Regional Redistribution through the US Mortgage Market

Erik Hurst, Benjamin Keys, Amit Seru, and Joseph Vavra, AER (2016)

March 20, 2023

Outline

Background

Government Sponsored Enterprises (GSEs) and Mortgage Markets

- Fannie Mae, Freddie Mac and Ginnie Mae are GSEs that purchase mortgage loans below a (county-specific) conforming loan threshold, securitizing them
- GSEs guarantee about half of the (single unit) US mortgage market
- Any loan above the conforming loan threshold is considered to be a jumbo loan, which does not have an implicit government backing and is securitized by the private market
- Mortgage debt accounts for over 70% of household debt in the US economy

Motivation

By holding mortgages rates constant across regions, GSEs are redistributing resources

- First part of the paper documents/estimates that conditional on loan and borrower characteristics, GSEs do not adjust their mortgage rates for local MSA default risks, unlike in the jumbo loans market.
- This is presumably due to political economy mechanisms discussed briefly
- Main idea is that this (implicit) policy of constant GSE mortgage rates generates redistribution from regions (MSAs) that carry less default risk to those that carry more
- Given (comparable) private jumbo loans adjust rates correctly for risks, we can analyze counterfactuals to quantify the overall welfare implications of constant GSE rates
- Second part of the paper builds a structural model that exploits spatial variation to account for the GE effects and provide a more accurate estimate of the welfare implications

GSE and Private Loan Samples

1. **Fannie Mae/Freddie Mac Sample**
   - Single Family Loan Performance Data: subset of the 30-year, fully amortizing, full documentation, single-family, conventional fixed-rate mortgages between 1999 and 2012 (around 25% percent of all GSE loans)
   - **Borrower:** FICO scores. **Loan:** LTV rations, date of origination, size, purchase or refinancing, three-digit zip code, and interest rate. **Performance:** age, months to maturity, outstanding balance, delinquency, prepayment
   - 13 million loans originated between 2001–2006 period and 5 million loans originated between 2007–2009
2. **Prime Jumbo Sample**
   - Loan Performance database: loan-level origination and performance data on near-universe of mortgages sold through the private secondary market during the housing boom (2001 - 2006)
   - Focus only on fixed-rate "prime jumbo" mortgages, want to create a set of mortgages that is as similar as possible to the Fannie/Freddie pool
   - The private market effectively disappeared in 2007

Sample Restrictions

Several restrictions were placed on the prime jumbo sample so that it became similar to the Fannie/Freddie loans in all respects except that the origination value of the loan is slightly higher (above conforming loan threshold):

- (i) origination value between the conforming mortgage limit and two times the conforming mortgage limit in the year of origination
- (ii) have a fixed interest rate
- (iii) LTV ratio at origination of less than 100 percent
- (iv) FICO score at origination of 620 or higher;
- (v) full documentation at the time of origination
- (vi) originated between 2001 and 2006
- (vii) only observations with at least five loan originations in an MSA and quarter-of-year cell

The unit of analysis for exploring spatial variation in mortgage rates is at the MSA level. Left with 70,327 prime private loans.

Descriptive Statistics

TABLE 1—DESCRIPTIVE STATISTICS

	2001–2006				2007–2009	
	GSE all	GSE restricted MSAs	GSE matched sample	Prime jumbo	GSE all	GSE restricted MSAs
Number of loans	13,110,212	8,052,967	70,327	70,327	4,861,259	3,677,984
Median FICO	728	727	658	656	756	757
Median LTV	0.78	0.75	0.79	0.80	0.76	0.75
MSAs covered	374	106	106	106	374	106
Mean interest rate (%)	6.25	6.22	6.33	6.66	5.65	5.63
Mean 2-yr. delinquency rate (%)	1.6	1.4	3.0	2.1	3.8	4.0
Cross-MSA SD of interest rates						
Unconditional (percentage points)	0.544	0.557	0.578	0.657	0.627	0.623
Conditional (percentage points)	0.076	0.072	0.086	0.165	0.070	0.064
Cross-MSA SD of delinquency rates						
Unconditional (percentage points)	1.5	1.2	3.2	2.7	4.0	4.3
Conditional (percentage points)	1.3	1.1	2.8	2.5	2.9	2.9

Regressing mortgage and default rates on Borrower and Loan Characteristics

$$
\begin{aligned}
r^j_{ikt} &= \alpha^j_0 + \alpha^j_1 X_{it} + \alpha^j_2 D_t + \alpha^j_3 D_t \cdot X_{it} + \eta^j_{ikt} \\
y^j_{ikt} &= \varphi^j_0 + \varphi^j_1 X_{it} + \varphi^j_2 D_t + \varphi^j_3 D_t \cdot X_{it} + \nu^j_{ikt,},
\end{aligned} \tag{1}
$$

