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ABSTRACT

Nominal interest rates have real effects. Residential mortgages and other real world debt contracts require a sequence of constant nominal payments. Combined with payment-to-income constraints, these nominal payments force borrowers to take on less debt when nominal interest rates rise, regardless of the behavior of the real interest rate. Survey data show that conditional on the real rate, higher nominal mortgage interest rates reduce home buying sentiment. And increases in nominal mortgage rates reduce mortgage origination more in cities where payment-to-income constraints are more likely to bind. We explore the macroeconomic implications of payment-to-income constraints in a new Keynesian model modified to include a credit good. The payment-to-income constraint amplifies the effect of current short-term nominal interest rates on output and inflation, making the model less forward-looking than the standard new Keynesian model.

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1 Introduction

In standard macroeconomic models nominal interest rates are irrelevant; what matters for economic activity are real interest rates, the nominal interest rate net of expected inflation (e.g., [Woodford, 2003](#); [Galí, 2015](#)). Nominal rates only matter if, for instance at the zero lower bound, they determine real rates or if agents are subject to money illusion and confuse real and nominal rates. We argue that the real world is different: even absent money illusion or the zero lower bound, the structure of debt contracts means that nominal interest rates have real effects.

The importance of nominal interest rates is easy to overlook in the data since real and nominal rates often move together. It is even easier to overlook in models since the single period real debt in standard models makes only the real rate relevant. But unlike in models, real world debt contracts often require a sequence of constant nominal payments across time. Multi-period nominal debt is, for instance, characteristic of car loans and mortgages.

When debt is multi-period and nominal, one-for-one increases in nominal rates and inflation tilt the real payment profile, increasing real payments today and lowering them in the future. If a borrower faces payment-to-income constraints, limits on what share of her income she can pay today, a higher nominal rate conditional on a given real rate is contractionary. It reduces the loan size and thus the purchase size that she can afford.

That the nominal interest rate has real effects almost directly implies that inflation does as well. In steady state, higher inflation leads to higher nominal interest rates. Outside of steady state, higher inflation often leads central banks to raise nominal interest rates. Our evidence on the real effects of nominal interest rates is thus also evidence that changes in inflation have larger real effects on the economy than standard macro models suggest. In particular, the interaction of higher nominal interest rates and payment-to-income constraints suggests that higher inflation imposes costs on new borrowers ([MacGee and Yao, 2025, 2026](#)). Indeed, this may be one reason why inflation is so unpopular; the higher nominal interest rates that accompany inflation make it more difficult for households to borrow money to purchase homes, cars, and other durable goods.¹

¹Others have also made this point. See, e.g., Mike Konczal on Substack (2/9/26) “[Why Affordability and the Vibeconomy Are Real Economic Problems.](#)”

In the next section, we expand on the intuition for how multi-period debt and payment-to-income constraints make it likely that the nominal rate will have real effects. We show that when payment-to-income constraints bind, it can be the nominal rather than the real rate that determines housing demand. Equipped with this intuition, in section 3 we turn to empirical evidence on the impact of nominal versus real interest rates in the Michigan Survey of Consumers. The survey evidence shows that it is nominal, not real, interest rates that drive home-buying sentiment. Indeed, conditional on the nominal rate, the real rate has the opposite from predicted effect, with a higher real rate *improving* home buying sentiment.

In section 4, we use cross-sectional data on U.S. cities to see whether the nominal rate effect works through payment-to-income constraints. While the mortgage interest rate varies little across cities,² its effect can vary greatly. Payment-to-income constraints are more likely to bind in cities where mortgage loans are large relative to incomes. In these high leverage cities, an increase in the nominal mortgage rate may make a mortgage unaffordable for many households. A proxy for payment-to-income constraints is the average loan-to-income (LTI) ratio in a city, which we calculate from mortgage-level data. We then bin cities into terciles based on their average LTI ratio, and we regress the growth rate of loans in a city on the nominal mortgage rate and its interaction with LTI terciles. The real mortgage rate and its interaction with LTI terciles is a control variable.

We find that the coefficient on the interaction of the nominal mortgage rate with the highest LTI tercile is consistently negative and statistically significant; in cities where mortgage loans are larger relative to household incomes, an increase in the nominal interest rate leads to a larger reduction in mortgage volume. The effect is economically significant with a one percentage point increase in the nominal mortgage rate reducing mortgage loan growth by roughly 4-5 percentage points more in cities in the highest LTI tercile relative to cities in the lowest LTI tercile. The size of the estimated nominal rate effect is stable as we add controls for house price growth and the federal funds rate (both interacted with LTI terciles). To the extent that new mortgage issuance is a good proxy for residential investment, the results suggest that the nominal interest rate has large real effects on the housing market.

In section 5, we use a new Keynesian model to study the macroeconomic implications of

²The mortgage capital market is nationally integrated, so geographic variation in the nominal mortgage interest rate is minimal.

payment-to-income constraints. We modify a standard new Keynesian model to include a credit good subject to a payment-to-income constraint. In the model, as in the data, changes in nominal interest rates have real effects. That means that relative to the standard model, an increase in the nominal interest rate has a larger contractionary effect. The effect of the real rate increase resulting from the nominal rate increase is the same as in the standard model. And there is an additional contractionary effect from the higher nominal rate itself.

The model has three more surprising features. First, the payment-to-income constraint means that the current short-term nominal interest rate affects output and inflation more than do future short-term nominal rates. The importance of the current relative to future short rates helps to address the forward guidance puzzle ([Del Negro, Giannoni, and Patterson, 2023](#)). Second, a higher nominal interest rate reduces labor supply through a wealth effect, but despite lower labor supply, consumption demand falls enough for inflation to decline when nominal rates rise. Third, the determinacy condition for the model remains the standard Taylor principle; determinacy still requires that the nominal interest rate rise more than one-for-one with inflation.

1.1 Related literature That the structure of mortgage contracts means that nominal rates have real effects was explored by macroeconomists during and in the aftermath of the 1970s Great Inflation. An early paper in the literature is [Lessard and Modigliani \(1975\)](#). They note that a higher nominal interest rate for a given real interest rate tilts the real payment profile, increasing real payments early in the life of a mortgage and decreasing those late in its life. Like us, although without econometric evidence, they argue that the tilt mechanism means that a higher nominal interest rate reduces housing demand. [Kearl \(1979\)](#), [Schwab \(1982\)](#), and [Schwab \(1983\)](#) use models and data to make the same point. More recently, [Haight \(2007\)](#) discusses the logic of how nominal interest rates interact with payment-to-income constraints to affect the housing market. And [MacGee and Yao \(2025, 2026\)](#) look at the long-run effect of steady-state inflation on the housing market. They argue that through its effect on nominal interest rates, higher inflation lowers mortgage debt, home ownership, and welfare. Their focus on the long-run impact of nominal interest rates on the housing market complements our focus on the short-run, business cycle impact of nominal versus real interest rate changes.

Most similar in intent though not method to our paper are [Wilcox \(1989\)](#) and [Wilcox \(1990\)](#). He argues that the nominal rather than the real rate determines aggregate demand. [Wilcox \(1990\)](#) concludes: “The evidence presented here suggests that nominal, as opposed to real interest rates are an important determinant of each category of consumer spending” (p. 36). Unlike our paper, however, [Wilcox \(1989\)](#) and [Wilcox \(1990\)](#) rely on macro time series to infer the importance of nominal versus real interest rates.

Recent work on housing and the macroeconomy shows the empirical relevance of payment-to-income constraints (e.g., [Kuttner and Shim \(2016\)](#), [Bhutta and Ringo \(2021\)](#), and [Bosshardt, Di Maggio, Kakhbod, and Kermani \(2024\)](#)). And [Greenwald \(2026\)](#) shows how changes in mortgage payment-to-income constraints matter in a macro model. Similarly, [Drechsel \(2023\)](#) looks at a model with income (earnings) based credit constraints on firms. None of these papers, however, link the importance of payment-to-income constraints to the effect of nominal versus real interest rate changes.³

The most closely related work to the model in our paper is [Garriga, Kydland, and Šustek \(2017, 2021\)](#) who look at long-term fixed nominal payment mortgages in macro models. [Garriga et al. \(2017\)](#) study the effect of long-term nominal mortgages in a flexible price macro model. They consider the effect of nominal mortgage interest rate changes on the time path of real mortgage payments, but they do not focus on how the changing time path of mortgage payments interacts with binding institutional payment to income constraints. And they focus more on how inflation affects existing homeowners, rather than on how changes in the time path of mortgage payments affect new homebuyers.

Like us, [Garriga et al. \(2021\)](#) examine a new Keynesian model with mortgages. But again, they do not focus on payment to income constraints. [Garriga et al. \(2021\)](#) emphasize the homeowner’s loan-to-value rather than payment-to-income constraint. The distinction matters because nominal interest rates do not directly affect the loan-to-value ratio, whereas they do directly affect the payment-to-income ratio.

2 Nominal debt contracts

Many real world debt contracts, such as mortgages, have the following three features:

³[Greenwald \(2026\)](#) does note (p. 36) that higher nominal interest rates tighten payment-to-income constraints.

1. Debt is multi-period.
2. One repays debt with a constant nominal payment each period. A homebuyer who obtains a 30-year fixed-rate mortgage in July 2026, for instance, will make 360 identical nominal payments from July 2026 through June 2056.
3. Lenders will not make loans in which the ratio of the mortgage payment to current income is high. Lenders' refusal to make such loans may stem from regulatory constraints or from asymmetric information and the risk of default.

These features of debt contracts are familiar to households, but their combination is generally absent from macroeconomic models.

Multi-period nominal debt means that a higher nominal interest rate increases real payments early in the life of a loan, tightening the payment-to-income constraint. To see why, consider the following hypothetical: a household earns \$100,000 in year t and wishes to buy as large a house as it can afford. Institutional constraints mean that a bank will not give the household a loan unless the payment in year t (the first year of the loan) plus other household debt payments and property taxes is less than 50 percent of the household's gross (pre-tax) income in year t .⁴ Even absent any institutional constraints, the household might be unwilling or unable to commit more than 50 percent of its current gross income to a mortgage payment.

Suppose that expected inflation and the real interest rate are zero, so that the nominal interest rate is also zero. Then the annual mortgage payment on a 30-year fixed rate mortgage will be one-thirtieth of the mortgage principal. And the household will be able to take out a $0.5 \cdot \$100,000 \cdot 30 = \1.5 million mortgage. Now suppose instead that the real interest rate remains zero, but expected inflation and the nominal rate are 10 percent. In order to keep the mortgage payment in the first year of the mortgage less than \$50,000, the household will only be able to borrow roughly \$470,000.⁵ Rising wages along with inflation will make the

⁴The industry and literature call the ratio (mortgage payment + other household debt payments + property tax payment) / gross income the “debt-to-income” ratio or DTI ratio. We adopt this convention going forward. For details of what is and is not included in the calculation of DTI ratios, see <https://guide.freddiemac.com/app/guide/section/5401.2>.

