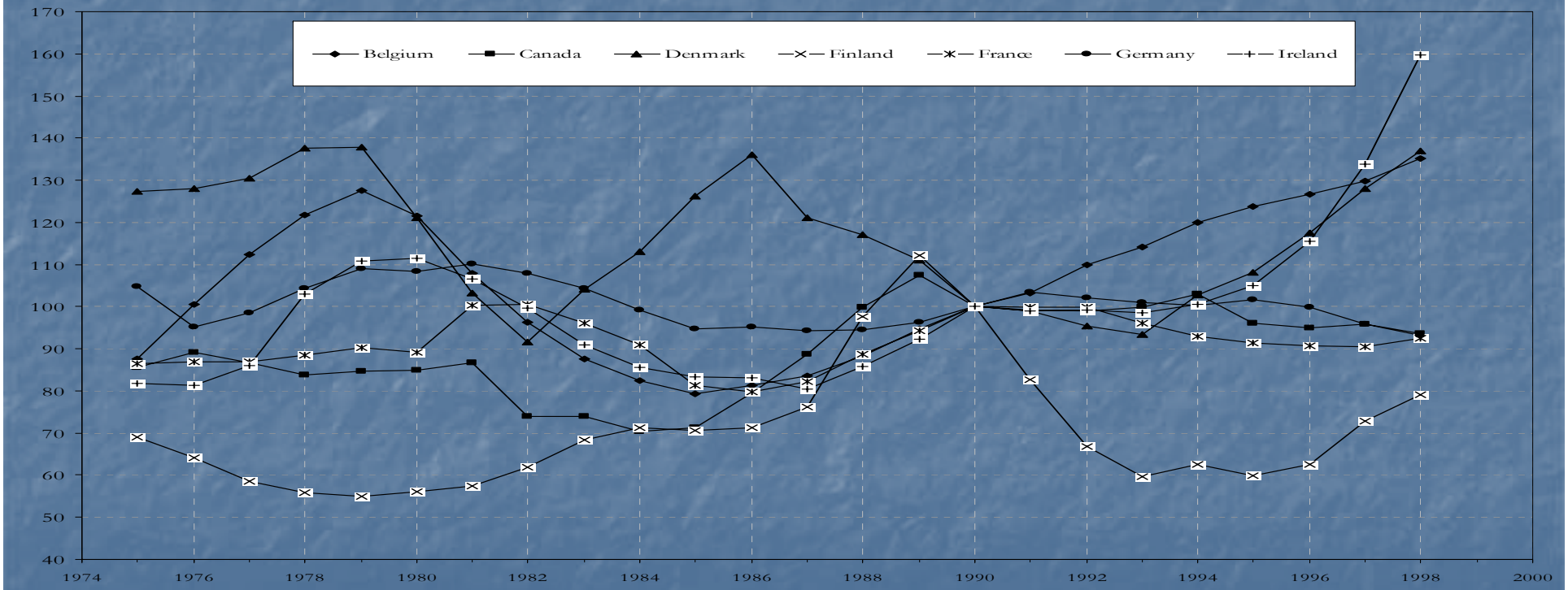
Mortgages Differ Greatly from Other Fixed Income Investments

- Cash flows and valuations depend upon the economic behavior of small time investors.
- Many of these decision makers don't view themselves as investors at all.
- Do homeowners *really* behave like MBAs?

Volatility in House Prices

Evolution of Real Housing Prices Across OECD Countries

(1990 =100)



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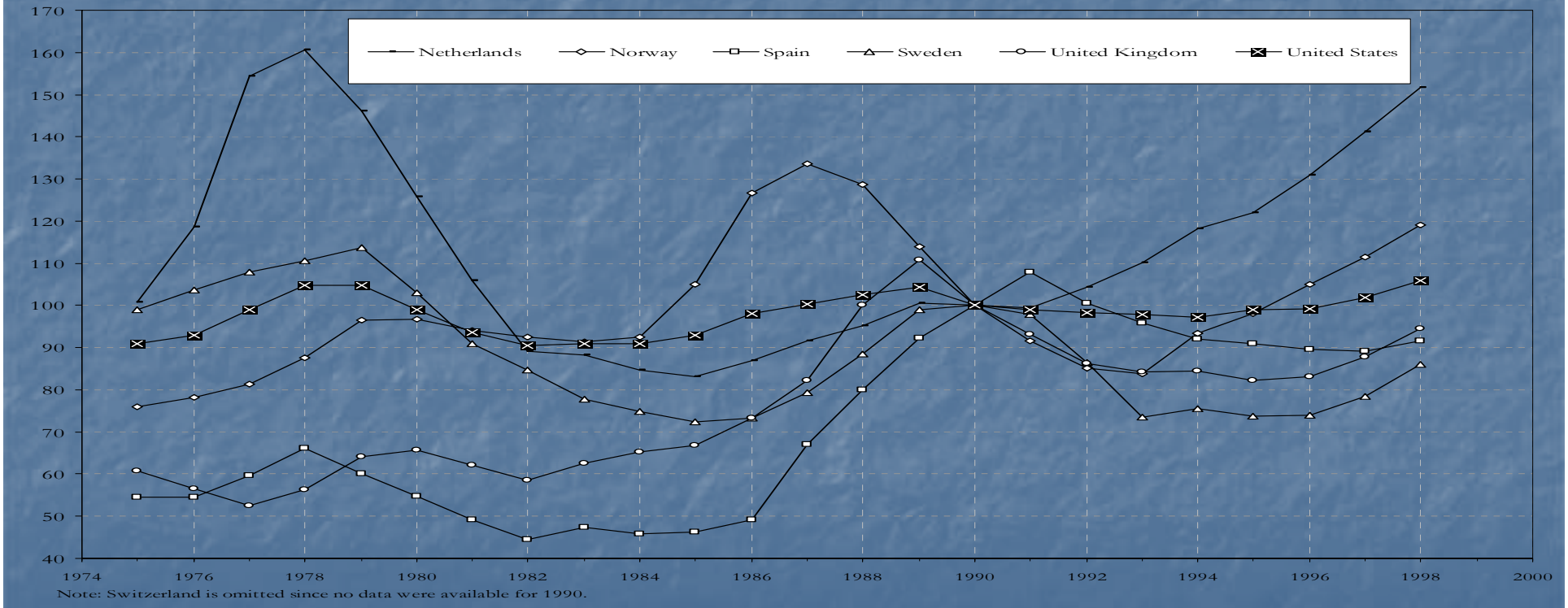

