Household Debt, Adjustable-Rate Mortgages, and the Shock-Absorbing Capacity of Monetary Policy

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Abstract

Theory predicts that the adverse effects of increases in the risk-free rate on homeowners' default rates would be significantly stronger if interest rates paid on mortgages were variable and initial household debt burden were higher. Given the direct negative relationship between these default rates and banks' capital, this prediction represents a necessary ingredient for a novel financial intermediary capital based mechanism by which monetary policy can dampen the macroeconomic effects of expansionary demand shocks. Using a flexible non-linear reduced form identification approach, this paper sheds important light on the relevance of this mechanism by estimating the U.S. economy's responses to expansionary credit supply shocks conditioned on a state in which both the adjustable-rate mortgage market share and household debt burden are high. The evidence conclusively suggests that being in the latter state greatly increases the capability of monetary policy to dampen the effects of an expansionary credit supply shock, and that the prevalence of a financial intermediary capital channel underlying these results is borne out by the data.

JEL classification: E32, E52, E58

Key words: Household debt; Adjustable-rate mortgages; Mortgage default rates; Systematic monetary policy

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1 Introduction

The role of systematic monetary policy in macroeconomic stabilization has long occupied the minds of policymakers and researchers alike. The ability of monetary policy to stabilize the economy in response to demand shocks, at least to some extent, is largely undisputed among macroeconomists and is strongly rooted in economic theory (see, e.g., Clarida et al. (1999), Woodford (2003), and Galí (2015)). The main transmission channel by which monetary policy is thought to moderate the effects of demand shocks is the conventional real interest rate channel, although the firm balance sheet channel pioneered in Bernanke et al. (1999) has also received significant attention, especially in recent years (see, e.g., Christiano et al. (2014)).

This paper puts forward a novel transmission channel by which monetary policy can significantly dampen the effects of demand shocks that is based on the level of household debt burden, measured by the ratio of debt service payments to disposable income, and the share of adjustable-rate mortgages. In particular, I provide robust empirical evidence for the U.S. economy that when the initial level of the latter two variables is relatively high in tandem, the positive effect of an expansionary demand shock is significantly dampened. This result is shown to be rooted in a novel financial intermediary capital channel which operates as follows. The favorable demand shock cause rates to rise which in turn, given the high share of adjustable-rate mortgages and straining household debt burden, increase homeowners' default rates; the higher default rate causes financial intermediaries' capital to decline, thereby decreasing their credit supply and economic activity.[1] The data seem to suggest that this shock-absorbtion mechanism is sufficient for significantly reducing the positive effect that an expansionary demand shock would have on the economy under normal circumstances, i.e., normal levels of debt burden and adjustable-rate mortgages.

[1]In a world in which only banks hold mortgage debt, the relevant financial intermediary would be a bank. However, nonbank financial institutions such as investment banks and insurance companies are non-negligible holders of mortgage debt in a large part of my sample due to the common practice of securitization in the U.S., i.e., the pooling of mortgages into bundled securities and selling them to investors; hence, the financial intermediary unit should be more broadly interpreted as including additional financial institutions, other than banks, such as investment banks and insurance companies. In accordance with this reasoning, my empirical focus in this paper is on a broad financial intermediary capital channel, rather than a narrower bank capital channel.

This paper is related to the emerging new literature studying the link between monetary policy and mortgage contracts. A recent paper by Garriga et al. (2013) provides a theoretical general-equilibrium framework with both ARM and FRM mortgage contracts in which larger responses of the economy to monetary policy shocks are generated under ARM than FRM contracts. Calza et al. (2013), estimating country-specific VARs, show that consumption and residential investment respond more strongly in economies in which ARM contacts are more prevalent; they further demonstrate that a two-sector DSGE model with price stickiness and collateral constraints is capable of producing results that accord well with their empirical counterparts. Villar Burke (2015) delivers empirical evidence that mortgage lending rates in European economies that rely more on ARM contracts respond much more strongly to monetary policy shocks.

Several other micro-data based empirical papers focused on the relation between consumption and monetary policy shocks, distinguishing between adjustable and fixed-rate contracts. Di Maggio et al. (2014) and Keys et al. (2014) show that the consumption response to the 2008 interest rate reduction is stronger in U.S. counties where the share of ARM contracts is greater. Lastly, Flodén et al. (2016) study the consumption response of Swedish households to monetary policy shocks while distinguishing between both ARM and FRM contracts as well as high and low debt levels; their conclusion supports a cash-flow channel of monetary policy in that changes in interest rates affect highly indebted households tied to ARM contracts much more strongly than households with little debt or FRM contracts.

This paper contributes to the above literature along two main dimensions. First, I focus on the shock-absorbtion capacity of monetary policy, rather than its independent effects on the economy via shocks to interest rates. While these two aspects are related in that there should be a connection between the roles of systematic and unsystematic monetary policy, I consider the former to be a more empirically relevant dimension of policy to concentrate on given that the data suggest that monetary policy is mostly systematic (see, e.g., the discussion in Bernanke et al. (1997)).

Second, and more importantly, I introduce a new transmission channel by which monetary policy can moderate the effects of demand shocks, termed in this paper as the *financial intermediary* *capital channel*; it coexists with the cash-flow channel focused upon by the existing literature, but rather than stressing the decline in consumption that occurs due to lesser resources, the channel I advance in this paper emphasizes how systematic policy can significantly raise mortgage default rates, and thus lower financial intermediaries' capital, when the economy is characterized by high debt and high share of ARM contracts.

This paper unfolds in two parts. In the first part, I provide a formal theoretical motivation for the empirical analysis undertaken in this paper by laying out a simple, partial equilibrium model of the housing market, at the center of which is a borrower-lender agency problem á la Bernanke et al. (1999) (henceforth BGG). The purpose of this model is to demonstrate the link between the risk-free rate, homeowners' default rate, and financial intermediaries' capital in a state in which homeowners' debt burden is high. The costly state verification (CSV) problem between borrowers and lenders facilitates achieving this purpose as the debt contract in the CSV framework is effectively an ARM contract. From a technical standpoint, I employ a second order solution method that computes the response of the economy to a rise in the risk-free rate conditioned on an initial homeowners' debt burden level that is higher than its steady state value.

The second part performs a thorough empirical investigation of the role that systematic monetary policy has in an environment with a high share of ARM contracts and relatively straining debt burdens. Towards this end, I make use of the monthly Gilchrist and Zakrajek (2012) credit supply shock series to measure global credit supply shocks to measure demand shocks. Gilchrist and Zakrajek (2012) use micro-level data to construct a credit spread index which they decomposed into a component that captures firm-specific information on expected defaults and a residual component that they termed as the excess bond premium (EBP).[2] Their shock series serves as an exogenous and pure demand shock; as such, it can be employed to study the research question of this paper. Then, using various outcome variables including unemployment, mortgage default rates, the federal funds rate, and financial intermediaries net worth and credit spreads, I employ the the Jorda (2005) local projections approach so as to be able to directly estimate the nonlinear

[2] Gilchrist and Zakrajek (2012) show that their spread measure has better predicative power for macroeconomic variables than more standard credit spread measures such as the Baa-Aaa Moody's bond spread.

impulse responses to the shocks to EBP by interacting a dummy variable capturing a state of high debt burdens and high ARM shares with the EBP shock.

My empirical findings can be summarized as follows. There is a statistically significant difference between the response of unemployment in a state where both households' debt burden and ARM contract share are above median levels relative to the complementary state. This difference is also economically significant, reaching over 0.5% after 1 year; in relative terms, this difference implies that the response of unemployment in a state of high debt and ARM share is more than 3 times higher that in a state of low debt and ARM share. To shed light on the mechanism behind this result, I turn my analysis to credit market related variables such as mortgage default rates, financial intermediaries market value and credit spread, the federal funds rate, and non-financial leverage. The non-linear impulse responses of these variables conclusively suggest that there is a financial intermediary capital channel underlying the unemployment response, as well as other real outcome variables' responses related to consumption and investment: default rates rise more in the high debt and ARM share state, in turn leading to a bigger decline in financial intermediary capital and their lending to businesses.