⁵The maximum size (principal) of a 30-year mortgage that can be borrowed for a nominal interest rate i and annual payment X is $\frac{X(1 - [\frac{1}{1+i}]^{30})}{i}$. $\frac{\$50,000(1 - [\frac{1}{1+0.1}]^{30})}{0.1} \approx \$470,000$.

mortgage payment a smaller share of income over time, but that does not affect how the payment-to-income constraint binds when the mortgage is originated.

Thus the nominal rate and not the real rate may determine the household's house purchase size. Figure 1 illustrates. It shows in time $t = 1$ (real) dollars the payment profile for a \$1.5 million mortgage when the nominal interest rate is zero and inflation is zero, and when the nominal interest rate is 10 percent and inflation is 10 percent. When the nominal rate and inflation are zero, the real payment profile is flat at \$50,000, half of the hypothetical household income of \$100,000. But when the nominal interest rate and inflation are 10 percent, the real payment profile is downward sloping, and the mortgage is unaffordable for the household. So changes in inflation and the nominal rate will affect housing affordability even if the real interest rate and the real wage are constant.

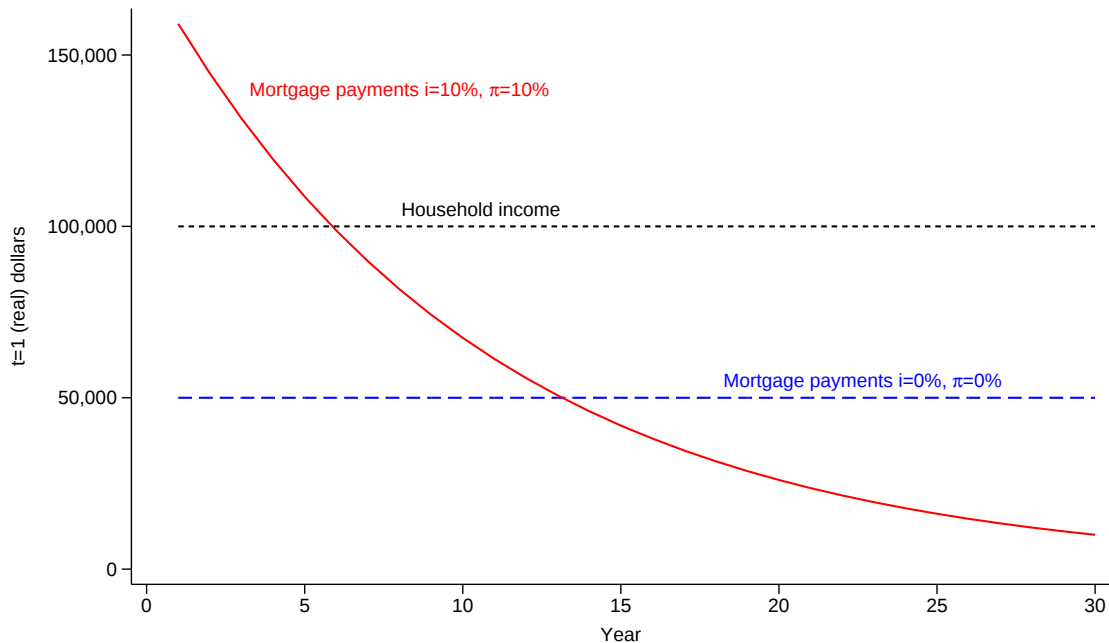


Figure 1 – Annual real mortgage payment on a \$1.5 million mortgage compared to real household income

3 Nominal and real rates: Survey evidence

The above intuition suggests that the nominal rate is likely to influence consumer attitudes about homebuying. We test for such a nominal rate effect using data from the Michigan Survey of Consumers. The Michigan survey asks consumers about their inflation

expectations and about whether they think it is a good time to buy a home.

We estimate

$$\text{Home buy attitude}_{j,t} = \beta_0 + \beta_1 i_t + \beta_2 r_{j,t} + \varepsilon_{j,t}. \quad (1)$$

Home buy attitude is a dummy variable equal to one if the survey respondent says that it is a good time to buy a home.⁶ It is measured at the level of a survey respondent j surveyed in month t . i_t is the actual nominal interest rate on a 30-year fixed rate mortgage (from FRED series MORTGAGE30US). $r_{j,t}$ is the respondent-specific real interest rate equal to i_t minus the respondent's expected annual inflation rate over the next five to ten years.⁷

Column (1) of table 1 shows results from estimating equation (1) controlling for a time trend. As expected, the coefficient on the nominal interest rate is negative and statistically significant. The coefficient of -0.11 means that for every one percentage point increase in the nominal mortgage rate, a respondent is 11 percentage points less likely to say that it is a good time to buy a home. By contrast, conditional on the nominal interest rate, the coefficient on the real interest rate is small and has the wrong sign: higher real interest rates make it *more* likely that a respondent says it is a good time to buy a home. Since the real interest rate is the nominal interest rate minus expected inflation, the positive coefficient on the real interest rate means that higher expected inflation worsens home-buying sentiment.⁸ That higher inflation expectations worsen home-buying sentiment is consistent with the finding in Grigoli, Sandri, Gorodnichenko, and Coibion (2026) that higher inflation expectations reduce planned consumption.

In a simple regression of home buying attitudes on the nominal or real interest rate, one would worry about omitted variable bias and reverse causality. Omitted variable bias would result, for instance, from an aggregate demand shock that leads to both lower nominal and / or real interest rates and to decreased interest in buying homes. Reverse causality would occur if changing home buying sentiment affected the macroeconomy and thus interest rates.

⁶Respondents are asked: "Generally speaking, do you think now is a good time or a bad time to buy a home?" (Variable HOM.) We set the dummy variable equal to one if the response is "good" (HOM=1). See the "Survey Description" at <https://data.sca.isr.umich.edu/survey-info.php>.

⁷Michigan Survey variable PX5.

⁸To see this, write equation (1) as $\text{Home buy attitude}_{j,t} = \beta_0 + \beta_1 i_t + \beta_2 (i_t - \pi_t^e) + \varepsilon_{j,t}$. So the effect of inflation expectations on home buying sentiment is $-\beta_2$, i.e. minus one times the coefficient on the real interest rate.

Table 1 – Michigan survey regressions

	(1)	(2)	(3)	(4)	(5)
	Buy home	Buy home	Buy home	Low int. rate	Buy home
Right hand side variables:					
Mortgage rate (%)	−0.11*** (0.0021)	−0.11*** (0.0022)	−0.11*** (0.0060)	−0.071*** (0.0025)	
Real mortgage rate (%)	0.0039*** (0.00031)	0.0039*** (0.00032)	0.0049*** (0.00049)	0.0027*** (0.00040)	
Expected house price inflation (%)			0.0075*** (0.00047)		0.0075*** (0.00047)
Expected 5-10 year inflation (%)					−0.0044*** (0.00042)
Unemployment rate (%)		−0.0022 (0.0021)			
Time trend (monthly)	−0.0021*** (0.000043)	−0.0021*** (0.000051)	−0.0025*** (0.000090)	−0.0015*** (0.000065)	
Survey month fixed effects					X
R^2	0.20	0.20	0.27	0.11	0.30
Sample period	2/79-2/26	2/79-2/26	3/07-2/26	2/79-2/26	3/07-2/26
Observations	236,987	235,923	91,940	232,666	91,940

Notes: In columns (1), (2), (3), and (5) the dependent variable is a dummy variable for whether or not the respondent says that it is a good time to buy a home. In column (4), the dependent variable is a dummy variable for whether or not the respondent says that low interest rates are a reason why it is a good time to buy a home. Standard errors are clustered by survey month. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Since April 1990, the Michigan survey has asked respondents every month about their 5-10 year inflation expectations. Before that, the series has gaps with respondents asked about expected inflation only in some months and not at all in 1988-89.

In our setting, omitted variable bias and reverse causality are less of a concern, since we look at the effect of the nominal interest rate conditional on the real interest rate. Thus for omitted variable bias or reverse causality to be a concern, there would need to be an omitted variable that changes both home buying sentiment and the difference between the nominal and real interest rate, i.e. expected inflation. Reverse causality would only result if changes in homebuying sentiment caused changes in expected inflation.

To get some sense of whether omitted variable bias is a concern, in column (2) we add a control for the unemployment rate. The coefficients on the nominal and real interest rate are unchanged, suggesting that any omitted variable bias from macroeconomic shocks affecting both expected inflation and home buying sentiment is minimal.⁹ It is less straightforward to

⁹Controlling for the unemployment rate in other specifications in table 1 also has almost no effect on the

test for reverse causality, for whether changes in home buying sentiment might be causing changes in expected inflation rather than vice-versa. But we can use the fact that the Michigan Survey asks respondents about their expected change in house prices.¹⁰ It is likely that changes in home buying sentiment would affect expected house price inflation more than they would affect expected consumer price inflation. So adding expected house price inflation to the regression, as we do in column (3), helps to control for possible reverse causality between home buying sentiment and expected inflation. Adding this control has little effect on the coefficients on the nominal and real rate. And reassuringly the coefficient on expected house price inflation is positive: higher house price expectations are associated with more respondents saying it is a good time to buy a house.

In column (4) we take advantage of another question in the Michigan Survey, in which respondents who say it is a good time to buy a house are asked why. The dependent variable in column (4) is a dummy variable equal to one if the respondent says that it is a good time to buy a home because interest rates are low.¹¹ We regress the dummy variable on the nominal and real mortgage rate. Respondents are not asked to specify whether they mean nominal or real interest rates. But the results in column (4) make clear that when households say that high interest rates mean it is a good time to buy a house, they mean the nominal rate: the coefficient on the nominal rate is negative while that on the real rate is positive.

In the final column, we look in more detail at what variation is driving our real rate results. We regress the dummy variable for whether or not a respondent says it is a good time to buy a home on expected consumer price inflation and expected house price inflation. We include date (survey month) fixed effects to isolate cross-sectional variation. (The date fixed effects mean we cannot include the nominal mortgage rate, since the nominal mortgage

coefficients of interest. Results are available upon request.

¹⁰Michigan Survey variable HOMPX5. Housholds are asked “By about what percent per year do you expect prices of homes like yours in your community to go (up/down), on average, over the next 5 years or so?” See <https://data.sca.isr.umich.edu/subset/codebook.php>. The Michigan Survey only added the question about expected house price inflation to the survey in March 2007, thus the smaller sample size in columns (3) and (5).

¹¹Our dummy variable equals one if Michigan Survey variable HOMRN1=16. Respondents are asked “Generally speaking, do you think now is a good time or a bad time to buy a house?” and then “Why do you say so? (Are there any other reasons?)” See the codebook, available here: <https://sda.umsurvey.org/sca/Doc/sca.htm>.

rate varies only across time, not survey respondent.) We obtain results similar to those in column (3); higher expectations of consumer price inflation are associated with worse home-buying sentiment, while higher expectations of house price inflation are associated with better home-buying sentiment.

The Michigan Survey results suggest that the nominal interest rate has real effects. Conditional on the real rate, higher nominal interest rates have large negative effects on home-buying sentiment. In the next section, we use mortgage origination data to better understand the mechanism and quantitative significance of the nominal rate effect on the housing market.

