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Financing Affordable and Sustainable Homeownership with Fixed-COFI Mortgages

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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 this sluggish 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 homeowners might have better uses for this money. Third, refinancing mortgages is often very costly. Expensive refinancing may prevent homeowners from taking advantage of falling rates.

To resolve these three flaws, we propose a new fixed-rate mortgage, called the Fixed-Payment-COFI mortgage (or "Fixed-COFI mortgage"). This mortgage has fixed monthly payments equal to payments for traditional fixed-rate mortgages and does not require a 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 lower monthly payments or toward purchasing the home. The Fixed-COFI mortgage exploits the often-present prepayment-risk "wedges" between the fixed-rate mortgage rate and the estimated cost of funds index (COFI) mortgage rate. In addition, the Fixed-COFI mortgage is a highly profitable asset for many mortgage lenders.

We discuss two variations of the Fixed-COFI mortgage. Homeowners with "affordable" Fixed-COFI mortgages are rebated the "wedges" between the traditional fixed-rate mortgage payments and the COFI mortgage payment. After the "wedges" are rebated, these homeowners may pay substantially less to purchase their homes in 30 years than homeowners with traditional fixed-rate mortgages. This mortgage design may help alleviate housing affordability pressures in many areas of the United States.

The other variation of Fixed-COFI mortgage is the "homeownership" Fixed-COFI mortgage. With the "homeownership" Fixed-COFI mortgage, the homeowner commits 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. The homeownership Fixed-COFI mortgages may help some renters gain access to homeownership. For example, these renters may be paying rents as high as comparable mortgage payments in high-cost metropolitan areas but may not have enough savings for a down payment. With less need for a down payment, the Fixed-COFI mortgage may help such renters with stable income—but no savings—purchase homes.

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1. Introduction

The 30-year fixed-rate fully amortizing mortgage (or "traditional fixed-rate mortgage") was a substantial innovation when developed during the Great Depression. It still dominates the U.S. 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 the down payments of conventional mortgages (Duncan et al., 2016). With our proposed mortgage product, homeowners can accumulate equity much more quickly, thus eliminating the need for large down payments.

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 benefit from directing this money to other purposes. In essence, homeowners purchase a lottery ticket embedded in traditional fixed-rate mortgage

[1] Since the beginning of 2009, adjustable-rate mortgages have 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 Tchistyi (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).

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, which is locked in 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 result in profitable refinancing. 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 toward either lower mortgage payments or 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 little to no down payment because these mortgages can encourage rapid home equity accumulation. Second, Fixed-COFI mortgages redirect prepayment risk compensation—paid to capital markets investors in traditional fixed-rate mortgages—either back to the

[5] Furthermore, 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."

homeowner in the form of lower monthly payments or toward home equity accumulation. Third, Fixed-COFI mortgages avoid many costs associated with refinancing. Homeowners with Fixed-COFI mortgages always reap benefits when interest rates fall.

In designing the Fixed-COFI mortgage, we aim to rethink mortgage design in general and the "levers" that can be pulled to customize mortgages in order to better fit the needs of individual households. In that vain, we discuss two variations of Fixed-COFI mortgages in this paper. In the "affordable" Fixed-COFI mortgage, homeowners are rebated the difference between fixed-rate mortgage payments and payments based on the COFI mortgage rate.[8] These rebates can drastically lessen the monthly payment burden for many households. In the "homeownership" Fixed-COFI mortgage, the homeowner commits to a savings program based on the "wedges" between the fixed-rate mortgage payment and the COFI mortgage rate. The homeowner accumulates home equity quickly and can purchase the home in far less than 30 years.

In this paper, we analyze the two extreme cases: all "wedges" are either directed to monthly payment rebates or to home equity accumulation. A continuum of intermediate contracts with more limited rebates and smaller home equity savings accounts are also possible. Figure 1 shows the expected total homeowner cost of the traditional fixed-rate mortgage, the affordable Fixed-COFI mortgage, and the homeownership Fixed-COFI mortgage for median-priced homes in the United States. Homeowners could save many thousands of dollars by choosing Fixed-COFI mortgages over traditional fixed-rate mortgages.

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;[9] (2) the household puts forth no down payment; (3) the household

[8] We leave the timing and form of the rebates to the discretion of the bank and the homeowner. In principle, the rebates could be immediately deducted from the monthly payment, sent back to the homeowner a month later, accumulated and sent back to the homeowner once a year, or directed back to the homeowner using some other arrangement. One possibility is that the rebates could be netted against possible costs of the bank (for example, property taxes). These netted rebates could create negative amortization, which is discussed at length in Passmore and von Hafften (2017).

[9] 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 refer to "U.S. commercial banks" as "banks."

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 mortgage payment calculated at origination; (5) excess payments are either placed into a home equity savings account or rebated back to the homeowner; 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 (ARM). Hancock and Passmore (2016a) estimate COFI-indexed mortgage rates from historical data between 2000 and 2014, inclusive, to analyze the feasibility of ARM products indexed by COFI. By design, banks can generally hold these mortgages profitably. Hancock and Passmore 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, ARMs inherently lack the desirable feature of fixed monthly payments.

The Fixed-COFI mortgage exploits the often-present "wedge" between the traditional fixed-rate mortgage rate and the COFI mortgage rate. In figure 2, the "wedge" is shown as the gap between the effective rates on 30-year fixed-rate first-lien prime conventional conforming home-purchase mortgages with 20 percent down (or "traditional fixed-rate mortgage rates"; red solid line) and the estimated COFI mortgage rates (blue dashed line).[10] 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

[10] The margin on the COFI mortgage rate is 2 percentage points (more discussion in section 5). 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 that 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).

deposit rates, which are a key component of COFI.[11] Indeed, greater inflows into insured deposits during times of market uncertainty may drive COFI lower.[12]

What do homeowners lose by choosing Fixed-COFI mortgages instead of traditional fixed-rate mortgages? First, some households may not be able to freely spend refinancing gains on non-housing items. When interest rates drop, homeowners with homeownership Fixed-COFI mortgages automatically pay less interest and pay down more mortgage principal. When interest rates drop, homeowners with affordable Fixed-COFI mortgages get larger payment rebates. Although such possibilities are outside the scope of this paper, such rebates could be directed to a savings account that can only be accessed by the household under certain circumstances (e.g., income shortfalls or unemployment). Using the analysis here, it is easy to see how such a mortgage could be designed. Other permutations of Fixed-COFI mortgages are discussed in Passmore and von Hafften (2017).

Second, homeowners can not "win the lottery" played with capital markets investors and refinance to lock in a substantially lower rate for the remainder of their mortgage. With Fixed-COFI mortgages, homeowners trade the option to prepay for either lower monthly payments or 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, or with a need for consistent savings, may prefer Fixed-COFI mortgages to renting.

[11] 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.

[12] 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, use a cost basis, and rely on poorly-suited financial instruments (such as "matrix priced" swap-options). Moreover, substantial payments for investor risk aversion may be built into model-based prepayment premiums because the 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. Because many homeowners miss refinancing opportunities, compensation for bearing prepayment risks is often too large (Grubb, 2015).

Widespread use of Fixed-COFI mortgages would result in four primary benefits.[13] First, because they can be offered with no down payment, homeownership Fixed-COFI mortgages 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 homeownership Fixed-COFI mortgages, these renters would be able to purchase homes and accumulate home equity quickly.

Second, affordable Fixed-COFI mortgages can alleviate housing affordability pressures.[14] In these mortgages, the "wedges" from prepayment premiums are directed back to the homeowner as payment rebates. In section 6, we show that payment rebates may be an effective method of alleviating housing affordability pressures in many areas.

Third, the homeownership Fixed-COFI mortgage can help diminish government involvement in the mortgage market (Passmore and von Hafften, forthcoming). Homeowners with traditional fixed-rate mortgages accumulate equity slowly, often refinance, and often extract home equity.[15] As 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.[16] In order to trade securitized traditional fixed-rate mortgages, secondary market investors rely on 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,

[13] With their rapid equity accumulation, homeownership Fixed-COFI mortgages could be offered as work-out products for underwater or delinquent borrowers.

[14] In this paper, we do not address general equilibrium effects on housing affordability. Lower down payments and lower monthly mortgage payments (through payment rebates) would make homeownership more accessible to some renters. These renters (and their banks) would be betting on the future path of interest rates. If the expected cost of mortgage finance was lower than the expected cost of renting, these new homeowners might increase the demand for homes. This higher demand for homes would put upward pressure on house prices. Dokko et al. (2011) show that affordable mortgage products may allow homeowners to purchase more expensive homes.

[15] 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."

[16] 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 refinances." This outcome occurs despite "…the stronger credit characteristics of refis, such as lower loan-to-value (LTV) and debt-to-income ratios."

mortgage mispricing, moral hazard, and adverse selection.[17] With rapid home equity accumulation from homeownership Fixed-COFI mortgages, the government would need to absorb less long-term credit risk.[18]

Increased financial stability is the final benefit of widespread Fixed-COFI mortgages. The traditional fixed-rate mortgage generates waves of refinancing, which may amplify interest rate spikes. Because Fixed-COFI mortgages limit refinancing and automatically link lower interest rates to larger payment rebates or greater household savings, widespread use of these mortgages might mitigate this financial stability concern. Indeed, during times of recession, the "wedges" are likely to increase, perhaps providing a much-needed source of wealth for households.

Indeed, the Fixed-COFI mortgage has the characteristics of mortgages that reduce housing market volatility, consumption volatility, and default. Guren, Krishnamurthy, and McQuade (2017) find that such mortgages provide immediate and substantial payment relief to liquidity-constrained households during market downturns. In general, interest rates fall following market downturns (due to central bank actions). When rates fall, all Fixed-COFI mortgages automatically refinance—even if the homeowner takes no actions; refinance, in this sense, means that the homeowner pays less interest to the bank. The mechanism that produces payment relief following interest rate drops is different for affordable Fixed-COFI mortgages and homeownership Fixed-COFI mortgages. In affordable Fixed-COFI mortgages, "wedges" are rebated back to the homeowner, so rebates are larger when rates fall; thus, the homeowners receive direct relief.

[17] 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 GSEs misprice catastrophic risk in the run-up to a crisis, see Hancock and Passmore (2016b).

[18] 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.

In homeownership Fixed-COFI mortgages, all "wedges" instead purchase the home. Thus, when rates fall, homeowner wealth increases, and the homeowner purchases the home faster. As we discuss in Passmore and von Hafften (2017), a household with the Fixed-COFI mortgage can retain the ability to refinance in response to an income shock; refinance, in this sense, means resetting the monthly household payment based on paying off the remaining mortgage balance over 30 more years at the prevailing traditional fixed-rate mortgage rate.[19] Importantly, because the equity in homeownership Fixed-COFI mortgages can amass much faster than the equity in traditional fixed-rate mortgages, homeownership Fixed-COFI mortgage payments after refinancing would likely be much lower than traditional fixed-rate mortgage payments after refinancing. As we emphasize throughout this paper (and in Passmore and von Hafften, 2017), the Fixed-COFI mortgage has many design options that allow the mortgage to be customized to fit the household's financial needs.

This paper proceeds as follows: Section 2 discusses housing affordability, mortgage design, and how Fixed-COFI mortgages relate to other proposals for alternative mortgage products. Section 3 presents an example of the potential homeowner welfare gains from Fixed-COFI mortgages. Section 4 details the mechanics of the Fixed-COFI mortgage contract. Section 5 discusses constructing COFI mortgage rates. Section 6 discusses homeowner welfare. Section 7 concludes.

2. Housing Affordability, Mortgage Design, and Fixed-COFI Mortgages

Rents in many metropolitan areas are high relative to mortgage payments. In the past few decades, rents have been increasing substantially in many metropolitan areas. Adjusted for inflation, rents in some metropolitan areas have increased more than 15 percent between 1990 and 2009 (Collinson, 2011).[20] Figure 3 compares the median mortgage payments and the median rents in metropolitan statistical areas (MSAs). Mortgage payments are calculated based on the median

[19] As shown in Passmore and von Hafften (2017), the Fixed-COFI mortgage can also be modified to allow borrowing against home equity.

[20] "Real rents in the metropolitan areas of Chicago, Illinois; New York, New York; San Francisco, California; Los Angeles, California; San Diego, California; Miami, Florida; Washington, District of Columbia increased by more than 15 percent during the time period.…18 of 24 metropolitan areas experienced an increase in real rents during this same period. The metropolitan areas with the largest increases in real rents are primarily major immigration hubs and supply-constrained rental housing markets" (Collinson, 2011).

home value and a traditional fixed-rate mortgage at the prevailing mortgage rate with down payments of 20 percent. The red and blue bands represent 90 percent of MSAs in the United States; the center lines represent the median MSA. In most periods, owning is relatively cheaper than renting. The first notable exception is the 1980s, when owning was relatively expensive because of high interest rates. The second is the 2000s, which saw a substantial increase and fall in home values in some metropolitan areas (the top of the band jumps up); however, the median increased only slightly.

Rent burden (i.e., spending over 30 percent of income on housing costs) also has become more widespread, especially in many metropolitan areas. Over 52 percent of renting households nationwide pay gross rents of 30 percent or more of their income (Federal Reserve Bank of Richmond, 2015). In addition, rent burden does not solely affect low-income renters; Gabriel and Painter (2017) show that the proportion of the middle income quintile who are rent burdened increased about 150 percent between 2000 and 2014. High rents prevent households from saving. Zillow finds that roughly 50 percent of households paying rents of more than 25 percent of their income do not save (Olsen, 2016b).