The remainder of the paper is organized as follows. In the next section, a simple theoretical framework that can be used to interpret the empirical results is laid out. Section 3 begins with a brief description of the data, after which it presents the methodology and main empirical evidence. Section 3 examines the robustness of the baseline results. The final section concludes.

2 Theoretical Motivation

In what follows, I sketch out a dynamic partial equilibrium model of the housing market that can establish a valuable conceptual framework upon which to build the discussion and interpretation of the empirical results in the next section. The main purpose of this model is to formalize the notion that, in the presence of ARM debt contracts, the negative relationship between the risk-free rate and homeowners' default rates is exacerbated when homeowners face high debt burdens. I model the agency problem between borrowers and lenders á la the CSV framework used in BGG as it conveniently captures the conception of an adjustable-rate debt contract.

To isolate the relationship between monetary policy and homeowners' default rate, I opt for formulating a partial equilibrium model that facilitates an exogenous risk-free interest rate rather than a full-blown general equilibrium model in which the risk-free rate is endogenous and other mechanisms are prevalent, which would in turn make it difficult to isolate the mechanism under study. Notwithstanding the model's relative simplicity, it will prove instrumental in facilitating our understanding of the monetary policy-homeowners' default rate nexus, which lies at the core of the financial intermediary capital channel put forward in this paper. In order to demonstrate that the relationship between the risk-free rate and mortgage default rates is dependent on the initial level of homeowners' debt burden, I employ a second order solution method that computes the response of the economy to a rise in the risk-free rate conditioned on an initial homeowners' debt burden level that is higher than its steady state value.

2.1 Homeowners and Financial Intermediaries

There is a continuum of identical, finitely-lived, and risk-neutral homeowners. The i-th homeowner produces good $Y_{i,t}$ using the following technology:

$$Y_{i,t} = \omega_{i,t} K_{i,t}^{\alpha} L_{i,t}^{1-\alpha}, \tag{1}$$

where $\omega_{i,t}$ is a random idiosyncratic productivity shock which is assumed to be log-normally distributed $ln\omega_{i,t} \sim N(\frac{-\sigma^2}{2}, \sigma^2)$ so that $\mathbb{E}(\omega_{i,t}) = 1$; and $K_{i,t}$ and $L_{i,t}$ are the housing stock and labor input of the i-th homeowner, respectively. The assumption that housing stock serves as a factor input in the production function of homeowners follows Iacoviello (2005). Since the modeling here takes a partial equilibrium perspective, $L_{i,t}$ will be conveniently normalized to unity in what follows for all i and t.

Homeowners purchase houses from housing producers in the beginning of period t at price

Q_{t-1}, which they then operate in period t and resell it at the end of the period at price Q_t. Here, the operation of the housing stock on the part of homeowners can be considered as their renting of housing services to other households, which is not modeled here explicitly due to the partial equilibrium formulation of the model. The gross real rate of return on capital for the i-th homeowner, denoted by $R^k_{i,t}$ is the sum of the marginal profitability of housing, i.e., the marginal profit from renting it, and the capital gain:

$$R^k_{i,t} = \frac{\alpha \frac{Y_{i,t}}{K_{i,t}} + (1-\delta)Q_t}{Q_{t-1}}, \tag{2}$$

where δ is the rate of housing stock depreciation. Homeowners' housing purchases are financed partly internally and partly by borrowing from risk-neutral financial intermediaries within a costly-state verification (CSV) framework á la Bernanke et al. (1999), such that the assets of the i-th homeowner $Q_t K_{i,t}$ are the sum of her debt $B_{i,t}$ and net worth $N_{i,t}$:

$$Q_{t-1}K_{i,t} = B_{i,t} + N_{i,t}. \tag{3}$$

Owing to constant returns to scale in production, law of large numbers, and the fact that $\mathbb{E}(\omega_{i,t}) = 1$, we can express the gross real rate of return on housing for the i-th homeowner as $R^k_{i,t} = \omega_{i,t} R^k_t$, where R^k_t is the average, or aggregate, gross real rate of return on housing in the economy. Hence, the gross proceeds from homeowner i's production activity in period t are $\omega_{i,t} R^k_t Q_{t-1} K_{i,t}$.

The focal assumption underlying the financial accelerator mechanism is that the realization of $\omega_{i,t}$ is private information of the entrepreneur and that in order to observe it the foreign lender has to pay a monitoring cost of $\mu \omega_{i,t} R^k_t Q_{t-1} K_{i,t}$, where $0 < \mu < 1$ is the monitoring cost parameter. The optimal debt contract between the homeowner and the lender specifies that, in the case of no default, the former pays the lender $Z_{i,t} B_{i,t}$, where $Z_{i,t}$ is the no-default contractual interest rate; that is, if $\omega_{i,t} R^k_t Q_{t-1} K_{i,t} \geq Z_{i,t} B_{i,t}$, the homeowner will pay the debt and retain any residual profit. In the case of default, i.e., $\omega_{i,t} R^k_t Q_{t-1} K_{i,t} < Z_{i,t} B_{i,t}$, the lender will pay the monitoring cost and obtain $(1-\mu)\omega_{i,t} R^k_t Q_{t-1} K_{i,t}$.

To facilitate fluctuations in financial intermediaries' profits in this model, I follow Zhang (2009) in assuming that both the borrower and the lender, at the time of signing the debt contract, do not yet observe the gross real rate of return. Hence, they sign the contract based on their expectations of the gross real rate of return. This assumption can be justified on the basis of their signing the contract in the beginning of the period immediately after or in conjunction with the realization of the idiosyncratic shock, while the gross real rate of return is realized only thereafter at the end of the period.[3] In accordance with this assumption, it is straightforward to define the expected default threshold value of $\omega_{i,t}$, $\bar{\omega}_{i,t}$, as $\bar{\omega}_{i,t} = \frac{Z_{i,t}B_{i,t}}{\omega_{i,t}\mathbb{E}_{t-1}R_t^k Q_{t-1}K_{i,t}}$. As formalized below, the optimal contract will specify $\bar{\omega}$ and $K_{i,t}$ as the choice variables, which is equivalent to specifying $Z_{i,t}$ and $B_{i,t}$ as the choice variables due to the relations $\bar{\omega}_{i,t} = \frac{Z_{i,t}B_{i,t}}{\omega_{i,t}R_t^k Q_{t-1}K_{i,t}}$ and $Q_{t-1}K_{i,t} = B_{i,t} + N_{i,t}$.[4]

