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Leaning against the credit cycle

AUTHORS:

PAOLO GELAIN
KEVIN J. LANSING
GISLE J. NATVIK

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Leaning Against the Credit Cycle[*]

Paolo Gelain[†]   Kevin J. Lansing[‡]   Gisle J. Natvik[§]

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Abstract

We study the interaction between monetary policy and household debt dynamics. To this end, we develop a dynamic stochastic general equilibrium model where household debt is amortized gradually, and only new loans are constrained by the current value of collateral. Long-term debt implies that swings in leverage do not simply reflect shifts in borrowing, and brings model-implied debt dynamics closer to their empirical counterparts. The model implies that contractive monetary policy has muted influence on household debt, *increasing* debt-to-GDP in the short run, while reducing it only in the medium run. If the interest rate is systematically raised whenever the debt-to-GDP ratio or the real debt level is high, equilibrium indeterminacy and greater volatility of debt itself follows. Responding to debt growth does not cast this destabilizing influence.

Keywords: *Monetary policy, credit, long-term debt.*

JEL Classification: E52, E32, E44.

1   Introduction

Credit typically moves in a gradual manner, as highlighted by several recent studies of the *credit cycle*, for instance Aikman, Haldane, and Nelson (2014) and Drehmann, Borio, and Tsatsaronis

(2012). Moreover, the historical evolution of household leverage has largely been driven by variation in income growth, inflation and interest rates, rather than active changes in borrowing, as documented by Mason and Jayadev (2014). In contrast, macroeconomic models typically assume that households refinance their debt each period, as in the influential work of Iacoviello (2005), with the implication that the entire stock of debt responds swiftly to shocks and policy changes. This simplifying assumption might be useful and innocuous for many purposes, but cannot be relied upon in the current policy debate, where a central question regards *if* and *how* monetary policy should respond to movements in household debt.[1] The likely performance of such policies can only be evaluated within frameworks that realistically account for debt dynamics.

We therefore develop a dynamic stochastic general equilibrium model where household debt is amortized gradually, and only new loans are constrained by the current value of collateral. Within this environment, we explore the joint dynamics of debt and other macroeconomic variables and answer our overriding questions: How is a monetary policy tightening likely to affect household indebtedness? What are the likely consequences of systematically increasing the interest rate when the debt-to-GDP ratio is high?

To model multiperiod debt within a DSGE-model suitable for policy analysis, we rely on the amortization framework proposed by Kydland, Rupert, and Sustek (2012). Here the amortization rate of debt follows a process calibrated to match the properties of a standard mortgage contract. Importantly, this framework implies a distinction between new loans and pre-existing debt. We embed this debt specification into a DSGE-model with collateral constraints, akin to Iacoviello (2005), Campbell and Hercowitz (2005) and Monacelli (2009). Naturally, pre-existing debt is not constrained by current swings in collateral value. Instead, it follows a gradual amortization process. Only new loans are constrained by collateral. Hence, the evolution of household leverage at the aggregate level, measured as debt relative to GDP or house prices, is decoupled from the evolution of new borrowing.

With an amortization structure approximating a 30-year mortgage contract, our model implies debt dynamics that are highly persistent. While there is feedback between debt and the macroeconomy via a collateral constraint on new loans, other macroeconomic variables than debt move faster, and revert considerably earlier to steady state than debt does after shocks. In this sense, our framework captures the coexistence of a low-frequent credit cycle together with a conventional business cycle, similar to what recent empirical studies, such as Drehmann, Borio, and Tsatsaronis (2012), emphasize. Moreover, in a simple exercise where we subject the model to technology shocks only and compare moments to the U.S. data, our stylized model does a

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[1]For instance, the role of household indebtedness in Swedish monetary policy has recently received much attention. See Financial Times, October 29, 2014: "Tactic of 'lean against the wind' has failed in Sweden", Financial Times, May 7, 2014: "Riksbank raises concern on household debt", Laséen and Strid (2013), and the multiple comments by Lars Svensson at http://larseosvensson.se.

considerably better job in matching not only the autocorrelation of debt-to-GDP, but also the correlations of real household debt with inflation, interest rates, house prices, and to a moderate extent output, than a standard one-quarter debt model does.

Because only new loans respond on impact, and these constitute a small fraction of total debt, monetary policy shocks cause only a moderate reduction of nominal debt. Inflation and output, in contrast, respond faster. Hence, real debt and debt-to-GDP are both likely to *rise* in the first quarters after a monetary policy shock. However, as inflation and output return to steady state some time after the initial impulse, real debt and the debt-to-GDP ratio drop moderately below their steady state levels, and then return to steady state only after a considerable period. With a 30-year debt contract, it takes approximately 20 years before real debt has reverted entirely back to its steady state level. Notably, the medium-run decline in debt after a monetary policy shock is influenced by the amortization process of debt. When mortgage debt is of the annuity loan type, the amortization rate increases over the lifetime of a mortgage. Hence, by reducing the share of new loans in the economy-wide stock of debt, a monetary tightening raises the average amortization rate in the economy. This effect propagates the extent to which debt falls in the medium run after a monetary policy shock.

It is not obvious that the persistence of debt actually matters for systematic monetary policy. We therefore analyze the consequences of pursuing a policy by which the interest rate systematically responds to household debt. We here find that it can be detrimental to mechanically lean against the level of households' debt burden.[2] With policy characterized by a simple interest rule, a positive response coefficient on steady state-deviations of real debt or debt-to-GDP induces equilibrium indeterminacy. Notably, the opposite conclusion is reached from a 1-period debt model. It is because debt is gradually amortized and persistent, policy should not respond to it. The reason is that when new loans constitute only a small fraction of the aggregate stock of debt, higher inflation expectations tend to reduce the total level of real debt relative to steady state. Thus, a policy of systematically raising the interest rate when real debt is high relative to steady state, indirectly induces a negative response of the interest rate to inflation. As consequence, expectations of higher inflation are likely to turn self-fulfilling, as increased inflation expectations feed into higher current inflation, which again pushes the debt level down. In order to curb this destabilizing influence of reacting to debt, the interest rate must react more strongly to inflation to prevent indeterminacy. Moreover, the persistent nature of debt means that the required coefficient on inflation in the interest rate rule increases strongly with the debt coefficient. The reason is that policy tightening in the short run triggers delayed and protracted debt reductions that will pull the future interest rate down if policy responds to debt. If the typical debt contract lasts 30 years, our model implies that when policy shifts

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[2]Within our model, we study interest rate reactions to debt in deviation from steady state. The real-world counterpart would naturally be deviations from trend, i.e. detrended real debt.

from not responding to debt at all, to systematically raising the yearly interest rate by 0.5 basis points per percentage point increase in debt-to-GDP, the minimal response to inflation required to prevent equilibrium indeterminacy, increases from 1 to 10.

Notably, by responding to the real debt level or the debt-to-GDP ratio, policy will destabilize not only inflation, but also debt itself. This begs the question whether there are other moments of debt that monetary policy should respond to instead. We show that by responding to real debt *growth*, in addition to inflation, policy may succeed in stabilizing debt. However, such a policy increases inflation volatility.

Our study is closely related to the arguments put forth by Svensson (2013), who challenges the conventional view that tighter policy reduces households' debt burden. His approach is to combine estimates of how inflation, output and house prices respond to monetary policy shocks, with an accounting formula for debt dynamics. The essential characteristic of Svensson's accounting formula, is that it assumes mortgage contracts are refinanced only infrequently. Our approach is different, as we propose one unified model where all macroeconomic variables, including debt, are jointly determined. This facilitates our analysis of the consequences of debt dynamics for systematic monetary policy. Notably, the debt dynamics that result from Svensson's exercise are similar to the short run impulse responses to a monetary policy shock in our model. Both approaches imply that an interest rate hike most likely raises households' debt-to-GDP ratio in the short run. Our results diverge from Svenssons's in the medium run, where our model implies that debt will fall. In a simultaneous paper to ours, Alpanda and Zubairy (2014) estimate a larger DSGE model than the one studied here, where they also distinguish between new loans and old debt. Consistently with our model, their impulse responses indicate that monetary policy shocks are likely to increase the debt-to-GDP ratio in the short run. Their model does not imply a medium run decline in the debt-to-GDP ratio as our model implies, the likely cause being that they assume a constant amortization rate.

On the more empirical side, Robstad (2014) considers a host of structural vector autoregressions (SVARs) on Norwegian data and finds that monetary policy shocks have had minor influence on household debt, even though house prices have responded a great deal, and that interest hikes have increased the debt-to-GDP ratio in the short-run. Laséen and Strid (2013) use a Bayesian VAR-model on Swedish data, and find somewhat stronger effects on debt, so that debt-to-GDP decreases after a monetary policy shock. Given the opposing views and findings on the qualitative effects of a monetary policy shock on debt-to-GDP, one should bear in mind that our model's implications for systematic monetary policy do *not* hinge on the short-run sign of this response. Rather, what matters is that debt is highly persistent, which is an indisputable feature of the debt.

The distinction between new loans and existing debt is key in our analysis. Recent work supports the importance of this distinction for understanding the debt dynamics in the data. As

highlighted by Justiniano, Primiceri, and Tambalotti (2013), in the recent boom-bust episode of the US housing market, the aggregate ratio of debt over real estate value peaked several quarters after house prices started falling. A standard model where all debt is continuously rebalanced, can only explain this pattern as the consequence of lending standards being loosened at the onset of the financial crisis. Such an interpretation of the housing bust is obviously misguided. In contrast, Gelain, Lansing, and Natvik (2015) show that when one takes into account that current collateral constraints primarily matter for new loans, the behavior of debt-to-real-estate does not imply that lending standards were suddenly relaxed just as the financial turmoil set in.

