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Improving the 30-Year Fixed-Rate Mortgage

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The 30-year fixed-rate fully amortizing mortgage (or “traditional fixed-rate mortgage”) was a substantial innovation when first developed during the Great Depression. However, it has three major flaws. First, because homeowner equity accumulates slowly during the first decade, homeowners are essentially renting their homes from lenders. With so little equity accumulation, many lenders require large down payments. Second, in each monthly mortgage payment, homeowners substantially compensate capital markets investors for the ability to prepay. The homeowner might have better uses for this money. Third, refinancing mortgages is often very costly.

We propose a new fixed-rate mortgage, called the Fixed-Payment-COFI mortgage (or “Fixed-COFI mortgage”), that resolves these three flaws. This mortgage has fixed monthly payments equal to payments for traditional fixed-rate mortgages and no down payment. Also, unlike traditional fixed-rate mortgages, Fixed-COFI mortgages do not bundle mortgage financing with compensation paid to capital markets investors for bearing prepayment risks; instead, this money is directed toward purchasing the home.

The Fixed-COFI mortgage exploits the often-present prepayment-risk wedge between the fixed-rate mortgage rate and the estimated cost of funds index (COFI) mortgage rate. Committing to a savings program based on the difference between fixed-rate mortgage payments and payments based on COFI plus a margin, the homeowner uses this wedge to accumulate home equity quickly. In addition, the Fixed-COFI mortgage is a highly profitable asset for many mortgage lenders.

Fixed-COFI mortgages may help some renters gain access to homeownership. These renters may be, for example, paying rents as high as comparable mortgage payments in high-cost metropolitan areas but do not have enough savings for a down payment. The Fixed-COFI mortgage may help such renters, among others, purchase homes.

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KEY WORDS: Fixed-rate mortgage, cost of funds, COFI, mortgages, interest rates, homeownership.

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1. Introduction

The 30-year fixed-rate fully amortizing mortgage (or “traditional fixed-rate mortgage”) was a substantial innovation when first developed during the Great Depression. It still dominates the United States single-family residential housing market.¹ Campbell (2013) and Shiller (2014) note the lack of mortgage contract innovation in the United States in the past 50 years despite compelling reasons to believe better mortgage contracts could be designed for households, bankers, investors, and policymakers alike.²

In this paper, we address three major flaws of the traditional fixed-rate mortgage that impede homeowner equity accumulation and access to homeownership; we then propose a new mortgage product that addresses these flaws.³ The first flaw is that many lenders require large down payments to offset default risk because homeowner equity accumulates very slowly during the first decade of traditional fixed-rate mortgages.⁴ Because early payments of traditional fixed-rate mortgages are almost entirely interest, homeowners are essentially renting their homes from lenders. High down payments are often cited as a barrier to homeownership (e.g., Gudell, 2017). In particular, with both rents and home prices at relatively high levels in many metropolitan areas, many renters may not be able to save enough for down payments of conventional mortgages (Duncan et al. 2016). Homeowners with our proposed mortgage product accumulate equity much quicker.

Second, homeowners substantially compensate capital markets investors for the option to prepay their mortgage. Prepayment risks associated with fixed-rate mortgages are notoriously difficult to hedge. Some homeowners may be better off directing this money to other purposes.

¹ Since the beginning of 2009, adjustable-rate mortgages accounted for, on average, only 5.6 percent of mortgage applications each week. From 1990 to 2008, they accounted for 17.4 percent of applications on average (Mortgage Bankers Association, 2017).

² See Green and Wachter (2005) for a history of mortgages in the United States.

³ Proposals and analysis of other new mortgage contracts include Brueckner, Calem, and Nakamura (2016), Chiang and Sa-Aadu (2014), LaCour-Little and Yang (2010), Pinto (2014), and Piskorski and Tchisty (2010).

⁴ Economists debate the effect of down payments on mortgage performance. Most economists find that lower down payments increase the likelihood of default. Others argue that low-down-payment mortgages, which increase access to housing, can perform very well if properly underwritten (Freeman and Harden, 2015).

Homeowners, in essence, purchase a lottery ticket embedded in traditional fixed-rate mortgage financing. Both homeowners and capital markets investors are betting on the direction of interest rates. Homeowners are betting that interest rates will fall substantially so they can exercise their prepayment option and refinance at a lower mortgage rate for the remainder of their mortgage. Not surprisingly, this “lock-in” feature is expensive. Capital markets investors are betting that interest rates will not fall enough to make refinancing profitable. If one party wins, the other loses. Like any lottery, the odds favor the owner of the lottery: The homeowner pays premiums that are often greater than the expected value of the prepayment option.⁵ Even if a homeowner “wins” the lottery (i.e., rates fall and the homeowner refinances at an appreciably lower mortgage rate), she has often already substantially compensated the mortgage holders. In our proposed mortgage product, we redirect these cash flows to home equity accumulation.

Third, refinancing traditional fixed-rate mortgages is often very costly. Typical refinancing costs are several percent of the mortgage principal.⁶ In addition, because many households miss optimal refinancing opportunities, not all households benefit when rates fall.⁷ Homeowners with our proposed mortgage product automatically benefit from lower interest rates.

In this paper, we propose a new mortgage design, which we call the Fixed-Payment-COFI mortgage (or “Fixed-COFI mortgage”). The Fixed-COFI mortgage resolves the three flaws of the traditional fixed-rate mortgage and preserves fixed monthly payments, which are a desirable feature of the traditional fixed-rate mortgage for many households. First, Fixed-COFI mortgages can be offered with negligible down payments because these mortgages encourage rapid home equity accumulation. Second, Fixed-COFI mortgages redirect prepayment risk compensation—

⁵ In addition, large payments for investor risk aversion and systemic risk may be built into model-based prepayment premiums (Chernov, Dunn and Longstaff, 2016).

⁶ A government consumer guide advises that it “...is not unusual to pay 3 percent to 6 percent of your outstanding principal in refinancing fees” (Board of Governors and Office of Thrift Supervision, 1996). According to Chaplin, Freeman, and Tracy (1997), an “...industry standard is that the transactions costs average from 1-3 percent of the value of the mortgage (excluding any up front points paid to the lender).”

⁷ Keys, Pope, and Pope (2016) find that many households missed substantial savings: “Using a random sample of outstanding US mortgages in December 2010, we estimate that approximately 20% of unconstrained households for whom refinancing was optimal had not done so. The median household would save \$160/month over the remaining life of the loan, for a total present-discounted value of forgone savings of \$11,500...” In a similar vein, Stanton (1995) finds that homeowners “wait an average of more than a year before refinancing, even when it is optimal to do so.”

paid to capital markets investors in traditional fixed-rate mortgages—toward home equity accumulation. Third, Fixed-COFI mortgages avoid many costs associated with refinancing. Homeowners with Fixed-COFI mortgages always reap the benefits when interest rates fall. *In almost all interest rate environments, homeowners could fully own their home in less than 30 years.*

Fixed-COFI mortgages have the following characteristics: (1) the bank receives a reasonable (and highly profitable) margin over the nationwide bank cost of funds index (COFI), which is equal to the total interest expenses of domestic commercial banks divided by their total interest-bearing liabilities;⁸ (2) the household puts forth little or no down payment; (3) the household makes constant monthly payments calculated to amortize the principal over 30 years at the 30-year fixed-rate fully amortizing mortgage rate prevailing at origination; (4) the bank assures the household that the mortgage payment never exceeds the original constant mortgage payment; (5) excess payments are placed into a home equity savings account, which can be used to pay down the principal and weather high interest rate periods; and (6) the bank assures the household that the mortgage will be fully paid off in 30 years.

Underlying the Fixed-COFI mortgage is a COFI adjustable-rate mortgage. The Fixed-COFI mortgage exploits the often-present wedge between the traditional fixed-rate mortgage rate and the COFI mortgage rate. In figure 1, the wedge is shown as the gap between the traditional fixed-rate mortgage rate (orange line) and the estimated COFI mortgage rates (blue band). Hancock and Passmore (2016a) analyze the feasibility of adjustable-rate mortgage products indexed by COFI by estimating COFI-indexed mortgage rates from historical data between 2000 and 2014, inclusive. By design, depository institutions can usually hold these mortgages profitably. They examine the costs and benefits of these contracts from household, banker, investor, and policymaker perspectives. Although they found substantial benefits for market participants had they used COFI-indexed mortgages, adjustable-rate mortgages inherently lack the desirable feature of fixed monthly payments.

⁸ Quarterly data of total interest expenses and interest-bearing liabilities for U.S. commercial banks are reported in Federal Financial Institutions Examination Council Consolidated Reports of Condition and Income (FFIEC, 2016). After merger adjustment, monthly COFIs are inferred by linearly interpolating between quarterly data points. Throughout this paper, we use “depository institutions” and “U.S. commercial banks” synonymously.

What do homeowners lose by choosing Fixed-COFI mortgages instead of traditional fixed-rate mortgages? First, they cannot freely spend refinancing gains on non-housing items. When mortgage rates fall, homeowners with Fixed-COFI mortgages automatically pay less interest and pay down the mortgage principal more. Second, they can no longer “win the lottery” played with capital markets investors and lock in a substantially lower rate for the remainder of their mortgage. With Fixed-COFI mortgages, homeowners trade the option of prepayment for faster home equity accumulation. We believe that many households may prefer Fixed-COFI mortgages to traditional fixed-rate mortgages. Furthermore, we believe that many renting households without savings for a down payment may prefer Fixed-COFI mortgages to renting.

Widespread Fixed-COFI mortgages would result in four primary benefits. First, since it can be offered with low or no down payment, the Fixed-COFI mortgage can increase homeownership. Some renters can qualify for mortgages on a cash-flow basis (e.g., they have a successful track record of paying high rents), but they have little or no savings for a down payment. With Fixed-COFI mortgages, these renters would be able to purchase homes and accumulate home equity quickly.

Second, Fixed-COFI mortgages can alleviate housing affordability pressures. In Passmore and von Hafften (forthcoming), we propose and analyze an extension of the Fixed-COFI mortgage that focuses on housing affordability.⁹

Third, the Fixed-COFI mortgage can help diminish government involvement in the mortgage market. Homeowners with traditional fixed-rate mortgages accumulate equity slowly, often refinance, and often extract home equity.¹⁰ Since many homeowners may have little home equity—even beyond the first decade of their traditional fixed-rate mortgage—they are vulnerable to income shocks and house price declines.¹¹ In order to trade securitized traditional fixed-rate

⁹ The monthly payment of an affordable Fixed-COFI mortgage is set at a proportion of median income—instead of setting the payment based on the prevailing traditional fixed-rate mortgage rate (Passmore and von Hafften, forthcoming). We analyze the viability of major housing markets across the U.S. for affordable Fixed-COFI mortgages.

¹⁰ Cash-out refinances, which drain home equity, are widespread; Goodman (2017) found that “Eighty-four percent of GSE refinances in 2006 and 2007 were cash-out refinances.”

¹¹ Indeed, Goodman (2017) finds that refinanced mortgages were *more* likely to default than mortgages for purchases: “At the height of the boom, mortgage refinances (refis) were more likely to default than mortgages taken out to purchase a home, mostly because many people were treating their homes as ATMs through cash-out

mortgages, secondary market investors rely upon government backing of some—or all—credit risk. Indeed, the wide-scale secondary market for traditional fixed-rate mortgages may be predicated on considerable government backing. In the past, this government involvement has led to government risk-taking, mortgage mispricing, moral hazard, and adverse selection.¹² With rapid home equity accumulation from Fixed-COFI mortgages, the government would need to absorb less long-term credit risk.¹³

The final benefit of widespread Fixed-COFI mortgages is increased financial stability. The traditional fixed-rate mortgage generates waves of refinancing, which may amplify interest rate spikes. Because Fixed-COFI mortgages automatically link lower interest rates to greater household savings and limit refinancing, widespread use of these mortgages might mitigate this financial stability concern.

The Fixed-COFI mortgage also has the characteristics of mortgages that reduce housing market volatility, consumption volatility, and default.¹⁴ Guren, Krishnamurthy, and McQuade (2017) find that such mortgages provide immediate and substantial payment relief to liquidity-constrained households during market downturns. With Fixed-COFI mortgages, all residual payments (in excess of a variable COFI-based interest component) go toward the purchase of the home. Thus, the Fixed-COFI mortgage automatically refinances, even if the homeowner does not take action to refinance her mortgage when interest rates fall. This results in homeowner wealth

refinances.” This result is despite “...the stronger credit characteristics of refis, such as lower loan-to-value (LTV) and debt-to-income ratios.”

¹² For a discussion of first mover and adverse selection problems in mortgage securitization, see Heuson, Passmore, and Sparks (2001). For a discussion about how the government sponsored enterprises (GSEs) misprice catastrophic risk in the run-up to a crisis, see Hancock and Passmore (2016b).

¹³ For Fixed-COFI mortgages, government involvement is limited to actuarial-based government-backed tail-risk insurance provided either directly to bankers or to investors who purchase pools of such mortgages. Included in the COFI-index adjustable-rate mortgage product presented in Hancock and Passmore (2016a), the premiums for this insurance were estimated using an expected loss distribution constructed in Hancock and Passmore (2016b). This insurance makes the mortgage more tradable in secondary mortgage markets, similar to traditional fixed-rate mortgages securitized by Fannie Mae and Freddie Mac. In this paper, we largely put aside the topic of secondary market viability (discussed at length in Hancock and Passmore, 2016a), and we use gross margins that include compensation for these risks. It should be noted that although capital markets investors with funding costs tied to short-term rates (e.g. LIBOR) face a certain degree of basis risk if they hold securities backed by COFI-indexed mortgages, these investors face myriad other risks (e.g. interest rate risk, prepayment risk) when holding securities backed by traditional fixed-rate mortgages.

¹⁴ The Fixed-COFI mortgage is also broadly consistent with the findings of Brueckner and Lee (2017) concerning optimal mortgages, who conclude that homeowners should bear more interest rate risk when mortgages can be terminated earlier.

increases, as the homeowner purchases the home faster.¹⁵ In addition, as we discuss in section 8, a household with the Fixed-COFI mortgage can retain the ability to refinance in response to an income shock. Importantly, because the equity accumulation in Fixed-COFI mortgages is faster than in traditional fixed-rate mortgages, Fixed-COFI mortgage payments (after refinancing) will likely be much lower than traditional fixed-rate mortgage payments (after refinancing).

This paper proceeds as follows: Section 2 details the mechanics of the Fixed-COFI mortgage contract. Section 3 provides an example of the potential gains from Fixed-COFI mortgages. Section 4 discusses constructing COFI mortgage rates. Section 5 introduces simulations we use to analyze Fixed-COFI mortgages. Section 6 discusses pricing insurance premiums that are built into Fixed-COFI mortgages. Section 7 develops an analytical argument about how simulation results should be characterized. Section 8 presents the results from the simulations, specifically from the perspective of homeowner welfare. Section 9 concludes.

2. Fixed-COFI Mortgage Contract Mechanics

In each month of a traditional fixed-rate mortgage, the remaining mortgage principal accrues interest at a rate fixed for the entire term of the mortgage. The homeowner pays a constant payment that fully amortizes the mortgage principal over 30 years. As a percent of the house price, the monthly payment for fully amortizing mortgages is calculated as follows:

$$FR_{payment} = LTV_0 * \frac{F_0 * (1 + F_0)^{360}}{(1 + F_0)^{360} - 1},$$

where F_0 is the fixed-rate mortgage rate at origination.

Figure 2 outlines the cash flows associated with Fixed-COFI mortgages. At origination, the fixed-rate mortgage payment, $FR_{payment}$, is calculated at the rate prevailing for traditional fixed-rate mortgages. The household makes this payment each month. For example, consider a homeowner purchasing a \$200,000 home. If the homeowner pulls out a Fixed-COFI mortgage with zero percent down, and the prevailing fixed-rate mortgage rate is 4.39 percent, the homeowner pays \$1,000 each month. The COFI mortgage rate is calculated as COFI plus a gross margin

¹⁵ As shown in section 8, the Fixed-COFI mortgage can also be modified to allow borrowing against this wealth.

(GM).¹⁶ The gross margin is constant over the term of the mortgage and covers servicing costs, insurance against credit risk, a return on equity, and premiums for “payment shortfall” insurance and “balloon payment” insurance.¹⁷ Based on Hancock and Passmore (2016a), we estimate that gross margins range between 1.75 and 2.5 percent. In each month, the interest due to the bank is the outstanding book loan-to-value (LTV) in the previous month (LTV_{t-1}) times the current COFI mortgage rate ($COFI_t + GM$).

As shown in the top panel, when the interest is less than the household payment, the residual payment is added to the home equity account. Continuing the example from above, if COFI is 2.5 percent in the first month and the gross margin is 2 percent, the homeowner’s payment is divided into two parts: \$750 goes to the bank to pay interest, and the remaining \$250 pays down the principal. Thus, the outstanding mortgage balance in the next period is \$199,750.

When the interest is greater than the household payment and the home equity account has sufficient funds (i.e., the current book LTV is less than 100), a withdrawal from the home equity account covers the shortfall, and the bank receives the full interest (middle panel). In the example, if COFI jumps up to 5.5 percent in the second month (which is highly unlikely), \$1,250 goes to the bank with \$250 from the home equity account covering the shortfall. The outstanding balance in the next period is \$200,000.

When the interest is greater than the household payment and the home equity account is exhausted (i.e., the current book LTV is greater than 100), the bank covers the shortfall (lower panel). In the example, if COFI remains at 5.5 percent in the third month, the bank covers the shortfall of \$250, which is the difference between the household payment and the interest due (i.e., \$1,250).

In addition to the bank covering payment shortfalls over the course of the mortgage, the bank covers any outstanding mortgage principal after 30 years, which would be a payout from the balloon payment insurance. Premiums for the payment shortfall and balloon payment insurance

¹⁶ We discuss the COFI mortgage rate in section 4. For details of how the gross margin of a COFI adjustable-rate mortgage used here covers guarantee fees for credit risk and fees for mortgage servicing as well as a hefty return on equity, see Hancock and Passmore (2016a).

¹⁷ Insurance against credit risk is set equal to what Fannie Mae and Freddie Mac charge, on average, for their 30-year fixed-rate mortgage guarantees.

are built into the gross margin at origination. The cost of this insurance determines the viability of Fixed-COFI mortgages. We measure these costs explicitly later in the paper.

Savings from the Fixed-COFI mortgage stem from the structure of the contract.¹⁸ In general, fixed-payment contracts may be described using two characteristics: home equity accumulation and refinancing opportunities (see table 1).¹⁹ The Fixed-COFI mortgage limits refinancing opportunities in two ways. First, as discussed, the homeowner is not allowed to pay capital markets investors for the option of locking in a lower mortgage rate for the term of the mortgage. Second, the homeowner must make home equity payments and reduce mortgage principal whenever interest is less than the monthly payment. Similarly, traditional fixed-rate mortgage contracts prevalent before the 1970's often had prepayment penalties, but homeowners with these contracts did not benefit from falling interest rates. In contrast, households with traditional fixed rate mortgages (post-1970's) can freely spend savings from refinancing.

We initially analyze Fixed-COFI mortgages without any refinancing or equity extraction, but the Fixed-COFI contract can be modified for different rules concerning refinancing and savings. When a household refinances, the monthly payment is recalculated to amortize the remaining mortgage balance over 30 years at the prevailing traditional fixed-rate mortgage rate. We discuss the effect of limited equity extraction and refinancing on homeowner welfare later in section 8.

3. A Fixed-COFI Mortgage Example

We present an example of a traditional fixed-rate mortgage and a Fixed-COFI mortgage, both originated in April 1985. Shown in figure 3 as a heavy black ball-and-chain line, the monthly

¹⁸ In principle, a financially sophisticated household could bundle together various financial products—a COFI adjustable-rate mortgage, a savings account, and an interest rate cap—and effectively mimic a Fixed-COFI mortgage. The design of the Fixed-COFI mortgage draws from behavioral economics and behavioral finance, including commitment devices (Bryan, Karlan, and Nelson, 2010), self-control (Thaler and Shefrin, 1981), and financial sophistication (Calvet, Campbell, and Sodini, 2009). The Fixed-COFI mortgage is in the spirit of the Save More Tomorrow™ savings program presented in Thaler and Benartzi (2004). In the Save More Tomorrow™ program, participants commit a portion of future salary increases toward retirement savings. In the same vein, the Fixed-COFI mortgage commits refinancing gains from interest rate drops toward purchasing the home.

¹⁹ Pinto (2014) details the Wealth Building Home Loan (WBHL). In essence, the WBHL is a 15-year fully amortizing fixed-rate mortgage with a permanent rate buy down instead of a down payment. This interest rate buy down limits refinancing. It may be hard to offer without subsidies. See Harmon (1963) for a discussion of prepayment penalties included in pre-1970's fixed-rate mortgages.

payment for the traditional fixed-rate mortgage is equal to 1.15 percent of the house price at origination. The payment can be broken into interest (red dashed line) and principal (solid blue line). By design, as more and more of the mortgage payment pays down principal, the mortgage amortizes over 30 years.

A household with a Fixed-COFI mortgage makes the same monthly payment as with a traditional fixed-rate mortgage. The payment can be similarly broken up into interest and principal. Unlike with the traditional fixed-rate mortgage, the bank receives interest based on COFI plus the gross margin.²⁰ Shown as a red right-slanted hatched band, interest follows the decline in the remaining principal as well as the historical decline of COFI (and interest rates generally) over this period (see figure 1).

In figure 3, we bifurcate the principal component of the Fixed-COFI mortgage payment. The blue left-slanted hatched band shows the principal payment that, by itself, would pay off the mortgage in 30 years. However, the household makes a fixed monthly payment. In this example, the fixed monthly payment is always larger than the sum of interest plus the 30-year-amortizing component of the principal. The green vertical hatched band is the residual portion of the monthly payment. This residual is put into the home equity savings account and further pays down the mortgage principal. These paydowns represent the “wedge” that is almost always present between traditional fixed-rate mortgage rates and COFI mortgage rates (see figure 1). This wedge accelerates paying down the principal in Fixed-COFI mortgages. As a result, the example Fixed-COFI mortgage pays off around 1998—only about 13 years after origination. By choosing the Fixed-COFI mortgage, the homeowner saves about 250 percent of the house price.

As shown in figure 4, equity accumulates quickly for the example Fixed-COFI mortgage. After just 5 years, the homeowner owns between 22 percent and 27 percent of the house depending on the gross margin (left-slanted blue band). After 10 years, homeowner equity rises to between 67 and 76 percent. In contrast, a traditional fixed-rate mortgage holder only owns 1.8 percent of her home after 5 years and 5.3 percent after 10 years (blue line). The Fixed-COFI mortgage holder owns her house after 12 to 14 years (orange dotted lines).

²⁰ Gross margins in Fixed-COFI mortgages are discussed in section 4. The height of Fixed-COFI payment bands represent the range of profitable gross margins.