I now turn to presenting the maximization problem that characterizes the optimal mortgage contract. Assuming that financial intermediaries operate in a perfectly competitive environment in which they earn, in expectation, the gross risk-free return R_t,[5] the optimal contract problem that maximizes expected entrepreneurial profit subject to the lenders' zero-profit condition is

$$\max_{K_{i,t},\bar{\omega}_{i,t}} \mathbb{E}_{t-1} \int_{\bar{\omega}_{i,t}}^{\infty} \left[\omega_{i,t}\mathbb{E}_{t-1}R_t^k Q_{t-1}K_{i,t} - Z_{i,t}B_{i,t}\right] dF(\omega_{i,t}) = \mathbb{E}_{t-1}[1-\Gamma(\bar{\omega}_{i,t})]\mathbb{E}_{t-1}R_t^k Q_{t-1}K_{i,t}$$

$$s.t \;\; R_t(Q_{t-1}K_{i,t} - N_{i,t}) = [\Gamma(\bar{\omega}_{i,t}) - \mu G(\bar{\omega}_{i,t})]\mathbb{E}_{t-1}R_t^k Q_{t-1}K_{i,t}, \tag{4}$$

where $F(\omega_{i,t})$ is the CDF; $\Gamma(\bar{\omega}_{i,t}) \equiv \int\limits_0^{\bar{\omega}_{i,t}} \omega_{i,t} dF(\omega_{i,t}) + \bar{\omega}_{i,t} \int\limits_{\bar{\omega}_{i,t}}^{\infty} dF(\omega_{i,t})$; and $G(\bar{\omega}_{i,t}) \equiv \int\limits_0^{\bar{\omega}_{i,t}} \omega_{i,t} dF(\omega_{i,t})$. The first component of $\Gamma(\overline{\omega}_{i,t})$ (which is also equal to $G(\bar{\omega}_{i,t})$) gives the expected homeowner's return in case of a default, whereas the second one gives the expected return in case of solvency;

[3]Note that this assumption is largely innocuous for the dynamics of the housing market in response to changes in the risk-free rate; however, without this assumption, the financial intermediaries' profits would always be zero (as in the original BGG model). Including this assumption implies that financial intermediaries' profits may differ from zero in each period, depending on the realized rate of return on housing relative to its expected level.

[4]Note that the actual, or realized, default threshold value is defined as $\bar{\omega}_{i,t}$, as $\bar{\omega}_{i,t} = \frac{Z_{i,t}B_{i,t}}{\omega_{i,t}R_t^k Q_{t-1}K_{i,t}}$.

[5]the risk-free rate in the economy can be interpreted here as the rate at which financial intermediaries borrow from either a central bank or households; given the abstraction from general equilibrium opted for here, both interpretations are reasonable and innocuous.

hence, the optimization constraint dictates that the expected returns of the lenders on a risky loan net of monitoring costs, given by the RHS of the constraint, be equal to the risk-free return given by the LHS of the constraint.

To accommodate shocks to the risk-free rate, I assume R_t follows the $AR(1)$ process

$$R_t = \bar{R}^{1-\rho} R_{t-1}^{\rho} exp(\epsilon_t), \tag{5}$$

where ρ governs the persistence of the process; $\bar{R}$ is the steady state level of R_t; and ϵ_t is a white noise shock.

An additional important piece of modeling related to homeowners is to lay out the dynamics of their aggregate net worth.[6] Towards this end, I make the standard assumption that homeowners "die" with a constant exogenous probability in each period, $1 - \upsilon$, in which case they simply consume their entire net worth and are replaced within the period by new entrepreneurs.[7] This setting implies the following law of motion for aggregate entrepreneurial net worth:

$$N_{t+1} = \upsilon[1 - \Gamma(\bar{\omega}_t)] R_t^k Q_{t-1} K_t, \tag{6}$$

where K_t is aggregate capital stock in the economy and $[1-\Gamma(\bar{\omega}_t)]R_t^k Q_{t-1} K_t$ is the aggregate profit of all entrepreneurs in period t, which also corresponds to the objective function in Problem (4).

As explained above, in each period financial intermediaries' profits may differ from zero depending on the realized gross real rate of return, thus accommodating a straightforward link between homeowners' default rates and financial intermediaries' profitability. Bank profits are defined as $\pi_t \equiv [\Gamma(\bar{\omega}_{i,t}) - \mu G(\bar{\omega}_{i,t})] R_t^k Q_{t-1} K_{i,t} - R_t(Q_{t-1}K_{i,t} - N_{i,t})$. Dividing financial intermediaries' profits by their assets, i.e., $Q_{t-1}K_{i,t} - N_{i,t}$, gives financial intermediaries' return on assets. I will use this variable to demonstrate how financial intermediaries' profitability is affected by a rise in the risk-free rate in the presence of high debt burden relative to normal levels of debt burden.

[6] BGG also show that the chosen optimal level of $\bar{\omega}_{i,t}$ is identical across borrowers. This result is important as it facilitates aggregation of net worth in the economy.

[7] This assumption grantees that homeowners will never accumulate enough net worth so as to avoid borrowing to finance their operations.

I end this section with a discussion on how debt burden is defined in this model. In the empirical analysis to follow, I will measure household debt burden as the ratio of households' debt service payments to their disposable income, also conventionally termed as the debt service ratio (DSR). The DSR effectively proxies for the absorbability of the mortgage and is a commonly used measure in the mortgage market on the part of lenders to asses the riskiness of borrowers.[8]

Since the aggregate DSR data for the U.S. economy is based on realized cash flows, I will use ex-post (i.e., actual) DSR's in the empirical analysis. However, in practice, when assessing the capacity of borrowers to meet debt payments, lenders use DSR's that are computed on the basis of projected cash flows; the reason for this is that they examine the borrower's DSR prior to deciding about whether to grant the loan or not, i.e., this screening takes place prior to the actual realization of the related cash flows. Hence, in my model, the natural theoretical counterpart to the projected DSR in the economy is $\frac{\mathbb{E}_{t-1}\{Z_t B_t\}}{\mathbb{E}_{t-1}\{R_t^k Q_{t-1} K_t\}}$, where the numerator represents expected principal and interest payments for non-defaulters and the denominator gives the expected total resources available for servicing the debt. The initial value of DSR will play a central role in the simulation below, whose objective would be to ascertain the non-linear role of the risk-free rate.

2.2 Housing Producers

There are perfectly competitive housing producers that use a linear technology to produce housing which are sold at the end of period t to homeowners at price Q_t. They use a fraction of final goods purchased from retailers (not modeled here due to the partial equilibrium framework) as investment goods, I_t, which are then used in conjunction with the existing housing stock to produce new housing stock, K_{t+1}. Housing producers are also subject to a convex capital adjustment cost

[8] Johnson and Li (2010) find that a household with a high DSR is significantly more likely to be turned down for credit than other households, which accords well with high DSR's being a good proxy for credit constraints. Using DSR's to differentiate between credit constrained and unconstrained households, Aladangady (2014) finds that the former have much higher marginal propensities to consume than the latter.

function resulting in the following capital accumulation equation:

$$K_{t+1} = (1-\delta)K_t + \Phi\left(\frac{I_t}{K_t}\right)K_t, \tag{7}$$

where Φ is the adjustment cost function meeting the following conditions: $\Phi(0) = 0, \Phi\left(\frac{\overline{I}}{\overline{K}}\right) = \frac{\overline{I}}{\overline{K}}, \Phi(\cdot)' > 0, \Phi(\cdot)'' < 0$, where $\overline{I}$ and $\overline{K}$ are the investment and capital steady state levels; and δ is the capital depreciation rate. The housing producers optimization problem consists of choosing the quantity of investment to maximize their profits:

$$\max_{I_t} Q_t\Phi\left(\frac{I_t}{K_t}\right) - I_t. \tag{8}$$

2.3 Solution and Calibration

Solution. I solve the model by taking a second order approximation of its system of equilibrium equations about the steady state values of the variables. Using a second order approximation for solving the model is necessary for properly studying the non-linear role of the risk-free rate, i.e., its effects for high compared to normal DSR levels.

To compute the DSR-dependent responses of the variables, I produce two simulations by drawing a realization of 50 basis points of the risk-free rate shock, but in one simulation I restrict the initial debt and housing stock values to their steady state values where in the other I let them deviate from their steady state values such that the initial projected DSR level is 25% higher that its steady state value. This is effectively done by letting homeowners increase their initial debt such that their initial net worth is unchanged; I also leave the projected contractual non-default mortgage rate and projected house prices at their steady state levels. For the calibration I use, this exercise implies that initial debt and housing stock are 46.8% and 17.9% higher than their steady state values, respectively.

