House Prices and Negative Nominal Interest Rates*

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Abstract

When borrowers have access to two types of debt, and the cost of one type of debt declines relative to the other, borrowers should substitute towards the type of debt that has become relatively cheaper. When household borrowers can choose between uncollateralized debt and mortgage debt any shock that drives up the spread between the interest rate on uncollateralized debt and the interest rate on mortgage debt will incentivize households to substitute towards mortgage debt. In turn households will demand more housing to collateralize this mortgage debt, pushing house prices up. I build a model that captures this novel *debt substitution channel* linking debt substitution to house prices. I study this channel in the context of negative nominal interest rate policy (NIRP) in Denmark. I show empirically that NIRP is associated with an increase in the spread between the interest rate on uncollateralized debt and the interest rate on mortgage debt. Using the model I show that the debt substitution channel amplifies the impact of monetary policy rate cuts on house prices and reduces the ability of monetary policy to stimulate the aggregate consumption of borrowers.

Keywords: Negative Interest Rates, Reversal Rate, Mortgage Credit, House Prices, Non-Banks.
JEL Codes: E43, E44, E51, G21, G23.

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1 Introduction

Recent experience with negative nominal interest rate policy (NIRP) suggests that once the nominal policy rate goes below zero, an erosion in bank profits means that there is an attenuation or even a reversal of the pass-through of monetary policy rate cuts to the interest rates on bank lending. This impacts the relative cost of bank loans vs other types of debt which are not intermediated by banks (e.g. mortgages in certain financial systems). In this paper I examine how households respond to this relative price change and how this impacts the transmission of monetary policy below zero. I find that below zero the transmission of monetary policy rate cuts to house prices and aggregate consumption changes. The impact on house prices is amplified but monetary policy is less effective at simulating consumption.

In July 2012 Denmark was the first country to introduce a negative nominal policy rate. Denmark is a particularly useful setting to study the implications of the pass-through of the negative interest rate policy to different consumer loan products. This is because, like the US, mortgages are provided by financial entities ("mortgage credit institutions") that do not issue deposits and therefore are not subject to the adverse impacts of the NIRP the way commercial banks are.

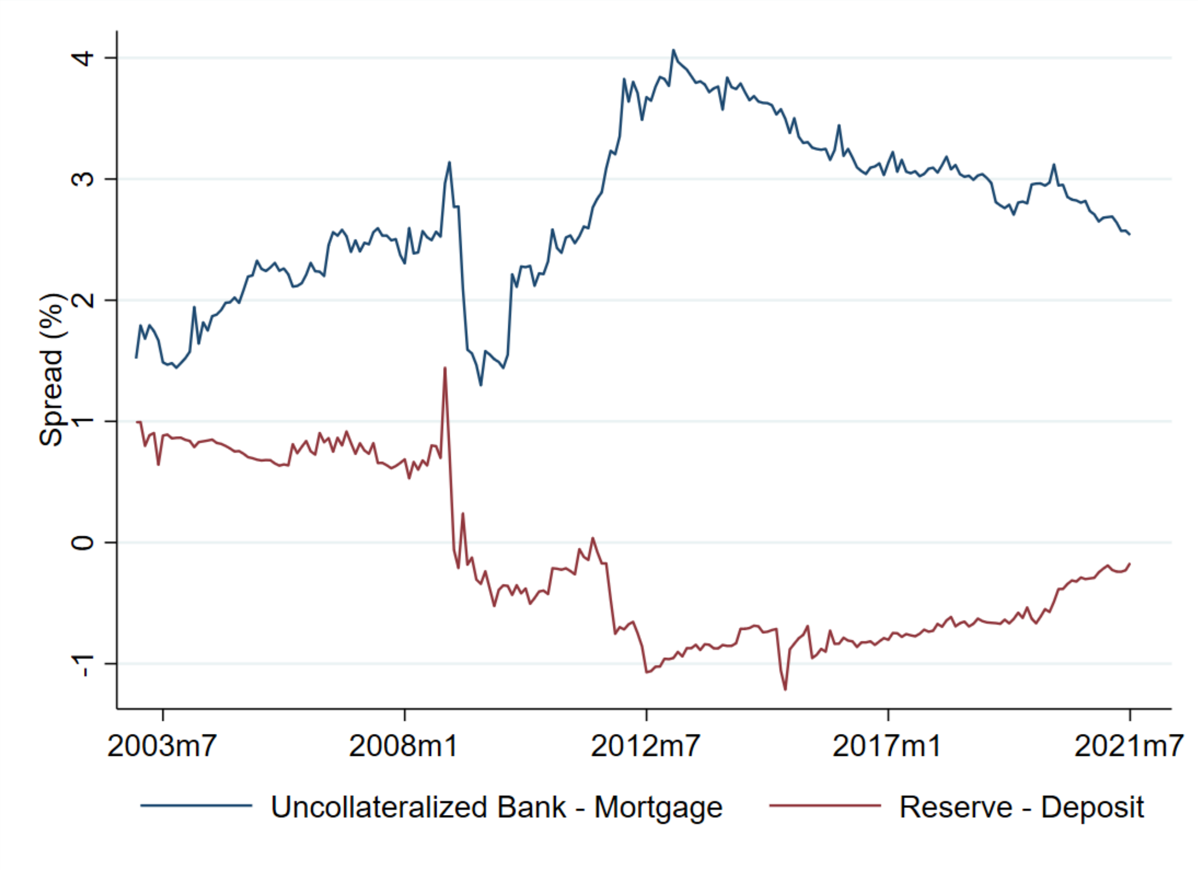
Figure 1 suggests that under very low or negative nominal policy rates the relative cost of uncollateralized bank loans vs mortgage loans is negatively correlated with banks' net interest margin. The blue line in this figure measures the spread between the average lending rate on uncollateralized bank loans (to households) minus the average interest rate on mortgages provided by mortgage credit institutions (MCIs). As this spread increases mortgages become relatively more attractive compared to alternative forms of lending. As I show in this paper this drives a substitution into mortgage debt and house prices go up because housing is more demanded as collateral.

