Adverse Selection in the Wholesale Mortgage Market

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Practice Job Talk:
October 25, 2023

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Setting: The Mortgage Market

The Wholesale Mortgage Market:
Small originators sell to large investors between origination and securitization

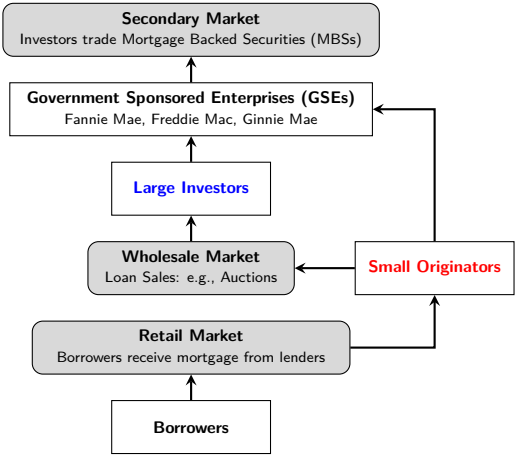

Figure: The Life of a Loan

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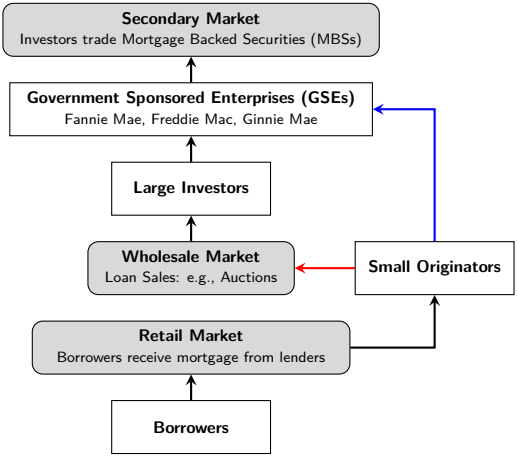
The Originator's Choice:

(a) **Sell** to Wholesale Investor
- *Release* of Servicing Rights

(b) **Sell** to GSEs
- *Retention* of Servicing Rights



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Motivating Observation:
Long term cash flows tied to servicing $\implies$ *only* in selling to the GSEs do originators have stake in loan performance

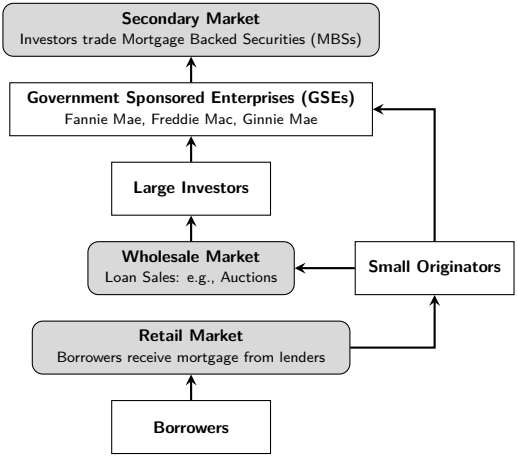

Figure: The Life of a Loan

Research Questions

Motivation: In wholesale transactions, originators may have more information than investors, raising concerns that originators will adversely select loans into the market

The allocation of loans matters because of returns to scale in servicing
— Efficiencies have up-stream and down-stream spillovers onto borrowers & MBS investors

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Research Questions:

1. **Adverse Selection:** Do originators choose to sell better-performing loans to the GSEs (keeping servicing right) on the basis of private information?
2. **Source of Private Information:** Is selection driven primarily by originator private information or investor private information?
3. **Consequences:** What are the consequences of private information and adverse selection for the allocation of loans in the wholesale market?

Modeling Strategy

Approach:
Build a simple model of the originator's decision and estimate using data from a wholesale market auction platform

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Build a simple model of the originator's decision and estimate using data from a wholesale market auction platform

Model Features: Joint model of loan performance, auction bids, originator signals

- Investors submit bids for loans in wholesale auctions
- Originators decide to sell to investors or keep servicing rights by selling to GSEs *after* observing price
- Model allows for originator private information and investor private information revealed through investor prices
- Consider counterfactual change in market design

Literature and Contribution

Adverse selection in mortgage markets:
Vickrey (2021), Mayock (2022), Huh & Kim (2022), Huh & Kim (2023), Becker et al. (2023)

— Focused on adverse selection in (1) borrower refinancing and (2) creation of securities

Mortgage funding and wholesale markets:
Stanton et al. (2014), Buchak & Jorring (2020), Kim et al. (2018), Zhang (2020), Buchak et al. (2023)

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— Focused on the effect of originators' access to up-front funding

Contribution: Diagnosis of the presence, magnitude, and consequences of private information at an important but understudied juncture in the wholesale mortgage market

Agenda

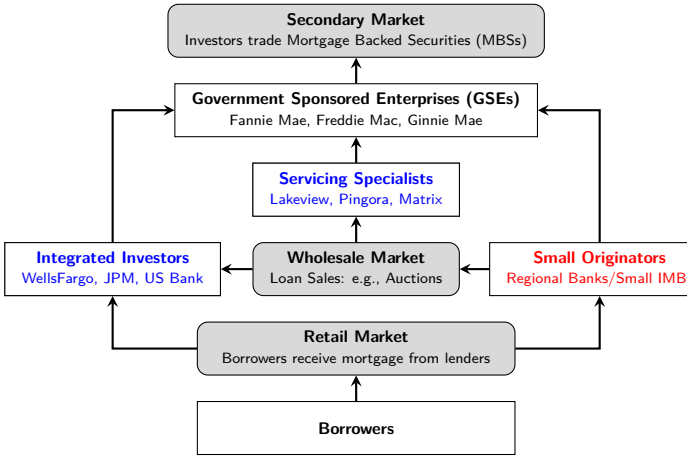
Market Description

Wholesale Market:
— Loans traded in posted-price or *auction markets*
— Small originators are regional banks, credit unions, and Independent Mortgage Banks (IMBs)
— Large investors are integrated investors or servicing specialists

