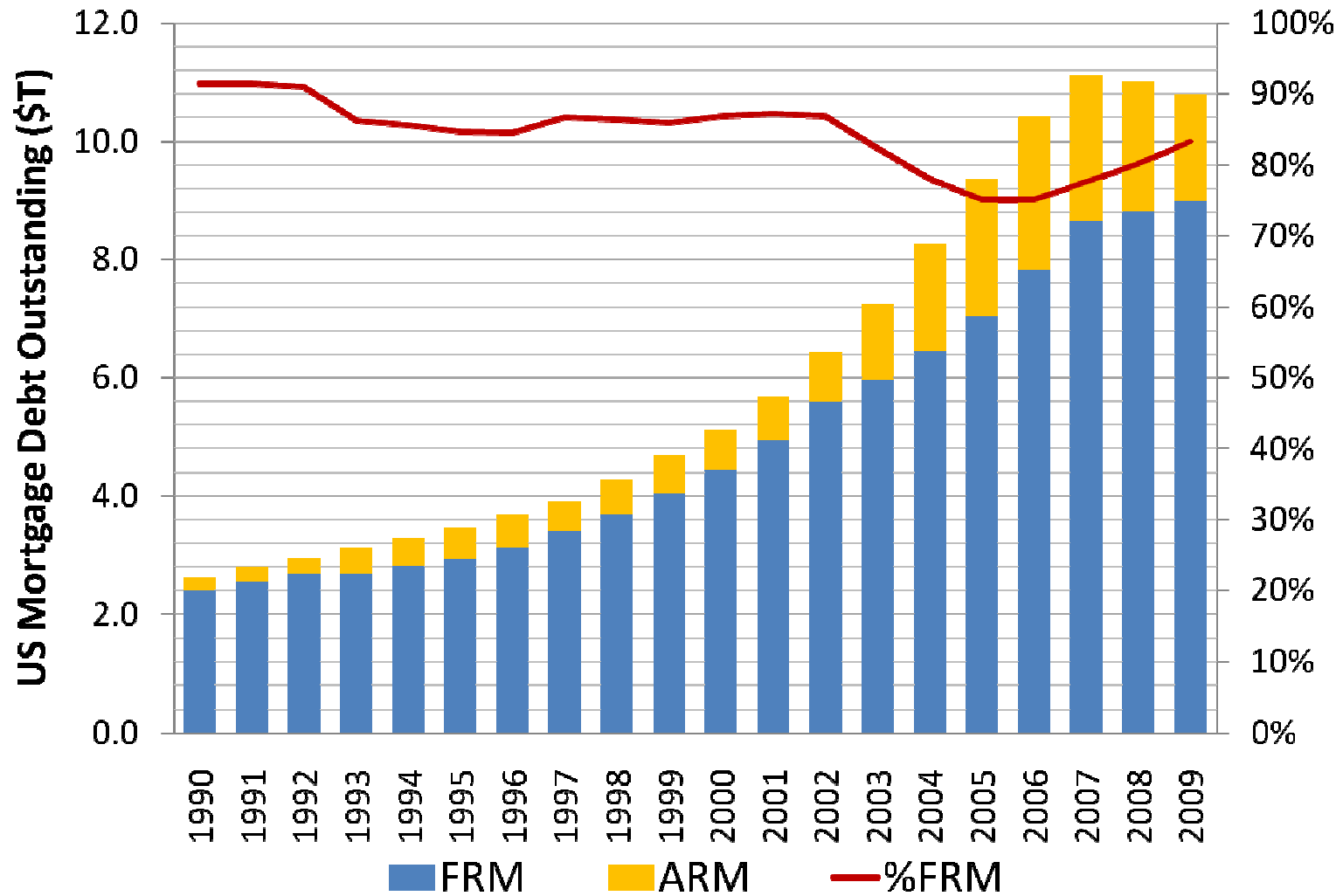


# Unobserved Heterogeneity and Its Effect on Mortgage Default and Prepayment Options

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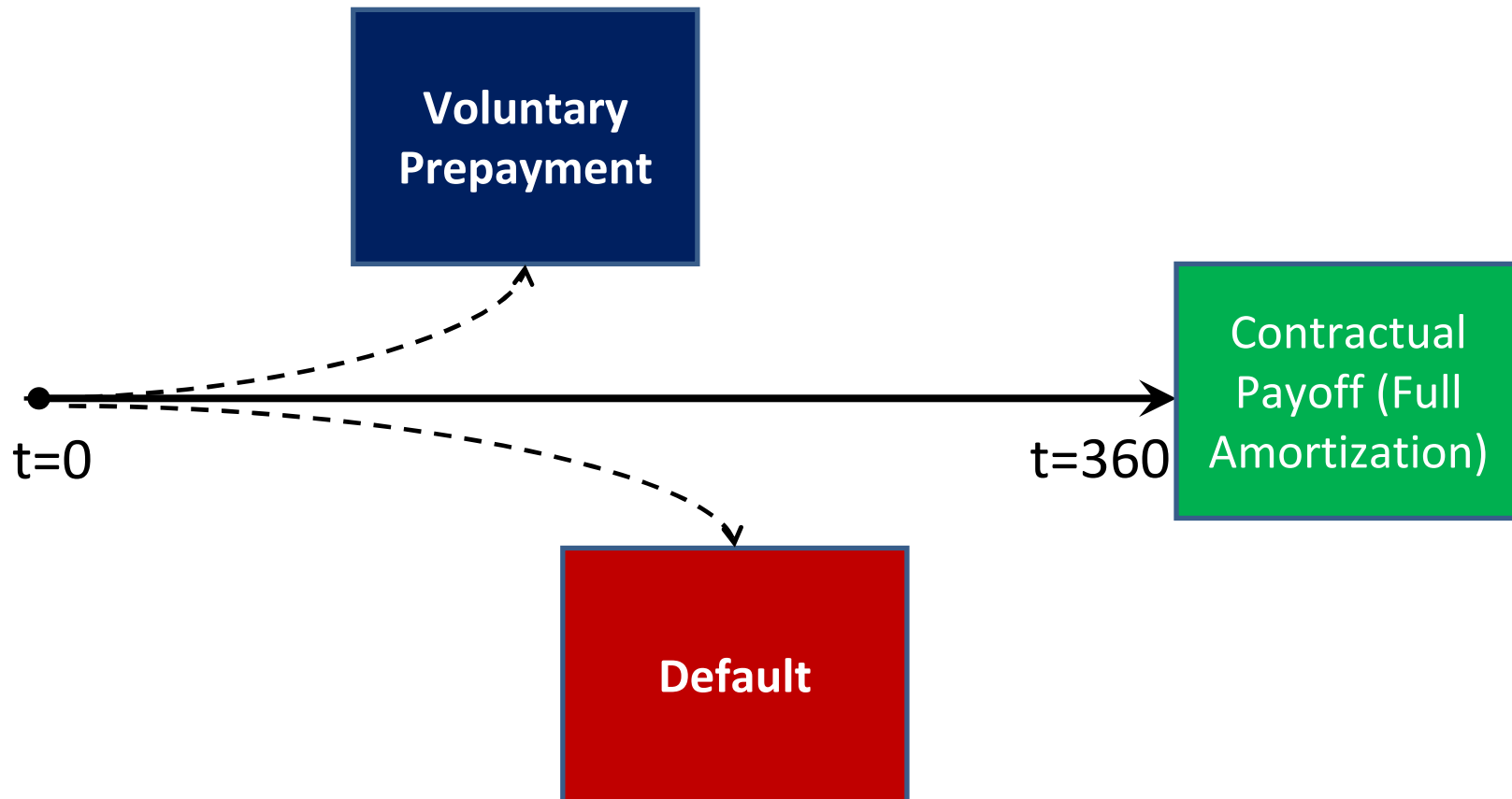
# The US mortgage market is huge and it is dominated by long-term fixed rate loans