The red line in figure 1 is the spread between the weighted average interest rate paid to banks on reserves (the interest rate on reserves is the policy rate[1]) minus a weighted average of the interest rate banks pay on household and firm deposits. This spread is a bank's net interest margin (NIM). The lower the net interest margin is the less profitable deposits are for banks. Because the nominal interest rate on deposits did not adjust as

[1]Technically *rates*, as there is more than one type of reserve in Denmark. See section 2.1 for an explanation of this and of the tiered reserve system in Denmark

quickly as the nominal interest rate on reserves the aggregate net interest margin fell below zero as the nominal policy rate dropped to very low and then negative levels. A negative nominal interest margin erodes the profitability of banks.

Figure 1: Evolution of Spreads



Note: "Uncollateralized Bank - Mortgage" is the spread between the weighted average interest rate charged by banks on uncollateralized lending to households minus the weighted average interest rate charged by mortgage credit institutions on mortgage lending (both including fees). "Reserve - Deposit" is an approximation of the weighted average of the interest rate banks earn on reserves minus the weighted average interest rate banks pay on firm and household deposits. *Source*: Danmarks Nationalbank's MFI Statistics.

When banks face constraints (e.g. capital regulation) the erosion of bank profits from the negative net interest margins will push banks against these constraints. This is the "net interest margin" channel. As this channel intensifies the response of banks to further monetary policy rate cuts will attenuate or ever reverse: i.e. interest rates on bank loans may not drop by much or may even increase. This generates a breakdown in the traditional bank lending channel of monetary policy. However financial intermediaries that do not fund themselves via deposits do not experience a reduction in their net interest margin. For example mortgage credit institutions in Denmark are funded by mortgage bonds, the interest rate on these bonds is not sticky downward in the same way as bank deposit rates.

Using Danish bank-level data on lending to households before and during the negative nominal policy rate period (July 2012 and after) in Denmark I find the following empirical results consistent with the net interest margin channel. One, the pass-through of monetary policy rate cuts to lending interest rates is positive across both uncollateralized bank loans and mortgage loans before July 2012. Two, the pass-through to mortgage loan interest rates is not statistically significantly different after July 2012. Three, the pass-through of monetary policy rate cuts to uncollateralized household loans is statistically significantly lower after July 2012. These results are consistent with a widening of the spread between uncollateralized lending and mortgage lending in response to monetary policy rate cuts when the nominal policy rate is already negative.

I build a model in which borrowers can access uncollateralized loans and mortgage loans. When uncollateralized loans become relatively more expensive borrowers substitute towards mortgage debt, capturing the *debt substitution channel*. Using this model I find that in response to a shock that increases the spread between the interest rate on uncollateralized lending and mortgage lending borrowers demand more housing to collateralize the increase in mortgage debt. This drives house prices up. Because the increase in the spread is a marginal tightening of credit conditions to households, this shock mutes consumption.

I also find using the model that the quantitative size of these results is increasing in the duration of the shock. This suggests important policy implications: minimizing the duration of the negative interest rate policy will minimize the unintended consequences on house prices and consumption of the debt substitution channel.

The paper proceeds as follows. Section 2 presents empirical evidence showing that the pass-through of monetary policy rate cuts to mortgage rate cuts remained positive during the negative interest rate period in Denmark, whereas there are signs of a strong drop off in pass-through in the rates on bank loans to households. Section 3 presents a simple model that illustrates the mechanism that links an increase in the spread between bank loan interest rates and mortgage interest rates to an increase in house prices (via the collateral channel). Section 4 sets out the full model. Section 5 presents the model calibration. Section 6 presents and discusses the simulation results. Section 7 concludes.

Related Literature This paper both relates most to the recent theoretical literature on the impacts of negative nominal interest rate policy.

The mechanism in this paper relies on the break-down of the traditional bank lending channel[2] of monetary policy. This breakdown explains why bank loans should become relatively expensive compared to mortgage loans under the negative interest rate policy (NIRP). The recent theoretical literature on NIRP establishes how negative policy rates break down the bank lending channel. Ulate (2021) shows using a DSGE model that the erosion in bank capital due to the "net interest margin" channel (he calls this the bank net-worth channel) will eventually push bank interest rates up in response to monetary policy rate cuts when policy rates are sufficiently low. He also finds empirical evidence supporting the bank net-worth channel using bank-level data from multiple advanced economies (including Denmark). Eggertsson, Juelsrud, Summers and Wold (2019) show using Swedish data a reversal in the pass-through of monetary policy rate cuts to certain bank lending interest rates, and similarly they find theoretically a break-down in the bank lending channel. Brunnermeier and Koby (2019) introduce a trade-off: a monetary policy rate cut increases the value of long-term fixed rate assets that banks hold but reduce banks' expected net interest income (i.e. the net interest margin channel) in the future. When the latter effect dominates the bank lending channel breaks down.

Groot and Haas (2021) find that the breakdown in the bank lending channel from the erosion of capital due to change in net interest margin is counteracted by the signally effect of negative interest rates: to the extent to which there is inertia in the policy rate, going negative makes maintain low interest rates for longer more credible, this in turn stimulates the economy today. Darracq Paris, Kok and Rottner (2021) find that the breakdown in the bank lending channel can be mitigated by macroprudential policy: they show that building up capital buffers reduces the risk of hitting the reversal rate.

To my knowledge is there no theoretical paper that looks at the debt substitution channel examined in this paper and its implications for the transmission of negative nominal interest rate policy.

There is also an active empirical literature on negative interest rates Ampudia and van den Heuvel (2019) find evidence that under low rates further monetary policy rate cut have adverse impacts on bank profitability. This is key to the breakdown in the bank

[2]The bank lending channel captures that if bank loan interest rates decline with policy rates this decline stimulates the economy via more consumption and investment due to lower borrowing costs.

lending channel essential to generate the dynamics in the spread between uncollateralized bank loans and mortgage loans studied here. Heider et al. (2019) find that high deposit banks experience a reduction in net worth relative to low deposit banks, low deposit banks also tend to lend less but to more risky borrowers. Bittner et al. (2021) examine risk taking induced by negative nominal policy rates by comparing the experience of Portuguese and German Banks. Adolfsen and Spange (2020) so there is an attenuation of the pass-through of monetary policy rate cuts to lending rates in Denmark. Abildgren and Kuchler (2020) examine how Danish firms react to the introduction of negative deposit rates on firm deposits.