Calibration. Table 1 presents the calibration used for the model's parameters. The calibration for the parameters that are unrelated to the financial accelerator side of the model follows BGG.

Although the depreciation rate and housing stock share in the production function in my model do not pertain to firm capital stock as in BGG, the calibration used in BGG (0.025 and 0.35) is quite similar to that used in Iacoviello (2005) (0.03 and 0.36), who also directly models housing stock in the procuration function. Hence, I simply follow BGG also for these two parameters.

The parameters related to the debt contract and entrepreneurs' net worth are the following: the monitoring cost, mu; homeowners' death rate υ; and the standard deviation of the idiosyncratic productivity shock, σ. I calibrate these parameters so as to match a steady state external finance premium ($\bar{R}^k - \bar{R}$)of 0.0047, steady state homeowner housing stock to net worth ($\frac{\bar{K}}{\bar{N}}$) of 1.62, and annual steady state mortgage default rate of 4.03%, resulting in the following calibration: $\mu = 0.0985$, $\upsilon 0.9831$, and $\bar{\sigma} = 0.3829$. The three matched steady states correspond to the average values observed for historical U.S. data on the spread between the 30-year conventional mortgage rate and 30-year Treasury rate, the inverse of homeowners'equity share in real estate, and the delinquency Rate on single-family residential mortgages. Lastly, the persistence parameter is set to $\rho = 0.8$.

2.4 The Non-Linear Effects of Risk-Free Rate Shocks

Figure 1 shows the response of the model economy to a 50 basis-point risk-free rate shock. The solid line depicts the response of the model when the initial projected DSR level is at its steady state value, and the dashed line shows the response of model when the initial projected DSR level is 25% higher than its steady state value.

The impulse responses clearly demonstrate dependence on the initial DSR level. The most notable difference in the responses, and which is most relevant for the channel this paper is trying to highlight, is observed for the realized mortgage default rate. On impact, homeowners' default rates rise by over 0.5 percentage points in the high DSR state compared to only rising by 0.16 percentage points in the normal state, i.e., more than three times as much. This significant difference is quite persistent also, maintaining very high gaps in relative terms for 5 years after the shock. The reason for this result lies in that the higher initial DSR level makes default much more more likely in response to an adverse shock, which in this case raises the borrowing cost of mortgages (see the contractual mortgage rate sub-figure), since the capacity to meet debt payments in the presence of rising borrowing costs is decreasing in the initial DSR level. The higher default rates reduce in turn financial intermediaries' return on their assets as the increased share of defaulting loans produces increased losses for financial intermediaries.[9]

In accordance with the stronger decline in default rates, homeowners' net worth, house prices, residential investment and the housing stock also decline more in the elevated DSR state. This result is related to the exacerbation of the agency problem between lenders and homeowners that is induced by the higher indebtedness of the latter and results in less demand for housing investment on the part of homeowners. Interestingly, because homeowners' net worth declines much more in the high DSR state, debt actually even rises in this state so as to substitute for the stronger decline in net worth. Ultimately, the more severe worsening in homeowners' balance sheets in the higher DSR state dictates that both housing stock and house prices decline more in this state.

In sum, Figure 1 stresses that the initial level of homeowners' DSR can have a material effect on the the negative relationship between homeowners default rates and the risk-free rate. Since mortgage default rates translate into bigger financial intermediaries' losses, the main takeaway from this Figure is that the presence of both a high share of ARM contracts and an initial high level of DSR can significantly exacerbate the effects of increases in the risk-free rate on the economy. In other words, we should expect the shock-absorbtion capacity of monetary policy to be stronger in the presence of these two conditions. I now turn to testing this prediction empirically.

[9] Note that, since financial intermediaries make a zero profit in expectations in each period by assumption, the adverse risk-free rate shock only reduces their profits on impact.

3 Empirical Analysis

3.1 Data

Data are monthly and span 1992:M1-2013:M12. The variable I use to measure demand shocks is the the non-financial excess bond premium (EBP) series from Gilchrist and Zakrajek (2012), who use micro-level data to construct a credit spread index computed from the spreads between non-financial firms' bond yields and U.S. government bond yields of comparable maturities. They then decomposed this credit spread series into a component that captures firm-specific information on expected defaults and a residual component that they termed as the excess bond premium. Hence, EBP is arguably a reliable proxy for exogenous credit supply shocks.

The ARM market share series is based on micro-level loan data from the Monthly Interest Rate Survey (MIRS) conducted by Federal Housing Finance Agency (FHFA). The series is computed as the share of originated mortgages in a given month whose interest rate is set to reset within 5 years in accordance with market interest rates. The ARM share data is directly available from Badarinza et al. (2014), which they computed from the the MIRS micro-level data.

I use household debt service payments as a percent of disposable personal income to measure the aggregate DSR in the U.S. economy. The series is taken from the FRED database, is quarterly, and is seasonally adjusted. To transform it into monthly frequency, I perform a cubic spline interpolation of the raw series.

The main outcome variable I consider is the seasonally adjusted civilian unemployment rate series taken from FRED. This series is available on a monthly basis and is a good proxy for the overall level of economic activity.

I also consider several other outcome variables in order to shed light on the mechanism underlying the unemployment response. First, I examine the response of prices, as measured by the seasonally Consumer Price Index (CPI) for All Urban Consumers; this series is available at a monthly frequency and is log-transformed. Second, I include the effective federal funds rate and the 1-year adjustable rate mortgage Average series; monthly values for the former are obtained by averaging over the daily observations, where for the latter monthly values are obtained by averaging over weekly observations.

Third, to measure the mortgage default rate, I employ the seasonally adjusted delinquency rate on single-family residential mortgages series. Since this series is available only at quarterly frequency, I transform it into monthly frequency by performing a cubic spline interpolation of the raw series.

Fourth, to examine the validity of a financial intermediary capital channel underlying my empirical results, I examine the behavior of the He et al. (2016) series of value-weighted equity return of primary dealers, the Gilchrist and Zakrajsek (2011) series of financial firms' credit spread, and the Chicago Fed non-financial leverage subindex.[10] The primary dealers' return on equity series is based on the monthly market equity return of the large financial institutions that serve as counterparties of the Federal Reserve Bank of New York in its implementation of monetary policy, which include commercial banks, investment banks, and insurance companies; I accumulate the raw series, which represents log-first-differences of the market value of primary dealers, such that the resulting series can be interpreted as the logged market value of primary dealers. The Gilchrist and Zakrajsek (2011) series is constructed on the basis of a monthly sample of month-end prices of fixed income securities issued by U.S. financial corporations, where the credit spread is computed from the spreads between financial firms' bond yields and U.S. government bond yields of comparable maturities.[11]

The non-financial leverage measure is a subindex of the high frequency (weekly frequency) Chicago Fed National Financial Conditions Index (NFCI). As explained in Brave et al. (2012), the NFCI is a a weighted average of 100 financial indicators where the weight given to each reflects the indicators ability to explain the total variation among them. The non-financial leverage subindex is constructed as a combination of two indicators, the quarterly growth rate of the ratio of nonfinancial

[10] The He et al. (2016) and Gilchrist and Zakrajsek (2011) series are available only through the end of 2012.

[11] Their sample consists of 193 publicly-traded financial firms engaged in the following financial activities: Credit Intermediation and Related Activities; Securities, Commodity Contracts and Other Financial Investments and Related Activities; Insurance Carriers and Related Activities; and Funds, Trusts and Other Financial Vehicles.

business debt outstanding to GDP and the quarterly growth rate of the ratio of household mortgage and consumer debt outstanding to the sum of residential investment and personal consumption expenditures on durable goods, with the latter receiving 1.3 times the weight of the former in accordance with the weighting from the systemic decomposition of the NFCI. As such, this variable can serve as a high frequency proxy for the level of leverage in the non-financial sector and can thus inform us about how the financial state of financial institutions affects the ultimate lending granted to the non-financial sector. Brave et al. (2012) show that this non-financial leverage variable is a consistent leading indicator of financial stress and economic downturns in the U.S., generally rising during expansions and falling during recessions. Monthly values for this variable are obtained by averaging over the weekly observations and it is available in standardized form (zero mean and unit variance).