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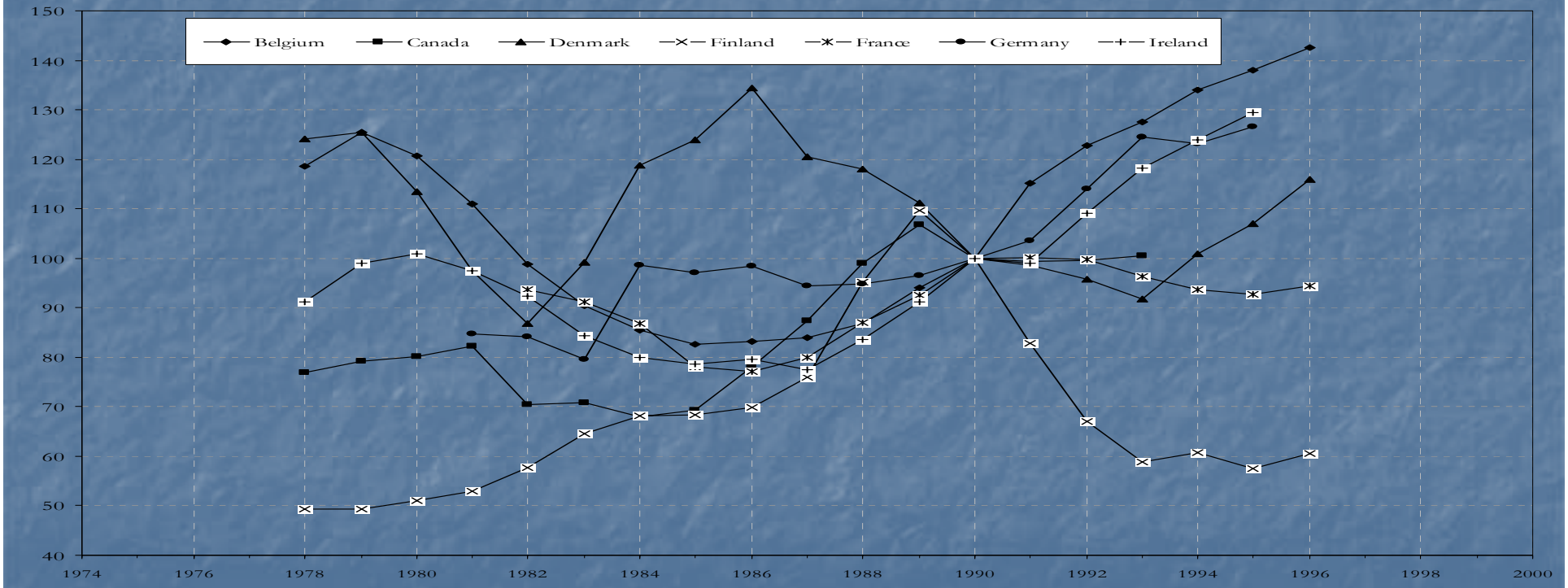
Volatility in Housing Wealth

Evolution of Real Housing Wealth Per Capita Across OECD Countries

(1990 =100)