2 Empirical

In this section I examine the pass-through of monetary policy rate changes to interest rates on bank loans vs mortgage loans. I find evidence consistent with a substantial reduction in the pass-through of policy rate changes to the interest rate on uncollateralized bank loans during the negative rate period. There is no statistically significant change in the pass-through of policy rate changes to mortgage rates during the negative period. This evidence is consistent with a widening of the spread between uncollateralized debt and mortgage debt during the negative period (as illustrated by figure 1).

2.1 Institutional Context

Danish Mortgage Credit System In Denmark residential mortgages are provided by mortgage credit institutions (MCIs) which operate differently to banks (see Gundersen et al. (2011) for a in depth explanation of the Danish system). The MCIs raise funds in the bond market, instead of from depositors. In this way Danish mortgage credit institutions are similar to government sponsored enterprises (GSEs) in the United States. See Kjeldsen (2003) for a more detailed description of the similarities and differences between the Danish and American systems. There is a close relationship between the interest rate on mortgage bonds and the interest rate on mortgages provided to borrowers.

In addition to mortgage credit, which households can access up to 80% of the value of their house, households can take out bank loans that are collateralized by housing. These top-up type loans are either accessible at the time of house purchase or later on for refinancing. In the model I present later I abstract from the existence of these loans.

Danish Negative Interest Rate Policy: Because of the fixed exchange rate regime, the policy rate in Denmark is not a traditional instrument of monetary policy. Rather it targets the exchange rate. Therefore the negative interest rate policy (NIRP) is not designed to stimulate the economy, rather it is intended to import the ECB's monetary policy via the fixed exchange rate and open capital markets. Nonetheless the prolonged Danish experience with negative policy rates provides a useful environment to examine the transmission of NIRP.

In Denmark there are two types of monetary policy reserves: certificates of deposit, which have a original maturity of 7 days, and current-account deposits, which are redeemable on demand. Normally the longer maturity certificates of deposit have a higher interest rate, however, July 2012 the certificate of deposit rate was reduced from 0.05 to -0.2. This introduced a negative nominal policy rate into Denmark for the first time. The certificate of deposit rate briefly return above zero between late April and early September 2014, but otherwise it has been negative.

Up until March 2021 the interest rate on the current-account deposits remained at zero. This was effectively a tiering system: banks could hold up to a certain individual amount in reserves, beyond which they were required to convert current-account deposits to certificates of deposit (incurring the negative interest rate). This individual limit on current-account deposits only applied if the banking system in aggregate hit a specific limit on total current-account deposits. Jorgensen and Risbjerg (2012) for an in depth explanation of the Danish reserve system under negative interest rates. In March 2021 the interest rate on current-account deposits was reduced from zero to -0.5 (to match the interest rate on certificates of deposit), this effectively ended the tiering of reserves.

Pass-through to Deposit Rates In Denmark deposit rates have been slower to fall than the interest rate on reserves, particularly for household deposits, but not stuck at zero. There was relatively quick introduction of negative nominal rates on deposits for firms. Abildgren and Kuchler (2020) study the response of firms to the introduction of negative interest rates on their deposits. Household deposits remained at zero for longer, and even today most banks only apply negative nominal interest rates on marginal household deposits above 100,000 DKK (about 13,400 EUR). Danish banks have not passed on the cost of negative nominal rates on reserves to their customers 1-for-1. This means that their net interest margin (the rate earned on reserves minus the rate paid on deposits) is now eroding bank profits.

2.2 The Data

The data used here is drawn from the MFI statistics collected at the bank level and monthly frequency by Danmarks Nationalbank.

2.3 Interest Rate Pass-Through

The regression in equation 2.1 tests if the pass-through of policy rate changes to lending rates has changed during the negative nominal interest rate period.

$$\Delta i_{i,t}^{b} = \alpha + \eta I_t^{negative} + \beta \Delta i_t^r + \gamma \Delta i_t^r \times I_t^{negative} + \delta_i + \epsilon_{i,t}, \tag{2.1}$$

where $\Delta i_{i,t}^{b}$ is the change in lending rate for loan type b (either bank loans not associated with housing, bank loans associated with housing, or mortgage loans) from bank i at time t. $I_t^{postbound}$ is an indicator variable equal to one if the month is July 2012 or later (the month during which the policy rate went negative in Denmark for the first time). δ_i captures bank fixed effects. Standard errors are clustered at the bank level. If γ is negative and statistically significant this is associated with a decline in the pass-through of policy rate changes to the relevant lending rate.

Table 1: Comparison of Pass-Through

	(1)	(2)	(3)
	Bank Loans	Housing related bank loans	Mortgage Loans
Δi_t^r	0.366***	0.322***	0.071***
	(0.03)	(0.04)	(0.01)
$I_t^{negative}$=1 $\times$ Δi_t^r	-0.525***	-0.365***	-0.066
	(0.11)	(0.08)	(0.03)
$I_t^{negative}$=1	-0.022***	-0.027***	0.012***
	(0.00)	(0.01)	(0.00)
Constant	-0.001	0.001	-0.028***
	(0.00)	(0.00)	(0.00)
Bank FE	Yes	Yes	Yes
F statistic	135.45	51.96	22.41
Observations	3,274	3,252	1,326

Note: ***p < 0.01, **p < 0.05, *p < 0.1. "Bank loans" are loans from banks to households, unrelated to housing. "Housing related bank loans" are loans from banks to households that are related to housing. "Mortgage Loans" are loans collateralized by housing from mortgage credit institutions to households. The interest rate on each lending type is the average interest rate in the stock of loans of that type.

The results in table 2.1 are consistent with attenuation of the pass-through from changes in the policy rate to changes in the lending rate, but only for loans provided by commercial banks, not for mortgages issued by mortgage banks in Denmark. In fact the size of the coefficient on the interaction term between the negative rate period dummy and the change in the policy rate is negative and large enough to suggest a potential reversal of the pass-through to interest rates on bank loans. This is consistent with the aggregate evidence in figure 1 which shows that the cost of uncollateralized bank loans relative to mortgage loans increased around this time. And suggests that this spread is being driven by a drop (or even reversal) of pass-through potentially associated with the negative interest rate policy.