This example highlights both potential homeowner equity gains and how default risks evolve for Fixed-COFI mortgages. Although the household quickly increases its wealth and its ability to weather financial stress, some default risk exists in the early years of the mortgage due to the lack of a down payment. Because home equity rapidly accumulates in Fixed-COFI mortgages, borrower default risks likely fall substantially in the early years of the mortgage.²¹ After 5 years, in terms of default risk, the bank essentially holds a 25-year fixed-rate mortgage with a 20 percent down payment in this example. Thus, the risk of homeowner default is substantially lower than in a traditional fixed-rate mortgage without a down payment. Indeed, if Fixed-COFI mortgages have the same underwriting standards as traditional fixed-rate mortgages, the credit risk from Fixed-COFI mortgages may be less than or equal to the credit risk from traditional fixed-rate mortgages.

4. COFI Mortgage Rates

The COFI mortgage rate is the sum of the nationwide average cost of funds index for the banking system and a gross margin. COFI is equal to the total interest expenses of domestic commercial banks divided by their total interest-bearing liabilities.²² COFI is determined by both short-term rates (e.g. one-year Treasury yields) and deposit rates.²³ Deposit rates are very different than short-term rates. Deposit rates barely move, and depositors keep their money in banks for very long periods despite relatively low rates of return. Thus, COFI is best modeled as a partial adjustment process that incorporates concurrent short-term Treasury yields (Stanton and Wallace 1995, Passmore 1993, Roll 1987, and Cornell 1987):

$$COFI_t = \alpha COFI_{t-1} + \beta T_t + \delta_t, \text{ where } \delta_t \sim N(0, \sigma_\delta^2) \text{ and } 0 < \alpha, \beta < 1.$$

Table 2 shows the partial adjustment model estimation. Because COFI is quarterly, we average one-year Treasury yields for each quarter. This model suggests that current COFI is

²¹ Negative equity is a necessary—but not sufficient—condition of mortgage default. Campbell and Cocco (2015), Gerardi et al. (2015), and Mayer, Pence, and Sherlund (2009) discuss the importance of negative home equity in determining mortgage default.

²² COFI is derived quarterly from FFIEC Call Reports.

²³ Using COFI as an index relates to the tension between average cost pricing and on-the-margin pricing. Strong assumptions (e.g. about market structure) are required in order to deduce that on-the-margin pricing is optimal; a bank with an investment in deposits can be very profitable charging a markup over COFI.

approximately a weighted average of lagged COFI (roughly 75 percent) and the concurrent average one-year Treasury yield (roughly 25 percent). As we show in appendix I, this estimated partial adjustment model suggests that the expected value of long-run COFI converges to 91 percent of the initial one-year Treasury yield. Figure 5 shows COFI (solid black line) and the average one-year Treasury quarterly yield (short-dashed blue line). COFI is clearly distinct from the one-year Treasury yield. Supporting the model's summary statistics, we see the partial adjustment model (long-dashed red line) tightly fits historical COFI.

Hancock and Passmore (2016a) show that profitable margins on COFI-indexed adjustable-rate mortgages are almost always between 1.75 and 2.5 percentage points.²⁴ These margins cover servicing costs, credit risk insurance, and a return on equity. Based on Hancock and Passmore, we assume the servicing fee is 35 basis points and the credit risk insurance premium (or “g-fee”) is 65 basis points. In addition to the gross margin charged on COFI adjustable-rate mortgages, the gross margin for Fixed-COFI mortgages includes premiums for payment shortfall insurance and balloon payment insurance. Because most mortgage insurance (either private or through the Federal Housing Authority) is based on the initial loan amount, households are charged a fixed dollar fee on top of their monthly mortgage payment. We adopt a time-varying markup that sits on top of the other components of the gross margin; we later determine an analytically grounded rule-of-thumb as a method to practically price Fixed-COFI mortgages. Each insurance premium is a fixed proportion of the *remaining* mortgage principal; as the mortgage principal is paid down, the premium shrinks in terms of dollars (or percent of house price). The size of the premium depends on the insurance payouts. Since insurance payouts themselves depend on the size of the premium, we need to use simulations (see section 6).

²⁴ The mean profitable gross margin is 2.2 percent with a standard deviation of 16 basis points. See table 2 in Hancock and Passmore (2016a). A time-varying technique is used to calculate net margins in Hancock and Passmore (2016a). However, the profitability can be readily established by the following “back of the envelope” calculation. Let the bank's net interest income for a COFI mortgage be $Income = (\alpha + COFI) * A - COFI * L$, where A is COFI-based assets, L is interest-bearing liabilities, and α is the gross margin. Let $L = A - K$, where K is equity capital. Then the return on equity is $\frac{Income}{K} = (\alpha * LEV + COFI)$, where LEV is the bank's leverage or A/K . If leverage is 20 times on a mortgage (the current risk-based capital weight on mortgages), then the gross return on equity for a margin of 2 percent and a COFI of 5 percent is 45 percent. For a leverage of 10 times capital, a gross margin of 2 percent, and a COFI of 2 percent, this gross return on equity is 22 percent. As long as non-interest bearing liabilities and non-interest expenses are not large, this calculation suggests a relatively high return.

In figure 1, we compare our estimated COFI-indexed adjustable-rate mortgage rates (blue band) and the effective rates on 30-year fixed-rate first-lien prime conventional conforming home-purchase mortgages with 20 percent down (i.e., “traditional fixed-rate mortgage rates;” orange line).²⁵ Although COFI mortgage rates are similar to traditional fixed-rate mortgage rates in some periods (e.g., during the thrift/banking crisis in the late 1980s and the run-up to the 2007-09 financial crisis), COFI mortgage rates are considerably below traditional fixed-rate mortgage rates in most periods. In general, traditional fixed-rate mortgage rates are higher than adjustable mortgage rates because borrowers compensate lenders both for the risk that rates will rise and for the option to prepay. Moreover, traditional fixed-rate mortgage rates may reflect uncertainty and market risk premiums that are absent from deposit rates, which are a key component of COFI.²⁶ Indeed, market uncertainty may drive COFI lower due to greater inflows into insured deposits.²⁷

5. Simulation of Fixed-COFI Mortgage Performance

How representative is the example Fixed-COFI mortgage in section 3? We run two phases of simulations to evaluate the viability of Fixed-COFI mortgages over a broad range of interest rate environments.²⁸ First, we simulate mortgages to calculate sufficient premiums for payment

²⁵ For figure 1, we present a range of credible gross margins. In addition, to calculate the effective traditional fixed-rate mortgage rate, we assume that the points and fees are divided over the life of a mortgage loan. Points and fees are reported in the Freddie Mac Primary Mortgage Market Survey. We assume the average life of a mortgage loan is six years, which is consistent both with low spread, low coupon conforming mortgages (Mattey and Wallace, 2001) and with estimated prepayment functions for conforming mortgages (Schwartz and Torous, 1989).

²⁶ We assume that credit risks are comparable between Fixed-COFI mortgages and traditional fixed-rate mortgages. Both mortgages would reflect limited credit risk to the lender because they conform to government-sponsored enterprise (GSE) underwriting standards for mortgages and incorporate the GSE credit guarantee fee.

²⁷ The traditional fixed-rate mortgage rate is heavily influenced by the marginal cost of capital markets investors who hold mortgage-backed securities (MBS). The risk of funding traditional fixed-rate mortgages can be broken into four components: interest rate risk, basis risk, prepayment risk, and uncertainty. Because many mortgage originators are reluctant to bear all these risks, traditional fixed-rate mortgages are often securitized by Fannie Mae and Freddie Mac (Fuster and Vickery, 2015). MBS investors often purchase hedges against these risks using a cost basis and poorly suited financial instruments. Moreover, substantial payments for investor risk aversion may be built into model-based prepayment premiums, and systemic risks associated with aggregate prepayment may impair successful hedging (Chernov, Dunn and Longstaff, 2016). Finally, MBS investors (and homeowners themselves) may consistently overestimate the ability of homeowners to refinance. Since many homeowners miss refinancing opportunities, compensation for bearing prepayment risks is too large (Grubb, 2015).

²⁸ In the simulations, we assume creditworthiness of borrowers and constant house prices. Since the purpose of the simulations is to compare Fixed-COFI mortgages and traditional fixed-rate mortgages, we would gain little insight from more sophisticated models of borrower default or house prices because these wrinkles would affect the two mortgage contracts in a similar fashion.

shortfall and balloon payment insurance. We show that an extremely small proportion of simulations result in appreciable insurance premiums. Second, we simulate mortgages to analyze homeowner welfare outcomes including maturity and interest savings. We show that homeowners with Fixed-COFI mortgages can save substantially by fully owning their homes in far less than 30 years.

In the simulations, historical quarterly combinations of Treasury yields, COFIs, and fixed-rate mortgage rates from 1985:Q1 to 2016:Q4 are interest rate conditions at origination. From each starting point, we generate many stochastic interest rate paths.

First, we model one-year Treasury yields as a random walk:²⁹

$$\begin{aligned} T_t &= T_{t-1} + \varepsilon_t \\ &= T_0 + \sum_{i=1}^t \varepsilon_i, \end{aligned}$$

where T_0 is the Treasury yield at origination, and ε_t is the change in Treasury yield in period t . For each simulation, we draw a sequence of shocks from a normal distribution with mean of zero and standard deviation of .23. The standard deviation is the residual standard error of the AR(1) model in table 3. These shocks are the stochastic driver of the simulations. The initial COFI and the Treasury random walk then feed into the COFI partial adjustment model (shown in table 2) to produce a path of COFI. With a path of COFI, a gross margin, and a down payment, we calculate the Fixed-COFI mortgage cash-flows as described in section 2. Appendix III presents a few examples of Fixed-COFI mortgage simulations.

We also run a separate set of simulations that allow homeowners to refinance. If a contract allows refinancing, we calculate a path of fixed-rate mortgage rates. In the spirit of Hancock and Passmore (2015), we model fixed-rate mortgage rates with an error correction model. The error correction model insures that both the spread between fixed-rate mortgage rates and COFI as well as the spread between fixed-rate mortgage rates and Treasury yields stay within the historical range. Table 4 shows the estimated equilibrium equation, which describes the long-run dynamics of the model. Table 5 shows the estimated difference equation, which

²⁹ Appendix II discusses the robustness of Fixed-COFI mortgage performance with other Treasury models.

describes the short-run dynamics of the model. This model suggests that the equilibrium fixed-rate mortgage rate is a markup over the sum of 82 percent of COFI and 9 percent of the one-year Treasury yield. Figure 6 shows the fitted values for the error correction model (long-dashed red line). In simulations with refinancing, we assume the household can refinance only when the fixed-rate mortgage rate falls 2 percentage points below the fixed-rate mortgage rate on the current contract. This restriction mimics a common marketplace rule of thumb. Also, when a homeowner refinances, 2 percentage points are added to the outstanding mortgage balance to cover closing costs.

We also run separate simulations that allow homeowners to extract limited equity. The equity extractions are 10 percent of the house price when the outstanding mortgage balance is 70 percent or less of the house price. This limitation prevents equity extractions from impacting credit risk concerns (i.e., the outstanding mortgage balance stays below 80 percent) and may be consistent with a sizeable non-housing expense that would require tapping into home equity (i.e., emergency expenses). We run simulations with one and two equity extractions.

6. Profit Margin and Hedging

An important element of the Fixed-COFI mortgage is the gross margin. In addition to COFI, this gross margin is charged on the remaining mortgage balance each month. A higher gross margin means more of the household's monthly payment is directed to interest instead of paying down the principal. Specifically, the gross margin can be broken down into three components: a guarantee fee (of "g-fee," which covers borrower credit risk), a servicing fee, and a return on equity (M).

$$GM = gfee + servicing\ fee + M$$

In this section, we assume the g-fee is 65 basis points and the servicing fee is 35 basis points; these values are consistent with Hancock and Passmore (2016a). Unlike COFI adjustable-rate mortgages or traditional fixed-rate mortgages, the net margin for Fixed-COFI mortgages includes premiums for payment shortfall and balloon payment insurance. Thus, we adopt the following strategy for determining the net margin.

First, we define a discount rate, which is a mark-up over the Treasury yield. For a given path of Treasury yields, the discount rate in t months after origination is the reciprocal of the cumulative product of one plus the net margin and the Treasury yield in each period:

$$d(t) = \prod_{i=1}^t (1 + T_i + M)^{-i}$$

This discount rate is based on an alternative investment yielding the same profitability over the risk-free rate as the Fixed-COFI mortgage.

Second, we consider the present value of the profit from holding Fixed-COFI mortgages. We now enumerate the revenue and five costs of holding Fixed-COFI mortgages: the cost of the liability side of the bank's balance sheet, the cost of servicing, the cost of the g-fee, the cost of the payment shortfall insurance, and the cost of the balloon payment insurance. The revenue is the discounted sum of COFI plus the gross margin times the LTV in each period:

$$revenue = \sum_{t=1}^{360} d(t) * (GM + COFI_t) * LTV_t$$

We assume that the bank's cost of funds is equal to the system average. Thus the cost of the liability side of the bank's balance sheet is the discounted sum of COFI times the LTV in each period.

$$cost_{liabilities} = \sum_{t=1}^{360} d(t) * COFI_t * LTV_t$$

Since the servicing fee and g-fee are fixed mark-ups over COFI, the cost of servicing and credit risk insurance is the discounted sum of each fee times the LTV in each period.

$$cost_{servicing} = \sum_{t=1}^{360} d(t) * servicing\ fee * LTV_t$$

$$cost_{gfee} = \sum_{t=1}^{360} d(t) * gfee * LTV_t$$

We now turn to calculating the costs of the payment shortfall and balloon payment insurance. When the bank covers the difference (i.e., the LTV is greater than one hundred), payment shortfall insurance payouts are the discounted sum of the amount LTV exceeds one hundred percent:

$$cost_{payment\ shortfall} = \sum_{t=1}^{360} d(t) * I(t) * (LTV_t - 100)$$

$$\text{where } I(t) = \begin{cases} 1, & \text{if } LTV_t \geq 100, \\ 0, & \text{otherwise.} \end{cases}$$

The indicator variable equals 1 if the bank covers the payment shortfall and 0 if the home equity account covers the payment shortfall (or if there is no payment shortfall). The balloon payment insurance payout is the discounted mortgage balance at 30 years:

$$cost_{balloon\ payment} = d(360) * LTV_{360}$$

The profit from holding Fixed-COFI mortgages is revenue minus the five costs.

$$\pi_{FixedCOFI} = \sum_{t=1}^{360} d(t) [M * LTV_t - I(t) * (LTV_t - 100)] - d(360) * LTV_{360}$$

To set M , we assume investors compare a portfolio of Fixed-COFI mortgages to a portfolio of Treasuries (both funded by COFI liabilities). We define M^* as the minimum net margin such that the expected value of profit from holding Fixed-COFI mortgage is equal to or greater than the profit from holding Treasuries:

$$M^* = \min\{M | E(\pi_{FixedCOFI}) \geq E(\pi_{Treasuries})\}$$

The profit from holding Treasuries is the discounted sum of the difference in the Treasury yield and COFI times the LTV in each period:

$$\pi_{Treasury} = \sum_{t=1}^{360} d(t) * (T_t - COFI_t) * LTV_t$$

For investors to be indifferent between Fixed-COFI mortgages and Treasuries, we set the profit from holding Fixed-COFI mortgages to the profit from holding Treasuries:

$$M^* = \frac{E[\sum_{t=1}^{360} d(t)[I(t) * (LTV_t - 100) - (T_t - COFI_t) * LTV_t] + d(360) * LTV_{360}]}{E[\sum_{t=1}^{360} d(t) * LTV_t]}$$

Since M^* is a function of the path of LTVs, and the path of LTVs is a function of the gross margin (and thereby M^*), we use simulations to solve for the net margin.

Figure 7 shows the time-varying gross margin based on M^* . We calculate M^* separately in each quarter. For each quarter, we produce 5,000 simulated Treasury yield paths, which all start at the Treasury yield in the given quarter, using the Treasury random walk process. For each Treasury path, we calculate a path of COFIs, which starts in the COFI in the given quarter, using the partial adjustment process (shown in table 2). Using each COFI path, we simulate the cash flows for a Fixed-COFI mortgage. On the first pass, we set the net margin at zero. Over the 5,000 simulations, we calculate the expected present value of the profit from a portfolio of Fixed-COFI mortgages and the expected present value of the profit from a portfolio of Treasury securities. If the expected profit of the Treasury portfolio is larger than that of the Fixed-COFI mortgage portfolio (which, on the first pass, is necessarily true because the net margin is set at zero), we increment the net margin by 5 basis points and re-simulate Fixed-COFI mortgages with the higher net margin over the 5,000 COFI paths. We continue incrementing the net margin and simulating Fixed-COFI mortgages until the expected profits of a portfolio of Fixed-COFI mortgages is larger than the expected profit of a portfolio of one-year Treasury securities. When we stop, the net margin is the smallest margin for which the expected return on a Fixed-COFI portfolio is equal to the expected return on a Treasury portfolio.

In section 8, we examine homeowner welfare using the range of gross margins estimated by Hancock and Passmore (2016a). They estimated that profitable gross margins of COFI adjustable rate mortgages range from 1.75 to 2.5 percentage points. This range is higher than our estimates of gross margins based on M^* for almost every period. Thus, mortgages simulated for the analysis of homeowner welfare are highly profitable for the bank.

Our approach for setting the net margin (and thereby the gross margin) yields profitable mortgage assets on average; however, since our approach is based on expected value calculations, these margins fail to protect banks against unlikely extreme events. Since banks or investors may be loss-averse, we consider the consequences of extreme scenarios. For example, some Fixed-COFI mortgage simulations are originated in a low interest rate environment and then experience

a string of positive Treasury shocks that push the path of COFI mortgage rates higher than the traditional fixed-rate mortgage rate for the remainder of the mortgage. Although very unlikely and very sensitive to assumptions about the future path of Treasury yields, such a scenario would yield a multitude of payment shortfalls for the bank to cover, a substantial balloon payment, and no homeowner equity accumulation.

A bank holding Fixed-COFI mortgages can hedge against low profit scenarios by holding Treasury securities. In essence, the bank's deposit franchise, which provides liabilities at COFI interest rates, is more profitable and less risky when invested in a mix of Fixed-COFI mortgages and Treasury securities than when invested in only Treasury securities. COFI-based asset pricing allows banks to generate more profit from their investments in a deposit franchise because it resolves the basis risk problems associated with investing in Treasury or LIBOR-based assets. In contrast, traditional fixed-rate mortgages are often sold by banks to investors outside the banking system because fixed-rates on traditional fixed-rate mortgages reflect the financing strategies used by capital markets investors.

For a given hedging ratio, α , the bank's hedged profit is the weighted average of the profit from holding Fixed-COFI mortgages and Treasuries:

$$\pi_{hedged} = (1 - \alpha)\pi_{FixedCOFI} + \alpha\pi_{Treasury}$$

We define the 99.5th percentile of hedged loss (i.e., 0.5th percentile of hedged profit) as $\pi_{hedged}^{0.5\%}$. We define α^* as the minimum hedging ratio such that $\pi_{hedged}^{0.5\%}$ does not deplete the capital the bank has allocated to back the mortgage (either a risk-weight on the asset or the result of a value-at-risk calculation):

$$\alpha^* = \min \left\{ \alpha \mid \pi_{hedged}^{0.5\%} \geq -\frac{K}{A} \right\}$$

Figure 8 shows α^* over time for 5,000 simulations for each quarter. The calculation assumes that the bank backs the mortgage with 4% capital. The blue solid line is α^* using the gross margin based on M^* , and the red dotted line is α^* using the rule-of-thumb gross margin (described below).

Of course, both banks and consumers may have reasons to prefer constant margins and hedging ratios over time. Based on figures 7 and 8, we propose the following rule-of-thumb: set the gross margin at 1.75 percentage points and hold half Fixed-COFI mortgages and half Treasury securities. In figure 9, we see that both this rule-of-thumb portfolio and an unhedged portfolio of Fixed-COFI mortgages is profitable in all periods because the expected profit of Fixed-COFI mortgages exceeds the expected profit of a portfolio of Treasury securities. Hedged profits are generally lower than unhedged profits. However, this hedging strategy is successful at mitigating the major dip in unhedged profits around the 2008 financial crisis. During this period, the Treasury yield substantially increased while the traditional fixed-rate mortgage rate only moderately increased (see figure 6). As discussed in section 7, a tightening of the spread between fixed-rate mortgage rates and Treasury yields caused expected unhedged Fixed-COFI mortgage profits to decrease; however, since the tightening of the spread was primarily due to higher Treasury yields, Treasury securities became a more profitable hedge at this time.

Figure 10 shows the unhedged and hedged 99.5th percentile loss using the rule of thumb. We see that this hedging strategy is generally successful in mitigating extreme losses. Again, we see that this hedging strategy is particularly effective around the 2008 financial crisis; in this period, unhedged losses bounce between 10 and 15 percent, but hedged losses are less than 4 percent. On the other hand, in late 2012 and early 2013, hedged losses crest about 50 basis points above 4 percent, reflecting the low level of Treasury yields near the zero lower bound.

7. Evaluating Fixed-COFI Mortgages

What factors at origination lead to a successful Fixed-COFI mortgage? Before analyzing simulation results, we approach this question from an analytical perspective. First, we approximate the household payment for tractability:

$$FR_{Payment} = LTV_0 * \frac{F_0(1 + F_0)^{360}}{(1 + F_0)^{360} - 1} \approx LTV_0 * F_0,$$

where LTV_0 is LTV at origination, and F_0 is the fixed-rate mortgage rate at origination.