Long-term debt has recently been emphasized by Garriga, Kydland, and Sustek (2013). They investigate how mortgage loans may act as a nominal rigidity which propagates the real effects of monetary policy, and find that policy is likely to be less influential if fixed rate mortgages are prevalent. The role of mortgage finance in the monetary transmission mechanism is studied by Calza, Monacelli, and Stracca (2013) and Rubio (2011) too, both emphasizing that monetary policy is likely to be less influential when fixed rate mortgages are prevalent. In our paper we ignore the issue of fixed versus flexible rate mortgages, and focus instead on the distinction between how pre-existing and new loans are affected by current borrowing constraints. As such, our paper is closer related to the recent work by Andrés, Arce, and Thomas (2014), who study structural reforms when households are overhung by debt. The key assumption they make, similarly to Justiniano, Primiceri, and Tambalotti (2013), is that households cannot be forced to deleverage faster than a given amortization rate, even if the collateral value of real estate falls faster than debt is actually amortized. In our model, the counterpart to that assumption would be to impose a non-negativity constraint on new loans. Such a constraint would most likely further stimulate the extent to which a contractive monetary policy shock raises the debt level. Ultimately, all these modeling approaches are reduced form representations of households' liquidity management, aiming to avoid the curse of dimensionality that necessarily follows with a deeper modeling of household choice. Iacoviello and Pavan (2013) make substantive progress in modeling the lumpiness of housing purchases, but are forced to treat house prices as given to ensure tractability. Chen, Michaux, and Roussanov (2013) impressively incorporate the many details relevant for mortgage refinancing at a micro level, and succeed in accounting for the US credit boom in the 2000s. However, this level of detail requires a partial equilibrium model and therefore is of limited use for monetary policy analysis.

The evidence that perhaps most convincingly points toward the need for distinguishing between new borrowing and existing debt, is the empirical decomposition of US household debt dynamics by Mason and Jayadev (2014). They account for how the "Fisher" factors inflation, income growth and interest rates have contributed to the evolution of US debt-to-income, in addition to the changes in borrowing and lending, since 1929. Their findings clearly show how the dynamics of debt-to-income cannot be attributed to variation in borrowing alone, but has

been strongly influenced by the Fisher factors, and often has gone in the opposite direction of households' primary deficits.

This paper is organized as follows. Section 2 presents our model, emphasizing particularly the amortization schedule. Section 3 compares unconditional moments of debt in the US data and in the model, and impulse responses to technology shocks. Section 4 discusses how long term debt alters the transmission of monetary policy shocks to households' debt burden. Section 5 discusses the consequences of conducting monetary policy with an eye to stabilize debt, emphasizing how these policy implications are affected by the speed with which households amortize their mortgages.

2   Model

We consider a standard New Keynesian Dynamic Stochastic General Equilibrium model with household debt and collateral constraints, similar to that of Iacoviello (2005). The novelty of our framework is to allow for gradual amortization of the outstanding stock of mortgage debt, and correspondingly modify the borrowing constraint so that it applies to new loans only.

2.1   Households

The economy is populated by two types of households: *patient* (indexed by $j = l$) and *impatient* (indexed by $j = b$), of mass $1 - n$ and n, respectively. Because the two types discount the future differently, $\beta_b < \beta_l$, the impatient households will want to borrow.

Households derive utility from a flow of consumption $c_{j,t}$ and services from housing $h_{j,t}$. They derive disutility from labor $L_{j,t}$. Each household maximizes

$$E_{j,t} \sum_{t=0}^{\infty} \beta_j^t \left\{ \log\left(c_{j,t} - \gamma c_{j,t-1}\right) + \nu_h \log\left(h_{j,t}\right) - \nu_{l,j} \frac{L_{j,t}^{1+\varphi_L}}{1 + \varphi_L} \right\}, \tag{1}$$

The parameter γ governs the importance of habit formation in utility, where $c_{j,t-1}$ is a reference level of consumption which the household takes into account when formulating its optimal consumption plan.[3] The parameter ν_h governs the utility from housing services, $\nu_{j,L}$ governs the disutility of labor supply, and φ_L governs the elasticity of labor supply. The total housing stock is fixed such that $(1 - n) h_{l,t} + n h_{b,t} = 1$ for all t

Impatient Households

Borrowers face the following budget constraint:

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[3]As part of the focus in this paper is on the debt-to-GDP ratio, we include habits in order for the model to imply realistically sluggish GDP movements. None of the monetary policy conclusions drawn below hinge on the presence of habits.

$$c_{b,t} + q_t h_{b,t} + \frac{r_{t-1} + \delta_{t-1}}{\pi_t} b_{b,t-1} = w_{b,t} L_{b,t} + q_t h_{b,t-1} + l_{b,t} \tag{2}$$

where r_{t-1} is the net nominal interest rate at the end of period $t-1$, $\pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate during period t, w_t is the real wage, q_t is the real price of housing, and $b_{b,t}$ is the borrower's real debt at the end of period t. Moreover, δ_t is the amortization rate on existing debt, and $l_{b,t}$ is the new borrowing incurred in period t. Naturally, new borrowing and total debt are tied together through the law of motion for debt

$$b_{b,t} = (1 - \delta_{t-1}) \frac{b_{b,t-1}}{\pi_t} + l_{b,t}. \tag{3}$$

The distinguishing feature of our analysis is to allow for $\delta_t \leq 1$. Our approach here is to follow Kydland, Rupert, and Sustek (2012), and specify a process for the amortization rate that can be calibrated to match the properties of a typical annuity loan. The amortization rate evolves as follows:

$$\delta_t = \left(1 - \frac{l_{b,t}}{b_{b,t}}\right) (\delta_{t-1})^\alpha + \frac{l_{b,t}}{b_{b,t}} (1 - \alpha)^\kappa \tag{4}$$

where $\alpha \in [0,1)$ and $\kappa > 0$ are parameters and $l_{b,t}/b_{b,t}$ represents the share of new loans in the end-of-period outstanding stock of debt. When $\alpha = 0$, we have $\delta_t = 1$ for all t from (4) and $l_t = b_t$ from (3), such that we recover a 1-period mortgage contract where all outstanding debt is repaid each period. When $\alpha > 0$, the above law of motion captures the realistic feature that the amortization rate is low during the early years of a mortgage (i.e., when mortgage payments consist mainly of interest) and thereafter rises during later years as more and more principal is repaid. Kydland, Rupert, and Sustek (2012) show that appropriate settings for the parameters α and κ can approximately match the amortization schedule of a typical 30-year mortgage.

By combining (4) and (3), we can express the law of motion for amortization in terms of the stock of debt only:

$$\delta_t = (1 - \alpha)^\kappa + \frac{b_{b,t-1}}{\pi_t b_{b,t}} (1 - \delta_{t-1}) \left[\delta_{t-1}^\alpha - (1 - \alpha)^\kappa\right] \tag{5}$$

By combining (2) and (3), we arrive at the conventional formulation of the borrowing constraint

$$c_{b,t} + q_t(h_{b,t} - h_{b,t-1}) = w_{b,t} L_{b,t} + b_{b,t} - \frac{R_{t-1}}{\pi_t} b_{b,t-1}, \tag{6}$$

where R_{t-1} is the gross nominal interest rate.

It follows that the introduction of long-term debt does not change the nature of impatient households' budget constraint. The reason why the amortization still matters in our model, is the existence of a borrowing constraint. As in the literature on household debt following Iacoviello (2005), we assume that borrowing is constrained by the collateral value of borrowers' housing

stock. However, because we allow for an amortization rate below unity, we must distinguish between new loans l_t and the entire stock of debt b_t in the borrowing constraint. Logically, a large part of the economy's debt stock is given by decisions made in the past, and will not be directly influenced by the borrowing constraint today. Instead, the constraint in any given period can only apply to new loans l_t. The collateral constraint is then

$$l_t \leq m \left[\frac{E_t \left[q_{t+1} \pi_{t+1} \right] h_{b,t}}{R_t} - b_{b,t} \right],$$

expressing that new loans cannot exceed a fraction m of households' net worth. Combined with the law of motion for debt in (3), and imposing that the constraint always binds, the constraint can be expressed in terms of debt rather than loans:[4]

$$b_{b,t} = \frac{m}{1+m} \frac{E_t \left[q_{t+1} \pi_{t+1} \right] h_{b,t}}{R_t} + \frac{1 - \delta_{t-1}}{1 + m_t} \frac{b_{b,t-1}}{\pi_t}. \tag{7}$$

We see that if all debt is amortized within one quarter, that is if $\delta_t = 1$, then the constraint collapses to the conventional formulation of Kiyotaki and Moore (1997) and Iacoviello (2005), where the current stock of debt is determined by collateral value only, and $\frac{m}{1+m}$ is the loan-to-value ratio. In contrast, if debt is longer-lasting, i.e. if $\delta_t < 1$, the current stock of debt is constrained by existing debt as well, as it is only the last period's loans that are constrained by the current period's collateral value.

The time t Langrangian of the impatient household is

$$
\begin{aligned}
\pounds_t \;=\; & \beta_b^t \left[U_t \left(c_{b,t}, h_{b,t}, L_{b,t} \right) \right] + \\
& \beta_b^t \lambda_t \left\{ w_{b,t} L_{b,t} + b_{2,t} - c_{b,t} + q_t (h_{b,t-1} - h_{b,t}) - \frac{b_{b,t-1} R_{t-1}}{\pi_t} \right\} + \\
& \beta_b^t \lambda_t \mu_t \left[\frac{m_t}{1+m_t} \frac{E_t \left[q_{t+1} \pi_{t+1} \right] h_{b,t}}{R_t} + \frac{1 - \delta_{t-1}}{1 + m_t} \frac{b_{b,t-1}}{\pi_t} - b_{b,t} \right] + \\
& \beta_b^t \lambda_t \eta_t \left\{ \delta_t - (1-\alpha)^\kappa - \frac{b_{b,t-1}}{\pi_t b_{b,t}} (1 - \delta_{t-1}) \left[\delta_{t-1}^\alpha - (1-\alpha)^\kappa \right] \right\}
\end{aligned}
$$

where λ_t, μ_t, and η_t are the Lagrange multipliers associated with the budget constraint (6), the borrowing constraint (7) and the law of motion for amortization (5), respectively. Together with the borrowing constraints, the impatient household's optimal choices are characterized by the following first-order conditions for $c_{b,t}$, $L_{b,t}$, $h_{b,t}$, $b_{b,t}$, δ_t:

$$U_{c_{b,t}} = \lambda_t, \tag{8}$$

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[4]Because $\beta_b < \beta_l$, the borrowing constraint binds in the non-stochastic steady state. We in addition assume that the constraint holds always in the vicinity of the steady state that we shall explore. As is well-known, this assumption can be rationalized as long as the difference between β_b and β_l is sufficiently high relative to the volatility of the shocks considered. The gap between β_b and β_l has no substantial influence on our results.

