Real Effects of Nominal Rates*

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PRELIMINARY AND INCOMPLETE.

Abstract

We show that nominal interest rates, and thus inflation, have real effects. Real world debt contracts, such as residential mortgages, require a sequence of constant nominal payments across time. When combined with payment-to-income constraints, these constant nominal payments force borrowers to take on less debt when nominal interest rates rise, regardless of the behavior of the real interest rate. Evidence from the Michigan Surveys of Consumers is consistent with this mechanism: conditional on the real rate, higher nominal interest rates reduce home buying sentiment. Cross-sectional data on mortgage origination provides evidence for the quantitative importance of this channel. To better understand the general equilibrium implications of this nominal rate effect, we analyze a new Keynesian model modified to include a payment-to-income constraint.

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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. Nominal rates only matter if, for instance at the zero lower bound, they determine real rates or if agents are subject to a "money illusion" where they conflate real and nominal rates. We argue that the real world is different: even without any money illusion, the structure of debt contracts means that nominal rates have real effects.

The importance of nominal rates is easy to overlook in the data since real and nominal rates often move together. And the importance of nominal rates is even easier to overlook in models, since the single period real debt in most 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. Such multi-period nominal debt is characteristic of residential mortgages, car loans, and corporate bonds.

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, or 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 size of a loan and thus the size of a purchase (e.g. of a house) that a borrower 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 an argument 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. Indeed, this may be one reason why inflation is so unpopular; the higher nominal interest rates that accompany inflation make it much more difficult for households to borrow money to purchase homes, cars, and other durable goods.

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 of the impact of nominal versus real interest rates in the Michigan Surveys of Consumers. The survey evidence strongly suggests 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 effects, with lower real rates depressing home buying sentiment.

In section 4, we use cross-sectional data on mortgages in Core-based Statistical Areas (CBSAs) to look at whether the nominal rate effect works through payment-to-income constraints. We exploit the fact that while interest rates do not vary within the U.S., their effects do. Payment-to-income constraints are more likely to bind in metropolitan areas (CBSAs) where mortgage loans are large relative to incomes. We proxy for payment-to-income constraints using the average loan-to-income (LTI) ratio in a CBSA, calculated from mortgage-level data. We then bin CBSAs into terciles based on their average LTI ratio. In our baseline regression we regress the growth rate of loans in a CBSA on the nominal mortgage rate, its interaction with the LTI terciles, the real mortgage rate, and its interaction with the LTI terciles. The identification assumption is that, holding fixed the real rate, the nominal interest rate only affects local mortgage origination through differences in local LTI constraints.

We find that the coefficient on the interaction of the nominal mortgage rate with the highest LTI tercile is consistently negative and statistically significant, whereas the coefficient on the interaction of the real mortgage rate with the highest LTI tercile is not. The nominal rate effect is a robust feature of the housing market. Our estimated effect sizes are stable as we add controls for house price growth and the Federal Funds Rate (both interacted with LTI terciles), as well as CBSA and year fixed effects. Since we are interested in household decisions, our preferred measures of inflation expectations to construct the real mortgage rate are those directly reported from households in the Michigan Survey of Consumers. Our results are robust to using mean or median long run inflation expectations from the Michigan survey. We also explore other measures of inflation expectations, the TIPS breakeven rate,

and inflation expectations from the Cleveland Fed model. We find similar qualitative results with these inflation measures.

To the extent that new mortgage issuance is a good proxy for residential investment, these results suggest that the nominal rate has important real effects on the housing market. Insofar has higher levels of inflation lead to higher nominal interest rates, our results also point to real effects of the level of inflation on the economy. To further understand the macroeconomic effects of the the interaction between the nominal rate and payment-to-income constraints, we turn to a model. 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 rates have real effects. The model shows that payment-to-income constraints amplify the effects of monetary policy on output.

1.1 Related literature That the structure of mortgage contracts means that nominal rates will have real effects was explored by macroeconomists during and in the aftermath of the 1970s Great Inflation. An early paper in this literature is Lessard and Modigliani (1975); they point out that higher nominal interest rates for a given real interest rate tilt 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 this mechanism means that higher nominal interest rates reduce housing demand. Kearl (1979), Schwab (1982), and Schwab (1983) use models and data to make the same point.

Most similar in intent though not method to our paper are Wilcox (1989) and Wilcox (1990). In these papers, Wilcox 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 rates. While intriguing, these results are open to concerns about endogeneity.

Recent work on housing and the macroeconomy has shown the empirical relevance of payment-to-income constraints (e.g., Bhutta and Ringo (2021), Bosshardt, Di Maggio, Kakhbod, and Kermani (2024) and Drechsel (2023)). And Greenwald (2018) shows how changes in payment-to-income constraints matter in a macro model. None of these papers, however,

link the importance of payment-to-income constraints to the effect of nominal versus real interest rate changes.

There is less recent literature related to the theory part of our paper. Closest is Garriga, Kydland, and Šustek (2017) who look at long-term fixed nominal payment mortgages in a macro model. But unlike our new Keynesian model, their model is one without price stickiness, and thus they are unable to discuss how the financial friction of a payment-to-income constraint interacts with the conventional monetary policy transmission mechanism in new Keynesian models.