Based on the Treasury random walk and the COFI partial adjustment model, we can derive $COFI_t$ in terms of $COFI_0$ and T_0 :

$$\begin{aligned}
COFI_t &= \alpha COFI_{t-1} + \beta T_t + \delta_t \\
&= \alpha[\alpha COFI_{t-2} + \beta T_{t-1} + \delta_{t-1}] + \beta T_t + \delta_t \\
&= \alpha[\alpha[\alpha COFI_{t-3} + \beta T_{t-2} + \delta_{t-2}] + \beta T_{t-1} + \delta_{t-1}] + \beta T_t + \delta_t \\
&= \alpha^3 COFI_{t-3} + \alpha^2 \beta T_{t-2} + \alpha^2 \delta_{t-2} + \alpha \beta T_{t-1} + \alpha \delta_{t-1} + \beta T_t + \delta_t \\
&= \alpha^t COFI_0 + \sum_{i=1}^t \alpha^{t-i} (\beta T_i + \delta_i) \\
&= \alpha^t COFI_0 + \sum_{i=1}^t \alpha^{t-i} \left(\beta \left[T_0 + \sum_{j=1}^i \varepsilon_j \right] + \delta_i \right) \\
&= \alpha^t COFI_0 + \beta T_0 \sum_{i=1}^t \alpha^{t-i} + \beta \sum_{i=1}^t \alpha^{t-i} \sum_{j=1}^i \varepsilon_j + \sum_{i=1}^t \alpha^{t-i} \delta_i.
\end{aligned}$$

Using the above formula for $COFI_t$, the percent change in LTV can be written in terms of current LTV, initial interest rates, and interest rate shocks:

$$\begin{aligned}
\Delta LTV_{t+1} &= \frac{LTV_{t+1} - LTV_t}{LTV_t} \\
&= \frac{LTV_t(1 + COFI_{t+1} + GM) - LTV_0 * F_0 - LTV_t}{LTV_t} \\
&= (1 + COFI_{t+1} + GM) - \frac{LTV_0}{LTV_t} * F_0 - 1 \\
&= 1 + (\alpha COFI_t + \beta T_t + \delta_{t+1}) + GM - \frac{LTV_0}{LTV_t} * F_0 - 1 \\
&= \alpha \left(\alpha^t COFI_0 + \beta T_0 \sum_{i=1}^t \alpha^{t-i} + \beta \sum_{i=1}^t \alpha^{t-i} \sum_{j=1}^i \varepsilon_j + \sum_{i=1}^t \alpha^{t-i} \delta_i \right) + \beta(T_t + \varepsilon_{t+1}) \\
&\quad + \delta_{t+1} + GM - \frac{LTV_0}{LTV_t} * F_0
\end{aligned}$$

$$\begin{aligned}
&= \alpha \left(\alpha^t COFI_0 + \beta T_0 \sum_{i=1}^t \alpha^{t-i} + \beta \sum_{i=1}^t \alpha^{t-i} \sum_{j=1}^i \varepsilon_j + \sum_{i=1}^t \alpha^{t-i} \delta_i \right) \\
&\quad + \beta \left(T_0 + \sum_{i=1}^t \varepsilon_i + \varepsilon_{t+1} \right) + \delta_{t+1} + GM - \frac{LTV_0}{LTV_t} * F_0 \\
&= \alpha^{t+1} COFI_0 + \beta \left(\sum_{i=1}^t \alpha^{t-i+1} + 1 \right) T_0 + \beta \left(\sum_{i=1}^t \alpha^{t-i+1} \sum_{j=1}^i \varepsilon_j + \sum_{i=1}^t \varepsilon_i \right) \\
&\quad + \sum_{i=1}^t \alpha^{t-i+1} \delta_i + \beta \varepsilon_{t+1} + \delta_{t+1} + GM - \frac{LTV_0}{LTV_t} * F_0
\end{aligned}$$

The expected percentage change of LTV conditional on current LTV can characterize the outcomes of a Fixed-COFI mortgage for a homeowner. Its negative, denoted $LTVdecline_{t+1}$, indicates whether a given initial condition improves homeowner welfare. If $LTVdecline_{t+1}$ is larger, households have better outcomes (e.g., the mortgage pays off faster, the household's interest savings are larger, and the home equity account buffer is bigger).

$$\begin{aligned}
LTVdecline_{t+1} &= -E[\Delta LTV_{t+1} | LTV_t = \overline{LTV_t}] \\
&= -E \left[\alpha^{t+1} COFI_0 + \beta \left(\sum_{i=1}^t \alpha^{t-i+1} + 1 \right) T_0 + \beta \left(\sum_{i=1}^t \alpha^{t-i+1} \sum_{j=1}^i \varepsilon_j + \sum_{i=1}^t \varepsilon_i \right) \right. \\
&\quad \left. + \sum_{i=1}^t \alpha^{t-i+1} \delta_i + \beta \varepsilon_{t+1} + \delta_{t+1} + GM - \frac{LTV_0}{LTV_t} * F_0 \mid LTV_t = \overline{LTV_t} \right] \\
&= -\alpha^{t+1} COFI_0 - \beta \left(\sum_{i=1}^t \alpha^{t-i+1} + 1 \right) T_0 \\
&\quad - E \left[\beta \left(\sum_{i=1}^t \alpha^{t-i+1} \sum_{j=1}^i \varepsilon_j + \sum_{i=1}^t \varepsilon_i \right) + \sum_{i=1}^t \alpha^{t-i+1} \delta_i + \beta \varepsilon_{t+1} \right. \\
&\quad \left. + \delta_{t+1} \mid LTV_t = \overline{LTV_t} \right] - GM + \frac{LTV_0}{LTV_t} * F_0
\end{aligned}$$

$$= -\alpha^{t+1}COFI_0 - \beta \left(\sum_{i=1}^t \alpha^{t-i+1} + 1 \right) T_0 - GM + \frac{LTV_0}{LTV_t} * F_0.$$

Right off the bat, lower gross margins and larger down payments increase $LTVdecline_{t+1}$. Intuitively, lower gross margins mean the homeowner pays less interest, and higher down payments mean the homeowner has less principal to pay off. How do interest rate conditions at origination effect mortgage outcomes? First, higher fixed-rate mortgage rates at origination, F_0 , result in better mortgage outcomes:

$$\frac{\partial LTVdecline_{t+1}}{\partial F_0} = \frac{LTV_0}{LTV_t} > 0$$

Because $\overline{LTV_t}$ is positive, the derivative of $LTVdecline_{t+1}$ with respect to a change in F_0 is also positive. Intuitively, if the household makes larger payments (as a result of a higher F_0), then the homeowner pays down more of the remaining mortgage principal each month.³⁰ Furthermore, if we assume that the remaining LTV is dropping:

$$\lim_{t \rightarrow \infty} \overline{LTV_t} = 0,$$

then the additional paydowns due to a higher F_0 accelerate as mortgages age:

$$\lim_{t \rightarrow \infty} \frac{\partial LTVdecline_{t+1}}{\partial F_0} = \infty.$$

This result directly follows from the design of the Fixed-COFI contract. Interest is calculated on the remaining mortgage balance, but the household payment is calculated based on the initial mortgage balance. As the remaining balance decreases and less interest is due, more of the monthly payment can pay down the mortgage principal.

³⁰ Note that pegging the fixed payment to the traditional fixed-rate mortgage payment is simply a convention that eases the comparison to traditional fixed-rate mortgages. The fixed payment could instead be set based on other criteria. Passmore and von Hafften (2017) use criteria based on housing affordability to set the monthly payment.

How does COFI at origination affect mortgage outcomes? We take the partial derivative of $LTVdecline_{t+1}$ with respect to $COFI_0$:

$$\frac{\partial LTVdecline_{t+1}}{\partial COFI_0} = -\alpha^{t+1} < 0.$$

Since this derivative is negative, a higher COFI at origination is worse for the household. However, the importance of COFI at origination diminishes over time:

$$\lim_{t \rightarrow \infty} \frac{\partial LTVdecline_{t+1}}{\partial COFI_0} = \lim_{t \rightarrow \infty} (-\alpha^{t+1}) = 0,$$

This limit suggests the influence of the initial COFI diminishes. Indeed, based on our parameter estimates for the COFI partial adjustment model, the influence of COFI at origination dissipates after just two years.

We now turn to the one-year Treasury yield at origination:

$$\begin{aligned} \frac{\partial LTVdecline_{t+1}}{\partial T_0} &= -\beta \left(\sum_{i=1}^t \alpha^{t-i+1} + 1 \right) \\ &= -\beta \left(\sum_{i=1}^t \alpha^{t-i+1} + 1 \right) < 0 \end{aligned}$$

Since this derivative is negative, a higher Treasury yield at origination is worse for the household. A higher Treasury yield at origination pushes up COFI and results in higher interest payments and, consequently, a slower decline in the LTV. How does the importance of the Treasury yield change over time?

$$\begin{aligned} \lim_{t \rightarrow \infty} \frac{\partial LTVdecline_{t+1}}{\partial T_0} &= -\beta \left(\sum_{i=1}^t \alpha^{t-i+1} + 1 \right) \\ &= -\beta \left(\frac{1}{1-\alpha} + 1 \right) \end{aligned}$$

$$= -\beta \left(\frac{2 - \alpha}{1 - \alpha} \right)$$

This limit shows that, unlike COFI at origination, the initial Treasury yield remains important for the life of the mortgage. Based on our parameter estimates of the COFI partial adjustment model, the derivative converges to 1.7. Thus, the LTV of a seasoned mortgage is expected to decline 1.7 percent more per month for each 1 percentage point drop in the Treasury yield at origination.

Overall, this analytical approach suggests that homeowners are better off with lower gross margins, higher down payments, higher fixed-rate mortgage rates, and larger spreads between fixed-rate mortgage rates and one-year Treasury yields at origination.³¹

8. Simulations Results and Homeowner Welfare

In a second phase of simulations, we examine home purchases and interest savings for households with Fixed-COFI mortgages; we also examine the number of months until homeowners accrue 20 percent equity, which may be important for the bank in terms of credit risk. Simulated mortgages have down payments that range from 0 to 5 percent and gross margins that range from 1.75 to 2.5 percent; the range of the gross margins is consistent with our earlier simulations that showed significant bank profitability.

In section 7, we show that both the fixed-rate mortgage rate and the one-year Treasury yield at origination influence the performance of Fixed-COFI mortgages. Thus, we split simulation results into quintiles by the spread between fixed-rate mortgage rates and one-year Treasury yields at origination. Spreads in the top, middle, and bottom quintiles range from 5.1 to 3.9 percent, 3.6 to 3.3 percent, and 2.8 to 1.5 percent, respectively. The top, middle, and bottom quintiles are plotted as blue left-slanted hatched bands, purple right-slanted hatched bands, and red horizontally hatched bands, respectively. Vertically, the bands cover the range of gross margins; the solid border of the bands indicate high gross margins, and the dotted border of the

³¹ This analysis, of course, maintains the assumption that the household has the ability to pay the higher fixed-rate mortgage payment.

bands indicate low gross margins. The dependent variable is on the y-axis, and the fixed-rate mortgage rate at origination is on the x-axis.

Figure 11 shows the average maturity of simulated Fixed-COFI mortgages. Over 80 percent of simulations pay off faster than 30 years. Mortgages have shorter maturities when fixed-rate mortgage rates are higher at origination (i.e., bands slope down). Mortgages have shorter maturities when spreads between fixed-rate mortgage rates and one-year Treasury yields are higher at origination (i.e., red band is higher than purple band, and purple band is higher than blue band). Furthermore, mortgages with lower gross margins have shorter maturities (i.e. solid borders are higher than dotted borders). For fixed-rate mortgage rates around 8 percent, Fixed-COFI mortgages with low spreads pay off in about 25 years (red band), and mortgages with high spreads pay off in about 18 years (blue band). For low fixed-rate mortgage rates and small spreads, Fixed-COFI mortgages last almost as long as traditional fixed-rate mortgages (left side of red band). For high fixed-rate mortgage rates and large spreads, Fixed-COFI mortgages can be as short as 15 years (right side of blue band). Overall, the average maturity of Fixed-COFI mortgages is 23 years.

Shown in figure 12, we calculate interest savings relative to a traditional fixed-rate mortgage originated with the same fixed-rate mortgage rate and down payment; these two mortgages have the same monthly payment.³² As with maturity, interest savings are greater when fixed-rate mortgage rates are higher (i.e., bands slope up), spreads are larger (i.e., blue band is higher than purple band, and purple band is higher than red band), and gross margins (i.e., dotted borders are higher than solid borders) are lower. Fixed-COFI mortgages represent substantial homeowner savings for all interest rate conditions. For fixed-rate mortgage rates around 8 percent, homeowners with low-spread Fixed-COFI mortgages save about 40 percent of the house price (red band), and homeowners with high-spread Fixed-COFI mortgages save about 100 percent of the house price (blue band). For low mortgage rates and small spreads, interest savings are smaller on average (left side of red band). For high mortgage rates and large spreads, interest savings can be over 200 percent of the house price (right side of blue band). On average, interest savings are 65 percent of the house price.

³² The fixed-rate mortgage rate reported by Freddie Mac includes a 20 percent down payment. Because fixed-rate mortgage rates for mortgages with 0 to 5 percent down are not available, the Freddie Mac rate is very conservative.

Figure 13 shows how long homeowners with Fixed-COFI mortgages take to accumulate 20 percent equity. As a common lending standard, 20 percent equity indicates that default risk is low except in extreme cases. Within the range of historical rates, traditional fixed-rate mortgages accumulate 20 percent equity between 7 and 19 years depending on the rate (green dotted line).³³ In total, about 88 percent of Fixed-COFI mortgage simulations accrue 20 percent equity quicker than a traditional fixed-rate mortgage with the same fixed-rate mortgage rate and no down payment. On average, homeowners accrue 20 percent equity in about five years for high spreads and all fixed-rate mortgage rates (blue band). For low spreads (red band), the number of years until 20 percent equity vary with the fixed-rate mortgage rate and the gross margin; for fixed-rate mortgage rates around 8 percent, homeowners with low-spread Fixed-COFI mortgages accrue 20 percent equity in 12 to 16 years. For fixed-rate mortgage rates around 8 percent, traditional fixed-rate mortgages accumulate 20 percent equity in about 14 years. On average, homeowners with Fixed-COFI mortgages accrue 20 percent equity in 8 years.

We also run two sets of simulations that allow limited refinancing. The homeowner has one opportunity to refinance in the first set and two opportunities in the second. In the first set, only 41 percent of homeowners actually exercise their refinancing option; in the second set, 28 percent of homeowners exercise their refinancing option once, and 13 percent exercise the refinancing option twice.

Figure 14 shows the average maturity of simulations with refinancing. The red horizontally-hatched band, the purple right-hatched band, and the blue left-hatched band indicate simulations with zero, one, and two options to refinance, respectively. Vertically, the bands range from the top quintile (solid border) to the bottom (dotted border) of the spreads between fixed-rate mortgage rates and one-year Treasury yields. Including one refinancing option extends the average maturity 5 years. Including a second refinancing option further extends the average maturity 2 years. Why do the three bands in figure 14 overlap at lower fixed-rate mortgage rates but jump up at higher fixed-rate mortgage rates? Higher fixed-rate mortgage rates have two effects. As with simulations without refinancing, higher fixed-rate mortgage rates

³³ Derived from the amortizing payment formula in section 2, the number of months, m , to accrue x percent equity follows:

$$m = \log_{1+F_0} [x(1 + F_0)^{360} + 1 - x]$$

encourage quicker home equity accumulation through higher monthly payments. However, higher fixed-rate mortgage rates also increase the likelihood that homeowners refinance, which lowers the homeowner payment. Because homeowners can only refinance if fixed-rate mortgage rates fall substantially, homeowners do not necessarily refinance in simulations that allow refinancing. For example, if the fixed-rate mortgage rate is 5 percent at origination, a homeowner is unlikely to have many opportunities to refinance.

Figure 15 also shows average maturity, but bands are differentiated by the actual number of times simulations refinance. The red horizontally-hatched band, the purple right-hatched band, and the blue left-hatched band indicate simulations that refinance zero, one, and two times, respectively. Refinancing adds significantly to the maturity of Fixed-COFI mortgages. An additional refinancing adds an average of 8 years to the maturity.

Figure 16 shows the average interest savings for simulations with refinancing.³⁴ Different bands represent different numbers of refinancing options. On average, including the first refinancing option reduces savings by 11 percent of the house price, and including the second refinancing option further reduces savings by 2 percent of the house price. Limiting opportunities to refinance may significantly increase homeowner wealth.

Figure 17 also shows the average interest savings, but bands show the number of times mortgages actually refinance. Because they have higher fixed-rate mortgage rates at origination, mortgages that refinance more have higher average savings.³⁵ Mortgages that refinance once save, on average, 25 percent of the house price more than mortgages that do not refinance, and mortgages that refinance twice save, on average, 29 percent of the house price more than mortgages that refinance once. Again, these savings are not due to refinancing, but due to the feature that mortgages with higher initial fixed-rate mortgage rates are more likely to refinance.

³⁴ To calculate interest savings for simulations with refinancing, the benchmark traditional fixed-rate mortgage refinances in the same months at the same rates for the same closing costs as the Fixed-COFI mortgage. When the benchmark traditional fixed-rate mortgage refinances, the new monthly payment is calculated based on the remaining balance of a traditional fixed-rate mortgage.

³⁵ The average fixed-rate mortgage rate at origination was 6.8 percent for homeowners who did not refinance, 8.5 percent for homeowners who refinanced once, and 10.2 percent for homeowners who refinanced twice.

We also run two simulations that allow limited equity extraction.³⁶ In these simulations, when the outstanding mortgage balance is 70 percent of the house price, the homeowner extracts 10 percent of the house price. The homeowner extracts equity once in the first simulation and twice in the second. The red horizontally-hatched band, the purple right-hatched band, and the blue left-hatched band indicate simulations that extract equity zero, one, and two times, respectively. In figure 18, we see that equity extraction lengthens the maturity of Fixed-COFI mortgages. On average, each equity extraction adds 22 months. Furthermore, in figure 19, we see that each equity extraction reduces interest savings.³⁷ On average, each extraction reduces savings by 15 percent of the house price. This reduction is directly due to a longer mortgage. Thus, the future value of the savings from a shorter mortgage (i.e., 15 percent) is greater than the extracted equity (i.e., 10 percent).

9. Conclusion

The 30-year fully amortizing fixed-rate mortgage (or “traditional fixed-rate mortgage”) has three major flaws. First, because homeowner equity accumulates slowly during the first decade, homeowners essentially rent their homes from lenders. With so little equity accumulation, many lenders require large down payments. Second, in each monthly mortgage payment, homeowners substantially compensate capital markets investors for the ability to prepay. The homeowner might have better uses for this money. Third, refinancing mortgages is often very costly.

We propose a new fixed-rate mortgage, the Fixed-COFI mortgage. The Fixed-COFI mortgage resolves the three flaws of the traditional fixed-rate mortgage and, by design, has the same monthly payment. Because Fixed-COFI mortgages pay off in far less than 30 years under a wide variety of interest rate scenarios, these mortgages allow for substantial homeowner savings. In addition, banks can hold Fixed-COFI mortgages profitably, and their credit risk concerns are often mitigated soon after origination because of rapid equity accumulation. Moreover, Fixed-COFI mortgages may help certain renters purchase homes. These renters pay rents as high as comparable mortgage payments in high-cost metropolitan areas, but they do not

³⁶ Unlike refinancing, all mortgages actually take the opportunity to extract equity the number of times permitted; equity extraction is based on decreasing principal instead of a stochastic path of fixed-rate mortgage rates.

³⁷ The interest savings in figure 15 exclude extracted equity.

have enough savings for a down payment. In general, many prospective homeowners would benefit substantially from Fixed-COFI mortgages, particularly if the spread between the fixed-rate mortgage rate and the one-year Treasury yield is relatively high.³⁸ Is it time to improve the traditional fixed-rate mortgage?

³⁸ This lending guideline is consistent with the comparison of fixed-rate mortgages to adjustable-rate mortgages from the perspective of optimal homeowner risk management in Campbell and Cocco (2003): “When the yield spread [between fixed-rate mortgage rates and adjustable-rate mortgage rates] is unusually high, more homeowners should take out adjustable-rate mortgages; when it is unusually low, more homeowners should take out fixed-rate mortgages.” Many homeowners take this advice; the share of originations that are adjustable-rate mortgages rises when spreads are wide (Nothaft and Wang, 1992).

Appendix I: COFI Distribution

We model COFI as a partial adjustment model in section 4 and one-year Treasury yields as a random walk in section 5. If we assume $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$, then the expected value of a path of Treasury yields is equal to the initial Treasury yield:

$$E[T_t] = T_0.$$

Because $COFI_t$ is a linear combination of independent normal random variables (δ_i and ε_j), $COFI_t$ is also normal with the following mean and variance:

$$\begin{aligned} E[COFI_t] &= E \left[\alpha^t COFI_0 + \beta T_0 \sum_{i=1}^t \alpha^{t-i} + \beta \sum_{i=1}^t \alpha^{t-i} \sum_{j=1}^i \varepsilon_j + \sum_{i=1}^t \alpha^{t-i} \delta_i \right] \\ &= \alpha^t COFI_0 + \beta T_0 \sum_{i=1}^t \alpha^{t-i} + \beta \sum_{i=1}^t \alpha^{t-i} \sum_{j=1}^i E[\varepsilon_j] + \sum_{i=1}^t \alpha^{t-i} E[\delta_i] \\ &= \alpha^t COFI_0 + \beta T_0 \sum_{i=1}^t \alpha^{t-i} + \beta \sum_{i=1}^t \alpha^{t-i} \sum_{j=1}^i (0) + \sum_{i=1}^t \alpha^{t-i} (0) \\ &= \alpha^t COFI_0 + \beta T_0 \sum_{i=1}^t \alpha^{t-i} \\ \\ Var[COFI_t] &= Var \left[\alpha^t COFI_0 + \beta T_0 \sum_{i=1}^t \alpha^{t-i} + \beta \sum_{i=1}^t \alpha^{t-i} \sum_{j=1}^i \varepsilon_j + \sum_{i=1}^t \alpha^{t-i} \delta_i \right] \\ &= 0 + Var \left[\beta \sum_{i=1}^t \alpha^{t-i} \sum_{j=1}^i \varepsilon_j \right] + Var \left[\sum_{i=1}^t \alpha^{t-i} \delta_i \right] \\ &= \beta^2 \sum_{i=1}^t \alpha^{2(t-i)} \sum_{j=1}^i \sigma_\varepsilon^2 + \sum_{i=1}^t \alpha^{2(t-i)} \sigma_\delta^2. \end{aligned}$$

With the distribution of $COFI_t$, we can derive long-run COFI by taking the limit of the expected value of $COFI_t$:

$$\begin{aligned}\lim_{t \rightarrow \infty} E[COFI_t] &= \lim_{t \rightarrow \infty} \alpha^t COFI_0 + \beta T_0 \sum_{i=1}^t \alpha^{t-i} \\ &= 0 * COFI_0 + \beta T_0 \frac{1}{1 - \alpha} \\ &= \frac{\beta}{1 - \alpha} T_0,\end{aligned}$$

Long-run COFI mortgage rates are usually below fixed-rate mortgage rates because one-year Treasury yields are rarely above concurrent fixed-rate mortgage rates, and $1 > \frac{\beta}{1-\alpha}$. The tendency for COFI to settle well below the fixed-rate mortgage rate is consistent with low probabilities that COFI mortgage rates will exceed fixed-rate mortgage rates.

Appendix II: Alternative Models of Treasury Rates

Throughout this paper, we model one-year Treasury yields as a random walk. In other words, the coefficient on the single autoregressive term is forced to be one. In addition, to prevent Treasury yields from skyrocketing, we cap simulated Treasury yields by the maximum observed Treasury yield in our sample (= 9.29 percent). We also impose a zero lower bound on Treasury yields. We use a random walk for three reasons. First, by employing a random walk process for Treasury yields, our Fixed-COFI mortgage simulations are agnostic about trends of interest rates and thus provide a broad range of estimates for the performance of Fixed-COFI mortgages. Second, the assumption is well justified by the coefficient on the first lag of Treasury yields approximately equaling one (table 3). Third, random walks greatly simplify the analytical treatment of Fixed-COFI mortgages in section 7.