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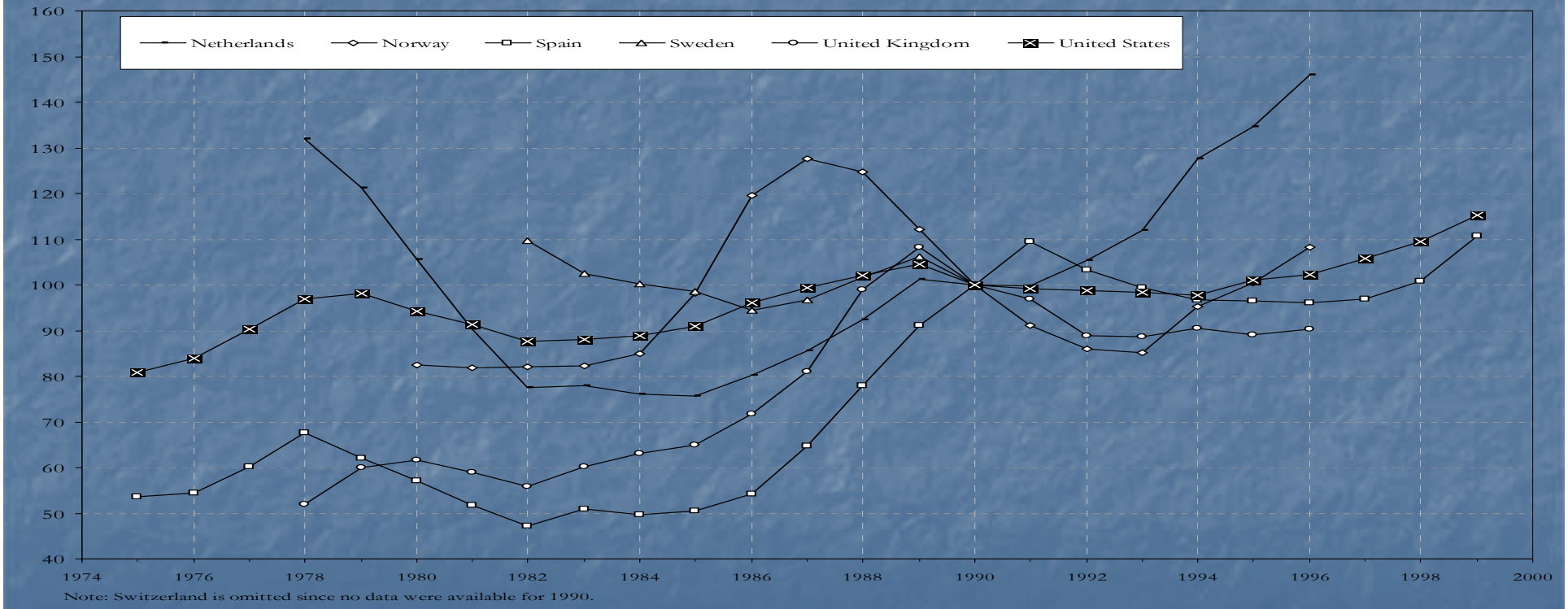

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Consensus on Economic Analysis of Mortgage Borrower Behavior

1. Option theory provides a coherent and useful framework for analyzing borrowers' prepayment or default behavior.

2. The jointness of the prepayment and default options is important in explaining behavior.

3. Duration or competing risks models provide a convenient analytical tool for analyzing borrower behavior.

1. Option Theory

- Only a rocket scientist needs to solve a complex model.
- A homeowner just needs market prices.
  - Prepay ("call") when:

    You can refinance the loan for the same term with a lower coupon.
  - Default ("put") when:

    You can have lower payments on a new zero down payment loan for the same term on the same house.

- Variables “measuring in the money” of options, say X_1, and X_2, are routinely computed by real people at time t.

- Call option = $X_1 = [PDV(c, t_1) – PDV(r, t_1)]$
- Put option = $X_2 = [PDV(r, t_1) – MKT(t_1)]$

TRANSACTIONS COSTS

2. Jointness

- Homeowners are less likely to exercise call option when put option is in the money. Why?

3. Competing Risks

- Models of survival from epidemiology and biometrics.

- Survival Function

  $F(t) = Pr\ (T > t)$

- Hazard of “Death”

  $h(t) = \Delta F(t)/F(t)$

- So:

  $h(t_p, t_d) = f(X_1, X_2, \text{other stuff})$

One Other Key Wrinkle
Borrower Heterogeneity

- Calculation, ability, attention ?

A. Ad hoc demographic variables.
B. Assumptions about transactions costs across pools of mortgages.
C. Models of unobserved differences.

