Equilibrium Mortgage Design with Heterogeneous Borrowers

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Residential mortgages punish "unsophisticated" borrowers

- Retail financial products frequently reward sophistication
- Major case: residential mortgages
- Sophisticated borrowers refinance at opportune times
  - FRM (e.g. US): refi when market rates fall
  - ARM (e.g. UK): refi when "teaser rate" expires
- Unsophisticated pay for refi option, which they won't use
  - Overpay by $\sim$15% relative to sophisticated borrowers
- Alternatives could exist, yet requiring costly refinancing is the norm
  - FRM: e.g. why not refinance automatically?
  - ARM: e.g. why are teaser rates pervasive?

Today: microfound costly refinancing as a feature of mortgages.

A Role for Lenders

- Getting good mortgage terms can be costly
- These search costs allow lenders to extract rents
- Borrowers vary widely in how well they search
    - E.g. 90-10 split in closing costs equivalent to 75bp on the interest rate

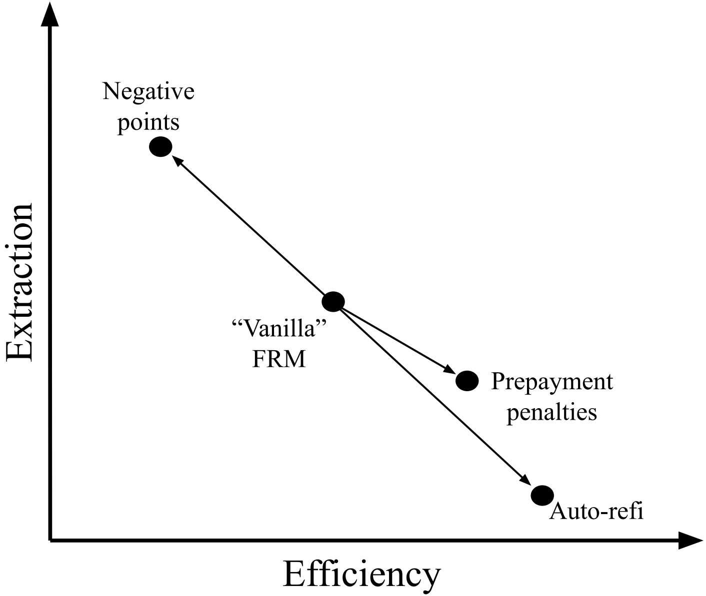
Today: "market power" has implications for how lenders <u>design</u> mortgages.

(...not just how they <u>price</u> them – i.e. set interest rates)

The Model's Key Tradeoff

- FRM's active refinancing achieves **price discrimination**
  - Unsophisticated borrowers have high search costs...
    - ... and don't refinance, so they pay more for credit
  - Sophisticated borrowers have low search costs...
    - ... and likely refinance, so they pay less for credit
- FRM's active refinancing creates **deadweight loss**
  - Less surplus to extract from

Results


Negative
points
"Vanilla"
FRM
Prepayment
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Auto-refi
Extraction
Efficiency

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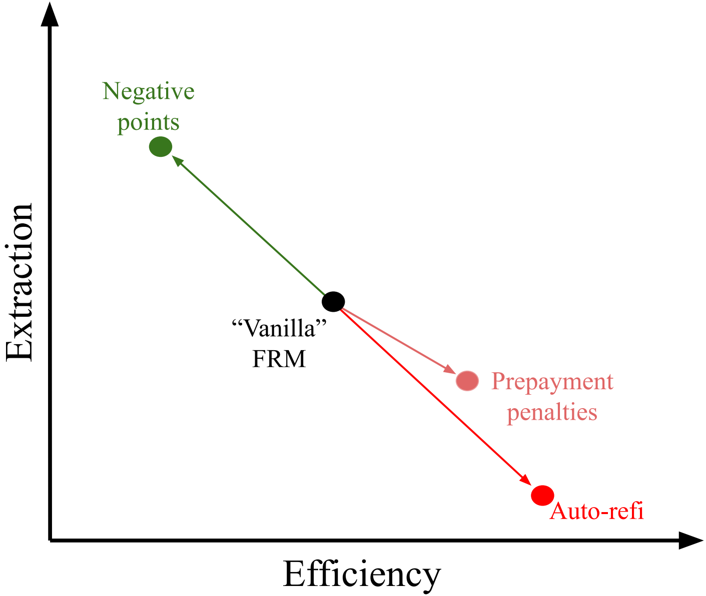


Extraction
Negative points
"Vanilla" FRM
Prepayment penalties
Auto-refi
Efficiency

Model Setting: Mortgage Origination

- At each instant t, measure-1 of risk-neutral homebuyers appears
- They take out interest-only mortgages (WLOG: $1)
  - Makes model very tractable
- Borrower receives captive offer(s) from a single lender
  - FRM with rate m^{FRM} and/or SRM with rate m^{SRM}
- Borrower accepts one or rejects all
  - If rejects all, pays C_j^{Search} to enter Bertrand phase
  - Bertrand: mortgage with expected cost equal to cost of capital

Model Setting: Refinancing Option

- After origination, cost of capital – and so, mortgage interest rates – follows Brownian Motion with volatility σ
- Borrower has option to refinance
- SRM: Refinance occurs costlessly and automatically whenever $m_t^{SRM} < m_0^{SRM}$
- FRM: Must pay cost C^{Refi} to execute a refi
  - Inattention: only aware of refi incentive during attention shocks, which arrive at rate χ_j

Borrower Cost and Lender Revenue

$$K^{FRM}(m_0^{FRM}, \chi_j) = \underbrace{P^{FRM}(m_0^{FRM}, \chi_j)}_{\text{Payments to lender}} + \underbrace{D^{FRM}(\chi_j)}_{\text{Deadweight refi effort}} \tag{1}$$