However, these results do not rule out other potential drivers of the increase in this spread. For example it is possible that other factors either drove or exacerbated the attenuation of monetary policy pass-through to bank lending interest rates. Adolfsen and Spange (2020) examine a wider range of loan types from Danish banks, they also find attenuation of the pass-through of monetary policy rate changes to this broader aggregate of interest rates on loans (including firm loans). Their analysis includes firm loans and finds slightly less attenuation in aggregate, suggesting the attenuation of pass-through is particularly strong for household uncollateralized loans. They suggest that post-financial crisis adjustment of Danish banks to risk as an alternative factor driving the change in pass-through.

The results in this section are suggestive that there may be a relationship between negative interest rates and the attenuation of pass-through of policy rate changes to uncollateralized lending rates. But the empirical evidence I present here is not causal. Further exploration with the Danish micro-data that is ongoing could help disentangle what is driving the attenuation of pass-through.

3 Stylized Model

This section sets out a stylized model with an exogenous spread between the rate on lending uncollateralized by housing and the rate on mortgage lending (i.e. lending collateralized by housing). This model illustrates the *debt substitution channel* that links borrower substitution between the two types of debt to fluctuations in house prices.

3.1 Households

There are two representative households: the saver and the borrower. Each household is of mass 1. Borrowers are relatively impatient individuals who value housing and face a collateral constraint when obtaining mortgage debt.

3.1.1 Savers' Problem

The savers have an un-modeled rigid demand for housing. As a result borrowers are the marginal buyers of housing. This reflects Geanakoplos (2010)'s idea that the asset is priced by the most levered individuals (the borrowers). Similar assumptions about segmentation are made by Justiniano et al. (2019), Ferrante (2019), and Greenwald (2018).

The savers are relatively patient (their discount factor $\tilde{\beta}_t$ is larger than the borrowers' discount factor), they consume and make loans directly to households. Their problem is:

$$\max_{\{\tilde{c}_t, l_t, b_t\}} \quad E_0 \sum_{t=0}^{\infty} (\tilde{\beta}_t)^t \Big[\tilde{u}(\tilde{c}_t) - \tilde{\beta}_t \tilde{v}(l_t) \Big] \tag{3.1}$$

subject to their budget constraint:

$$\tilde{c}_t + l_t + b_t \leq \tilde{y} + R^l_{t-1} l_{t-1} + R^b_{t-1} b_{t-1}. \tag{3.2}$$

Saver specific notation is denoted with tildes: $\tilde{c}_t$ denotes consumption of non-durable goods, $\tilde{y}$ is the saver's per period endowment. b_t are mortgage loans to borrowers (which pay the interest rate R^b_t). l_t are uncollateralized loans to borrowers (which pay the interest rate R^l_t). $\tilde{v}(l_t)$ is a utility cost for holding uncollateralized debt. The functional form is:

$$\tilde{v}(l_t) = \tau_{l,t} l_t. \tag{3.3}$$

$\tau_{l,t}$ determines the spread spread between uncollateralized lending and mortgage lending ($R^l_t - R^b_t$). This spread captures in reduced form that mortgage lending is generally cheaper or less risky than uncollateralized forms of household lending. Shocks to the savers' discount factor ($\tilde{\beta}_t$) impact the level of the mortgage rate, but due to the discounting of the savers' dis-utility for uncollateralized lending $\tilde{\beta}_t$ shocks do not impact the spread.

Mapping to a Richer Model with Financial Intermediaries: Shocks to $\tau_{l,t}$ capture exogenous fluctuations in the savers' required return on uncollateralized lending relative to the return on mortgage lending. This in reduced form captures the dynamics of the spread in a richer model with banks. For example a model where lending is split between commercial banks that provide uncollateralized loans, so are subject to the adverse effects from losses on their net interest margin, and mortgage credit institutions that are not impacted by negative interest rates via the net interest margin channel. The dynamics generated in such a model by a monetary policy rate cut in negative territory (with sticky deposit rates) would generate upward pressure on this spread.

3.1.2 Borrowers' Problem

Borrowers are relatively impatient (discount factor: $\hat{\beta}_t < \tilde{\beta}_t$), they receive loans directly from savers, consume, and purchase housing. Their problem is:

$$\max_{\{\hat{c}_t, l_t, b_t, \hat{h}_t\}} \quad E_0 \sum_{t=0}^{\infty} (\hat{\beta}_t)^t \Big[\hat{u}(\hat{c}_t) + \hat{v}(\hat{h}_t)\Big], \tag{3.4}$$

subject to their budget constraint:

$$\hat{c}_t + R^l_{t-1} l_{t-1} + R^b_{t-1} b_{t-1} + p_{h,t}\hat{h}_t = l_t + b_t + p_{h,t}\hat{h}_{t-1} + \hat{y}, \tag{3.5}$$

a collateral constraint on mortgage loans:

$$b_t \leq m_b \frac{E_t p_{h,t+1}\hat{h}_t}{R^b_t}, \qquad (\hat{\mu}_{b,t} \geq 0) \tag{3.6}$$

and an overall borrowing limit:

$$l_t + b_t \leq m_y \hat{y}, \qquad (\hat{\mu}_{y,t} \geq 0) \tag{3.7}$$

Borrower specific notation is denoted with hats: $\hat{c}_t$ denotes consumption of non-durable goods, $\hat{h}_t$ denotes borrower housing, and $\hat{y}$ the borrower's per period endowment. m_b is the exogenous collateral value of housing and $p_{h,t}$ is the price of housing. m_y captures the extent that borrowers can borrow against their endowment income.