GSE Prices:
— *Cash window* prices for small originators

Details

Loan Performance:
— Adverse events include *default* and ***prepayment***



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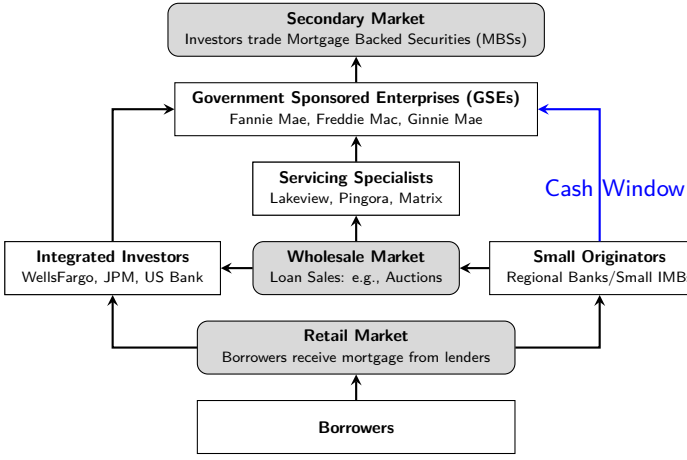

The Auction Market

Optimal Blue Auctions:

- Originators solicit bids from investors in fixed networks
- Auctions held $\sim$1 week or less *after* origination
- Loan-level auctions, effectively first price
- Selling to GSEs is integrated into the platform
- *No commitment to sell*

Data Sources and Sample

Data Sources:

- Originations: Home Mortgage Disclosure Act (HMDA)
  — Loan and borrower characteristics
- Wholesale: Optimal Blue Auctions
  — GSE cash window prices
  — Investor bids
- Secondary: Mortgage Backed Securities (Fannie/Freddie)
  — Loan performance outcomes

Linked to form unique dataset covering all stages of the mortgage market

Estimation Sample: 30-year fixed-rate mortgages auctioned on Optimal Blue from January 2018 – February 2020

Loan Characteristics

Data Highlights:

- Large variation in loan size
- Interest rates significantly higher than Covid's 2% rates
- High quality borrowers
- Investor prices higher than GSE prices
- Loans prepaying early
- Medium-sized originators with variation in network size

	mean	sd
Loan and Borrower Characteristics		
Original Loan Amount	247850.2	115183.7
Note Rate	4.44	0.56
Credit Score	747.4	43.8
Loan-to-Value Ratio	80.8	14.7
Debt-to-Income Ratio	36.3	9.12
Monthly Income	8880.7	6752.3
Auction Characteristics		
Number of Participants	13.0	4.73
Max Investor Bid	103.7	1.30
GSE Price	103.2	1.54
Loan Survival Characteristics		
$1\,(36 - \text{month Survival})$	0.35	
36-month Servicing Revenues	0.47	0.21
Originator Characteristics		
Number of Loans Auctioned	3190.9	3241.5
Network Size	16.8	6.61

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Motivating Facts

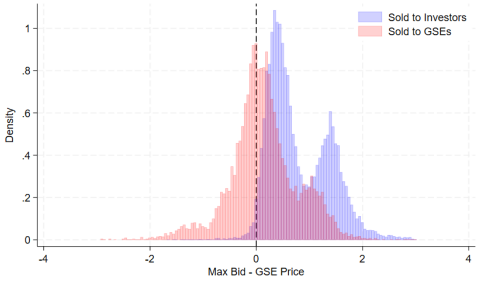
Descriptive motivation for a model of adverse selection:

1. Originators highly responsive to spread between investor bids and GSE prices
2. Noticeable differences in loan survival between loans sold to investors and loans sold to GSEs
3. Selection of high quality loans for selling to GSEs on unobservables

Fact 1: Price Spreads

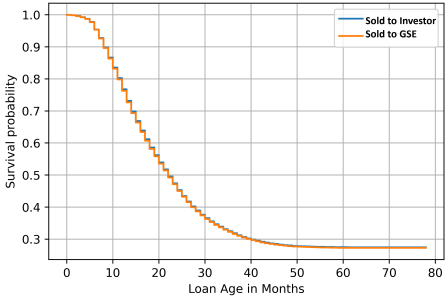
Originators respond to price spreads:

- 70% of loans are sold to investors
- $< 2\%$ loans sold to investors with a winning bid lower than the GSE price
- Propensity to sell strongly increasing in price spread
- Median loan sold to GSEs has positive (.25) price spread $\implies$ originators value servicing cash flows

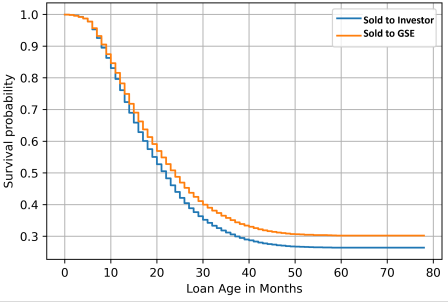


Fact 2: Survival Differences

Figure: Nonparametric Predicted Survival



Model trained on observables only



Model trained on observables + sale decision

Takeaway: Knowing realized selection outcome important for predicting loan survival — Loans sold to GSEs pay addition month worth of servicing fees after three years