2 Nominal debt contracts

Many real world loans, specifically fixed rate mortgages, have the following three features:

1. Debt is multi-period.

2. One repays debt with a constant nominal payment each period. e.g. A homebuyer who obtains a 30-year fixed-rate mortgage in July 2025 will make 360 identical nominal payments from July 2025 through June 2055.

3. Lenders resist making loans in which the ratio of this payment to current income is high.

These features are familiar to consumers, or at least to homebuyers. But their combination is generally absent from macroeconomic models. These features impact home purchases in multiple ways. Tight monetary policy raises nominal payments and reduces income, thereby tightening the payment constraint unless house prices fall dramatically. Increases in nominal interest rates also leads to front-loading of payments which tightens the constraint. This happens regardless of why nominal interest rates rise. To see why this happens, consider the following hypothetical: a household earns \$100,000 in year t and wants to buy as large as 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) is less than 50 percent of the households' income in year t. Even absent any institutional constraints, many households would be uncomfortable or unable to commit more than 50 percent of their current income to paying their mortgage.

Suppose that expected inflation and the real interest 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 dollar mortgage. Now suppose instead that the real interest 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 be able to borrow roughly $500,000.[1] It is true that in this case rising wages along with inflation will make the mortgage payment a smaller share of income over time, but this does not affect how the payment-to-income constraint binds at the time of mortgage origination.

In this situation, it will then be the nominal rate, and not the real rate, that determines the consumer's house purchase size. Unless the real rate rises enough to reduce the consumer's optimal home purchase size below $500,000, changes to the real rate will be irrelevant to her housing demand. By contrast, changes to the nominal rate will affect how the payment-to-income constraint binds, and thus how much housing she demands.

Figure 1 illustrates the above example. It shows in time $t = 1$ (real) dollars the payment profile for a $1.5 million dollar mortgage when the nominal interest 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. As discussed above, the household can afford the mortgage. When nominal interest rates and inflation are 10 percent, the real payment profile is downward sloping, and the mortgage is obviously unaffordable for the household.

This example shows that even if the real interest rate and the real wage are constant, changes in inflation and the nominal rate will matter for housing affordability to the extent that there are either formal or informal borrowing limits.

[1] The maximum size (principal, P) of a 30-year mortgage that can be borrowed for an interest rate i and annual payment X is the P that solves $X = \frac{iP}{1-(\frac{1}{1+i})^{30}}$.

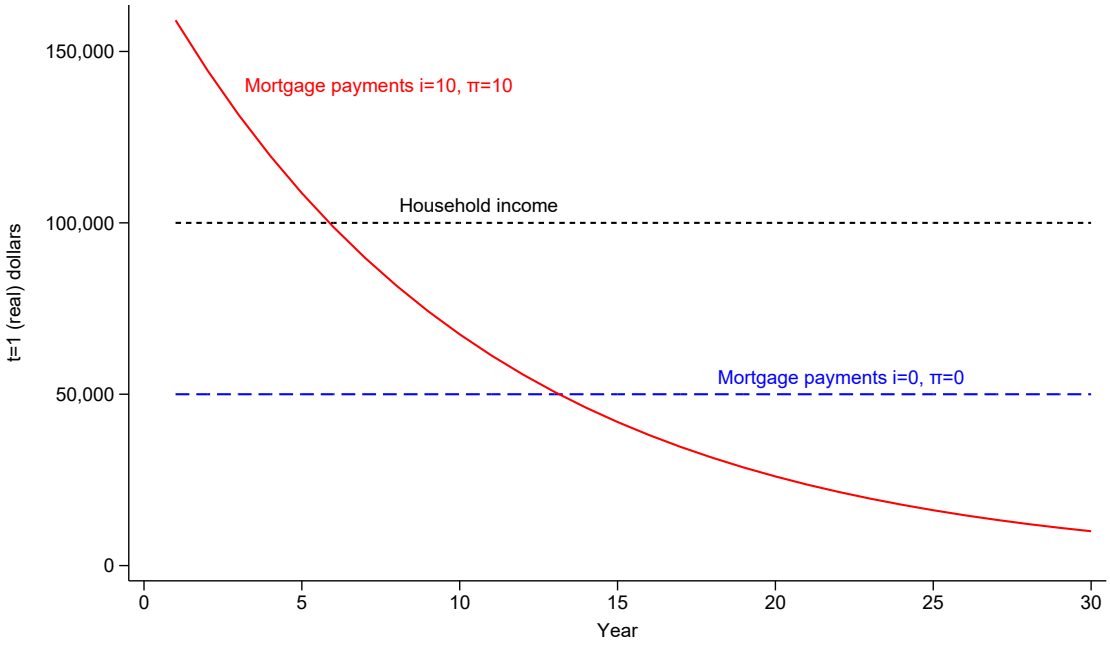


Figure 1 – Annual real mortgage payment on a $1.5 million mortgage compared to real household income

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 buy a home.[2]

Thus we estimate

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

Home buy attitude is a dummy variable equal to 1 if the survey respondent says that it is a good time to buy a home. 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 respondents expected annual inflation rate over the next five to ten years. Column (1) of table 1 shows results from estimating equation 1, controlling for a time trend. As expected,

[2]Respondents are asked: "Generally speaking, do you think now is a good time or a bad time to buy a home?". See the "Survey Description" at https://data.sca.isr.umich.edu/survey-info.php.

the coefficient on the nominal interest rate is negative and statistically significant. The coefficient of -0.1 means that for every percentage point increase in the nominal mortgage rate, a respondent is 10 percent less likely to say that it is a good time to buy a house. By contrast, conditional on the nominal interest rate, the coefficient on the real interest rate has the wrong sign: higher real interest rates make it *more* likely that respondents say it is a good time to buy a house.