4 The mortgage market and the nominal rate

We would like to identify the effect of changes in nominal mortgage interest rates on mortgage originations. More precisely, we would like to know β_1 from:

$$\% \Delta \text{Mortgage originations}_t = \beta_0 + \beta_1 \Delta i_t^{\text{exog}} + \beta_2 \Delta r_t + \varepsilon_t, \quad (2)$$

where Δi_t^{exog} is an exogenous change in the nominal interest rate, and Δr_t is the change in the real interest rate. Unfortunately, we know of no plausible strategy for separately identifying exogenous changes in the nominal and real interest rate. Monetary policy shocks are, for instance, changes to both the nominal and the real rate.

Therefore we turn to cross-sectional evidence. The nominal interest rate does not vary within the U.S. but its effects do. Our hypothesis is that the nominal interest rate affects the volume of mortgage originations because an increase in the nominal rate tightens payment-to-income (DTI) constraints. DTI constraints can be explicitly imposed by lenders, e.g., to conform with Fannie Mae and Freddie Mac guidelines, or implicitly adopted by borrowers, e.g., because borrowers have other consumption commitments or are risk averse. We use the fact that DTI constraints are more likely to bind in cities (core-based statistical areas, CBSAs) where the average mortgage loan size is large relative to average incomes. Thus an increase in the nominal interest rate is likely to reduce mortgage originations more in high housing cost cities.

DTI ratios are only available at the loan level since 2018, but they are proportional to the

loan-to-income (LTI) ratio, the ratio of the loan’s size to the borrower’s income.¹² To build intuition for how LTI ratios and nominal interest rates interact and thus for our identification strategy, figures 2 and 3 show the distribution of LTI ratios in Houston and Los Angeles in 2021 and 2023. Mortgage rates increased from an average of 3.0 percent in 2021 to 6.8 percent in 2023 (FRED series MORTGAGE30US), and in both cities, the distribution of LTI ratios shifted down. The shift was not the same in the two cities, however. The distribution of LTI ratios is more right-skewed in Los Angeles than in Houston. We observe relatively few small loans and relatively more large loans in Los Angeles, reflecting high house prices there. And because payment-to-income ratios are higher when loans are larger, the increase in mortgage rates had a larger effect on the affordability of housing in Los Angeles than in Houston. This is reflected in the change in the number of loans issued in the two cities in 2023 compared to 2021. In Los Angeles, the number of loans fell 50 percent from 2021-23, while in Houston the number of loans fell 27 percent.

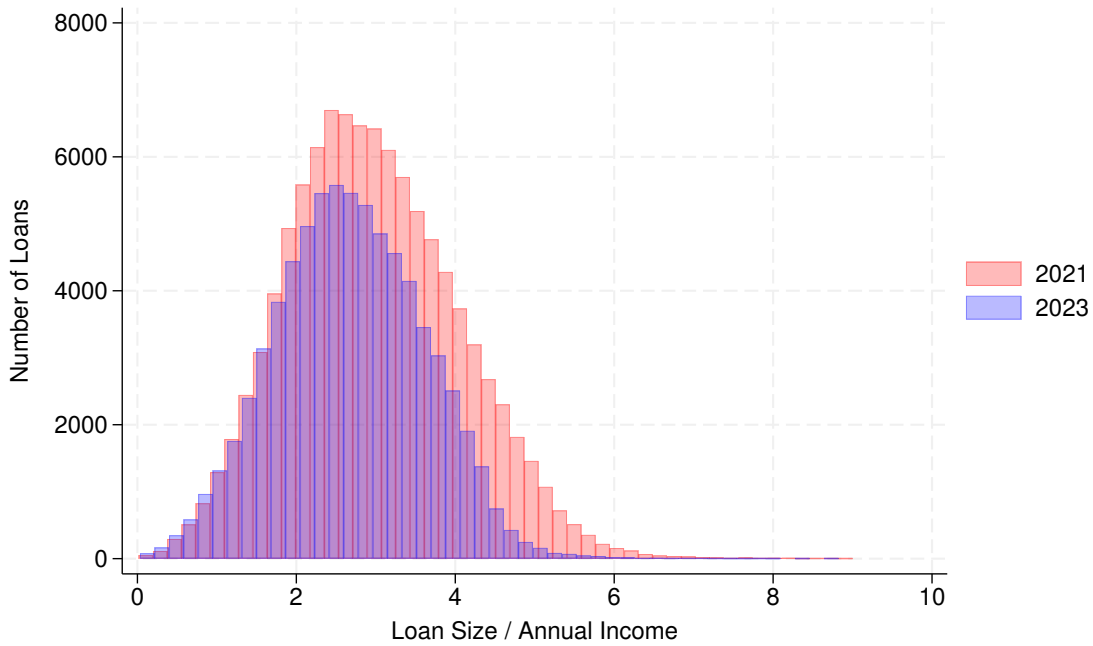


Figure 2 – Loan-to-Income (LTI) Distribution in Houston, 2021 and 2023. Source: HMDA data.

To see the intuition for this mechanism, suppose (hypothetical) Houston households with

¹²If the DTI ratio includes only mortgage payments, then for $i > 0$, $DTI = i \frac{(1+i)^m}{(1+i)^m - 1} LTI$, where i is the monthly mortgage rate, and m is the duration of the mortgage in months.



Figure 3 – Loan-to-Income (LTI) Distribution in L.A., 2021 and 2023. Source: HMDA data.

relatively expensive mortgages have loans of about \$500,000 and incomes of about \$125,000, for an LTI of four. If the nominal mortgage rate is three percent, the annual mortgage payment on a 30-year mortgage will be roughly \$25,000, for a DTI ratio of 20 percent. If the mortgage rate rises to 7 percent, the annual payment will rise to \$40,000, for a DTI ratio of 32 percent. Thirty-two percent is well below the cut-off for the DTI ratio above which lenders will not approve mortgages, which is 45 or 50 percent. Even with other monthly debt payments (e.g. for a car loan), their DTI may well be below the cut-off.

Now suppose in Los Angeles hypothetical borrowers get mortgages of \$1.2 million with incomes of \$200,000 for an LTI of six. The annual payment when the mortgage rate is three percent will be about \$61,000, for a DTI of 31 percent. Any increase in the mortgage rate to above 6.4 percent will push the DTI ratio above 45 percent, and borrowers will be unable to afford mortgages. Thus we would expect an increase in the nominal rate to reduce mortgage volume more in Los Angeles than in Houston, exactly as we see in figures 2 and 3.

The effect on mortgage volume in Houston versus Los Angeles is a pure nominal rate effect. It is the nominal, not the real, rate that affects the ratio of payments to income. In the above example, we assume nothing about what happens to expected inflation when the

nominal rate increases.

4.1 Specification We apply the identification strategy illustrated with Houston and Los Angeles in 2021 and 2023 to 704 U.S. cities and all years from 1996-2023. We do so by estimating

$$\begin{aligned} \Delta \ln \text{Loans}_{jt} = & \beta_0 \Delta i_t + \sum_{k=1}^3 \gamma_k \text{Tercile } k: \text{LTI}_j + \sum_{k=1}^3 \theta_k [\Delta i_t \times \text{Tercile } k: \text{LTI}_j] \\ & + \delta_0 \Delta r_t + \sum_{k=1}^3 \zeta_k [\Delta r_t \times \text{Tercile } k: \text{LTI}_j] + \varepsilon_{jt}. \end{aligned} \quad (3)$$

$\Delta \ln \text{Loans}_{jt}$ is the four-quarter percent (log) change in the number of mortgages originated in CBSA j and quarter t . Δi_t and Δr_t are four-quarter changes in the nominal and real mortgage interest rate, which vary across time but not CBSA. Tercile $k: \text{LTI}_j$ is a dummy variable for the loan-to-income bin containing CBSA j . Bin 3 is the tercile of CBSAs with the highest average LTI. Los Angeles, for instance, is in bin 3, and Houston is in bin 1. Our hypothesis is that θ_3 will be negative: conditional on the real interest rate, an increase in the nominal interest rate will reduce mortgage issuance more in places where LTI ratios are highest.

LTI is highly correlated with payment-to-income (DTI) constraints, which our hypothesis suggests are the channel through which nominal rates impact the housing market. Figure 4 is a binscatter showing the correlation between average payment-to-income (DTI) and loan-to-income (LTI) ratios in 2019 across cities (CBSAs). There is a high correlation between DTI ratios and LTI ratios.¹³ Changes in nominal interest rates ought to have the most affect on households borrowing a lot relative to their income. Figure 5 shows that the average LTI in a city is strongly correlated with the fraction of loans in the city with a high LTI, an LTI above 5.

An advantage of our identification strategy is that it tests both for effects of the nominal rate conditional on the real rate and specifically for our hypothesized channel through which the nominal rate matters: payment-to-income constraints. Whereas the Michigan Survey re-

¹³One might think that the high correlation between DTI and LTI ratios is mechanical. But in theory the correlation could be lower since LTI measures only the ratio of mortgage debt to income, while DTI includes other debt payments (e.g. car loan payments) and property taxes.

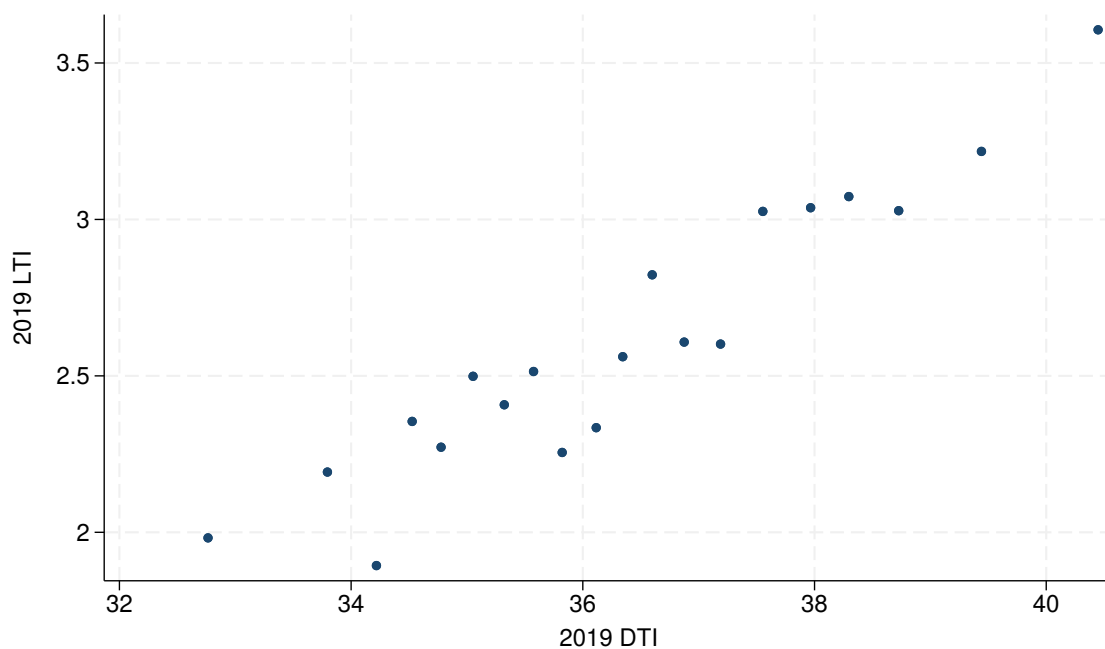


Figure 4 – Binscatter of the distribution of debt-to-income (DTI) and loan-to-income (LTI) ratios in 2019 across CBSAs. Source: HMDA data and authors' calculations.