How robust is the performance of Fixed-COFI mortgages to different Treasury models? In this appendix, we consider two alternative Treasury yield models. The two alternative models are the best ARIMA fit to the monthly Treasury yield time-series using the Akaike information criterion. If we use the entire period of available Treasury yield data (February 1962 to March 2017), we find that an ARIMA(1, 1, 1) is best (shown in table A1). ARIMA(3, 1, 3) is best (shown in table A2) if Treasury yields are restricted to the period for which we have data for COFI (Q1:1985 to Q2:2016). To understand the differing results between the random walk and the ARIMA models, it is important to note that, since these ARIMA model specifications include moving average terms, simulated Treasury series have a tendency to revert to the mean Treasury yield over the given period of model estimation. Between 1985 and 2016, the mean one-year Treasury yield is 3.89 percent, and the mean one-year Treasury yield between 1962 and 2017 is 5.26 percent. Mean reversion does not exist in random walk models; as shown in appendix I, the expected value of a random walk is the initial value.

Figure A2.1 shows the gross margin based on M^* for the random walk used in the body of the paper and the two alternative ARIMA models.³⁹ We see that the two alternative Treasury models produce gross margins that are more or less in line with the estimates produced by the random walk between 1985 and 2000. Between 2001 and 2006, the ARIMA models produce

³⁹ The calculation of M^* is discussed in section 6.

slightly higher gross margin estimates. The major divergence is between 2008 and 2016, when the ARIMA(1, 1, 1) and ARIMA(3, 1, 3) estimate gross margins near 2.5 percentage points and 4 percentage points, respectively. During this period, Treasury rates were at or near the zero lower bound, and traditional fixed-rate mortgage rates were at very low levels. Indeed, the average traditional fixed-rate mortgage rate was 4.28 percent since the end of the most recent business recession (June 2009). Because of the mean reversion built in the simulated ARIMA Treasury yield paths, simulated Fixed-COFI mortgages originated near the zero lower bound are far more likely to experience COFI mortgage rates higher than the initial traditional fixed-rate mortgage rate. This effect is more pronounced for the ARIMA(3, 1, 3) because of the higher mean one-year Treasury yield.

Figure A2.2 shows the hedging ratio, α^* , for the three models.⁴⁰ The effect of the mean reversion in the ARIMA models is also apparent in the hedging ratio, with wide swings in the proportion of the portfolio that needs to be held in Treasury securities. The purpose of this hedging ratio is to avoid extremely adverse outcomes by holding both Fixed-COFI mortgages and Treasury securities.

Figure A2.3 shows the expected hedged profit for the three Treasury models using the rule of thumb. Recall that our rule of thumb is a gross margin of 1.75 and a hedging ratio of 50 percent. Expected profits remain positive even with ongoing persistence of these models to return Treasury rates to levels higher than fixed-rate mortgage rates in the post-2008 period. Figure A2.4 shows the extremely adverse hedged profit for the three Treasury models using the rule of thumb. Losses in the 0.5 percent poorest scenario are greater than our proposed risk standard (4 percent of the mortgage loan) in the post-2008 period, again reflecting the model of Treasury rates and the tendency of this model to return to very high rates relative to those experienced over the past decade.

⁴⁰ The calculation of α^* is discussed in section 6.

Appendix III: Simulation Examples

This appendix presents five Fixed-COFI mortgage simulation examples. This behind-the-scenes look illustrates the mechanics underlying the simulations results discussed in sections 6 and 8. All mortgage examples are originated with 5 percent down and a gross margin of 1.75 percentage points. The initial interest rates are the average interest rates between 1985 and 2016; the one-year Treasury yield is 3.89 percent, COFI is 3.91 percent, and the traditional fixed-rate mortgage rate is 7.30 percent. For each example, we present the simulated one-year Treasury yields, COFIs, traditional fixed-rate mortgage rates, the path of LTVs, the breakdown of the household payments into interest components and principal components, and (if positive) the payment shortfalls.

The first three examples do not include refinancing or equity extraction and differ by payment shortfall and balloon payment insurance payouts. The first example lacks any insurance payouts (figure A3.1). This mortgage takes about 16 years to pay off. A string of negative Treasury shocks in the first five years allows for rapid home equity accumulation early. After the first five years, even as Treasury yields rise, less interest from each payment is due because the mortgage is already about 30 percent paid off. The payment of principal dominates the mortgage payment for the next ten years. About 91 percent of simulations lack any insurance payouts like this example for these initial interest rates, gross margins, down payments, and rules about refinancing and equity extraction.

The second example does not experience any payment shortfalls but does not fully pay off (figure A3.2). Compared to the previous example, Treasury shocks are positive in the first few years. Initial home equity accumulation is commensurately slower than the previous example. The COFI mortgage rate (COFI plus the gross margin) hovers around the traditional fixed-rate mortgage rate for the following ten years and then rises above the fixed-rate mortgage rate for the rest of the mortgage. There are no payment shortfalls in this period because the interest due to the bank is based on the remaining mortgage balance, which is low enough to be covered by the household payment (calculated on the initial mortgage balance). After 30 years, 40 percent of the mortgage has not been paid off. For these initial conditions, about 8 percent of simulations have a balloon payment insurance payout and no payment shortfalls.

The third example experiences a prolonged period of payment shortfalls and a large balloon payment (figure A3.3); it is the “nightmare” scenario. Treasury yields increase in the first seven years of the mortgage, and COFI hovers about 2 percent above the traditional fixed-rate mortgage rate for the next fifteen years. Although the LTV decreases slightly in the first five years, the LTV increases once COFI is high enough. Payment shortfall insurance payouts occur between about year 12 and year 24. Once Treasury yields fall, limited equity accumulates. The balloon payment ends up being more than 90 percent of the house price. For these initial conditions, only about 1 percent of simulations have both payment shortfall insurance payouts and a balloon payment.

The fourth example allows one opportunity to refinance (figure A3.4).⁴¹ After 17 years, the example mortgage refinances. The path of LTVs has a very apparent kink since the household is making a significantly smaller payment after refinancing. The mortgage lasts for another 25 years and ends after about 42 years. By breaking down the payment, we can see that the amount of interest the household is paying does not change after refinancing (red solid line), but the principal component of the household payment drops significantly. Had the household not refinanced, the mortgage would have lasted only 19 years, and the household would have saved about 15 percent of the house price. For these initial conditions, about 48 percent of simulations do not refinance, and 52 percent of simulations refinance once.⁴²

The fifth example allows one opportunity to extract equity (figure A3.5). As discussed in section 5, homeowners extract 10 percentage points of home equity when the remaining mortgage balance reaches 70 percent of the house price. In this example, after about 10 years, the LTV reaches 70 percent. The homeowner pulls out 10 percent equity. The LTV path jumps up to 80 percent. The remaining mortgage balance continues to decline, and the mortgage pays

⁴¹ As discussed in section 5, simulated Fixed-COFI mortgages refinance only if the traditional fixed-rate mortgage rate drops by 2 percentage points. In addition, the remaining mortgage balance is increased 2 percentage points to account for closing costs. The path of fixed-rate mortgage rates is modelled using the error correction model (shown in tables 4 and 5).

⁴² Since the minimum observed traditional fixed-rate mortgage rate is 3.43 percent in our sample, it is extremely unlikely for the traditional fixed-rate mortgage to fall to 3.30 percent (7.30 percent minus two drops of 2 percentage points); thus, no simulated mortgages refinance twice or more.

off after 27 years. Had the homeowner not extracted equity, the mortgage would have lasted only 24 years, and the household would have saved 16 percent of the house price.

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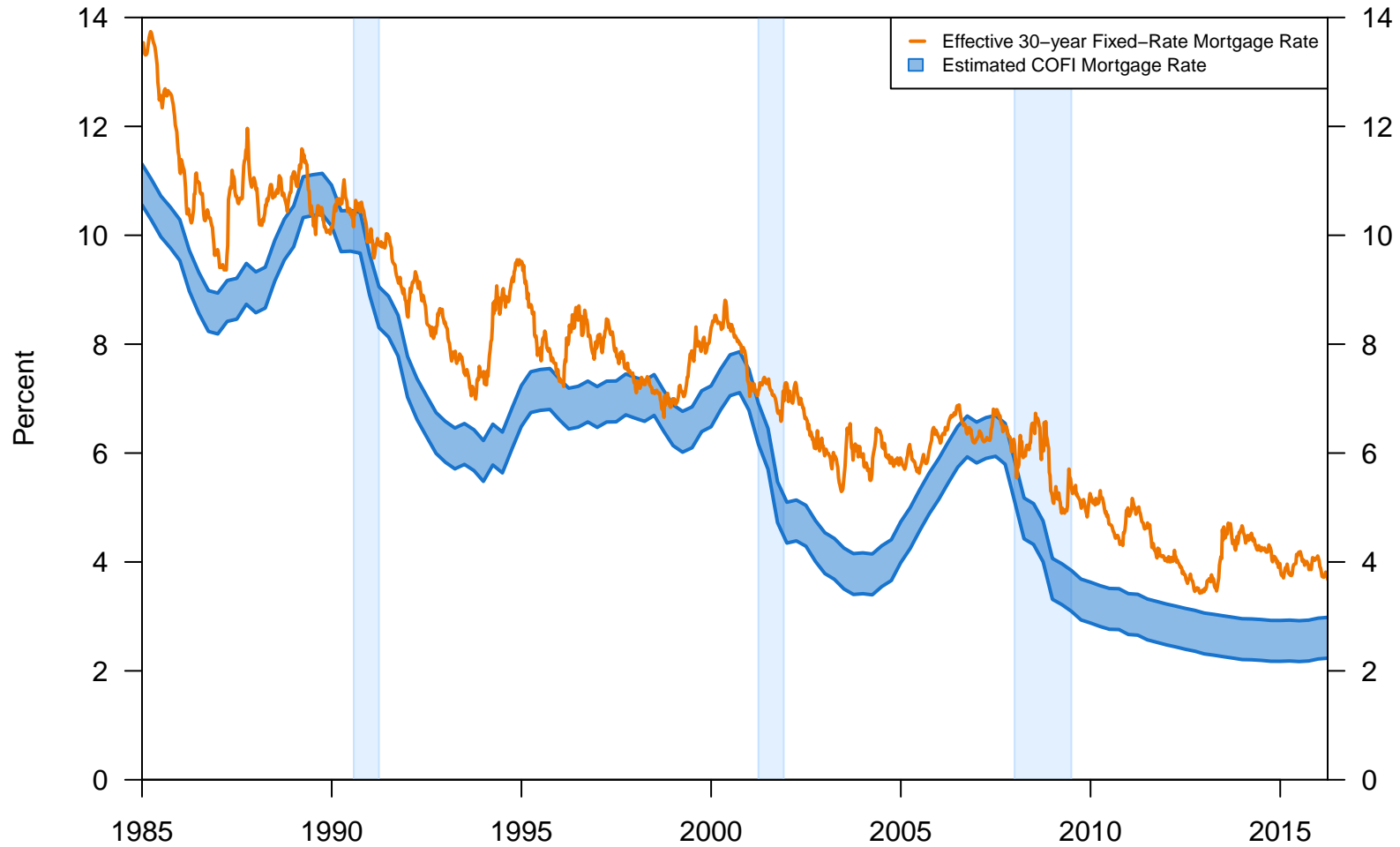
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Figure 1

Comparison of Actual Fixed-Rate Mortgage Rates and Estimated COFI Mortgage Rates



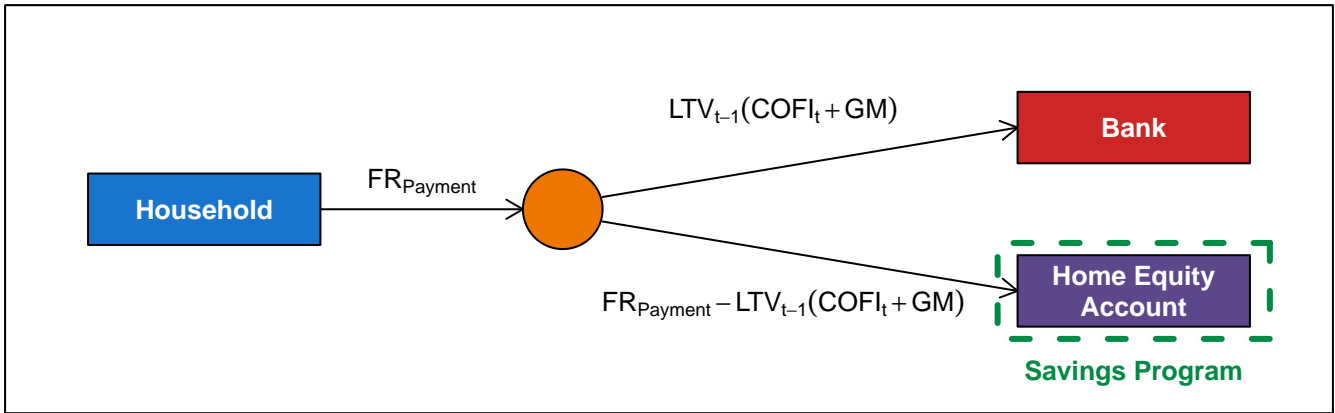
Note: Estimated COFI mortgage rates are quarterly with gross margins ranging from 1.75 to 2.5 percentage points. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016.

Figure 2

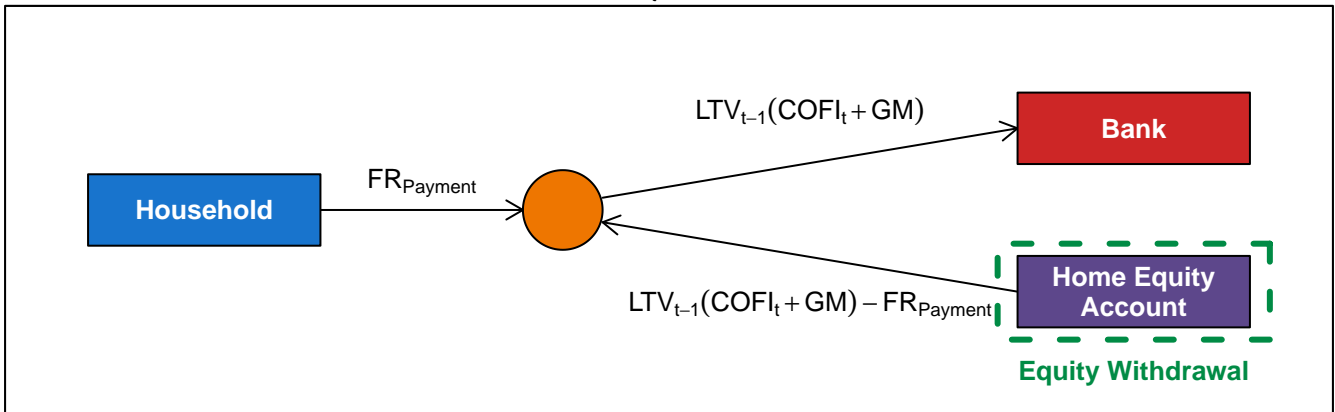
Fixed-COFI Mortgage Contract Mechanics

$$LTV_{t-1}(COFI_t + GM) < FR_{Payment}$$



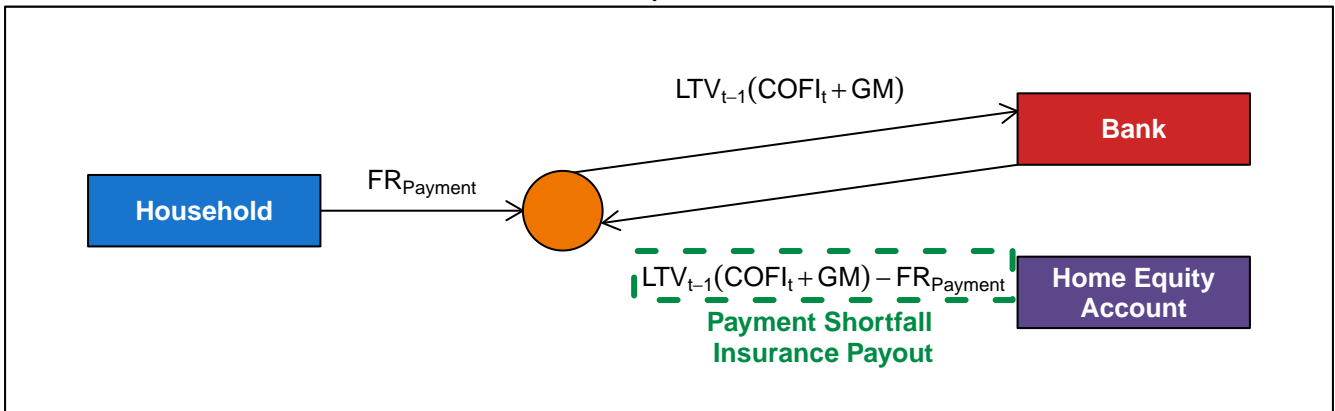
$$LTV_{t-1}(COFI_t + GM) > FR_{Payment}$$

$$LTV_t \leq 100$$



$$LTV_{t-1}(COFI_t + GM) > FR_{Payment}$$

$$LTV_t > 100$$



Note: FR_{Payment} is the fully amortizing payment associated with the fixed-rate mortgage rate at origination. COFI is the nationwide cost of funds index for the commercial banking system. GM is the gross margin. LTV is the loan-to-value ratio.

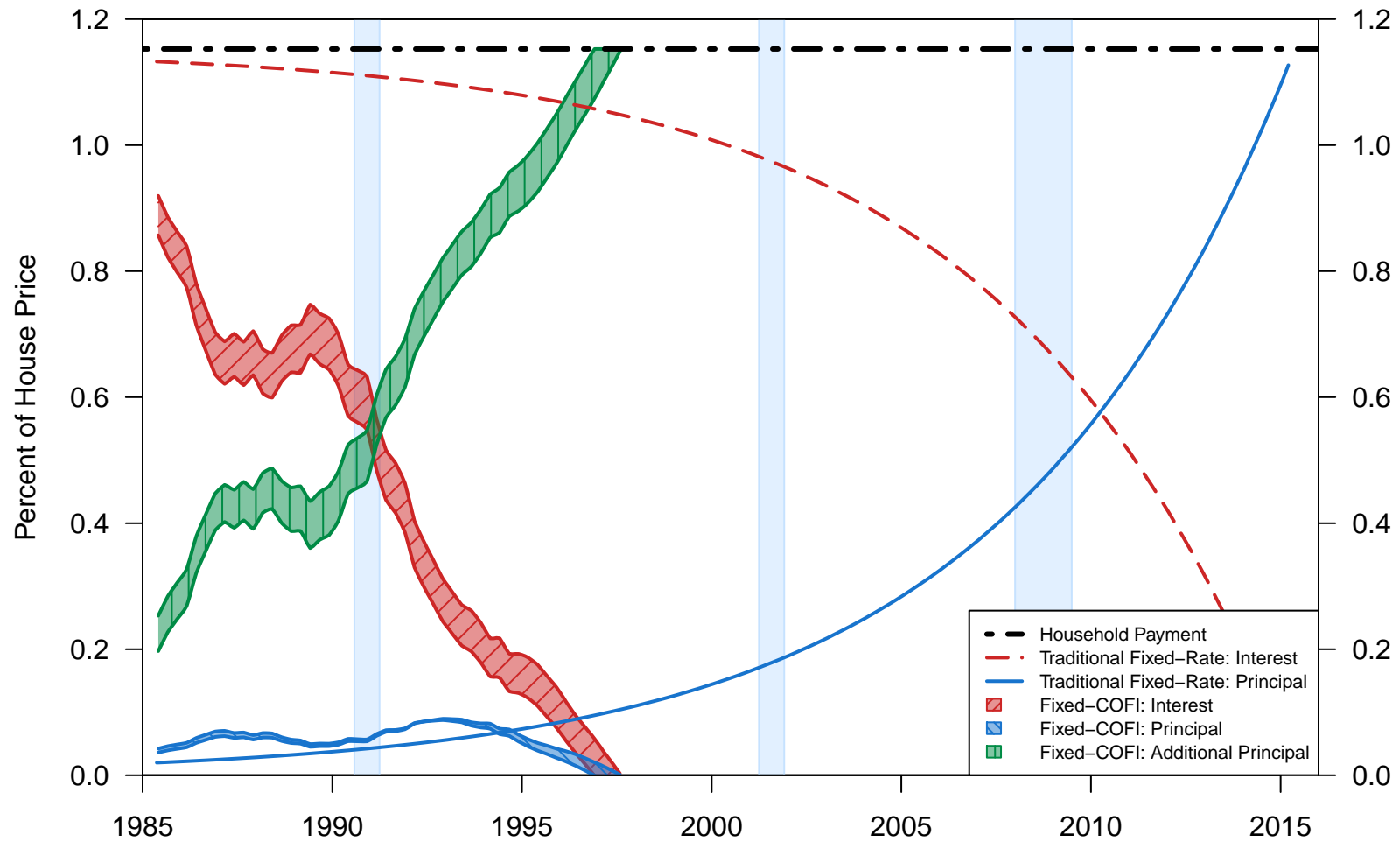
Table 1: Possible Fixed-Rate Mortgage Contracts

	<i>With Refinancing Penalties</i>	<i>Without Refinancing Penalties</i>
<i>Household Savings Contract Included</i>	Fixed-COFI Mortgage	Wealth Building Home Loan
<i>Household Savings Contract Not Included</i>	Historical Fixed-Rate Mortgage	Post-1970's 30-Year Fixed-Rate Mortgage

Source: Pinto (2014) presents the Wealth Building Home Loan.