Fact 3: Private Information

Model selection using a bivariate probit:

$$Y_i = \mathbf{1}_{\{Y_i^* \geq 0\}}, \quad Y_i^* = X_i\beta_i + \varepsilon_i, \quad \begin{bmatrix}\varepsilon_1 \\ \varepsilon_2\end{bmatrix} \sim \mathcal{N}\left(\begin{bmatrix}0 \\ 0\end{bmatrix}, \begin{bmatrix}1 & \rho \\ \rho & 1\end{bmatrix}\right)$$

where Y_1 is a binary performance outcome and Y_2 is a dummy for selling to GSEs

Table: Performance Probits: Correlation w/ Securitization

	Outcome					
	1(Default)	1(12m Surv)	1(18m Surv)	1(24m Surv)	1(30m Surv)	1(36m Surv)
ρ	-0.0929***	.0033	.0105	.0179**	.0206***	.0235***
	(0.0225)	(.0069)	(.0060)	(.0059)	(.0060)	(.0061)

Regressions control for loan and borrower characteristics

Takeaway: Higher quality loans are selected for sale to GSEs
— Source of selection is *ambiguous*; could be originator *or* investor private information

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Model Timing:

1. Originator j originates loan i and receives signal ω_{ij} about its performance

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Performance measure: Servicing cash flows

$$M_i = \sum_{t=0}^{T_i} \delta^t L_{i,t} s_i$$

where $L_{i,t}$ is loan balance at t and s_i is a servicing markup of 0.25%

The Originator's Decision

The originator's valuation of the two options are:

$$\underbrace{v_{ij}^K = P_i^0 + \mathbb{E}\left[M_i|\omega_{ij}, P_{ij}\right] - c_O}_{Keep} \quad \text{and} \quad \underbrace{v_{ij}^S = P_{ij}}_{Sell}$$

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Originators sell when $v_{ij}^S > v_{ij}^K \implies$ the value of going to auction is:

$$\begin{aligned} v_{ij}^A &= \underbrace{\left(P_i^0 + \mathbb{E}\left[M_i|\omega_{ij}, v_{ij}^K > P_{ij}\right] - c_O\right)}_{\text{Expected Value of Loan Sold to GSEs}} \cdot \underbrace{Pr(v_{ij}^K > P_{ij}|\omega_{ij})}_{\text{Probability of Selling to GSEs}} \\ &+ \underbrace{\mathbb{E}\left[P_{ij}|\omega_{ij}, v_{ij}^K \leq P_{ij}\right]}_{\text{Expected Value of Loan Sold to Investor}} \cdot \underbrace{Pr(v_{ij}^K \leq P_{ij}|\omega_{ij})}_{\text{Probability of Selling to Investor}} \end{aligned}$$

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The Empirical Model

For each loan i:

$$M_i = \mu^M(X_i) + \varepsilon_i \quad \text{(Cash Flows)}$$

$$\omega_{ij} \quad \text{(Signal)}$$

$$P_{ij} = \mu_j^P(X_i) + \eta_{ij} \quad \text{(Bids)}$$

where X_i is a set of loan characteristics, borrower characteristics, market controls for yield curve and To-Be-Announced ('resale') prices

Information structure:

$$\begin{pmatrix} \varepsilon \\ \omega \\ \eta \end{pmatrix} \sim \mathcal{N}\left(0, \begin{pmatrix} \sigma_{MM} & \sigma_{MS} & \sigma_{MP} \\ \sigma_{MS} & \sigma_{SS} & \sigma_{SP} \\ \sigma_{MP} & \sigma_{SP} & \sigma_{PP} \end{pmatrix}\right)$$

Model Assumptions

Simplifying Assumptions:

- Uninformative GSE prices: GSE prices don't change originators' expectations about loan performance
- GSE prices are not seller-specific
- Additive separability of errors
- Rational Expectations: Originators know μ^M (up to a mean zero time-trend) and μ^P
- Bid model: P_{ij} model is reduced-form representation of winning bid formation

The Originator's Decision Revisited

Value of keeping a loan:

$$v_{ij}^{K} = P_i^0 + \mu_i^M + \omega_{ij}\left(\frac{\sigma_{MS}\sigma_{PP} - \sigma_{MP}\sigma_{SP}}{\sigma_{SS}\sigma_{PP} - \sigma_{SP}^2}\right) + \eta_{ij}\left(\frac{\sigma_{MP}\sigma_{SS} - \sigma_{MS}\sigma_{SP}}{\sigma_{SS}\sigma_{PP} - \sigma_{SP}^2}\right) - c_O$$

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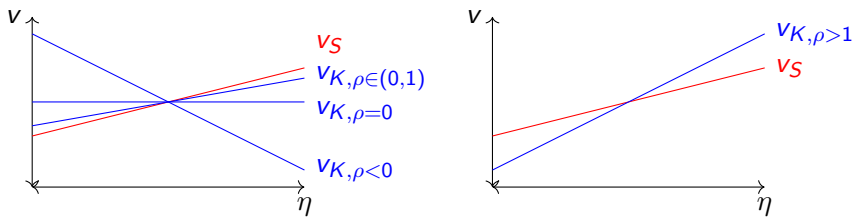
Equating this quantity with $v_{ij}^{S} = \mu_{ij}^{P} + \eta_{ij}$ gives a threshold function $\bar{\eta}(\omega)$:

$$\bar{\eta_{ij}}(\omega_{ij}) = \frac{P_i^0 + \mu_i^M - \mu_{ij}^P - c_O + \omega_{ij}\left(\frac{\sigma_{MS}\sigma_{PP} - \sigma_{MP}\sigma_{SP}}{\sigma_{SS}\sigma_{PP} - \sigma_{SP}^2}\right)}{\left(1 - \left(\frac{\sigma_{MP}\sigma_{SS} - \sigma_{MS}\sigma_{SP}}{\sigma_{SS}\sigma_{PP} - \sigma_{SP}^2}\right)\right)}$$

which partitions the space into Ω_{Keep} and Ω_{Sell}.