$$-U_{L_{b,t}} = U_{c_{b,t}} w_{b,t}, \tag{9}$$

$$U_{h_{b,t}} - U_{c_{b,t}} q_t + U_{c_{b,t}} \mu_t \frac{m_t}{1 + m_t} \frac{E_t [q_{t+1} \pi_{t+1}]}{R_t} + \beta_b U_{c_{b,t+1}} q_{t+1} = 0, \tag{10}$$

$$\begin{aligned}
U_{c_{b,t}} &= \beta_b E_t \left[\frac{U_{c_{b,t+1}}}{\pi_{t+1}} \right] R_t + U_{c_{b,t}} \mu_t - \beta_b E_t \left[\frac{U_{c_{b,t+1}} \mu_{t+1}}{(1 + m_{t+1}) \pi_{t+1}} \right] (1 - \delta_t) - \\
&\quad U_{c_{b,t}} \eta_t \frac{b_{b,t-1}}{\pi_t b_{b,t}^2} (1 - \delta_{t-1}) \left[\delta_{t-1}^\alpha - (1 - \alpha)^\kappa \right] + \\
&\quad \beta_b E_t \left[\frac{U_{c_{b,t+1}} \eta_{t+1}}{\pi_{t+1}} \right] \frac{1}{b_{b,t+1}} (1 - \delta_t) \left[\delta_t^\alpha - (1 - \alpha)^\kappa \right],
\end{aligned} \tag{11}$$

$$\begin{aligned}
U_{c_{b,t}} \eta_t &= \beta_b E_t \left[\frac{U_{c_{b,t+1}} \mu_{t+1}}{(1 + m_{t+1}) \pi_{t+1}} \right] b_{b,t} + \\
&\quad \beta_b E_t \left[\frac{U_{c_{b,t+1}} \eta_{t+1}}{\pi_{t+1} b_{b,t+1}} \right] b_{b,t} \left[\alpha \delta_t^{(\alpha-1)} (1 - \delta_t) - \delta_t^\alpha + (1 - \alpha)^\kappa \right].
\end{aligned} \tag{12}$$

Patient Households

Patient households lend to the borrowers. They also choose how much to consume, work, and invest in housing. They receive the firm's profits ϕ_t. The budget constraint of the patient household is given by:

$$c_{l,t} + q_t(h_{l,t} - h_{l,t-1}) + \frac{b_{l,t-1} R_{t-1}}{\pi_t} = b_{l,t} + w_{l,t} L_{l,t} + \phi_t, \tag{13}$$

where $(1 - n) b_{l,t-1} = -n b_{b,t-1}$. In other words, the aggregate savings of patient households correspond to the aggregate loans of impatient households.

The patient household's optimal choices are characterized by the following first-order conditions:

$$-U_{L_{l,t}} = U_{c_{l,t}} w_t, \tag{14}$$

$$U_{c_{l,t}} = \beta_l R_t E_t \left[\frac{U_{c_{l,t+1}}}{\pi_{t+1}} \right], \tag{15}$$

$$U_{c_{l,t}} q_t = U_{h_{l,t}} + \beta_1 E_t \left[U_{c_{l,t+1}} q_{t+1} \right], \tag{16}$$

2.2 Firms and Price Setting

Firms are owned by the patient households.

Final Good Production

There is a unique final good y_t that is produced using the following constant returns-to-scale technology:

$$y_t = \left[\int_0^1 y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}, \quad i \in [0,1], \tag{17}$$

where the inputs are a continuum of intermediate goods $y_t(i)$ and $\varepsilon > 1$ is the constant elasticity-of-substitution across goods. The price of each intermediate good $P_t(i)$ is taken as given by the firms. Cost minimization implies the following demand function for each good $y_t(i) = [P_t(i)/P_t]^{-\varepsilon} y_t$, where the price index for the intermediate good is given by $P_t = \left[\int_0^1 P_t(i)^{1-\varepsilon} di \right]^{1/(1-\varepsilon)}$.

Intermediate Good Production

In the wholesale sector, there is a continuum of firms indexed by $i \in [0,1]$ and owned by patient households. Intermediate goods-producing firms act in a monopolistic market and produce $y_t(i)$ units of each intermediate good i labor:

$$y_t(i) = \exp(z_t) L_t(i)^{1-\xi}, \tag{18}$$

where z_t is an AR(1) productivity shock with autocorrelation coefficient ρ_z, and $L_t(i) = (nL_{bt}(i))^{\varpi} ((1-n) L_{lt}(i))^{1-\varpi}$.

Cost minimization implies the following relationships between marginal cost, mc_t, and real wages

$$mc_t = w_{l,t} \exp(-z_t) \left[\frac{y_t}{(1-n) L_{lt}} (1-\xi)(1-\varpi) \right]^{-1}$$

$$mc_t = w_{b,t} \exp(-z_t) \left[\frac{y_t}{nL_{bt}} (1-\xi) \varpi \right]^{-1}$$

Finally, intermediate firms set prices in a staggered fashion as in Calvo (1983), adjusted to include partial indexation as in Smets and Wouters (2003).[5] Each period a firm may reset its price only with a constant probability of magnitude $1 - \theta$, otherwise the price is partially indexed to past inflation with the degree of indexation governed by the parameter $\upsilon \in (0,1)$. If υ is 1, prices are fully indexed to past inflation, and if υ is 0, there is no indexation. As we shall consider only a first-order approximation of the model, we refrain from summarizing the nonlinear equations of the pricing problem which are completely standard, see for instance Smets and Wouters (2003). As a first-order approximation, linearized around a steady state

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[5]As part of the focus in this paper is on real debt, which depends on inflation, we include price indexation in order for the model to imply a reasonably sluggish inflation response. None of the monetary policy conclusions hinge on the existence of price indexation.

with zero inflation, inflation will evolve according to

$$\pi_t = \frac{\beta}{1 + \beta\upsilon} E_t \pi_t + \frac{\upsilon}{1 + \beta\upsilon} \pi_{t-1} + \frac{(1 - \beta\theta)(1 - \theta)}{(1 + \beta\upsilon)\theta} (\widehat{mc}_t),$$

where all variables are expressed in percentage point deviations from their steady state levels.

2.3 Monetary Policy

In the baseline model, we assume that the central bank follows a simple Taylor-type rule of the form:

$$R_t = R_{t-1}^{\phi_R} \left[R^{ss} (1 + \pi_t)^{\phi_\pi} \right]^{1-\phi_R} \varsigma_t, \tag{19}$$

where R_t is the gross nominal interest rate, $R^{ss} = 1/\beta_1$ is the steady-state real interest rate, $\pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate, and ς_t is an i.i.d. monetary policy shock. In the policy experiments, we will modify this rule to assess the consequences of responding directly to debt.

2.4 Parameter Values

Table 1 reports our parametrization of the model. We set the patient households' discount factor, β_l, consistently with a 1% quarterly nominal interest rate. The impatient agents' discount rate, β_b, is set consistently with an interest rate that is 50 percent higher, as in Campbell and Hercowitz (2005). The labor supply elasticity parameter φ is set to 1, a relatively standard value in the literature.

For the parameters n, $\nu_{l,l}$, $\nu_{l,b}$ and ϖ, we choose their values so the model's steady state matches key statistics of the US economy documented in Justiniano, Primiceri, and Tambalotti (2013) for the stable period of the 1990s. The share of borrowers is set to 0.61, the share of liquidity constrained households reported by JPT. The preference weights $\nu_{l,l}$ and $\nu_{l,b}$ are set so that borrower households work 1.08 times as much as lenders. The labor share parameter ϖ is chosen so that the ratio of borrowers' labor income to lenders' labour income is 0.64. The housing preference weight, ν_h, is chosen to match a ratio of housing wealth to yearly consumption of 2, consistently with Iacoviello and Neri (2010).[6]

The parameters governing the amortization process, α and κ, are set so that the consequent evolution of the amortization rate (δ_t) and interest rate payments resemble those of a 30-year, flexible interest rate, annuity loan contract, as in Kydland, Rupert, and Sustek (2012). More precisely, we pick α and κ so as to minimize the distance between the steady state profiles of amortization and interest rate payments implied by equation (4) and the same profiles implied by an actual annuity loan. When we vary the duration of the loan contract in the paper, we necessarily recalibrate these parameters with the same procedure. Given the consequent

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[6]Both Iacoviello and Neri (2010) and Justiniano, Primiceri, and Tambalotti (2013) calibrate ν_h to match housing wealth relative to output ratio. Because there is no capital accumulation in our model, we instead target housing wealth relative to consumption, in similar spirit as Campbell and Hercowitz (2005).

steady state amortization rate δ, the parameter m, which controls the tightness of the borrowing constraint, is set so that the steady state loan-to-value ratio of the economy, $ltv \equiv \frac{Rb_b}{qh_b} = \frac{m}{m+\delta}$, equals 0.75. According to data from The Federal Housing Finance Agency, the average U.S. loan-to-value ratio has hovered around this level between 1973 and 2012.[7]

The remaining parameters are simply set to conventional levels in the existing literature. The labor elasticity of production, $1 - \xi$, is 0.67. The price adjustment probability θ is set so that prices adjust on average once a year. The elasticity of substitution between goods, ε, is set to imply a 20% steady state markup. In the monetary policy rule, the weights on lagged interest rate and inflation are set to 0.75 and 1.5 as a starting point. The price indexation parameter υ and the habit parameter γ are both set to 0.5. Finally, the technology shock process has an AR-coefficient, ρ_z, of 0.95 and a standard deviation, σ_z, of 0.0124, chosen so that the model matches the standard deviation of GDP growth over the period $1960 - 2012$ when driven by technology shocks alone.

We solve a first-order Taylor-approximation of the model, linearized around its steady state.

3   The Dynamics of Debt

In this section we evaluate how the long-term nature of household borrowing affects debt dynamics in our model, as driven by technology shocks only. The shocks' standard deviation is set to match the volatility of output in the data, as explained above.