- For SRM, $\chi \to \infty$ and $C^{Refi} = 0$:

$$K^{SRM}(m_0^{SRM}) = \underbrace{P^{SRM}(m_0^{SRM})}_{\text{Payments to lender}} \tag{2}$$

- 2 key distinctions between the mortgage designs:
  1. FRM creates DWL; SRM does not
  2. FRM creates disparities based on χ_j; SRM does not

Equations

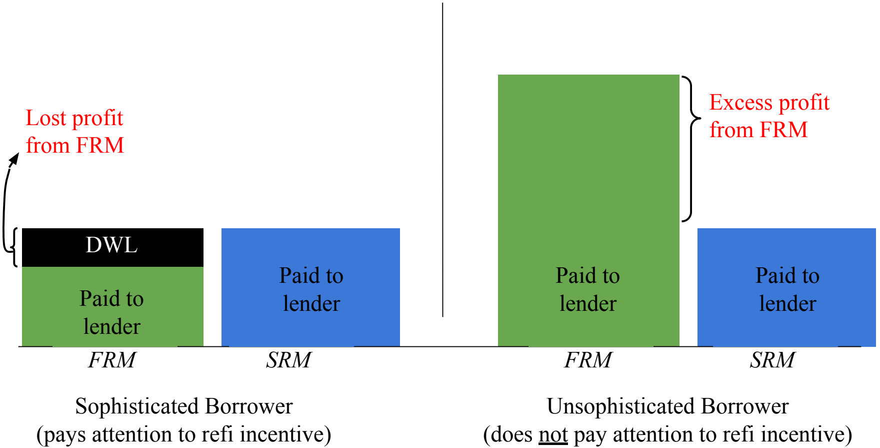
Equilibrium Mortgage Design

Consider market with 2 types:

1. Sophisticated: $\chi_{Soph} > 0$, C^{Search}_{Soph} low
2. Unsophisticated: $\chi_{Uns} = 0$, C^{Search}_{Uns} high

Reservation interest rates

Equilibrium Mortgage Design



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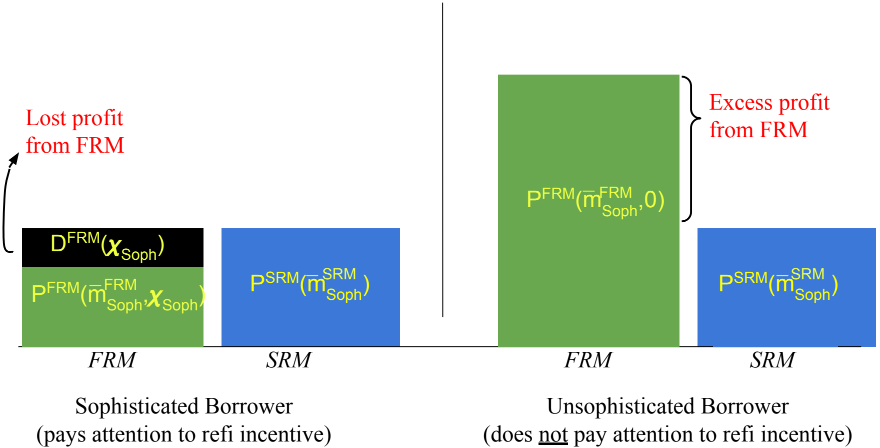
Equilibrium Mortgage Design



▸ Reservation interest rates

Equilibrium Mortgage Design

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2. Unsophisticated: $\chi_{Uns} = 0$, C^{Search}_{Uns} high

If $C^{Search}_{Uns} - C^{Search}_{Soph}$ is "large enough," lenders do not offer SRM if and only if:

$$\underbrace{S_{Uns} \cdot \left(P^{FRM}(\bar{m}^{FRM}_{Soph}, 0) - P^{SRM}(\bar{m}^{SRM}_{Soph})\right)}_{\text{Lost revenue from SRM}} > \underbrace{S_{Soph} \cdot D^{FRM}(\chi_{Soph})}_{\text{Additional revenue from SRM}} \tag{3}$$

Reservation interest rates

Quantitative Evaluation

- Based on Berger et al (2023), I use 2 levels of attention:
  1. $\chi_j = 0$: 45% of the population
  2. $\chi_j = 0.56$: 55% of the population
- The model then considers 3 types of borrowers:
  1. "Sophisticated:" $\chi_j = 0.56$, C_j^{Search} is low (55% of population)
  2. "Unsophisticated:" $\chi_j = 0$, C_j^{Search} is high (30% of population)
  3. "Mixed:" $\chi_j = 0$, C_j^{Search} is low (15% of population)

$$\underbrace{S_{Uns} \cdot \left(P^{FRM}(\bar{m}^{FRM}_{Soph}, 0) - P^{SRM}(\bar{m}^{SRM}_{Soph})\right)}_{\text{Lost revenue from SRM}} > \underbrace{S_{Soph} \cdot D^{FRM}(\chi_{Soph})}_{\text{Additional revenue from SRM}}$$

Other parameters | Search cost dispersion

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$$\underbrace{0.3 \cdot 0.037}_{\text{Lost revenue from SRM}} > \underbrace{0.55 \cdot 0.011}_{\text{Additional revenue from SRM}} \quad \checkmark$$