These trends raise one of our motivating question: Why are more renters not purchasing homes?[21] One answer is that an inability to purchase homes is a consequence of less wealth accumulation, particularly for households with low and moderate incomes (Grinstein-Weiss et al., 2013).[22] Indeed, hefty rent burdens may prevent households from accumulating savings for a down payment.[23] Because households cannot afford down payments, they are stuck paying high rents. Mortgage products that can be offered with low or no down payments could break this cycle and create opportunities for households to accumulate wealth through home equity.

[21] In a similar vein, the popular real estate website Zillow.com calculated that the nationwide average renter would need to rent a house "a scant 1.9 years" before purchasing the home would have been more financially advantageous (Olsen, 2016a). *Importantly, this calculation assumes households can afford a 20 percent down payment.*

[22] A recent survey of people born between 1987 and 1998 (millennials) found a lack of savings was in part due to high rents (DiClerico, 2016). The survey also found that the top reason for not owning a home is not enough savings for a down payment. Other survey evidence indicates that the down payment is the major impediment to homeownership for relatively poor households (Fuster and Zafar, 2014).

[23] Another explanation is that homeownership is prevented by student debt burden (see Tarkazikis, 2017).

The Fixed-COFI mortgage allows quicker home equity accumulation or lower mortgage payments relative to the traditional fixed-rate mortgage. However, new mortgage contract designs have historically not succeeded in the U.S. mortgage market. As described by Shiller (2014), "Experimentation with new mortgage forms is costly since it must deal directly with the broad public, creating costs of publicity, battles with regulators, and risks of lawsuits. The benefits of the experimentation are usually public goods, available to other mortgage originators, so benefits to innovators do not defray the experimental costs." As a result, alternative mortgage products (AMPs) are costly to introduce.

Generally, using AMPs as affordable housing finance products can be problematic. Garmaise (2017) finds that current research regarding AMPs and housing affordability lacks compelling evidence to conclude that AMPs are directly harmful for lower-income less-educated households, but this research also lacks evidence to conclude that AMPs could alleviate housing affordability issues for these households.[24] Similarly, Cocco (2013) argues that AMPs "allow borrowing-constrained households to transfer resources from the future to the present, and, in this way, better smooth consumption over the life-cycle. This is welfare enhancing for individuals who expect their future labor income to be higher, perhaps because of good career prospects." LaCour-Little and Yang (2010) discuss AMPs labeled as affordable "because they allow households to borrow more relative to current income by accepting reduced (possibly negative) amortization and a greater degree of interest rate risk."

In sum, most AMPs discussed in the literature (i.e., option ARMs and interest-only mortgages) allow household payments to vary over time and are oriented toward financially sophisticated households with high expected income. In option ARMs, mortgage payments are left to the discretion of the borrower, and the borrower defaults if their total debt reaches a maximum level. In interest-only mortgages, the homeowner is only required to make interest payments; the principal is not amortized. Mortgage payments can follow the expected evolution of a homeowner's earnings, where payments are low initially but increase as the homeowner's income increases. Such mortgage designs may be optimal for many households regardless of

[24] Garmaise (2017) finds that AMPs are most effective at helping young, highly educated households buy more expensive houses. Barlvey and Fisher (2010) examine the role of alternative mortgage designs—specifically, interest only (IO) mortgages—in housing bubbles. They find that IO mortgages were used to speculate on house prices.

concerns about affordability, and, in addition, Gerardi, Rosen, and Willen (2010) find that housing markets may have become more efficient with the advent of a wider variety of mortgage contract options.

The Fixed-COFI mortgage does more than simply redesign mortgage payments to reflect the growth of borrower income. As we described previously, the Fixed-COFI mortgage actually lowers the cost of borrowing because the household agrees to forgo the type of prepayment allowed in the traditional fixed-rate mortgage. In addition, as we describe below, like other AMPs, the Fixed-COFI mortgage can be designed to shift mortgage payments such that they are lower earlier in the mortgage and larger later. These payment dynamics are a design choice, not a necessary feature. Similarly, negative amortization and greater interest rate risk can be built into the Fixed-COFI mortgage (we describe these options extensively in Passmore and von Hafften, 2017). But for the Fixed-COFI affordable housing product developed here, there is no negative amortization of the mortgage and no additional interest rate risk for the household relative to that of a traditional fixed-rate mortgage. Indeed, as shown by new mortgage designs such as the Wealth Building Home Loan and shared-equity mortgage, amortization as well as payments can act as tools for better mortgage design.[25]

Another concern about AMPs is that they are too complex for many households relative to a traditional fixed-rate mortgage. Complexity, of course, is often the nature of mortgage lending. Chambers, Garriga, and Schlagenhauf (2009) outline the complexity homeowners face when determining the best mortgage contract for them: "Households have to take into consideration many dimensions such as the downpayment, maturity of the contract, repayment structure, the ability to refinance, the possibility of being subject to borrowing constraints, and the evolution of economic variables such as the interest rate, inflation, house appreciation, and income growth." The Fixed-COFI mortgage is no more complex than a traditional fixed-rate mortgage; in particular, the Fixed-COFI mortgage has a level monthly payment, just like the traditional fixed-rate mortgage. The appealing "simplicity" of both mortgages stems from the level monthly payment.[26]

[25] 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.

[26] Of course, level payment mortgages are not simple, and households need to be educated about their borrowing options. Gathergood and Weber (2015) argue that financial literacy itself is a barrier to homeownership. They find

Some of the concern about complexity is based on the experience with subprime mortgages during the most recent financial crisis. Many observers worry that the complexity of AMPs may encourage mortgage defaults. However, Mayer, Pence, and Sherlund (2009) document the rise of mortgage defaults during and after the financial crisis. They found that looser underwriting standards, low down payments, and falling house prices resulted in many homeowners having little to no equity in their mortgages and led to the rise of mortgage defaults after house prices dropped, and "the complexity of these products does not appear to be the primary culprit for the skyrocketing delinquency and foreclosure rates." They also find that about three-fourths of subprime mortgages were "short-term hybrid" mortgages (i.e., a fixed-rate mortgage with a low teaser interest rate for a couple years that then turns into an ARM). Fixed-COFI mortgages have little in common with "short-term hybrid mortgages."

Indeed, the Fixed-COFI mortgage is designed to encourage home equity accumulation and to provide more income to the median or lower income households. In contrast, many AMPs are oriented toward higher income households. Amromin et al. (2011) "…find that such mortgages [AMPs] are used by relatively sophisticated households with high income levels and prime credit scores." Furthermore, they argue that the higher level of "…defaults are driven not only by the backloaded feature of complex mortgage payments but also by the characteristics of complex borrowers who are more strategic in their default decisions than other types of mortgage borrowers."[27]

Thus, because AMPs are often oriented to financially sophisticated borrowers with high income, AMPs may be optimal for these types of households, particularly if such households hold views about the macro economy (e.g., home price or interest rates). For example, Piskorski and Tchistyi (2010, 2011) find that option ARMs are optimal in the face of stochastic interest rates and constant house prices.[28] The welfare benefits are particularly apparent for households with volatile

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that financial literacy is lower for renters and predict that improved financial literacy would increase homeownership for younger households. Lusardi and Mitchell (2007) document widespread financial illiteracy and connect this financial illiteracy to poor household decisions regarding savings and mortgages. Survey results generally support the idea that riskier mortgages are taken on by more financially literate households (van Ooijen and van Rooij, 2016).

[27] Backloading is the deferment of mortgage costs until later in the life of the mortgage.

[28] Ghent (2015) examines mortgage choice with hyperbolic—as opposed to exponential—discounting.

incomes, households who purchase expensive homes relative to their income, and households who make negligible down payments. Similarly, Brueckner, Calem, and Nakamura (2016) find that mortgage contracts that allow backloading are more optimal when house prices are increasing and default rates are low. The Fixed-COFI mortgage is designed to create sustainable homeownership and does not embed a view about the direction of interest rates or home prices.

3. Fixed-COFI Mortgage Example

The following example highlights the potential homeowner welfare gains from Fixed-COFI mortgages. A traditional fixed-rate mortgage (with no down payment), an affordable Fixed-COFI mortgage, and a homeownership Fixed-COFI mortgage are all originated in January 1985 at the same traditional fixed-rate mortgage rate of 13.4 percent, which was the average prevailing traditional fixed-rate mortgage rate in January, and for the same house price of $64,000, which was the median in the United States in 1985:Q1.

All three mortgages have the same monthly payment of $740. Figure 4 breaks down this monthly payment into three components. The blue left-hatched area is the principal component associated with the traditional fixed-rate mortgage rate at origination. The green vertical-hatched area is the interest associated with the COFI mortgage rate, which is COFI plus a margin.[29] The interest component follows the decline in the remaining principal as well as the historical decline of COFI (and interest rates generally) over this period (see figure 2). The red right-hatched area is the residual or "wedge" between the monthly payment and the principal and interest components. These "wedges" are almost always present between traditional fixed-rate mortgage rates and COFI mortgage rates (see figure 2). In a traditional fixed-rate mortgage, the homeowner pays both the COFI interest (green vertical-hatched area) and the "wedge" (red right-hatched area) as interest to the bank. In an affordable Fixed-COFI mortgage, the homeowner only pays the COFI interest (green vertical-hatched area) to the bank and is rebated back the "wedge" (red right-hatched area). Affordable Fixed-COFI mortgages adopt the amortization schedule of a traditional fixed-rate mortgage (i.e., principal components start small and grow). Thus, the rebates are generally large earlier in the mortgage; this feature is somewhat similar to AMPs that allow backloading. In a homeownership Fixed-COFI mortgage, the homeowner pays the COFI interest

[29] In this example, the margin is set at 2 percentage points. In section 5, we discuss the margin in detail.

(green vertical-hatched area) as interest to the bank and commits to placing the "wedges" (red right-hatched area) into a home equity savings account to pay down the mortgage principal.

Figure 5 shows the remaining mortgage balance and home equity savings account balance over the life of each mortgage. The black short-dashed line shows the remaining mortgage balance for all three mortgages. The black short-dashed line follows the amortization schedule of a traditional fixed-rate mortgage. For the affordable Fixed-COFI mortgage, the long-dashed green line shows the cumulative sum of payment rebates (i.e., the cumulative sum of the red right-hatched areas from figure 4) over the term of the mortgage. After 30 years, the total amount rebated is about $100,000. The solid blue line is the home equity savings account balance for the homeownership Fixed-COFI mortgage. Each month, the balance of the home equity savings account is the previous balance plus interest and any current "wedge." The interest on the home equity savings account pushes the home equity savings account balance higher than the cumulative payment rebates. After about 12 years (dotted orange line), the homeownership Fixed-COFI mortgage is fully paid off because the balance of the home equity savings account exceeds the remaining mortgage balance.

Figure 5 also highlights how default risks evolve for homeownership Fixed-COFI mortgages. In this homeownership Fixed-COFI mortgage, the homeowner owns over 25 percent of the house after just 5 years, and homeowner equity rises to almost 75 percent after 10 years; in contrast, a homeowner with this traditional fixed-rate mortgage (or this affordable Fixed-COFI mortgage) owns only 1.8 percent of her home after 5 years and 5.3 percent after 10 years. 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 because of the lack of a down payment. Because home equity rapidly accumulates in homeownership Fixed-COFI mortgages, borrower default risks likely fall substantially in the early years of the mortgage.[30] 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 homeownership Fixed-COFI mortgages have

[30] 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.

the same underwriting standards as traditional fixed-rate mortgages, the credit risk from homeownership Fixed-COFI mortgages may be less than or equal to the credit risk from traditional fixed-rate mortgages.

Figure 6 shows the cumulative homeowner costs over the life of each mortgage. For a traditional fixed-rate mortgage, the homeowner makes the same monthly payment for 30 years, so the cumulative cost is simply a straight line with a slope of the monthly payment of $740 (red short-dashed line). The total cost of the example traditional fixed-rate mortgage is $266,400 ($= \$740 \text{ per month} * 30 \text{ years} * 12 \text{ months}$). For an affordable Fixed-COFI mortgage, the homeowner makes the same monthly payment but is rebated the "wedges." Thus, the cumulative cost of an affordable Fixed-COFI mortgage (green long-dash line) is the cumulative cost of a traditional fixed-rate mortgage minus the cumulative payment rebates (i.e., the difference between the green long-dashed line and the red short-dashed line is the long-dashed green line from figure 5). The total cost of the example affordable Fixed-COFI mortgage is about $166,000 ($\approx \$740 \text{ per month} * 30 \text{ years} * 12 \text{ months} - \$100{,}000 \text{ of rebates}$). For a homeownership Fixed-COFI mortgage, the homeowner makes the same monthly payment until the home equity savings account is sufficient to cover the remaining mortgage balance. The cumulative cost of the homeownership Fixed-COFI mortgage (solid blue line) follows the cumulative cost of the traditional fixed-rate mortgage for the first 12 years (i.e., left of orange dotted line). After 12 years, the homeownership Fixed-COFI mortgage is fully paid off, and the homeowner makes no more monthly payments (i.e., the blue line is horizontal right of the orange dotted line). The total cost of the homeownership Fixed-COFI mortgage is about $107,000 ($\approx \$740 \text{ per month} * 12 \text{ years} * 12 \text{ months}$).

This example highlights potential homeowner equity gains. By choosing an affordable Fixed-COFI mortgage, the homeowner saves about $100,000 (or over 150 percent of the house price), and by choosing a homeownership Fixed-COFI mortgage, the homeowner saves about $160,000 (or about 250 percent of the house price). We now turn to a more general description of the Fixed-COFI mortgage.