In column (2), we take advantage of another question in the Michigan survey, in which respondents who say its a good time to buy a house are asked why. The dependent variable in this regression is a dummy variable equal to 1 if the respondent says that it is a good time to buy a home because interest rates are low. Respondents are not asked to specify whether they mean nominal or real interest rates. But the results in column (2) make clear that they mean the nominal rate: the coefficient on the nominal rate is negative while that on the real rate is positive.

Prospective home buyers ought to care not only about the real rate in terms of the general price and wage level, but also the real rate measured relative to the expected change in house prices. In column (3), we again use the dummy variable from column (1) (whether or not it is a good time buy a house) as the dependent variable, but now we add a control for this measure of the real rate. Reassuringly, the coefficient is negative. Conditional on the nominal rate, higher house price expectations make purchasing a house more attractive. Adding this control has little affect on the coefficients on the nominal rate and conventionally measured real rate. Again, we see large effects of the nominal rate on home buying sentiment.

In the final column, we look in more detail at what variation is driving our real rate results. We regress the same dependent variable, whether or not it is a good time buy a house, 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 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.

Table 1 – Michigan survey regressions

	(1)	(2)	(3)	(4)
	Buy home	Low int. rate	Buy home	Buy home
Right hand side variables:				
Nominal mortgage rate	−0.10***	−0.072***	−0.099***	
	(0.0022)	(0.0027)	(0.0058)	
Real mortgage rate	0.0040***	0.0030***	0.0051***	
	(0.00035)	(0.00043)	(0.00064)	
Real house price mortgage rate			−0.0081***	
			(0.00054)	
Expected 5-10 year inflation				−0.0043***
				(0.00054)
Expected 5 year house price inflation				0.0082***
				(0.00054)
Time trend	−0.0020***	−0.0015***	−0.0025***	
	(0.000050)	(0.000071)	(0.000096)	
Survey month fixed effects				X
R^2	0.17	0.09	0.24	0.28
Observations	231,470	231,470	86,140	86,140

Notes: In columns (1), (3), and (4) 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 (2), 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. All right hand side variables are in annualized percentage terms. Standard errors are clustered by survey month. $^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

Overall, the Michigan survey results strongly 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 origination. More precisely, we would like to know β_1 from:

$$\%\Delta\text{Mortgage origination}_t = \beta_0 + \beta_1 \Delta i_t^{\text{exog}} + \beta_2 \Delta r_t + \varepsilon_t, \tag{2}$$

where Δi_t^{exog} are exogenous changes in the nominal interest rate, and Δr_t is the change in the real interest rate. Unfortunately, we know of no plausible identification 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.

Thus we turn to cross-sectional evidence. Interest rates do not vary within the U.S. but their effects do. Our hypothesis is that nominal interest rates matter for the volume of mortgage origination because they tighten mortgage payment to income to income (DTI) constraints.[3] DTI constraints can be either explicitly imposed by lenders, e.g. to conform with Fannie Mae and Freddie Mac guidelines, or implicitly adopted by borrowers, e.g. because they have other consumption commitments or are risk averse. The key feature we exploit is that DTI constraints are more likely to bind in CBSAs where the average mortgage loan size is large relative to average incomes.

DTI ratios are only available at the loan level since 2018, but they are proportional to the loan-to-income (LTI) ratio, which is the ratio of the loan size to the borrower's income.[4] To build intuition for how LTI ratios and nominal interest rates interact and thus for the identification strategy of this paper, figures 2 and 3 show the distribution LTI ratios in Houston and Los Angeles in 2021 and 2023. In both cities, the distribution of LTI ratios shifted down as mortgage rates increased from an average of 3.0 percent in 2021 to 6.8 percent in 2023 (FRED series MORTGAGE30US).

But the shift has not been uniform across the two cities. The distribution of LTI ratios is more right-skewed in Los Angeles than in Houston. We observe relatively few small loans (LTI < 5) and relatively more large loans (LTI > 8) in Los Angeles, reflecting very high house prices there. And because payment-to-income ratios are more sensitive to changes in interest rates for larger loans, the increase in mortgage rates has a larger effect on the affordability of housing in Los Angeles compared to 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 issued in 2023 declined by 54%, while in Houston, the number

[3]The industry and literature call the ratio of mortgage payments to income the "debt to income constraint" or DTI. We adopt this convention going forward.

[4]They are proportional by a factor $i\frac{(1+i)^m}{(1+i)^m-1}$, where i is the monthly mortgage rate, and m is the duration of the mortgage in months.



Figure 2 – Loan-to-Income (LTI) Distribution in Houston, 2021 and 2023. Source: Freddie Mac Single Family Loan-Level Dataset and authors calculations.



Figure 3 – Loan-to-Income (LTI) Distribution in L.A., 2021 and 2023. Source: Freddie Mac Single Family Loan-Level Dataset and authors calculations.

of loans issued in 2023 declined by 37%. It is this differential exposure that we exploit to determine the importance of the nominal rate in the housing market.