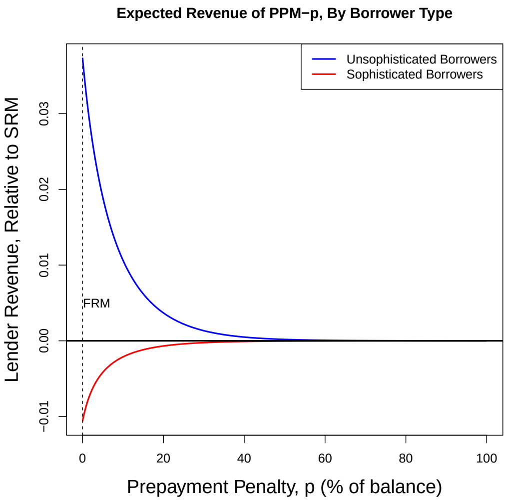
Do not offer SRM

▸ Other parameters ▸ Search cost dispersion

The "PPM$-p$:" A Mortgage with Prepayment Penalties

- Consider a fixed-rate mtg where borrower must pay $p \geq 0$ to refi
- Note:
  1. $p = 0$: FRM
  2. $p \to \infty$ generates same (expected) outcomes as SRM
     - No DWL
     - No disparities between borrowers
- This "PPM$-p$" thus generalizes the earlier discussion
- Increasing p affects lender profit by:
  1. Extracting more from Sophisticated (decreases DWL)
  2. Extracting less from Unsophisticated (decreases interest rate)
  - "Convexifies" the FRM/SRM tradeoff

Calibration: FRM IS the Profit-Maximizing PPM$-p$



Comparative static (C^{Refi}) Zoom

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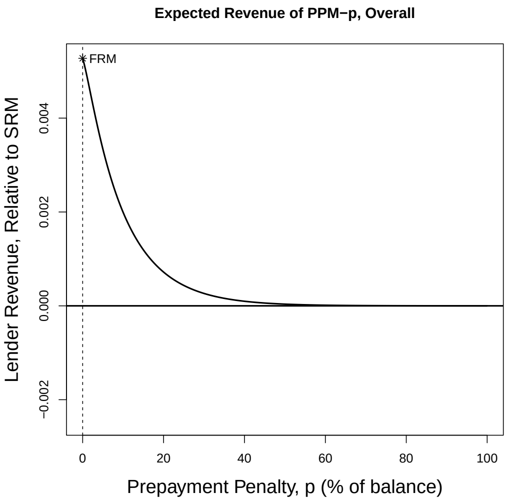
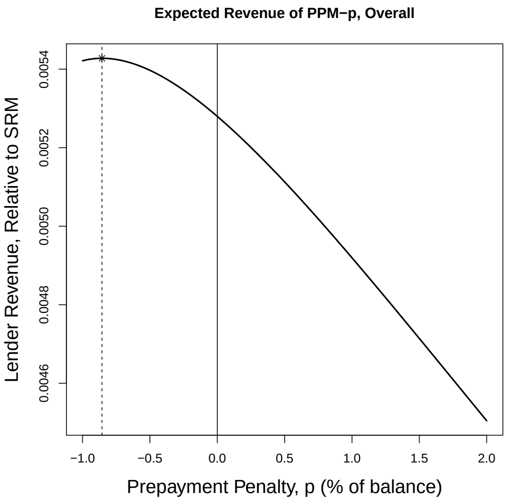


Comparative static (C^{Refi}) Zoom

Prepayment Penalties in Equilibrium

- This suggests prepayment penalties have little appeal to lenders
  - Causes Sophisticated borrowers to demand lower interest rates...
  - ...which leads to less extraction from Unsophisticated borrowers
- Lenders would in fact benefit from prepayment *bonuses*
  - Sophisticated borrowers will accept a higher interest rate...
  - ...which leads to more extraction from Unsophisticated borrowers
- Covering part of borrowers' closing costs effectively does this!

Optimal Prepayment Penalty as a Function of C^{Refi}



Back

Core Intuition

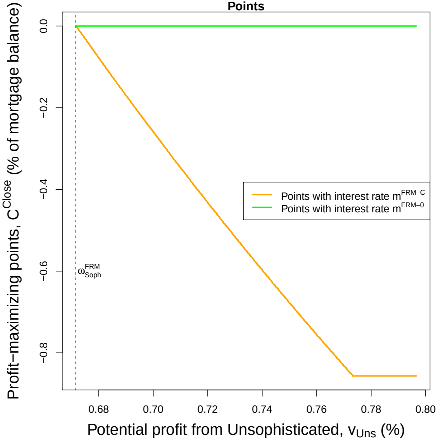
- Why don't lenders offer mortgages that refinance automatically?
- To a non-economist, the answer is easy:
  - "They don't want borrowers to refinance!"
- This answer falls flat in standard models:
  1. Lenders compete, so it does not matter what they "want"
  2. Lenders don't mind if you refi, they can build it into the price
- This paper recovers the non-economist's answer
- Lenders can get unsophisticated borrowers to pay a high sticker price for credit
- The market does not discipline this because:
  - Search costs limit competition from other lenders
  - The refi option satisfies sophisticated borrowers

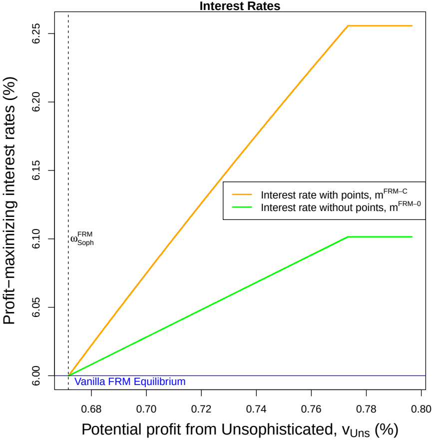
Appendix

A Menu of FRMs: Points

- In model so far, lenders do not extract all surplus possible from Unsophisticated
- Now suppose they offer a menu of FRMs:
  1. (m^{FRM-C}, C^{Close})
  2. $(m^{FRM-0}, 0)$
- Setting $C^{Close} < 0$, they can attract Sophisticated to #1 with high interest rate $(m^{FRM-C} > m^{FRM-0})$
  - Willing to accept the high rate because of future refis
- Can then ratchet up m^{FRM-0} to increase extraction from Unsophisticated