Lastly, I consider seasonally adjusted industrial production indices of consumer durable goods, consumer non-durable goods, and business equipment goods, as well as seasonally adjusted housing starts. All of these series are available at a monthly frequency and are log-transformed.

3.2 Methodology

I follow the econometric framework employed in Auerbach and Gorodnichenko (2012), Owyang et al. (2013), Ramey and Zubairy (2014), and Tenyero and Thwaites (2016), who use the local projection method developed in Jorda (2005) to estimate impulse responses. This method allows for state-dependent effects in a straightforward manner while involving estimation by simple regression techniques. Moreover, it is more robust to misspecification than a non-linear VAR. Inference is based on Newey-West robust standard errors that allow arbitrary correlations of the error term across time.

In particular, I estimate the impulse responses to the credit supply shock by projecting a variable of interest on its own lags and current and lagged values and lags Gilchrist and Zakrajek (2012)'s EBP variable, while allowing the estimates to vary according to the level of both the ARM share and the level of DSR. For example, when I use the unemployment rate (u_t) as the dependent variable, which is the main variable of interest in this paper, the response of unemployment rate at horizon h is estimated from the following non-linear regression:

$$
\begin{aligned}
u_{t+h} = I_{t-1}^{ARM} \times I_{t-1}^{DSR}[\alpha_{A,h} + \Xi_{A,h} EBP_t + \Omega_{A,h}(L) EBP_{t-1} + \Gamma_{A,h}(L) u_{t-1}] + \\
+(1 - I_{t-1}^{ARM}) \times (1 - I_{t-1}^{DSR})[\alpha_{B,h} + \Xi_{B,h} EBP_t + \Omega_{B,h}(L) EBP_{t-1} + \Gamma_{B,h}(L) u_{t-1}] + \epsilon_{t+h},
\end{aligned}
\tag{9}
$$

where all the coefficients vary according to whether we are in state "A", i.e., high ARM share and DSR, or state "B", i.e., low ARM share and DSR. I is a dummy variable that takes the value of one when both the ARM share and the DSR are above certain thresholds. To maintain a reasonable number of observation in state "A" while still being able to distinguish between high and low ARM share and DSR states, I define $I_{i,t-1}^{A}RM = I_{i,t-1}^{D}SR = 1$ when the level of ARM share and DSR are at or above their median levels. This threshold dictates that 23.5% of the observations, or a total of 62 observations, are consistent with being in a state of both high ARM share and high DSR.

Lags of unemployment and EBP are included in the regression to remove any predictable movements in EBP; this facilitates the identification of the unanticipated shock to EBP, which is what is sought after. I assign the value of the order of lag polynomials $\Omega(L)$ and $\Gamma(L)$ to 12, i.e., I allow for 12 lags of unemployment and EBP in the regression. Note that Specification (9) is suitable for the case in which the dependent variable is stationary, as is unemployment; when the dependent variable is non-stationary, as will be the case for some of the variables considered below, the following specification will be used:

$$
\begin{aligned}
y_{t+h} - y_{t-1} = I_{t-1}^{ARM} \times I_{t-1}^{DSR}[\alpha_{A,h} + \Xi_{A,h} EBP_t + \Omega_{A,h}(L) EBP_{t-1} + \Gamma_{A,h}(L) \Delta y_{t-1}] + \\
+(1 - I_{t-1}^{ARM}) \times (1 - I_{t-1}^{DSR})[\alpha_{B,h} + \Xi_{B,h} EBP_t + \Omega_{B,h}(L) EBP_{t-1} + \Gamma_{B,h}(L) \Delta y_{t-1}] + \epsilon_{t+h},
\end{aligned}
\tag{10}
$$

where y_t denotes the log of the non-stationary variable.

For both the stationary and non-stationary specifications, the impulse responses to the credit supply shock for the two states at horizon h are simply $\Xi_{A,h}$ and $\Xi_{B,h}$, respectively. The EBP credit supply shock is normalized so that it has a zero mean and unit variance over the entire sample;

moreover, to facilitate proper comparison of the shock's effect across the two states, I normalize the shock's variance in the high ARM share and DSR state to equal that in the complementary state. Inference is based on Newey-West robust standard errors that account for the serial correlation of $u_{i,t+h}$. Note that a separate regression is estimated for each horizon. Since my focus is on the first five years following the shocks, I will estimate a total of 20 regressions and collect the impulse responses from each estimated regression.

For comparison purposes, I will also estimate a linear analogue of Specification (9):

$$u_{t+h} = \alpha_h + \Xi_h EBP_t + \Omega_h(L)EBP_{t-1} + \Gamma_{A,h}(L)u_{t-1} + \epsilon_{t+h}. \tag{11}$$

The coefficient of interest from this linear regression is Ξ_h, which gives the linear impulse response to the credit supply shock at horizon h. The linear specification effectively assumes equality of the model's coefficients across the two states.

3.3 Results

This section presents the main results of the paper. It is first established that the main outcome variable, the unemployment rate, responds significantly more moderately to expansionary credit supply shocks. All impulse response are computed in response to a negative realization of the EBP shock so as to facilitate an interpretation of responses to an expansionary demand shock.

Unemployment Rate and Prices. The first set of results, shown in Figure 2a, depicts the unemployment rate response to expansionary credit supply shocks in the non-linear model described in Specification (9). For comparison purposes, the results from the linear model (Specification (11)) are also shown in Figure 2a. Specifically, the first sub-figure jointly shows the point estimates of the linear model (solid lines), high ARM share and DSR state (dotted lines), and low ARM share and DSR state (dashed lines); the next three sub-figures depict the impulse responses along with 95% confidence bands for the linear model, the high ARM share and DSR state, and the low ARM share and DSR state; and the last sub-figure shows the t-statistics from the hypothesis that the impulse responses in the high ARM share and DSR state are larger than in the low ARM share and DSR state. I treat the unemployment rate as a stationary variable and thus estimate Specification (9).

The results from Figure 2a clearly indicate that being in a state of both high ARM share and high DSR significantly reduces the effects of credit supply shocks on unemployment. The reduction is both economically and statistically significant, with the t-statistics of the differences in the responses across the two states far exceed conventional significance levels. The strongest unemployment response in the low ARM share and DSR takes place after 15 months reaching -0.85%, compared to only -0.33% in the low ARM share and DSR state. Furthermore, while the unemployment response is statistically significant for all the shown horizons (30 months following the shock) in the low ARM share and DSR state, the response in the complementary state is insignificant for a non-negligible numbers of the horizons. I.e., being in the latter state strongly dampens the expansionary effect of the credit supply shock. Note that merely focusing on the linear model, in which the effect is largely significant (both economically and statistically), conceals the important and strong dependence of the unemployment response on the initial level of the ARM share and DSR level, a dependence which is well captured by estimating the non-linear model.

Figure 2b shows the response of CPI. I treat CPI as a non-stationary variable and thus estimate Specification (10) with CPI log-transformed. Uncovering the response of prices is important for confirming the interpretation of the credit supply shock as a pure demand shock. It is clear that prices rise much more significantly in the low ARM share and DSR state than in the complementary state. While the response in the former state is significant for the majority of the horizons, the response in the latter state is insignificant for most of the horizons following the shock. This result is consistent with the unemployment response: the expansionary effect of the credit supply supply shock is significantly moderated by conditioning on the a state of high ARM share and DSR level.