Where r^j_{ikt} is the loan-level mortgage rate for a loan made to borrower i, in MSA k, during period t, and y^j_{ikt} is an indicator variable for whether the loan made by borrower i, in MSA k, during period t, defaulted at some point during the subsequent24 months. X_{it} is a set of control variables for borrower i in period t. Sample j refers to whether we use individuals from the GSE sample or the private jumbo sample. D_t is a vector of time dummies based on the quarter of origination. The goal of these specifications is to recover η^j_{ikt} and $\nu^j_{ikt,}$, the residual mortgage

rate and residual ex-post-delinquency rate, respectively, for borrower i in MSA k during time t for loans in sample j after controlling for borrower/loan characteristics and time FEs.

Aggregating into location-specific average mortgage rates and ex-post default rates

$$R^j_{kt} = \frac{1}{N^j_{kt}} \sum_{i=1}^{N^j_{kt}} \eta^j_{ikt}$$

$$Y^j_{kt} = \frac{1}{N^j_{kt}} \sum_{i=1}^{N^j_{kt}} \nu^j_{ikt}, \tag{2}$$

Where N^j_{kt} is the number of loans in the MSA k during period t within each sample. Formally, R^j_{kt} (Y^j_{kt}) will be the average mortgage rate residual

(ex-post delinquency residual) in an MSA for loans originated during a given period for a given sample.

Key Empirical Facts

Relation between Current Local Mortgage Rates and Lagged Local Default

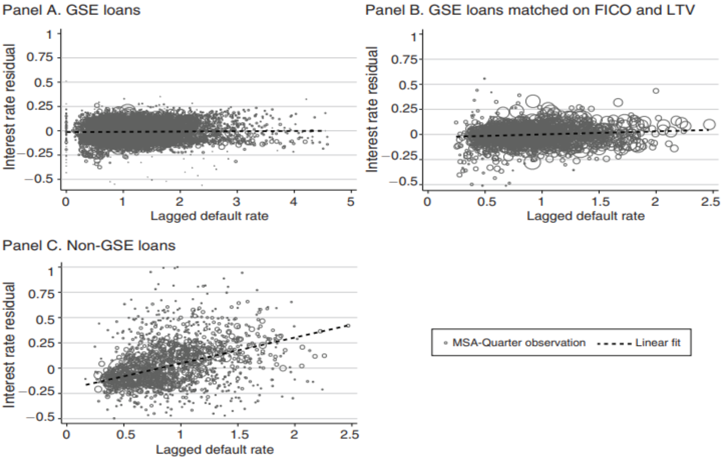

FIGURE 1. RELATIONSHIP BETWEEN INTEREST RATES AND LAGGED LOCAL DEFAULT, 2001–2006

Key Empirical Facts

Relation between Current Local Mortgage Rates and Lagged Local Default

TABLE 2—RESPONSIVENESS OF CONDITIONAL MSA INTEREST RATES TO LAGGED GSE DEFAULT RATE

	2001–2006				2007–2009	
	GSE all (1)	GSE restricted MSAs (2)	GSE matched sample (3)	Prime jumbo (4)	GSE all (5)	GSE restricted MSAs (6)
Coefficient on lagged GSE default rate	0.16	2.40	3.54	30.55	1.12	1.09
	(0.29)	(2.84)	(2.75)	(2.49)	(0.23)	(0.27)
Implied basis point change in mortgage: rate to a two-standard-deviation change in lagged GSE default	0.28	1.78	2.56	20.77	3.18	3.27
Observations	13,109,968	8,052,967	70,327	70,327	4,861,218	3,677,984

Relation between Predicted Default and Mortgage Rates

Estimating future default

What lenders are really interested in when adjusting rates is how past economic conditions translate into future default risk. Authors employ three measures of predicted default $\hat{Y}^j_{kt}$

1. $\hat{Y}^j_{kt} = \lambda^j E^{GSE}_{k,t-1}$, λ^j is such that:
   $y^j_{ikt} = \theta^j_0 + \theta^j_1 X_{it} + \theta^j_2 D_t + \theta^j_3 D_t \cdot X_{it} + \lambda^j E^{GSE}_{k,t-1} + \nu^j_{ikt}$,
2. $\hat{Y}^j_{kt} = E^j_{k,t-1}$,
3. $\hat{Y}^j_{kt} = Y^j_{k,t}$.