To see the intuition for this mechanism, suppose in Houston a typical mortgage is $500,000 and the typical household income is $100,000, for an LTI of five. 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 25 percent. If the mortgage interest rate rises to 7 percent, the annual payment will rise to $40,000, for a DTI ratio of 40 percent. This is still below the cut-off for the DTI ratio above which lenders will not approve mortgages, which is 45 or 50 percent.

Now suppose in Los Angeles, a typical mortgage is $1.2 million and the typical income is $150,000 for an LTI of eight. The annual payment when the mortgage rate is three percent will be $60,708, for a DTI of 40.5 percent. Any increase in the mortgage rate to above roughly 4.5 percent will push the DTI ratio above 50 percent, and borrowers will be unable to afford new homes. Thus we would expect increases in nominal rates to reduce mortgage issuance more in Los Angeles than in Houston, exactly as we see in figures 2 and 3

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

4.1 Specification We estimate

$$\%\Delta Loans_{jt} = \beta_0 \Delta i_t + \sum_{k=1}^{3} \gamma_k \text{Tercile } k\text{: LTI}_j + \sum_{k=1}^{3} \theta_k [\Delta i_t \times \text{Tercile } k\text{: LTI}_j] \qquad (3)$$
$$+\delta_0 \Delta r_t + \sum_{k=1}^{3} \zeta_k [\Delta r_t \times \text{Tercile } k\text{: LTI}_j] + \varepsilon_{jt}.$$

$\%\Delta Loans_{jt}$ is the percent change in the number or dollar volume of mortgages originated in CBSA j and year t; i_t and r_t are the nominal and real mortgage interest rate, which vary across time but not CBSA; and Tercile k: LTI_j is a dummy variable for the loan-to-income (LTI) bin containing CBSA j. Bin 3 is the tercile of CBSAs with the highest average LTI. 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 how nominal rates are likely to impact the housing market. Figure 4 correlates the average Debt-to-Income (DTI) and Loan-to-Income (LTI) ratios in 2019 across Metropolitan Statistical Areas (MSAs). It shows a high correlation between city DTI ratios and city LTI ratios. Figure 5 shows that average LTI is also strongly correlated with the fraction of loans with very high LTI, above 7, in 2019 across MSAs.

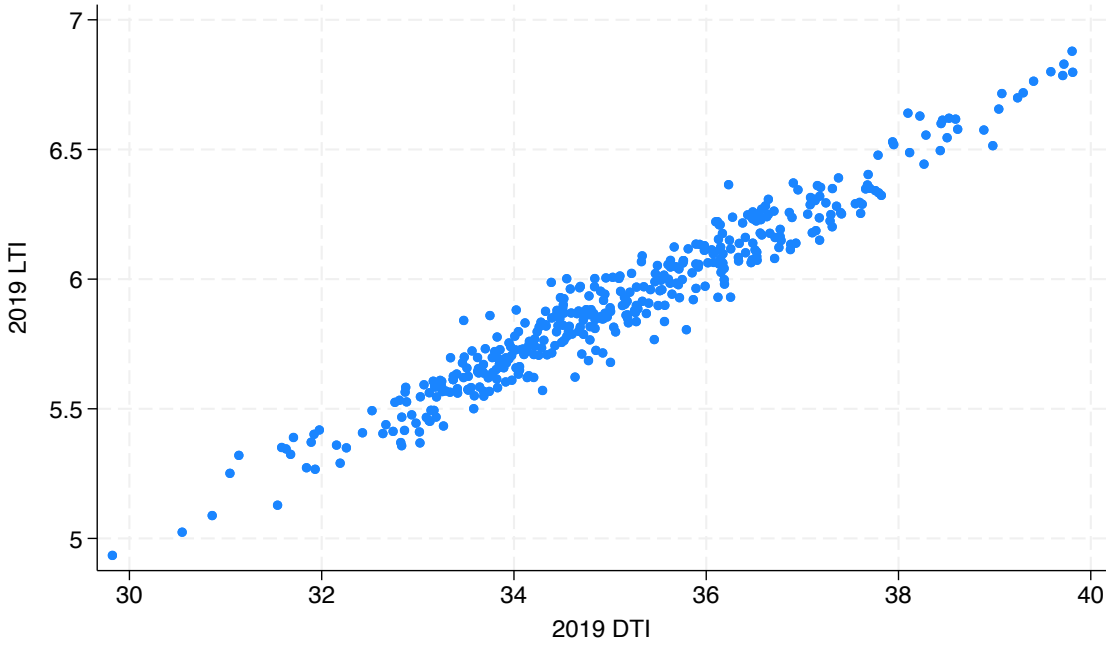


Figure 4 – Distribution of Debt-to-Income (DTI) and Loan-to-Income (LTI) ratios for the year 2019 across MSAs. Source: Freddie Mac Single Family Loan-Level Dataset and authors calculations.