Federal Funds Rate and ARM Rate. The result shown in Figures 3a and 3b pertain to the federal funds rate and average 1-year adjustable rate mortgage interest rate responses to credit supply shocks in the non-linear model, respectively. I treat both variables as stationary variable and thus estimate Specification (9). Uncovering the behavior of these variables is important for illuminating the mechanism underlying the unemployment responses from Figure 2a. If a mortgage default rate channel is truly in place here, then we should be observing monetary policy-makers raising rates following an expansionary demand shock and, in turn, the interest rates on ARMs should be adjusted upwardly in response to the rise in the federal funds rate.[12]

The results reveal that an expansionary credit supply shocks raises both the federal funds rate and the ARM rate in both states, where response differences between the two states are largely insignificant. These results are consistent with the fact that margins on ARMs, i,e., the premium that mortgage lenders charge over the risk-free rate, do not fluctuate that much over time. Hence, since the response of the federal funds rate is largely similar across the two states, we do not observe any noticeable difference in the ARM interest rate across the two states.

Mortgage Default Rate. Figure 4 depicts the responses of the overall delinquency rate on single-family mortgages for all commercial banks in the U.S. I treat the default rate variable as a stationary variable and thus estimate Specification (9). The results from 4 indicate that, essentially from the impact period, there is a statistically significant difference between the response of default rates across the two states that lasts for 20 months, with the corresponding t-statistics far exceeding conventional significance levels; while default rates significantly decline in the low ARM share and DSR state, they actually rise in the high ARM share and DSR state.

That default rates rise in the high ARM share and DSR state can be explained by considering two opposing forces at work here. On the one hand, the expansionary credit supply shock pushes down default rates by improving borrowers' repayment capacity. On the other hand, the fact that the ARM share and DSR level are high makes it difficult for these borrowers to meet their debt payments. The results from Figure 4 seem to indicate that the latter force is moderately stronger

[12]Lenders mostly index ARM rates to a variety of indices, the most common of which are rates on one-, three-, or five-year Treasury securities, depending on the fixation period of the ARM. Another common index is the national or regional average cost of funds to savings and loan associations, which is closely linked to the level of the federal funds rate. The federal funds rate change resulting from the expansionary demand shock should have a direct and strong effect on all of these rate types, especially considering that the demand shock considered in this paper has quite persistent effects on the federal funds rate.

than the former, at least for the first 16 months following the shock, whereas in the low ARM share and DSR state only the first force is relevant thus pushing default rates down.

Evidence for a Financial Intermediary Capital Channel. The results from Figure 4 establish that being in an initial state of high ARM share and high DSR level not only prevents mortgage default rates from declining in response to an expansionary credit supply shock, but even causes them to rise. Therefore, we should expect to observe a financial intermediary capital channel whereby the initial state of high ARM share and DSR level also keeps financial intermediary net worth from increasing in response to the shock, or even causing them to decline, in turn moderating the positive effect of credit supply shocks on financial intermediaries' credit supply. To investigate the empirical validity of this channel, I now present responses of several variables related to financial intermediaries' net worth, perceived riskiness by investors, and credit supply.

Figure 5a presents the response of the market value of primary dealers to an expansionary credit supply shock. I treat primary dealers' market value as a non-stationary variable and thus estimate Specification (10), with the latter variable log-transformed. Understanding this variable's behavior is important for ascertaining the relevance of a financial intermediary capital channel given that it constitutes a good proxy for financial intermediaries' net worth. While the response in the low ARM share and DSR state is significantly positive from the impact period through the two year mark, the response in the high ARM share and DSR state is only significantly positive in the first two months after the shock. Furthermore, there are actually a few periods around the one- and two-year marks in which there is a negative response in the latter state. Consistent with these results, the t-statistics of the differences in responses across the states far exceed conventional significant levels for the bulk of the horizons. In sum, being in the high ARM share and DSR state effectively eliminates the rise in the market value of primary dealers that would take place had the initial state were characterized by low ARM share and DSR level.

Figure 5b shows the response of the Gilchrist and Zakrajsek (2011) financial firms' credit spread series. This variable is a good proxy for the perceived riskiness of financial intermediary in credit markets; I treat primary dealers' market value as a stationary variable and thus estimate Specification (9). While the credit spread significantly drops in the low ARM share and DSR state, it only moderately drops in the first 1.5 years after the shock in the high ARM share and DSR state, and actually begins to significantly rises after 10 months for about a year. Accordingly, the t-statistics of the difference in responses across the two states exceed conventional statistical significance levels from the impact period through 18 months following the shock. We can deduce from these results that the decline in the perceived riskiness of financial intermediaries that occurs in the low ARM share and DSR state is effectively overturned by being in the high ARM share and DSR state.[13]

Figure 6 depicts the response of the Chicago Fed non-financial leverage subindex. Since this high frequency leverage measure is a weighted average of the growth rates of *i*) the quarterly growth rate of the ratio of nonfinancial business debt outstanding to GDP and *ii*) the quarterly growth rate of the ratio of household mortgage and consumer debt outstanding to the sum of residential investment and personal consumption expenditures on durable goods, where the weighting is based on the systemic decomposition of the NFCI (Brave et al. (2012)), its response can inform us about whether the observed relative decline in financial intermediaries' net worth translates into a lesser credit supply on their part.

Figure 6 delivers a conclusive message: while significantly rising in the low ARM share and DSR state, non-financial leverage does not change significantly in the high ARM share and DSR state, resulting in significant differences in responses across the two states as reflected by t-statistics that far exceed conventional significance levels. This result indicates that private sector debt rises more in proportion than economic activity in the high ARM share and DSR state. Given that economic activity rises less in the latter state, as shown in Figure 2a for unemployment and further confirmed below for consumption and investment, the result from 6 reveals to us that financial intermediaries not only provide more credit to the private sector in the low ARM share and DSR state, but it does so such that the size of debt relative to the economy also grows significantly more.

In sum, taken together, the results of this section indicate that being in the high ARM share

[13]Importantly, the excess bond premium of the Gilchrist and Zakrajsek (2011) series, which is constructed in accordance with the methodology of Gilchrist and Zakrajsek (2012) and arguably represents the exogenous component of the credit spread series, does not exhibit significantly different responses across the two states.

and DSR state reduces financial intermediaries' net worth and increases their riskiness as perceived by credit market participants, which in turn leads to a relative reduction in the supply of credit to the private sector. These results epitomize the general notion of a financial intermediary capital channel, whereby less capital produces less lending on the part of financial intermediaries.

Consumer Durables, Consumer Non-Durables, Housing Starts, and Business Equipment. I end this section with an examination of the responses of industrial production of durable consumer goods (Figure 7a), non-durable consumer goods (Figure 7b), housing starts (Figure 8a),[14] and business equipment (Figure 8b). For all four variables, there is a significantly stronger response in the low ARM share and DSR state, where differences in responses are particularly strong for business equipment and consumer durables. This indicates that being in an initial state of both high ARM share and high DSR level moderates the effects of credit supply shocks on both consumption and investment, where equipment investment and durable goods consumption are the components whose responses are most strongly dampened. And this result is consistent with the significantly moderated response of unemployment in the latter state.

4 Robustness Checks

This section examines the robustness of the baseline results along three dimensions: allowing for lagged moving averages of the ARM share series; removing from the sample the zero lower bound period; and including only short fixation period ARMs. To examine whether the financial intermediary capital channel is also supported by the data in the presence of the above modifications, I consider the unemployment rate, mortgage default rate, primary dealers' market value, and non-financial leverage as the outcome variables.[15]

[14] I have also examined the state-dependent response of house prices and found insignificant differences in the responses across the two states; these results are available upon request. This indicates that house prices do not play a role in driving the differential response of mortgage default rates, which is consistent with the recent micro-level based evidence from Gerardi et al. (2015) that house prices have an insignificant effect on the likelihood of mortgage default.