The Keep/Sell Decision Revisited

Figure: Expected Value of the Keep and Sell Options



(a) Relatively Informed Sellers (b) Relatively Informed Investors

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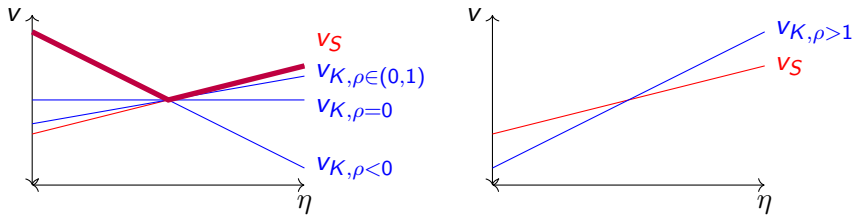

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Estimation and Identification

Estimation:

Details

- Model estimated via MLE using Gauss-Hermite quadrature

Estimation and Identification

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- Model estimated via MLE using Gauss-Hermite quadrature

Sources of Identification: Visualization

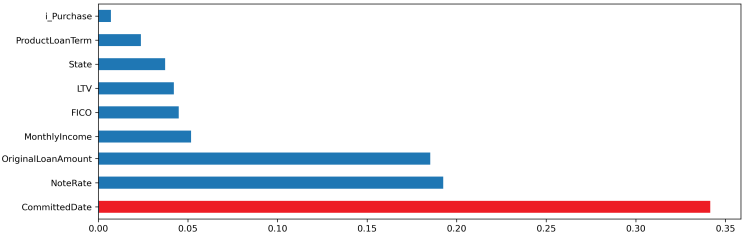
- Variance terms identified through (offline) performance and price regressions
- No selection in prices or performance $\implies$ σ_{MP} identified
- Servicing costs identified from selling decision
- Variation in GSE prices at the loan level shifts v_K
- Price function depends on originator characteristics
  $\implies$ originators face same (unconditional) performance expectations w/ different prices

Measuring Cash Window Prices

Contribution: Cash-window prices are *observed* in $\sim 50\%$ of cases

When not observed, GSE prices are well-approximated by their Random Forest estimates $\hat{P}^0$
– Only goal is prediction & minimizing estimation error $\implies$ Use origination date as covariate

Figure: Importance Plots - Enterprise Price Offers

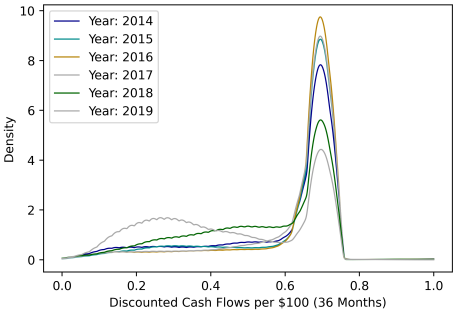


Modeling Loan Performance

Performance measure: Servicing cash flows

Model: Tobit using 36-month cash flows:

$$M_i^* = \mu^M(X_i) + \varepsilon_i, \quad M_i = \begin{cases} \bar{M}, & M_i^* \geq \bar{M} \\ M_i^*, & M_i^* < \bar{M} \end{cases}$$



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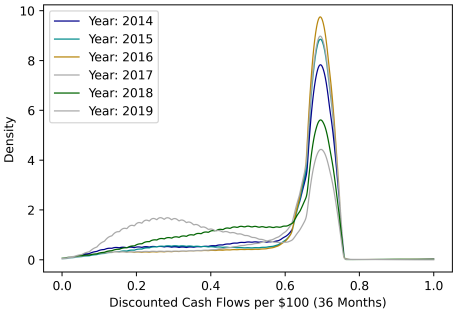
Estimation Sample: 2013-2017 originations — Want to avoid implicitly conditioning on realized interest rate path if estimating in-sample



Model Estimates

	Performance Tobit Model			Max Bid OLS Model		
	Coefficient	Std. Err.		Coefficient	Std. Err	
Seller Characteristics						
Seller Network Size	—	—		0.028*	(0.00069)	
Market Controls						
TBA Price	0.0011*	(0.00012)		1.07*	(0.0041)	
Yield Curve	-0.044***	(0.0027)		-1.489*	(0.0203)	
Covariance Terms						
ε (Cash Flows)	0.098*	(0.00011)	0.159*	(0.00023)	0.038*	(0.00019)
ω (Signal)	0.159*	(0.00023)	1.000	—	0.592*	(0.00015)
η (Prices)	0.038*	(0.00019)	0.592*	(0.00015)	0.452*	(0.00221)
Servicing Costs						
c_O	0.231*	(0.00049)				

Additional controls and fixed effects suppressed for ease of interpretation.

▸ Performance Details ▸ Price Details

Benchmark: For originators lacking option to keep or sell, investors at auction bid ∼$0.05-0.07 higher (per $100 volume)

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Covariance Estimates (Discussion)

Information structure:[1]

$$\hat{\Sigma} = \begin{pmatrix} \sigma_M^2 & \rho_{MS}\sigma_M\sigma_2 & \rho_{MP}\sigma_M\sigma_P \\ \rho_{MS}\sigma_M\sigma_2 & \sigma_S^2 & \rho_{SP}\sigma_S\sigma_P \\ \rho_{MP}\sigma_M\sigma_3 & \rho_{SP}\sigma_S\sigma_P & \sigma_P^2 \end{pmatrix}$$

Takeaways:

- Originators have *very accurate* expectations about prices received at auction
- Value of keeping a loan *decreases* in bid residual (*given* signal)
- For loans with idiosyncratically favorable private information component, sellers require higher price to sell
- Originators' signals *more informative* about loan performance than investors' bids

[1] $dv^K/d\eta \approx -0.523 \quad dv^K/d\omega \approx 0.48$

Covariance Estimates (Discussion)