4.2 Data We measure LTI and mortgage origination across CBSAs from confidential home mortgage disclosure act (cHMDA) data, which contains application-level characteristics on the majority of originated loans. These are the same data underlying public HMDA data, but the advantage of the confidential data is that we are able to use the origination date to construct higher-frequency measures of lending activity than is possible with the public data. The origination date will generally correspond to the day when the loan was closed or when the borrower becomes responsible for the loan's repayment. We start our sample

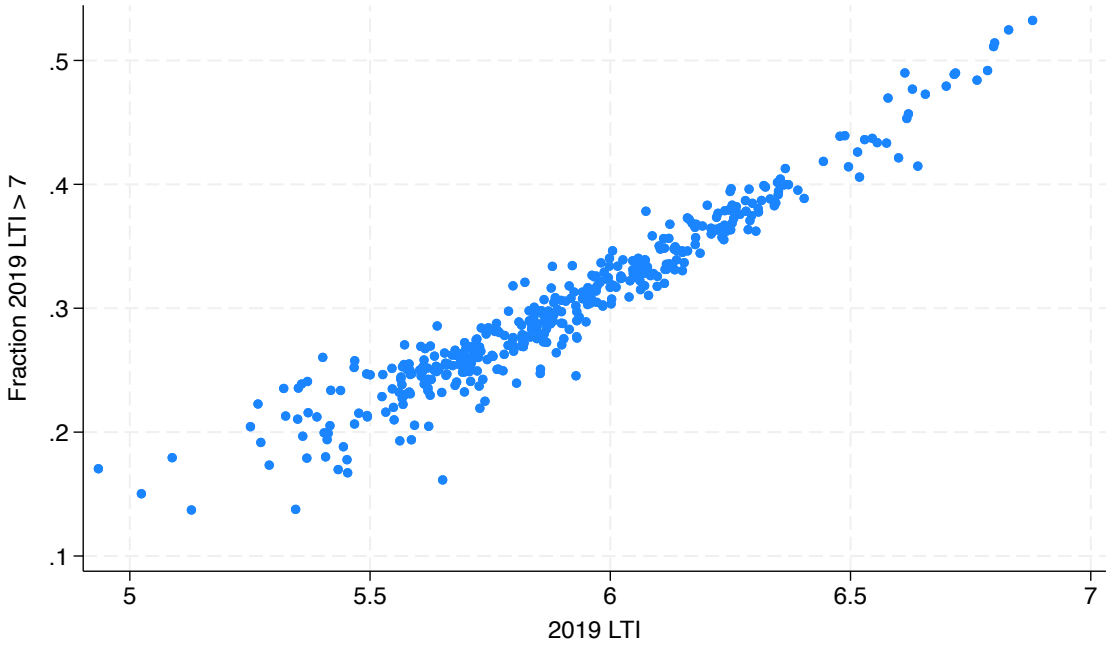


Figure 5 – Loan-to-Income (LTI) ratios and Fraction of Loans with LTI above 7 for the year 2019 across MSAs. Source: Freddie Mac Single Family Loan-Level Dataset and authors calculations.

in 1995, when there was sufficiently stable coverage following a significant expansion to the scope and coverage of HMDA reporting (Avery, Brevoort, and Canner, 2007). Since the increase in coverage these data are generally thought to cover at least 80%, often more, of the mortgage market. When constructing our sample we restrict ourselves to purchase loans for owner-occupied / principle occupancy homes, which will include both detached and attached single-family homes. Starting in 2004 when the requisite codes become available, we also restrict the data to first liens.[5] We then aggregate these data to the Core-based Statistical Area (CBSA) and quarter level to construct measures of the count of mortgage purchase originations.[6] To improve precision we also winsorize the top and bottom 2.5 percentiles of the log growth in loan count and we drop the smallest 25 percent of CBSAs, which typically have fewer than 30 loans in a quarter.

We use the national 30-year fixed mortgage rate as our nominal interest rate. We con-

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

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

struct real mortgage rates using inflation expectations from several sources. From the Michigan Survey we take the 5-year mean expected inflation rate and the 5-year median expected inflation.[7] We also use the TIPS 5-year breakeven inflation rate and the Cleveland Fed 5-year expected inflation rate.

Table 2 reports summary statistics for these data. We see the typical year-over-year growth in purchase loan counts is about 1pp, but with significant volatility. The statistics on the real rate do suggest potentially important variation across the measures of inflation with the survey-based measures generally showing declines in the real rate that are not as apparent in the other two measures.

	Observations	Mean	SD	25th Pct	50th Pct	75th Pct
ΔLog Loan Count (Winsorized)	78848	0.01	0.22	-0.13	0.02	0.15
Δ Mortgage Rate	78848	-0.04	0.84	-0.64	-0.17	0.41
$\%\Delta$ HPI	78848	0.05	0.06	0.02	0.05	0.09
Δ Fed Funds	78848	-0.03	1.47	-0.49	0.01	0.68
Δ Real Rate (Michigan Mean)	78848	-0.04	0.78	-0.54	-0.11	0.36
Δ Real Rate (Michigan Median)	78848	-0.03	0.82	-0.51	-0.20	0.36
Δ Real Rate (Cleveland)	78848	-0.00	0.61	-0.40	-0.13	0.23
Δ Real Rate (Breakeven)	56320	0.02	1.07	-0.60	-0.14	0.33

Table 2 –
Summary Statistics

4.3 Results Our identification strategy relies on LTI changing the effect of nominal interest rates on mortgage origination only through its effects on payment-to-income constraints.