4. Fixed-COFI Mortgage Contract Mechanics

Savings from the Fixed-COFI mortgage stem from the structure of the contract.[31] In general, fixed-payment contracts may be described using two characteristics: home equity accumulation and refinancing opportunities (see table 1). Prepayment penalties were prevalent in traditional fixed-rate mortgage contracts before the 1970s, but homeowners with these contracts did not benefit from falling interest rates.[32] After the 1970's, households with traditional fixed rate mortgages can freely spend savings from refinancing. The Fixed-COFI mortgage limits refinancing opportunities in two ways. First, as discussed, the homeowner does not pay capital markets investors for the option of locking in a lower mortgage rate for the term of the mortgage. Second, the homeowner benefits from falling interest rates. With affordable Fixed-COFI mortgages, the homeowner is rebated more of her payment when interest rates fall. With homeownership Fixed-COFI mortgages, the homeowner makes home equity payments and reduces mortgage principal whenever interest rates are low. The homeowner commits the savings from low interest rates to paying down her mortgage.

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. The monthly payment for such a mortgage (with no down payment) is calculated as follows:

$$Payment = \frac{F_0 * (1 + F_0)^{360}}{(1 + F_0)^{360} - 1} * House\ Price,$$

where F_0 is the traditional fixed-rate mortgage rate at origination. As discussed in the previous section, this mortgage payment can be broken into principal and interest. Early in the term of the mortgage, the payments are mostly interest; as time passes, more of each payment goes to paying

[31] 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 an increasing 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.

[32] See Harmon (1963) for a discussion of prepayment penalties included in pre-1970s fixed-rate mortgages.

down the principal. We can isolate the principal component of each monthly payment by subtracting interest due on a traditional fixed-rate mortgage ($= F_0 * Mortgage_t$):

$$Principal_t = Payment - F_0 * Mortgage_t$$

where t is the number of months after origination. As the homeowner pays down this amount of principal each month, the mortgage balance ($Mortgage_t$) is paid off over 30 years:

$$Mortgage_t = \frac{(1 + F_0)^{360} - (1 + F_0)^t}{(1 + F_0)^{360} - 1} * House\ Price$$

Figure 7 outlines the contract mechanics and cash flows associated with Fixed-COFI mortgages. Many elements of the traditional fixed-rate mortgage extend to the Fixed-COFI mortgage. Each month, a homeowner with a Fixed-COFI mortgage makes the same monthly payment as a homeowner with a traditional fixed-rate mortgage. In figure 7, the payment is represented by the arrow from the household. In addition, the amount of the payment that pays down the principal in a Fixed-COFI mortgage is the same as the principal component of the traditional fixed-rate mortgage.

The primary difference between the Fixed-COFI mortgage and the traditional fixed-rate mortgage is that *the interest paid to the bank for Fixed-COFI mortgages is based on the COFI mortgage rate* (instead of the traditional fixed-rate mortgage rate):

$$Interest_t = (COFI_t + GM) * Mortgage_t$$

where $COFI_t$ is the COFI t months after origination and GM is the gross margin. In figure 7, the sum of the principal component and the interest component is represented by the arrow toward the bank.

Because interest in Fixed-COFI mortgages is not tied to the traditional fixed-rate mortgage rate at origination, the sum of the principal component and the interest component does not necessarily equal the payment. In most periods, there is money left over, or a "wedge" (shown in the top panel of figure 7). Define $I(t)$ to indicate months with a "wedge." "Wedges" occur if the interest due is less than the payment after subtracting the principal component:

$$I(t) = \begin{cases} 1, COFI_t + GM \leq F_0, \\ 0, otherwise. \end{cases}$$

The "wedge" is the difference between the payment and the principal component and the interest component:

$$\begin{aligned} Wedge_t &= I(t) * (Payment - Principal_t - Interest_t) \\ &= I(t) \\ &\quad * [Payment - (Payment - F_0 * Mortgage_t) - (COFI_t + GM) * Mortgage_t] \\ &= I(t) * (F_0 - COFI_t - GM) * Mortgage_t \end{aligned}$$

In figure 7, α indicates the destination of the "wedge." In affordable Fixed-COFI mortgages, the "wedges" are rebated back to the household. In figure 7, α equals one, and the payment rebate is represented by an arrow toward the household. These payment rebates effectively lower the household's monthly payment. In homeownership Fixed-COFI mortgages, the "wedge" is instead placed into a home equity savings account. In figure 7, α equals zero, and the home equity savings account deposit is represented by an arrow toward the home equity savings account. The accumulated "wedges" in the home equity savings account effectively pay down the principal, so the household purchases the home quicker. The home equity savings account balance ($Balance_t$) is the previous balance with interest plus the current "wedge":

$$Balance_t = Balance_{t-1} * (1 + COFI_t + GM) + Wedge_t$$

By the choice of α, the homeowner is choosing between lowering her monthly payments and purchasing her home faster. The affordable Fixed-COFI mortgage and the homeownership Fixed-COFI mortgage may appear to be two different mortgages, but they represent the two extreme cases of a single mortgage design. A homeowner can choose a balance between lower monthly payments and more rapid home equity accumulation from the continuum between the affordable Fixed-COFI mortgage and the homeownership Fixed-COFI mortgage.

In some periods, the payment is insufficient to cover principal and interest (shown in the bottom panel of figure 7). In these months, the household's entire payment goes to the bank (i.e., no payment rebate and no home equity savings account deposit), and insurance covers the shortfall between principal and interest and the payment:

$$
\begin{aligned}
Insurance_t &= \big(1 - I(t)\big) * (Principal_t + Interest_t - Payment) \\
&= \big(1 - I(t)\big) \\
&\quad * [(Payment - F_0 * Mortgage_t) + (COFI_t + GM) * Mortgage_t - Payment] \\
&= \big(1 - I(t)\big) * (COFI_t + GM - F_0) * Mortgage_t
\end{aligned}
$$

Premiums for this insurance are built into the gross margin from the outset of the mortgage. The cost of this insurance determines the viability of Fixed-COFI mortgages. We measure these costs explicitly in section 5.

When do Fixed-COFI mortgages mature? Define n as the maturity of a mortgage in months. For affordable Fixed-COFI mortgages, the mortgage is fully paid off after 30 years: $n = 360$. For homeownership Fixed-COFI mortgages, once the home equity savings account has enough funds to pay off the remaining mortgage balance, the mortgage ends:

$$n = \min\{t | Balance_t \geq Mortgage_t\} \leq 360$$

We now turn to estimating the COFI mortgage rate.

5. COFI Mortgage Rates

The COFI mortgage rate is the nationwide average cost of funds index for the banking system plus a gross margin. COFI is equal to the total interest expenses of domestic commercial banks divided by their total interest-bearing liabilities.[33] COFI is determined both by short-term rates (e.g., one-year Treasury yields) and by deposit rates.[34] 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):

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

[33] COFI is derived quarterly from FFIEC Call Reports.

[34] Using COFI as an adjustable-rate mortgage 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.

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 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 of Passmore and von Hafften (2017), 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 8 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.

An important element of the COFI mortgage rate 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 that more of the household's monthly payment is directed to interest (instead of being rebated or paying down the principal). Hancock and Passmore (2016a) show that profitable margins on COFI-indexed ARMs are almost always between 1.75 and 2.5 percentage points (shown in figure 9).[35]

The gross margin covers credit risk insurance, servicing costs, and a return on equity (M):

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

Based on Hancock and Passmore (2016a) and FHFA (2016), we assume that the credit risk insurance premium (or "g-fee") is 65 basis points, and the servicing fee is 35 basis points. In periods when the COFI mortgage rate is below the traditional fixed-rate mortgage rate at origination, a higher return on equity means the bank takes more of the "wedge."

[35] Hancock and Passmore (2016a) use a time-varying technique to calculate net margins, which results in a mean profitable gross margin of 2.2 percent with a standard deviation of 16 basis points (see their table 2). 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 $Income = (COFI + GM) * A - COFI * L$, where A is COFI-based assets and L is interest-bearing liabilities. Let $L = A - K$, where K is equity capital. Then the return on equity is $\frac{Income}{K} = (GM * LEV + COFI)$, where $LEV = A/K$ is the bank's leverage. If leverage is 20 times a mortgage (the current risk-based capital weight on mortgages), then the return on equity for a gross margin of 2 percent and COFI of 5 percent is 45 percent. For a leverage of 10 times capital, a gross margin of 2 percent, and COFI of 2 percent, the 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.

Unlike COFI ARMs, Fixed-COFI mortgages include premiums for payment shortfall insurance. Because most mortgage insurance (either private or through the Federal Housing Administration) is based on the initial loan amount, households are charged a fixed dollar fee on top of their monthly mortgage payment. However, our mortgage insurance is provided as a contractual commitment by a mortgage originator to cover mortgage payment shortfalls. As a result, we instead adopt a time-varying markup that is calculated as part of the return on equity.

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

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

The profit from holding Fixed-COFI mortgages is the interest revenue minus the four costs (interest, servicing fees, g-fees, and payment shortfall insurance payouts):

$$\begin{aligned}\pi_{FixedCOFI} = &\sum_{t=1}^{n}[(COFI_t + GM) * Mortgage_t] - [COFI_t * Mortgage_t] \\ &- [servicing\ fee * Mortgage_t] - [gfee * Mortgage_t] \\ &- \left[\left(1 - I(t)\right) * (COFI_t + GM - F_0) * Mortgage_t\right] \\ = &\sum_{t=1}^{n}\left[M - \left(1 - I(t)\right) * (COFI_t + GM - F_0)\right] * Mortgage_t\end{aligned}$$

where $I(t)$ equals one when the COFI mortgage rate exceeds the traditional fixed-rate mortgage rate at origination.

The profit from holding Treasuries funded by COFI liabilities is the sum of the difference between the Treasury yield and COFI times the remaining mortgage balance:[36]

[36] The profit from holding Treasuries is a measure of the return from investing in a deposit franchise. One element of a deposit franchise is the availability of nonmarket-based funds. Fixed-COFI mortgages allow the bank to exploit this feature of a deposit franchise.

$$\pi_{Treasury} = \sum_{t=1}^{n} T_t * Mortgage_t - \sum_{t=1}^{n} COFI_t * Mortgage_t$$
$$= \sum_{t=1}^{n} (T_t - COFI_t) * Mortgage_t.$$

For investors to be indifferent between Fixed-COFI mortgages and Treasuries, we set the expected profit from a portfolio of Fixed-COFI mortgages to the expected profit from a portfolio of Treasuries:

$$M^* = \min\left\{M \left| E\left[\sum_{t=1}^{n} M * Mortgage_t - I(t) * (COFI_t + GM - F_0) * Mortgage_t\right]\right.\right.$$
$$\left.\left. \geq E\left[\sum_{t=1}^{n} (T_t - COFI_t) * Mortgage_t\right]\right\}\right.$$

The size of the profit margin is a factor in determining whether a period has a payment shortfall. An increase in the net margin increases both interest revenue and the payment shortfalls. Because of this circularity, we cannot specify the exact function for M^*; we instead calculate M^* using numerical simulations.[37]

We calculate M^* separately for each quarter of historical initial conditions. For each quarter, we produce 5,000 simulated Treasury yield paths, which each start at the Treasury yield in the given quarter and evolve based on the following Treasury random walk process:[38]

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

where T_0 is the Treasury yield at origination, and ε_t is the change in Treasury yield in period t. For each path, we draw a sequence of ε_t from a normal distribution with mean of zero and standard

[37] We assume creditworthy borrowers and constant house prices. As our purpose is comparing 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.

[38] Appendix II of Passmore and von Hafften (2017) discusses the robustness of Fixed-COFI mortgage performance with other Treasury models.

deviation of .23. The standard deviation is the residual standard error of the AR(1) model in table 3. These shocks are the stochastic drivers of the simulations. For each Treasury path, we calculate a path of COFIs. Each COFI path starts at the COFI in the given quarter, using the partial adjustment process (shown in table 2). For each COFI path, we can simulate the cash flows of a Fixed-COFI mortgage based on the contract mechanics outlined in section 4.[39]

On the first pass, we set M to zero. Over the 5,000 interest rate environments, we calculate the expected profit from a portfolio of Fixed-COFI mortgages and the expected 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 is necessarily true on the first pass because the net margin is set at zero), we increment M 5 basis points and recalculate the Fixed-COFI mortgage cash flows with the (incremented) M over the same 5,000 COFI paths. We continue incrementing M and recalculating Fixed-COFI mortgage cash flows until the expected profit of the Fixed-COFI mortgage portfolio is larger than the expected profit of the Treasury portfolio. When we stop, M is the smallest margin (within 5 basis points) for which the expected return on a Fixed-COFI portfolio exceeds the expected return on a Treasury portfolio.

Figure 9 shows time-varying gross margins based on M^*. Gross margins based on M^* for affordable Fixed-COFI mortgages and for homeownership Fixed-COFI mortgages are very similar. Gross margins based on M^* generally fall below or at the lower end of the range of gross margin estimates from Hancock and Passmore (2016a). The notable exception is during the housing bubble in the 2000s, when gross margins crest to about 3 percentage points.

Because both banks and consumers may prefer constant margins over time (i.e., menu costs, simplicity, etc.), we propose the following rule of thumb: Set the gross margin to 2 percentage points. Using this rule of thumb, figure 10 shows the expected profit from a Fixed-COFI portfolio minus the expected profit from a Treasury portfolio. As suspected, the Treasury portfolios are more profitable in periods when the gross margin based on M^* is higher than the rule of thumb. Profits from affordable Fixed-COFI mortgages are higher than profits from homeownership Fixed-COFI mortgages in periods when the latter end particularly quickly. In

[39] Appendix III of Passmore and von Hafften (2017) presents more detailed examples of our Fixed-COFI mortgage simulation technique.

section 6, we examine homeowner welfare using Fixed-COFI mortgages with rule-of-thumb gross margins. Because 2 percentage points is higher than the gross margin based on M^* in nearly every period, our analysis of homeowner welfare is predicated on the fact that the mortgages are highly profitable assets for the bank.