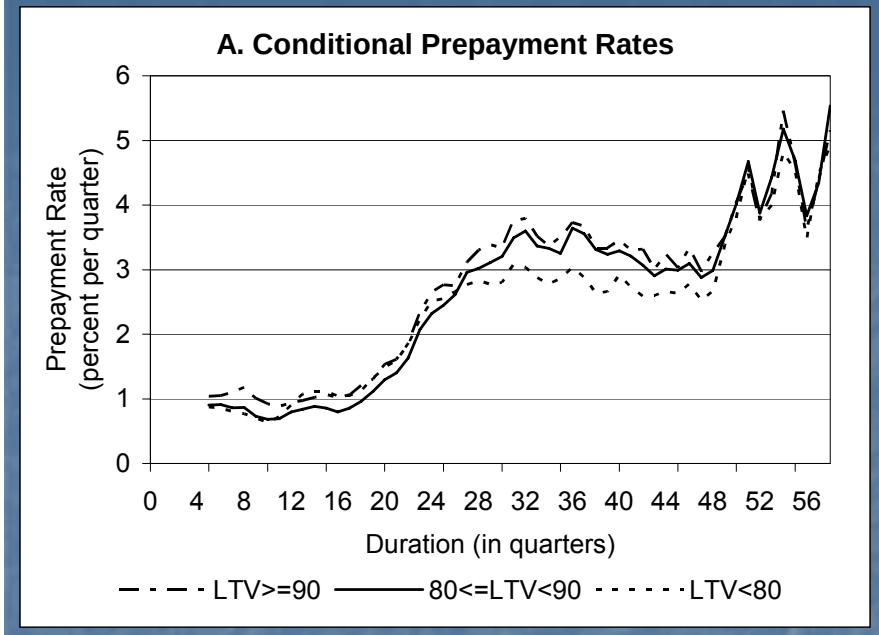
ENORMOUS PRACTICAL IMPORTANCE

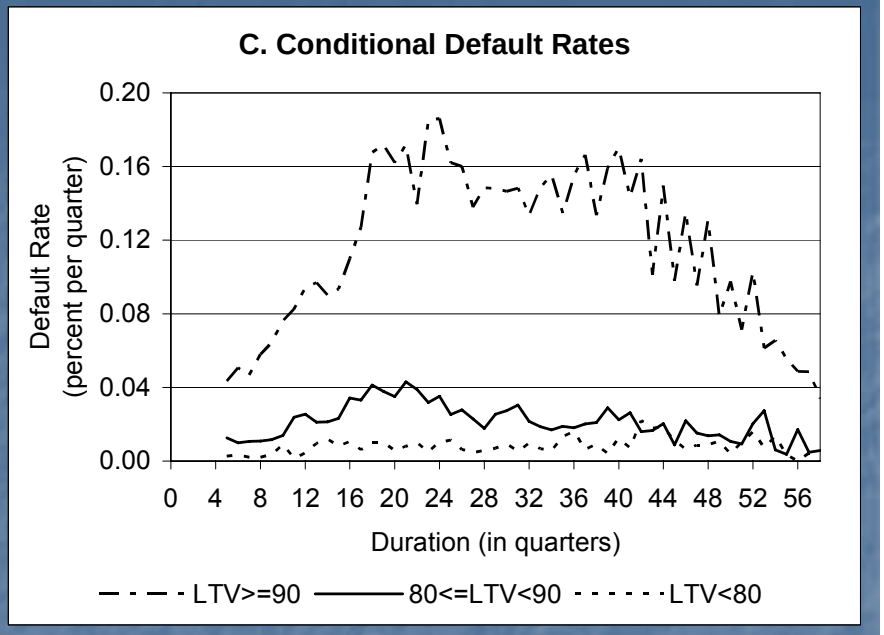
Applications Using Real Data

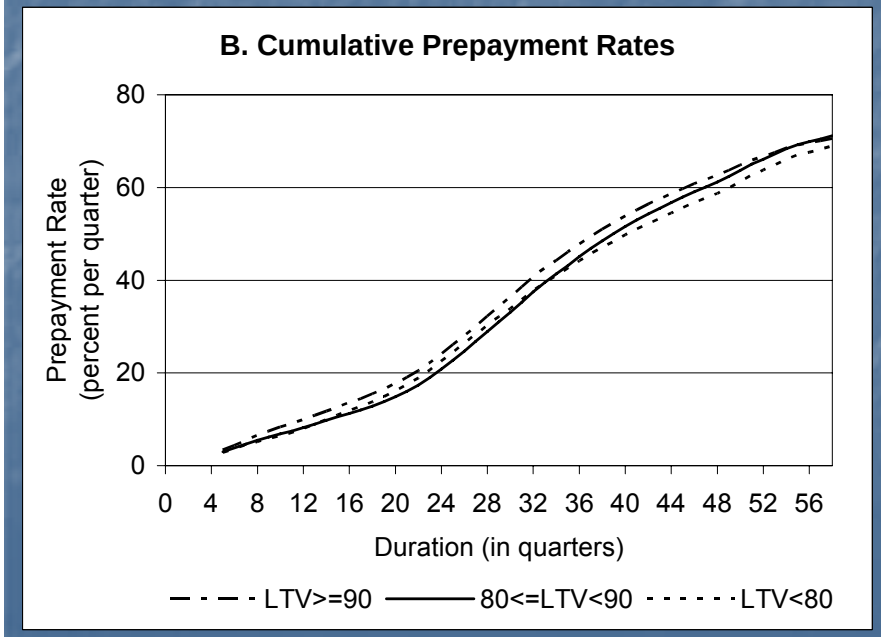
1. Mortgages Purchased by Freddie Mac
   Originated in 1976-1983.
2. Mortgages Originated by “Large Private Bank”
   Originated in 1994-2003.

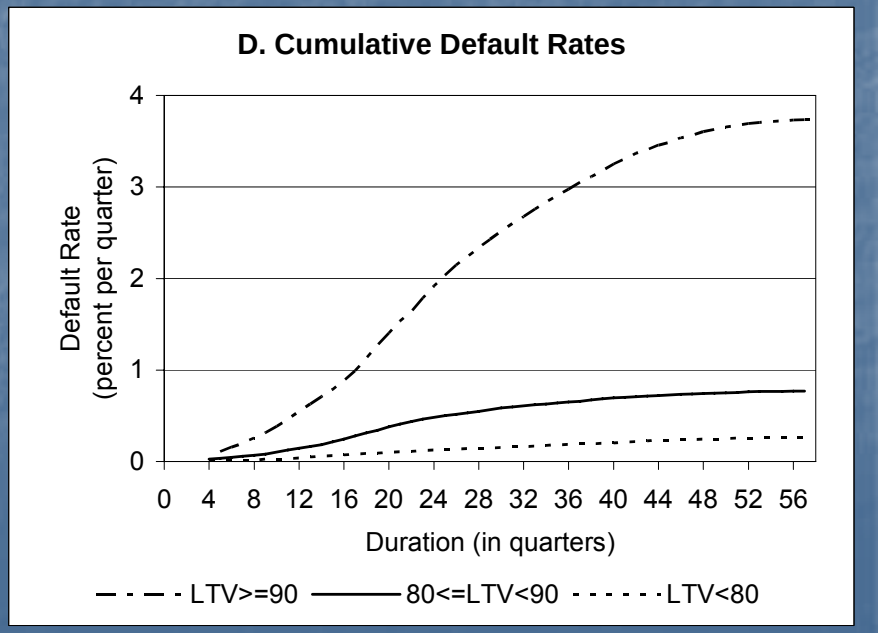
- Mortgages followed quarterly from origination to termination, maturation, or censoring...
- Distribution of house prices followed quarterly in each metropolitan region.