Where $E_{k,t-1}$ represents the local GSE default rates, during the 2001–2006 period. Already used in the regressions in Figure 1 and Table 2.

OLS: (for each sample)

$$r_{ikt}^{j} = \omega_0^j + \omega_1^j X_{it} + \omega_2^j D_t + \omega_3^j D_t \cdot X_{it} + \beta^j \hat{Y}_{kt}^j + \eta_{ist}^j. \quad (3)$$

Interested in $(\beta_{jumbo} - \beta_{GSE})$

RDD: (around conforming-loan threshold)

$$\begin{aligned} r_{ikt}^{j} &= \delta_0 + \delta_1 X_{it} + \delta_2 D_t + \delta_3 D_t \cdot X_{it} \\ &+ \left(\tilde{\delta}_1 X_{it} + \tilde{\delta}_2 D_t + \tilde{\delta}_3 D_t \cdot X_{it}\right) D_{it}^{\text{jumbo}} \\ &+ \delta_4 \,\text{Bin}_{it} + \beta \,\text{Bin}_{it} \cdot \hat{Y}_{kt}^j + \eta_{ist}^j \quad (1) \end{aligned}$$

Where D^{jumbo} is a dummy (running/forcing) variable indicating that the loan is from the prime jumbo sample. The specification allows the responsiveness of mortgage rates to observables (FICO, LTV) and time effects to differ across the two samples.

Relation between Predicted Default and Mortgage Rates

Regression Results

Table 3—Relationship between Conditional MSA Interest Rates on MSA Predictive Defaults, 2001–2006

	Base specification				Regression discontinuity specification
Predictive default measure	GSE matched sample (1)	Prime jumbo sample (2)	Difference in coefficients (3)	p-value of difference (4)	RD coefficient (5)
Predicted default using lagged local GSE default	2.10 (1.78)	12.04 (1.68)	9.94	<0.001	13.48 (4.56)
Lagged default (random walk)	3.56 (2.76)	12.60 (3.16)	9.04	<0.001	13.04 (4.57)
Actual default (perfect foresight)	0.26 (0.14)	2.12 (0.40)	1.86	<0.001	2.06 (0.44)
Observations	70,327	70,327			70,327
Time, FICO, and LTV controls included	Yes	Yes			Yes

Relation between Predicted Default and Mortgage Rates

RD - addressing selection concerns

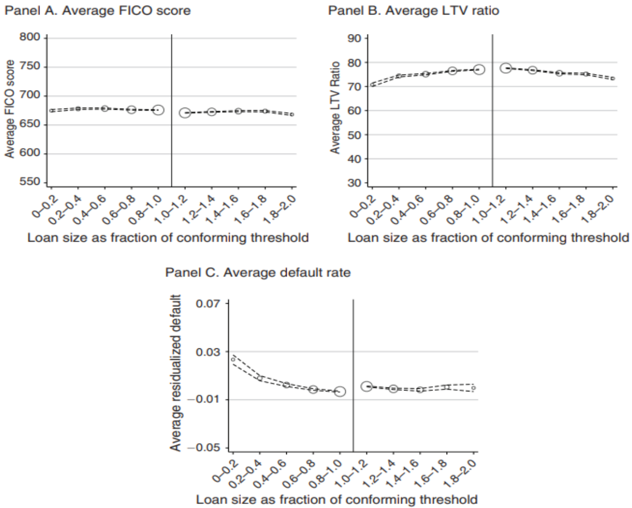

Figure 2. Average FICO Score, LTV Ratio, and Default Rate, by Loan Amount, 2001–2006

Relation between Predicted Default and Mortgage Rates

RD - clear discontinuity in rates above cutoff

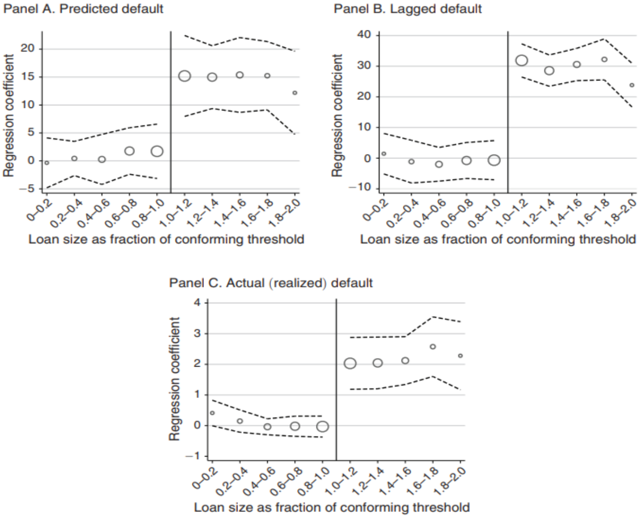

Figure 3. Relationship between Interest Rates and Three Measures of Default, 2001–2006

Relation between Predicted Default and Mortgage Rates

How much should rates have varied with predicted default?