Information structure:[1]

$$\hat{\Sigma} = \begin{pmatrix} \sigma_M^2 & 0.48\sigma_M\sigma_S & 0.21\sigma_M\sigma_P \\ 0.48\sigma_M\sigma_S & \sigma_S^2 & 0.88\sigma_S\sigma_P \\ 0.21\sigma_M\sigma_P & 0.88\sigma_S\sigma_P & \sigma_P^2 \end{pmatrix}$$

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Servicing Cost Estimates (Discussion)

Estimated Cost of Servicing: \$0.231 (per \$100 loan volume)

Takeaways:

- Translates to servicing costs of $\sim$1 year of servicing revenues
  — Dollar value of $\sim$\$350-950 per loan
- Mortgage Banker's Association reports servicing costs of \$240-\$320 per loan
  — Note: Survey respondents mostly *large* institutions (e.g., Quicken, Wells Fargo, JPM, PennyMac)

Counterfactuals: Discussion

Stepping back: What is the value of auctions?

- Non-committal auctions allow sellers to act on information conveyed via auctions
  ▸ Problems
- Auctions allow for submission of fine-grained *bulk* bids in addition to coarse-grained *lock* prices

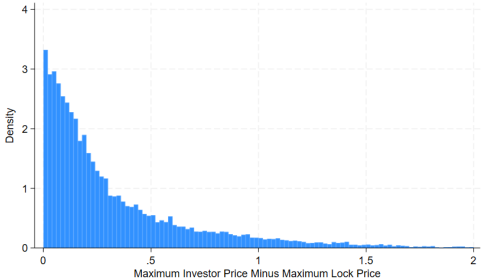
Market Design Counterfactual: Replace auction market with existing posted-price (lock) market

Counterfactual: Introduction

Counterfactual: Shut down the auction channel

- Alternative to auctions in wholesale market is *lock market*: coarse-grained pricing
- Data: Have data on max lock prices from Jan 2018 - Sept 2018
- Plausibility: Auction market small relative to lock market $\implies$ plausible to hold locks fixed in counterfactual environment

Figure: Distribution of Price − Lock



Counterfactual: Model

Absent a fine-grained price, the value to the originator of keeping a loan is now:

$$v^K = P^0 + \mu^M + \omega \left(\frac{\sigma_{MS}}{\sigma_{SS}} \right) - c_O$$

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$$v^K = P^0 + \mu^M + \omega \left(\frac{\sigma_{MS}}{\sigma_{SS}} \right) - c_O$$

Equating this quantity with $v_{ij}^S = P^{Lock}$ gives a threshold in ω:

$$\bar{\omega} = \frac{\sigma_{SS}}{\sigma_{MS}} \left(P^{Lock} - P^0 - \mu^M + c_O \right)$$

For signal values above this, the originator chooses to keep the loan.

Counterfactual: Results

			Outcome			
Lock Outcome	Auction Outcome	Share	Average Residual	Residual Cash Flow	Bulk Minus Lock (Norm)	Bulk Minus Lock (Cash)
Sold to GSEs	Sold to GSEs	41%	0.032	\$88±40	0.140	\$385±175
Sold to GSEs	Sold to Inv.	23%	-0.036	-\$99±45	0.613	\$1675±760
Sold to Inv.	Sold to GSEs	4%	0.100	\$275±125	0.015	\$41±19
Sold to Inv.	Sold to Inv.	32%	-0.027	-\$75±34	0.177	\$485±220

Takeaways:

- With wholesale auctions, a greater fraction of loans are serviced by large investors
- By allowing originators to elicit information from investors, auctions allow originators to make better allocative decisions

Concluding Remarks

- Originators and investors in the wholesale market are differentially informed about loan quality
- Private information and the non-committal auctions create an incentive for originators to offload lemons

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Concluding Remarks

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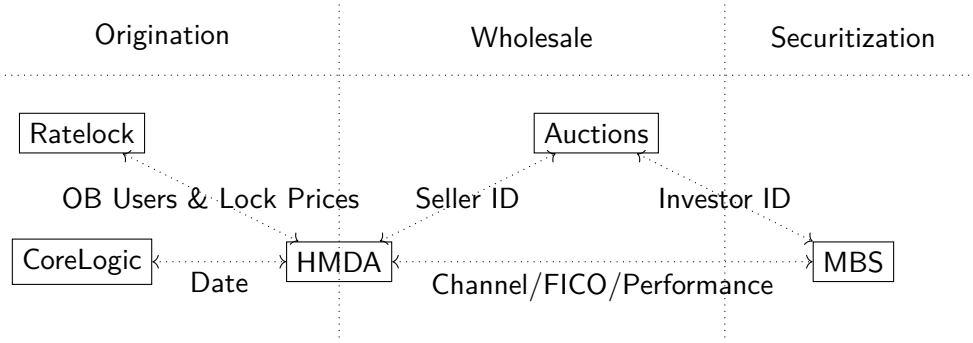
- Private information and the non-committal auctions create an incentive for originators to offload lemons
- Descriptive Results:
  - Evidence of asymmetric information surrounding originators' decision to sell in mortgage auctions
- Model Results:
  - Originators are 'better informed' than investors, but have large servicing costs
  - Relative to a lock price dominated wholesale market, auctions allow investors to service greater loan volume but improve originators' ability to discriminate

Thanks.

Data: Relationships



Additional fields noted in figure are relative to baseline fields in HMDA.