In figure 2, we compare our estimated COFI mortgage rates using our rule-of-thumb gross margin (blue dotted line) and the effective rates on 30-year fixed-rate first-lien prime conventional conforming home-purchase mortgages with 20 percent down (or "traditional fixed-rate mortgage rates;" red line). 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 sit considerably below traditional fixed-rate mortgage rates in most periods.

6. Homeowner Welfare

The "wedges" are the key to homeowner welfare gains from Fixed-COFI mortgages. If "wedges" are frequent and large, homeowners either receive frequent large payment rebates or own their home much sooner. What interest rates at origination make "wedges" more likely and larger? We first calculate the expected value of $I(t)$, which indicates whether month t has a "wedge":

$$\begin{aligned} E[I(t)] &= 1 * \Pr\{COFI_t + GM \leq F_0\} + 0 * \Pr\{COFI_t + GM > F_0\} \\ &= \Pr\{COFI_t \leq F_0 - GM\} \end{aligned}$$

Thus, higher traditional fixed-rate mortgage rates at origination increase the likelihood of "wedges." Lower gross margins also increase the likelihood of "wedges." Furthermore, based on the Treasury random walk and the COFI partial adjustment model, $COFI_t$ is normally distributed with the following mean:[40]

[40] Detailed derivations are in appendix I of Passmore and von Hafften (2017). The variance of $COFI_t$ is as follows:

$$Var[COFI_t] = \beta^2 \sum_{i=1}^{t} \alpha^{2(t-i)} \sum_{j=1}^{i} \sigma_\varepsilon^2 + \sum_{i=1}^{t} \alpha^{2(t-i)} \sigma_\delta^2.$$

$$E[COFI_t] = \alpha^t COFI_0 + \beta T_0 \sum_{i=1}^{t} \alpha^{t-i}$$

Lower COFIs and/or lower one-year Treasury yields at origination decrease the expected value of $COFI_t$ and, thus, increase the likelihood of "wedges." The importance of COFI at origination diminishes over time (because $\alpha < 1$), but the one-year Treasury yield at origination persists as an important factor:

$$\lim_{t\to\infty} E[COFI_t] = \frac{\beta}{1-\alpha}\, T_0.$$

We now derive the expected size of the "wedge." A "wedge" exists when the current COFI mortgage rate is less than the traditional fixed-rate mortgage rate at origination ($I(t) = 1$). We condition the expected "wedge" on the remaining mortgage balance:

$$\begin{aligned} &E[Wedge_t | Mortgage_t, I(t) = 1] \\ &\quad = E[I(t) * (F_0 - COFI_t - GM) * Mortgage_t | Mortgage_t, I(t) = 1] \\ &\quad = (F_0 - E[COFI_t] - GM) * Mortgage_t \\ &\quad = \left(F_0 - \alpha^t COFI_0 - \beta T_0 \sum_{i=1}^{t} \alpha^{t-i} - GM\right) * Mortgage_t. \end{aligned}$$

The same interest rate conditions that make "wedges" more likely also make them larger. "Wedges" are larger for higher traditional fixed-rate mortgage rates, lower COFIs, and lower one-year Treasury yields at origination. Lower gross margins also increase the size of "wedges." As seen in figures 11, 12, and 13, Fixed-COFI mortgages perform better for higher traditional fixed-rate mortgage rates and for wider spreads between traditional fixed-rate mortgage rates and one-year Treasury yields.

We provided an example of the Fixed-COFI mortgage in section 3. How representative are the homeowner welfare gains from that example? Using the simulation technique described in section 5, we examine homeowner welfare across a variety of interest rate environments. We consider each historical quarter separately. For each quarter, the COFI, one-year Treasury yield, and traditional fixed-rate mortgage rate from that quarter are the interest rates at origination. For each quarter, we produce 5,000 paths of one-year Treasury yields using a random walk process

(described in section 5). These paths are then fed into a partial adjustment model (shown in table 2) to produce 5,000 paths of COFI. With the gross margin set at 2 percentage points (the black dotted line in figure 9), we calculate the cash flows for Fixed-COFI mortgages over these 5,000 COFI paths.

Affordable Fixed-COFI mortgages aim to lower mortgage payments. How low can affordable Fixed-COFI mortgages push monthly mortgage payments through payment rebates? Figure 11 shows the 5th, 50th, and 95th percentiles of total payment rebates for affordable Fixed-COFI mortgages on median-priced homes in the U.S. Consistent with the analytical argument above, the total payment rebates increase for periods with higher traditional fixed-rate mortgage rates and wider spreads between the traditional fixed-rate mortgage rate and the one-year Treasury yield.[41] In particular, during periods of interest rate declines (e.g., 2007:Q2 through 2009:Q2), the payment rebates increase sharply. In these periods, premiums for prepayment options embedded in traditional fixed-rate mortgage rates often increase substantially; thus, the savings of Fixed-COFI mortgages also increase. These rebate dynamics are consistent with mortgages that reduce housing market volatility, consumption volatility, and default, as described by Guren, Krishnamurthy, and McQuade (2017); the key characteristic of such mortgages is immediate and substantial payment relief to liquidity-constrained households during market downturns.

Table 4 shows the front-end debt-to-income ratios (DTIs) for the 25 largest MSAs in the United States in 2008:Q3 and 2016:Q2.[42] For these quarters, we calculate DTIs before payment rebates and expected DTIs after payment rebates. Front-end DTIs are calculated as the annual sum of mortgage payments (with or without subtracting the expected payment rebate) for the median-priced house divided by moderate income.[43] In contrast, back-end DTIs would include the cost of servicing nonmortgage-related debts (e.g., credit card payments).

[41] This observation 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).

[42] MSAs are ordered by size of population.

[43] We define moderate income as 80 percent of median income.

In general, maximum acceptable DTI standards range between 28 and 43 percent. On the low end of maximum acceptable DTIs, the commonplace rule of thumb for the front-end DTIs for conventional mortgages is 28 percent (e.g., in Investopedia, 2017). This cutoff may be too low for high-cost metropolitan areas. On the high end of maximum acceptable DTIs, some mortgage conventions—such as Qualified Mortgages and FHA-insured mortgages—use back-end ratios of 43 percent and do not specify a front-end ratio.[44] For the purposes of this paper, we consider DTIs over 43 percent as unaffordable, DTIs between 43 percent and 28 percent as a gray area, and DTIs under 28 percent as affordable.

In 2016:Q2 (second column of table 4), the expected after-rebate DTIs for three Californian MSAs—San Francisco, Los Angeles-Long Beach-Anaheim, and San Diego—exceed 43 percent. Redirecting the prepayment risk "wedges" toward lower monthly mortgage payments are unlikely to alleviate affordability pressures in these MSAs. The expected after-rebate DTIs for New York, Miami-Fort Lauderdale, Boston, Riverside, Seattle, Denver, Portland, and Sacramento fall between 28 percent and 43 percent. These MSAs may be helped by affordable Fixed-COFI mortgages, depending on the affordability benchmark adopted. The expected after-rebate DTIs in all other MSAs fall below 28 percent. This analysis suggests that, in 2016:Q2, affordable Fixed-COFI mortgages are only marginally helpful in alleviating affordable housing pressures in many areas in the United States because the traditional fixed-rate mortgage rate is nearly at a historic low and the zero lower bound constrains the one-year Treasury yield.

In contrast, when traditional fixed-rate mortgage rates are higher and spreads between traditional fixed-rate mortgage rates and one-year Treasury yields are wider, the rebates from affordable Fixed-COFI mortgages can be substantial. For example, the difference between before-rebate DTIs and expected after-rebate DTIs for mortgages originated in 2008:Q3 can be greater than 10 percentage points (first column of table 4).

[44] For example, FHA mortgage insurance has the following requirement: "The relationship of total obligations to income is considered acceptable if the total mortgage payment and all recurring monthly obligations do not exceed 43% of the gross effective income" (HUD Handbook 4155.1, Chapter 4, Section F). A back-end DTI of 43 percent is also the standard for qualified mortgages: "…the general rule requires that monthly payments be calculated based on the highest payment that will apply in the first five years of the loan and that the consumer have a total (or "back-end") debt-to-income ratio that is less than or equal to 43 percent." (CFPB, 2013).

The homeownership Fixed-COFI mortgage is oriented toward speeding up home purchase. The savings from the homeownership Fixed-COFI mortgage stem from the mortgage ending earlier than the traditional fixed-rate mortgage (instead of monthly payment rebates, as in affordable Fixed-COFI mortgages). How quickly can homeowners buy their homes with homeownership Fixed-COFI mortgages? For traditional fixed-rate mortgages, the number of months, m, to accrue x percent equity is as follows:

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

Because the affordable Fixed-COFI mortgage accumulates equity in the same fashion as the traditional fixed-rate mortgage, this formula extends to the affordable Fixed-COFI mortgage. A deterministic formula cannot be used to determine equity accumulation for homeownership Fixed-COFI mortgages. The expected time for repayment of these mortgages requires simulations because the stochastic "wedges" help purchase the home.

Figure 12 shows the 5th, 50th, and 95th percentiles of homeownership Fixed-COFI mortgage maturity (blue lines). By construction, both traditional fixed-rate mortgages and affordable Fixed-COFI mortgages pay off after 30 years (red and green dashed line). However, if a homeownership Fixed-COFI mortgage experiences any "wedges," it pays off early. As usual, homeownership Fixed-COFI mortgages end particularly early in periods with higher traditional fixed-rate mortgage rates and wider spreads between traditional fixed-rate mortgage rates and one-year Treasury yields. Indeed, under favorable conditions the homeowner can fully own her home in fewer than 20 years.

Homeownership Fixed-COFI mortgages are also oriented toward rapid home equity accumulation in order to offset the need for a down payment. Figure 13 shows the time mortgages take to accrue 20 percent equity, or "the credit risk threshold."[45] In figure 13, the green and red dashed line indicates how long traditional fixed-rate mortgages and affordable Fixed-COFI mortgages take to accrue 20 percent equity. For homeownership Fixed-COFI mortgages, the "wedges" accelerate home equity accumulation. In figure 13, the blue solid lines show the 5th, 50th, and 95th percentiles of the time homeownership Fixed-COFI mortgages take to reach the

[45] At this equity threshold, the credit risk of a mortgage with no down payment is equal to the credit risk of a mortgage with the more prototypical down payment of 20 percent (assuming similar underwriting, etc.).

credit risk threshold. Once again, homeownership Fixed-COFI mortgages reach the credit risk threshold particularly quickly in periods with higher traditional fixed-rate mortgage rates and wider spreads between traditional fixed-rate mortgage rates and one-year Treasury yields. In many periods, homeownership Fixed-COFI mortgages reach the threshold in less than 8 years.

As described in section 1, figure 1 shows the expected total homeowner cost for traditional fixed-rate mortgages, affordable Fixed-COFI mortgages, and homeownership Fixed-COFI mortgages. Homeowners could save many thousands of dollars by choosing Fixed-COFI mortgages over traditional fixed-rate mortgages. The cash flow produced by the homeowner forfeiting their option to refinance can lower the total cost of borrowing either by lowering monthly mortgage payments or by speeding up the purchase of their home—or an intermediate combination of these features.

7. 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. Moreover, Fixed-COFI mortgages may help many renters purchase homes and become homeowners with substantial home equity wealth. Is it time to improve the traditional fixed-rate mortgage and make homeownership more affordable?

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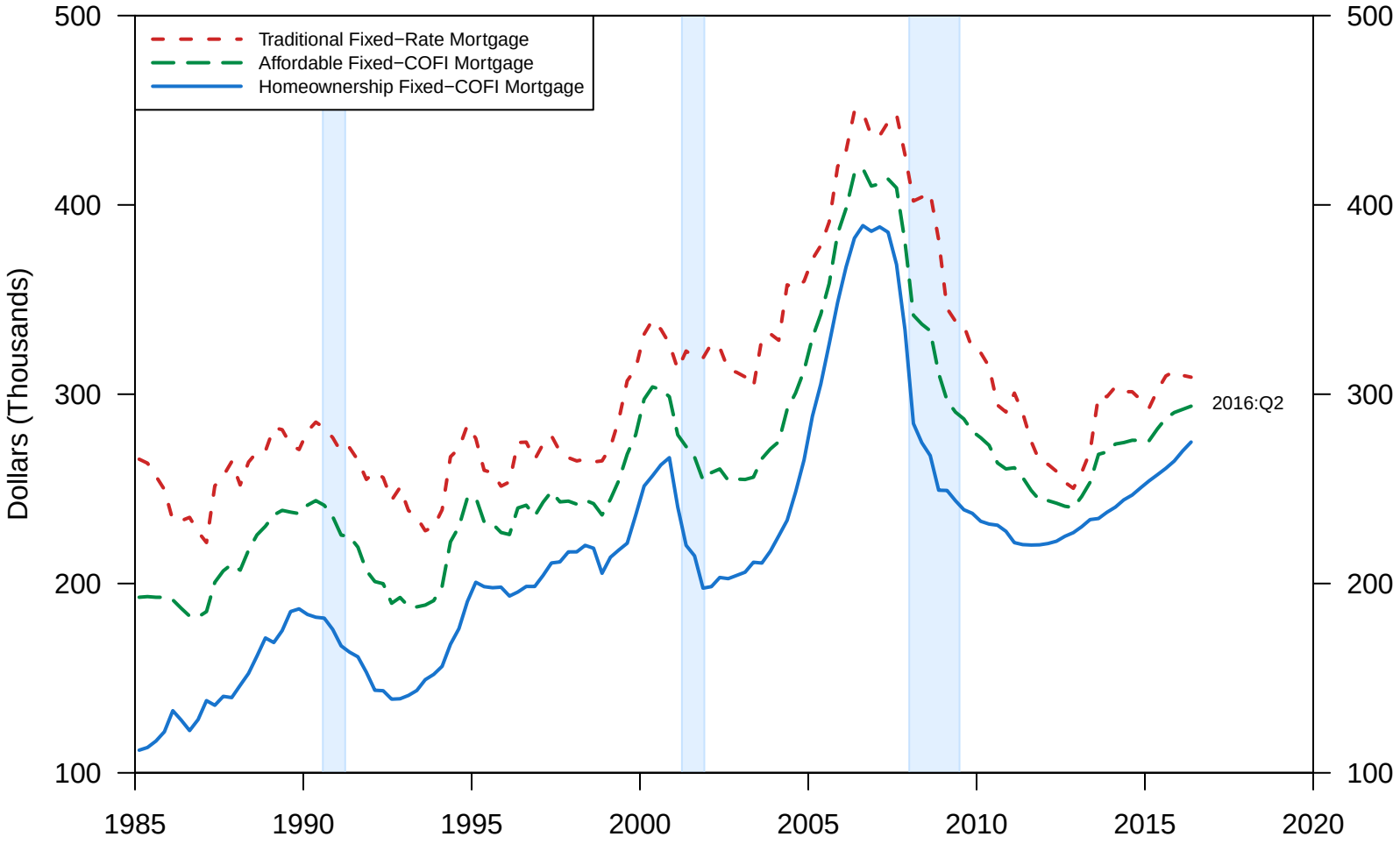
Figure 1