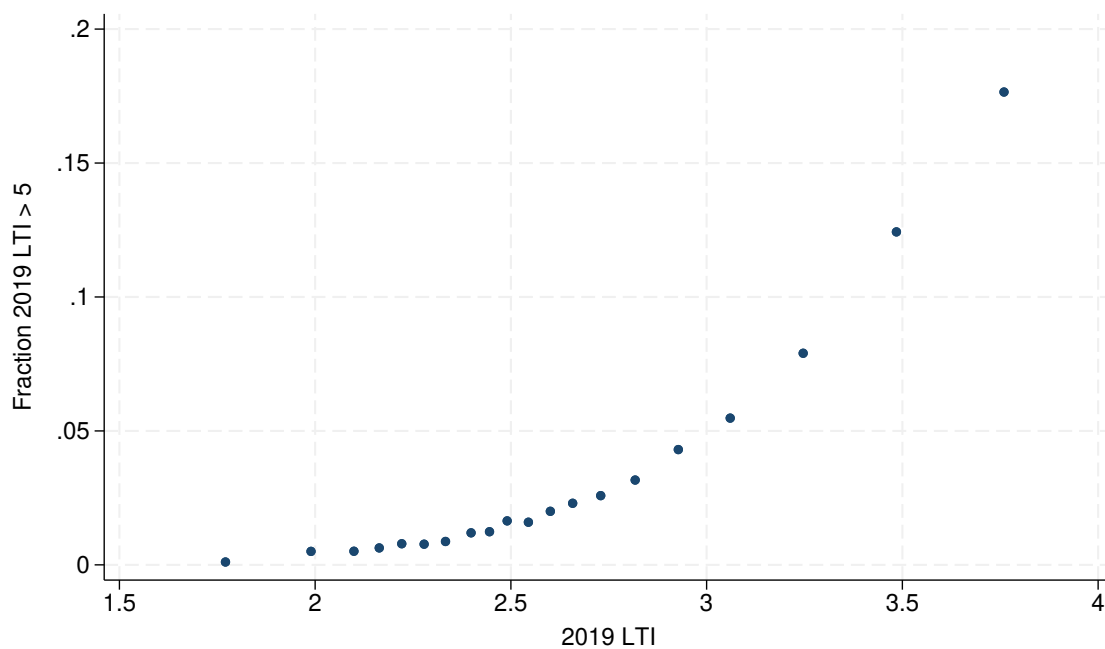


Figure 5 – Binscatter of the average loan-to-income (LTI) ratio and the fraction of mortgage loans with an LTI above 5 in 2019 across CBSAs. Source: HMDA data and authors' calculations.

sults are consistent with the importance of payment-to-income constraints or money illusion, our identification strategy in this section rules out money illusion effects; there is no reason why money illusion would have larger effects in cities where payment-to-income constraints bind more.

4.2 Data We measure LTI and mortgage origination across CBSAs from confidential home mortgage disclosure act (cHMDA) data, which contains application-level characteristics for the majority of originated mortgages. These are the same data underlying public HMDA data; but while the public data are only annual, we can use the confidential data to construct a quarterly measure of the number of originated loans. HMDA data begin in 1975. But coverage of the mortgage market was limited in initial years. So we start our sample in 1995 (with four-quarter differences, 1996), following a significant expansion to the scope and coverage of HMDA reporting (Avery, Brevoort, and Canner, 2007). Since 1995, the HMDA data are generally thought to cover at least 80 percent of the mortgage market. We restrict the sample to purchase loans for owner-occupied / principal occupancy homes, which includes both detached and attached (e.g., condominiums) single-family homes. Starting in 2004, we can and do restrict the sample to first liens, thus excluding second mortgages.¹⁴ We then aggregate the data to the CBSA and quarter level to construct our measure of the count of mortgage purchase originations.¹⁵ To improve precision we also winsorize the top and bottom 2.5 percentiles of the log growth in loan count, meaning that we make observations with origination growth below the 2.5th or above the 97.5th equal to origination growth at the 2.5th and 97.5th percentiles (-48 and plus 48 percent). We also drop the 25 percent of CBSAs with the smallest number of loans. These are CBSAs that typically have fewer than 30 loans in a quarter.

We use the national 30-year fixed mortgage rate as our nominal interest rate. We construct real mortgage rates using four different measures of inflation expectations. From the Michigan Survey we take the 5-10 year mean and the 5-10 year median expected inflation rate.¹⁶ We also use the TIPS 5-year breakeven inflation rate and the Cleveland Fed 5-year

¹⁴We also drop all loans with zero or negative reported application income or those with loan-to-income ratios greater than seven.

¹⁵CBSAs are constructed from combinations of counties in order to reflect geographic units that share a high degree of economic and social integration. See [here](#).

¹⁶Survey respondents are asked about their expectations of inflation “during the next five to ten years”

expected inflation rate. To construct expected inflation, the Cleveland Fed uses a model with data on actual inflation and nominal interest rates plus data from inflation swaps and inflation expectation surveys.¹⁷ Table 2 reports summary statistics for our data. The typical year-over-year growth in purchase loan counts is about one percent but with significant volatility. The statistical characteristics of the real rate vary depending on what measure of expected inflation is used to construct it.

	Observations	Mean	SD	25th pct	50th pct	75th pct
$100 \times \Delta \ln$ Loan count (winsorized)	78,848	0.80	21.65	-12.73	1.97	14.84
Δ Nominal mortgage rate	78,848	-0.04	0.84	-0.64	-0.17	0.41
$100 \times \Delta \ln$ House price index	78,848	4.74	6.26	2.32	5.15	8.54
Δ Fed funds rate	78,848	-0.03	1.47	-0.49	0.01	0.68
Δ Real rate (michigan mean)	78,848	-0.04	0.78	-0.54	-0.11	0.36
Δ Real rate (michigan median)	78,848	-0.03	0.82	-0.51	-0.20	0.36
Δ Real rate (Cleveland)	78,848	-0.00	0.61	-0.40	-0.13	0.23
Δ Real rate (breakeven)	56,320	0.02	1.07	-0.60	-0.14	0.33

Table 2 – Notes: The table reports summary statistics for variables in our CBSA-quarter level analysis. All variables are in percent / percentage point terms. The sample is from 1995Q1 to 2023Q4. We drop the CBSAs in the bottom 25th percentile of average loan count. All differences are four-quarter differences. (So differenced data begin in 1996Q1.) We winsorize log loan count at the 2.5th and 97.5th percentiles.

Sources: Loan counts come from HMDA. House prices are from the S&P/Case-Shiller U.S. National Home Price Index (FRED series CSUSHPINSA). The federal funds rate is the effective federal funds rate (FRED series DFF). The mortgage rate is the 30-year fixed rate mortgage average from Freddie Mac (FRED series MORTGAGE30US). The Michigan mean and median real rates are calculated with inflation expectations from the Michigan Survey of Consumers. The Cleveland real rate uses the model-implied 5-year expected inflation rate from the Cleveland Fed (FRED series EXPINF5YR). The breakeven real rate uses the 5-year breakeven inflation rate (FRED series T5YIE). Breakeven inflation data begin in 2003, thus the smaller number of observations in the last line of the table.

4.3 Results Table 3 shows estimates of equation (3) with inflation expectations measured using mean 5-10 year expectations from the Michigan Survey. Column 1 shows results using only the real interest rate as a control. Columns 2 and 3 add control variables for house prices (HPI) and the federal funds rate. In column 4, we add CBSA and date fixed effects. The coefficient of interest is that on the interaction of the high LTI bin with the nominal interest rate (θ_3 in equation (3)). The coefficient is negative, statistically significant, and stable across specifications. Our balanced panel and specification structure means that adding fixed effects in column (4) has no impact on the interaction coefficients and minimal effect on the clustered standard errors. The estimated coefficient of roughly 4 on the high

(<https://data.sca.isr.umich.edu/fetchdoc.php?docid=75445>).

¹⁷See “Inflation Expectations.” Federal Reserve Bank of Cleveland. <https://doi.org/10.26509/frbc-infexp>. Accessed on June 9, 2026.

LTI bin interacted with the change in the nominal mortgage interest rate means that a one percentage point increase in the nominal rate reduces mortgage volume by 4 percentage points more in the tercile of CBSAs with the highest LTI ratio relative to the tercile of CBSAs with the lowest LTI ratio. Consistent with figures 2 and 3, the result shows that when nominal rates rise, mortgage volume falls more in high housing cost cities like Los Angeles than in low housing cost cities like Houston. The effect is large. It implies that the four percentage point increase in the mortgage rate from 2020 to 2022 reduced mortgage issuance by 16 percentage points more in high LTI CBSAs than in low LTI CBSAs. We also see evidence that mortgage issuance falls more in the middle LTI tercile than in the lowest LTI tercile, with the coefficient averaging roughly 3 across columns.

By contrast, the coefficient on the interaction of the real interest rate with the highest LTI tercile, ζ_3 , is positive and statistically significant. The positive coefficient implies that conditional on the nominal interest rate, higher real interest rates lead to *more* mortgage issuance in high LTI CBSAs. In the middle LTI tercile, the coefficient is again positive, though smaller.

Table 4 repeats the exercise using alternative inflation expectation measures to construct the real mortgage rate. As in column (4) of table 3, we include all controls. While the quantitative magnitude of the coefficient on the interaction of the high LTI bin and the nominal interest rate changes, the qualitative effect remains. There is again no evidence of a negative effect of the real interest rate interacted with the high LTI bin.

Table 3 – Mortgage loan count regressions

	(1)	(2)	(3)	(4)
Δ Mortgage rate	-4.36*** (0.39)	-13.93*** (0.42)	-15.69*** (0.46)	
Mid LTI x Δ Mortgage rate	-2.40*** (0.54)	-2.97*** (0.58)	-2.87*** (0.63)	-2.87*** (0.64)
High LTI x Δ Mortgage rate	-5.51*** (0.60)	-5.50*** (0.64)	-3.90*** (0.70)	-3.90*** (0.70)
Δ Real rate (Michigan mean)	2.31*** (0.41)	10.24*** (0.43)	10.73*** (0.44)	
Mid LTI x Δ Real rate (Michigan mean)	1.23** (0.57)	1.71*** (0.61)	1.68*** (0.62)	1.68*** (0.62)
High LTI x Δ Real rate (Michigan mean)	2.90*** (0.62)	2.89*** (0.66)	2.44*** (0.67)	2.44*** (0.67)
$\Delta \ln$ HPI		1.25*** (0.02)	1.20*** (0.02)	
Mid LTI x $\Delta \ln$ HPI		0.07*** (0.03)	0.08*** (0.03)	0.08*** (0.03)
High LTI x $\Delta \ln$ HPI		-0.00 (0.03)	0.04 (0.03)	0.04 (0.03)
Δ Fed funds			1.38*** (0.10)	
Mid LTI x Δ Fed funds			-0.08 (0.15)	-0.08 (0.15)
High LTI x Δ Fed funds			-1.25*** (0.18)	-1.25*** (0.18)
CBSA FEs				X
Date FEs				X
CBSAs	704	704	704	704
R2	0.03	0.14	0.14	0.55
Number of observations	78,848	78,848	78,848	78,848

Notes: The dependent variable is 100 times the 4-quarter log-change in the number of loans, winsorized at the top and bottom 2.5th percentiles. HPI is the house price index, also expressed as 100 times the 4-quarter log-change. Changes in the nominal and real interest rate are in percentage point units. Coefficients on interest rate variables can therefore be interpreted as percentage point changes in loan growth per percentage point change in the interest rate. Column 4 controls for quarterly date and CBSA fixed effects. See the text for a discussion of why it is expected that the coefficients in columns 3 and 4 are identical. The sample is 1996q1-2023q4. Standard errors are clustered at the CBSA level. Sources: See the notes to table 2.