3.2 Exogenous Shocks & Market Clearing

Housing is in fixed supply:

$$\hat{h}_t = H \tag{3.8}$$

The resource constraint is:

$$\hat{c}_t + \tilde{c}_t = \hat{y} + \tilde{y} \tag{3.9}$$

The shock process for the dis-utility cost to savers of holding uncollateralized loans evolves according to:

$$\tau_{l,t} = \tau_l + \epsilon_{\tau_l,t}, \tag{3.10}$$

where τ_l is calibrated to match the target spread between the interest rate on uncollateralized lending and mortgage lending $(R^l - R^b)$ in steady state. The shock process for the savers' time preference evolves according to:

$$\tilde{\beta}_t = \tilde{\beta} + \epsilon_{\tilde{\beta},t}. \tag{3.11}$$

3.3 Functional Forms

Savers have linear utility:

$$\tilde{u}(\tilde{c}_t) = \tilde{c}_t \tag{3.12}$$

Borrowers have log utility in consumption and housing:

$$\hat{u}(\hat{c}_t) = \log(\hat{c}_t) \tag{3.13}$$

$$\hat{v}(\hat{h}_t) = \log(\hat{h}_t) \tag{3.14}$$

3.4 House Pricing Equation

Appendix B derives the borrowers' pricing equation[3] for housing from the borrowers' optimality conditions for housing, uncollateralized loans and mortgages (eq A.8,A.7,A.6):

$$p_{h,t} = j\hat{c}_t + j\sum_{i=0}^{\infty}\hat{c}_{t+i+1}\left\{\Pi_{k=0}^{i}\left[\frac{\hat{c}_{t+k}}{\hat{c}_{t+k+1}}\hat{\beta}\left(1 + m_b\frac{R^l_{t+k} - R^b_{t+k}}{R^b_{t+k}}\right)\right]\right\} \tag{3.15}$$

Other things equal, this expression makes it clear that house prices increase when the spread between the interest rates on uncollateralized debt and mortgage debt increases ($R^l_{t+k} - R^b_{t+k}$). An increase in this spread decreases the relative price of mortgage debt which incentivizes borrowers to substitute from uncollateralized debt to mortgage debt. In order to access mortgage debt households need collateral (i.e. housing) so an increase in the demand for mortgage debt also drives house prices up because its role as collateral is now more valuable. This is the *debt substitution channel*.

This debt substitution behavior is supported by the empirical literature, for example Pennington-Cross and Chomsisengphet (2010) find that subprime households in the United States are more likely to refinance their mortgages or take up other types of debt collateralized by housing when uncollateralized forms of debt become relatively more expensive.

The house pricing equation also indicates that (keeping the spread constant) house prices are inversely related to the level of the mortgage rate. Intuitively: borrowers demand more (less) housing when the level of the interest rate on mortgage credit is lower (higher).

[3] Assuming perfect foresight and that housing consumption is normalized to unity $\forall t$.

Shifts in consumption also impact house prices. Households desire a balanced basket between consumption of housing and consumption of non-durable goods ($\hat{c}$). Therefore as consumption of non-durable goods go up housing demand also goes up, pushing up house prices. It is clear to see in equation (3.15) that the level of consumption enters positively. Additionally house prices are inversely related to the growth rate of consumption (the inverse growth rate ($\hat{c}_{t+k}/\hat{c}_{t+k+1}$) enters positively into equation 3.15).

4 Parameter Values

Table 2: Calibrated Parameters

Parameter	Value	Description
$\tilde{\beta}$	0.9943	Saver's discount factor
$\hat{\beta}$	0.97	Borrower's discount factor
H	1	Total inelastic supply of housing
$\hat{y}$	0.5	borrower endowment income
$\tilde{y}$	0.5	saver endowment income

Table 3: Steady State Targets

Target	Value	Description
$R^l - R^b$	200	Spread between uncollateralized and mortgage debt (annual basis points)
$B/(p_h H)$	80%	loan-to-value ratio
$B/(4(\hat{y}+\tilde{y}))$	0.7	ratio of mortgage debt to annual GDP
$L/(4\hat{y})$	0.2	ratio of mortgage debt to borrower annual income

Note: The parameters τ_l, m_b, j, and m_y are calibrated to match these targets.

5 Simulation Results & Discussion

To review, the credit conditions faced by borrowers can be characterized by three different model objects: (a) the interest rate on uncollateralized lending, (b) the interest rate on mortgage lending, and the spread between (a) and (b)[4]. The simulations presented here explore how changes in this spread impact house prices and mortgage credit.

[4]The spread is the difference between the interest rate on uncollateralized lending (R_t^l) and mortgage lending (R_t^b). Spread = $R_t^l - R_t^b$

I find that an increase in the spread between the interest rate on uncollateralized lending and the mortgage rate (keeping the mortgage rate constant) drives households to substitute towards mortgage credit. This substitution pushes house prices up but borrower consumption down. This is the *debt substitution channel*. The size of this effect on house prices is increasing in the expected persistence of the shock that drives the spread up.

5.1 Stylized Negative Interest Rate Shock

Figure 2: Easing Shocks, 10 quarters

Note: The shocks last 10 periods, on the realization of the first shock the agents also realize news about the future shock process."RB drop, spread increase" (sold black line) is a 50 basis point drop in the mortgage rate, keeping the interest rate on uncollateralized bank lending constant. "RB drop, spread unchanged" (dashed blue line) is a 50 basis point drop in both the mortgage rate and interest rate on uncollateralized bank lending. "RB unchanged, spread increase" (dotted red line) keeps the mortgage rate unchanged, with a 50 basis point drop in the interest rate on uncollateralized bank lending.

The first set of simulations (figure 2) compares three different shocks to credit conditions faced by borrower households. They are i) a 50 basis point drop in the housing collateralized lending rate + spread increases by 50 basis points (black solid line), ii) a 50 basis point drop in both lending rates + spread unchanged (dashed blue line), and iii) a 50 basis point increase in the spread (mortgage rate unchanged, uncollateralized lending rate increases by 50 basis points, red dotted line).

The first simulation (a 50 basis point drop in the housing collateralized lending rate + spread increases by 50 basis points, black solid line) captures in reduced form the dynamics of the hypothetical richer model (discussed in section 3.1.1) in response to a negative monetary policy shock when the policy rate is already negative. Under such a shock mortgage rates should follow the policy rate down (because mortgage credit institutions are not subject to the adverse impacts of negative rates), however bank lending rates are sticky due to the net margin channel.

The second and third simulations decompose this shock. The second simulation (Mortgage Rate Drop + Spread Unchanged, dashed blue line), captures purely the effect of lower lending rates with the spread unchanged. The third simulation (Mortgage Rate Unchanged + Spread Increase, red dotted line), purely captures the effect of an increase in the spread between uncollateralized debt and mortgage debt: the debt substitution channel.

All three shocks drive house prices up, however only the first two shocks loosen credit conditions for borrowers. The third shock actually tightens credit conditions, but via the *debt substitution channel* pushes house prices up. This is because due to the relative increase in the price of uncollateralized debt, borrowers want to substitute toward mortgage debt. This increases the house price, because housing is now more valuable as a form of collateral for the now relatively cheaper type of debt.