Source: Moody's Economy.com

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# Borrowers always have options to terminate the mortgage contract at any time



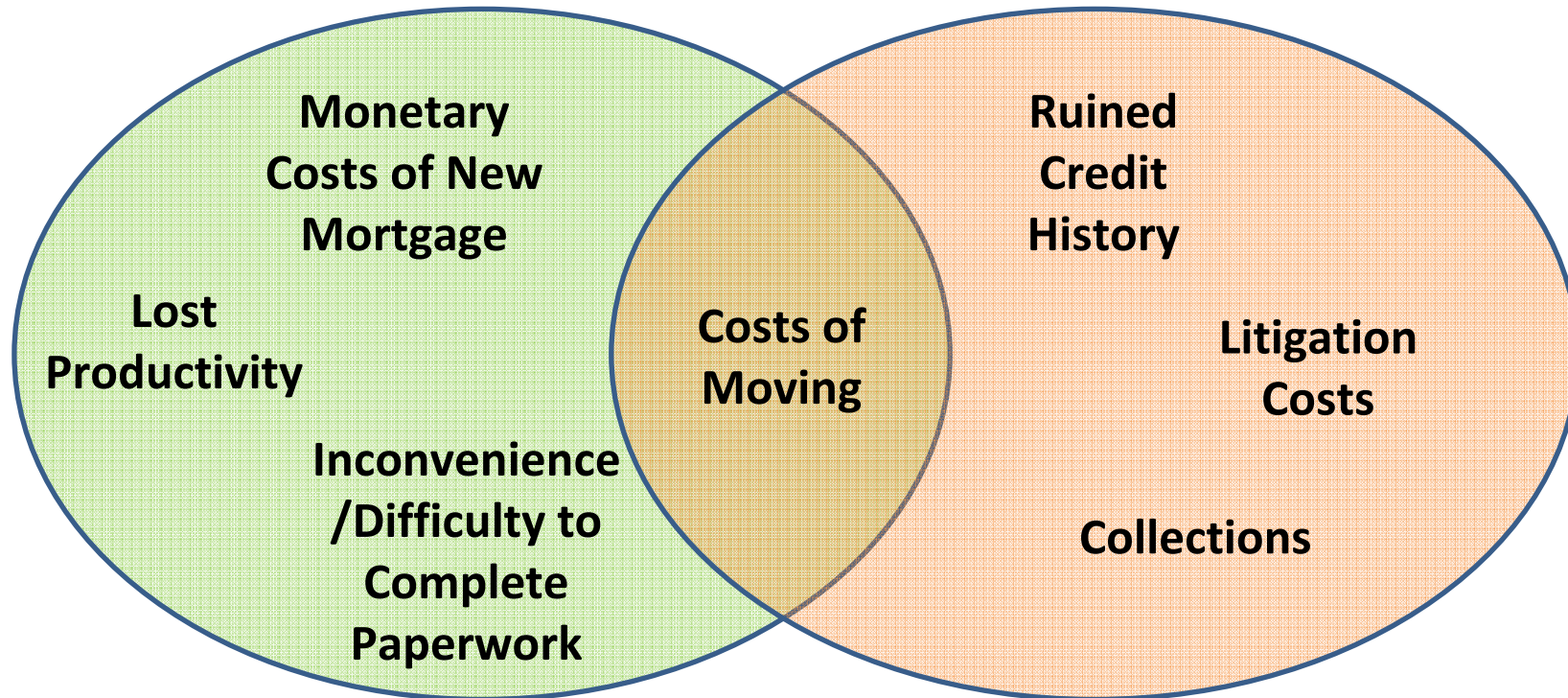
# The theoretical underpinning of rational option exercising has been discussed since late 1980s-early 1990s

- Option pricing models of mortgage consumer behavior
  - Borrowers are rational
    - Compare the value of (discounted) future payments against outstanding mortgage balance
    - Compare the value of collateral against outstanding mortgage balance
  - Both prepayment and default options must be considered jointly:
    - Cannot accurately value the mortgage contract without taking both options into consideration
  - Epperson *et al.* (1985)
  - Kau *et al.* (1992, 1993, 1994, 1995)
  - Capozza, Kazarian, and Thomson (1998)
  - and others

# Exercising options is far from costless

Costs of Prepayment:

Costs of Default:



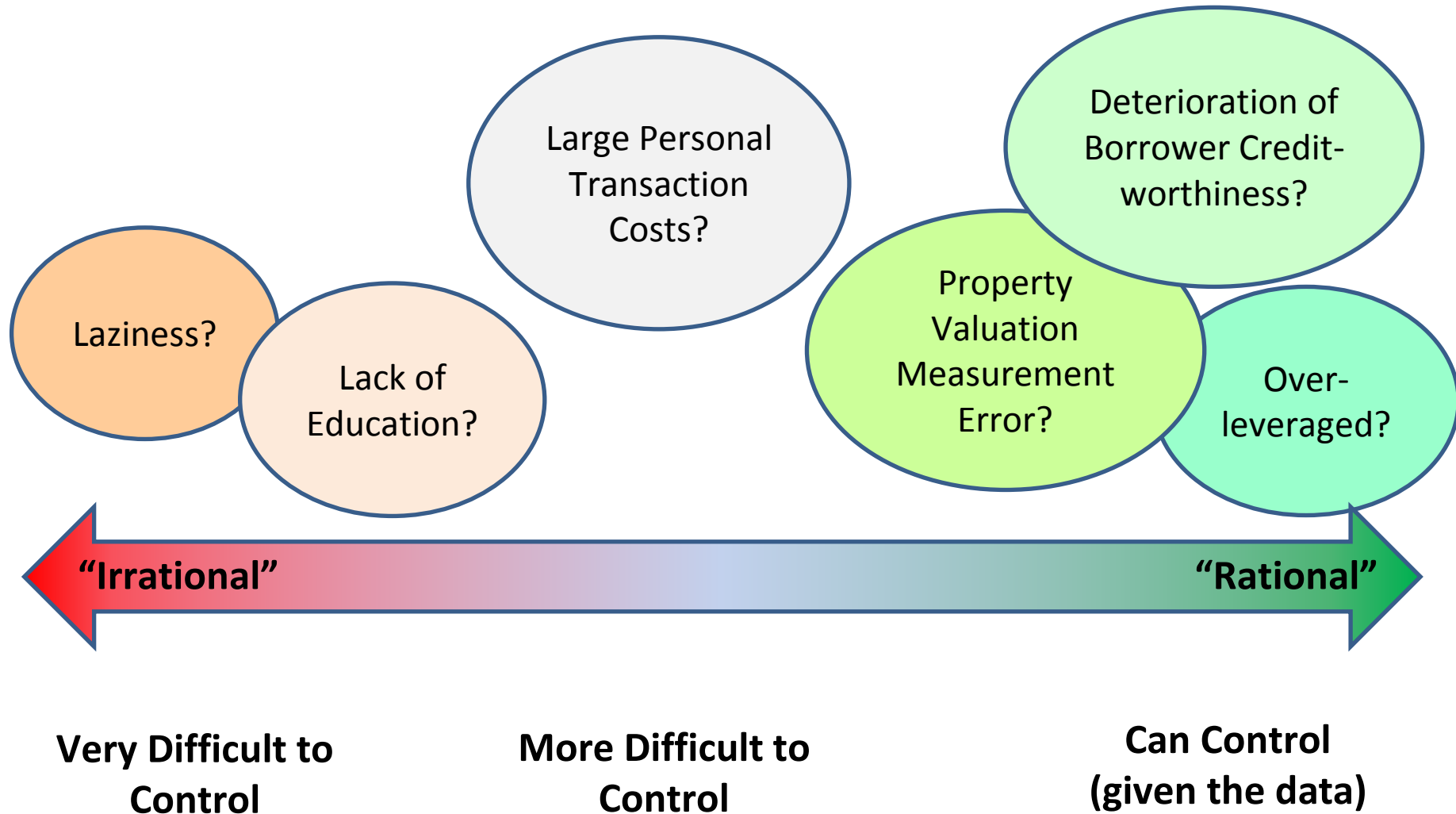
# Previous studies tried introducing costs heterogeneity into mortgage valuation models

- Stanton (1995)
  - Structural option-based prepayment model
  - Incorporates three exogenous components
    - Heterogeneous transaction costs
    - Random discrete time intervals at which prepayment decisions are evaluated
    - Random process of forced prepayments (“housing turnover”)
- However,
  - Default options were not considered in Stanton’s model
  - Estimated heterogeneity of transaction costs was a distribution with mean value of 41% of the loan balance
    - Too high to be plausible

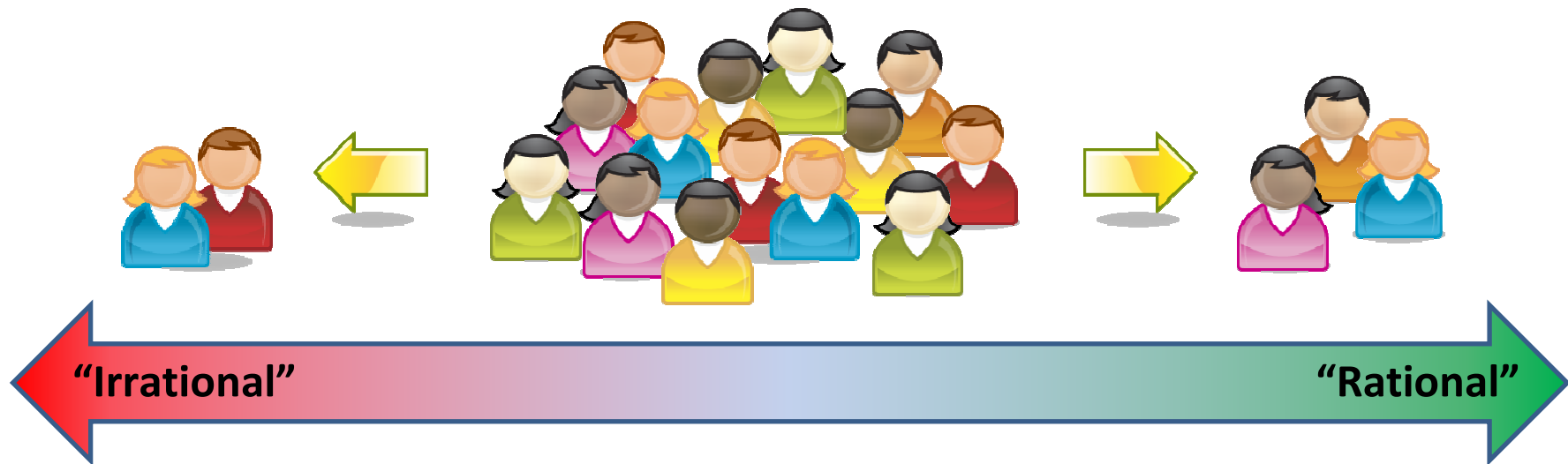
## Deng, Quigley, Van Order (DQV, 2000 – *Econometrica*)