3.1   Correlations

Table 2 reports the cyclical behavior of debt in the data and in our model under alternative amortization schemes. Because the model generated series are expressed in percent deviations from steady state, we compare these to linearly detrended data, as this yields the most consistent comparison.

The first line shows that under all debt maturities, the standard deviation of debt-to-GDP is quite similar to the data. Volatility is somewhat too high with 30- and 20-year debt, while it is somewhat too low with one-quarter debt.

More interesting are the autocorrelations of debt-to-GDP. In the first column, we see that debt-to-GDP is highly autocorrelated in the data, reflecting the persistence of credit emphasized by recent studies of the credit cycle, such as Drehmann, Borio, and Tsatsaronis (2012). The long-term debt model captures this feature well, although it exaggerates autocorrelation somewhat in both the 30- and 20-year models. With one-quarter debt, in contrast, the model-implied autocorrelations are substantially below their empirical counterparts.

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[7]See The Federal Housing Finance Agency's historical summary tables, table 17, downloadable from http://www.fhfa.gov/DataTools/Downloads/Pages/Monthly-Interest-Rate-Data.aspx

The final four rows of Table 2 show the contemporaneous correlations of real household debt with inflation, house prices, the policy interest rate, and GDP. When we compare the data to the model where all debt is amortized within a quarter, we see that the correlations are systematically too high in the model. In contrast, with gradual amortization the model captures these comovements considerably better. The model with 30-year debt performs particularly well for the debt-correlation with inflation, but implies a contemporaneous correlation of debt with house prices that is too low. Debt comoves too strongly with output and the interest rate in all models, but the improvement with long term debt instead of quarterly amortization still is substantial.[8] That even the 30-year debt model greatly overstates the correlation between debt and GDP, reflects the nature of this exercise, as the model here is driven entirely by technology shocks which necessarily feed directly into GDP. For instance, with a monetary policy shock the correlation between debt and GDP is negative. We later study monetary policy in great detail. Taken together, the correlations in Table 2 show that a one-quarter model is likely to overstate the response of household debt to economic activity.

The comovement between debt and house prices is particularly interesting, as it reflects the contrasting mechanics of the models with one-quarter and gradual amortization. The upper left panel of Figure 1 therefore plots the correlogram between house prices at time $t = 0$ with debt at different leads and lags up to 5 quarters away. When a house price increase raises collateral value, the entire stock of debt follows immediately in the one-quarter model, while only new loans respond on impact in the long-term debt models. Hence, the contemporaneous correlation ($k = 0$ in Figure 1) between debt and house prices is particularly high with one-quarter debt, as we saw in Table 2. Moreover, we see that in the data, house prices lead debt, reflected in the increasing slope of the correlogram after $k = 0$. The long-term debt models capture this well. In contrast, if all debt is assumed to be amortized each period, the model implies that the correlation between debt and house prices declines sharply after $k = 0$.

The remaining three panels of Figure 1 give the correlograms of debt with inflation, the policy rate, and GDP. Just like we saw for house prices, each macroeconomic variable is more strongly correlated with debt in the future than with contemporaneous debt swings. The one-quarter debt model gets this wrong always, while the long-term debt captures it quite well.

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[8]One might find the extremely low correlation between debt and GDP in the data surprising, in particular given the contemporary correlation reported in Iacoviello and Pavan (2013), which is 0.78 over their full sample period. The reason for this dramatic difference lies in the filtering of the series. By utilizing a linear trend, we remove little of the low-frequent developments in credit before computing the correlations, whereas Iacoviello and Pavan (2013) use a Hodrick-Prescott filter with a smoothing parameter of 1600. Using such a filter would necessarily remove the substantial low-frequent credit swings that we want our models to capture, and hence entirely contradicts our purposes.

3.2 The Persistent Credit Cycle

In order to further gauge the importance of capturing the long-term nature of household debt, Figure 2 displays how the main variables respond to a one standard deviation technology shock in the model. The solid lines display the effects when all debt is amortized each quarter ($\delta_t = 1$). The dashed lines display the effects when the amortization rate evolves as if all debt were of 30-year maturity. We see that the duration of the amortization process does not affect the responses of output, inflation and house-prices. However, we do see a markedly different response of both real debt and debt-to-GDP. The stock of real household debt responds positively to a technology shock both with one-quarter and 30-year debt, but that debt builds up gradually and takes a long time to revert in the latter case. Moreover, the peak response with long-term debt, reached after about 3 years, is greater than the maximum response with one-quarter debt, occurring on impact. We also see that the close link between house prices and aggregate debt that arises via the collateral constraint under one-quarter debt, is broken when only part of the debt is amortized every period. With long-term debt, when the interest rate falls and house prices rise, more new loans are issued, and this effect accumulates over some time so that the real stock of household debt peaks far later than the endogenous monetary stimulus and house prices do. Debt-to-GDP follows a similar trajectory to the real debt level, and even falls in the very short run, as GDP now responds faster to productivity than debt does.

Finally, we subject our model to technology shocks, and simulate it over an extended period. The simulated trajectories of output, inflation, real debt and debt-to-GDP are displayed in Figure 3, with a one-quarter and a 30-year amortization process. First, as expected from the impulse responses before, we see that the amortization process has almost no effect on the behavior of output and inflation. In contrast, the movements of real debt now vary considerably with the assumed amortization process, as we would expect from our previous results. With 30-year debt, fluctuations are markedly more persistent. Our model seems to at least qualitatively capture the property that credit moves at a low frequency, as stressed by the recent empirical literature.

4   Does an Interest Rate Hike Reduce the Debt Burden?

In this section we analyze how the duration of debt influences the effects of a monetary policy shock. This investigation is motivated by Svensson (2013), who points out that the conventional view that tighter monetary policy dampens households' debt burden need not hold, once one acknowledges that only a limited fraction of the population adjust their stock of debt in any given period.

Figures 4, 5 and 6 disentangle the impulse responses to a one standard deviation shock to monetary policy in our model. As before, we see that the dynamics of inflation, output and

house prices are largely unaffected by the speed of amortization. However, the dynamics of the debt burden, measured either as the stock of real debt or as debt-to-GDP, are starkly affected. With one-quarter debt, real debt and debt-to-GDP fall sharply on impact and thereafter return gradually to their steady state levels. Qualitatively, this behavior is consistent with the conventional view that a policy tightening will reduce the debt burden. In sharp contrast, with a 30-year amortization process the effect of monetary policy is far more muted than in the one-quarter case, and the debt burden displays a hump-shaped *increase* before decreasing, as best seen in Figure 5. On impact, real debt hardly moves, but it thereafter continues to rise to a peak response of approximately 0.3 percent after about a year. It thereafter falls gradually, and approaches its steady state level after approximately two years. Importantly though, the debt burden does not stabilize here, but instead it drops below its steady state level for an extended period. Figure 5 shows that real debt and debt-to-GDP stay moderately below their state levels for approximately thirty years, reaching a trough 0.4 percent below steady state after about ten years. In short, we see that while monetary tightening increases the debt burden in the short run, it does decrease the debt burden at a somewhat longer horizon.

What explains the dynamics of debt under the 30-year amortization profile? It is here useful to consider the responses of inflation and GDP. With 30-year amortization, debt becomes highly persistent, as revealed by equation (7). Hence, on impact real debt and debt-to-GDP are both largely driven by the responses of inflation and GDP, respectively. The fall in these two variables tends to increase the debt burden. However, since house prices fall, fewer new loans will be issued, as seen in the lower right panel of Figure 4. Because the initial drop in house prices is relatively strong, this force counteracts the influence of reduced inflation and output. As house prices revert faster than output and inflation, the debt burden gradually builds up. The peak response of debt is reached when house prices are back to steady state. Thereafter, as inflation and output revert to steady state, the debt burden also falls. However, after the effects on the other variables have died out, the total debt stock keeps falling. The reason is the initial contraction in new loans. This contraction, although modest enough to be dominated by output and inflation dynamics in the short run, has long-lived effects due to the long-term nature of debt. Moreover, because households have annuity loans, the aggregate amortization rate, δ_t, falls as new loans constitute a declining fraction of the total debt stock. Hence, when the other macroeconomic variables have settled down at steady state, the initial contraction in new loans causes a persistent fall in the aggregate debt burden. A nominal decomposition of these debt dynamics is provided in Figure 6.

How important are the dynamics of the amortization rate for these results? Figure 5 gives an answer, comparing the benchmark model with annuity loans, to one where δ is constant at the same steady state level as in the benchmark. We see that the dynamics of the amortization are unimportant for the initial increase in debt, but that they matter for the subsequent decline.

The reason is that with annuity loans, the amortization rate is higher for older loans. Hence, as new loans fall in response to the monetary tightening, the total stock of debt becomes "older", and the aggregate amortization rate increases which brings the total debt stock down. With constant amortization, the debt stock hardly falls below its steady state level even in the medium run.

Finally, we compare debt dynamics under alternative durations of debt. Figure 7 plots the debt-to-GDP ratio following a monetary policy shock with 5-, 10-, 20-, and 30-year debt, with constant amortization rate and annuity loans. We see that the shorter is the duration, the smaller and more short-lived is the initial increase and the greater is the subsequent decline of debt-to GDP. When households pay back their debt in only 10 years, the initial positive response peaks at 0.2 percent, while the maximum decline is 0.8 percent below steady state. If debt is paid back in 5 years or faster, debt-to-GDP does not increase in the short run. As before, we see that in all cases the medium run debt reduction is substantively greater with annuity loans.

With regard to the question of how monetary policy affects the aggregate debt burden, we thus see that the answer depends on the horizon one has in mind. Consistently with the back-of-the envelope calculation of Svensson (2013), and in contrast to the conventional view, our model implies that tighter policy increases the debt burden in the short run. In the intermediate run, though, monetary tightening is likely to cause a mild, but prolonged reduction of the debt burden, more in line with the conventional view on how debt is affected by monetary tightening. The extent to which this reduction comes about, is heavily influenced by the prevalence of annuity loan contracts in the economy. More generally, and perhaps more importantly, we see that by assuming that all debt is re-financed and subject to the prevailing tightness of collateral constraints, which existing macroeconomic models typically do, one is likely to greatly exaggerate the extent and the speed with which monetary policy can affect the debt level.