Expected Total Homeowner Cost

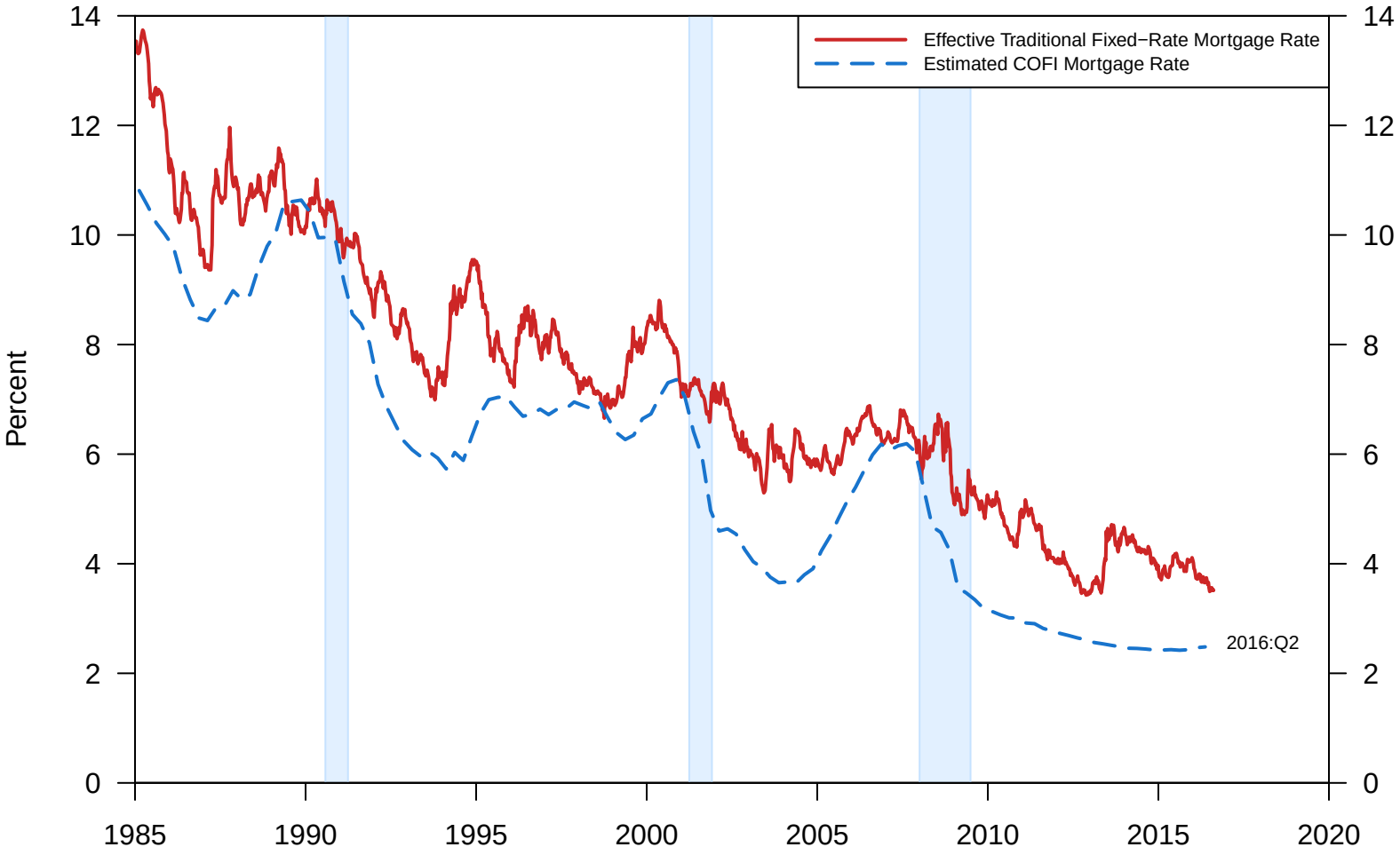


Note: Simulation results are based on 5,000 stochastic interest rate environments per quarter. Gross margins are 2 percentage points. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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 2

Mortgage Rates

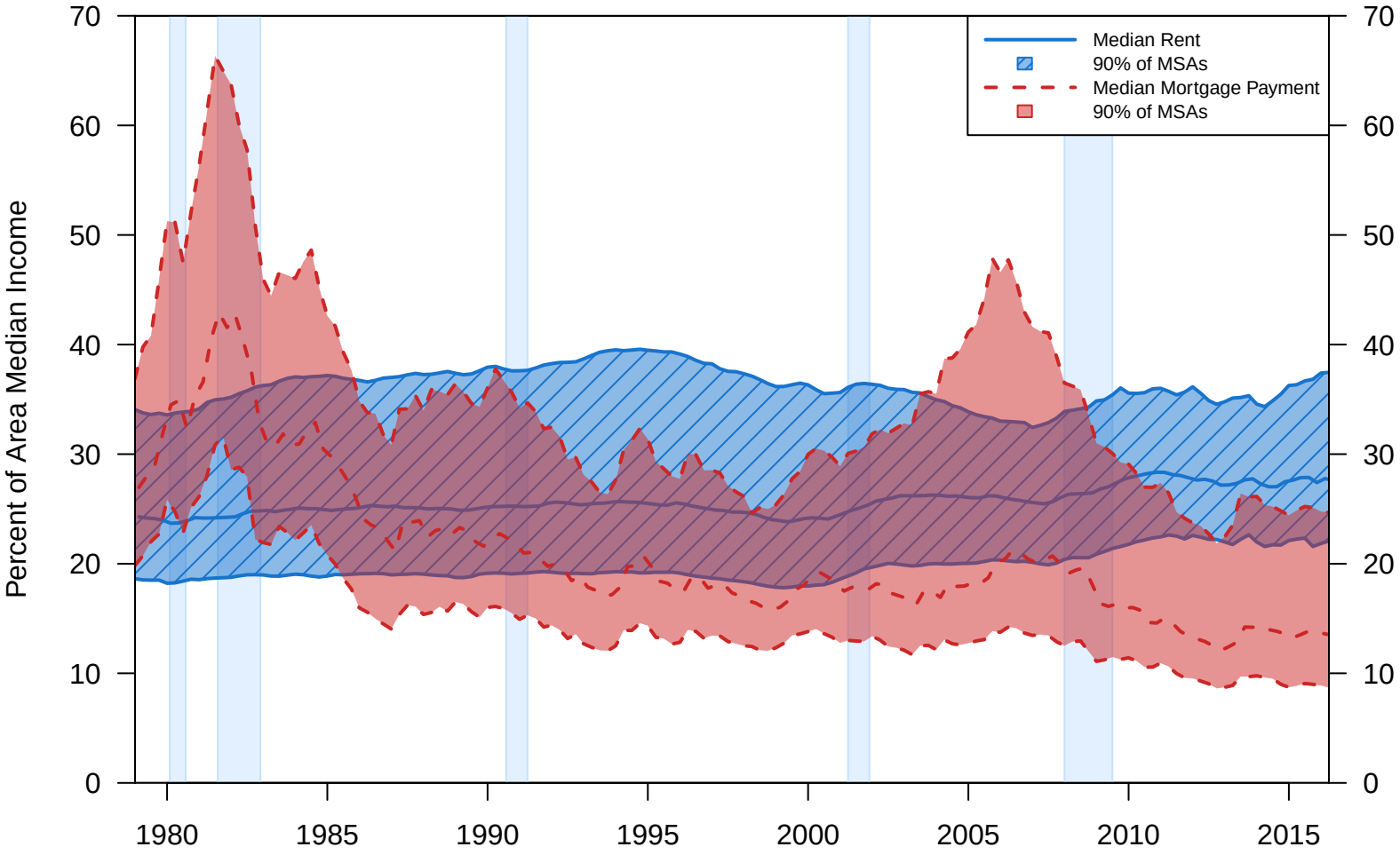


Note: Estimated COFI mortgage rates are quarterly with a gross margin of 2 percentage points. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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.

Figure 3

Changing Relative Housing Affordability

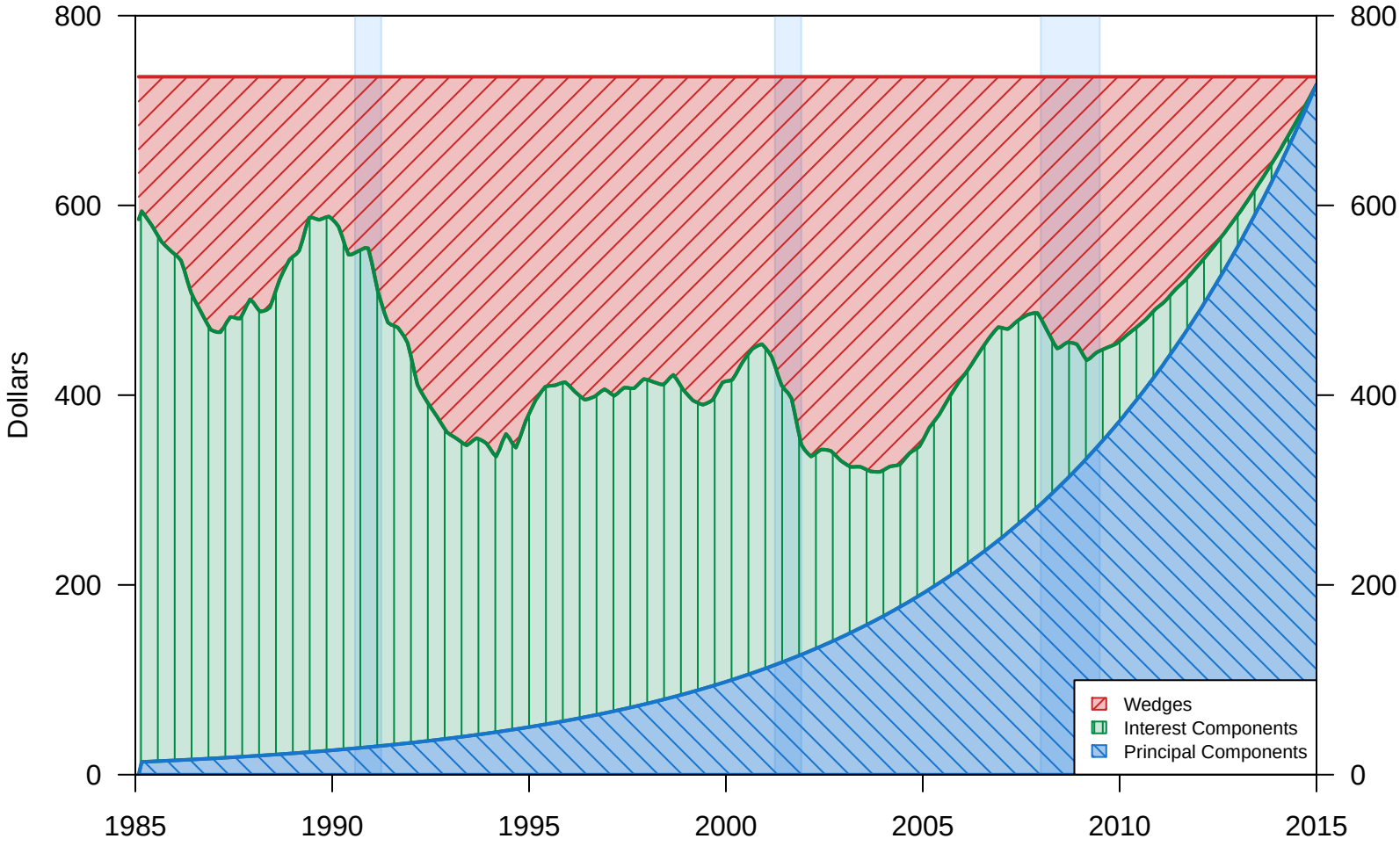


Note: Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research. Authors' calculations use Zillow Rent Index and Zillow Home Value Index of 916 metropolitan statistical areas (MSAs). Mortgage payments are based on a 30−year fixed−rate fully amortizing mortgage with 20 percent down. Mortgage rates are quarterly averages.

Source: Fixed−Rate Mortgage Rates are weekly Freddie Mac Primary Mortgage Market Survey data available at http://www.freddiemac.com/pmms/pmms_archives.html. Zillow data are available at https://www.zillow.com/research/data/.