5.1.1 Mortgage Rate Drop, Spread Unchanged

The path of consumption drives the dynamics of the house price under the mortgage rate shock (keeping the spread constant - blue dashed line). This shock eases the cost of both types of debt, giving borrowers the incentive to move consumption forward in time. This applies to both non-durable consumption ($\hat{c}_t$) and consumption of housing ($\hat{h}_t$). Non-durable consumption jumps in the period following the shock, stays at a higher level, and then returns close to steady state when the shock series subsides. As is clear from the house pricing equation (section 3.4, eq 3.15) the level of non-durable consumption, and the inverse of the growth in non-durable consumption ($\hat{c}_{t+k}/\hat{c}_{t+k+1}$) both effect the house price.

On impact of the shock (and realization of future shocks) there are two counteracting effects: i) R_t^b has dropped (spread unchanged) which pushes the house price up, ii) non-durable consumption is expected to increase in the next period, meaning there is an on impact decline in the inverse growth rate of non-durable consumption which has a negative impact on the house price. In the following periods (while the shock persists) the growth rate of non-durable consumption is approximately zero so the effect of the drop in the mortgage rate wins out and house prices experience a level shift up. When the mortgage rate reverts back to its old (higher) level there is an expected drop in non-durable consumption, so these effects again balance each other out and the drop in house prices (driven by the inverse of consumption growth) lags the end of the shock series by one period.

5.1.2 Mortgage Rate Unchanged, Spread Increase

The debt substitution effect in isolation (i.e. an increase in the uncollateralized lending rate keeping the housing collateralized lending rate fixed - the red dashed line) has the following dynamics. House prices and mortgage debt increase on impact. The effect of the shock on house prices and mortgage debt decays over time, and in the last period of the shock the house price actually drops below the steady state level.

The driver of the on-impact jump in house prices is clear from the house pricing equation (eq 3.15 in section 3.4). This expression shows that house prices depend on the sum of future spreads (between the uncollateralized debt and mortgage debt). Intuitively a shock that drives the spread up for a number of periods will cause the house price to jump on impact (when the initial shock and announcement of future shocks are realized). The effect on the house price will slowly decline as the sum of future shocks declines.

This shock tightens credit conditions for borrowers: now the cost of bringing consumption forward in time has increased, so it has a negative impact on consumption. The drop in consumption somewhat mutes the impact on house prices because borrowers want to consume a balanced basket of non-durable consumption and housing (see section 3.4 for further discussion). The final drop in house prices is driven by this negative consumption effect dominating. The next section will show that this negative consumption effect becomes more dominant if the persistence of the spread shock is less.

5.2 Shock Persistence Amplifies the Debt Substitution Channel's Impact on House Prices & Mortgage Debt

Figures 3 and 4 plot the same three shocks as above, but with a shock persistence of only 1 and 5 periods respectively. Comparing figures 3, 4 and 2 it is clear to see that the shock persistence matters highly for the quantitative importance of the debt substitution effect. The shorter the shock persistence, the more the effect of the drop in consumption due to credit tightening dominates the debt substitution effect. In the 1-period shock (figure 3) the negative consumption effect is so dominate house prices and mortgage debt actually decline. In the 5 and 10 period simulations (figures 4 & 2) this effect does not dominate (house prices and mortgage debt increase) but following the end of the shock series, house prices and mortgage credit drop before converging towards steady state (due to the negative consumption effect).

Figure 3: Easing Shocks, 1 off

Note: The shocks last 1 period. They are unexpected. "RB drop, spread increase" (sold black line) is a 50 basis point drop in the mortgage rate, keeping the interest rate on uncollateralized bank lending constant. "RB drop, spread unchanged" (dashed blue line) is a 50 basis point drop in both the mortgage rate and interest rate on uncollateralized bank lending. "RB unchanged, spread increase" (dotted red line) keeps the mortgage rate unchanged, with a 50 basis point drop in the interest rate on uncollateralized bank lending.

The impact of persistence has relevant policy implications. The existing literature

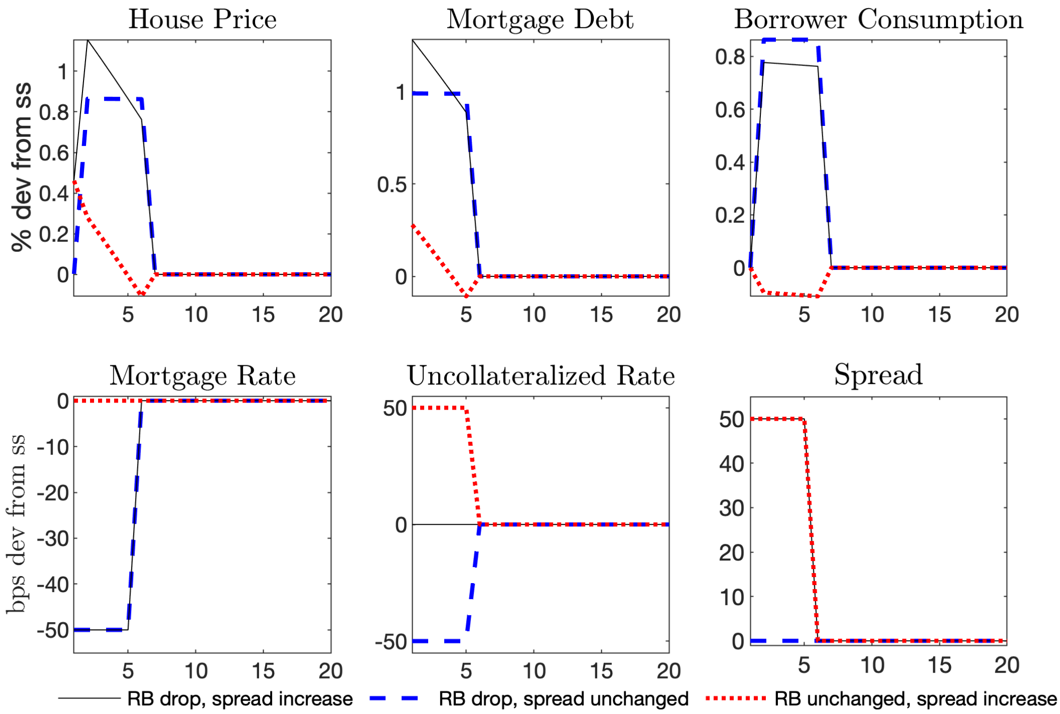


Figure 4: Easing Shocks, 5 quarters

Note: The shocks last 5 periods, on the realization of the first shock the agents also realize news about the future shock process. They are unexpected. "RB drop, spread increase" (sold black line) is a 50 basis point drop in the mortgage rate, keeping the interest rate on uncollateralized bank lending constant. "RB drop, spread unchanged" (dashed blue line) is a 50 basis point drop in both the mortgage rate and interest rate on uncollateralized bank lending. "RB unchanged, spread increase" (dotted red line) keeps the mortgage rate unchanged, with a 50 basis point drop in the interest rate on uncollateralized bank lending.