5   Should Monetary Policy React to Debt?

We now turn to the question of how the long-term nature of household debt matters for the systematic conduct of monetary policy. Specifically, we aim to understand how systematic monetary policy reactions to credit swings are likely to affect the economy.

5.1   Reacting to the Debt Burden and Equilibrium Determinacy

We first study the consequences of responding to debt via a simple interest rate rule of the type

$$R_t = (1 + \pi_t)^{\phi_\pi} \left(\frac{b_t/y_t}{b/y} \right)^{\phi_{b/y}}. \tag{20}$$

A fundamental guideline for systematic monetary policy is that it must satisfy the "Taylor principle" (Woodford (2001)). The Taylor principle states that the nominal interest rate must

react more than one-for-one to changes in inflation. If this principle is not satisfied, expectations of higher inflation might turn self-fulfilling and induce macroeconomic fluctuations, as increased inflation expectations raise actual inflation and thereby lower the path of real interest rates in the absence of a sufficient monetary policy response. Hence, in terms of the policy rule specified in equation (20), the constraint from the Taylor principle is that $\phi_\pi > 1$ when $\phi_{b/y} = 0$. Should monetary also respond to other variables, the critical coefficient on inflation might well vary, so as to ensure that the ultimate response to inflation is greater than one. For instance, several studies have explored how the joint response to output and inflation together determine the scope for equilibrium (in)determinacy, with Bullard and Mitra (2002) as a prominent example. In our setting, it is therefore natural to ask how systematic responses to debt in addition to inflation, alter the scope for equilibrium indeterminacy.

The upper-left panel in Figure 8 plots the determinacy region in the $\left(\phi_\pi, \phi_{b/y}\right)$-space when debt is fully amortized within a quarter. When $\phi_b = 0$, the critical value for the inflation coefficient is one, as we would expect from the Taylor principle. If policy starts responding to deviations of debt-to-GDP from its steady state, the required inflation coefficient falls moderately. This pattern implies that in terms of ensuring equilibrium determinacy, responding to inflation and responding to the debt-to-GDP ratio are substitutes. To understand why, consider the effects of a non-fundamentally motivated increase in inflation expectations. Through the forward-looking phillips curve, actual inflation increases too. Hence the real interest rate drops. From the borrowing constraint with $\delta_t = 1$, we see that this makes the real debt level increase. Debt therefore moves in the same direction as inflation, and a positive interest rate response to debt-to-GDP has the same stabilizing properties as responding positively to inflation.

Next, we consider the effects of responding to the debt-to-GDP ratio in the scenarios with gradual amortization. The remaining three panels in Figure 8 plot the determinacy regions under 10-, 20- and 30-year debt amortization profiles respectively. We see that now the relationship between the threshold inflation response and the debt-to-GDP reaction is increasing, in sharp contrast to the one-quarter debt case. Intuitively, this occurs because an expectations driven increase in activity no longer moves the stock of real debt in the same direction as inflation. Instead, if inflation expectations rise without fundamentals to justify it, the inflationary pressure this generates will reduce the stock of real debt. A positive value of $\phi_{b/y}$ will then in itself push the nominal interest rate *down*, making the real interest rate fall even further. To counteract this destabilizing force, the response to inflation, ϕ_π, must be greater than if debt had not been reacted to. As one would expect, the relationship between the critical values of ϕ_π and $\phi_{b/y}$ is steeper, the longer is the horizon over which household debt is amortized.

The relationship between $\phi_{b/y}$ and ϕ_π in Figure 8 is steep due to medium-run debt dynamics. A moderate increase in the real interest rate will induce a reduction of debt in the future, as we saw in the analysis of monetary policy shocks in Figure 4. With a positive value of $\phi_{b/y}$,

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this implies a reduction of the future interest rate, which in itself tends to support a sunspot induced increase of inflation expectations. Thus, responding positively to the debt-to-GDP ratio is destabilizing for two reasons: (i) in the short run the real debt level falls when inflation increases, and (ii) in the medium-run debt-to-GDP falls if the current real interest rate increases.

Reflecting the two forces at play here, the upper-right panel of Figure 8 shows that with 10-year debt, there is a narrow intermediate region of $(\phi_\pi, \phi_{b/y})$-combinations over which the equilibrium is determinate. For instance, if $\phi_{b/y} = 0.1$, the panels shows that when ϕ_π is around 1.2, the equilibrium is determinate, while a slightly higher response to inflation, say $\phi_\pi = 1.3$, causes indeterminacy again. The knife-edge region with determinacy is one where the inflation coefficient ϕ_π is barely big enough to compensate for the fact that a positive reaction to debt implies a negative contemporaneous response to inflation, and barely small enough to avoid causing a substantive medium-run decline in mortgage debt. This intermediate region is similar to that which can arise when there is investment in productive capital, as emphasized by Benhabib and Eusepi (2005), Carlstrom and Fuerst (2005) and Sveen and Weinke (2005). However, the region seems of little practical relevance in our case, as it is narrow.

In Figure 9 we plot the determinacy regions when the interest reacts to steady state deviations of the real debt level instead of the debt-to-GDP ratio. Because real debt is non-stationary in the data, ons should interpret this exercise as reacting to debt in deviations from trend. That is, we consider a rule of the type $R_t = (1 + \pi_t)^{\phi_\pi} \left(\frac{b_t}{b} \right)^{\phi_b}$. Consistently with the intuitions provided above, we see that the effects of reacting to the real debt level are similar to those that arise from reacting to the debt-to-GDP ratio.

5.2 Debt and Inflation Volatility when Monetary Policy Reacts to Debt

Equilibrium determinacy aside, could a moderate response to debt serve to prevent the persistent debt swings induced by fundamental shocks to the economy? To address this question, we simulate our model subject to technology shocks under alternative monetary policy formulations. In addition to steady state deviations of the real debt level and the debt-to-GDP ratio considered above, we allow for a reaction to debt growth. We consider the monetary policy rule

$$ R_t = R_{t-1}^{\phi_R} \left[R^{ss} (1 + \pi_t)^{\phi_\pi} \left(\frac{b_t}{b} \right)^{\phi_b} \left(\frac{b_t/y_t}{b/y} \right)^{\phi_{b/y}} \left(\frac{b_t}{b_{t-4}} \right)^{\phi_{\Delta b}} \right]^{1-\phi_R}, \tag{21} $$

with ϕ_π and ϕ_R set as in the baseline parameterization, and in addition consider positive values for either ϕ_b, $\phi_{b/y}$, or $\phi_{\Delta b}$.

The results of this exercise are displayed in Figure 10. The upper two panels show that a small response to the real debt level, $\phi_b = 0.025$, generates a somewhat higher volatility of inflation and a substantially increased volatility of real debt itself. Similarly, the middle two plots show that responding to the debt-to-GDP ratio instead of the debt level, has similar

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consequences. A moderate response to the debt-to-GDP ratio, $\phi_{b/y} = 0.025$, destabilizes debt, and (not displayed here) the debt-to-GDP ratio itself. The destabilizing consequences of even a slightly positive debt response follow from the same forces that were discussed above regarding equilibrium indeterminacy.

In contrast, the bottom plots of Figure 10 show that responding to debt *growth* does not have the same destabilizing influence. Because positive values of $\phi_{\Delta b}$ do not cause equilibrium indeterminacy, we may simulate the model with $\phi_{\Delta b} = 0.25$, and we see that now debt movements are dampened. However, the same does not apply to the inflation rate, which now is considerably more volatile. Hence, our results suggest that if monetary policy aims to stabilize household debt, the policy rate should react to the *growth* rate rather than the *level* of household indebtedness, but that the costs in terms of inflation volatility are likely to be considerable.

6   Conclusion

After the 2007-2009 financial crisis, household indebtedness has been high on the policy agenda. Unfortunately, discussions of household debt tend to implicitly assume that variation in debt-to-income ratios reflect active shifts in borrowing and lending, which is misguided. By introducing a reasonable distinction between new loans and pre-existing debt, our model implies debt dynamics that are substantially closer to empirical patterns than what follows from standard New Keynesian models with household debt.

Our results show that the persistence of household debt matters for monetary policy, and that policy advice from models with one-quarter debt should be treated with caution. First, with plausible debt dynamics, interest rate changes have far weaker influence on household debt than a conventional one-quarter debt model implies. Moreover, with long-term debt the qualitative effect of a policy tightening on household debt-to-GDP is likely to be positive in the short run. Second, a policy that systematically increases the interest rate in response to high debt-to-GDP or real debt levels is destabilizing. Not only does such a policy induce greater inflation volatility, but it will destabilize debt itself. Moreover, by reacting to the debt level, monetary policy induces equilibrium indeterminacy, so that economic fluctuations driven solely by expectations are possible. If policy aims to stabilize debt, it should therefore respond to new loans, or debt *growth*, rather than the *level* of real debt or debt-to-GDP.

This paper is part of a broader agenda to establish the principles behind "leaning against the wind" policies. It is notable that our findings go somewhat against the conventional wisdom. There is a parallel to Galí (2014), who shows how a monetary policy that systematically responds to rational asset price bubbles may actually raise the volatility of the bubbles themselves. Of course, these types of results cannot necessarily be taken at face value in actual policy design, as they stem from models that abstract from many of the aspects that feature in the policy debate.

For instance, in our model there is no mechanism through which debt accumulation might trigger a financial crisis or raise the cost of recovering from one. Still, our findings do illustrate that conventional wisdom on the field cannot necessarily be relied upon without further scrutiny.