- Reduced-form early termination model
- Introduced unobserved heterogeneity under competing risk survival framework to mortgages
  - Two hazards – *prepayment* and *default* – are dependent competing risks
  - Estimated jointly (using MLE)
  - Unobserved heterogeneity was measured through discretely distributed mass point mixed hazard
  - Considered cases of  $m=2$  and  $m=3$
- Identified borrowers with high propensity to prepay
- Still, DQV and other models left many questions about suboptimal option exercising unanswered

# Why do borrowers fail to take advantage of refinance opportunities?



**Whatever the cause, an approach incorporating unobserved heterogeneity is important to model real behavior**



# Joint competing risks hazard mortgage termination model with unobserved heterogeneity can be estimated using MLE

- The unconditional survivor function:

$$S(t_p, t_d|X) = \int \exp \left( -\eta_p \sum_{k=1}^{t_p} e^{(\gamma_{pk} + \beta'_p X)} - \eta_d \sum_{k=1}^{t_d} e^{(\gamma_{dk} + \beta'_d X)} \right) dG(\eta_p, \eta_d)$$

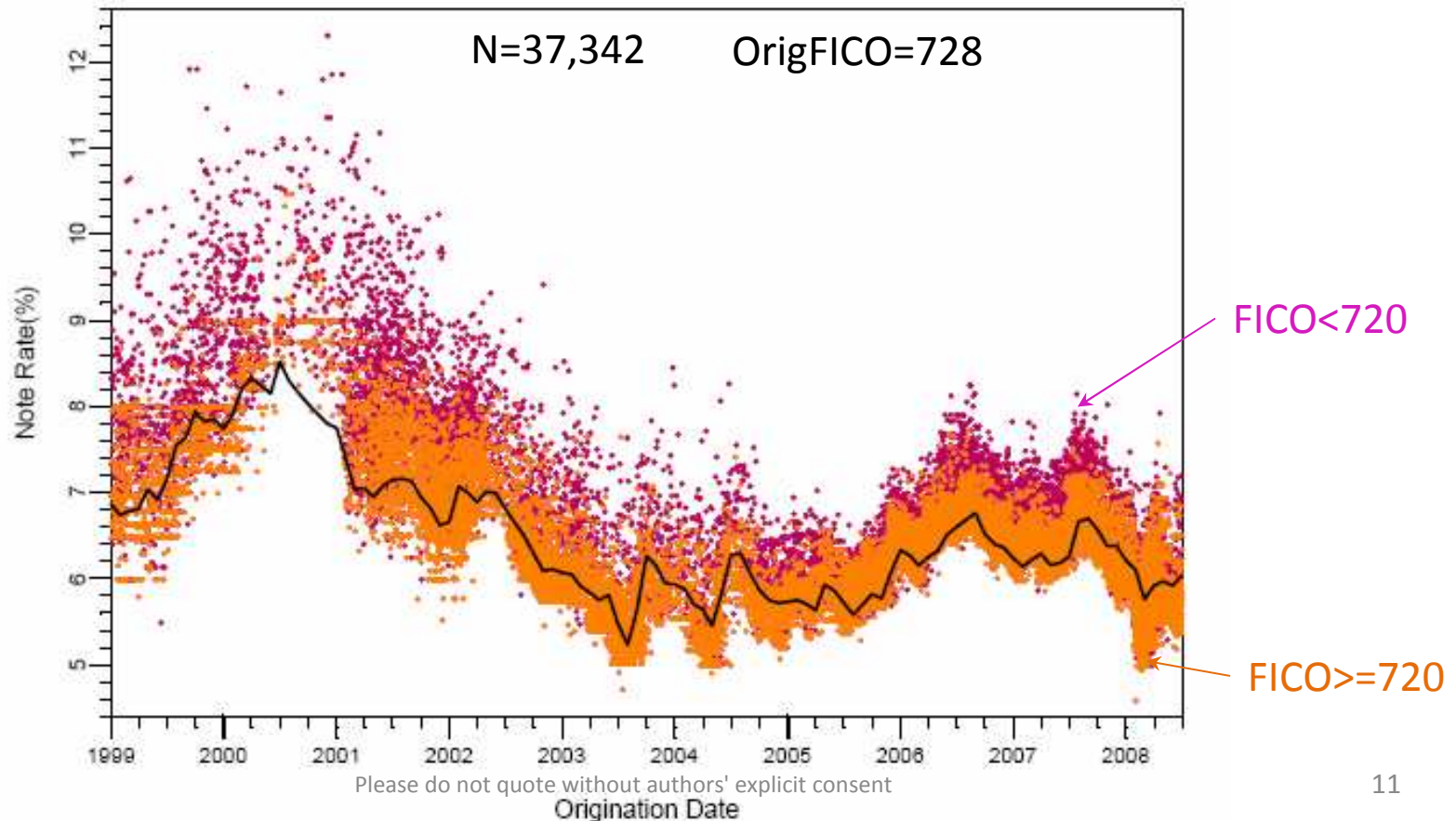
- Log-likelihood function:

$$\begin{aligned} \ln(L) = & \sum_{j=1}^N \left[ \delta_j^p \ln \left( \int \{S(t-1, t-1|X_j, \eta_p, \eta_d) - S(t-1, t|X_j, \eta_p, \eta_d) \right. \right. \\ & \left. \left. - A(t|X_j, \eta_p, \eta_d)\} dG(\eta_p, \eta_d) \right) \right. \\ & + \delta_j^d \ln \left( \int \{S(t-1, t-1|X_j, \eta_p, \eta_d) - S(t, t-1|X_j, \eta_p, \eta_d) \right. \\ & \left. \left. - A(t|X_j, \eta_p, \eta_d)\} dG(\eta_p, \eta_d) \right) \right. \\ & \left. + \delta_j^c \ln \left( \int \{S(t-1, t-1|X_j, \eta_p, \eta_d)\} dG(\eta_p, \eta_d) \right) \right] \end{aligned}$$