Figure 3

Payment Breakdown for Example Traditional Fixed-Rate Mortgage and Fixed-COFI Mortgage

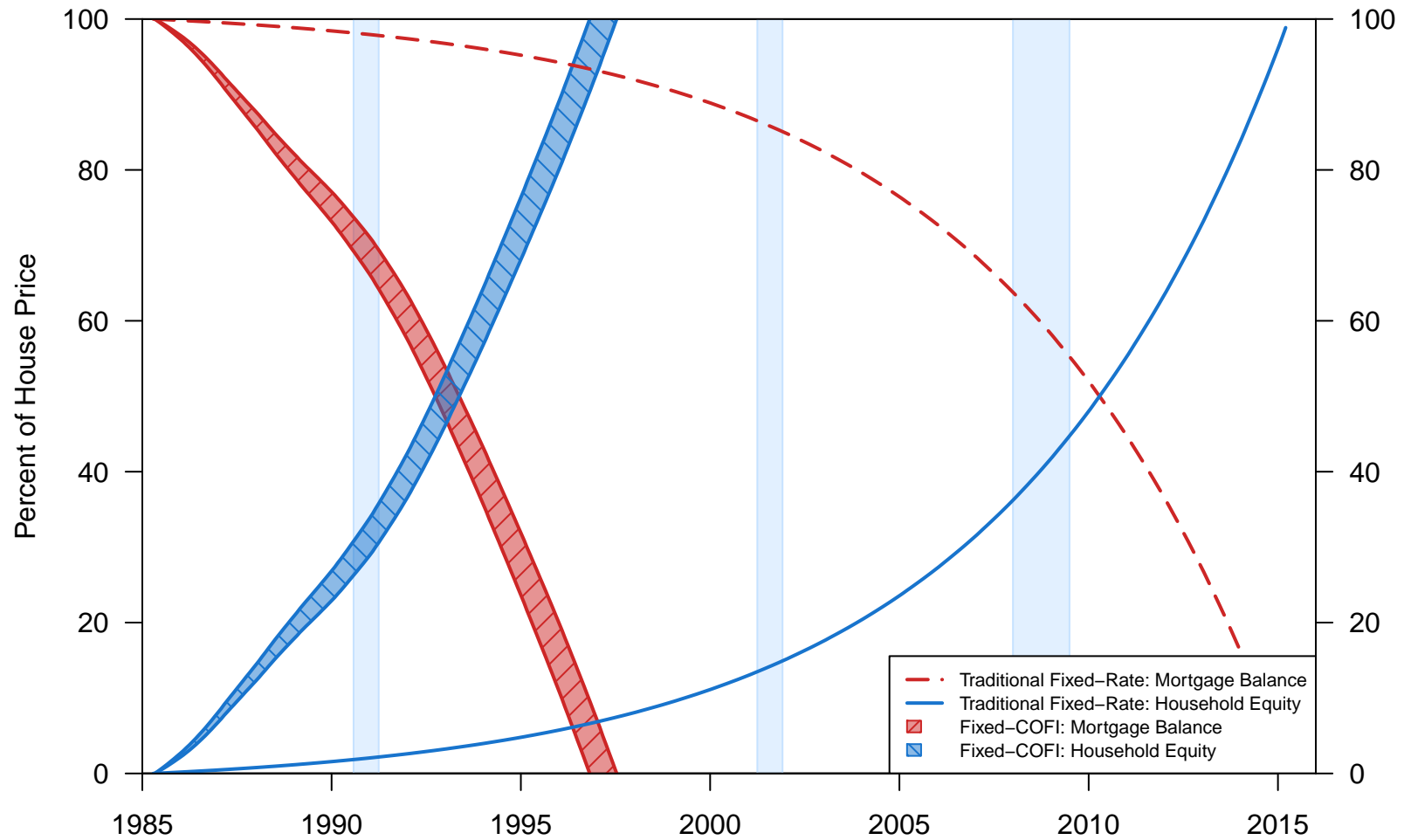


Note: Mortgages are originated in April 1985 with a loan-to-value ratio of 100 percent and 30-year maturity. COFI mortgage gross margins range from 1.75 percentage points to 2.5 percentage points. For both mortgages, the household payment is 1.15 percent of house price. The effective length of the Fixed-COFI mortgage is between 147 months and 138 months. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016.

Figure 4

Mortgage Balance and Household Equity for Traditional Fixed-Rate Mortgage and Fixed-COFI Mortgage



Note: Mortgages are originated in April 1985 with a loan-to-value ratio of 100 percent and 30-year maturity. COFI mortgage gross margins range from 1.75 percentage points to 2.5 percentage points. The effective length of the Fixed-COFI mortgage is between 12 months and 12 months. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016.

Table 2: Cost of Funds Partial Adjustment Model

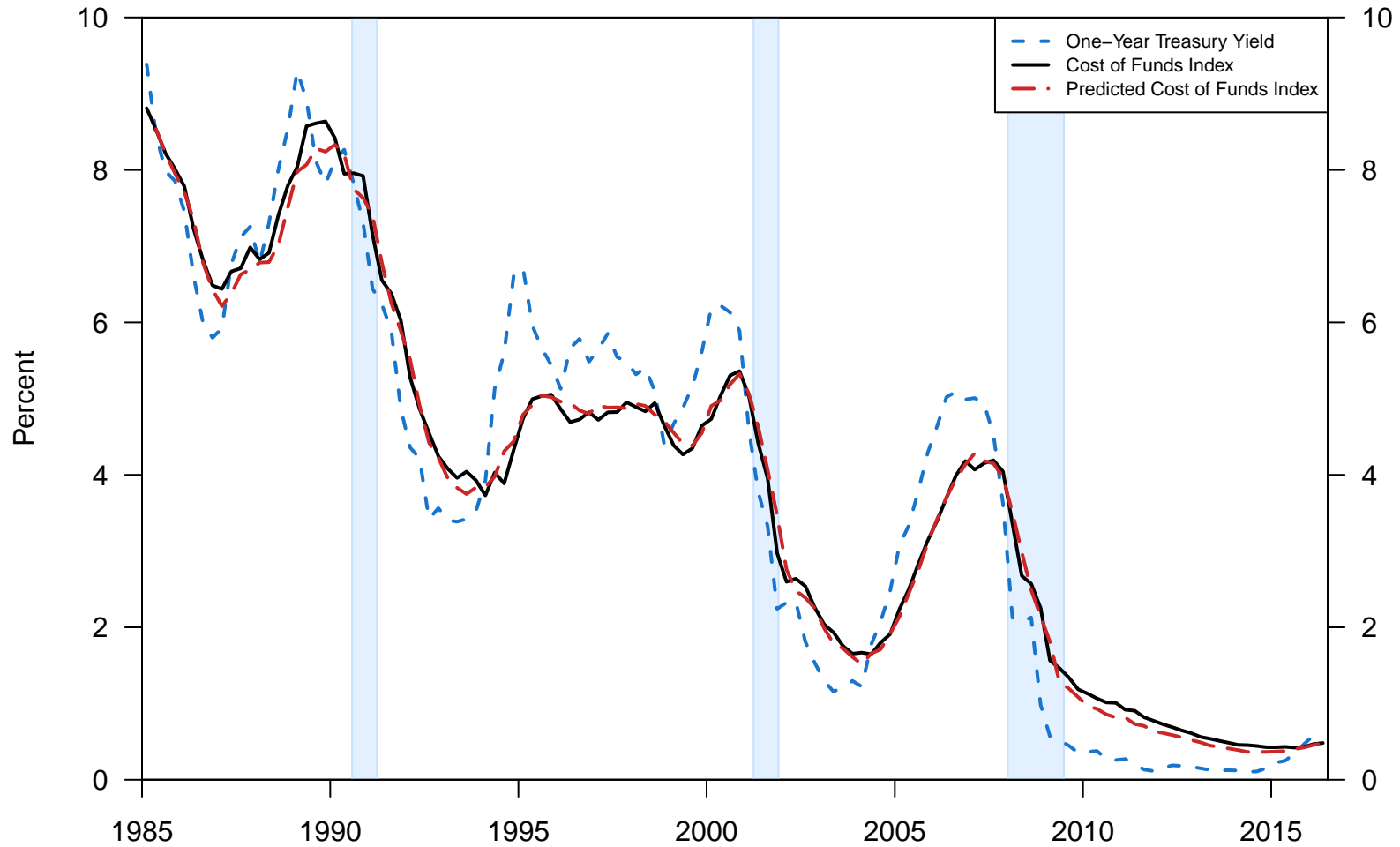
	<i>Dependent variable:</i>
	Cost of Funds Index
Lag Cost of Funds Index	0.745*** (0.016)
One-Year Treasury Yield	0.233*** (0.015)
Constant	0.036 (0.027)
Observations	125
R ²	0.996
Adjusted R ²	0.996
Residual Std. Error	0.156 (df = 122)
Quarterly	*p<0.1; **p<0.05; ***p<0.01

Note: One-year Treasury yields are averages. Data are from 1985:Q1 to 2016:Q2.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 5

Cost of Funds Index Partial Adjustment Model Fitted Values



Note: One-year Treasury yields are quarterly averages. Predicted cost of funds indexes are based on table 1. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Table 3: AR(1) One-Year Treasury Yield Model

	<i>Dependent variable:</i>
	One-Year Treasury Yield
Lag One-Year Treasury Yield	0.994*** (0.004)
Constant	0.001 (0.021)
Observations	378
R ²	0.993
Adjusted R ²	0.993
Residual Std. Error	0.230 (df = 376)
Monthly	*p<0.1; **p<0.05; ***p<0.01

Note: One-year Treasury yields are averages. Data are from January 1985 to July 2016.

Source: One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Table 4: Fixed-Rate Mortgage Rate Error-Correction Model (Level)

	<i>Dependent variable:</i>
	Fixed-Rate Mortgage Rate
One-Year Treasury Yield	0.090* (0.048)
Cost of Funds Index	0.823*** (0.053)
Constant	3.744*** (0.068)
Observations	379
R ²	0.916
Adjusted R ²	0.915
Residual Std. Error	0.692 (df = 376)
Monthly	*p<0.1; **p<0.05; ***p<0.01

Note: Fixed-rate mortgage rates and one-year Treasury yields are averages. Cost of funds indexes are linearly interpolated. Data are from January 1985 to July 2016.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Table 5: Fixed-Rate Mortgage Rate Error-Correction Model (Difference)

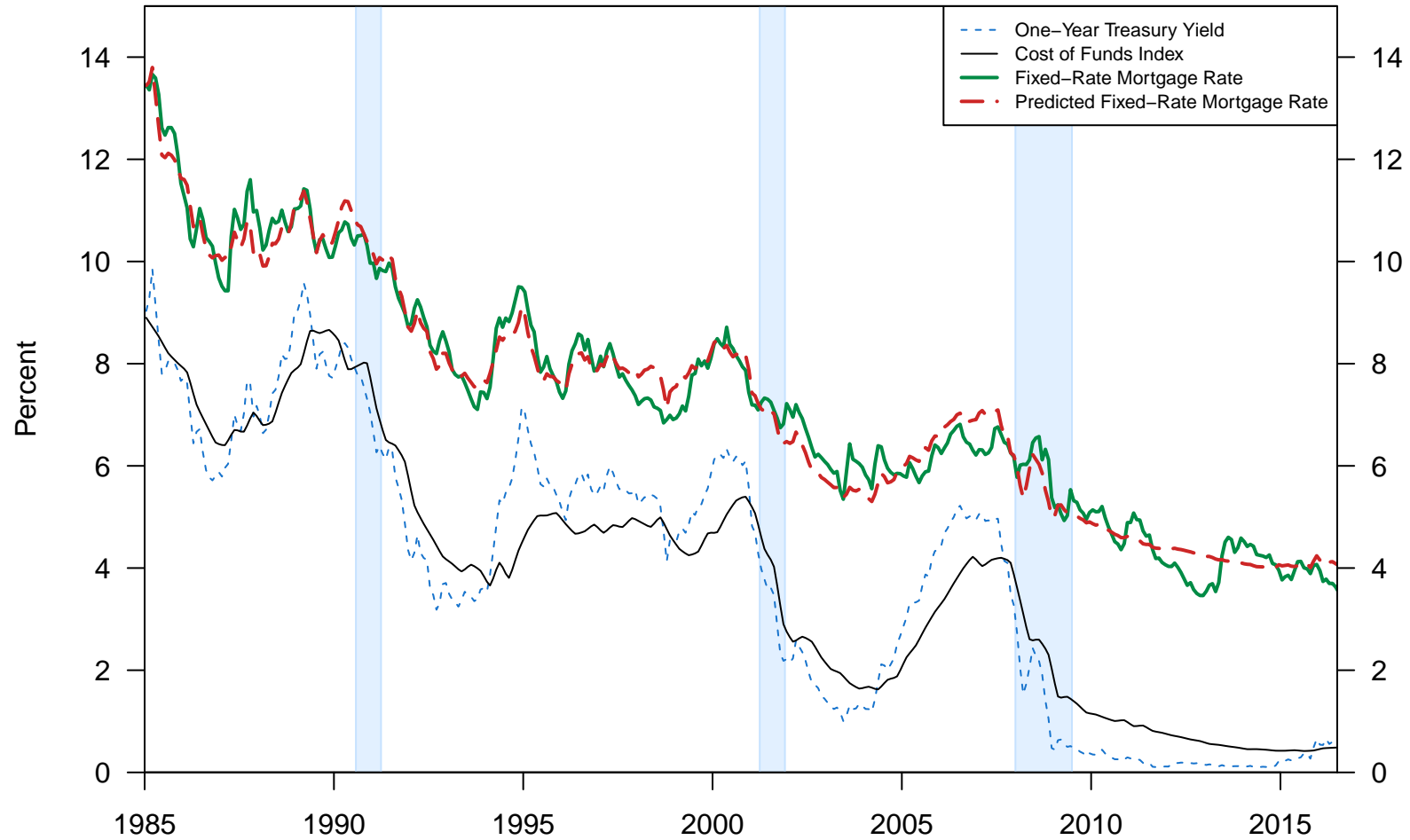
	<i>Dependent variable:</i>
	Δ Fixed-Rate Mortgage Rate
Δ One-Year Treasury Yield	0.661*** (0.038)
Δ Cost of Funds Index	-0.280*** (0.087)
Lag Δ Fixed-Rate Mortgage Rate	0.105*** (0.038)
Lag Disequilibrium	-0.067*** (0.012)
Constant	-0.014* (0.008)
Observations	377
R ²	0.522
Adjusted R ²	0.517
Residual Std. Error	0.151 (df = 372)
Monthly	*p<0.1; **p<0.05; ***p<0.01

Note: Fixed-rate mortgage rates and one-year Treasury yields are averages. Cost of funds indexes are linearly interpolated. Data are from January 1985 to July 2016.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 6

Fixed-Rate Mortgage Rate Error Correction Model Fitted Values

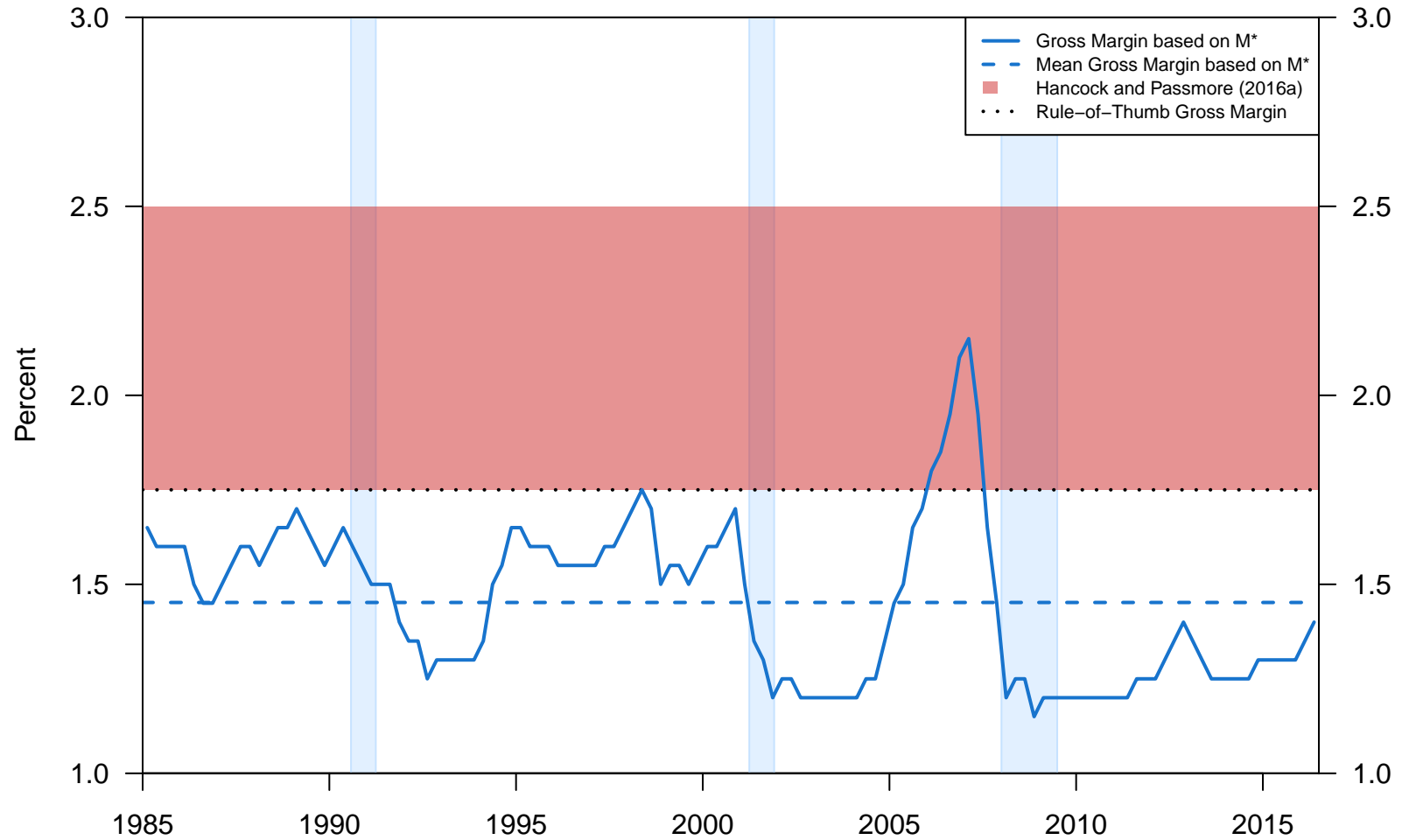


Note: Predicted fixed-rate mortgage rates are based on table 3 and table 4. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 7

Gross Margin

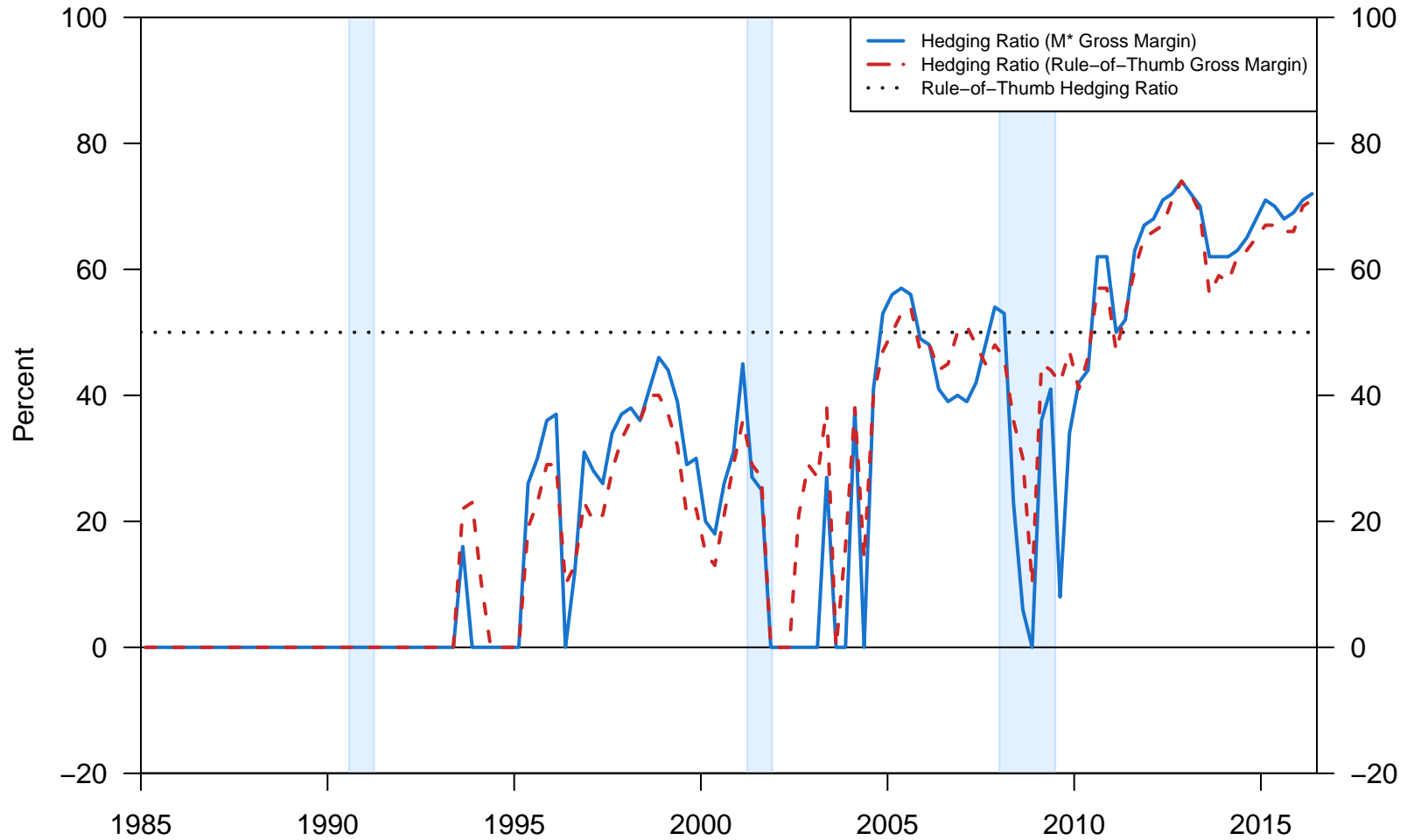


Note: The gross margin based on M* equates the expected profit from holding Fixed-COFI mortgages and holding Treasuries. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 8

Hedging Against Extremely Adverse Fixed-COFI Mortgage Outcome

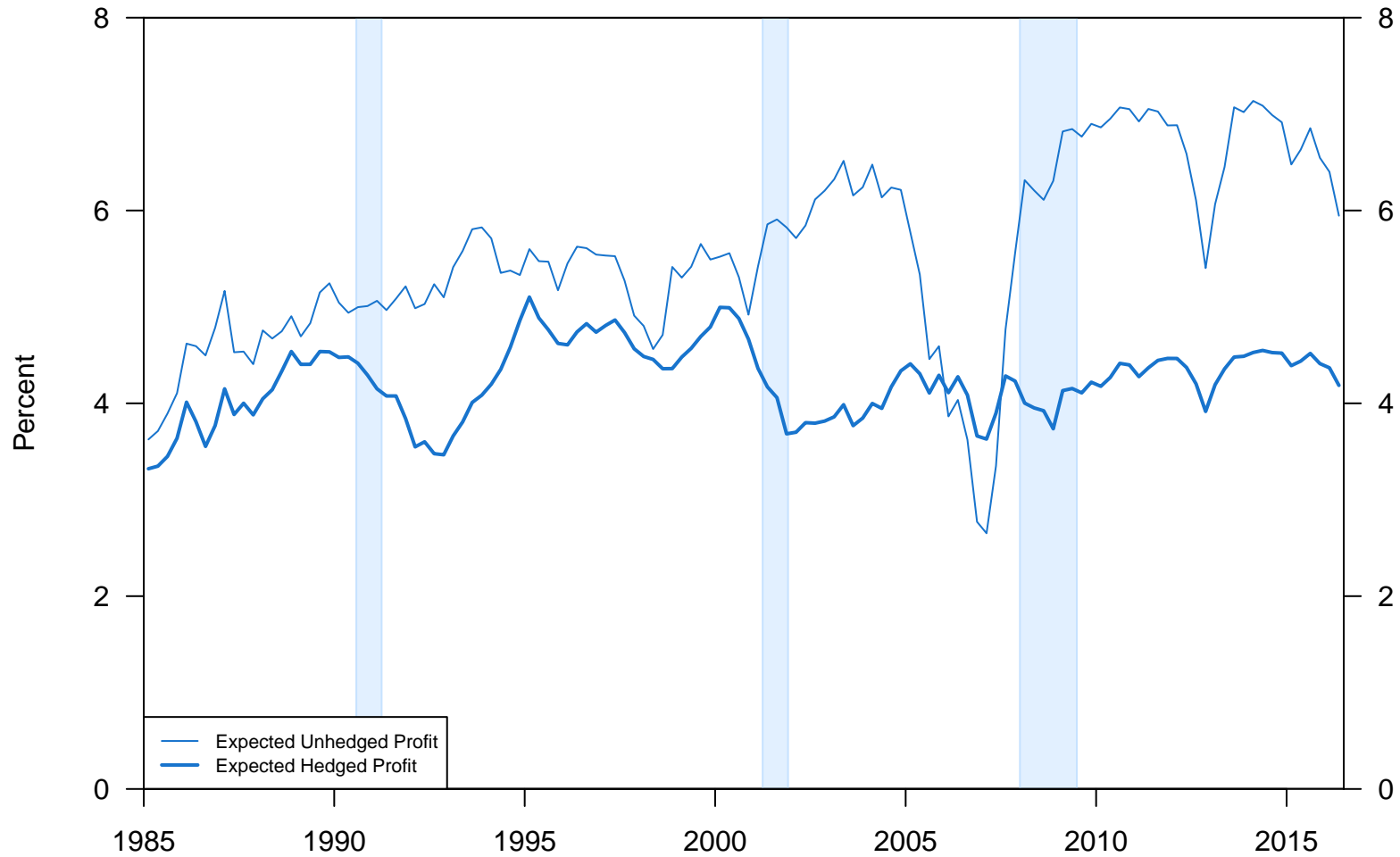


Note: This calculation assume mortgages are backed by 4% capital. The mean hedging ratio (based on both the M* gross margin and the rule-of-thumb gross margin) is 27 percent. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 9