already tells us that the adverse impact of the negative interest rate via losses to banks via the net margin channel creeps up over time: Eggertsson et al. (2019), Brunnermeier and Koby (2019), and Ulate (2021). These papers tell us that this adverse profitability hits bank lending rates will be sticky, and not declining as much with further policy rate cuts (or even reversing). The spread shocks here capture this effect in reduced form. And the results here show a further channel for why the adverse aspects of negative nominal interest rate policy are increasing in the duration of the policy.

Here it is clear that the persistence of the shock that drives the spread (between uncollateralized debt and mortgage debt) up amplifies the increase on house prices and and mortgage debt. The debt substitution channel here introduces a new unintended consequence of negative nominal interest rate policy: a housing boom with increased household leverage. Household expectations matter a lot, suggesting that forward guidance would further amplify this unintended consequence.

6 Conclusion

In this paper I show that substitution from uncollateralized debt to mortgage debt driven by negative interest rate policy (NIRP) amplifies the impact of monetary policy on house prices but mutes the ability of monetary policy to stimulate consumption. This is the *debt substitution channel*. Furthermore the quantitative impact of this channel is increasing in the expected duration of NIRP policy.

I have focused on negative nominal interest rate policy as a driver of the debt substitution effect. However this channel could be triggered by any shock that drives the spread between uncollateralized debt and mortgage debt up. In financial systems where uncollateralized debt is primarily provided by traditional commercial banks and mortgage debt is provided by other credit institutions, then any shock that asymmetrically impacts the profitability of commercial banks will also trigger the debt substitution channel. For example a change in market power in the commercial banking sector, a change in regulation of commercial banks, or a release of the capital buffer could also trigger the debt substitution channel.

References

Abildgren, Kim and Andreas Kuchler, "Do Firms Behave Differently when Nominal Interest Rates are Below Zero?," Working Paper 164, Danmarks Nationalbank November 2020. [Cited on pages 5 and 6.]

Adolfsen, Jakob Feveile and Morten Spange, "Negative Nominal Interest Rates and the Bank Lending Channel," Working Paper 154, Danmarks Nationalbank April 2020. [Cited on pages 5 and 8.]

Ampudia, Miguel and Skander J. van den Heuvel, "Monetary Policy and Bank Equity Values in a Time of Low and Negative Interest Rates," Finance and Economics Discussion Series 2019-064, Board of Governors of the Federal Reserve System (U.S.) August 2019. [Cited on page 4.]

Bittner, Christian, Diana Bonfim, Florian Heider, Farzad Saidi, Glenn Scheppens, and Carla Soares, "Why so negative? The effect of monetary policy on bank credit supply across the euro area," Technical Report August 2021. [Cited on page 5.]

Brunnermeier, Markus K. and Yann Koby, "The Reversal Interest Rate," IMES Discussion Paper Series 19-E-06, Institute for Monetary and Economic Studies, Bank of Japan June 2019. [Cited on pages 4 and 18.]

Eggertsson, Gauti B, Ragnar E Juelsrud, Lawrence H Summers, and Ella Getz Wold, "Negative Nominal Interest Rates and the Bank Lending Channel," Working Paper 25416, National Bureau of Economic Research January 2019. [Cited on pages 4 and 18.]

Ferrante, Francesco, "Risky lending, bank leverage and unconventional monetary policy," *Journal of Monetary Economics*, 2019, *101* (C), 100–127. [Cited on page 9.]

Geanakoplos, John, "The Leverage Cycle," *NBER Macroeconomics Annual*, 2010, *24*, 1–66. [Cited on page 9.]

Greenwald, Daniel, "The Mortgage Credit Channel of Macroeconomic Transmission," Working Paper, Sloan School of Management, MIT February 2018. [Cited on page 9.]

Groot, Oliver De and Alexander Haas, "The signalling channel of negative interest rates," Economics Series Working Papers 956 JEL classification: E, University of Oxford, Department of Economics December 2021. [Cited on page 4.]

Gundersen, Poul, Stig Secher Hesselberg, and Sean Hove, "Danish Mortgage Credit," *Danmarks Nationalbank Monetary Review*, 2011, *4th Quarter, Part 1.* [Cited on page 5.]

Heider, Florian, Farzad Saidi, and Glenn Schepens, "Life below Zero: Bank Lending under Negative Policy Rates," *Review of Financial Studies*, 2019, *32* (10), 3728–3761. [Cited on page 5.]

Jorgensen, Anders and Lars Risbjerg, "Negative Interest Rates," *Danmarks Nationalbank Monetary Review*, 2012, *3rd Quarter, Part 1.* [Cited on page 6.]

Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti, "Credit Supply and the Housing Boom," *Journal of Political Economy*, May 2019, *127* (3), 1317–1350. [Cited on page 9.]

Kjeldsen, Kristian, "Mortgage Credit in the USA and Denmark," *Danmarks Nationalbank Monetary Review*, 2003, *3rd Quarter.* [Cited on page 5.]

Paris, Matthieu Darracq, Christoffer Kok, and Matthias Rottner, "Reversal interest rate and macroprudential policy," Discussion Papers 24/2021, Deutsche Bundesbank 2021. [Cited on page 4.]

Pennington-Cross, Anthony and Souphala Chomsisengphet, "Subprime Renancing: Equity Extraction and Mortgage Termination," *Real Estate Eeconomics*, 2010, *25* (2), 223–263. [Cited on page 12.]