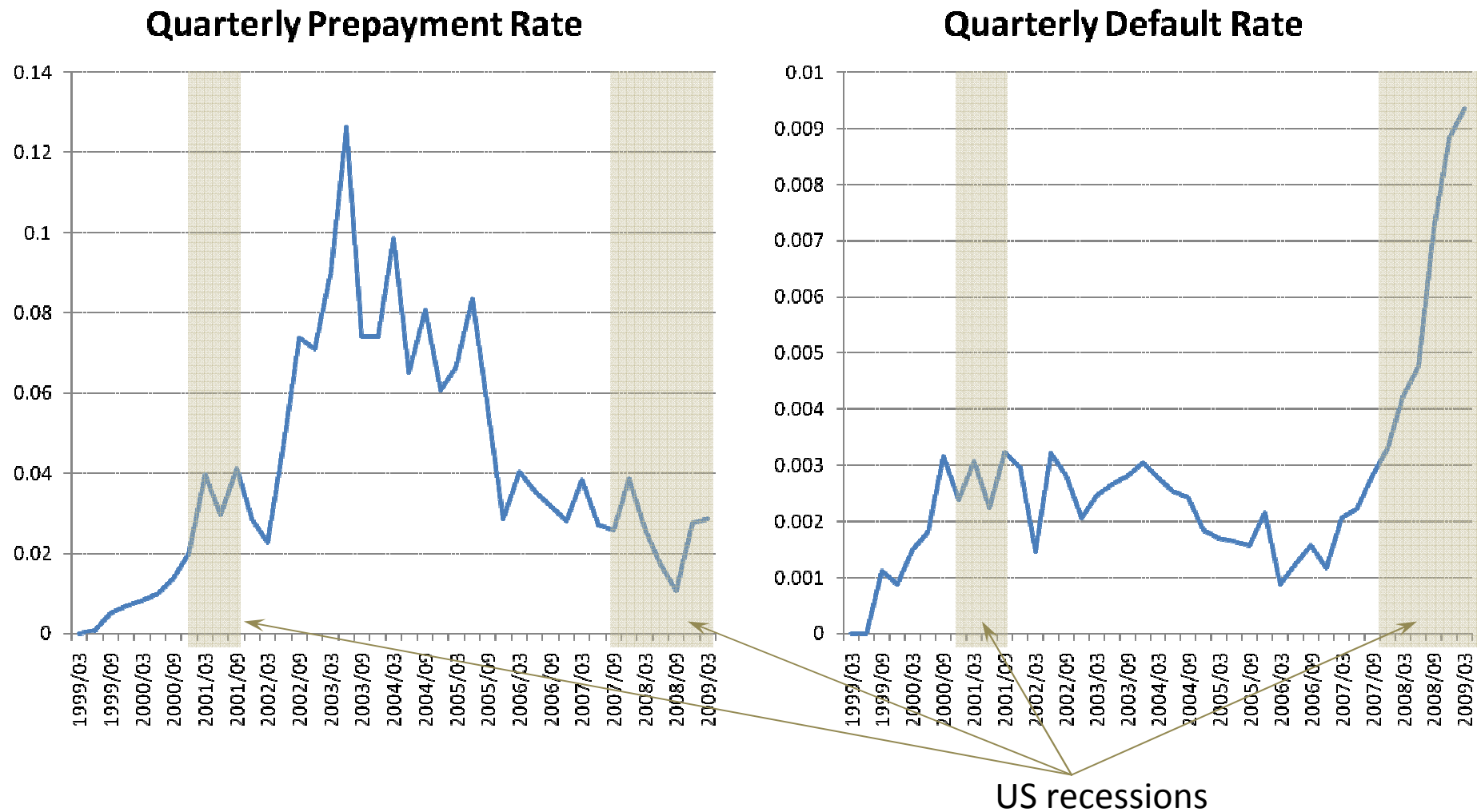
- Computationally burdensome for practical purposes
  - Trick is to assume discrete mass-point distribution for  $(\eta_p, \eta_d)$

# We had access to rich loan-level data on which to empirically test new JCRH models

- First-lien mortgages originated from 1999 through 2008
  - Large national mortgage lender
  - Mix of prime and Alt-A type FRM30 products