Rule of Thumb: Expected Unhedged and Hedged Profit

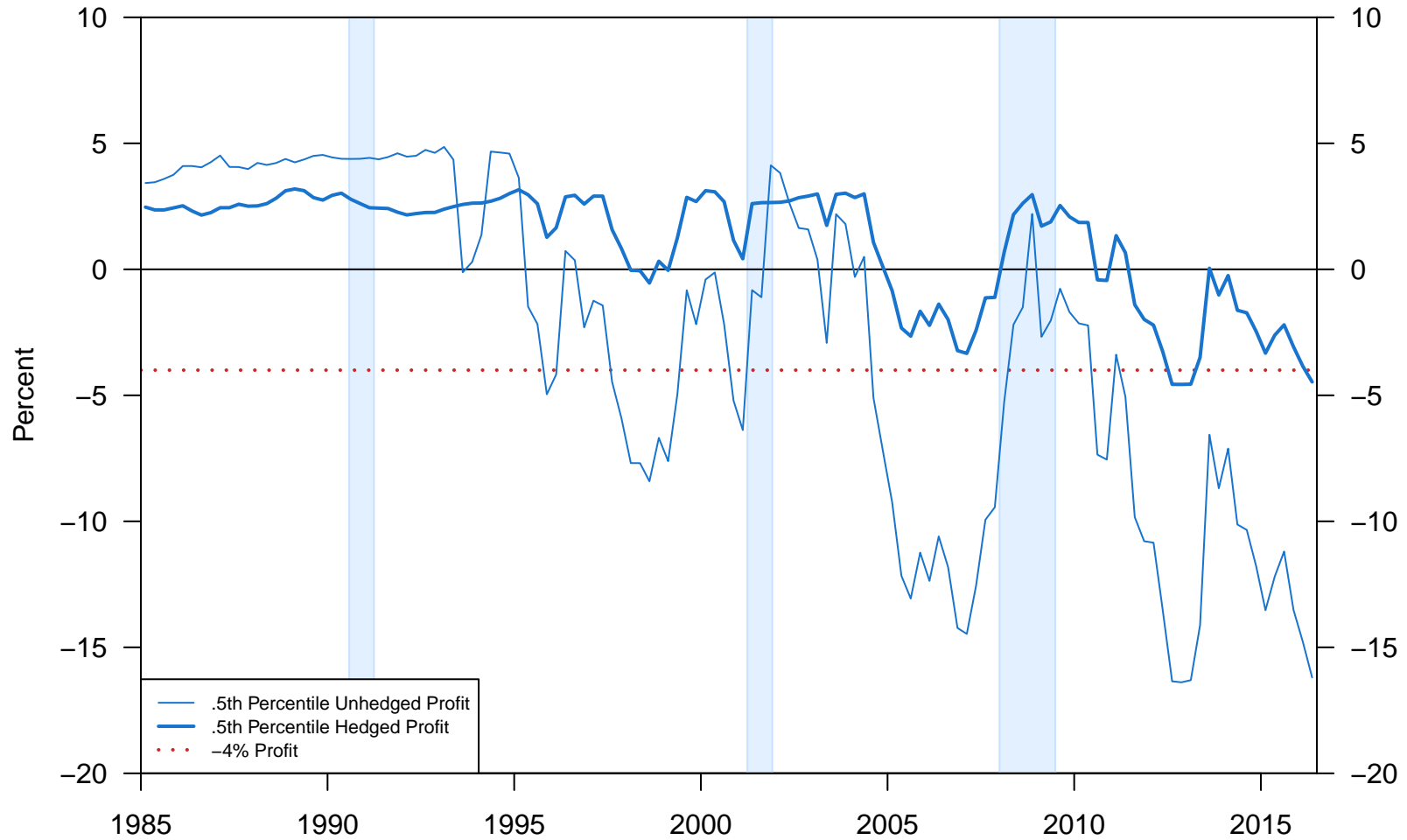


Note: The rule of thumb is a gross margin of 1.75 percentage points and a hedging ratio of 50%. This calculation assume mortgages are backed by 4% capital. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 10

Rule of Thumb: Extremely Adverse Unhedged and Hedged Profit

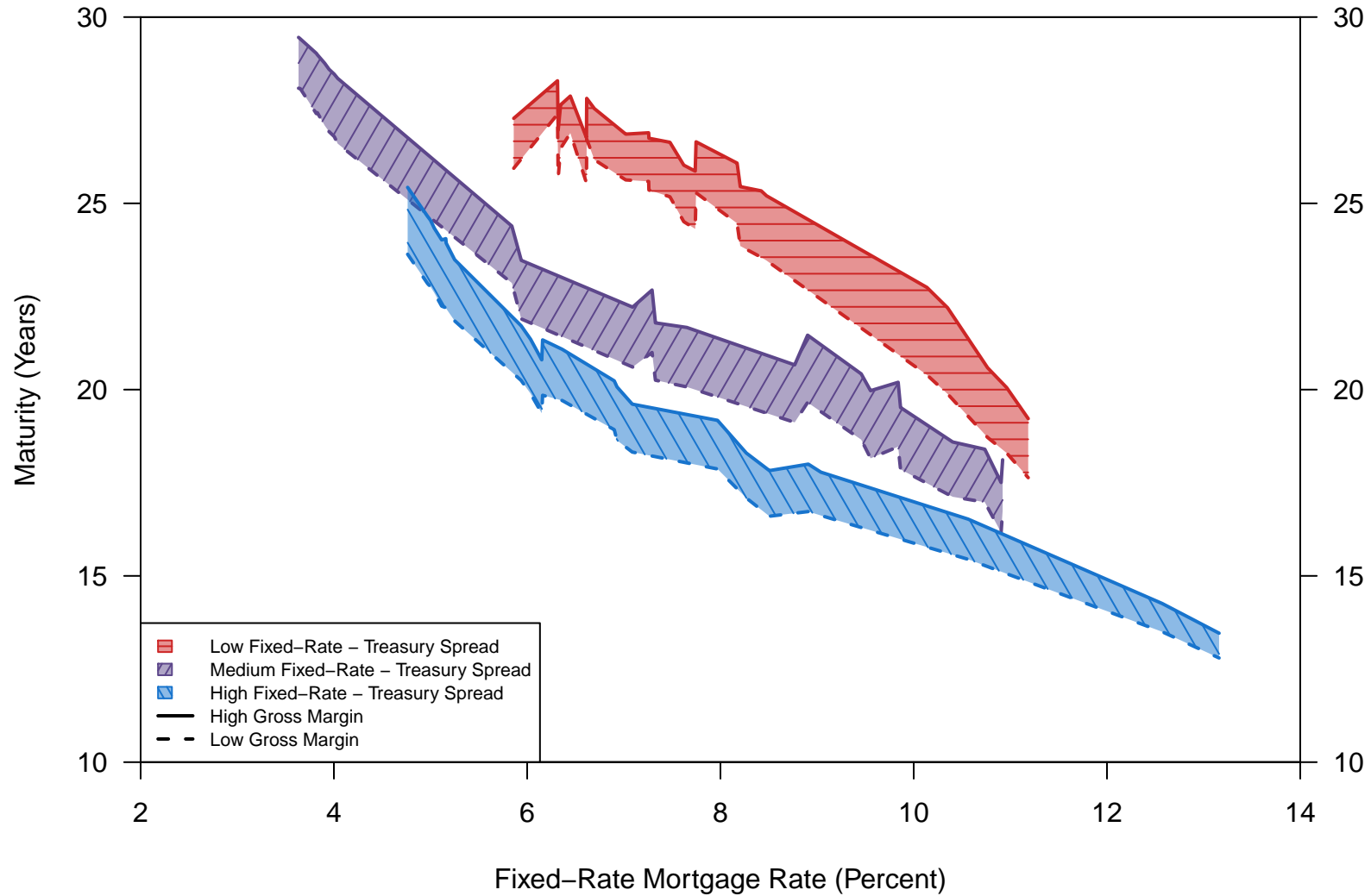


Note: The rule of thumb is a gross margin of 1.75 percentage points and a hedging ratio of 50%. This calculation assume mortgages are backed by 4% capital. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 11

Simulation Results: Average Maturity

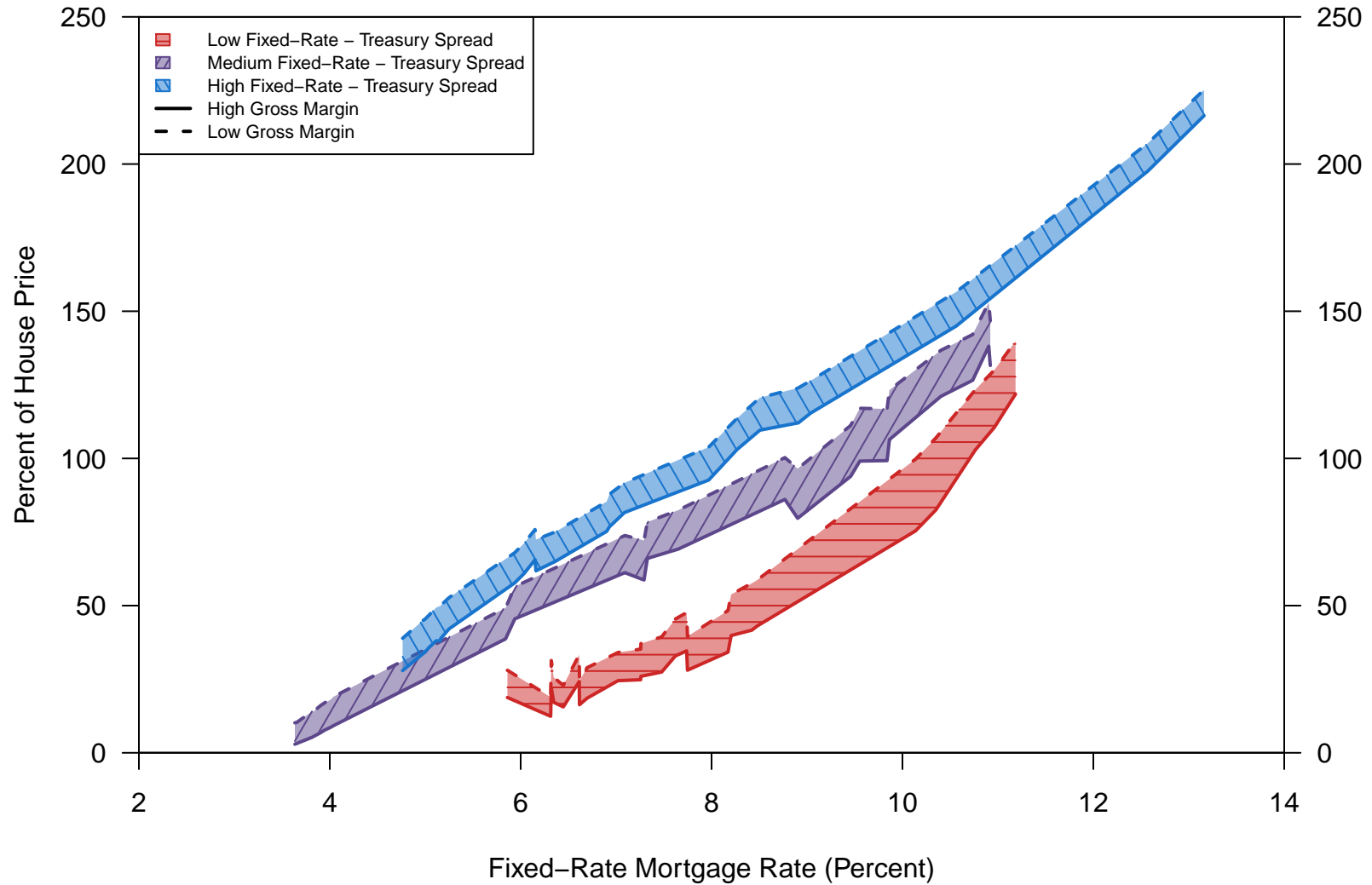


Note: Low, medium, and high spreads between the fixed-rate mortgage rate and the one-year Treasury yield at origination are the bottom, medium, and top quintile, respectively. Simulated mortgages have no opportunities to refinance and no opportunities to extract equity. 2.52 million simulations are run in total.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 12

Simulation Results: Average Interest Savings

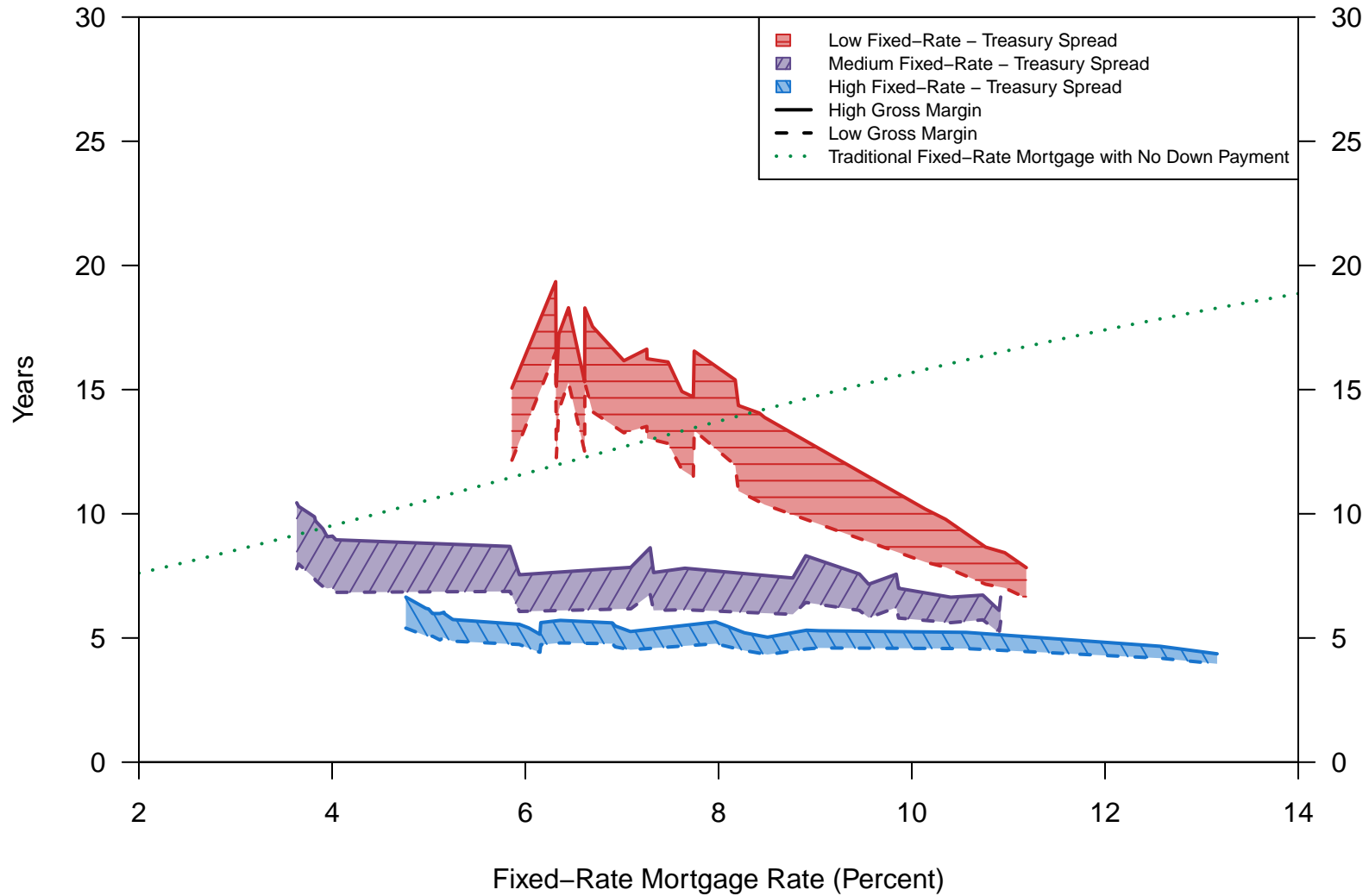


Note: Low, medium, and high spreads between the fixed-rate mortgage rate and the one-year Treasury yield at origination are the bottom, medium, and top quintile, respectively. Simulated mortgages have no opportunities to refinance and no opportunities to extract equity. 2.52 million simulations are run in total.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 13

Simulation Results: Average Number of Years Until 20 Percent Equity



Note: Low, medium, and high spreads between the fixed-rate mortgage rate and the one-year Treasury yield at origination are the bottom, medium, and top quintile, respectively. Simulated mortgages have no opportunities to refinance and no opportunities to extract equity. 2.52 million simulations are run in total.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 14

Simulation Results with Refinancing: Average Maturity

By Number of Refinancing Options



Note: Low and high spreads between the fixed-rate mortgage rate and the one-year Treasury yield are the bottom quintile and the top quintile, respectively. We run 7.56 million simulations in total.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 15

Simulation Results with Refinancing: Average Maturity

By Number of Actual Refinancings



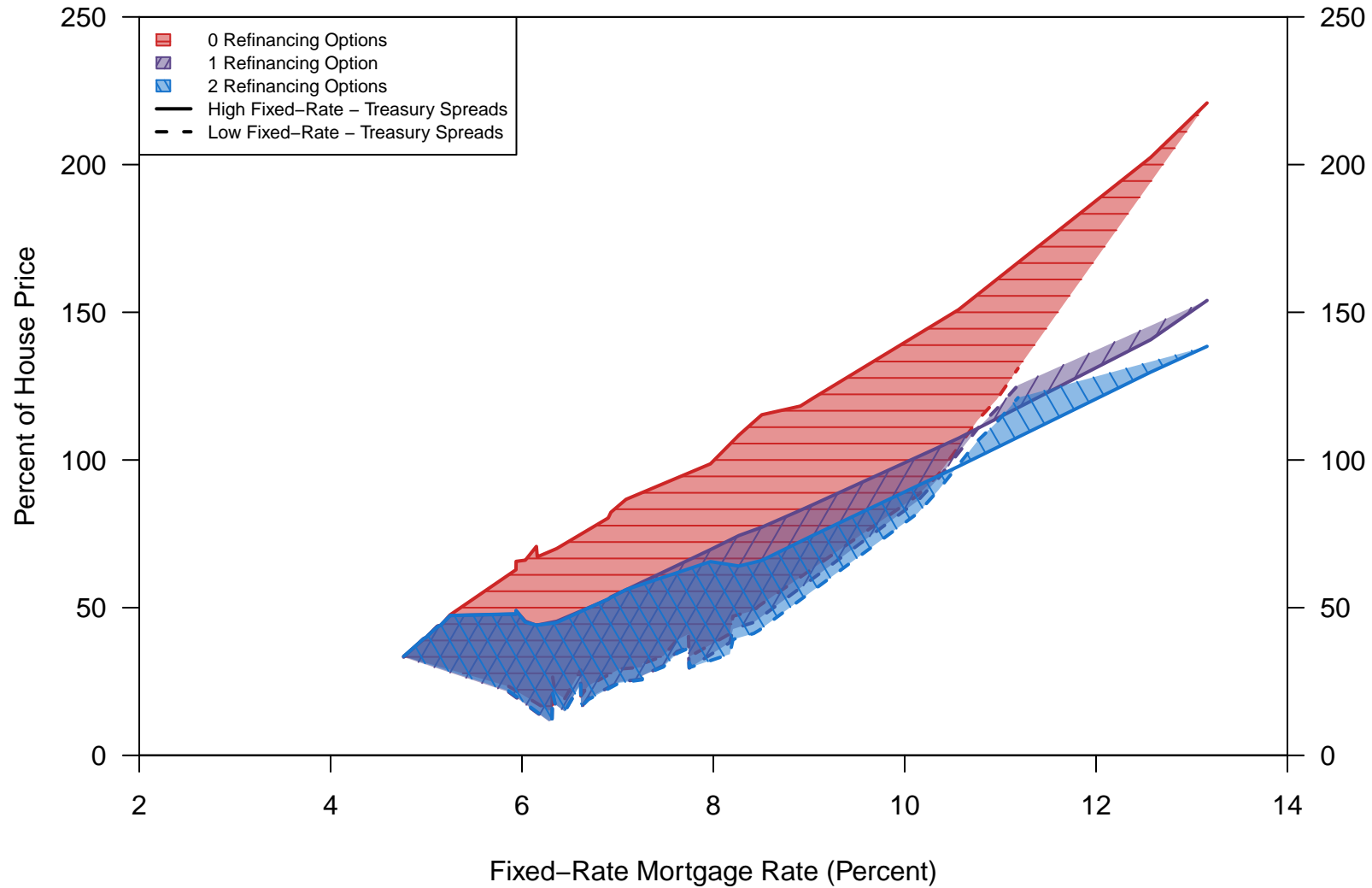
Note: Low and high spreads between the fixed-rate mortgage rate and the one-year Treasury yield are the bottom quintile and the top quintile, respectively. We run 7.56 million simulations in total.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 16