Table 4 – Mortgage loan count regressions: Alternative inflation expectation measures

	(1)	(2)	(3)
Mid LTI x Δ Mortgage rate	-5.62*** (1.15)	-1.07* (0.56)	-0.97** (0.43)
High LTI x Δ Mortgage rate	-9.46*** (1.34)	-1.81*** (0.57)	-1.85*** (0.44)
Mid LTI x Δ Real rate (Michigan median)	4.44*** (1.16)		
High LTI x Δ Real rate (Michigan median)	8.08*** (1.32)		
Mid LTI x Δ Real rate (Cleveland)		-0.38 (0.71)	
High LTI x Δ Real rate (Cleveland)		0.21 (0.75)	
Mid LTI x Δ Real rate (breakeven)			-0.54* (0.30)
High LTI x Δ Real rate (breakeven)			0.26 (0.34)
Mid LTI x Δ ln HPI	0.10*** (0.03)	0.05* (0.03)	0.03 (0.04)
High LTI x Δ ln HPI	0.08** (0.03)	0.02 (0.03)	-0.02 (0.04)
Mid LTI x Δ Fed funds	-0.15 (0.15)	-0.10 (0.15)	0.13 (0.17)
High LTI x Δ Fed funds	-1.38*** (0.17)	-1.30*** (0.18)	-1.24*** (0.23)
CBSA FEs	X	X	X
Date FEs	X	X	X
CBSAs	704	704	704
R2	0.55	0.55	0.55
Number of observations	78,848	78,848	56,320

Notes: The dependent variable is 100 times the 4-quarter log-change in the number of loans, winsorized at the top and bottom 2.5th percentiles. HPI is the house price index, also expressed as 100 times the 4-quarter log-change. Changes in the nominal and real interest rate are in percentage point units. Coefficients on interest rate variables can therefore be interpreted as percentage point changes in loan growth per percentage point change in the interest rate. All columns control for quarterly date and CBSA fixed effects. The sample is 1996q1-2023q4 except in column (3), in which the sample begins in 2003q1 when the TIPS breakeven series starts. Standard errors are clustered at the CBSA level. Sources: See the notes to table 2.

5 Macroeconomic Implications of Payment-to-Income Constraints

Our empirical results document the relevance of payment-to-income constraints and thus of nominal interest rates. We now explore the macroeconomic implications of such constraints in a simple model. The model is as close as possible to [Gali \(2015\)](#) and is in the spirit of [Lucas and Stokey \(1987\)](#) with a cash good and a credit good. Purchases of the credit good are subject to a payment-to-income constraint like that discussed in [section 2](#). We keep firm behavior simple by assuming that the two goods are produced using the same production function.

The model shows how a payment-to-income constraint leads to real effects of nominal interest rates. An increase in the nominal interest rate shifts demand away from the credit good and toward the cash good. Diminishing marginal utility for the cash good then reduces labor supply and output. Perhaps surprisingly, despite the effect of the nominal interest rate on output, the conditions for determinacy in the model are the same as those in the standard new Keynesian model.

5.1 Set-up We consider an economy with two nondurable goods, one cash good and one credit good. Consumers purchase the credit good today but pay for it tomorrow. We impose a borrowing constraint on the credit good to mimic the way in which the nominal interest rate typically affects a household's ability to borrow with a real world debt contract.¹⁸ The production function for both goods is the same, so their prices are the same. This simplification allows us to isolate the role of the payment-to-income constraint.

Time is discrete and indexed by t . The representative household consumes the two non-durable goods, the cash good indexed by n , and the credit good indexed by d . Let P^n and P^d denote the prices of the two goods and C^n and C^d their consumption. The household chooses consumption and labor supply to maximize the present value of utility,

$$\sum_t \beta^t U_t \text{ with } U_t = \frac{(C_t^n)^{1-\sigma}}{1-\sigma} + \lambda \frac{(C_t^d)^{1-\sigma}}{1-\sigma} - \frac{1}{1+\gamma} N_t^{1+\gamma}.$$

$1/\sigma$ is the elasticity of intertemporal substitution, γ is the inverse Frisch elasticity of labor

¹⁸Similar constraints appear in the literature on firm borrowing. [Drechsel \(2023\)](#) analyzes the importance of current earnings as a constraint on firm borrowing. [Chodorow-Reich and Falato \(2022\)](#) document the importance of financial covenants in loan contracts, e.g. the interest coverage ratio, in limiting firms' access to credit during the Great Recession.

supply, and λ is a parameter that determines the relative importance of the cash and credit goods in utility.

Purchases are subject to the budget constraint

$$P_t^n C_t^n + (1 + i_{t-1})P_{t-1}^d C_{t-1}^d + B_t = W_t N_t + \Pi_t + (1 + i_{t-1})B_{t-1}.$$

B_t is the purchase or issuance of nominal bonds at date t maturing at date $t + 1$.¹⁹ i_t is the nominal rate of return between t and $t + 1$; W_t is the nominal wage, and Π_t is firm profits. What distinguishes the credit good (d) is that the consumer pays the price plus interest in the next period. We assume that these purchases are limited by the payment-to-income constraint:

$$(1 + i_t)P_t^d C_t^d \leq \theta P_t Y_t.$$

Here P is the aggregate price level (to be determined below), so PY is nominal income. θ is the share of income that a consumer can commit to spending on the credit good. It is strictly greater than zero and less than one, ensuring that the consumer can always purchase both the credit and cash good. The payment-to-income constraint depends on current income as in [Drechsel \(2023\)](#), and as is true in the U.S. mortgage market (see, e.g., figures 2 and 3).²⁰ Firms use current income to judge whether or not a borrower is credit worthy; they do not attempt to forecast future income. θ captures the tightness of the payment-to-income constraint.

We assume that debt contracts are one-period nominal bonds. This assumption means that we do not need to keep track of debt as a separate state variable and keeps the model close to the standard new Keynesian framework. Nevertheless, the payment-to-income constraint captures the key feature of real world debt contracts: a higher nominal interest rate increases the payment obligations of borrowers and thus tightens their borrowing constraints.

¹⁹Normally bonds would be in zero net supply. In the model, however, consumers go into debt to purchase the credit (d) good. The debt is issued by producers of the credit good, and these producers are owned by the consumers. In equilibrium $B_t = P_t^d C_t^d$.

²⁰Most existing work on mortgages in macro models focuses on other constraints. [Iacoviello \(2005\)](#), for instance, assumes that borrowing is limited by the expected present value of collateral, which in his case is the value of the house. [Garriga et al. \(2017, 2021\)](#) emphasize the importance of revaluation and cash-flow channels of existing long-term debt in response to monetary policy shocks. (As discussed in the introduction, [Garriga et al. \(2017\)](#) do consider how nominal shocks change the time path of real mortgage payments. But their quantitative simulations emphasize the effect of nominal shocks on the real mortgage payments of existing homeowners.)

Labor-leisure choice gives

$$\frac{W_t}{P_t^n} = (C_t^n)^\sigma N_t^\gamma.$$

The two consumption goods are produced from a continuum of intermediate goods by competitive firms with access to constant returns to scale technology. Intermediate goods are indexed by $j \in [0, 1]$. The production functions in the two sectors are

$$\begin{aligned} Y_t^n &= \left(\int_0^1 (y_{t,j}^n)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \text{ and} \\ Y_t^d &= \left(\int_0^1 (y_{t,j}^d)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}. \end{aligned}$$

$y_{t,j}^n$ is the use of input j in the n sector, and $y_{t,j}^d$ is the use of input j in the d sector. Cost minimization yields

$$P_t = P_t^d = P_t^n = \left(\int_0^1 (P_{t,j})^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}.$$

Since the sectors are competitive, symmetric, and constant returns to scale, the price of the cash and credit good are equal and equal to the aggregate price level.

Each of the intermediate goods producers has access to a constant returns to scale production technology:

$$Y_{t,j} = N_{t,j}.$$

The demand for each intermediate good is

$$y_{t,j} = \left(\frac{P_{t,j}}{P_t} \right)^{-\varepsilon} (Y_t^n + Y_t^d).$$

Intermediate goods producers face a Calvo pricing friction. They can only change their price with probability $(1 - \alpha)$. A firm that adjusts its price at date t maximizes

$$\max_{P_{t,j}^*} \sum_{k=0}^{\infty} \alpha^k \Lambda_{t,t+k} \left[\left(\frac{P_{t,j}^*}{P_{t+k}} \right) - \frac{W_{t+k}}{P_{t+k}} \right] \left(\frac{P_{t,j}^*}{P_{t+k}} \right)^{-\varepsilon} (Y_{t+k}^n + Y_{t+k}^d),$$

where $\Lambda_{t,t+k}$ is the stochastic discount factor between t and $t + k$.

We close the model with equilibrium in the goods and labor markets,

$$\begin{aligned} Y_t^n &= C_t^n; \\ Y_t^d &= C_t^d; \\ \int_0^1 N_{t,j} dj &= N_t; \end{aligned}$$

and a monetary policy rule,

$$i_t = \phi \pi_t + \eta_t.$$

η_t is a monetary policy shock.

5.2 Solution

5.2.1 Firm behavior

Firm behavior is conventional. Solving the intermediate firm's optimization problem, linearizing the model, and aggregating yields the standard new Keynesian Phillips curve

$$\pi_t = \kappa(w_t - p_t) + \beta E_t \pi_{t+1},$$

where $\kappa = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}$, and $w - p$ is marginal cost.

5.2.2 Consumer demand

Optimal choice of the n good leads to the linearized Euler equation

$$c_t^n = -\frac{1}{\sigma}(i_t - \pi_{t+1}) + c_{t+1}^n.$$

We want to express marginal cost and c^n in terms of the output gap, inflation, and the interest rate. Consider first the definition of GDP:

$$Y_t = C_t^n + C_t^d.$$

Linearizing yields

$$\bar{Y} y_t = \bar{C}^n c_t^n + \bar{C}^d c_t^d,$$

where bars indicate steady state values. Linearizing the constraint on the purchase of the d good yields

$$i_t + c_t^d = y_t,$$

and substituting into the aggregate market clearing condition gives

$$\bar{Y} y_t = \bar{C}^n c_t^n + \bar{C}^d (y_t - i_t),$$

or

$$c_t^n = y_t + \frac{\bar{C}^d}{\bar{C}^n} i_t.$$

So if the nominal interest rate rises, then C^n must rise or Y must fall. How much they rise or fall depends on the relative size of the d sector.