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Table 1: Model Parameter Values

Parameter	Value	Description
β_l	0.99	Discount factor lenders
β_b	0.985	Discount factor borrowers
ν_h	0.0839	Housing preference weight
$\nu_{l,l}$	0.1055	Leisure preference weight lenders
$\nu_{l,b}$	0.2218	Leisure preference weight borrowers
φ	1	Inverse labor supply elasticity
γ	0.5	Habit parameter
n	0.61	Population share of borrowers
ϖ	0.5	Labor share borrowers
ξ	0.33	Labor elasticity in production
ε	6	Demand elasticity for goods
θ	0.75	Calvo price stickiness parameter
υ	0.5	Price indexation parameter
κ	1.0487	Debt contract parameter
α	0.9959	Debt contract parameter
m	0.0446	Borrowing constraint tightness
ρ_z	0.95	Autocorrelation of technology shocks
σ_z	0.0124	Standard deviation of technology shocks
ϕ_π	1.5	Interest rate rule inflation coefficient
ϕ_r	0.75	Interest rate rule smoothing coefficient

Table 2: Household debt moments in the data and in the model

Moment	Data	Model 30y	Model 20y	Model 1q
Standard Deviation Debt/GDP	0.0834	0.1078	0.0994	0.0728
First Order Autocorrelation Debt/GDP	0.9940	0.9979	0.9975	0.9544
Second Order Autocorrelation Debt/GDP	0.9818	0.9929	0.9913	0.9231
Third Order Autocorrelation Debt/GDP	0.9642	0.9855	0.9820	0.8970
Correlation(Debt,Inflation)	-0.2902	-0.3100	-0.3432	-0.7705
Correlation(Debt,House Prices)	0.7969	0.6340	0.6851	0.9812
Correlation(Debt,Policy Rate)	-0.3120	-0.5078	-0.5635	-0.9605
Correlation(Debt,GDP)	0.0012	0.6982	0.7503	0.9908

Notes: Moments from the U.S. data and from the model with 3 different amortization profiles. Debt is mortgage debt from the Federal Reserve Flow of Funds, House Prices is the Real Home Price Index by Robert Shiller. Both these series and GDP are logged and linearly detrended. The interest rate is the effective Federal Funds rate, and inflation is the PCE-index less food and energy, both demeaned. The sample is 1960q2-2012q4.

Figure 1: Household Debt Comovement
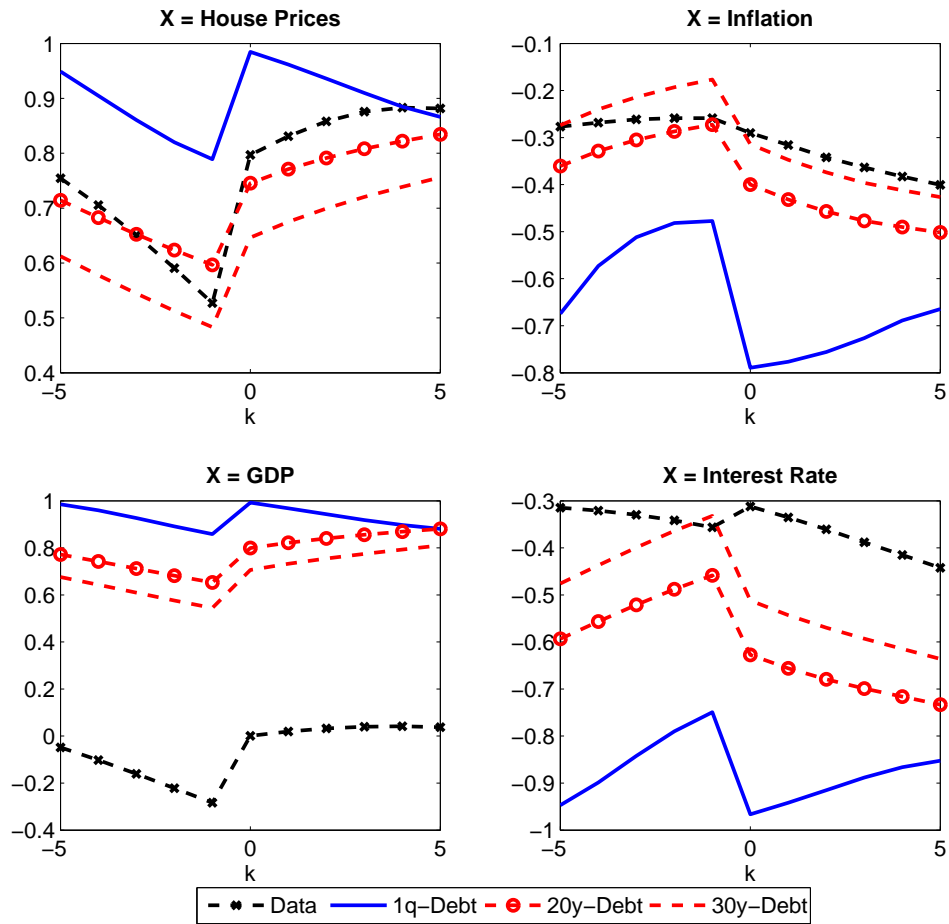
Notes: Correlations of 4 different variables X at time t with household debt at $t+k$, in the data and in the model driven by technology shocks with different amortization profiles. The data are logged and linearly detrended.

Figure 2: Technology Shock

Interest Rate

Inflation Rate

Output

House Prices

Household Debt

Debt/GDP

1q-Debt — — — 30y-Debt
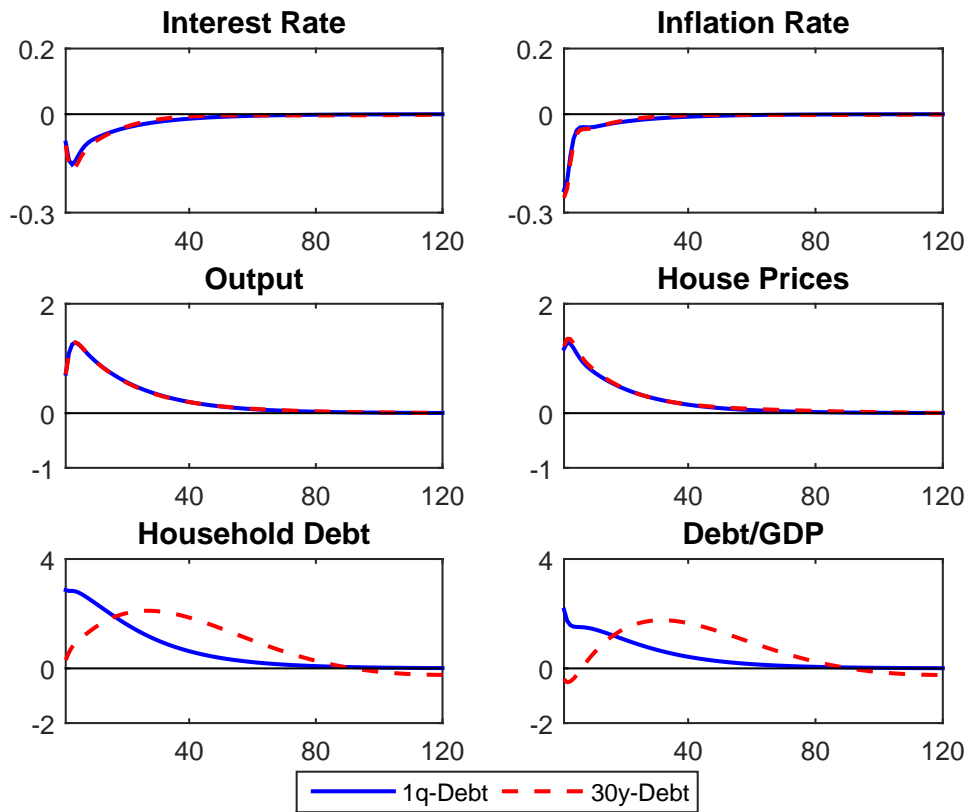
Notes: Impulse responses to a one standard deviation TFP-shock. For output, house prices, debt, and new loans, the vertical axes report percent deviations from steady state. For the interest rate and inflation, deviations are in percentage points.

Figure 3: Credit Cycles
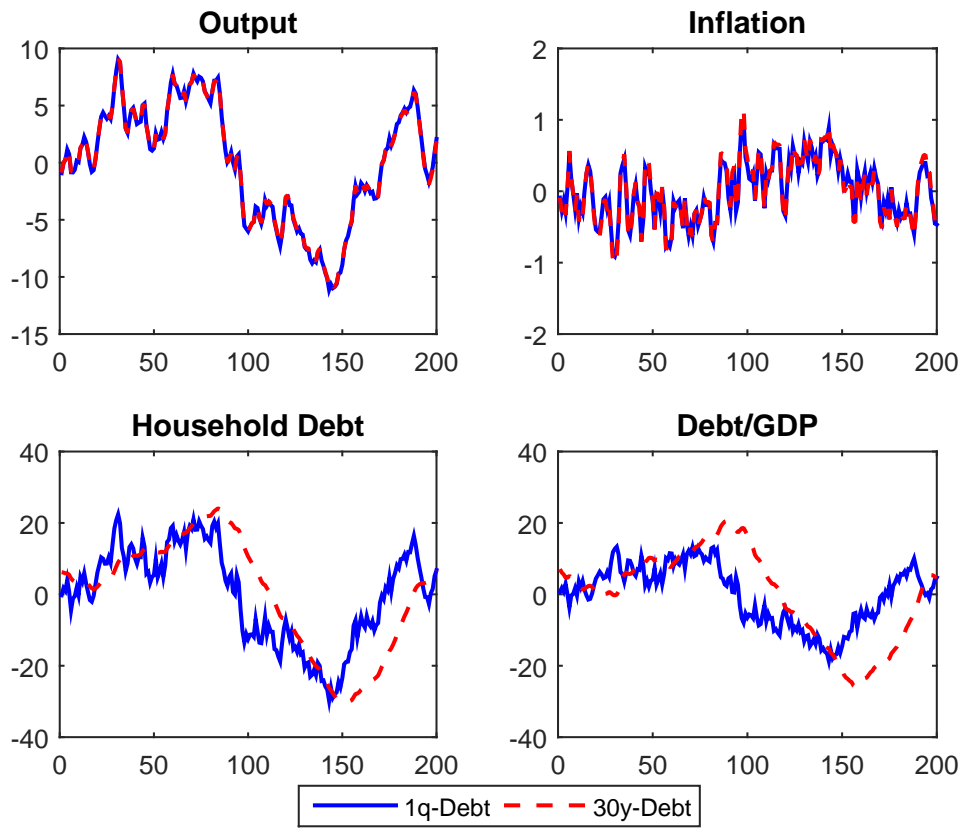
Notes: Simulation of the model driven by TFP-shocks, 200 quarters. For output and debt, the vertical axes report percent deviations from steady state. For inflation, deviations are in percentage points.