Figure 4

Example: Payment Breakdown

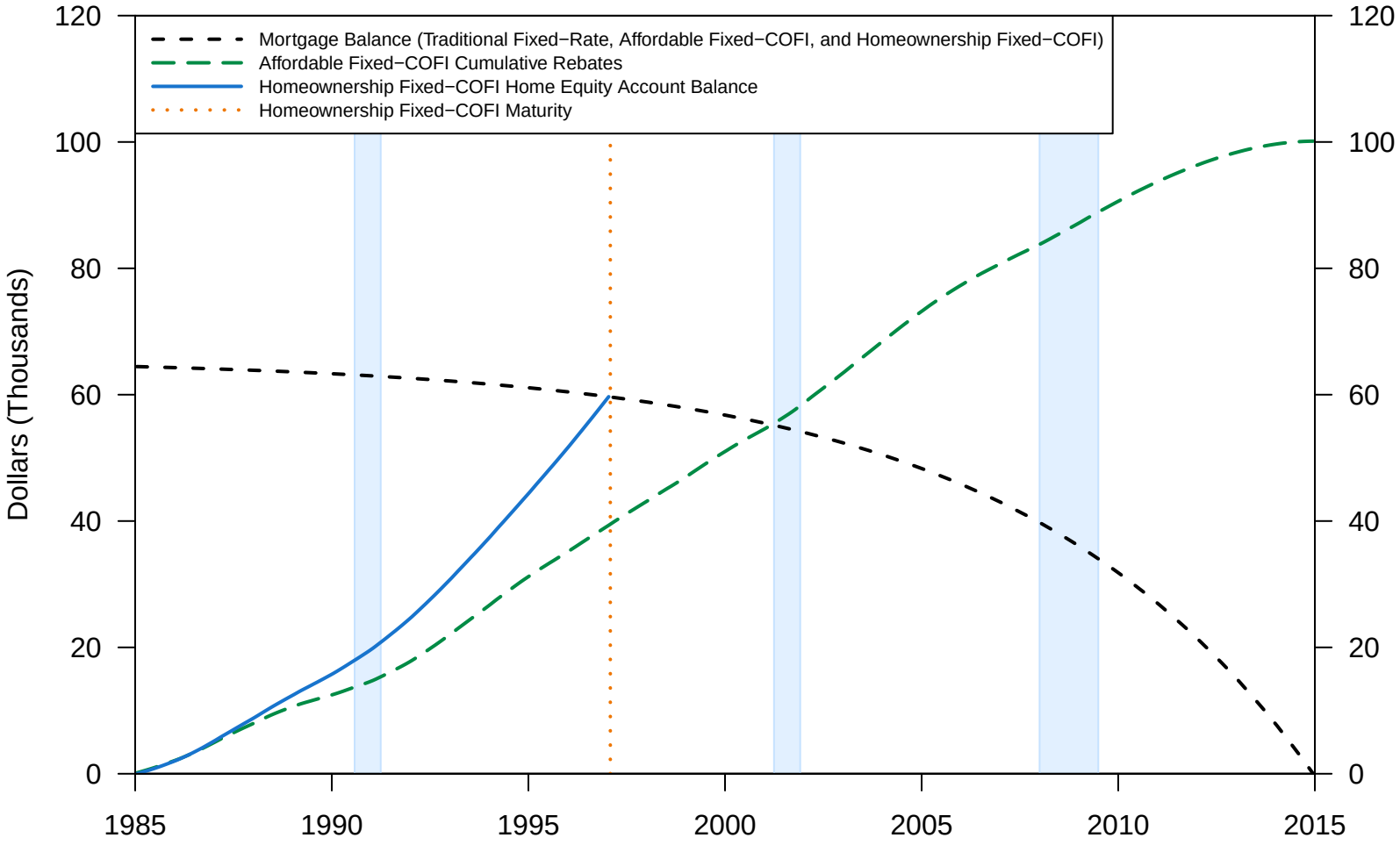


Note: Mortgages are originated in January 1985 with no down payment and 30−year maturity. The house price is $64,000, which was the median for the United States in 1985:Q1. The household payment is $740. Gross margins are 2 percentage points. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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.

Figure 5

Example: Mortgage Balance and Home Equity Account Balance

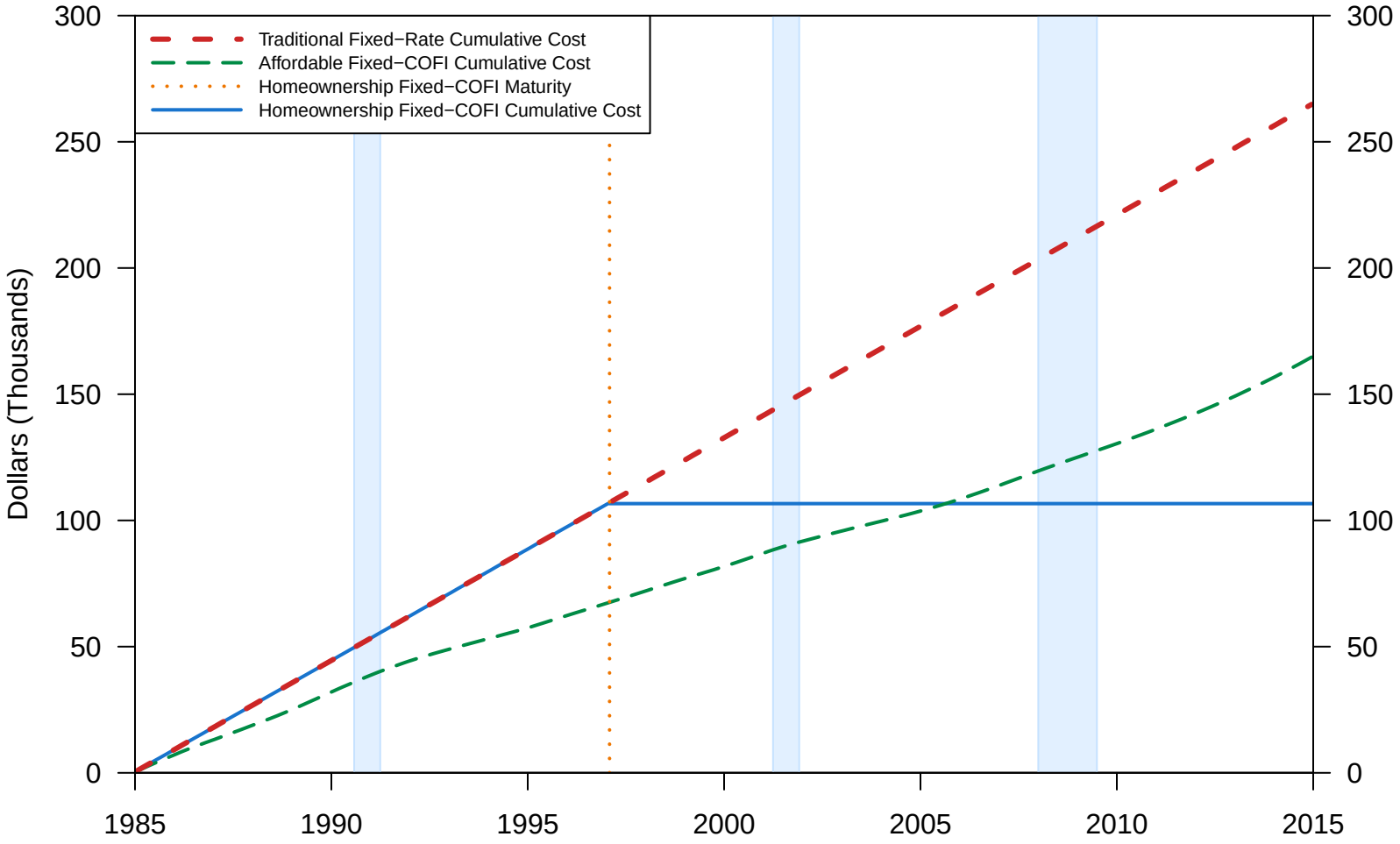


Note: Mortgages are originated in January 1985 with no down payment and 30−year maturity. The house price is $64,000, which was the median for the United States in 1985:Q1. Gross margins are 2 percentage points. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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.

Figure 6

Example: Cumulative Homeowner Cost



Note: Mortgages are originated in January 1985 with no down payment and 30−year maturity. The house price is $64,000, which was the median for the United States in 1985:Q1. Gross margins are 2 percentage points. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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.

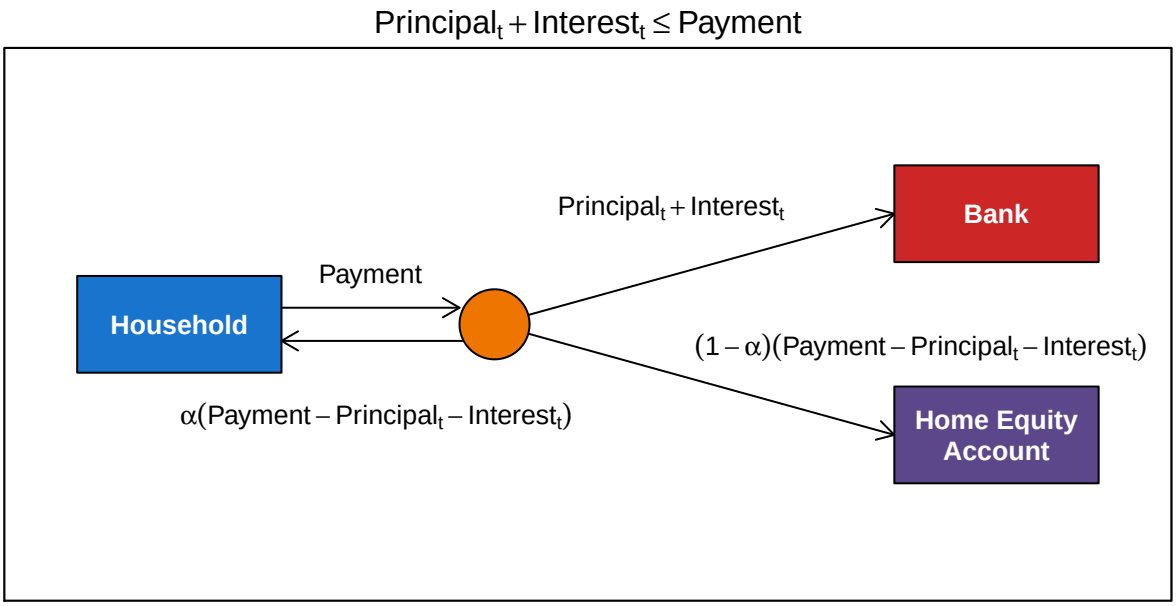
Table 1: Possible Fixed-Rate Mortgage Contracts

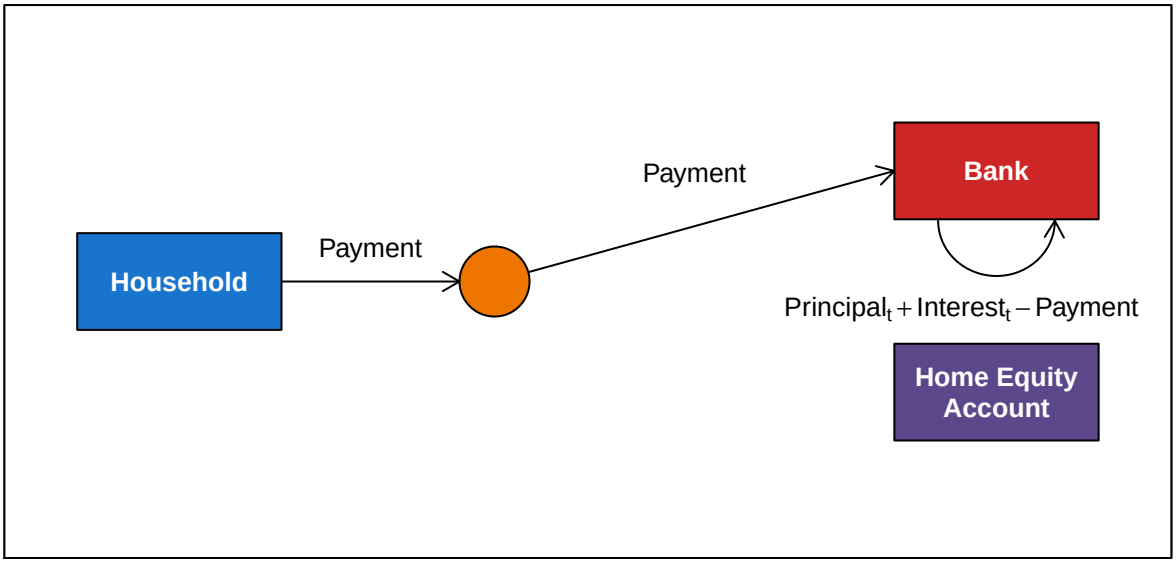
	With Refinancing Penalties	*Without Refinancing Penalties*
Household Savings Contract Included	Fixed-COFI Mortgage	Wealth Building Home Loan
Household Savings Contract Not Included	Historical Fixed-Rate Mortgage	Post-1970s 30-Year Fixed-Rate Mortgage

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

Figure 7

Fixed−COFI Mortgage Contract Mechanics





Note: The payment is the fully amortizing payment associated with the loan size and traditional fixed−rate mortgage rate at origination. The principal component follows the amortization schedule of a traditional fixed−rate mortgage. The interest component is the product of the remaining mortgage balance and the COFI mortgage rate. The COFI mortgage rate is the nationwide cost of funds index for the commercial banking system plus a margin. Alpha ranges from zero to one. Alpha equals one for the Affordable Fixed−COFI mortgage, and alpha equals zero for the Homeownership Fixed−COFI Mortgage.