Return

Pricing Public Covariates

Figure: FNMA LLPA Matrix (April 2019)

Table 1: All Eligible Mortgages – LLPA by Credit Score/LTV Ratio

Representative Credit Score	LTV Range									
	Applicable for all mortgages with terms greater than 15 years									
	≤ 60.00%	60.01 – 70.00%	70.01 – 75.00%	75.01 – 80.00%	80.01 – 85.00%	85.01 – 90.00%	90.01 – 95.00%	95.01 – 97.00%	>97.00%	SFC
≥ 740	0.000%	0.250%	0.250%	0.500%	0.250%	0.250%	0.250%	0.750%	0.750%	N/A
720 – 739	0.000%	0.250%	0.500%	0.750%	0.500%	0.500%	0.500%	1.000%	1.000%	N/A
700 – 719	0.000%	0.500%	1.000%	1.250%	1.000%	1.000%	1.000%	1.500%	1.500%	N/A
680 – 699	0.000%	0.500%	1.250%	1.750%	1.500%	1.250%	1.250%	1.500%	1.500%	N/A
660 – 679	0.000%	1.000%	2.250%	2.750%	2.750%	2.250%	2.250%	2.250%	2.250%	N/A
640 – 659	0.500%	1.250%	2.750%	3.000%	3.250%	2.750%	2.750%	2.750%	2.750%	N/A
620 – 639	0.500%	1.500%	3.000%	3.000%	3.250%	3.250%	3.250%	3.500%	3.500%	N/A
< 620[1]	0.500%	1.500%	3.000%	3.000%	3.250%	3.250%	3.250%	3.750%	3.750%	N/A

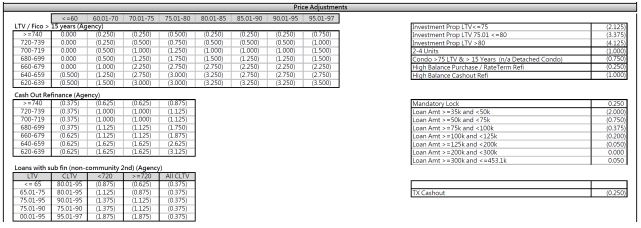
Table 2: All Eligible Mortgages – LLPA by Product Feature

PRODUCT FEATURE	LTV Range									
	≤ 60.00%	60.01 – 70.00%	70.01 – 75.00%	75.01 – 80.00%	80.01 – 85.00%	85.01 – 90.00%	90.01 – 95.00%	95.01 – 97.00%	>97.00%	SFC
Adjustable-rate mortgage	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.250%	0.250%	0.250%	N/A
Manufactured home [2]	0.500%	0.500%	0.500%	0.500%	0.500%	0.500%	0.500%	0.500%	0.500%	235
Second home*	**0.000%**	**0.000%**	**0.000%**	**0.000%**	**0.000%**	**0.250%**	**0.250%**	**0.250%**	**0.250%**	**N/A**
Investment property	2.125%	2.125%	2.125%	3.375%	4.125%	4.125%	4.125%	4.125%	4.125%	N/A

Return

Pricing Public Covariates

Figure: Rate Sheet Example



Price Adjustments

LTV / Fico > 15 years (Agency)

	<=60	60.01-70	70.01-75	75.01-80	80.01-85	85.01-90	90.01-95	95.01-97
>=740	0.000	(0.250)	(0.250)	(0.500)	(0.250)	(0.250)	(0.250)	(0.750)
720-739	0.000	(0.250)	(0.500)	(0.750)	(0.500)	(0.500)	(0.500)	(1.000)
700-719	0.000	(0.500)	(1.000)	(1.250)	(1.000)	(1.000)	(1.000)	(1.500)
680-699	0.000	(0.500)	(1.250)	(1.750)	(1.500)	(1.250)	(1.250)	(1.500)
660-679	0.000	(1.000)	(2.250)	(2.750)	(2.750)	(2.250)	(2.250)	(2.250)
640-659	(0.500)	(1.250)	(2.750)	(3.000)	(3.250)	(2.750)	(2.750)	(2.750)
620-639	(0.500)	(1.500)	(3.000)	(3.000)	(3.250)	(3.250)	(3.250)	(3.500)

Cash Out Refinance (Agency)

>=740	(0.375)	(0.625)	(0.625)	(0.875)
720-739	(0.375)	(1.000)	(1.000)	(1.125)
700-719	(0.375)	(1.000)	(1.000)	(1.125)
680-699	(0.375)	(1.125)	(1.125)	(1.750)
660-679	(0.625)	(1.125)	(1.125)	(1.875)
640-659	(0.625)	(1.625)	(1.625)	(2.625)
620-639	(0.625)	(1.625)	(1.625)	(3.125)

Loans with sub fin (non-community 2nd) (Agency)

LTV	CLTV	<720	>=720	All CLTV
<= 65	80.01-95	(0.875)	(0.625)	(0.375)
65.01-75	80.01-95	(1.125)	(0.875)	(0.375)
75.01-95	90.01-95	(1.375)	(1.125)	(0.375)
75.01-90	75.01-90	(1.375)	(1.125)	(0.375)
90.01-95	95.01-97	(1.875)	(1.875)	(0.375)

Investment Prop LTV <=75	(2.125)
Investment Prop LTV 75.01 <=80	(3.375)
Investment Prop LTV >80	(4.125)
2-4 Units	(1.000)
Condo > 75 LTV & > 15 Years (n/a Detached Condo)	(0.750)
High Balance Purchase / RateTerm Refi	(0.250)
High Balance Cashout Refi	(1.000)