Calibration: Points



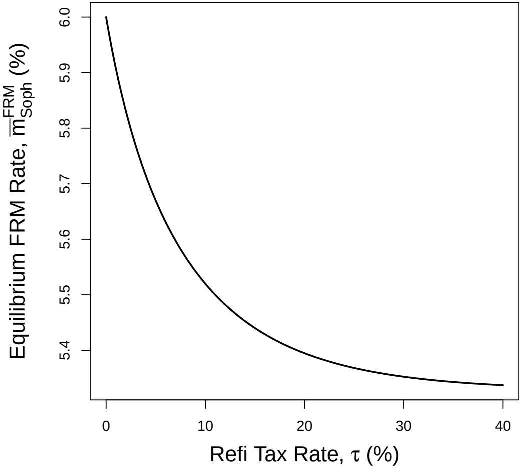


Profit

A Refinancing Tax

- How can policy help unsophisticated when market forces set mortgage *design*, in addition to rates?
- Model: "Tax people for refinancing!"
- The "problem" is that sophisticated people refinance too much
  - Inefficient use of effort
  - **Allows for price discrimination to extract from unsophisticated**
- A refi tax would:
  1. Reduce wasteful refinancing effort
  2. Reduce equilibrium mortgage *rates*
     - Windfall for unsophisticated
  3. Alter mortgage *design*
     - This amplifies the 2 effects above

Calibration: Refi Tax



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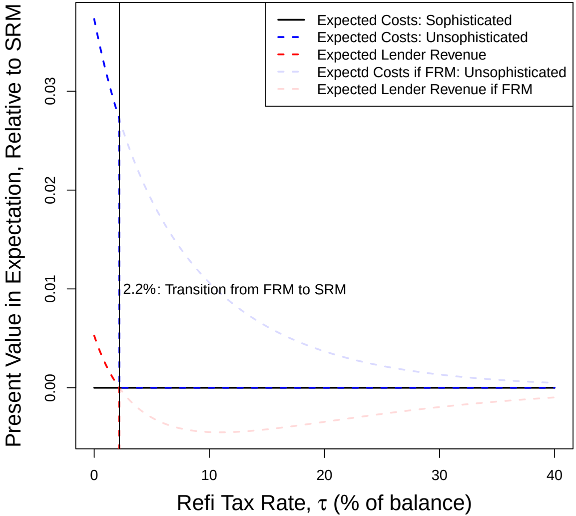

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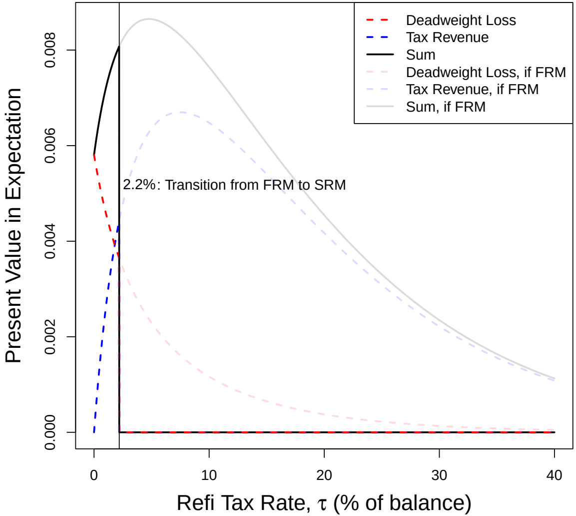
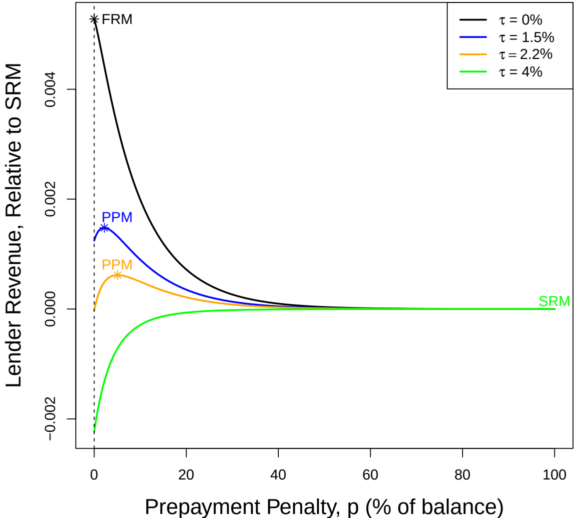


Refi Tax with Endogenous Prepayment Penalties



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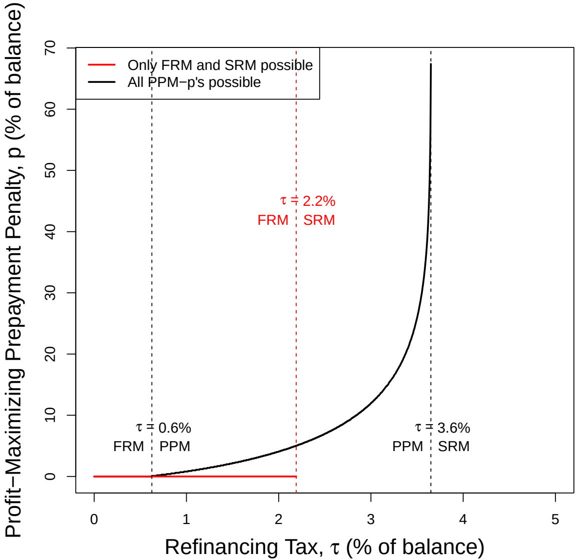