We can now write the Euler equation in terms of the output gap, inflation, and the nominal interest rate:

$$c_t^n = -\frac{1}{\sigma}(i_t - \pi_{t+1}) + c_{t+1}^n$$

becomes

$$y_t + \frac{\bar{C}^d}{\bar{C}^n} i_t = -\frac{1}{\sigma}(i_t - \pi_{t+1}) + y_{t+1} + \frac{\bar{C}^d}{\bar{C}^n} i_{t+1};$$

or

$$y_t = -\frac{1}{\sigma}(i_t - \pi_{t+1}) + y_{t+1} - \frac{\bar{C}^d}{\bar{C}^n} (i_t - i_{t+1}). \quad (4)$$

Relative to the standard Euler equation, the d sector adds an additional term, a term that depends on the change in the nominal interest rate. To understand the intuition, we solve the equation forward:

$$y_t = -\frac{1}{\sigma} \lim_{T \rightarrow \infty} \sum_{k=0}^T [(i_{t+k} - \pi_{t+k+1})] - \frac{\bar{C}^d}{\bar{C}^n} i_t + \underbrace{\lim_{T \rightarrow \infty} y_{t+T}}_{=0}. \quad (5)$$

The first term is the long-run real interest rate, as in the standard Euler equation. The second term shows that by tightening the payment-to-income constraint on the credit good, a higher nominal interest rate reduces current demand (and output). The magnitude of the demand effect depends on the size of the d sector relative to the n sector.

5.2.3 Forward Guidance

Equation 5 shows that aggregate demand is a function of current not future nominal interest rates. (It is a function of future real rates.) The dependence on the current interest rate is notable, since the degree to which demand is forward-looking in the standard new Keynesian model has bizarre implications for forward-guidance (e.g., [Del Negro et al., 2023](#); [McKay, Nakamura, and Steinsson, 2016](#); [McKay and Wieland, 2022](#), among others). In the standard model, a commitment by the central bank to lower the short term interest rate for one year 100 years in the future increases output more than does an interest rate cut today. That only the current nominal interest rate matters in our model is a consequence of the one-period debt contract. With longer-term debt contracts, higher future nominal rates over the duration of the debt contract also increase current nominal payments, tighten the payment-to-income constraint, and reduce demand for the credit good. Nonetheless, even with long term debt contracts, the qualitative implication for forward guidance remains: current short-rates affect the economy more than future short rates.

In Appendix A, we derive the Euler equation with M -period debt contracts,

$$y_t = -\frac{1}{\sigma} \sum_{j=0}^{\infty} (i_{t+j} - \pi_{t+j+1}) - \frac{\bar{C}^d}{\bar{C}^n} \sum_{s=0}^{M-1} \omega_s i_{t+s}; \quad (6)$$

ω_s are positive weights that are decreasing in s . The payment-to-income constraint depends on the long-term mortgage rate ρ_t , which by the expectations hypothesis is equal to $\rho_t = \sum_{s=0}^{M-1} \omega_s i_{t+s}$. Since ω_s is declining in s (time), the expected one-year interest rate 29 years in the future affects 30-year mortgage rates less than the expected one-year interest rate one year in the future. Intuitively, future rates matter less for the long-term mortgage rate because of compound interest: the current nominal rate affects all future payments, whereas the $M - 1$ period nominal rate affects only the last payment.

Another way to see the intuition is to consider the lender's profit maximization condition. The mortgage principal is paid back over time and lenders can invest these repayments and earn future short rates. In later years of the mortgage term, most of the mortgage principal has been paid back, and so the lender can earn future short rates on most of the mortgage. By contrast, early in the life of the mortgage, only a small amount of principal has been paid

back, and thus changes in near term rates (like i_{t+1}) have little effect on what the lender earns from a mortgage. Thus increases in near-term short rates have larger effects on the ρ that a lender will need to charge to earn the same amount on a mortgage as investing in a succession of short-term bonds.²¹ Since the short rate today affects the mortgage rate more than does the short rate in the future, our model can explain why current short rates affect output more than expected future short rates.

5.3 Labor supply We want to express marginal cost in terms of the output gap, inflation, and the interest rate. From labor-leisure choice

$$\frac{W_t}{P_t} = (C_t^n)^\sigma N_t^\gamma.$$

Linearizing

$$w_t - p_t = \sigma c_t^n + \gamma n_t.$$

Given prices, the share of each intermediate good in output is constant. Hence doubling labor input will double the output of all intermediate goods. Aggregate output is proportional to labor input

$$y_t = n_t.$$

Using the above derivation of c_t^n , we obtain a modified new Keynesian Phillips curve:

$$\begin{aligned} \pi_t &= \kappa (\sigma c_t^n + \gamma n_t) + \beta \pi_{t+1}; \\ &= \kappa (\sigma + \gamma) y_t + \kappa \sigma \frac{\bar{C}^d}{\bar{C}^n} i_t + \beta \pi_{t+1}. \end{aligned}$$

²¹Formally, consider a lender choosing between lending X dollars in a long-term, fixed rate amortizing mortgage at rate ρ or purchasing a succession of one-year bonds paying interest rates $i_1, i_2, \dots, i_M$. The latter strategy will yield $X(1+i_1)(1+i_2)\dots(1+i_M)$ dollars. If the lender lends X dollars for a long-term mortgage, it receives a constant payment of interest and principal combined of Z every year for M years. Z is a function of the size of the mortgage (X) and the mortgage interest rate (ρ): $Z(X, \rho) = [X\rho(1+\rho)^M]/[(1+\rho)^M - 1]$. $\partial Z/\partial X > 0$ and $\partial Z/\partial \rho > 0$. The lender can reinvest the payments Z at the prevailing short-run interest rate, so the payoff to giving the mortgage is $Z(X, \rho) \prod_{t=2}^M (1+i_t) + Z(X, \rho) \prod_{t=3}^M (1+i_t) + \dots + Z(X, \rho)(1+i_M) + Z(X, \rho)$.

A profit maximizing lender will be indifferent between these two strategies, and will set ρ such that $X(1+i_1)(1+i_2)\dots(1+i_M) = Z(X, \rho) \prod_{t=2}^M (1+i_t) + Z(X, \rho) \prod_{t=3}^M (1+i_t) + \dots + Z(X, \rho)(1+i_M) + Z(X, \rho)$. The effect of current and future short-run rates (e.g., i_2 vs i_{M-1}) has a symmetric effect on the left-hand side. But an increase in current interest rates (e.g., i_2) increases the right-hand side less than an increase in future rates (e.g., i_{M-1}). Thus for the equality to hold, an increase in the short rate today must increase mortgage rates more than does an increase in the short rate in the future.

The nominal interest rate now enters the Phillips curve directly. It does so because a higher nominal interest rate shifts demand from the credit good to the cash good, which reduces the marginal utility of consumption and thus labor supply through a positive wealth effect.

Nevertheless, a higher nominal interest rate reduces both output and inflation. To see this, solve the Phillips curve forward:

$$\pi_t = \kappa \lim_{T \rightarrow \infty} \sum_{k=0}^T \beta^k \left[(\sigma + \gamma) y_{t+k} + \sigma \frac{\bar{C}^d}{\bar{C}^n} i_{t+k} \right],$$

and then substitute in the expression for y_t derived above. The result is

$$\begin{aligned} \pi_t &= \kappa \sum_{k=0}^{\infty} \beta^k \left[(\sigma + \gamma) \left(-\frac{1}{\sigma} \sum_{j=0}^{\infty} [(i_{t+k+j} - \pi_{t+k+j+1})] - \frac{\bar{C}^d}{\bar{C}^n} i_{t+k} \right) + \sigma \frac{\bar{C}^d}{\bar{C}^n} i_{t+k} \right] \\ &= \kappa \sum_{k=0}^{\infty} \beta^k \left[-\frac{\sigma + \gamma}{\sigma} \sum_{j=0}^{\infty} [(i_{t+k+j} - \pi_{t+k+j+1})] - \gamma \frac{\bar{C}^d}{\bar{C}^n} i_{t+k} \right]. \end{aligned}$$

Inflation is solely a function of the long-term real interest rate and the discounted path of nominal interest rates. Holding the real interest rate fixed, a higher nominal interest rate always reduces inflation. The lower output due to a higher nominal interest rate reduces marginal cost by more than the wealth effect increases marginal cost.

We thus have a modified three equation system

$$\begin{aligned} y_t &= -\frac{1}{\sigma}(i_t - \pi_{t+1}) + y_{t+1} - \frac{\bar{C}^d}{\bar{C}^n}(i_t - i_{t+1}); \\ \pi_t &= \kappa(\sigma + \gamma)y_t + \kappa\sigma\frac{\bar{C}^d}{\bar{C}^n}i_t + \beta E_t \pi_{t+1}; \\ i_t &= \phi\pi_t + \eta_t. \end{aligned}$$

In Appendix B we show that the determinacy condition for this system is identical to that in the standard new Keynesian model, $\phi > 1$. Intuitively, the presence of the payment-to-income constraint only affects the short-run dynamics of the model, not the long-run relationship between inflation, output, and the nominal interest rate.

5.4 Summary of macroeconomic implications of the payment-to-income constraint

Relative to the standard new Keynesian model, the presence of the payment-to-income constraint on the credit good has four novel implications:

1. The constraint on the credit good makes output a function of the current nominal interest rate, amplifying the effect of monetary policy on the economy. Monetary policy has a larger effect since the addition to the model of the credit good and payment-to-income constraint leaves the standard intertemporal substitution channel intact while add a new channel through which the nominal interest rate affects demand.
2. Output is less sensitive to future nominal interest rates than to current nominal interest rates. This aspect of the model helps to address the forward guidance puzzle.
3. The borrowing constraint for the credit good affects supply as well as demand. A higher nominal interest rate shifts demand to the cash good. Diminishing marginal utility of consumption of the cash good then reduces labor supply. But despite lower labor supply, when the nominal interest rate rises consumption demand falls enough for inflation to decline .
4. The determinacy condition for the model remains the standard Taylor principle (see appendix B).

6 Conclusion

The multi-period, fixed nominal payment structure of debt contracts means that the nominal interest rate almost certainly has real effects. In particular, a higher nominal mortgage rate makes it more difficult for households to meet payment-to-income constraints, limiting how much they can spend on a house. We find support for this simple theory from two sources. First, in the Michigan Survey of Consumers, there is strong evidence that a higher nominal — but not real — interest rate reduces housing demand. Second, and consistent with the importance of payment-to-income constraints, the nominal rate has a larger impact on mortgage originations in cities where loan-to-income ratios are higher.