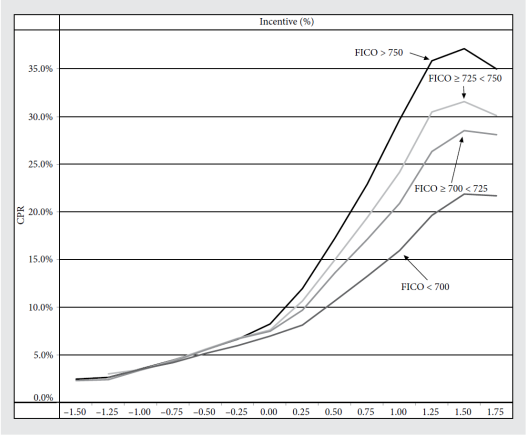
Mandatory Lock	0.250
Loan Amt >=35k and <50k	(2.000)
Loan Amt >=50k and <75k	(0.750)
Loan Amt >=75k and <100k	(0.375)
Loan Amt >=100k and <125k	(0.200)
Loan Amt >=125k and <200k	(0.050)
Loan Amt >=200k and <300k	0.000
Loan Amt >=300k and <=453.1k	0.050

TX Cashout	(0.250)

Return

Pricing Public Covariates

Figure: Conditional Prepayment Rate Example



Return

Estimation - Likelihood Function

Likelihood Function:

$$\begin{aligned}\mathcal{L}(\{M_i, P_{ij}, Y_i\}_1^n | Z, \mu, \Sigma) \;=\; & \prod_{i=1}^n \quad f_U(M_i, P_{ij}, Sell | Z_i, \mu, \Sigma)^{\mathbf{1}\{Sell\}} \\ & \cdot \quad f_T(M_i, P_{ij}, Sell | Z_i, \mu, \Sigma)^{\mathbf{1}\{Sell, M_i = \tilde{M}\}} \\ & \cdot \quad f_U(M_i, P_{ij}, Keep | Z_i, \mu, \Sigma)^{\mathbf{1}\{Keep\}} \\ & \cdot \quad f_T(M_i, P_{ij}, Keep | Z_i, \mu, \Sigma)^{\mathbf{1}\{Keep, M_i = \tilde{M}\}}\end{aligned}$$

where

$$\begin{aligned}f_U(M_i, P_{ij}, Keep/Sell | X_i, \mu, \Sigma) &= \int_{\omega \in \Omega_{Keep/Sell}} f_\varepsilon(M_i - \mu^M(X_i), \omega, P_{ij} - \mu_j^P(X_i)) d\omega \\ f_T(M_i, P_{ij}, Keep/Sell | X_i, \mu, \Sigma) &= \int_{\omega \in \Omega_{Keep/Sell}} \int_{\tilde{\varepsilon}_1}^{\infty} f_\varepsilon(\varepsilon, \omega, P_{ij} - \mu^P) d\varepsilon d\omega\end{aligned}$$

Note: $\Omega_{keep/sell}$ regions are convex $\Longrightarrow$ integrals well-estimated by Gaussian quadrature

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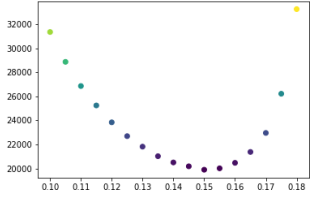
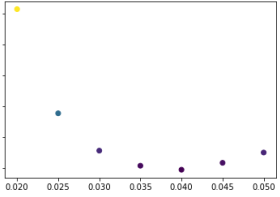
Visualizing Identification

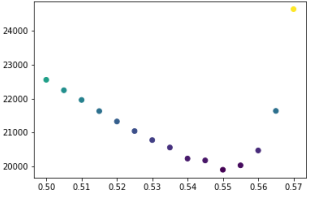
Figure: Marginal Log-Likelihood Function



(a) σ_{12}



(b) σ_{13}



(c) σ_{23}

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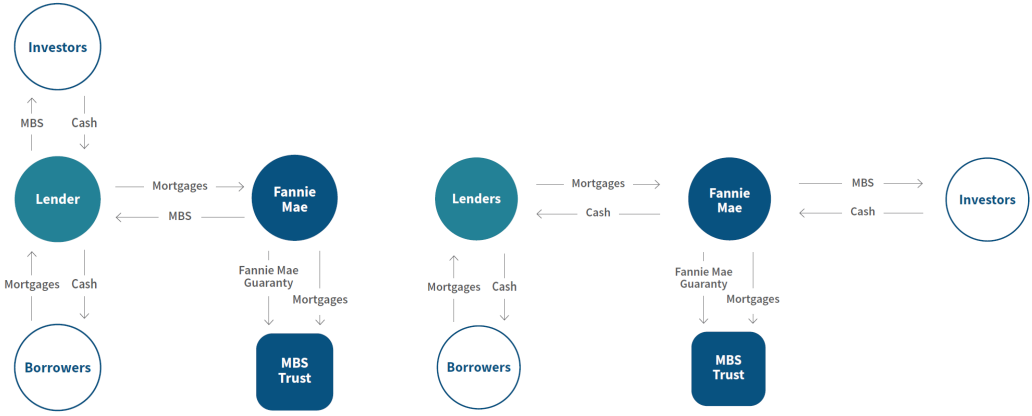
Figure: FNMA Securitization Options: Cash Window (Left) vs. Lender Swaps (Right)



Note: Cash window and lender swaps shown for FNMA only. FHLMC is comparable. Lender swaps used primarily by larger investors.