Table 2 shows estimates of equation (3) where inflation expectations are measured using mean long-run expectations from the Michigan Survey. Column 1 shows results using only the real interest rate as control. Columns 2 and 3 add control variables for house prices (HPI) and the Fed Funds rate. In column 5, we add fixed effects for metropolitan area (CBSA) and year. The coefficient of most interest is that on the interaction of the high LTI bin with the nominal rate (θ_3 in equation (3)). The coefficient is negative, statistically significant, and stable across specifications. The magnitude of roughly -0.04 means that a one percentage point increase in the nominal interest rate reduces mortgage issuance by 4 percentage points more in the tercile of CBSAs with the highest LTI ratio relative to the tercile with the lowest

[7]For convenience, we refer to these measures as 5-year expected inflation. Survey respondents are actually asked about their expectations of inflation "during the next five to ten years" (https://data.sca.isr.umich.edu/fetchdoc.php?docid=75445).

LTI ratio. This is a large effect. It implies that the four percentage point increase in the mortgage rate from 2020 to 2022 would have 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 -0.03 across columns.

Table 3 – ΔLog Loan Count (winsorized)

	(1)	(2)	(3)	(4)
Δ Mortgage Rate	-0.044***	-0.139***	-0.157***	0.027
	(0.004)	(0.004)	(0.005)	(0.029)
Mid LTI x Δ Mortgage Rate	-0.024***	-0.030***	-0.029***	-0.029***
	(0.005)	(0.006)	(0.006)	(0.006)
High LTI x Δ Mortgage Rate	-0.055***	-0.055***	-0.039***	-0.039***
	(0.006)	(0.006)	(0.007)	(0.007)
Δ Real Rate (Michigan Mean)	0.023***	0.102***	0.107***	0.101***
	(0.004)	(0.004)	(0.004)	(0.025)
Mid LTI x Δ Real Rate (Michigan Mean)	0.012**	0.017***	0.017***	0.017***
	(0.006)	(0.006)	(0.006)	(0.006)
High LTI x Δ Real Rate (Michigan Mean)	0.029***	0.029***	0.024***	0.024***
	(0.006)	(0.007)	(0.007)	(0.007)
%Δ HPI		1.250***	1.201***	-6.860***
		(0.019)	(0.019)	(0.286)
Mid LTI x %Δ HPI		0.074***	0.077***	0.077***
		(0.028)	(0.027)	(0.027)
High LTI x %Δ HPI		-0.002	0.042	0.042
		(0.032)	(0.031)	(0.031)
Δ Fed Funds			0.014***	-0.197***
			(0.001)	(0.008)
Mid LTI x Δ Fed Funds			-0.001	-0.001
			(0.001)	(0.001)
High LTI x Δ Fed Funds			-0.013***	-0.013***
			(0.002)	(0.002)
CBSA FEs				X
Year FEs				X
Clusters	704	704	704	704
R2	0.03	0.14	0.14	0.55
Number of Observations	78,848	78,848	78,848	78,848
Number of Years	28	28	28	28

In contrast, the coefficient on the interaction of the real interest rate with the highest LTI tercile, ζ_3, is positive and statistically significant. This implies that conditional on the

nominal interest rate, higher real interest rates lead to *more* mortgage issuance in high LTI CBSAs, the opposite sign from the effect predicted by standard models. In the middle LTI tercile, the coefficient is again positive, though smaller.

Table 4 repeats this exercise using alternative inflation expectation measures to construct the real mortgage rate, this time including all of our 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. And again, there is no evidence of a negative effect of real interest rates interacted with the high LTI bin.

4.4 Further empirical evidence We plan to also look at geographic cross-sectional evidence on employment. The housing market is more affected by changes in nominal interest rates in high LTI areas, so we suspect that interest rate changes (e.g. monetary policy shocks) may also have larger employment effects in high LTI areas. We will test this hypothesis using QCEW employment data. Of course, a complication for this exercise that we will consider is varying housing supply elasticities across areas.

Table 4 – ΔLog Loan Count (winsorized)

	(1)	(2)	(3)
Δ Mortgage Rate	0.030	0.210***	0.125***
	(0.034)	(0.018)	(0.023)
Mid LTI x Δ Mortgage Rate	-0.056***	-0.011*	-0.010**
	(0.012)	(0.006)	(0.004)
High LTI x Δ Mortgage Rate	-0.095***	-0.018***	-0.019***
	(0.013)	(0.006)	(0.004)
Δ Real Rate (Michigan Median)	0.092***		
	(0.030)		
Mid LTI x Δ Real Rate (Michigan Median)	0.044***		
	(0.012)		
High LTI x Δ Real Rate (Michigan Median)	0.081***		
	(0.013)		
%Δ HPI	-6.176***	-7.599***	-1.278***
	(0.304)	(0.350)	(0.353)
Mid LTI x %Δ HPI	0.096***	0.052*	0.026
	(0.029)	(0.027)	(0.036)
High LTI x %Δ HPI	0.083**	0.016	-0.018
	(0.032)	(0.030)	(0.036)
Δ Fed Funds	-0.199***	-0.199***	-0.045***
	(0.007)	(0.008)	(0.012)
Mid LTI x Δ Fed Funds	-0.002	-0.001	0.001
	(0.001)	(0.001)	(0.002)
High LTI x Δ Fed Funds	-0.014***	-0.013***	-0.012***
	(0.002)	(0.002)	(0.002)
Δ Real Rate (Cleveland)		-0.117***	
		(0.026)	
Mid LTI x Δ Real Rate (Cleveland)		-0.004	
		(0.007)	
High LTI x Δ Real Rate (Cleveland)		0.002	
		(0.007)	
Δ Real Rate (Breakeven)			-0.107***
			(0.025)
Mid LTI x Δ Real Rate (Breakeven)			-0.005*
			(0.003)
High LTI x Δ Real Rate (Breakeven)			0.003
			(0.003)
CBSA FEs	X	X	X
Year FEs	X	X	X
Clusters	704	704	704
R2	0.55	0.55	0.55
Number of Observations	78,848	78,848	56,320
Number of Years	28	28	28