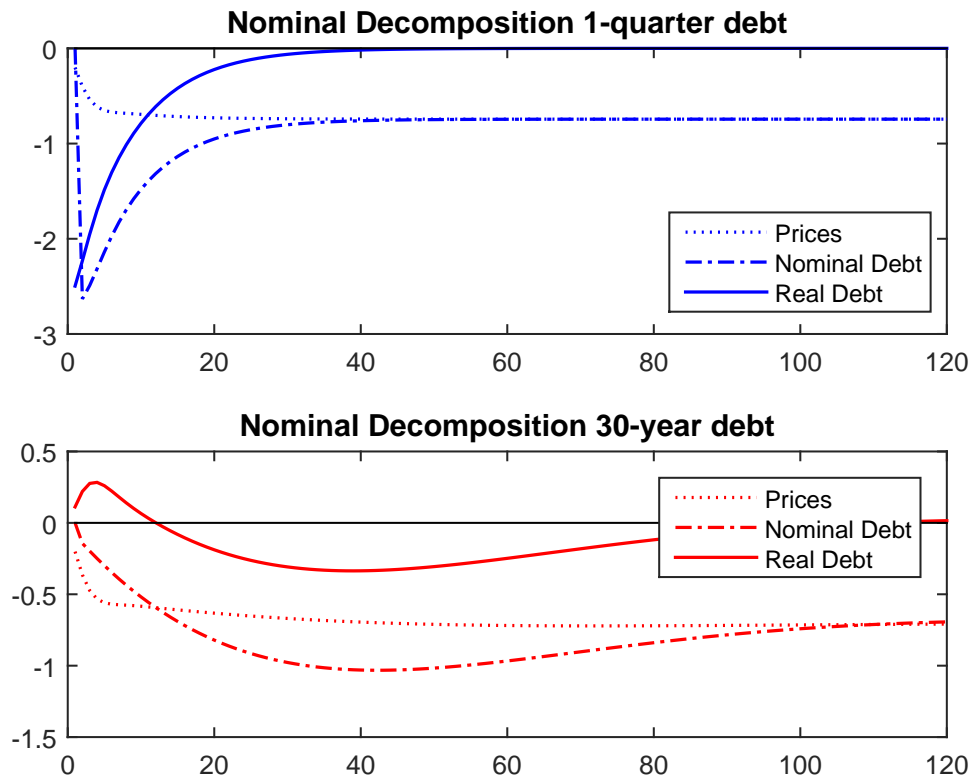Figure 4: Contractionary Monetary Policy Shock
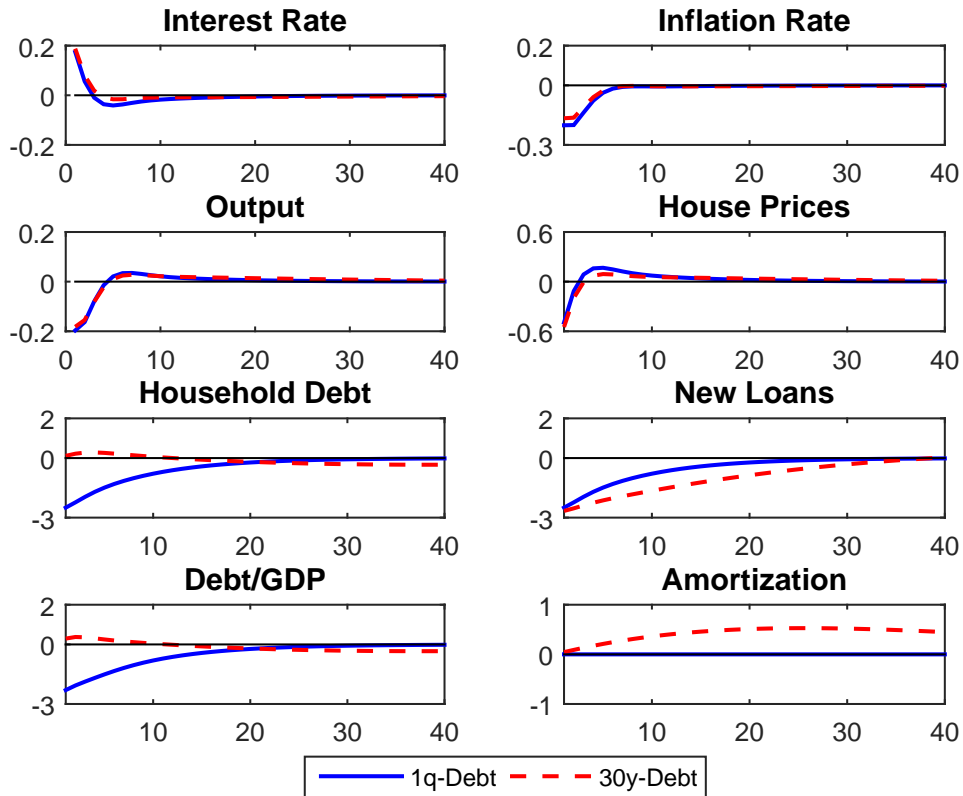
Notes: Impulse responses to a 25 basis point increase in the quarterly interest rate. For output, house prices, debt, new loans, and amortization, the vertical axes report percent deviations from steady state. For the interest rate and inflation, deviations are in percentage points.

Figure 5: Contractionary Monetary Policy Shock – Debt Dynamics under Annuity Loans and Fixed Amortization Loans
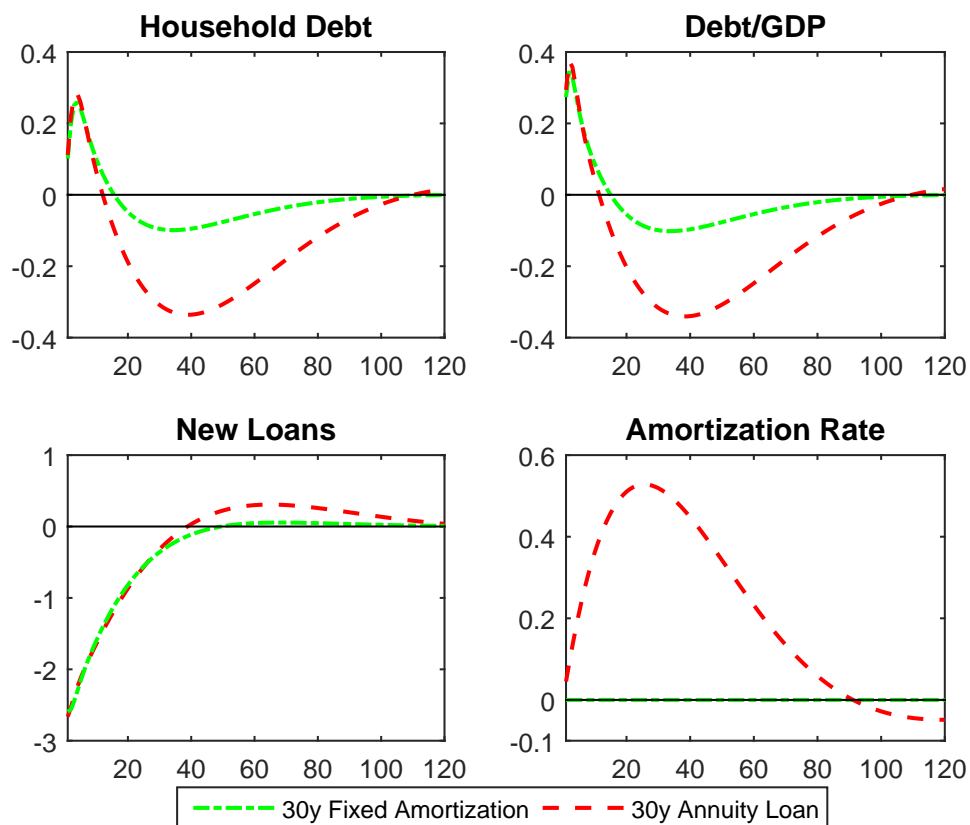
Notes: Impulse responses to a 25 basis point increase in the quarterly interest rate, percent deviations from steady state.
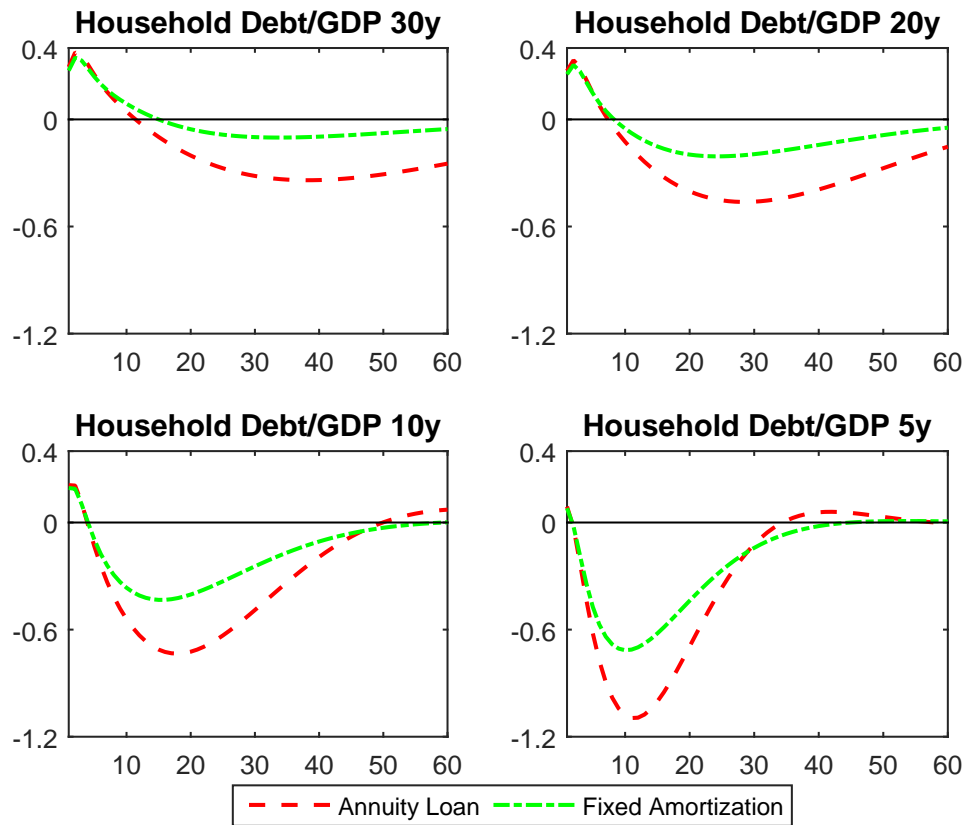
Figure 6: Contractionary Monetary Policy Shock – Nominal Decomposition