Simulation Results with Refinancing: Average Interest Savings

By Number of Refinancing Options



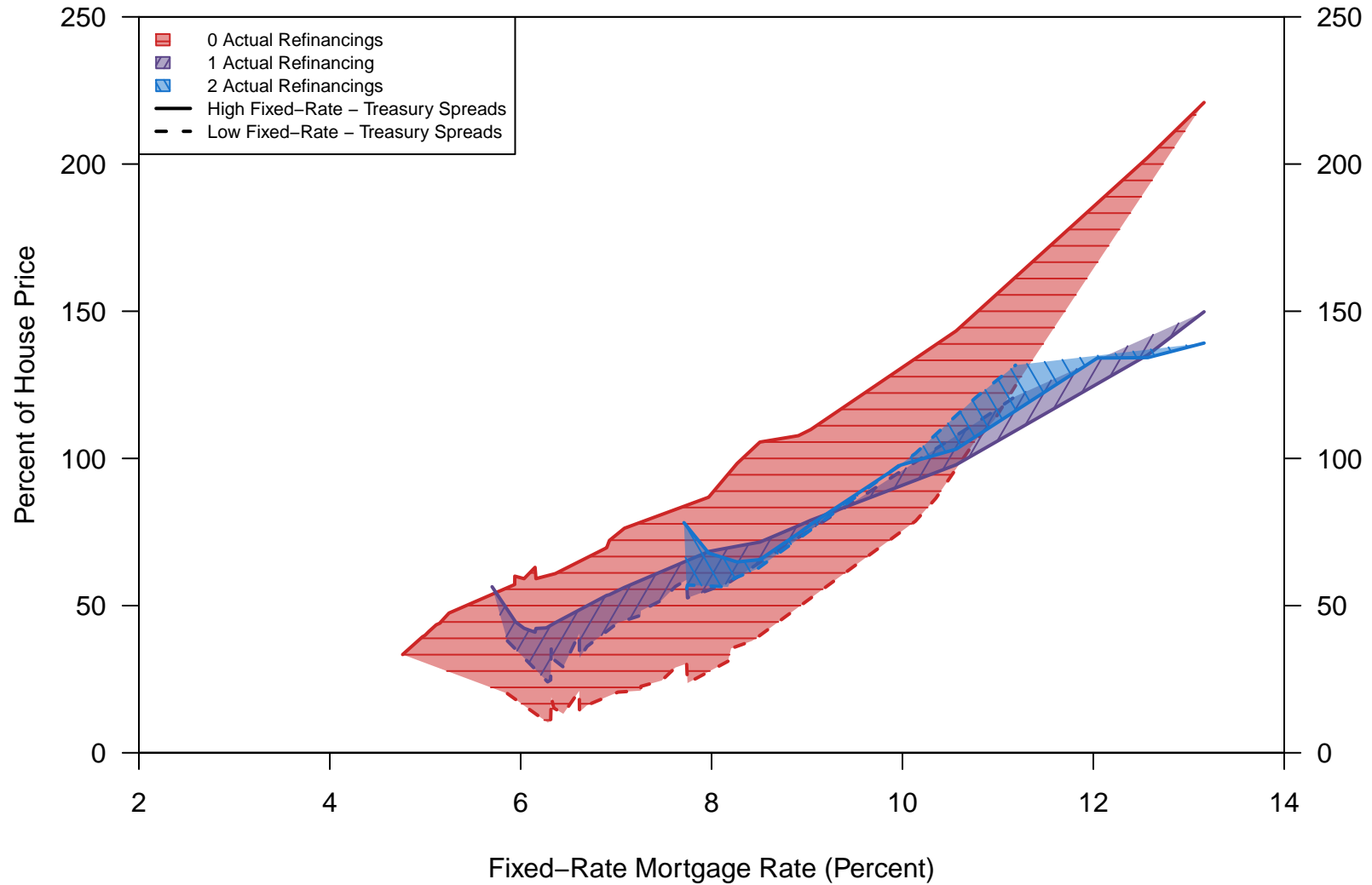
Note: Low and high spreads between the fixed-rate mortgage rate and the one-year Treasury yield are the bottom quintile and the top quintile, respectively. We run 7.56 million simulations in total.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 17

Simulation Results with Refinancing: Average Interest Savings

By Number of Actual Refinancings



Note: Low and high spreads between the fixed-rate mortgage rate and the one-year Treasury yield are the bottom quintile and the top quintile, respectively. We run 7.56 million simulations in total.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 18

Simulation Results with Equity Extraction: Average Maturity

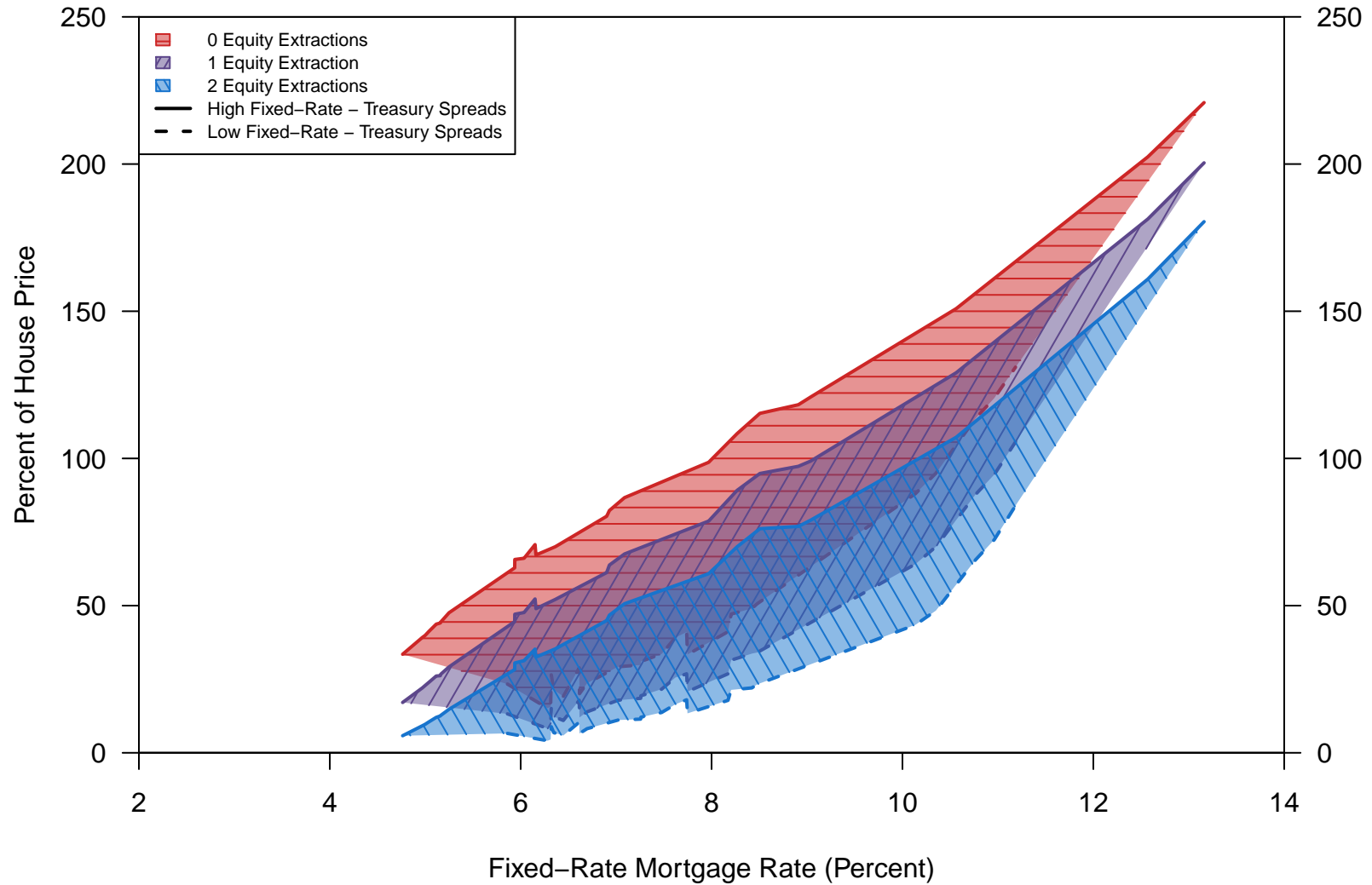


Note: Low and high spreads between the fixed-rate mortgage rate and the one-year Treasury yield are the bottom quintile and the top quintile, respectively. We run 7.56 million simulations in total.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure 19

Simulation Results with Equity Extraction: Average Interest Savings



Note: Low and high spreads between the fixed-rate mortgage rate and the one-year Treasury yield are the bottom quintile and the top quintile, respectively. We run 7.56 million simulations in total.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Table A2.1: ARIMA(1, 1, 1) One-Year Treasury Yield Model

<i>Dependent variable:</i>	
Δ One-Year Treasury Yield	
AR(1)	-0.217*** (0.076)
MA(1)	0.701*** (0.058)
Observations	661
Log Likelihood	-311.087
σ^2	0.150
Akaike Inf. Crit.	628.174
Monthly	*p<0.1; **p<0.05; ***p<0.01

Note: One-year Treasury yields are averages. Data are from February 1962 to March 2017. AR is the autoregressive term. MA is the moving average term.

Source: One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Table A2.2: ARIMA(3, 1, 3) One-Year Treasury Yield Model

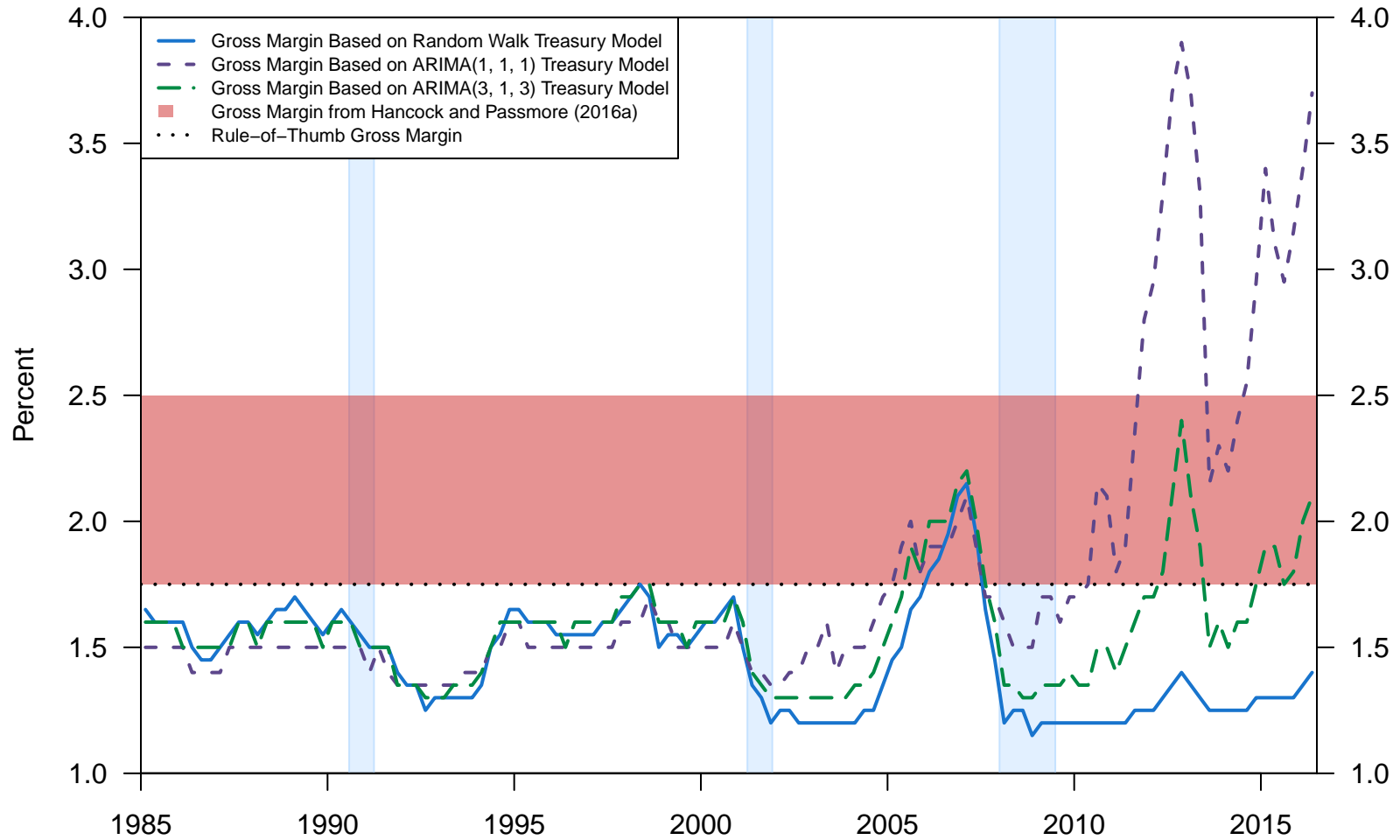
<i>Dependent variable:</i>	
Δ One-Year Treasury Yield	
AR(1)	0.957*** (0.109)
AR(2)	-0.957*** (0.110)
AR(3)	0.055 (0.111)
MA(1)	-0.434*** (0.100)
MA(2)	0.506*** (0.096)
MA(3)	0.485*** (0.099)
Observations	378
Log Likelihood	70.430
σ^2	0.040
Akaike Inf. Crit.	-126.861
Monthly	*p<0.1; **p<0.05; ***p<0.01

Note: One-year Treasury yields are averages. Data are from January 1985 to July 2016. AR are the autoregressive terms. MA are the moving average terms.

Source: One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure A2.1

Gross Margin: Treasury Model Robustness

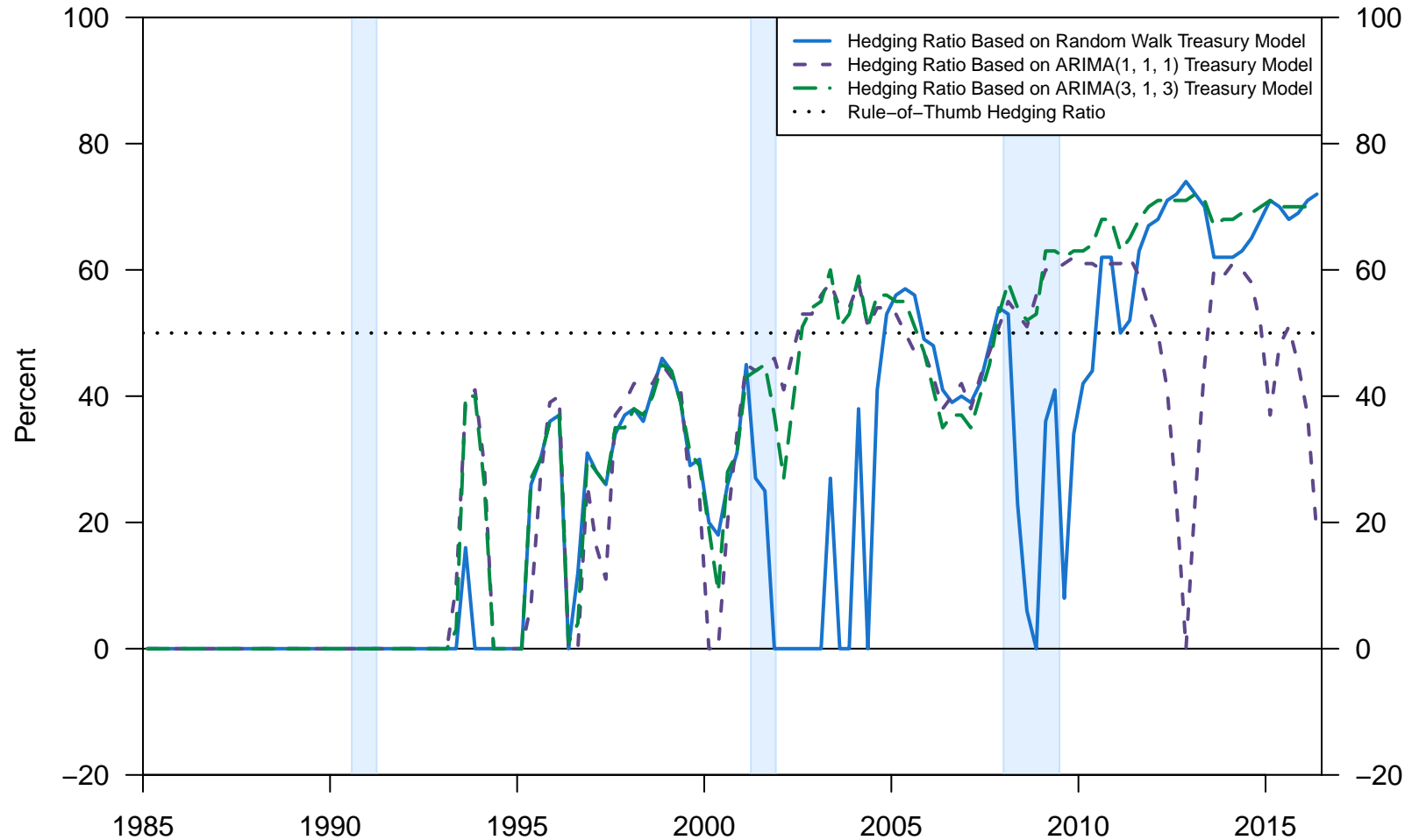


Note: The Treasury random walk estimation (shown in table 3) results in a mean gross margin of 1.45 percentage points. The ARIMA(1, 1, 1) Treasury model (shown in table A2.1) results in a mean gross margin of 1.79 percentage points. The ARIMA(3, 1, 3) Treasury model (shown in table A2.2) results in a mean gross margin of 1.58 percentage points. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure A2.2

Hedging Against Extremely Adverse Fixed-COFI Mortgage Outcome: Treasury Model Robustness

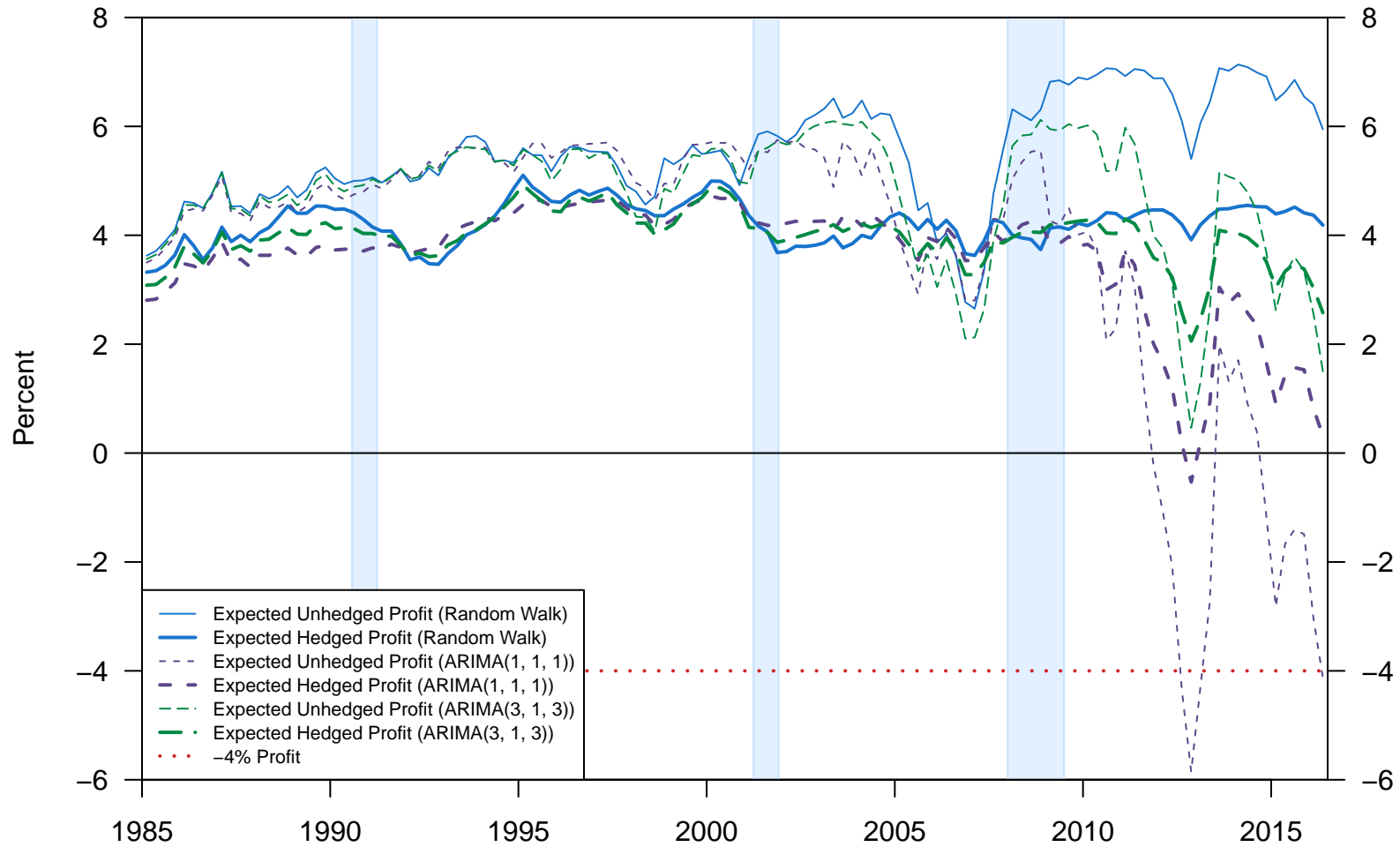


Note: This calculation assume mortgages are backed by 4% capital. The Treasury random walk estimation (shown in table 3) results in a mean hedging ratio of 27 percent. The ARIMA(1, 1, 1) Treasury model (shown in table A2.1) results in a mean hedging ratio of 30 percent. The ARIMA(3, 1, 3) Treasury model (shown in table A2.2) results in a mean hedging ratio of 35 percent. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure A2.3