Ulate, Mauricio, "Going Negative at the Zero Lower Bound: The Effects of Negative Nominal Interest Rates," *American Economic Review*, January 2021, *111* (1), 1–40. [Cited on pages 4 and 18.]

A Model Equations

Savers' FoC wrt housing collateralized loans:

$$\tilde{u}_{c,t} = \tilde{\beta}_t E_t\big[\tilde{u}_{c,t+1} R^b_t\big] \tag{A.1}$$

Savers' FoC wrt uncollateralized loans:

$$\tilde{u}_{c,t} + \tilde{\beta}_t \tau_{l,t} = \tilde{\beta}_t E_t\big[\tilde{u}_{c,t+1} R^l_t\big] \tag{A.2}$$

Borrowers' budget constraint:

$$\hat{c}_t + R^l_{t-1} l_{t-1} + R^b_{t-1} b_{t-1} + p_{h,t}\hat{h}_t = l_t + b_t + p_{h,t}\hat{h}_{t-1} + \hat{y}. \tag{A.3}$$

Borrowers' collateral constraint on housing collateralized loans:

$$b_t \leq m_b \frac{E_t p_{h,t+1}\hat{h}_t}{R^b_t}, \qquad\qquad (\hat{\mu}_{b,t} \geq 0). \tag{A.4}$$

Borrowers' total borrowing limit:

$$l_t + b_t \leq m_y \hat{y}, \qquad\qquad (\hat{\mu}_{y,t} \geq 0). \tag{A.5}$$

Borrowers' FoC wrt housing collateralized loans credit:

$$\hat{u}_{c,t} - \hat{\beta} E_t\big[\hat{u}_{c,t+1} R^b_t\big] = \hat{\mu}_{b,t} + \hat{\mu}_{y,t}. \tag{A.6}$$

Borrowers' FoC wrt uncollateralized loans:

$$\hat{u}_{c,t} - \hat{\beta} E_t\big[\hat{u}_{c,t+1} R^l_t\big] = \hat{\mu}_{y,t}. \tag{A.7}$$

Borrowers' FoC wrt housing:

$$\frac{j}{\hat{h}_t} - \hat{u}_{c,t} p_{h,t} + \hat{\beta} E_t\big[\hat{u}_{c,t+1} p_{h,t+1}\big] + \frac{m_b E_t p_{h,t+1}}{R^b_t}\hat{\mu}_{b,t} = 0 \tag{A.8}$$

Resource Constraint:

$$\hat{c}_t + \tilde{c}_t = \hat{y} + \tilde{y}. \tag{A.9}$$

Housing market clearing:

$$\hat{h}_t = H \tag{A.10}$$

Shock to savers' dis-utility for uncollateralized lending:

$$\log\left(\frac{\tau_{l,t}}{\tau_l}\right) = \rho_{\tau_l}\log\left(\frac{\tau_{l,t}}{\tau_l}\right) + \epsilon_{\tau_l,t}, \tag{A.11}$$

Shock to savers' time preference:

$$\log\left(\frac{\tilde{\beta}_t}{\tilde{\beta}}\right) = \rho_{\tilde{\beta}}\log\left(\frac{\tilde{\beta}_{t-1}}{\tilde{\beta}}\right) + \epsilon_{\tilde{\beta},t}, \tag{A.12}$$

B Borrowers' House Pricing Equation

Assuming perfect foresight, log utility at that $\hat{h}_t = 1 \forall t$ the borrower's first order condition w.r.t. housing can be written as:

$$p_{h,t} = \hat{c}_t\left[j + p_{h,t+1}\left(\frac{\hat{\beta}}{\hat{c}_{t+1}} + \frac{m_b}{R_t^b}\hat{\mu}_{b,t}\right)\right] \tag{B.1}$$

$$= j\hat{c}_t + p_{h,t+1}\underbrace{\left(\hat{\beta}\frac{\hat{c}_t}{\hat{c}_{t+1}} + \frac{m_b}{R_t^b}\hat{\mu}_{b,t}\hat{c}_t\right)}_{\equiv\Psi_t} \tag{B.2}$$

$$= j\hat{c}_t + p_{h,t+1}\Psi_t \tag{B.3}$$

Iterate this expression forward:

$$p_{h,t} = j\hat{c}_t + \Psi_t\left[j\hat{c}_{t+1} + \Psi_{t+1}p_{h,t+2}\right] \tag{B.4}$$

$$= j\hat{c}_t + j\hat{c}_{t+1}\Psi_t + \Psi_t\Psi_{t+1}p_{h,t+2} \tag{B.5}$$

$$= j\hat{c}_t + j\hat{c}_{t+1}\Psi_t + j\hat{c}_{t+2}\Psi_t\Psi_{t+1} + \Psi_t\Psi_{t+1}\Psi_{t+2}p_{h,t+3} \tag{B.6}$$

$$= j\hat{c}_t + j\sum_{i=0}^{\infty}\hat{c}_{t+i+1}\left\{\Pi_{k=0}^{i}\Psi_{t+k}\right\} \tag{B.7}$$

Substituting the expression for Ψ_t back in:

$$p_{h,t} = j\hat{c}_t + j\sum_{i=0}^{\infty}\hat{c}_{t+i+1}\Big\{\Pi_{k=0}^{i}\Big[\hat{c}_{t+k}\Big(\frac{\hat{\beta}}{\hat{c}_{t+k+1}} + \frac{m_b}{R^b_{t+k}}\hat{\mu}_{b,t+k}\Big)\Big]\Big\} \tag{B.8}$$

Subtracting the borrowers optimality condition for uncollateralized debt from the optimality condition for mortgage debt (A.6-A.7):

$$\hat{\mu}_{b,t+k} = \frac{\hat{\beta}(R^l_{t+k} - R^b_{t+k})}{\hat{c}_{t+k+1}} \tag{B.9}$$

Plugging this into the house pricing expression results in:

$$p_{h,t} = j\hat{c}_t + j\sum_{i=0}^{\infty}\hat{c}_{t+i+1}\Big\{\Pi_{k=0}^{i}\Big[\frac{\hat{c}_{t+k}}{\hat{c}_{t+k+1}}\hat{\beta}\Big(1 + m_b\frac{R^l_{t+k} - R^b_{t+k}}{R^b_{t+k}}\Big)\Big]\Big\} \tag{B.10}$$