Sample of thirty year mortgages









Determinants of termination at t

- Value of call option:

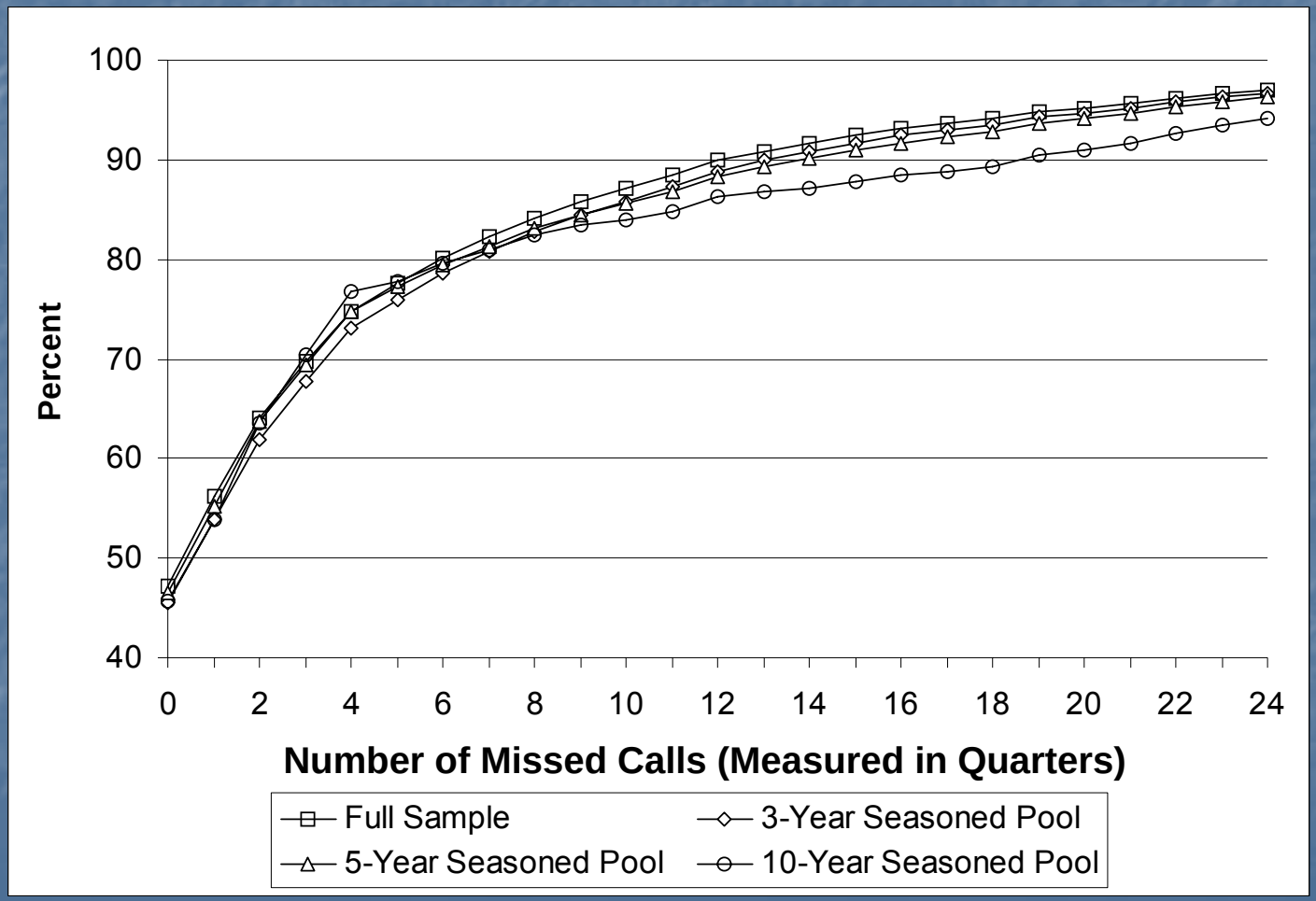
  Computed from mortgage contract and current interest rates.

- Probability that put option is in the money:

  Computed from UPB and the course of metropolitan housing prices.

- LTV at origination
- Metropolitan unemployment rate
- Metropolitan divorce rate
- Measures of “Astuteness”

"ASTUTENESS"
Cumulative Frequency of Missed Call Opportunities



Mean Values of the Extent to Which the Call Options are In The Money at Termination

"Missed Opportunities"	Full Sample	3-Year Seasoned Pool	5-Year Seasoned Pool	10-Year Seasoned Pool
W = 0	-15.16	-14.66	-13.30	-6.45
W = 1-2	-4.50	-4.53	-3.92	-1.81
W = 3-4	3.28	2.71	2.98	1.02
W = 5-8	5.41	5.35	4.85	3.91
W = 9-12	11.91	11.69	9.46	5.39
W > 12	16.85	16.85	16.10	13.71

Conclusions I

- As missed opportunities increase, call values are higher at termination.
- As seasoning increases, so does the value of the call at termination.