Rule of Thumb: Expected Unhedged and Hedged Profit

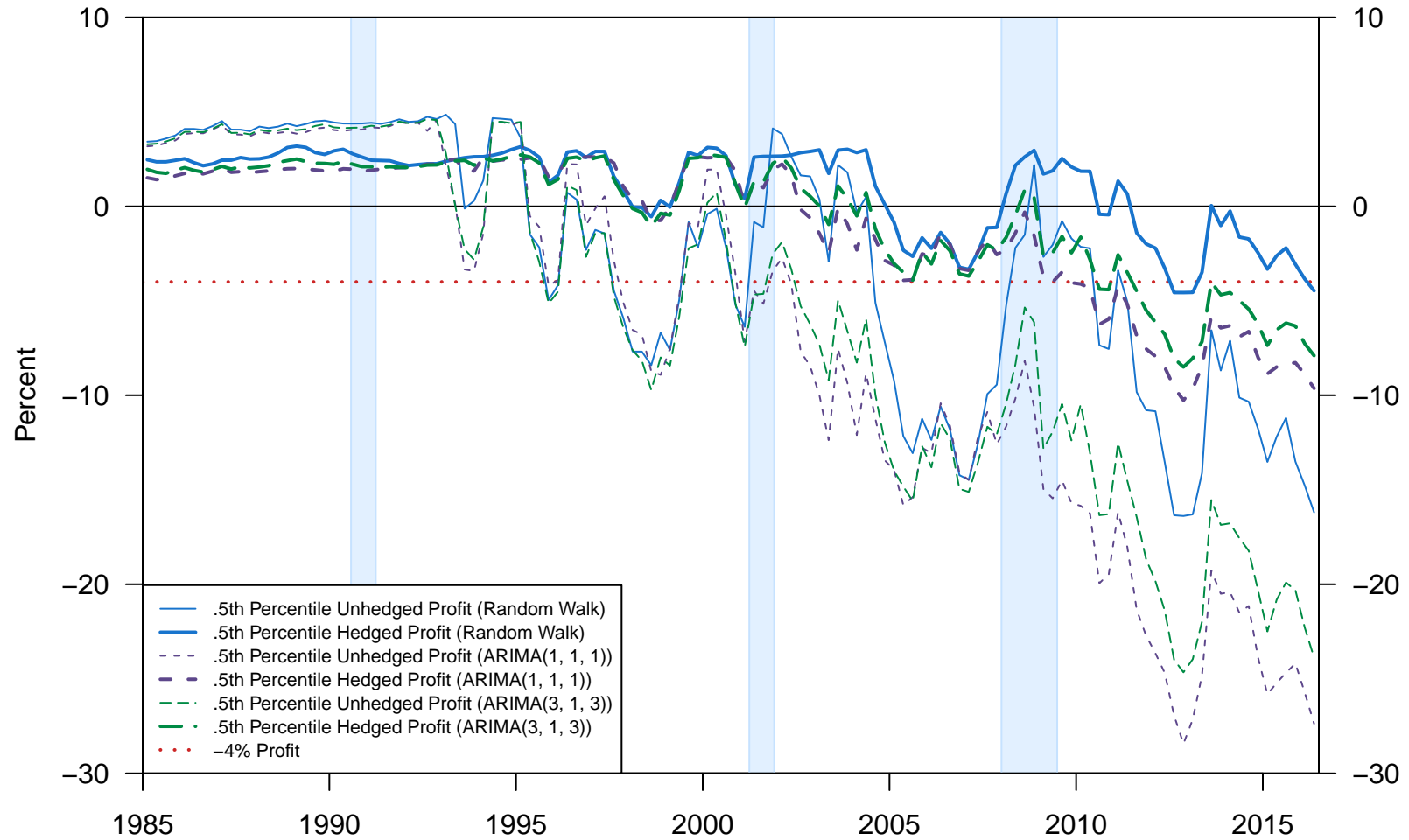


Note: The rule of thumb is a gross margin of 1.75 percentage points and a hedging ratio of 50%. This calculation assume mortgages are backed by 4% capital. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure A2.4

Rule of Thumb: Extremely Adverse Unhedged and Hedged Profit

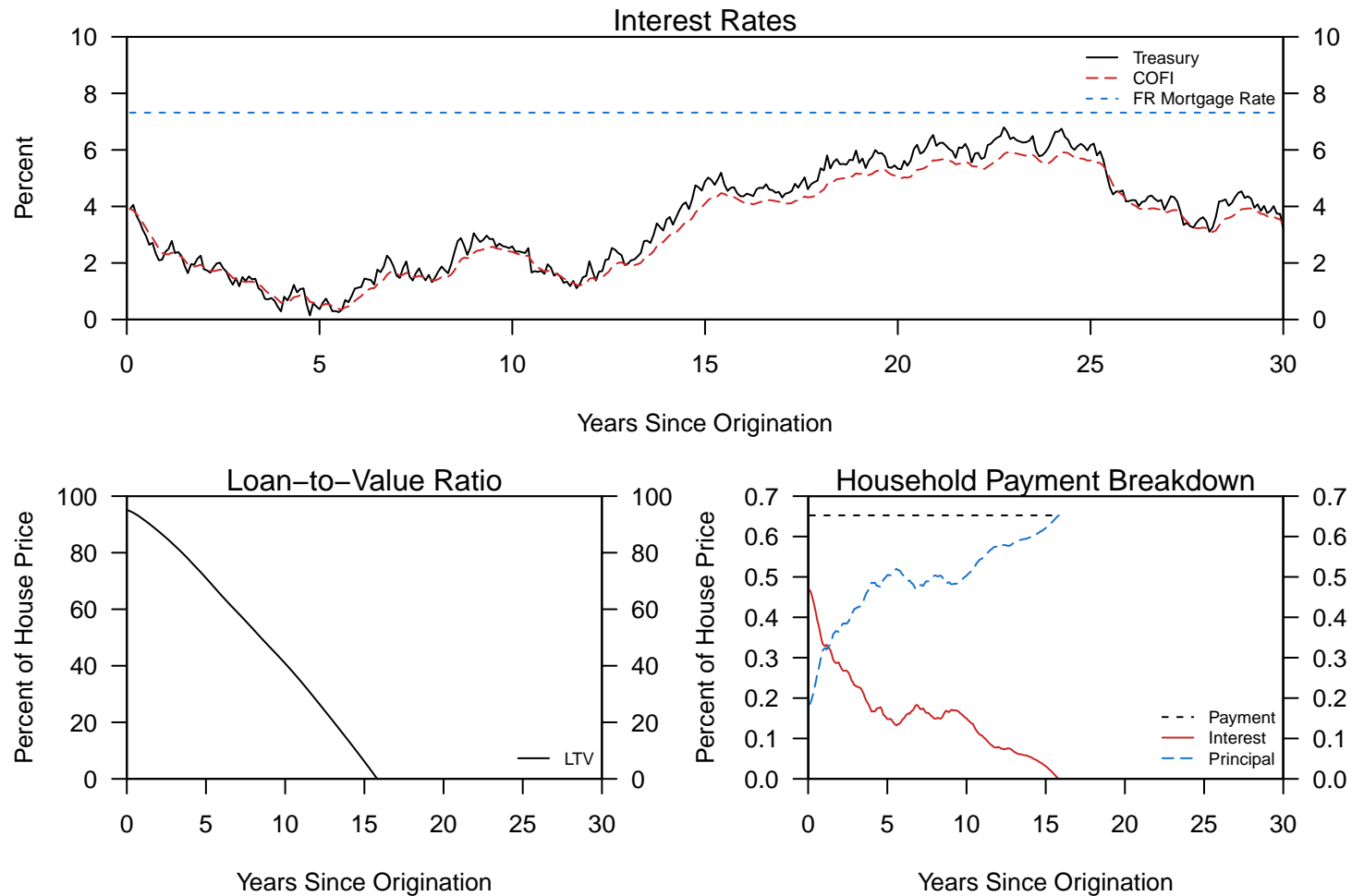


Note: The rule of thumb is a gross margin of 1.75 percentage points and a hedging ratio of 50%. This calculation assume mortgages are backed by 4% capital. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure A3.1

Fixed-COFI Mortgage Simulation Example With No Balloon Payment and No Payment Shortfalls

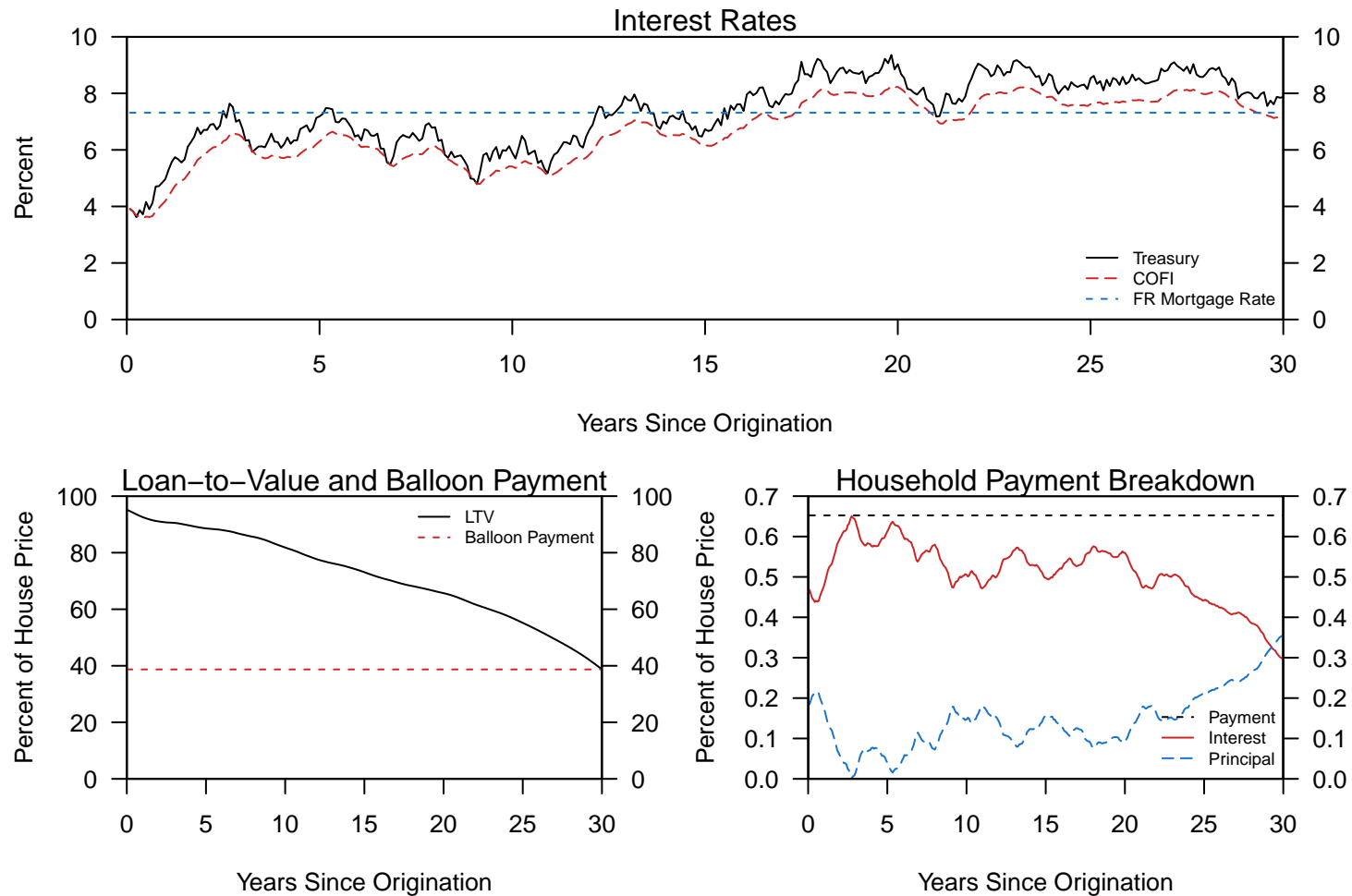


Note: Interest rates start at the mean interest rates between 1985 and 2016.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure A3.2

Fixed-COFI Mortgage Simulation Example With Balloon Payment and No Payment Shortfalls

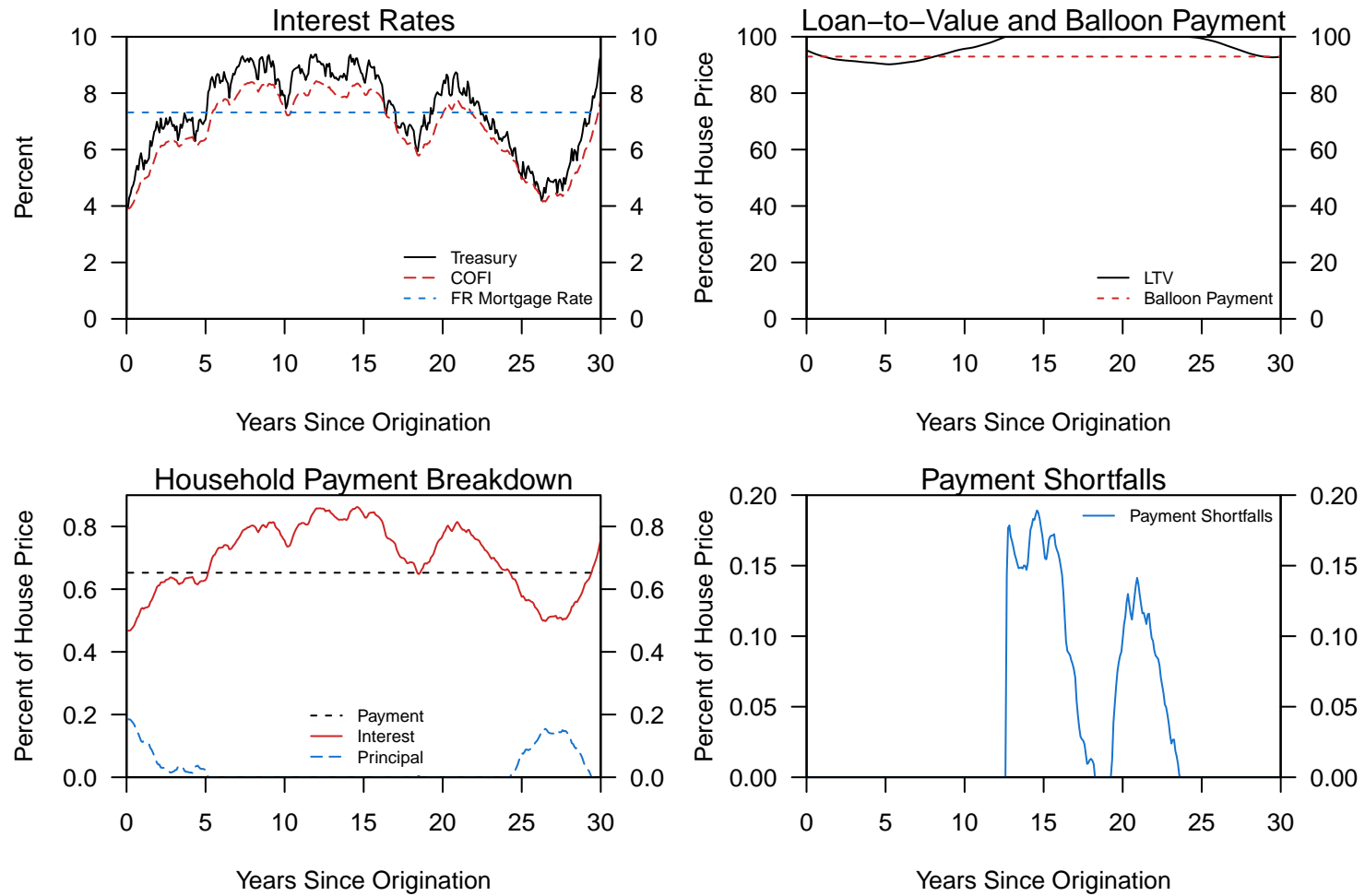


Note: Interest rates start at the mean interest rates between 1985 and 2016.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddie.mac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure A3.3

Fixed-COFI Mortgage Simulation Example With Balloon Payment and Payment Shortfalls

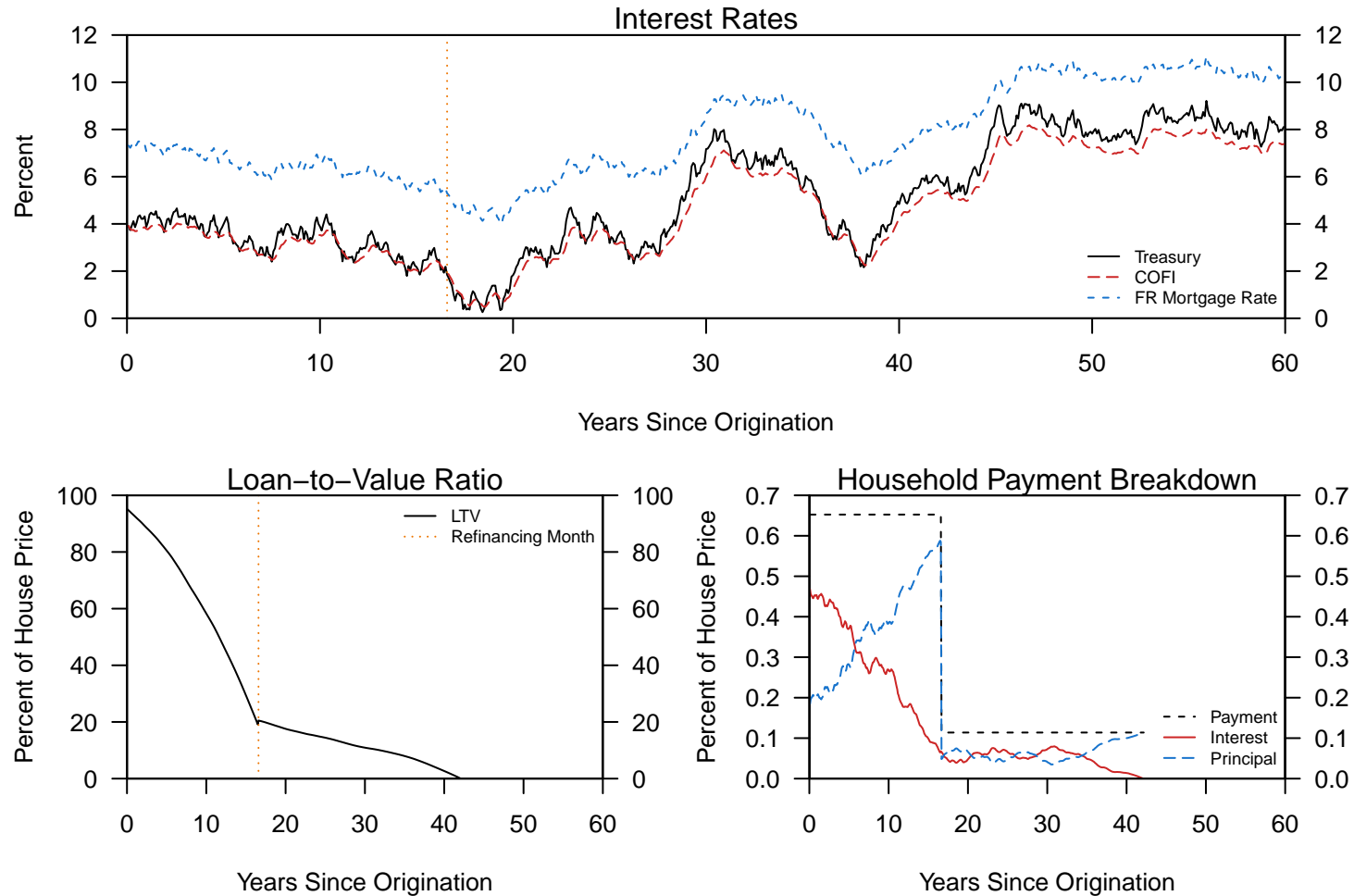


Note: Interest rates start at the mean interest rates between 1985 and 2016.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure A3.4

Fixed-COFI Mortgage Simulation Example With Refinancing

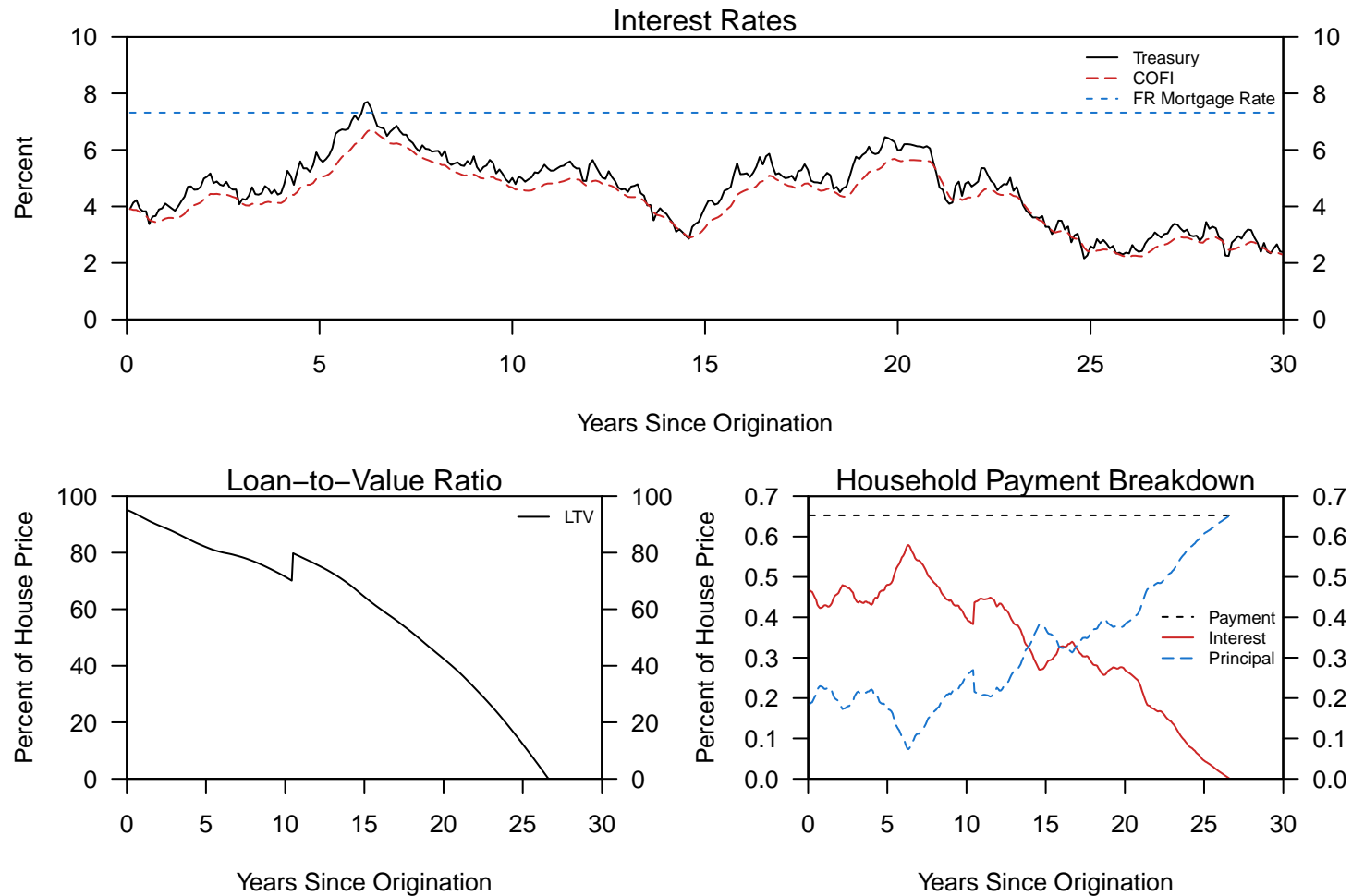


Note: Interest rates start at the mean interest rates between 1985 and 2016.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.

Figure A3.5

Fixed-COFI Mortgage Simulation Example With Equity Extraction



Note: Interest rates start at the mean interest rates between 1985 and 2016.

Source: Cost of Funds Index is constructed from quarterly Federal Financial Institutions Examination Council Call Report data available at <https://cdr.ffiec.gov/public/>. Fixed-Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Estimated COFI-Cat Mortgage Gross Margins is from Hancock and Passmore, 2016. One-Year Treasury Yields are daily U.S. Treasury data available at <https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield>.