Winning Prices (β_3, α, and σ_{33})

		Bid Model			
		(1)	(2)	(3)	(4)
	Credit Score	0.00032	0.00018	0.00017	0.00088*
	Loan Size	-0.97*	-0.49*	-1.19*	-0.53*
	Loan-to-Value	-0.0051*	0.0022*	0.00070	-0.014*
	Debt-to-Income	0.00042	0.00086	0.00011	-0.00024
	Income	-0.0092*	-0.0069*	-0.0012	-0.013*
	Seller Network Size	0.037*	0.0026	0.030*	0.028*
		(0.0010)	(0.0015)	(0.00065)	(0.00069)
Market Control	Reserve Price (True)		0.97*		
			(0.0060)		
	Reserve Price (Imputed)			0.79*	
				(0.0027)	
	TBA Price				1.07*
					(0.0041)
	σ_{33}	0.747*	0.098*	0.266*	0.361*
	Observations	57436	5991	53573	56588
	R^2	0.407	0.941	0.773	0.735

Takeaway:

— Old model w/o market controls has high variance and low R^2

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	TBA Price				1.07*
					(0.0041)
	σ_{33}	0.747*	0.098*	0.266*	0.361*
	Observations	57436	5991	53573	56588
	R^2	0.407	0.941	0.773	0.735

Takeaway:

— Sign of coefficients comparable across models

Winning Prices (β_3, α, and σ_{33})

		Bid Model			
		(1)	(2)	(3)	(4)
	Credit Score	0.00032	0.00018	0.00017	0.00088*
	Loan Size	-0.97*	-0.49*	-1.19*	-0.53*
	Loan-to-Value	-0.0051*	0.0022*	0.00070	-0.014*
	Debt-to-Income	0.00042	0.00086	0.00011	-0.00024
	Income	-0.0092*	-0.0069*	-0.0012	-0.013*
	Seller Network Size	0.037*	0.0026	0.030*	0.028*
		(0.0010)	(0.0015)	(0.00065)	(0.00069)
log	Reserve Price (True)		0.97*		
			(0.0060)		
	Reserve Price (Imputed)			0.79*	
				(0.0027)	
	TBA Price				1.07*
					(0.0041)
	σ_{33}	0.747*	0.098*	0.266*	0.361*
	Observations	57436	5991	53573	56588
	R^2	0.407	0.941	0.773	0.735

Takeaway:

— Market controls important for price model

Winning Prices (β_3, α, and σ_{33})

	Bid Model			
	(1)	(2)	(3)	(4)
Credit Score	0.00032	0.00018	0.00017	0.00088*
Loan Size	-0.97*	-0.49*	-1.19*	-0.53*
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Market Control: Reserve Price (True)		0.97*		
		(0.0060)		
Market Control: Reserve Price (Imputed)			0.79*	
			(0.0027)	
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Takeaway:

— Variance depends considerably on model. Market controls ↓ variance considerably

Cash Flows Estimates (β_1 and σ_{11})

	Model			
	(1)	(2)	(3)	(4)
Interest Rate	-0.15*	-0.17*	-0.073*	-0.082*
Loan Size (/100k)	-0.038*	-0.060*	-0.073*	-0.074*
Credit Score	-0.00022*	-0.00013*	-0.000078*	-0.00035*
Loan-To-Value	0.0018*	0.0015*	0.0013*	0.00097*
Debt-To-Income	0.00019*	0.00030*	0.00046*	0.0011*
1(Refinance)	-0.000087	-0.039*	-0.019*	-0.0050*
$\sigma_{11}^{\dagger}$	0.098*	0.084*	0.063*	0.062*
	(0.00011)	(0.000063)	(0.000063)	(0.00025)
Observations	5485296	9008877	3523581	207776
Time Period	2013-2017	2013-2020	2018-2020	2018-2020
Sample	MBS	MBS	MBS	OB Auctions

Not Shown: Controls for yield curve, TBA price, state, and occupancy.

†Note: Variance is for full model w/ interactions. Linear model coefficients shown for simplicity.

Takeaway:

— Old model estimated 'in-sample' implicitly conditions on ex-post realized outcomes

Cash Flows Estimates (β_1 and σ_{11})

	Model			
	(1)	(2)	(3)	(4)
Interest Rate	-0.15*	-0.17*	-0.073*	-0.082*
Loan Size (/100k)	-0.038*	-0.060*	-0.073*	-0.074*
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Not Shown: Controls for yield curve, TBA price, state, and occupancy.

†Note: Variance is for full model w/ interactions. Linear model coefficients shown for simplicity.

Takeaway:

— New model estimated 'out-of-sample' better captures originator's beliefs at time of auction

Cash Flows Estimates (β_1 and σ_{11})

	Model			
	(1)	(2)	(3)	(4)
Interest Rate	-0.15*	-0.17*	-0.073*	-0.082*
Loan Size (/100k)	-0.038*	-0.060*	-0.073*	-0.074*
Credit Score	-0.00022*	-0.00013*	-0.000078*	-0.00035*
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Sample	MBS	MBS	MBS	OB Auctions

Not Shown: Controls for yield curve, TBA price, state, and occupancy.

†Note: Variance is for full model w/ interactions. Linear model coefficients shown for simplicity.

Takeaway:

— Sign of covariates same for 'in-sample' and 'out-of-sample'

Cash Flows Estimates (β_1 and σ_{11})

	Model			
	(1)	(2)	(3)	(4)
Interest Rate	-0.15*	-0.17*	-0.073*	-0.082*
Loan Size (/100k)	-0.038*	-0.060*	-0.073*	-0.074*
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Sample	MBS	MBS	MBS	OB Auctions

Not Shown: Controls for yield curve, TBA price, state, and occupancy.

†Note: Variance is for full model w/ interactions. Linear model coefficients shown for simplicity.

Takeaway:

— (Tobit) Estimated variance artificially low when estimated 'in-sample'

Committal Auctions

If auctions were committal, the decision whether use direct retail vs. soliciting prices would follow a threshold rule in S_{ij} where the optimal allocation about the threshold depends on the relative magnitude of σ_{12} and σ_{23}

- Case 1 $\sigma_{23} > \sigma_{12}$: for large enough S_{ij}, requesting prices is preferred to direct retail
- Case 2 $\sigma_{23} < \sigma_{12}$: for large enough S_{ij}, direct retail is preferred to requesting prices

Problem: Interpretation of η residual is residual price *given* current auction environment

$\implies$ can't count on pricing behavior remaining fixed in a counterfactual world with committal auctions

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