TABLE 4—STANDARD DEVIATION OF PREDICTED DEFAULT

Predicted default measure	2001–2006 GSE matched sample	2001–2006 Prime jumbo sample	2007–2009 GSE restricted MSAs
Predicted default using lagged local GSE default	0.006	0.009	0.011
Lagged default (random walk)	0.004	0.005	0.015
Actual default (perfect foresight)	0.030	0.027	0.043

Relation between Predicted Default and Mortgage Rates

How much should rates have varied with predicted default?

TABLE 5—PREDICTED COUNTERFACTUAL TWO-STANDARD-DEVIATION CROSS-MSA VARIATION IN GSE IN INTEREST RATES

Predicted default measure	2001–2006	2007–2009
Predicted default using lagged local GSE default	0.162	0.297
Lagged default (random walk)	0.104	0.391
Actual default (perfect foresight)	0.124	0.177

Notes: This table presents the interest rate response to a two-standard-deviation change in each predicted default measure for two time periods, 2001–2006 and 2007–2009. These values are obtained by multiplying the values in Table 3, column 5 with two times the standard deviations found in Table 4 for GSE loans.

Estimating Welfare Impacts of GSEs' Constant Rate Policy

Using counterfactual deviations in rates

First estimating how much the interest rate on each loan would change under a counterfactual in which the GSEs priced regional risk like the private market:

$$\Delta \hat{r}_{kt}^{\text{cfactual, } GSE} = \left(\beta^{\text{jumbo}} - \beta^{GSE}\right) \hat{Y}_{kt}^{GSE} \quad (1)$$

Then multiplying this counterfactual change in interest rates by the size of loan i originated in MSA k during 2007–2009 to arrive at the annual change in payment arising from the constant interest rate policy:

$$\text{Transfer}_{ikt} = \left(\beta^{\text{jumbo}} - \beta^{GSE}\right) \hat{Y}_{kt}^{GSE} \text{ LoanAmount }_{ikt}, \quad (2)$$

Putting all of this together, our back-of-the-envelope estimate suggests that the GSE constant interest rate policy resulted in direct transfers of **$14.5 billion** across regions for loans that were newly originated during the 2007–2009 period.

Estimating Welfare Impacts of GSEs' Constant Rate Policy

Resulting redistribution across MSAs

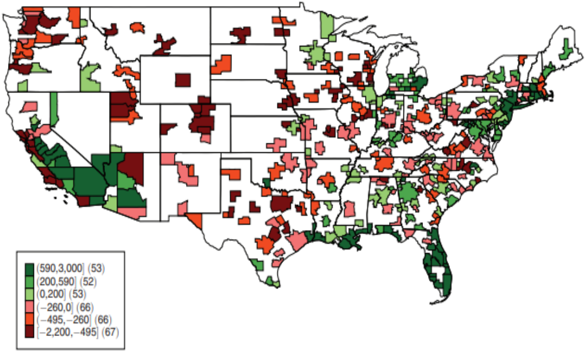

FIGURE 4. TRANSFERS BY MSA, 2007–2009

Across all MSAs, the tenth, twenty-fifth, fiftieth, seventy-fifth, and ninetieth percentiles of the Transferikt PV distribution were –\$680, –\$420, –\$80, \$290, and \$780, respectively.

Model setup

Basic Characteristics

- multi-region life-cycle consumption model
- households face region-specific shocks to house prices and labor earnings as well as purely idiosyncratic labor earnings risk
- Individuals in the model can choose whether to own a home or to rent, in addition to choosing nondurable consumption and liquid savings
- Owner-occupied housing is subject to fixed adjustment costs but serves as collateral against which individuals can borrow using mortgages
- initially assumes that there is no regional variation in mortgage rates and calibration matches various features of the data from 2007 to 2009

Model setup

What it accomplishes:

- Used to explore what would happen if the constant interest rate policy was removed so that mortgage rates vary with local economic conditions like in the extinct prime jumbo market
- Allows for regional variation in mortgage rates to affect welfare via three key channels:
  1. households are able to borrow against their houses subject to holding some minimum equity
  2. households typically borrow all but the required down payment when purchasing houses
  3. increases in mortgage rates depress local prices and economic activity
- Accounts for endogenous changes in household behavior in response to changes in mortgage rates and thus can be used for counterfactual policy analysis
- Allows us to measure the distributional consequences of the constant interest rate policy for households with different incomes and ages

Model setup

Demographics and Location

- continuum of households indexed by i
- Household age is indexed by j = 1, . . ., J
- Households enter the labor force at age 25 and retire at age 60.
- After retirement, households face stochastic mortality risk with probability of death d_j.
- When retired, households receive Social Security benefits based on lifetime earnings prior to retirement, and they are deterministic until household death
- Households live to a maximum age of 85, so $d_{85} = 1$
- Households live in specific regions indexed by k and never move

The measure of economic activity ($\gamma_{k,t}$) in region k and period t follows the process:

$$\log \gamma_{k,t} = \rho_\gamma \log \gamma_{k,t-1} + \varepsilon_{k,t} \quad (3)$$

This is our key stochastic variable and it affects other local variables such as income and house prices

Model setup

Preferences and Household Choices

Household i's Flow utility at age j in region k

$$U_{ijk} = \frac{\left(c_{ijk}^{\alpha} h_{ijk}^{1-\alpha}\right)^{1-\sigma}}{1-\sigma} \tag{4}$$

Where c_{ijk} is non-durable consumption h_{ijk} represents housing services

Model setup

Income Shocks

Time t household labor earnings y for working-age households are given by

$$\begin{aligned} \log y_{ijk,t} &= \chi_j + z_{i,t} + \phi^y \gamma_{k,t} + \phi^y_r \phi^r \gamma_{k,t} \\ \log z_{i,t} &= \rho_z \log z_{i,t-1} + \eta_{i,t}, \end{aligned} \tag{5}$$

Where χ_j is a deterministic age profile common to all households, $z_{i,t}$ is a purely idiosyncratic persistent income shock, ϕ^y is a parameter that governs the sensitivity of household income to the underlying latent local economic conditions. ϕ^y (described later) determines the response of interest rates to local economic activity, and ϕ^y_r then determines the response of local income to local interest rates.

Model setup
Housing Markets

Exogenous housing supply! Assume prices move with exogenous local economic activity. Housing can be purchased at price:

$$p_{k,t} = (\gamma_{k,t})^{\phi^h + \phi_r^h \phi_r} \tag{6}$$

or rented at price $p_{k,t} r^f$. Where ϕ^h governs the strength of the correlation between prices and local activity. ϕ_r^h captures feedback from interest rates to local house prices in the event that interest rates are not constant ($\phi^r > 0$). Note if housing supply is perfectly elastic in all periods, $\phi^h = 0$.
Why Exogenous? Argue that housing demand falls only mildly in response to a 25-basis-point increase in interest rates, so there wouldn't be significant equilibrium effects from changes in GSE interest rate that could alter historical relationships used to calibrate these parameters and hence the price of housing.

Model setup

Mortgages

Buying or selling an owner-occupied house requires paying a fixed cost that is proportional to the current value of the house. That is, the fixed fraction lost for household i when the owners buy or sell their home takes the following form:

$$F_{i,t} = \begin{cases} F \text{ if } h_{i,t+1} \neq h_{i,t} \\ 0 \text{ if } h_{i,t+1} = h_{i,t}. \end{cases}$$

Note that owner-occupied houses are denoted as $h_{i,t}$ and rented houses as $h^f_{i,t}$. Households can borrow against houses subject to a minimum equity requirement. θ is the minimum down payment or equity that must be held in the house.

$$m_{ik,t} \leq (1-\theta)p_{k,t}h_{i,t}, \tag{7}$$

Model setup

Equilibrium Rental and Mortgage Rates

Standard assumption that the rental stock depreciates at rate $\delta^f > \delta^h$. Provides a reason that individuals prefer to own. In equilibrium, the rental price of housing will be the risk-free rate plus depreciation

$$r^f = r + \delta^f \tag{8}$$

The current market interest rate on new mortgages is equal to the risk-free rate plus a risk adjustment. They assume this form because most mortgages in the US are eligible for refinancing at the market rate (with a cost of risk adjustment). Risk adjustment is declining in regional economic activity

$$\begin{aligned} r_{k,t}^{m,\text{ market}} &= r + \Psi_{k,t}, \\ \log \Psi_{k,t} &= \bar{\Psi} - \phi^r \log \gamma_{k,t} \end{aligned} \tag{9}$$