# The observation period covers full business cycle, several refi booms, and the Great Recession



# Such rich loan-level data on mortgage performance allowed expanding research in new directions

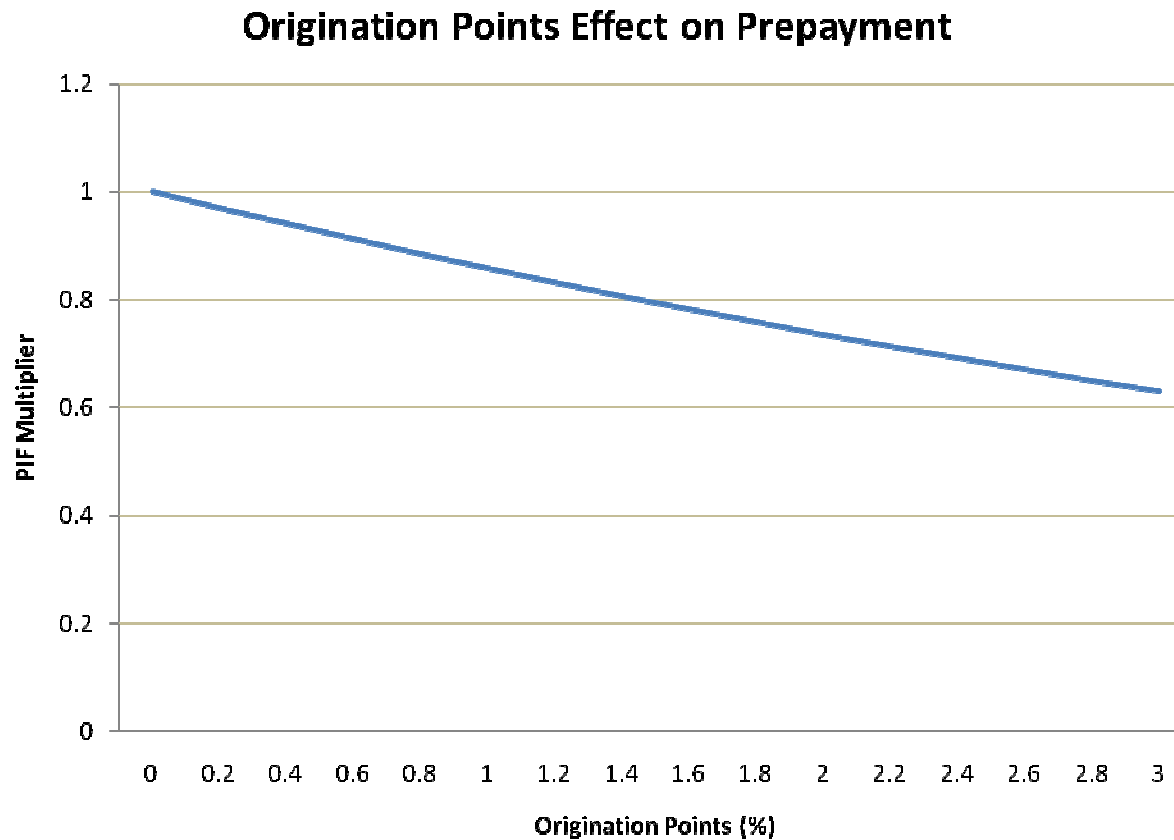
Borrower-Level	Loan-level (Static)	Loan-level (Time-varying)	Macro-economic
<ul style="list-style-type: none"><li>• Origination FICO</li><li>• Borrower Age</li><li>• Family Status</li><li>• Employment</li><li>• Years at Current Residence</li></ul>	<ul style="list-style-type: none"><li>• Loan-to-Value</li><li>• Debt-to-income</li><li>• Loan term</li><li>• Loan purpose</li><li>• Documentation level</li><li>• Occupancy</li><li>• Property location</li><li>• Number of borrowers</li><li>• Loan note rate</li><li>• Points paid</li></ul>	<ul style="list-style-type: none"><li>• Updated balance</li><li>• Current equity</li><li>• Refinance incentive</li><li>• Updated FICO</li><li>• Bankruptcy indicator</li></ul>	<ul style="list-style-type: none"><li>• Unemployment rate (MSA-level)</li><li>• HPI (MSA-level)</li><li>• Underwriting index (US-level)</li></ul>

Some of the covariates have been absent from prior research on JCRH framework

## Results: Adding asymmetric information helps reduce unobserved heterogeneity

- Some borrowers did not refinance because they were no longer considered credit-worthy
  - For every 50 points drop in FICO:
    - Prob(prepayment) decreases by 17%
    - At the same time, Prob(default) more than doubles
- Borrower's age, family status, current residency track also found to explain mortgage terminations
- For model with 2 mass points, the distance between “fast” prepayers and “slow” prepayers shrinks by 15% (3% in DQV)

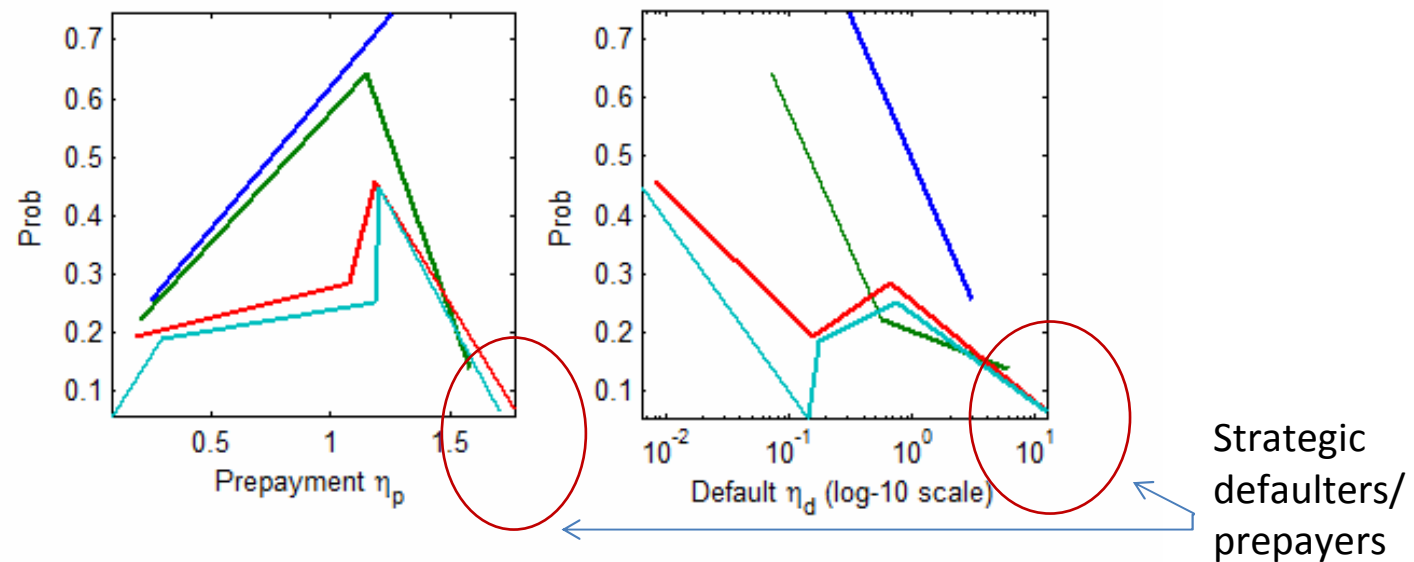
# Results: By paying origination points borrowers send a signal that they plan to stay in the house for a long time



- With each extra point paid, prepayment rate drops by about 14%

# Results: Increasing the number of mass points provides new insights about possible unobserved heterogeneity distribution