[15] Results for the other variables are largely consistent with the baseline results of the paper and are available upon request from the author.

4.1 Lagged Moving Averages of the ARM Share Series

The ARM share series employed in this paper represents the share of mortgage originations in a given month, rather than outstanding mortgages, that are predicated on adjustable rates. One may argue that a more suitable measure for studying the effect of systematic monetary policy is the ARM share of outstanding mortgages, as it is possible that a given month may see a high share of ARM originations while the stock itself of ARM mortgages may not reflect this due to the particular month at hand being unrepresentative of the ARM share originations in past months. While I view this criticism as generally valid, it does not seem to be particularly relevant for this paper since the ARM share series is strongly auto-correlated, having a serial correlation of 97%. This implies that, on average, if there is a large share of ARM originations in a given month, it is likely that there is a similar trend in lagged months and thus outstanding mortgages should also reflect this trend.

That said, this issue can be addressed quite straightforwardly by considering lagged moving averages of the ARM share series, as these account for the past trend in the ARM originations rather than just the previous month. Importantly, note that this approach may induce difficulty in purging the ARM share series of its endogenous variations using lagged realizations of credit supply shocks and the dependent outcome variable due to the inclusion of effectively longer lags of the ARM share series; nevertheless, it is still worthwhile doing to confirm that not accounting for more distant realizations of the ARM share series in constructing I_{t-1}^{ARM} does not have material implications for the baseline conclusions of this paper.

Accordingly, Figures 13a, 13b, 14a, and 14b show the responses of unemployment, mortgage default rate, primary dealers' market value, and non-financial leverage for the case where I_{t-1}^{ARM} takes on the value of one if the lagged 3-months moving average of the ARM share is above it median level, while Figures 9a-10b present the corresponding responses for the lagged 6-months ARM share moving average specification. It is clear from both sets of figures that accounting for longer lags in the ARM share series does not change the baseline results of this paper: the unemployment response continues to be significantly dampened in the high ARM share and DSR state, and the presence of a financial intermediary capital channel as the basis for the differential unemployment response is strongly supported by the responses of the mortgage default rate, primary dealers' market value, and non-financial leverage.

4.2 Excluding the Zero Lower Bound Period

The zero lower bound (ZLB) period, which started in the first month of 2009, is included in the baseline analysis and constitutes about 23% of the entire available sample size. This period is also characterized by low ARM shares and DSR levels and thus adds considerable variation in these variables that can greatly facilitate identification. Nevertheless, one may argue that the results found in this paper are potentially erroneously driven by the ZLB period in the sense that in this period there were low levels of ARM shares and DSR in conjunction with a non-existent real interest rate channel; in other words, my results could be driven not by the financial intermediary capital channel put forward in this paper, but rather by the real interest rate channel. While this conjecture seems unlikely due to the similar responses of interest rates across the two states, it is still worthwhile to address the latter issue.

Towards this end, I redo the baseline estimation with the 2009-2013 period now removed from my sample. I present here the responses of unemployment (Figure 11a, mortgage default rate (Figure 11b), primary dealers' market value (Figure 12a), and non-financial leverage (Figure 12b). Although the quantities difference in the unemployment response across the two states is weakened in the considered smaller sample, it is still the case that the unemployment response continues to be significantly more moderated in the high ARM share state than in the low state. In total, there are 6 months in which the t-statistic of the response difference across the states exceed conventional significance levels, whereas it never goes below levels indicating a significantly stronger response in the high ARM share and DSR state.

The results for the other variables are strongly consistent with a financial intermediary capital channel being in place following the shock. As Figure 11b demonstrates, mortgage default rates do not significantly change in the low ARM share and DSR state and significantly rise in the complementary state, resulting in t-statistics of the response differences that far exceed conventional significant levels. Consistent with the mortgage default rate response, the significant rise in primary dealers' market value and non-financial leverage in the low ARM share and DSR state is effectively eliminated and overturned in the high ARM share and DSR state.

4.3 Alternative ARM Share Measure

The baseline ARM share series used in this paper includes mortgages whose interest rates are due to reset within five years from the time of their origination. I prefer to include longer fixation periods than one year since these ARMs may be relevant given the quite persistent nature of systematic monetary policy. Moreover, since the ARM share series is extremely auto-correlated, a given state of high ARM share likely includes longer fixation period ARMs that have been originated in the past and are thus due to reset sooner, hence making them very much relevant for the monetary transmission mechanism put forward in this paper.

Nevertheless, it is still worthwhile to investigate whether my results are sensitive to including only short fixation period ARMs. Towards this end, I redo the baseline estimation exercise using an ARM share series that is based only on mortgages whose interest rates are due to reset within one year, rather than five years. I present here the responses of unemployment (Figure 15a, mortgage default rate (Figure 15b), primary dealers' market value (Figure 16a), and non-financial leverage (Figure 16b). It is apparent from these figures that considering the alternative ARM share series measure has no noticeable effect on the baseline results. The unemployment response is still significantly moderated in the high ARM share and DSR state, and the same is true for the responses of mortgage default rates, primary dealers' market value, and non-financial leverage.

5 Conclusion

The question of whether monetary policy is capable of significantly moderating the effects of demand shocks is a focal one in macroeconomics. The usual transmission channel focused on so far in the literature have been the real interest rate channel and the firm balance sheet channel. This paper has put forward robust empirical evidence in favor of a novel transmission channel of monetary policy whose relevance depends on the initial state of ARM share and household debt burdens. Specifically, this paper shows that if the level of these two variables is initially high, then a novel monetary transmission channel arises whereby a decline in financial intermediary net worth and, consequently, lending to the private sector arises from increased mortgage default rates.

The empirical results of this paper bear important policy implications in suggesting that policy-makers need not consider the role of systematic monetary policy in linear terms alone, but rather think about this role in more broad terms that encapsulate possible non-linear features. The non-linearity of systematic monetary policy advanced in this paper is based on the way by which the initial state of the economy can possibly alter the shock-absorbtion capacity of monetary policy.

To the extent that this non-linearity can be significant, the decisions of policy-makers may need to account for it by also changing accordingly. E.g., in the years leading up to the Great Recession we have seen both high market shares of adjustable-rate mortgages as well as relatively straining household debt levels; consistent with the empirical evidence of this paper, the rise in the federal funds rate by over 5% over the course of roughly two years was largely coincident with a significant rise in homeowners' default rates. I am hopeful that the evidence presented in this paper would at least contribute to raising a discussion on whether monetary policy should respond more gradually than otherwise to an economic expansion in an economic environment similar to that observed in the mid 2000s, even at the cost of moderately higher inflation.[16]

[16] Garriga et al. (2015) illustrate how a more gradual rise in interest rate may be more suitable than a fast one in an environment where adjustable-rate mortgages are prevalent.