Where $\bar{\Psi}$ is a fixed risk adjustment associated with mortgage lending that is constant across locations. ϕ^r represents the sensitivity of local mortgage rates to local economic conditions. In base specification $\phi^r = 0$

Model setup

Additional Assumptions

- Assume that households have access to fixed-rate mortgages, so the current interest rate that households pay on their mortgages, $r_{k,t}^{m,\text{ fixed}}$, may differ from the market rate, $r_{k,t}^{m,\text{ market}}$
- Also assume that when households move houses or purchase for the first time, then they must reset their rate so that $r_{k,t}^{m,\text{ fixed}} = r_{k,t}^{m,\text{ market}}$
- When not moving households have the option of keeping their previous fixed rate or refinancing to the current market interest rate at cost F^{refi}, which is proportional to the value of the house
- In addition to borrowing through mortgages and saving through the purchase of durable housing, households can save in a one-period bond b with risk-free rate r. Assume that households are otherwise liquidity constrained in that they can only borrow against the value of their home

Household Problem and Solution to Model

The Household model is solved recursively via backwards induction starting from the last possible period of life. The household state vector is defined as:

$$\mathbf{s}_{jk} = \left(b_j, m_j, h_j, z_j, r_j^{m,fixed}; \gamma_{jk}\right) \tag{10}$$

Within each period households choose whether to move houses, to stay in their initial home, or to rent. If they stay in their current owner-occupied home, then they must choose whether to refinance.
When working, households solve:

$$V_j\left(\mathbf{s}_{jk}\right) = \max\left\{V_j^{\text{adjust}}\left(\mathbf{s}_{jk}\right), V_j^{\text{noadjust}}\left(\mathbf{s}_{jk}\right), V_j^{\text{refi}}\left(\mathbf{s}_{jk}\right), V_j^{\text{rent}}\left(\mathbf{s}_{jk}\right)\right\} \tag{11}$$

Click here to see value functions
Adjusters include homeowners who remain homeowners but change the size of their house, those homeowners who become renters, and those renters who become homeowners. Conditional on their adjustment decision, households choose the level of their consumption, their savings in

Model Calibration

- Standard Externally Calibrated Parameters: ρ_z, σ_η, χ, σ, r, $\bar{\Psi}$, δ_h, θ, F, F^{refi}
- Regional Externally Calibrated Parameters: ρ_γ, σ_ϵ, ϕ_y, ϕ_h ϕ_r, ϕ_r^y, ϕ_r^h
- Internally Calibrated Parameters: β, Ω, r^f, α

Note: Model Period is Annual and, thus, so are all moments that parameters target. For internal calibration initialize households in the model to match the distribution of income, liquid wealth net of debt, and housing for 25- to 30-year-old households in the Survey of Consumer Finances (SCF) data. Authors do not go into details about estimation method. I'm assuming they do some non-linear simulated methods of moments (SMM) estimation.

Model Fit

Looking at some not-targted moments

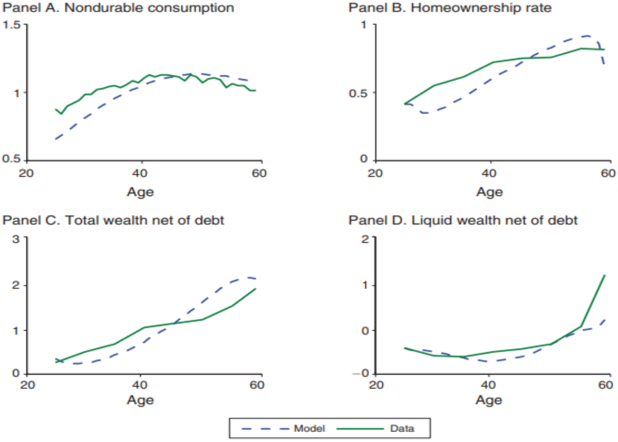

FIGURE 5. AVERAGE LIFE-CYCLE PROFILES: MODEL SIMULATIONS VERSUS DATA

Quantifying counterfactual

One-Time Consumption Equivalent to Accept Region-Specific Rates

How much households in a given region would be willing to pay in units of consumption to change from a variable interest rate policy to a constant interest rate policy. Solve for λ so that:

$$E_{\gamma,z,j} V_j^{\text{constant r}}(\mathbf{s}_{jk}) = E_{\gamma,z,j}^{\text{variable r}} \left\{ U(\tilde{c}(1+\lambda), \tilde{h}(1+\lambda)) + \beta E_j V_{j+1}^{\text{variable r}}(\mathbf{s}_{jk}) \right\} \tag{11}$$