Models of Prepayment and Default (t ratios in parentheses)

	Model 1		Model 2		Model 3		Model 4	
	Prepay	Default	Prepay	Default	Prepay	Default	Prepay	Default
Call Option (fraction of contract value)	4.799 (112.00)	6.801 (16.64)	6.343 (82.01)	5.735 (8.19)	6.523 (76.90)	5.753 (8.09)	7.348 (88.02)	5.667 (8.05)
Put Option (probability of negative equity)	-5.300 (-10.74)	8.852 (8.58)	-5.804 (-11.75)	8.854 (8.72)	-5.733 (-11.41)	9.346 (9.15)	-5.217 (-9.34)	8.955 (8.73)
Call Option Squared	1.427 (9.53)	0.608 (0.49)	4.085 (21.49)	-1.656 (-1.02)	4.637 (21.33)	-0.350 (-0.21)	5.982 (31.27)	-1.731 (-1.06)
Put Option Squared	5.710 (9.10)	-9.174 (-6.80)	6.313 (10.02)	-9.217 (-6.92)	6.267 (9.80)	-9.629 (-7.19)	6.052 (8.59)	-9.379 (-6.95)
State Unemployment Rate (percent)	-0.039 (-7.58)	0.083 (1.67)	-0.042 (-8.15)	0.093 (1.84)	-0.043 (-8.13)	0.096 (1.88)	-0.080 (-14.45)	0.095 (1.87)
State Divorce Rate (percent)	-0.009 (-0.81)	0.471 (3.95)	-0.016 (-1.43)	0.477 (4.00)	-0.022 (-1.84)	0.482 (4.02)	0.010 (0.77)	0.472 (3.93)

Conclusions II

- Values of both options are very important in prepayment & default decisions.
- As interest rate drops, prepayments increase more than proportionately.
- Other factors, unemployment, divorce are important.

Models of Prepayment and Default Hazard (t ratios in parentheses)

	Model 1		Model 2		Model 3		Model 4	
	Prepay	Default	Prepay	Default	Prepay	Default	Prepay	Default
0.6<LTV≤0.75	0.065	2.145	0.059	2.154	0.052	2.137	0.068	2.144
	(2.48)	(2.65)	(2.18)	(2.65)	(1.77)	(2.62)	(2.16)	(2.64)
0.75<LTV≤0.8	0.044	2.491	0.044	2.495	0.036	2.493	0.059	2.492
	(1.90)	(3.12)	(1.83)	(3.13)	(1.38)	(3.11)	(2.20)	(3.12)
0.8<LTV≤0.9	0.094	3.438	0.110	3.439	0.100	3.416	0.149	3.427
	(3.77)	(4.37)	(4.24)	(4.37)	(3.54)	(4.31)	(5.07)	(4.35)
LTV>0.9	-0.024	3.878	0.004	3.879	0.010	3.896	-0.011	3.875
	(-0.78)	(4.94)	(0.12)	(4.93)	(0.29)	(4.92)	(-0.31)	(4.92)
W			-0.044	0.034	-0.037	0.053	-0.029	0.042
			(-22.01)	(1.89)	(-14.81)	(2.86)	(-14.77)	(2.35)

Conclusions III

- Default rates increase with LTV. Attitude towards risk?
- Link between prepay rates and LTV is less clear.
- Measures of heterogeneity are important.

Models of Prepayment and Default (t ratios in parentheses)

	Model 1		Model 2		Model 3		Model 4	
	Prepay	Default	Prepay	Default	Prepay	Default	Prepay	Default
Baseline Intercept	3.709 (7.58)	0.001 (0.83)	4.070 (7.55)	0.001 (0.82)			3.471 (7.22)	0.001 (0.81)
Baseline Intercept ("ruthless")					4.407 (7.36)	0.001 (0.81)		
Baseline Intercept ("woodheads")					0.604 (2.98)	0.000 (0.00)		
Fraction "woodheads"					0.044 (3.34)			
Log Likelihood	-73,974		-73,734		-73,683		-65,570	
Schwarz B.I.C.	74,094		73,864		73,823		65,700	

Conclusions IV

- More careful measures of borrower differences explain option behavior better.