Table 2: Cost of Funds Partial Adjustment Model

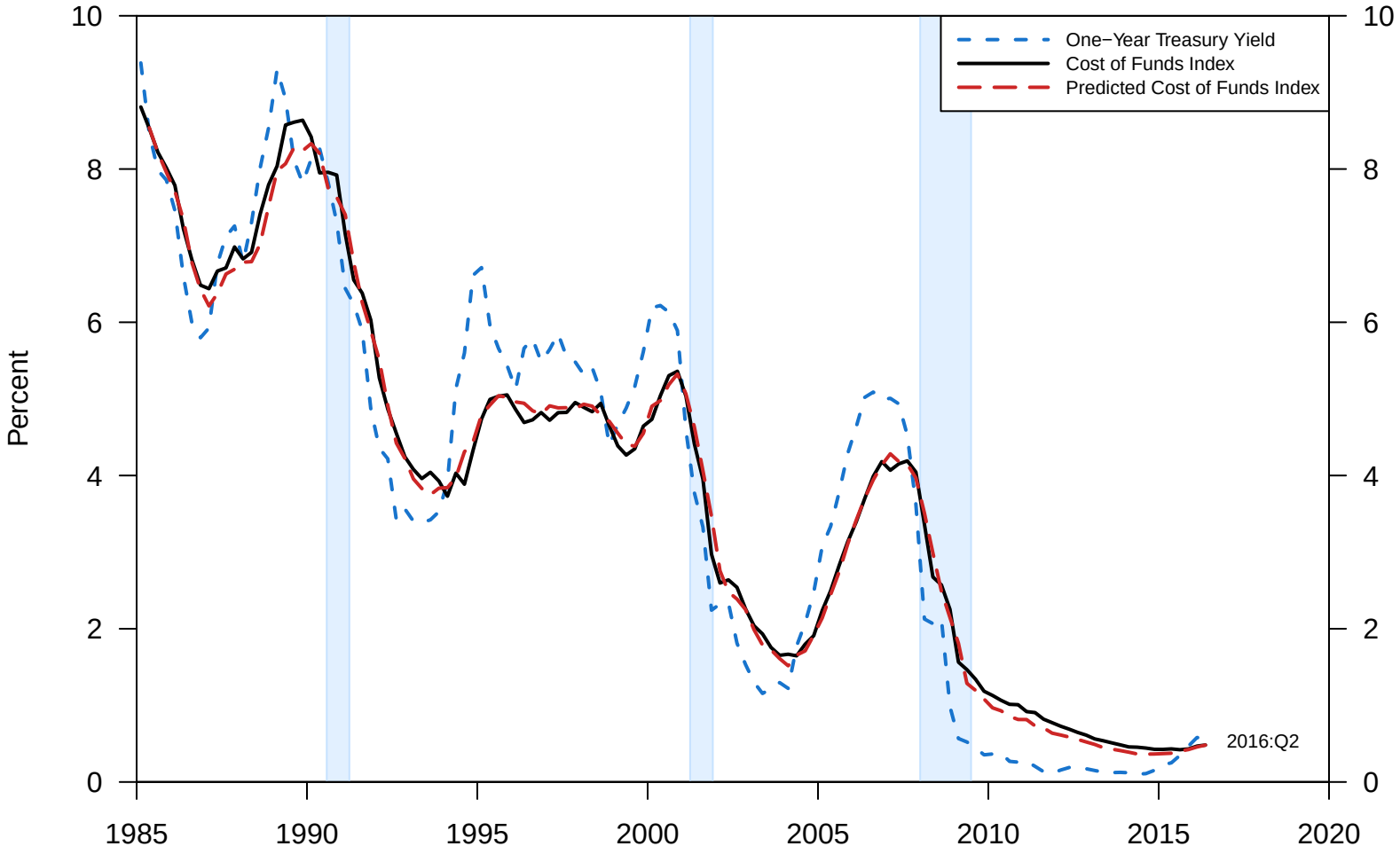
	Dependent variable:
	Cost of Funds Index
Lag Cost of Funds Index	0.745***
	(0.016)
One-Year Treasury Yield	0.233***
	(0.015)
Constant	0.036
	(0.027)
Observations	125
R^2	0.996
Adjusted R^2	0.996
Residual Std. Error	0.156 (df = 122)
Quarterly	*p<0.1; **p<0.05; ***p<0.01

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

Source: COFI 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 8

Cost of Funds Index Partial Adjustment Model



Note: One−year Treasury yields are quarterly averages. The predicted cost of funds index is based on table 2. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

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

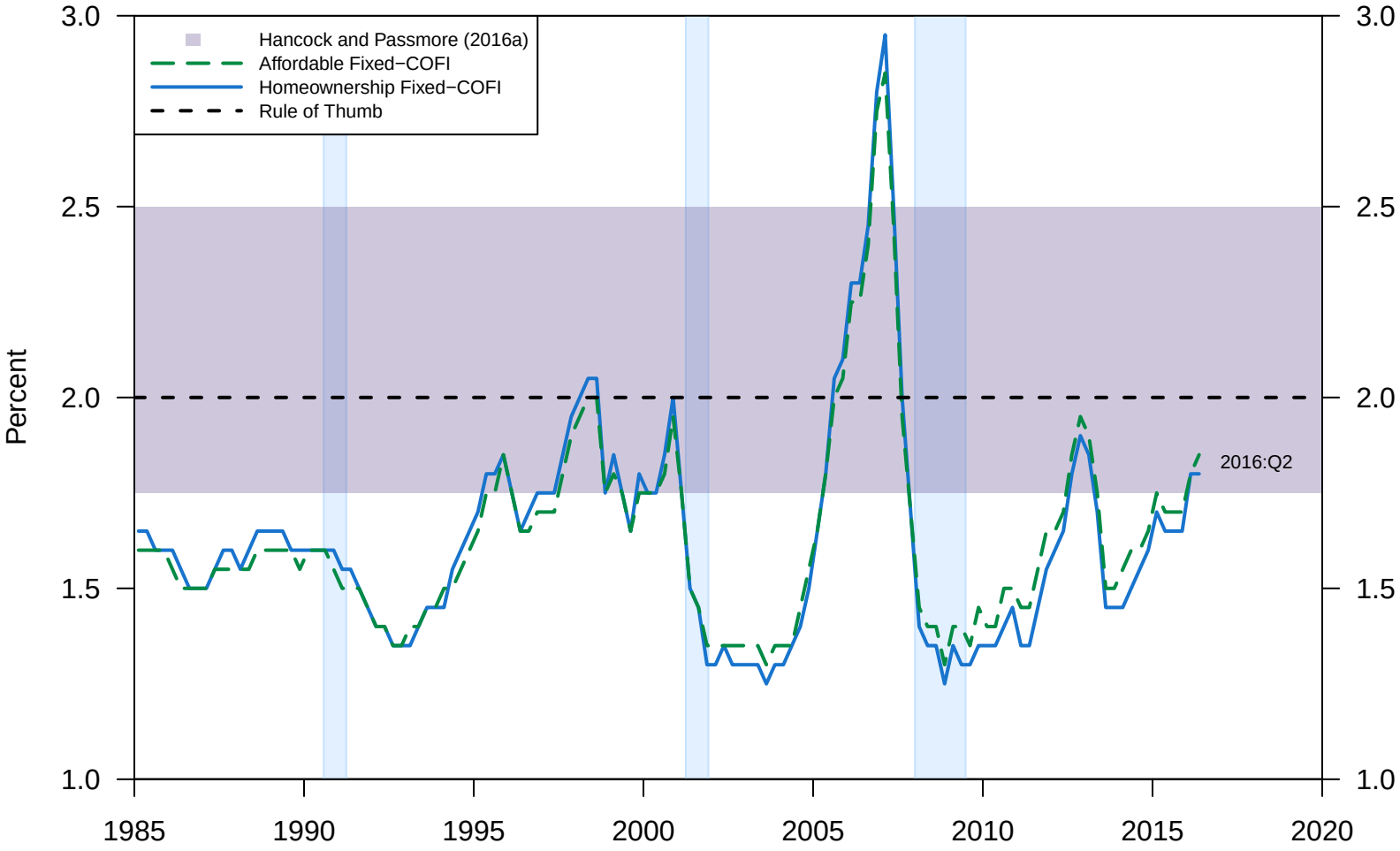
	Dependent variable:
	One-Year Treasury Yield
Lag One-Year Treasury Yield	0.994***
	(0.004)
Constant	0.001
	(0.021)
Observations	378
R^2	0.993
Adjusted R^2	0.993
Residual Std. Error	0.230 (df = 376)
Monthly	*p<0.1; **p<0.05; ***p<0.01

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`.

Figure 9

Gross Margin

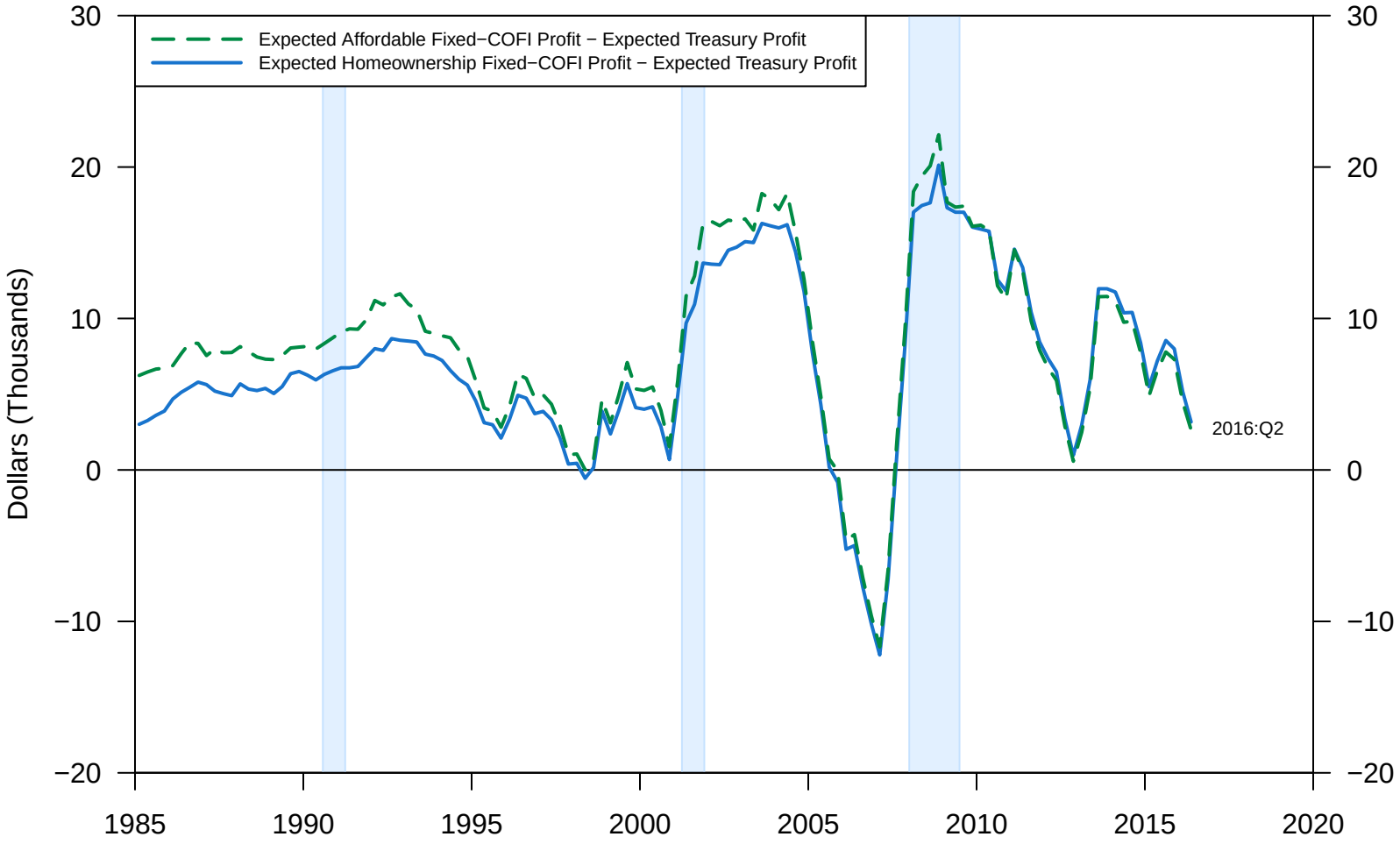


Note: Simulation results are based on 5,000 stochastic interest rate environments per quarter. Gross margin for affordable and homeownership Fixed−COFI mortgages are calculated to equate the expected profit from a portfolio of Fixed−COFI mortgages and a portfolio of Treasuries. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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