5 A model

Our goal is to illustrate how the nominal interest rate might directly impact the economy, consistent with the above empirical evidence. In this section, we present a very simple model that is as close as possible to Galí (2015). It is a model 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 income constraint as discussed in section 2 of the paper and Drechsel (2023). The supply side is kept simple by assuming that the two goods are purchased using the same production function.

The simple model shows how the income constraint amplifies the impact of interest rate shocks, and how this amplification increases with the size of the credit goods sector. Increases in interest rates shift demand away from the credit good. Diminishing marginal utility for the cash good then reduces labor supply and output. Surprisingly, the conditions for determinacy are unaffected by the presence of the income constraint on the cash good.

After presenting this simplest of models, we discuss a number of extensions. We replace the credit good with a durable good. We consider a TANK model in which only a fraction of agents are subject to the constraint. We allow for separate production functions for the two goods. The basic story survives these extensions and other interesting phenomenon appear.

5.1 Set up We consider an economy with one cash good and one credit good. What distinguishes the credit good is that consumers purchase it today but pay for it tomorrow. We suppose that both goods are produced in the same manner so that their prices are the same. We impose a borrowing constraint on the credit good to mimic the way in which nominal interest rates typically affect agents' ability to borrow with real world contracts.[8] We now present the details of the model.

Time is discrete and indexed by t. There is a single representative household that derives utility from the consumption of two non-durable goods, a cash good indexed by n, and a credit good indexed by d. Let P^n and P^d denote the prices of the two good and C^n and C^d their consumption. The agent chooses consumption of the two goods and labor supply to

[8]Similar 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 such as the interest coverage ratio in limiting firm's access to credit during the great recession.

maximize the present value of utility

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

Here $1/\sigma$ is the elasticity of intertemporal substitution, and γ is the inverse Frisch elasticity of labor supply, and λ is a parameter that determines the relative importance of the two goods in utility.

These purchases are subject to the budget constraint

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

Here B_t represents the agents purchase or issuance of nominal bonds at date t maturing at date $t+1$.[9] i_t is the nominal rate of return between t and $t+1$. W_t is the nominal wage and Π_t is profits of firms. What distinguishes the credit good is that the consumer pays the price plus interest in the next period. We assume that these purchases are limited by the 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 that PY is nominal income and θ is a parameter less than one. The constraint depends on current income as in Drechsel (2023) and as documented in figures 2 and 3.[10] The idea is that firms use current income to judge whether or not a borrower is credit worthy, rather than attempting to forecast future income. θ captures the tightness of the financial constraint.

Labor-leisure choice gives

$$\frac{W_t}{P_t^n} = (C_t^n)^\sigma N^\gamma \text{ and } \frac{W_t}{P_t^{n'}} = (C_t^n)^\sigma N^\gamma$$

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

[9] Normally bonds would be in zero net supply. In this model, however, consumers go into debt to purchase the d good. The debt is issued by producers of d which are owned by the consumers. In equilibrium $B_t = P^d C_t^d$.

[10] In contrast Iacoviello (2005) assumes that borrowing is limited by the expected present value of the collateral which in his case is the value of the house.

are indexed by $j \in [0,1]$. The production functions in the two sectors are

$$\begin{aligned} Y^n &= \left(\int \left(y_j^n\right)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \\ Y^d &= \left(\int \left(y_j^d\right)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \end{aligned}$$

where y_j^n is the use of input j in the n sector and y_j^d is the input in the d sector. Cost minimization yields,

$$P_t = P_t^d = P_t^n = \left(\int \left(P_j\right)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$$

Given that the sectors are competitive, symmetric and constant returns to scale, their prices 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:

$$Y_j = N_j$$

The demand for each intermediate good is easily shown to be

$$y_j = \left(\frac{P_i}{P} \right)^{-\varepsilon} \left(Y^n + Y^d\right)$$

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

$$\max_{P_j} = E_t \sum_{k=o}^{\infty} \alpha^k \Lambda_{t,t+k} \left[\left(\frac{P_j}{P_{t+k}} \right)^{-\varepsilon} - \frac{W}{P} \right] \left(Y_{t+k}^n + Y_{t+k}^d\right)$$

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

$$\begin{aligned} Y^n &= C^n \\ Y^d &= C^d \\ \int N_j dj &= N \end{aligned}$$

and a monetary rule

$$\iota_t = \phi \pi_t + \eta_t$$

where ι is the percent change in the gross nominal interest and η_t is a monetary policy shock

5.2 Solution The supply side is entirely 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.

On the demand side, the optimal choice of the n good yields the linearized euler equation

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

To connect with the literature we need 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

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

where bars indicate steady state values.