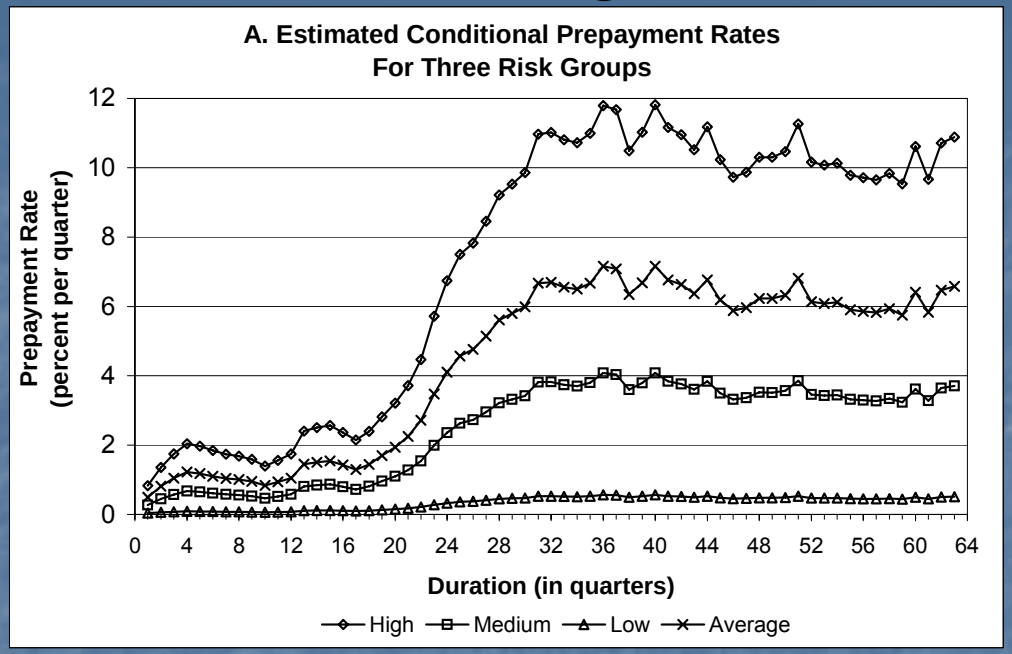
Practical Implications

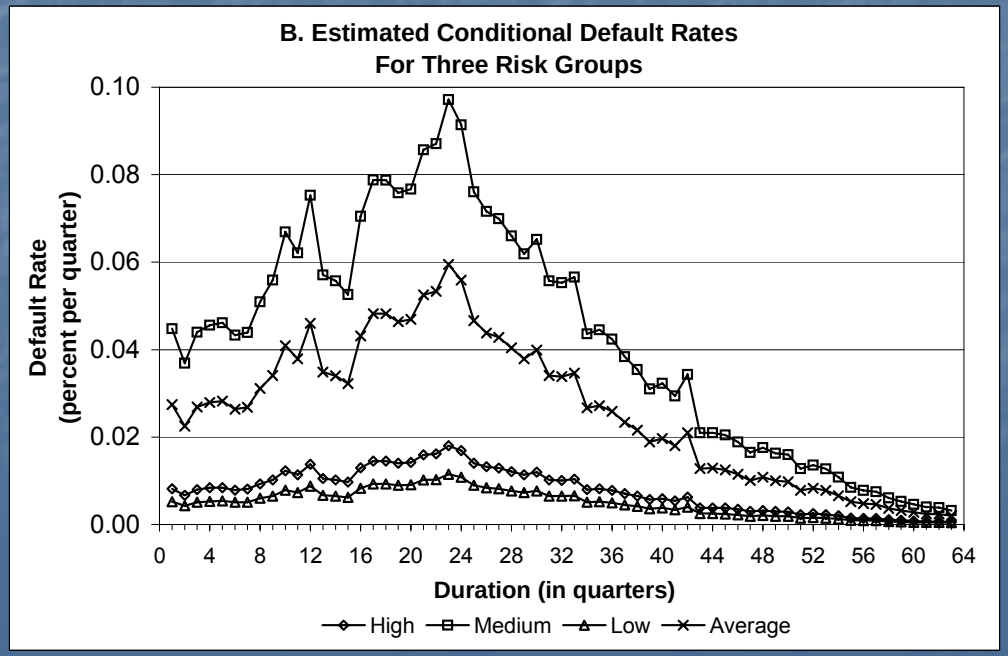
1. Measuring, anticipating and reacting to risk.

2. Computing cash flows, mortgage pool valuations, and the pricing implications of market conditions.

HOW LARGE ARE EFFECTS?