Where $V_j^{\text{constant r}}(\mathbf{s}_{jk})$ is the indirect utility obtained from solving the household problem with state $\mathbf{s}_{jk}$ in a world with $\phi_r = 0$. Similarly, let $V_j^{\text{variable)r}}(\mathbf{s}_{jk})$ be the indirect utility obtained from solving the model in a world with $\phi_r > 0$, and let $\tilde{c}_{jk}$ and $\tilde{h}_{jk}$ be the choice for nondurable consumption and housing services, respectively, that obtain this maximal value. Finally, let $E_{\gamma,z,j}$ denote the expectation of these value functions over values of the idiosyncratic shock and age, conditional on living in a region with economic activity γ.

Main Results

One-Time Consumption Equivalent Necessary to Accept Region-Specific Rates

Table 7—One-Time Consumption Equivalent Necessary to Accept Region-Specific Rates

	Regional employment				
	−2 Standard deviations	−1 Standard deviation	0 Standard deviation	+1 Standard deviation	+2 Standard deviations
Baseline					
Percent consumption gain	2.26	1.18	−0.02	−1.04	−2.12
Dollar per household effect	$870	$470	−$8	−$457	−$988
No feedback multiplier					
Percent consumption gain	1.36	0.70	−0.04	−0.64	−1.26
Dollar per household effect	$524	$279	−$17	−$281	−$586

Model implies that about **$47 billion** is transferred via the mortgage market from regions receiving better than average economic shocks to regions receiving worse than average economic shocks. Click here for robustness checks.

Main Results

One-Time Consumption Equivalent Heterogeneity by Age and Income

TABLE 8—ONE-TIME CONSUMPTION EQUIVALENT NECESSARY TO ACCEPT REGION-SPECIFIC RATES, BY AGE AND INCOME (*Percent*)

	Regional employment				
Consumption gain	−2 Standard deviations	−1 Standard deviation	0 Standard deviation	+1 Standard deviation	+2 Standard deviations
Overall	2.26	1.18	−0.02	−1.04	−2.12
Young	1.76	1.02	−0.08	−0.90	−1.98
Middle-aged	2.50	1.26	0.00	−1.14	−2.18
Low-income	1.46	0.76	−0.06	−0.82	−1.74
Middle-income	2.64	1.36	−0.02	−1.16	−2.32
High-income	2.18	1.22	0.04	−0.92	−1.60

Value function of working-age adjusters of housing

$$V_j^{adjust}(\mathbf{s}_j) = \max_{c_j, b_{j+1}, m_{j+1}, h_{j+1}} U_{jk}(c_j, h_{j+1}) + \beta E_j (V_{j+1}(\mathbf{s}_{j+1,k}))$$

s.t.

$$c_j = b_j(1+r) - b_{j+1} + (\chi_j + z_j)(\gamma_{k,j})^{\phi_y + \phi_r^y \phi^r} - \left(1 + r_{k,j}^{m,market}\right) m_j + m_{j+1}$$

$$+ (\gamma_{k,t})^{\phi^h + \phi_r^h \phi_r} h_j \left(1 - \delta^h\right)(1 - F) - (\gamma_{k,t})^{\phi^h + \phi_r^h \phi_r} h_{j+1}$$

$$b_{j+1} \geq 0, m_{j+1} \geq 0$$

$$\log z_{j+1} = \rho_z \log z_j + \eta_{j+1}$$

$$\log \gamma_{k,j+1} = \rho_\gamma \log \gamma_{k,j} + \varepsilon_{k,j+1}$$

$$m_{j+1} \leq (1 - \theta)(\gamma_{k,t}) \phi^{\phi^h + \phi_r^h \phi_r} h_{j+1}.$$

$$r_{k,j}^{m,market} = r + \bar{\Psi} \gamma_{k,j}^{-\phi_r}$$

$$r_{j+1}^{m,fixed} = r_{k,j}^{m,market},$$

Value function of working-age non-adjusters of housing

$$V_j^{\text{noadjust}}(\mathbf{s}_j) = \max_{c_j, b_{j+1}, m_{j+1}} U_{jk}(c_j, h_j) + \beta E_j(V_{j+1}(\mathbf{s}_{j+1,k}))$$

$$\text{s.t.}$$

$$c_j = b_j(1+r) - b_{j+1} + (\chi_j + z_j)(\gamma_{k,j})^{\phi_y + \phi_r^y \phi^r} - \left(1 + r_j^{m, fixed}\right) m_j + m_{j+1}$$