Tax Discussion

- We'd like to see prepayment penalties, but lenders' incentive is the opposite
  - They instead give prepayment bonuses
- Tax imposes the penalty
  - Revenue goes to government rather than lender
- Tax may lead to SRM
- Tax may lead to prepayment penalties
- Is that good?
  - From equity/efficiency, yes
  - From macroprudential perspective, no

Takeaways

- Literature mostly uses perfect-competition/exogenous-design models ("PCEx")
  - Recommendation: adopt automatic refinancing provision
- This paper: search costs and endogenous design ("SCEn")
  - Cannot simply impose a new mortgage design
- Key difference: lenders play an active role
- Consider refi tax:
  - Both model types say this would transfer towards unsophisticated
    - In PCEx models, the transfer comes from sophisticated borrowers
    - In SCEn model, the transfer comes from lenders
  - SCEn shows a role for policy in mortgage *design*
- Richer understanding of policy when we micro-found institutions

Payment and DWL Equations

- FRM (recall, $\psi \equiv \frac{\sqrt{2\cdot(\rho+\mu+\pi)}}{\sigma}$ and $\eta \equiv \frac{\sqrt{2\cdot(\rho+\mu+\pi+\chi)}}{\sigma}$):

$$P^{FRM}(m_0^{FRM},\chi) = \frac{m_0^{FRM}+\mu}{\rho+\mu+\pi} + \frac{\chi\cdot\left(\eta\cdot\frac{y^*(\chi)}{\rho+\mu+\pi}-\frac{1}{\rho+\mu+\pi}\right)}{(\rho+\mu+\pi+\chi)\cdot(\eta+\psi)\cdot exp(-\psi\cdot y^*(\chi))-\chi\cdot\eta} \tag{4}$$

$$D^{FRM}(\chi) = \frac{\chi\cdot\eta\cdot C^{Refi}}{(\rho+\mu+\pi+\chi)\cdot(\eta+\psi)\cdot exp(-\psi\cdot y^*(\chi))-\chi\cdot\eta} \tag{5}$$

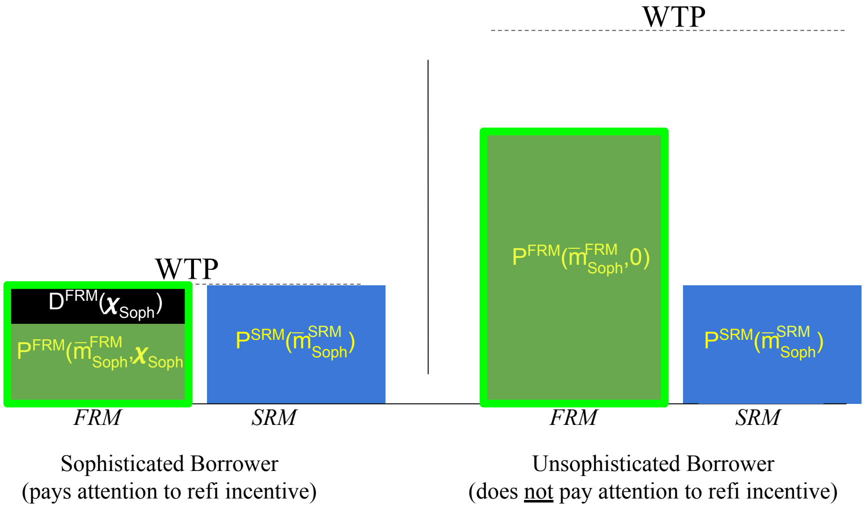
- SRM: $P^{SRM}(m_0^{SRM}) = \left(m_0^{SRM}+\mu-1/\psi\right)\cdot\frac{1}{\rho+\mu+\pi}$; $D^{SRM}=0$

Back

Dispersion in C_j^{Search}

- If $C_H^{Search} - C_L^{Search}$ is large, SRM not offered
- SRM emerges when $C_H^{Search} - C_L^{Search}$ falls

Dispersion in C_j^{Search}



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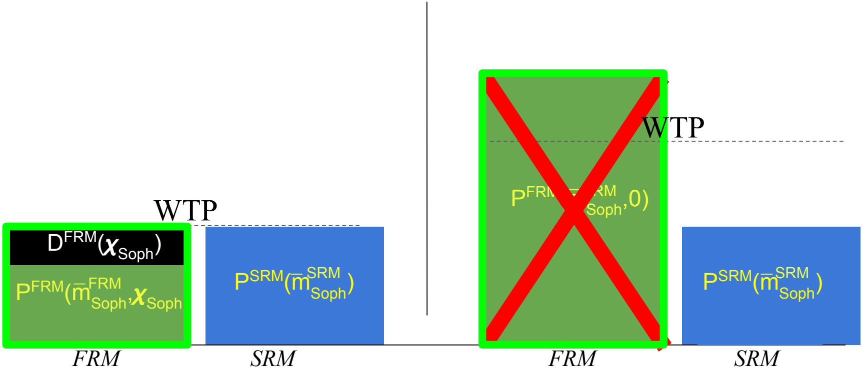

Sophisticated Borrower
(pays attention to refi incentive)

Unsophisticated Borrower
(does <u>not</u> pay attention to refi incentive)