Linearizing the constraint on the purchase of d goods

$$\iota_t + c_t^d = y_t$$

and substituting into the aggregate market clearing condition

$$\bar{Y} y_t = \bar{C}^n c_t^n + \bar{C}^d \left(y_t - \iota_t\right)$$

or

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

What this equation says is that if interest rates rise, then C^n must rise or Y must fall. How much they must 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 interest

rate.

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

becomes

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

or

$$y_t = -\left(\frac{1}{\sigma} + \frac{\bar{C}^d}{\bar{C}^n}\right)(\iota_t - \pi_{t+1}) + y_{t+1} + \frac{\bar{C}^d}{\bar{C}^n}(\iota_{t+1} - \pi_{t+1})$$

The presence of the d sector has two effects on this equation. The first is to increase the effective elasticity of intertemporal substitution from $\frac{1}{\sigma}$ to $\frac{1}{\sigma} + \frac{\bar{C}^d}{\bar{C}^n}$. The second is to add the term $\frac{\bar{C}^d}{\bar{C}^n}(\iota_{t+1} - \pi_{t+1})$. Note that this term in brackets is not tomorrow's real interest rate as that would be $\iota_{t+1} - \pi_{t+2}$. Given our monetary policy rule, this term will depend only on π_{t+1}.

We now turn to the supply side where we need to write marginal cost in terms of the output gap, inflation and the interest rate. From labor-leisure choice

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

Linearizing

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

Now given prices the share of each intermediate good in output is constant. Hence doubling the labor input will double the otuput of all intermediate goods. Aggregate output is proportionate to the labor input

$$y_t = n_t$$

Using the above derivation of c_t^n, we therefore arrive at

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

so that a rise in the nominal interest rate raises the cost of producing a given level of output y_t due to the diminishing marginal utility of consuming more of the n good.

We therefore arrive at the three equation system

$$\begin{aligned}
\hat{y}_t &= -\left(\frac{1}{\sigma}+\frac{C^d}{C^n}\right)(i_t - E_t\pi_{t+1}) + \hat{y}_{t+1} + \frac{C^d}{C^n}(i_{t+1} - E_t\pi_{t+1}) \\
\pi_t &= \kappa\left(\sigma+\gamma\right) y_t + \kappa\sigma\frac{\bar{C}^d}{\bar{C}^n}\iota_t + \beta E_t\pi_{t+1} \\
\iota_t &= \phi\pi_t + \eta_t
\end{aligned}$$

5.3 Results: We can show the following

- The constraint on the credit good increases the effective elasticity of intertemporal substitution, thereby amplifying the impact of monetary policy on the economy.
- The constraint on the credit good impacts both supply and demand. On the supply side, higher interest rates shift demand to the cash good. Diminishing marginal utility of consumption of the cash good reduces labor supply.
- The condition on the responsiveness of interest rates to inflation that guarantees that the economy is determinate (Bullard and Mitra, 2002) is unaffected by the presence of the credit good.

5.4 Extensions We have experimented with a number of straight forward extensions of this simple model. The results of the simple model survive all of these extensions, although the model equations become somewhat more complicated. Each extension adds a new dimension to the analysis.

- It is straightforward to replace the non-durable credit good with a durable good that either depreciates for N periods or depreciates in any period with probability χ. In this model, steady state inflation reduces durable demand through the front-loading channel discussed in section 2, and interest rate changes have heterogeneous effects on the population as an increase in interest rates falls most heavily on those who are currently contemplating a durable purchase.
- It is straightforward to construct a TANK model in which a fraction of agents are subject to the constraint on purchases of the durable. Again monetary policy creates winners and losers, as increases in interest rates affect mainly the constrained.

- We have not done this yet, but we can allow for the cash and the credit goods to be produced in separate sectors. This should adds several features. First, it will be less easy for the economy to shift production from the credit good to the cash good in response to a monetary tightening. The decline in demand for the credit good will reduce household income and should amplify the contraction. Second, the relative price of the credit good will fall in response to a monetary tightening. In a model in which the credit good is durable (such as housing), this will have a negative wealth effect which will also amplify the impact of tight monetary policy.

6 Conclusion

In our conclusion we will discuss some broader implications of our work for inflation and monetary policy. Among other points, we will emphasize that the nominal rate effect we document means that the level of inflation is likely to have real effects. Higher inflation and resulting higher nominal interest rates will, all else equal, reduce housing demand and GDP.

We will also point out that the importance of the nominal rate can help to rationalize some empirical mysteries in recent macroeconomic policy. For instance, a conventional new Keynesian model suggests that lower real rates will have dramatic expansionary effects. Given evidence for large effects of monetary policy shocks, this model implication is often taken for granted. Yet, empirical evidence suggests that when real rates fall due to higher expected inflation, we do not see large expansions (Wieland, 2019). Our paper can help to rationalize this result: monetary policy shocks have large effects since they are nominal rate shocks and thus relax payment-to-income constraints; but when real rates fall without nominal rates falling (i.e. because expected inflation rises), there is no similar channel for large macroeconomic effects.

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