$$-\delta^h (\gamma_{k,t})^{\phi^h + \phi_r^h \phi_r} h_j$$

$$b_{j+1} \geq 0, m_{j+1} \geq 0$$

$$\log z_{j+1} = \rho_z \log z_j + \eta_{j+1}$$

$$\log \gamma_{k,j+1} = \rho_\gamma \log \gamma_{k,j} + \varepsilon_{k,j+1}$$

$$m_{j+1} \leq (1-\theta)(\gamma_{k,t})^{\phi^h + \phi_r^h \phi_r} h_j$$

$$h_{j+1} = h_j$$

$$r_{j+1}^{m, fixed} = r_j^{m,\text{ fixed}}$$

Value function of working-age households refinancing but not moving

$$V_j^{\text{refi}}\ (\mathbf{s}_j) = \max_{c_j, b_{j+1}, m_{j+1}} U_{jk}\left(c_j, h_j\right) + \beta E_j\left(V_{j+1}\left(\mathbf{s}_{j+1,k}\right)\right)$$

s.t.

$$c_j = b_j(1+r) - b_{j+1} + \left(\chi_j + z_j\right)\left(\gamma_{k,j}\right)^{\phi_y + \phi_r^y \phi^r} - \left(1 + r_{k,j}^{m,market}\right) m_j + m_{j+1}$$

$$-\delta^h \left(\gamma_{k,t}\right)^{\phi^h + \phi_r^h \phi_r} h_j - F^{refi} \left(\gamma_{k,t}\right)^{\phi^h + \phi_r^h \phi_r} h_j \left(1 - \delta^h\right)$$

$$b_{j+1} \geq 0, m_{j+1} \geq 0$$

$$\log z_{j+1} = \rho_z \log z_j + \eta_{j+1}$$

$$\log \gamma_{k,j+1} = \rho_\gamma \log \gamma_{k,j} + \varepsilon_{k,j+1}$$

$$m_{j+1} \leq (1-\theta)\left(\gamma_{k,t}\right)^{\phi^h + \phi_r^h \phi_r} h_j$$

$$r_{k,j}^{m,market} = r + \bar{\Psi} \gamma_{k,j}^{-\phi_r}$$

$$r_{j+1}^{m,\text{ fixed}} = r_{k,j}^{m,\text{ market}}$$

$$h_{i+1} = h_i,$$

Value function of a working-age household that choose to sell current house and rent

$$V_j^{\text{rent}}(\mathbf{s}_j) = \max_{c_j, b_{j+1}, m_{j+1}, h^f_{j+1}} U_{ijk}\left(c_j, h^f_{j+1}\right) + \beta E_j\left(V_{j+1}\left(\mathbf{s}_{j+1,k}\right)\right)$$

s.t.

$$c_j = b_j(1+r) - b_{j+1} + (\chi_j + z_j)\left(\gamma_{k,j}\right)^{\phi_y + \phi_r^y \phi^r} - \left(1 + r_{k,j}^{m,market}\right) m_j$$

$$+ \left(\gamma_{k,t}\right)^{\phi^h + \phi_r^h \phi_r} h_j \left(1 - \delta^h\right)(1 - F) - r^f \left(\gamma_{k,t}\right)^{\phi^h + \phi_r^h \phi_r} h^f_{j+1}$$

$$b_{j+1} \geq 0, m_{j+1} = 0$$

$$\log z_{j+1} = \rho_z \log z_j + \eta_{j+1}$$

$$\log \gamma_{k,j+1} = \rho_\gamma \log \gamma_{k,j} + \varepsilon_{k,j+1}$$

$$r_{k,j}^{m,market} = r + \bar{\Psi}\gamma_{k,j}^{-\phi_r}$$

$$h_{j+1} = 0$$

Note: The problem for a retired household is identical except that social security benefits replace labor earnings, and future payoffs are discounted at rate β (1 - d_j) where d_j is an age-specific probability of death. back

Robustness

Sensitivity to Different Values of ϕ_r (Percent)

Table 9—Sensitivity to Different Values of ϕ^r (*Percent*)

	Regional employment				
	−2 Standard deviations	−1 Standard deviation	0 Standard deviation	+1 Standard deviation	+2 Standard deviations
Consumption gain: benchmark (25 bp)	2.26	1.18	−0.02	−1.04	−2.12
Larger variation (35 bp)	3.16	1.56	−0.05	−1.50	−2.63
Smaller variation (15 bp)	1.39	0.74	0.00	−0.67	−1.32

Back to main.