- The higher the  $m$ , the more the distribution of  $\eta_p$  resembles “humped-shaped” distribution (normal? lognormal?)
- However, distribution of  $\eta_d$  remains difficult to parameterize
- Highlights the challenges one might face when trying to impose parametric assumptions on  $(\eta_p, \eta_d)$



## Results: Estimated correlation between prepayment and default options

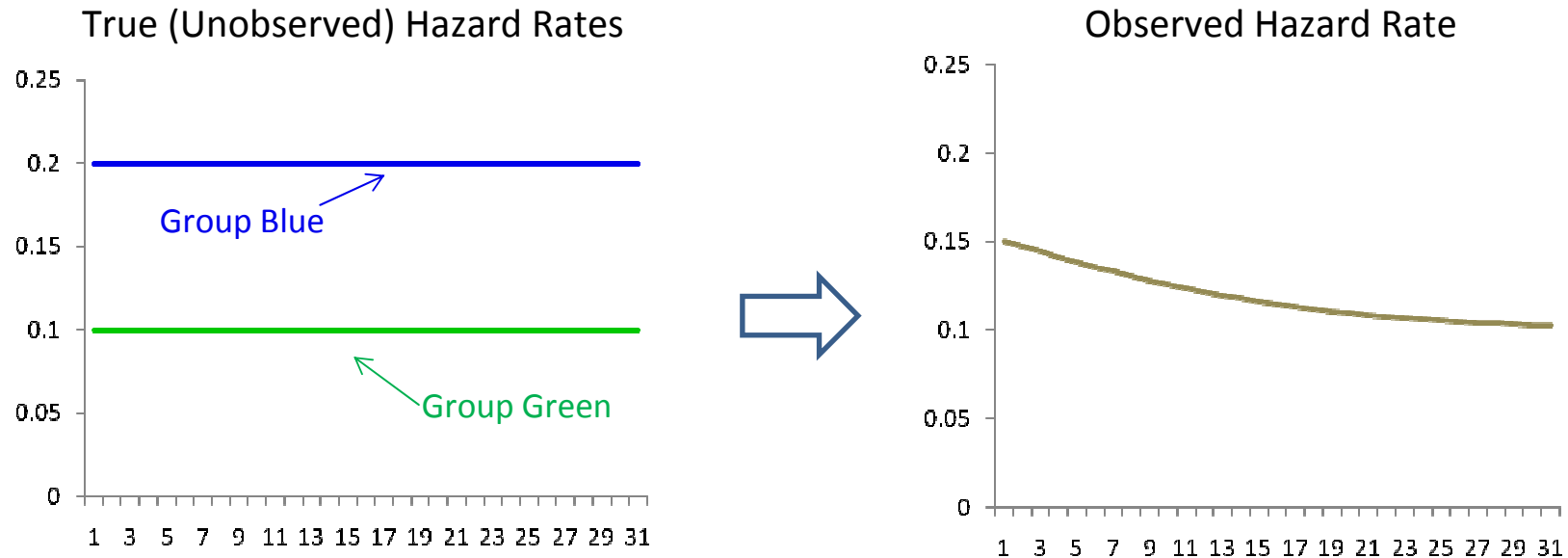
- ... is positive and economically significant

Number of mass points	Estimated correlation between $\eta_p$ and $\eta_d$
3	0.43362
4	0.47813
5	0.42446

## Competing risks survival model is a good candidate for PD model under Basel II Advanced-IRB approach

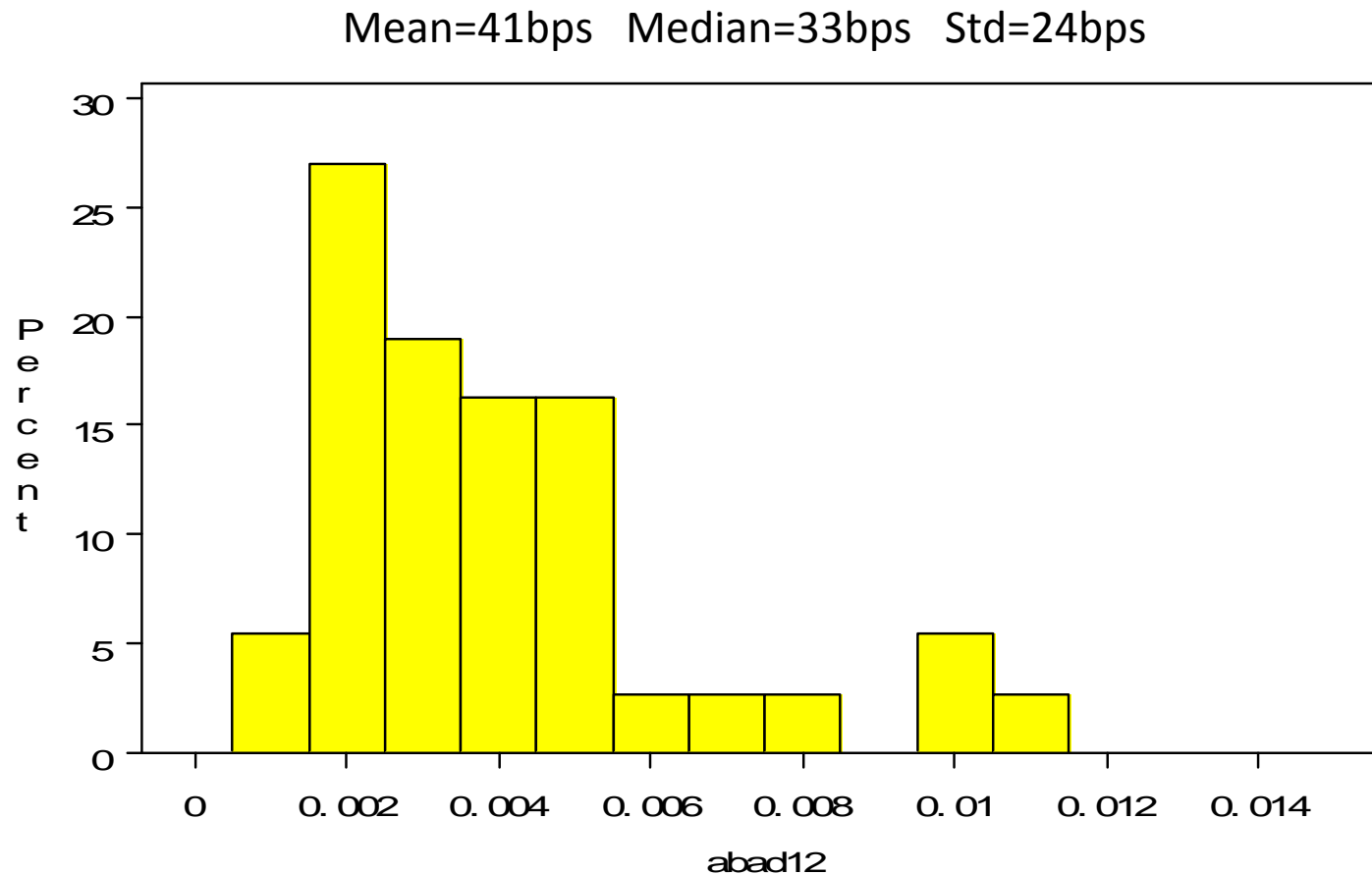
- PD is probability of exposure default in the next 12 months
- Competing risks survival approach has several advantages over simpler Basel PD models (12 mos. cumulative logit, regression tree models):
  - Explicitly accounts not only for default but also for prepayment
  - Accounts for correlation between default and prepayment
  - Allows explicit alignment between loss forecasting, (internal) economic capital, and regulatory capital (Basel II) frameworks (Basel II “use test”)