1. Measuring Risks



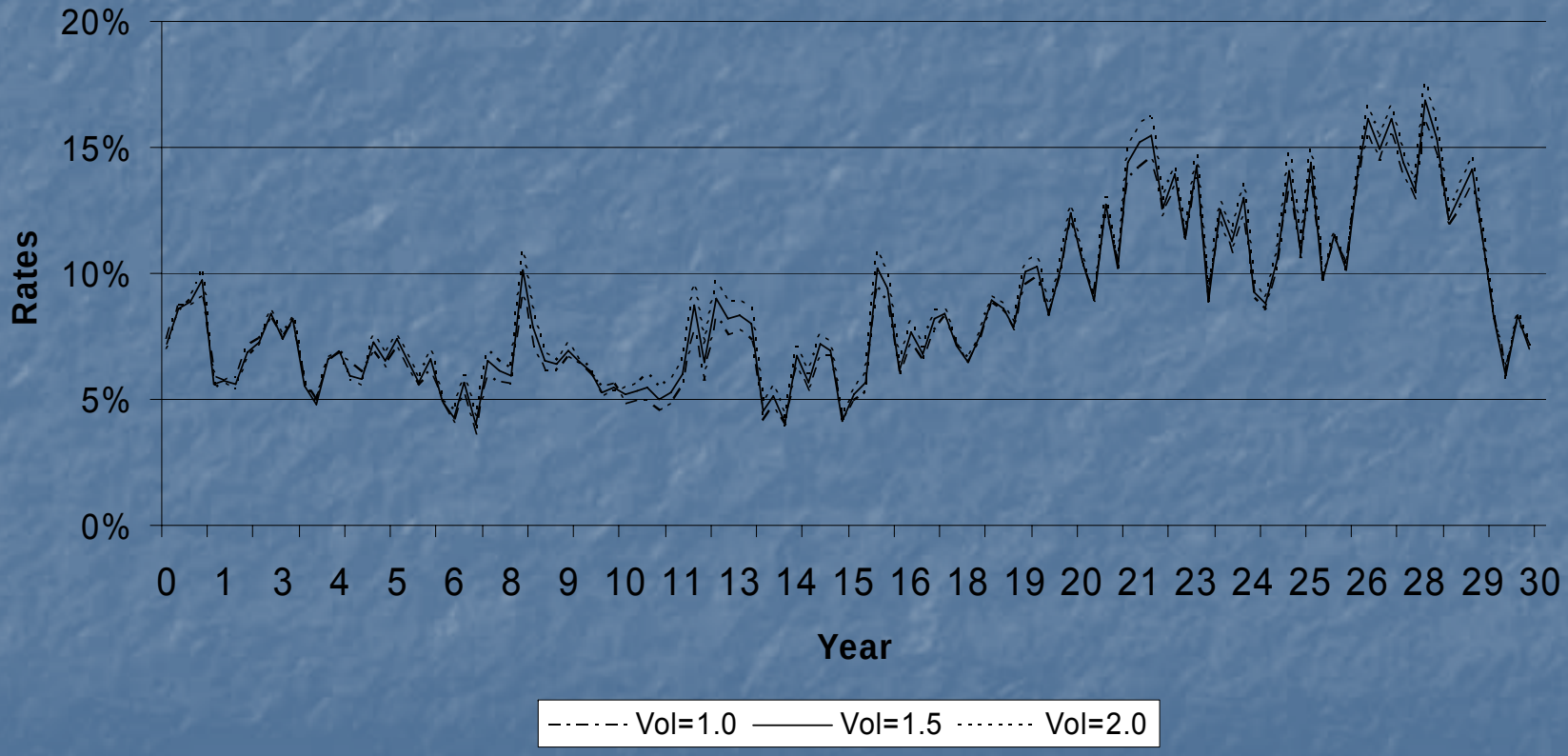


2. Cash Flows and Pricing

Monte Carlo Simulation

1. Dynamic Changes in Housing Prices
2. Interest Rate Paths
   A. Simulate many paths using dynamic term structure model.
   B. Sample from quarterly paths.
   C. At each quarter, use model to compute prepayment and default risks.
   D. Discount the risk-adjusted mortgage amortization cash flows along interest rate paths

Simulated Interest Rates – DS ATSM $A_1(3)$



Mean Percentage Differences in Mortgage Pool Prices

	Model 1 vs. Model 4	Model 2 vs. Model 4	Model 3 vs. Model 4
A. 8.25 PERCENT			
Full Sample	1.56% (127)	0.52% (114)	0.27% (88)
3-Year Seasoned Pool	1.30 (161)	0.62 (167)	0.45 (151)
5-Year Seasoned Pool	1.50 (256)	0.83 (157)	0.64 (232)
10-Year Seasoned Pool	2.42 (417)	1.72 (447)	1.45 (389)

Mean Percentage Differences in Mortgage Pool Prices

	Model 1 vs. Model 4	Model 2 vs. Model 4	Model 3 vs. Model 4
9.25 PERCENT			
Full Sample	2.55% (176)	0.68% (133)	0.35% (101)
3-Year Seasoned Pool	1.92 (202)	0.68 (176)	0.47 (163)
5-Year Seasoned Pool	2.01 (261)	0.87 (188)	0.65 (1.74)
10-Year Seasoned Pool	3.47 (417)	1.98 (306)	1.59 (270)

Mean Differences in Prices for One Million Dollar Pool

	Model 1 vs. Model 4	Model 2 vs. Model 4	Model 3 vs. Model 4
8.25 PERCENT			
Full Sample	$16,512 (129)	$5,463 (115)	$2,801 (89)
3-Year Seasoned Pool	13,488 (163)	6,492 (168)	4,681 (152)
5-Year Seasoned Pool	15,480 (262)	8,589 (260)	6,644 (233)
10-Year Seasoned Pool	25,036 (435)	17,834 (452)	14,969 (391)

Mean Differences in Prices for One Million Dollar Pool

	Model 1 vs. Model 4	Model 2 vs. Model 4	Model 3 vs. Model 4
9.25 PERCENT			
Full Sample	$26,978 (181)	$7,236 (135)	$3,655 (101)
3-Year Seasoned Pool	19,979 (208)	7,142 (179)	4,885 (165)
5-Year Seasoned Pool	20,847 (271)	8,991 (190)	6,708 (176)
10-Year Seasoned Pool	35,907 (442)	20,532 (310)	16,428 (271)

Summary

1. Economic behavior of relatively unsophisticated borrowers is key to cash flows and valuation of mortgage investments.
2. Options framework provides a powerful tool for analyzing and understanding behavior.
3. Well-known statistical methods, using data routinely gathered and maintained by financial institutions, can be applied.
4. Empirical results from the U.S. suggest that the magnitudes are large.
5. We need to know a lot more about the differences among borrowers.