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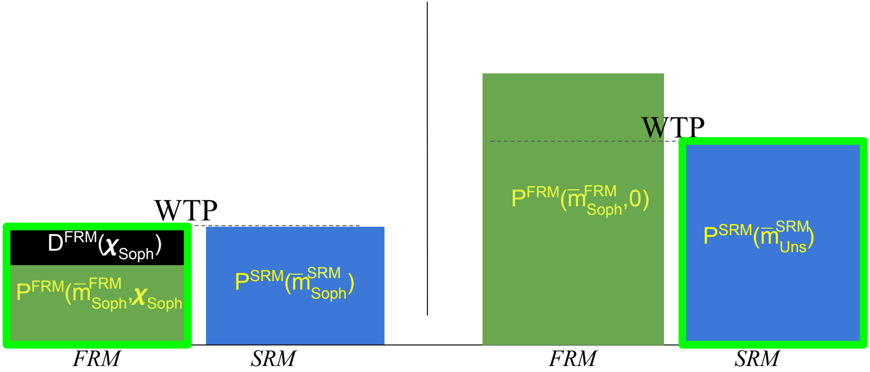

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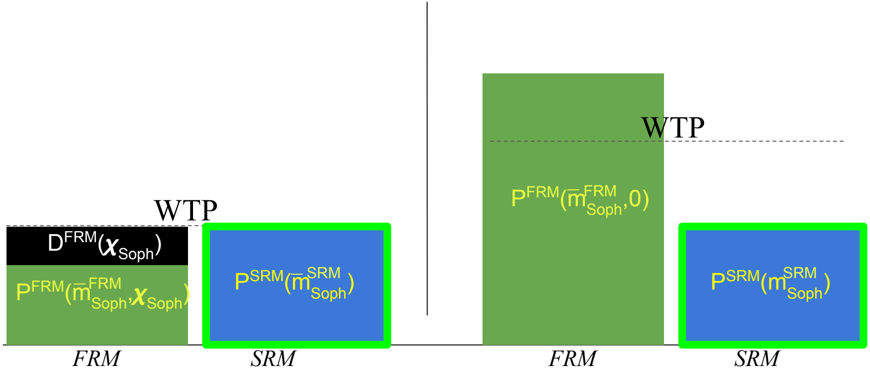

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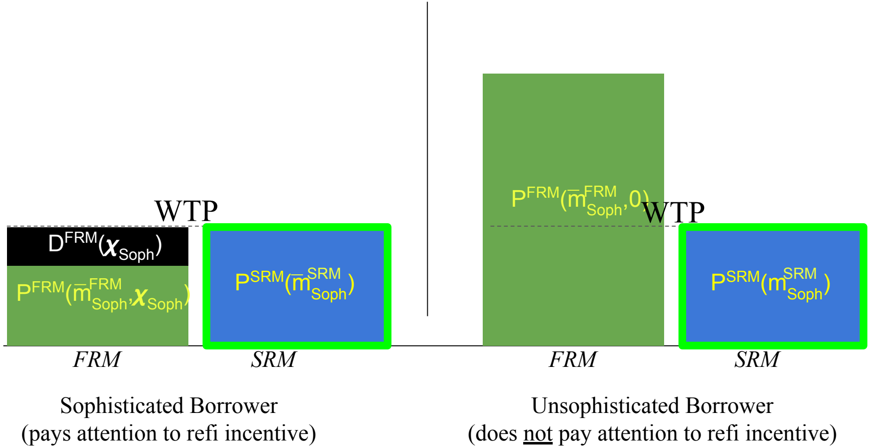
- SRM emerges when $C_H^{Search} - C_L^{Search}$ falls

If $C_{Uns}^{Search} - C_{Soph}^{Search}$ is small enough, lenders offer SRM and FRM if and only if:

$$\underbrace{S_{Uns} \cdot \left(P^{SRM}(\bar{m}_{Uns}^{SRM}) - P^{SRM}(\bar{m}_{Soph}^{SRM})\right)}_{\text{Additional revenue from separating borrowers}} > \underbrace{S_{Soph} \cdot D^{FRM}(\chi_{Soph})}_{\text{Lost revenue from separating borrowers}} \tag{6}$$

Dispersion in C_j^{Search}



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- When there is no dispersion in search costs (perfect competition), SRM dominates the market!

$$S_{Uns} \cdot 0 < S_{Soph} \cdot D^{FRM}(\chi_{Soph})$$

Evidence on Dispersion in C_j^{Search}

- Calibration: If Unsophisticated would not search to save 67bp on FRM interest rate, the no-SRM equilibrium will result.
- Empirical studies find meaningful dispersion in apparent market power across borrowers
  - Agarwal et al (2024): 90^{th}-10^{th} interest rate difference of 90bp
  - Bhutta et al (2024): 55bp
  - Woodward and Hall (2012): 75bp
- No perfect analogue to stylized model, but suggestive of sufficient variation
- Other factors that help no-SRM equilibrium's conditions hold:
  - Difficulty in getting borrowers to sort properly
  - Overconfidence
  - "Inertia"/comfort with FRM

Back

Reservation Interest Rates

- During captive offer phase, the highest interest rates borrowers are willing to accept are:

$$\bar{m}^{FRM}(C_j^{Search}, \chi_j) = \underbrace{i_0}_{\text{Cost of capital}} + \underbrace{\omega^{FRM}(\chi_j)}_{\text{Refi premium}} + \underbrace{v(C_j^{Search})}_{\text{Profit margin}} \tag{7}$$

$$\bar{m}^{SRM}(C_j^{Search}) = \underbrace{i_0}_{\text{Cost of capital}} + \underbrace{\omega^{SRM}}_{\text{Refi premium}} + \underbrace{v(C_j^{Search})}_{\text{Profit margin}} \tag{8}$$