In the standard new Keynesian model, there is no such nominal rate effect, since households do not face a payment-to-income constraint. We show that when the new Keynesian model is modified to include a (realistic) payment-to-income constraint, the nominal interest rate has real effects. As in the real world, a higher nominal interest rate tightens the payment-to-income constraint, limiting how much consumers can spend on a credit good.

The effect of nominal interest rates on consumers' ability to purchase goods on credit may be a partial explanation for why consumers dislike inflation. Of course, the argument that high interest rates are unpopular is hardly novel. But standard models miss that nominal interest rates themselves have real effects, so consumers may be unhappy when nominal rates are high even if real rates are low. And inflation is almost inevitably accompanied by higher nominal interest rates. These higher nominal interest rates, while unmeasured in the CPI, make it more difficult for consumers to purchase houses, cars, and other durable goods. Consumers will be unhappy about the decline in their purchasing power, and they may correctly blame inflation.

References

- Avery, Robert, Kenneth Brevoort, and Glenn Canner, "Opportunities and Issues in Using HMDA Data," *Journal of Real Estate Research*, 2007, 29 (4), 351–380.
- Bhutta, Neil and Daniel Ringo, "The Effect of Interest Rates on Home Buying: Evidence from a Shock to Mortgage Insurance Premiums," *Journal of Monetary Economics*, 2021, 118, 195–211.
- Bosshardt, Joshua, Marco Di Maggio, Ali Kakhbod, and Amir Kermani, "The Credit Supply Channel of Monetary Policy Tightening and Its Distributional Impacts," *Journal of Financial Economics*, 2024, 160, 103914.
- Chodorow-Reich, Gabriel and Antonio Falato, "The Loan Covenant Channel: How Bank Health Transmits to the Real Economy," *Journal of Finance*, 2022, 77 (1), 85–128.
- Drechsel, Thomas, "Earnings-Based Borrowing Constraints and Macroeconomic Fluctuations," *American Economic Journal: Macroeconomics*, 2023, 15 (2), 1–34.
- Galí, Jordi, *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework and Its Applications*, Princeton University Press, 2015.
- Garriga, Carlos, Finn E. Kydland, and Roman Šustek, "Mortgages and Monetary Policy," *Review of Financial Studies*, 2017, 30 (10), 3337–3375.
- , —, and —, "MoNK: Mortgages in a New-Keynesian Model," *Journal of Economic Dynamics and Control*, 2021, 123, 104059.
- Greenwald, Daniel, "The Mortgage Credit Channel of Macroeconomic Transmission," 2026. Working paper.
- Grigoli, Francesco, Damiano Sandri, Yuriy Gorodnichenko, and Olivier Coibion, "Monetary Policy According to Households: Perceptions, Reactions and Channels," 2026. NBER Working Paper 35127.
- Haight, Alan Day, "A Keynesian Angle for the Taylor Rule: Mortgage Rates, Monthly Payment Illusion, and the Scarecrow Effect of Inflation," *Journal of Post Keynesian Economics*, 2007, 30 (2), 259–277.
- Iacoviello, Matteo, "House Prices, Borrowing Constraints, and Monetary Policy in the Busi-

- ness Cycle,” *American Economic Review*, 2005, 95 (3), 739–764.
- Kearl, James R., “Inflation, Mortgages, and Housing,” *Journal of Political Economy*, 1979, 87 (5), 1115–1138.
- Kuttner, Kenneth N. and Ilhyock Shim, “Can Non-Interest Rate Policies Stabilize Housing Markets? Evidence from a Panel of 57 Economies,” *Journal of Financial Stability*, 2016, 26, 31–44.
- Lessard, Donald R. and Franco Modigliani, “Inflation and the Housing Market: Problems and Potential Solutions,” *Sloan Management Review*, 1975, 17 (1), 19–35.
- Lucas, Robert and Nancy Stokey, “Money and Interest in a Cash-in-Advance Economy,” *Econometrica*, 1987, 55 (3), 491–513.
- MacGee, James and Yuxi Yao, “Housing and the Welfare Cost of Inflation,” 2025. Working paper.
- MacGee, James C. and Yuxi Yao, “Housing and the Long-Term Real Effects of Changes in Trend Inflation,” 2026. Bank of Canada Staff Working Paper 2026-1.
- McKay, Alisdair and Johannes F. Wieland, “Forward Guidance and Durable Goods Demand,” *American Economic Review: Insights*, 2022, 4 (1), 106–122.
- , Emi Nakamura, and Jón Steinsson, “The Power of Forward Guidance Revisited,” *American Economic Review*, 2016, 106 (10), 3133–3158.
- Negro, Marco Del, Marc P. Giannoni, and Christina Patterson, “The Forward Guidance Puzzle,” *Journal of Political Economy Macroeconomics*, 2023, 1 (1), 43–79.
- Schwab, Robert M., “Inflation Expectations and the Demand for Housing,” *American Economic Review*, 1982, 72 (1), 143–153.
- , “Real and Nominal Interest Rates and the Demand for Housing,” *Journal of Urban Economics*, 1983, 13 (2), 181–195.
- Wilcox, James A., “Liquidity Constraints on Consumption: The Real Effects of ‘Real’ Lending Policies,” *Federal Reserve Bank of San Francisco Economic Review*, 1989, (Fall), 39–52.
- , “Nominal Interest Rate Effects on Real Consumer Expenditure,” *Business Economics*, 1990, 25 (4), 31–37.
- Woodford, Michael, *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press, 2003.

A Extension With Long-Term Debt

This appendix derives the household Euler equation and the New Keynesian Phillips curve when the payment-to-income (PTI) constraint depends on a long-term mortgage rate ρ_t rather than the one-period nominal rate i_t .

A.1 Long-term mortgage rate as a function of short rates Assume a fixed-rate mortgage of maturity M periods. The mortgage rate ρ_t is set at time t such that the present value of a unit stream discounted at the mortgage rate equals the present value discounted

at the sequence of one-period nominal rates:

$$\sum_{s=0}^{M-1} \frac{1}{\prod_{k=0}^s (1 + \rho_t)} = \sum_{s=0}^{M-1} \frac{1}{\prod_{k=0}^s (1 + i_{t+k})}. \quad (7)$$

Define

$$F(\rho) \equiv \sum_{s=0}^{M-1} (1 + \rho)^{-(s+1)}, \quad (8)$$

$$G_t \equiv \sum_{s=0}^{M-1} \prod_{k=0}^s (1 + i_{t+k})^{-1}. \quad (9)$$

Then (7) is

$$F(\rho_t) = G_t. \quad (10)$$

$F(\rho)$ is a finite geometric series:

$$\begin{aligned} F(\rho) &= (1 + \rho)^{-1} \sum_{s=0}^{M-1} (1 + \rho)^{-s} = (1 + \rho)^{-1} \cdot \frac{1 - (1 + \rho)^{-M}}{1 - (1 + \rho)^{-1}} \\ &= (1 + \rho)^{-1} \cdot \frac{1 - (1 + \rho)^{-M}}{\rho/(1 + \rho)} = \frac{1 - (1 + \rho)^{-M}}{\rho}. \end{aligned} \quad (11)$$

A.2 First-order approximation of ρ_t in terms of $\{i_{t+s}\}$ Let the steady state be constant: $i_{t+s} = i$ for all s and $\rho = i$. We log-linearize/linearize around this steady state.

A first-order Taylor expansion of (10) around $(\rho = i, i_{t+s} = i)$ gives

$$F'(i) (\rho_t - i) = \sum_{s=0}^{M-1} \left. \frac{\partial G_t}{\partial i_{t+s}} \right|_{ss} (i_{t+s} - i). \quad (12)$$

Step 1: compute $F'(i)$. From (11),

$$F(\rho) = \frac{1 - (1 + \rho)^{-M}}{\rho}.$$

Let $A(\rho) = 1 - (1 + \rho)^{-M}$ so $A'(\rho) = M(1 + \rho)^{-M-1}$. By the quotient rule,

$$F'(\rho) = \frac{A'(\rho)\rho - A(\rho)}{\rho^2} = \frac{M\rho(1 + \rho)^{-M-1} - [1 - (1 + \rho)^{-M}]}{\rho^2}. \quad (13)$$

Evaluate at $\rho = i$:

$$F'(i) = \frac{Mi(1 + i)^{-M-1} - [1 - (1 + i)^{-M}]}{i^2}. \quad (14)$$

Define the positive constant

$$\Gamma \equiv -F'(i) = \frac{[1 - (1+i)^{-M}] - Mi(1+i)^{-M-1}}{i^2} > 0. \quad (15)$$

Step 2: compute $\partial G_t / \partial i_{t+s}|_{ss}$. Write the m -th discount factor term as

$$Q_m \equiv \prod_{k=0}^m (1 + i_{t+k})^{-1}.$$

Then $G_t = \sum_{m=0}^{M-1} Q_m$. For a given s , i_{t+s} affects Q_m only for $m \geq s$. For $m \geq s$,

$$\frac{\partial Q_m}{\partial i_{t+s}} = Q_m \cdot \frac{\partial}{\partial i_{t+s}} (-\log(1 + i_{t+s})) = -\frac{Q_m}{1 + i_{t+s}}.$$

Hence

$$\frac{\partial G_t}{\partial i_{t+s}} = -\sum_{m=s}^{M-1} \frac{Q_m}{1 + i_{t+s}}. \quad (16)$$

At the steady state, $Q_m = (1+i)^{-(m+1)}$ and $1 + i_{t+s} = 1 + i$, so

$$\left. \frac{\partial G_t}{\partial i_{t+s}} \right|_{ss} = -\sum_{m=s}^{M-1} \frac{(1+i)^{-(m+1)}}{1+i} = -\sum_{m=s}^{M-1} (1+i)^{-(m+2)}. \quad (17)$$

Rewrite the sum (geometric series):

$$\begin{aligned} \sum_{m=s}^{M-1} (1+i)^{-(m+2)} &= (1+i)^{-(s+2)} \sum_{u=0}^{M-1-s} (1+i)^{-u} \\ &= (1+i)^{-(s+2)} \cdot \frac{1 - (1+i)^{-(M-s)}}{1 - (1+i)^{-1}} \\ &= (1+i)^{-(s+2)} \cdot \frac{1 - (1+i)^{-(M-s)}}{i/(1+i)} \\ &= \frac{(1+i)^{-(s+1)} [1 - (1+i)^{-(M-s)}]}{i}. \end{aligned} \quad (18)$$

Therefore

$$\left. \frac{\partial G_t}{\partial i_{t+s}} \right|_{ss} = -\frac{(1+i)^{-(s+1)} [1 - (1+i)^{-(M-s)}]}{i}. \quad (19)$$

Step 3: solve for ρ_t as a weighted sum of (expected) short rates. Plug (19) and $F'(i) = -\Gamma$ into (12):

$$(-\Gamma)(\rho_t - i) = \sum_{s=0}^{M-1} \left(-\frac{(1+i)^{-(s+1)} [1 - (1+i)^{-(M-s)}]}{i} \right) (i_{t+s} - i). \quad (20)$$

Multiply by -1 :

$$\Gamma(\rho_t - i) = \sum_{s=0}^{M-1} a_s (i_{t+s} - i), \quad a_s \equiv \frac{(1+i)^{-(s+1)} [1 - (1+i)^{-(M-s)}]}{i}. \quad (21)$$

Divide by Γ and define weights

$$\omega_s \equiv \frac{a_s}{\Gamma}. \quad (22)$$

Then

$$\rho_t - i = \sum_{s=0}^{M-1} \omega_s (i_{t+s} - i). \quad (23)$$

The weights satisfy $\omega_s > 0$ and decline with s ,

$$\frac{\partial \omega_s}{\partial s} = \frac{1}{\Gamma} \frac{\partial a_s}{\partial s} = \frac{1}{i\Gamma} \frac{\partial (1+i)^{-(s+1)}}{\partial s} = -\frac{\log(1+i)}{i\Gamma} (1+i)^{-(s+1)} < 0. \quad (24)$$

In what follows we treat ρ_t and i_t as their log-linearized values, so (23) becomes

$$\rho_t = \sum_{s=0}^{M-1} \omega_s i_{t+s}. \quad (25)$$

This is the standard expectations hypothesis formula for the long-term interest rate as a weighted average of current and expected future short-term interest rates.