Notes: Impulse responses to a 25 basis point increase in the quarterly interest rate, percent deviation from steady state. The upper panel refers to a model where all debt is amortized within a quarter, the lower panel refers to a model where all debt is amortized over 30 years.
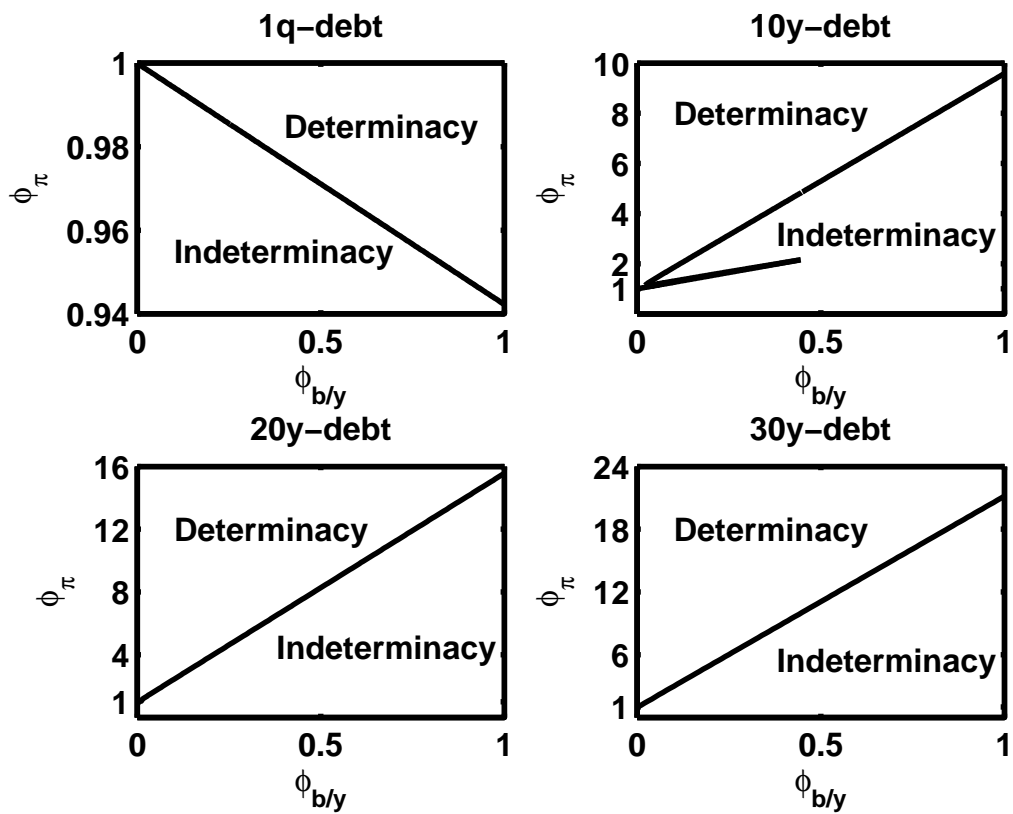
Figure 7: Contractionary Monetary Policy Shock – Debt Dynamics under Alternative Amortization Schedules


Notes: *Impulse responses to a 25 basis point increase in the quarterly interest rate, percent deviations from steady state.*

Figure 8: Equilibrium Determinacy with Debt-to-GDP in the Interest Rate Rule

Notes: *Regions of equilibrium determinacy for alternative constellations of the interest rate response to debt-to-GDP ($\phi_{b/y}$) and inflation (ϕ_π).*

Figure 9: Equilibrium Determinacy with Debt Level in the Interest Rate Rule
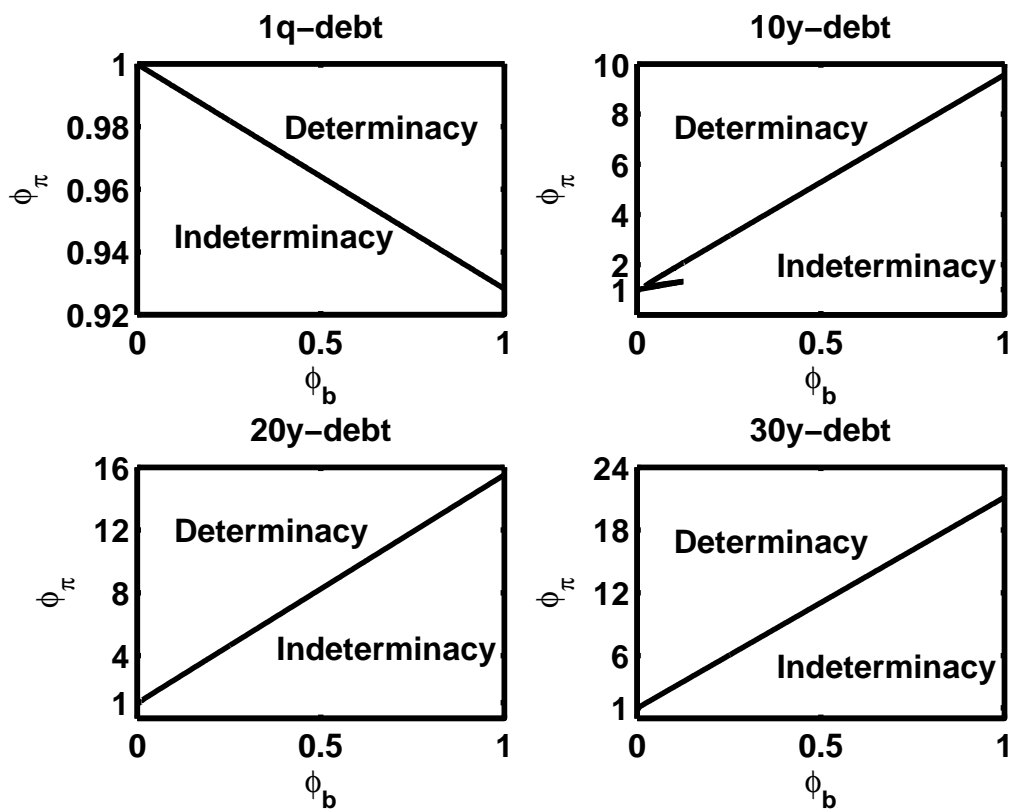
1q–debt

10y–debt

20y–debt

30y–debt

Notes: Regions of equilibrium determinacy for alternative constellations of the interest rate response to the real debt debt level (ϕ_b) and inflation (ϕ_π).

Figure 10: Debt and Inflation Dynamics under Alternative Policy Rules
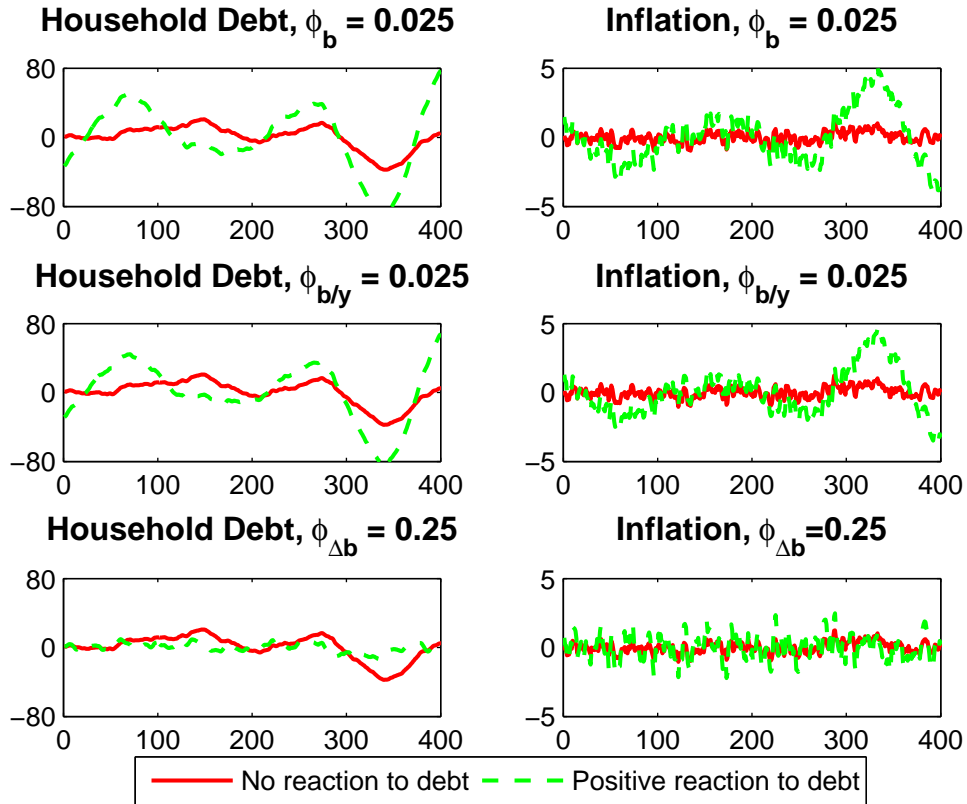
Notes: Simulated series of real household debt and inflation with alternative interest responses to debt. Model subject to TFP-shocks. The solid red curves always display the case where the interest responds to inflation only. In the upper two plots, the dashed curve display the case where the interest rate responds to the real debt level. In the middle two plots, the dashed green curve displays the case where the interest rate responds to debt-to-GDP. In the bottom two plots, the dashed green curve displays the case where the interest rate responds to debt growth.