- Note: $\omega^{FRM}(\chi_j)$ and $v(C_j^{Search})$ are increasing functions

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Calibration

Parameter	Meaning	Value	Source
ρ	Discount rate	0.05	ADL (2013)
π	Inflation rate	0.03	ADL (2013)
μ	Hazard rate of move	0.1	ADL (2013)
σ	Interest rate volatility	0.0109	ADL (2013)
C^{Refi}	Refinancing cost	0.018	ADL (2013)
S_{Soph}	Sophisticated share	0.55	Berger et al (2023)
χ	Attention for Sophisticated	0.56	Berger et al (2023)
C^{Search}_{Soph}	Sophisticated search cost	0	Generate $m_0^{FRM} = 0.06$,
i_0	Short-term rate at origination	0.0533	as in ADL (2013)
S_{Mixed}	Share of non-Sophisticated with low search costs	0.34	Generates profit margin of 0.62%

Table: Parameters used in baseline calibration

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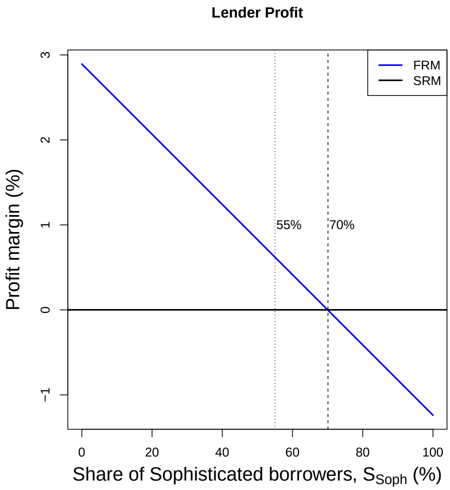
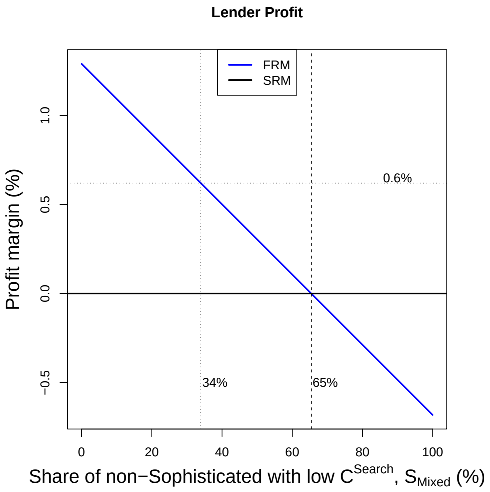
Comparative Statics: Attention and Rate Volatility





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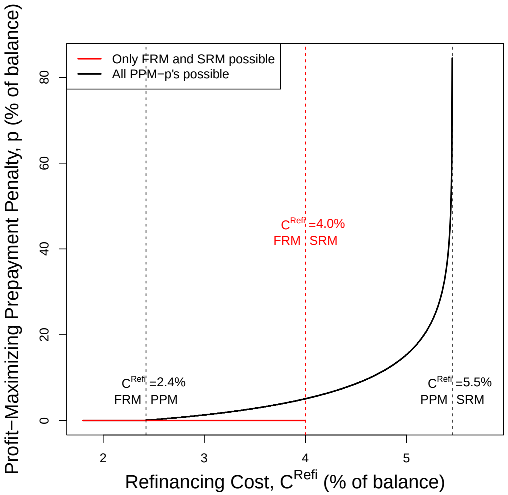
Optimal Prepayment Penalty as a Function of C^{Refi}



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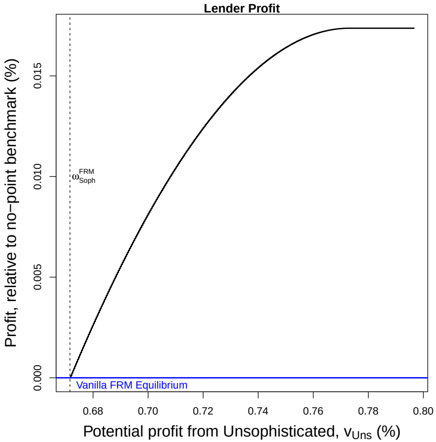
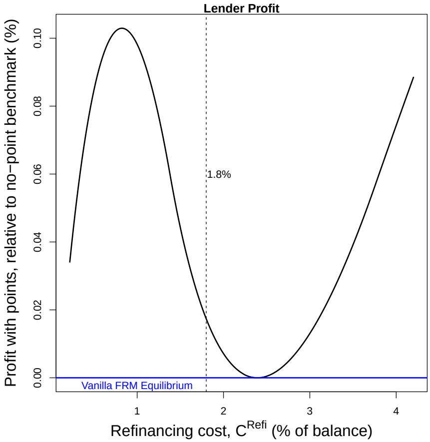
Calibration: Points





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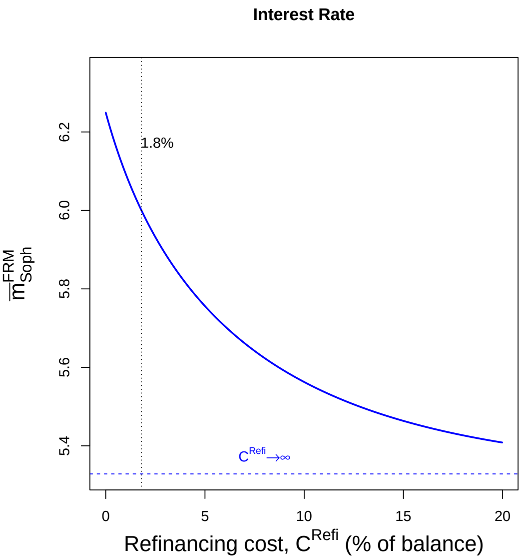
Comparative Statics: Refinancing Cost