# However, not accounting for unobserved heterogeneity can lead to mis-estimation of baseline hazard



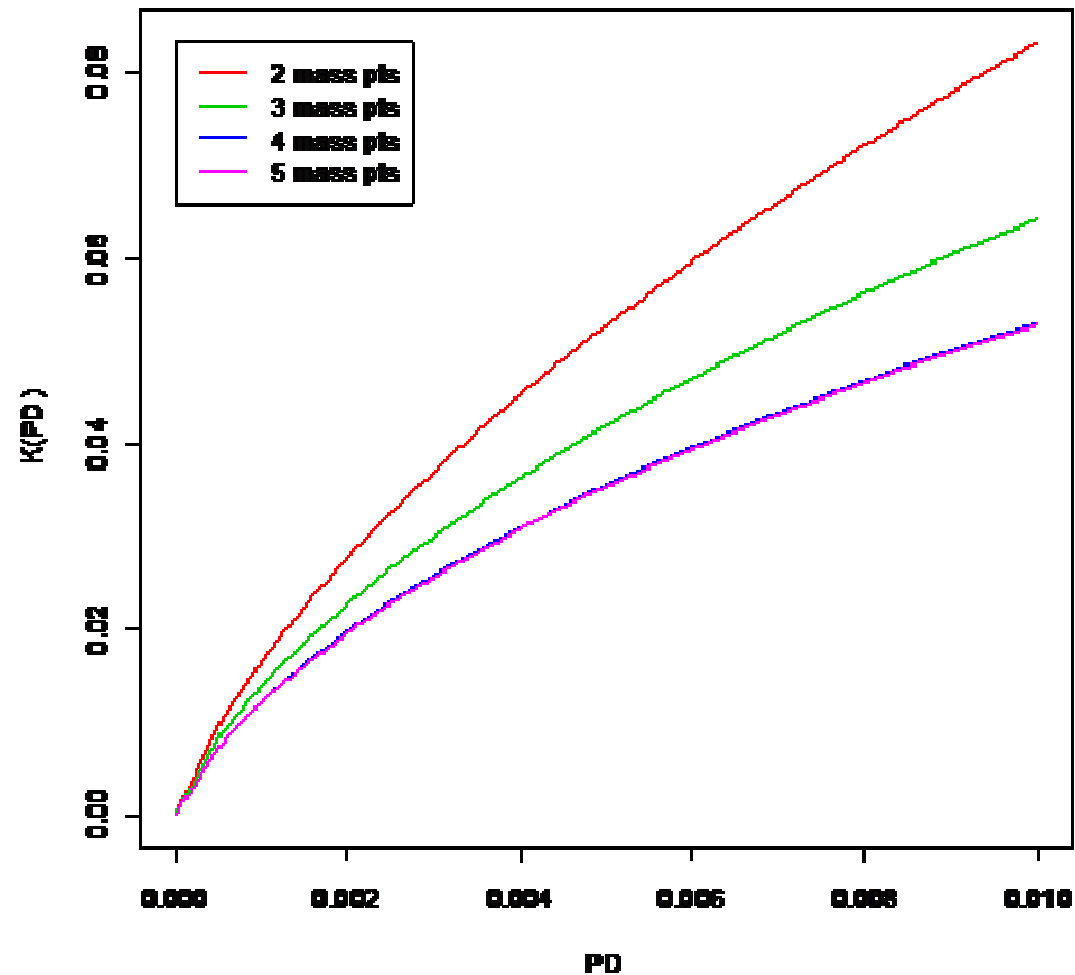
- Unobserved heterogeneity can bias the duration dependence downward
  - Bias exists even if the unobserved heterogeneity is uncorrelated with observed variables
- If unobserved risk factors are correlated with fixed covariates included in the model, there could be spurious time-covariate interactions
- Obtaining better model specification by including additional covariates can help mitigate the problem

# Distribution of empirical 12-mos PD rate is skewed and has heavy right tail



# Results: Increasing number of mass points (groups) could significantly impact Basel capital ratios

$$\Phi\left(\frac{\Phi^{-1}(PD) + \Phi^{-1}(0.999)\sqrt{\rho(PD)}}{\sqrt{1-\rho(PD)}}\right) \cdot LGD - PD \cdot LGD$$



# Conclusions

- Additional borrower-specific and time-varying information helps reduce unobserved heterogeneity among mortgage holders
- Suggested a way for how the distribution of unobserved heterogeneity can be discretely approximated by increasing number of mass points in the joint competing risk hazard framework
- Found positive correlation between prepayment and default mortgage options
- Proper estimation of unobserved heterogeneity could impact calculation of minimum regulatory capital