Expected Profit

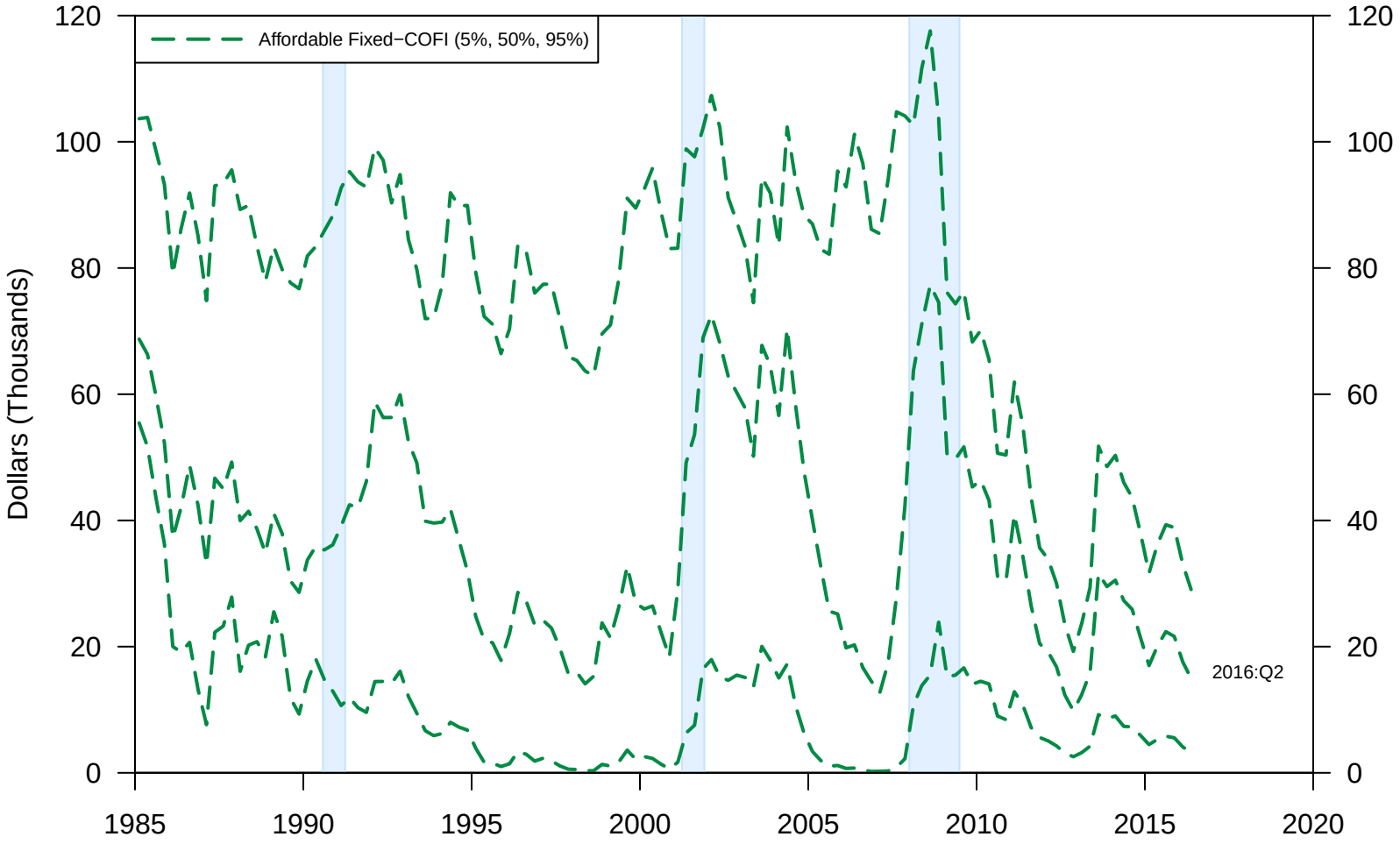


Note: Simulation results are based on 5,000 stochastic interest rate environments per quarter. Gross margins are 2 percentage points. Calculations are based on the United States median house price. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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

Total Payment Rebates



Note: Simulation results are based on 5,000 stochastic interest rate environments per quarter. The three lines for the total payment rebates of Affordable Fixed−COFI mortgages are the 5th, 50th, and 95th percentiles. Gross margins are 2 percentage points. Calculations are based on the U.S. median house price. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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 4: Front-End Debt-To-Income Ratios in Largest Metropolitan Statistical Areas

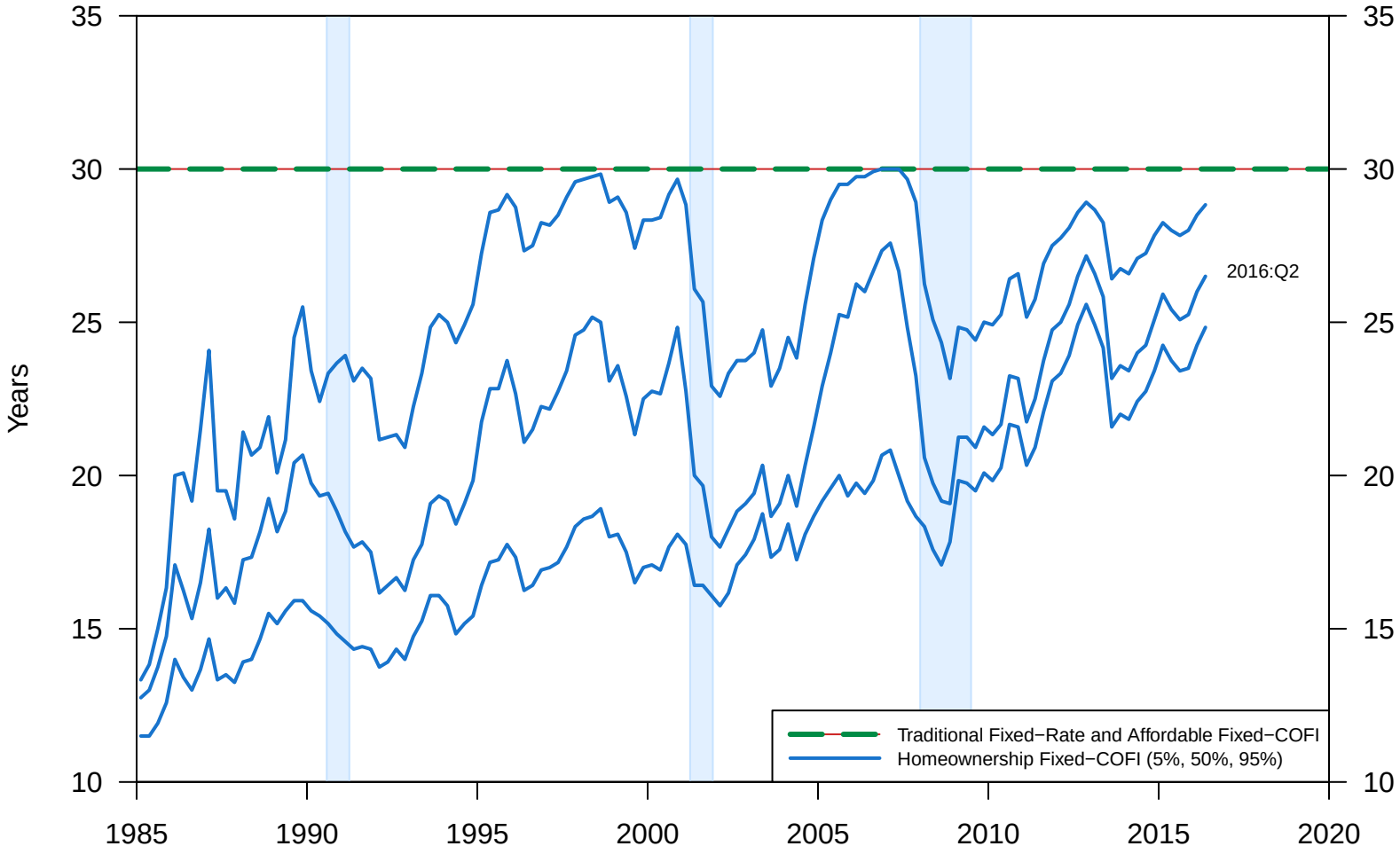
Name	2008:Q3	2016:Q2
New York, NY	57 / 47	38 / 36
Los Angeles-Long Beach-Anaheim, CA	74 / 61	62 / 59
Chicago, IL	35 / 29	21 / 20
Dallas-Fort Worth, TX	23 / 19	21 / 20
Philadelphia, PA	35 / 28	22 / 20
Houston, TX	22 / 18	19 / 18
Washington, DC	37 / 30	27 / 26
Miami-Fort Lauderdale, FL	42 / 34	31 / 30
Atlanta, GA	25 / 21	18 / 18
Boston, MA	44 / 36	34 / 32
San Francisco, CA	73 / 60	61 / 58
Detroit, MI	21 / 17	16 / 15
Riverside, CA	46 / 38	37 / 35
Phoenix, AZ	36 / 29	27 / 26
Seattle, WA	51 / 42	35 / 33
Minneapolis-St Paul, MN	30 / 25	22 / 21
San Diego, CA	60 / 50	51 / 49
St. Louis, MO	26 / 22	17 / 16
Tampa, FL	32 / 26	23 / 22
Baltimore, MD	38 / 31	24 / 22
Denver, CO	35 / 29	33 / 31
Pittsburgh, PA	22 / 18	16 / 15
Portland, OR	45 / 37	36 / 34
Charlotte, NC	27 / 22	20 / 19
Sacramento, CA	46 / 38	36 / 34

Note: We calculate two debt-to-income ratios (DTIs) for each quarter: the larger ratio is the before-rebate DTI and the smaller ratio is the expected after-rebate DTI. Before-rebate DTIs are calculated as 12 times the traditional fixed-rate mortgage payment (with no down payment) for the median-priced house divided by moderate income (i.e., 80 percent of median income). Before-rebate DTIs apply to the traditional fixed-rate mortgage and the Homeownership Fixed-COFI mortgage. Expected after-rebate DTIs subtract the average annual rebate from the total before-rebate mortgage payments. Expected after-rebate DTIs apply to the Affordable Fixed-COFI mortgage.

Source: COFI 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`. Zillow data are available at `https://www.zillow.com/research/data/`.

Figure 12

Maturity

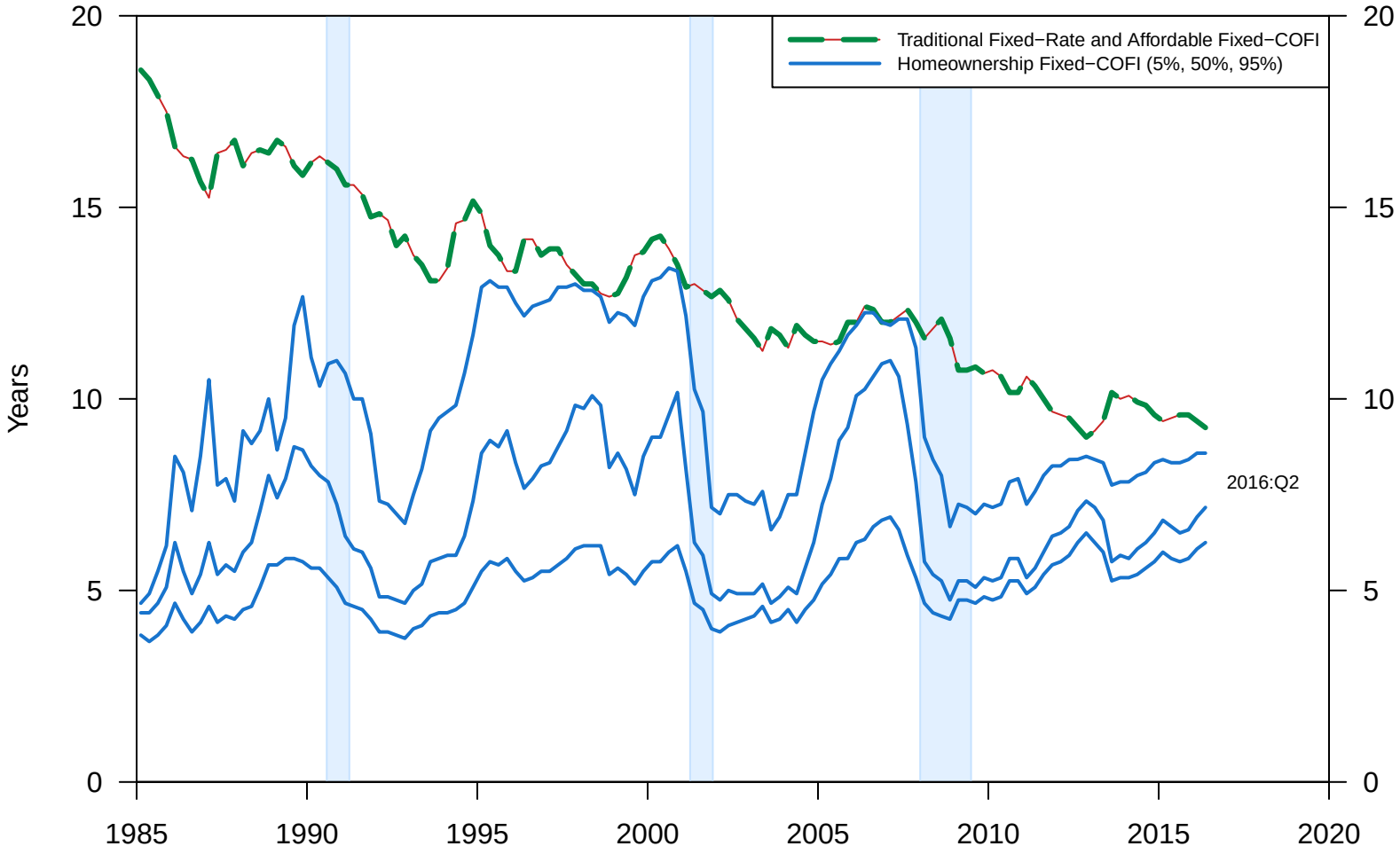


Note: Simulation results are based on 5,000 stochastic interest rate environments per quarter. The three lines for the maturity of Homeownership Fixed−COFI mortgages are the 5th, 50th, and 95th percentiles. Gross margins are 2 percentage points. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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 13

Credit Risk Threshold



Note: Simulation results are based on 5,000 stochastic interest rate environments per quarter. The credit risk threshold is the time a mortgage takes to accrue 20 percent equity. The three lines for the credit risk threshold of Homeownership Fixed−COFI mortgages are the 5th, 50th, and 95th percentiles. Gross margins are 2 percentage points. Shaded bars indicate periods of business recession as defined by the National Bureau of Economic Research.

Source: COFI 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.