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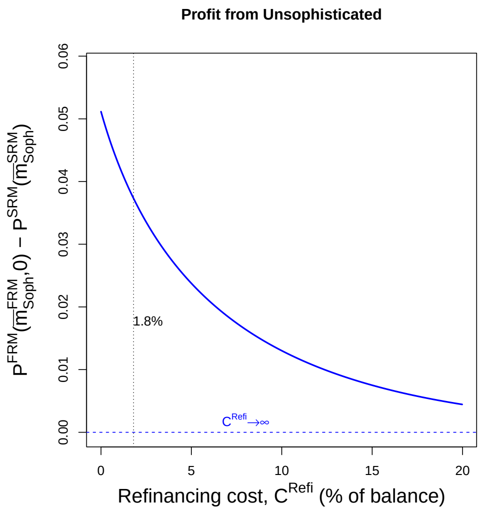

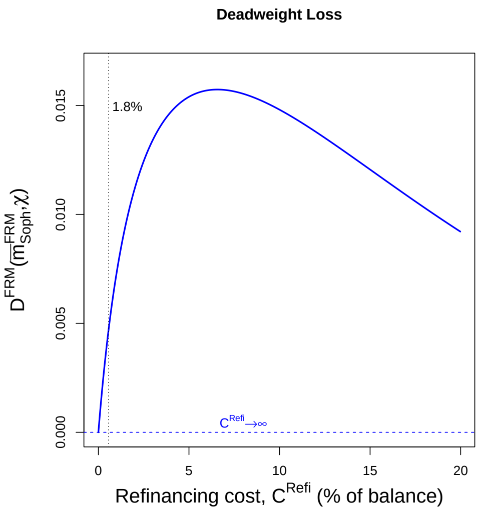

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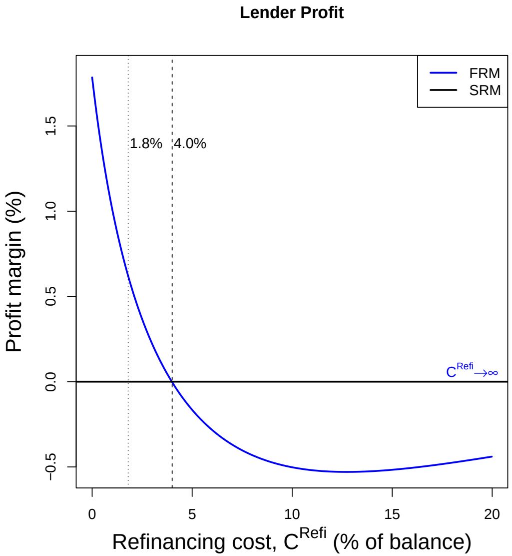
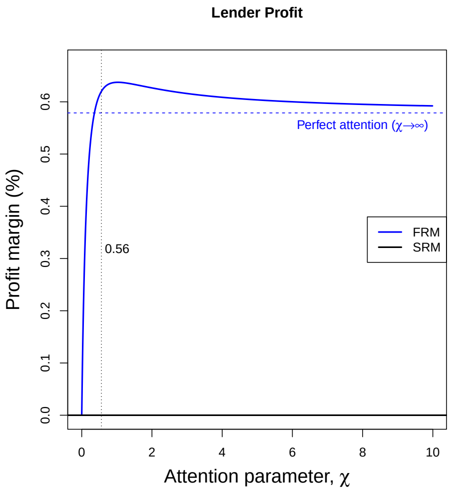
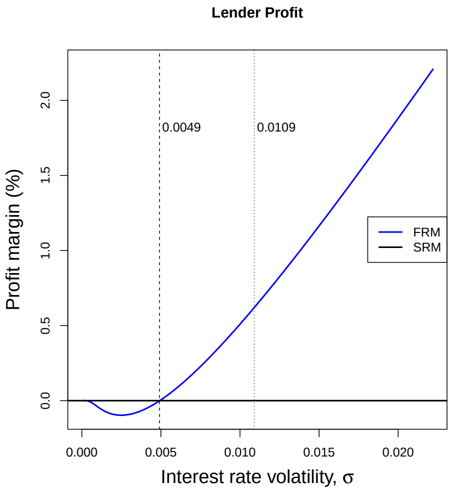


Comparative Statics: Attention and Rate Volatility





▸ Other comparative statics

FRM Refinancing Rules

- Follow Agarwal, Driscoll, and Laibson (2013) and Berger et al (2023)
- Define $y_{it} = m_t^{FRM} - m_{i0}^{FRM}$
- Option value results from second-order ODE:

$$\Omega^{FRM}(y,\chi) = \begin{cases} J_\psi \cdot exp(-\psi \cdot (y - y^*(\chi))) & \text{if } y \geq y^*(\chi) \\ J_\eta \cdot exp(\eta \cdot (y - y^*(\chi))) + \frac{\chi}{\rho+\mu+\pi+\chi} \cdot (J_\psi \cdot exp(\psi \cdot y^*(\chi)) + C^{Refi} + \frac{y}{\rho+\mu+\pi}) & \text{if } y \leq y^*(\chi) \end{cases}, \tag{9}$$

where $\psi = \sqrt{2 \cdot (\rho + \mu + \pi)}/\sigma$ and $\eta = \sqrt{2 \cdot (\chi + \rho + \mu + \pi)}/\sigma$.

- 3 unknowns: J_ψ, J_η, y^*
- Solution characterized by 3 conditions
  1. Value matching at $y = y^*$
  2. Smooth pasting at $y = y^*$
  3. Indifference between refi and no action at $y = y^*$
     - $\Omega(y^*, \chi) = \Omega(0, \chi) + C^{Refi} + \frac{y^*}{\rho+\mu+\pi}$