A.3 PTI constraint with long-term rate Replace the one-period PTI constraint with a constraint that depends on the long mortgage rate:

$$(1 + \rho_t) P_t C_t^d \leq \theta P_t Y_t. \quad (26)$$

Assume it binds. Cancel P_t :

$$(1 + \rho_t) C_t^d = \theta Y_t. \quad (27)$$

Linearize the binding condition around the steady state ($\rho = i$). As in the main text, we use the normalization that yields the compact form

$$\rho_t + c_t^d = y_t. \quad (28)$$

(If one keeps exact scaling, the term ρ_t becomes $\frac{1}{1+i}(\rho_t - i)$; this only rescales constants below.)

A.4 Goods-market clearing

$$Y_t = C_t^n + C_t^d. \quad (29)$$

Linearize:

$$\bar{Y} y_t = \bar{C}^n c_t^n + \bar{C}^d c_t^d. \quad (30)$$

Use (28) to eliminate c_t^d :

$$c_t^d = y_t - \rho_t. \quad (31)$$

Substitute (31) into (30):

$$\bar{Y} y_t = \bar{C}^n c_t^n + \bar{C}^d (y_t - \rho_t). \quad (32)$$

Use $\bar{Y} = \bar{C}^n + \bar{C}^d$ and rearrange:

$$\begin{aligned} (\bar{C}^n + \bar{C}^d) y_t &= \bar{C}^n c_t^n + \bar{C}^d y_t - \bar{C}^d \rho_t \\ \bar{C}^n y_t &= \bar{C}^n c_t^n - \bar{C}^d \rho_t \\ c_t^n &= y_t + \frac{\bar{C}^d}{\bar{C}^n} \rho_t = y_t + \chi \rho_t. \end{aligned} \quad (33)$$

A.5 Euler equation The optimality condition for C_t^n delivers the same linearized Euler equation as in the baseline model:

$$c_t^n = -\frac{1}{\sigma} (i_t - \pi_{t+1}) + c_{t+1}^n. \quad (34)$$

Using (33) at t and $t+1$,

$$c_t^n = y_t + \chi \rho_t, \quad c_{t+1}^n = y_{t+1} + \chi \rho_{t+1}.$$

Plug into (34):

$$y_t + \chi \rho_t = -\frac{1}{\sigma} (i_t - \pi_{t+1}) + (y_{t+1} + \chi \rho_{t+1}). \quad (35)$$

Rearrange:

$$y_t = -\frac{1}{\sigma} (i_t - \pi_{t+1}) + y_{t+1} - \chi (\rho_t - \rho_{t+1}). \quad (36)$$

Solving (36) forward gives

$$y_t = -\frac{1}{\sigma} \sum_{j=0}^{\infty} (i_{t+j} - \pi_{t+j+1}) - \chi \sum_{j=0}^{\infty} (\rho_{t+j} - \rho_{t+j+1}) \quad (37)$$

$$= -\frac{1}{\sigma} \sum_{j=0}^{\infty} (i_{t+j} - \pi_{t+j+1}) - \chi \rho_t. \quad (38)$$

This is the Euler/IS equation with a long-term PTI constraint: relative to the standard IS curve, there is an additional term involving the change in the long mortgage rate. Relative to the one-period PTI Euler equation (4), the long-term mortgage rate replaces the one-period nominal rate.

We can express the Euler equation purely in terms of short rates by substituting (25),

$$y_t = -\frac{1}{\sigma} \sum_{j=0}^{\infty} (i_{t+j} - \pi_{t+j+1}) - \chi \sum_{s=0}^{M-1} \omega_s i_{t+s}. \quad (39)$$

This makes explicit how current and expected future nominal short rates determine aggregate

demand, since the weights, ω_s , decline with s .

A.6 Phillips curve with long-term PTI Labor supply (from the main text) is:

$$\frac{W_t}{P_t} = (C_t^n)^\sigma N_t^\gamma. \quad (40)$$

Linearize:

$$w_t - p_t = \sigma c_t^n + \gamma n_t. \quad (41)$$

With linear technology $Y_t = N_t$, aggregate output is proportional to labor input:

$$y_t = n_t. \quad (42)$$

Combine (41)–(42):

$$w_t - p_t = \sigma c_t^n + \gamma y_t. \quad (43)$$

Use (33) to eliminate c_t^n :

$$w_t - p_t = \sigma(y_t + \chi \rho_t) + \gamma y_t = (\sigma + \gamma)y_t + \sigma \chi \rho_t. \quad (44)$$

The Calvo price-setting block is unchanged, so the NKPC is

$$\pi_t = \kappa(w_t - p_t) + \beta \pi_{t+1}, \quad \kappa = \frac{(1 - \alpha)(1 - \alpha\beta)}{\alpha}. \quad (45)$$

Substitute (44) into (45):

$$\pi_t = \kappa(\sigma + \gamma)y_t + \kappa\sigma\chi\rho_t + \beta\pi_{t+1}. \quad (46)$$

Thus, the long-term mortgage rate enters inflation dynamics directly via its effect on the composition of demand and hence marginal utility and labor supply.

Using (25) to express ρ_t in terms of short rates, the NKPC can be written purely in terms of expected short rates:

$$\pi_t = \kappa(\sigma + \gamma)y_t + \kappa\sigma\chi \sum_{s=0}^{M-1} \omega_s i_{t+s} + \beta\pi_{t+1}. \quad (47)$$

B Determinacy Conditions

The system of equations is

$$\begin{aligned} y_t &= y_{t+1} - \frac{1}{\sigma}(i_t - \pi_{t+1}) - \chi(i_t - i_{t+1}), \\ \pi_t &= \kappa(\sigma + \gamma)y_t + \kappa\sigma\chi i_t + \beta\pi_{t+1}, \\ i_t &= \phi\pi_t + \eta_t, \quad \text{where } \chi = \frac{\bar{C}^d}{\bar{C}^n}. \end{aligned}$$

Substituting the Taylor rule and using $i_{t+1} = \phi\pi_{t+1}$ (setting $\eta_t = 0$), the IS curve becomes

$$y_t = y_{t+1} - \left(\frac{\phi}{\sigma} + \chi\phi\right)\pi_t + \left(\frac{1}{\sigma} + \chi\phi\right)\pi_{t+1}. \quad (\text{IS})$$

The Phillips curve is

$$\pi_t = \kappa(\sigma + \gamma)y_t + \kappa\sigma\chi\phi\pi_t + \beta\pi_{t+1}. \quad (\text{PC})$$

Solving the Phillips curve for y_t and one step ahead yields

$$y_t = \frac{\pi_t - \kappa\sigma\chi\phi\pi_t - \beta\pi_{t+1}}{\kappa(\sigma + \gamma)},$$

$$y_{t+1} = \frac{\pi_{t+1} - \kappa\sigma\chi\phi\pi_{t+1} - \beta\pi_{t+2}}{\kappa(\sigma + \gamma)}.$$

Substituting into the IS curve and multiplying by $\kappa(\sigma + \gamma)$ gives:

$$(1 - \kappa\sigma\chi\phi)\pi_t - (\beta + 1 - \kappa\sigma\chi\phi)\pi_{t+1} + \beta\pi_{t+2} = -\kappa(\sigma + \gamma)\phi\left(\frac{1}{\sigma} + \chi\right)\pi_t + \kappa(\sigma + \gamma)\left(\frac{1}{\sigma} + \chi\phi\right)\pi_{t+1}.$$

Collecting terms yields

$$A_0\pi_t + A_1\pi_{t+1} + A_2\pi_{t+2} = 0, \quad (48)$$

where

$$A_0 = 1 + \kappa\phi\left(\frac{\sigma + \gamma}{\sigma} + \chi\gamma\right),$$

$$A_1 = -\beta - 1 - \kappa\frac{\sigma + \gamma}{\sigma} - \kappa\chi\gamma\phi,$$

$$A_2 = \beta.$$

The characteristic equation is

$$A_2r^2 + A_1r + A_0 = 0. \quad (49)$$

For determinacy, the two roots must lie outside the unit circle. The solution for the two roots is

$$r_{1,2} = \frac{-A_1 \pm \sqrt{A_1^2 - 4A_0A_2}}{2A_2}$$

$$= \frac{1}{2\beta} \left[\beta + 1 + \kappa\frac{\sigma + \gamma}{\sigma} + \kappa\chi\gamma\phi \pm \sqrt{\left(-\beta - 1 - \kappa\frac{\sigma + \gamma}{\sigma} - \kappa\chi\gamma\phi\right)^2 - 4\beta\left(1 + \kappa\phi\left(\frac{\sigma + \gamma}{\sigma} + \chi\gamma\right)\right)} \right].$$

For the second root to lie outside the unit circle, we need $|r_2| > 1$. This requires

$$\begin{aligned}
-\beta + 1 + \kappa \frac{\sigma + \gamma}{\sigma} + \kappa \chi \gamma \phi &> \sqrt{\left(-\beta - 1 - \kappa \frac{\sigma + \gamma}{\sigma} - \kappa \chi \gamma \phi\right)^2 - 4\beta \left(1 + \kappa \phi \left(\frac{\sigma + \gamma}{\sigma} + \chi \gamma\right)\right)} \\
(-\beta + 1 + \kappa \frac{\sigma + \gamma}{\sigma} + \kappa \chi \gamma \phi)^2 &> \left(-\beta - 1 - \kappa \frac{\sigma + \gamma}{\sigma} - \kappa \chi \gamma \phi\right)^2 - 4\beta \left(1 + \kappa \phi \left(\frac{\sigma + \gamma}{\sigma} + \chi \gamma\right)\right) \\
-4\beta \left(1 + \kappa \frac{\sigma + \gamma}{\sigma} + \kappa \chi \gamma \phi\right) &> -4\beta \left(1 + \kappa \phi \left(\frac{\sigma + \gamma}{\sigma} + \chi \gamma\right)\right) \\
\phi &> 1,
\end{aligned}$$

which is the standard Taylor principle.