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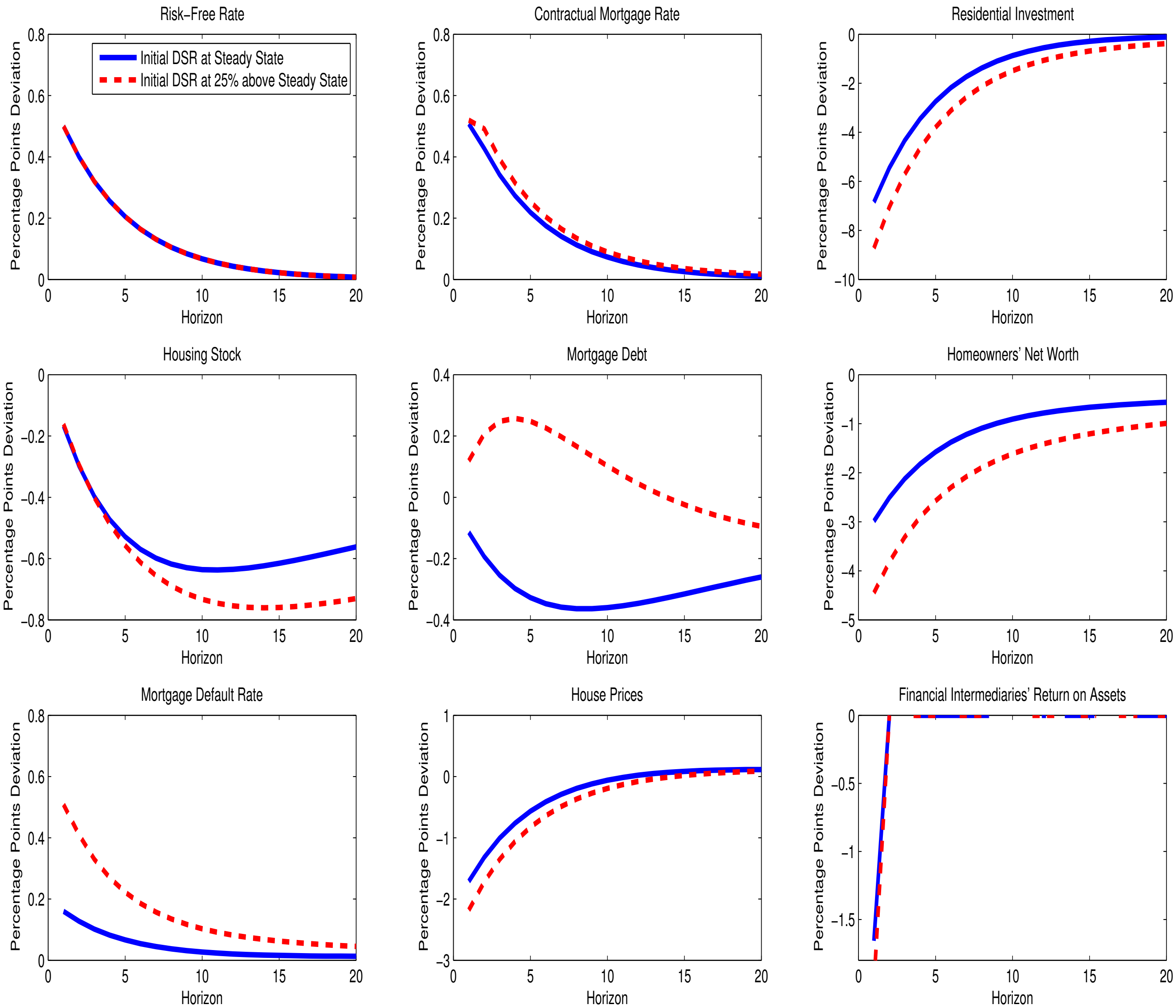
Table 1: **Model Parameterization**.

Parameter	Description	Value
$\bar{R}$	Steady State Gross Risk-Free Rate	1.01
α	Housing Stock Share	0.35
η	Elasticity of Capital Price to Capital Adjustment Cost Function	0.25
δ	Depreciation Rate	[0.025,0.025]
υ	Homeowners' Survival Rate	0.9831
μ	Monitoring Cost	0.0985
σ	S.D. of Idiosyncratic Productivity	0.3829
ρ	Risk-Free Rate Shock Persistence	0.8

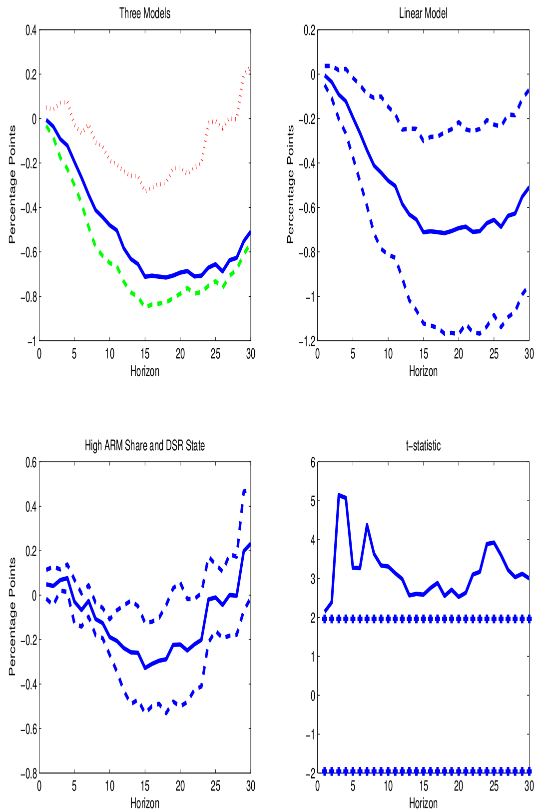
Notes: The table consists of the parameters values used for the model of Section 2.

Figure 1: **Impulse Responses to a 50 Basis-Point Risk-Free Rate Shock**.

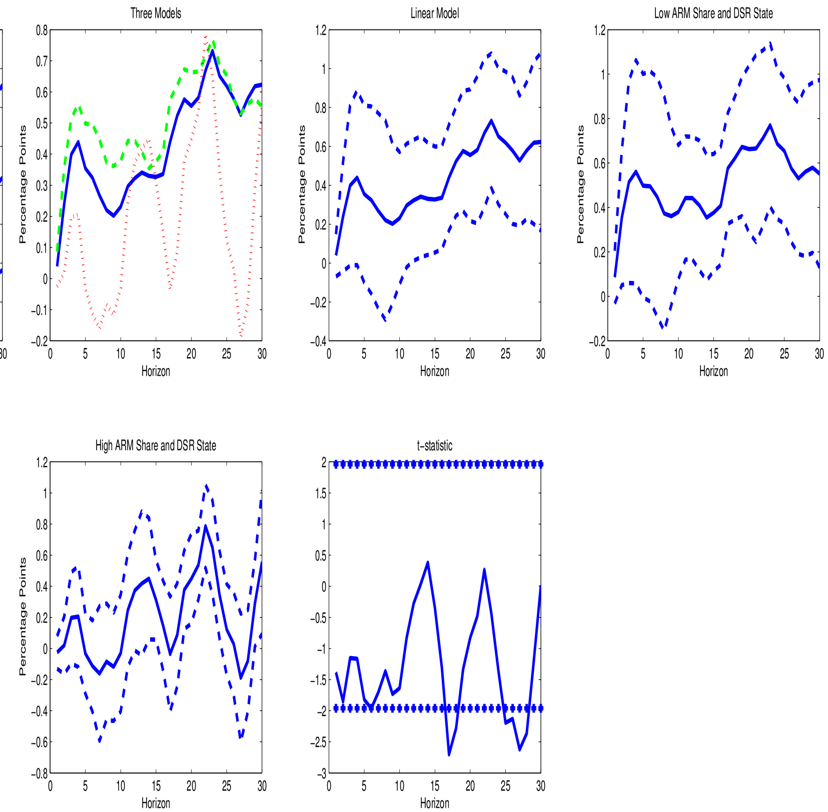


Notes: This figure presents the impulse responses to a 50 basis-point risk-free rate shock from the model presented in Section 2. The responses are shown in terms of percentage deviations from steady state values. Solid lines depict responses in the model when the initial level of the projected debt service ratio (DSR) is at its steady state level, whereas dashed lines present responses from the model when DSR is 25% above its steady state level. Horizon is in quarters.

Figure 2: **State-Dependent Effects of Credit Supply Shocks: (a) Unemployment Rate; (b) Consumer Price Index**.



(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Unemployment Rate).

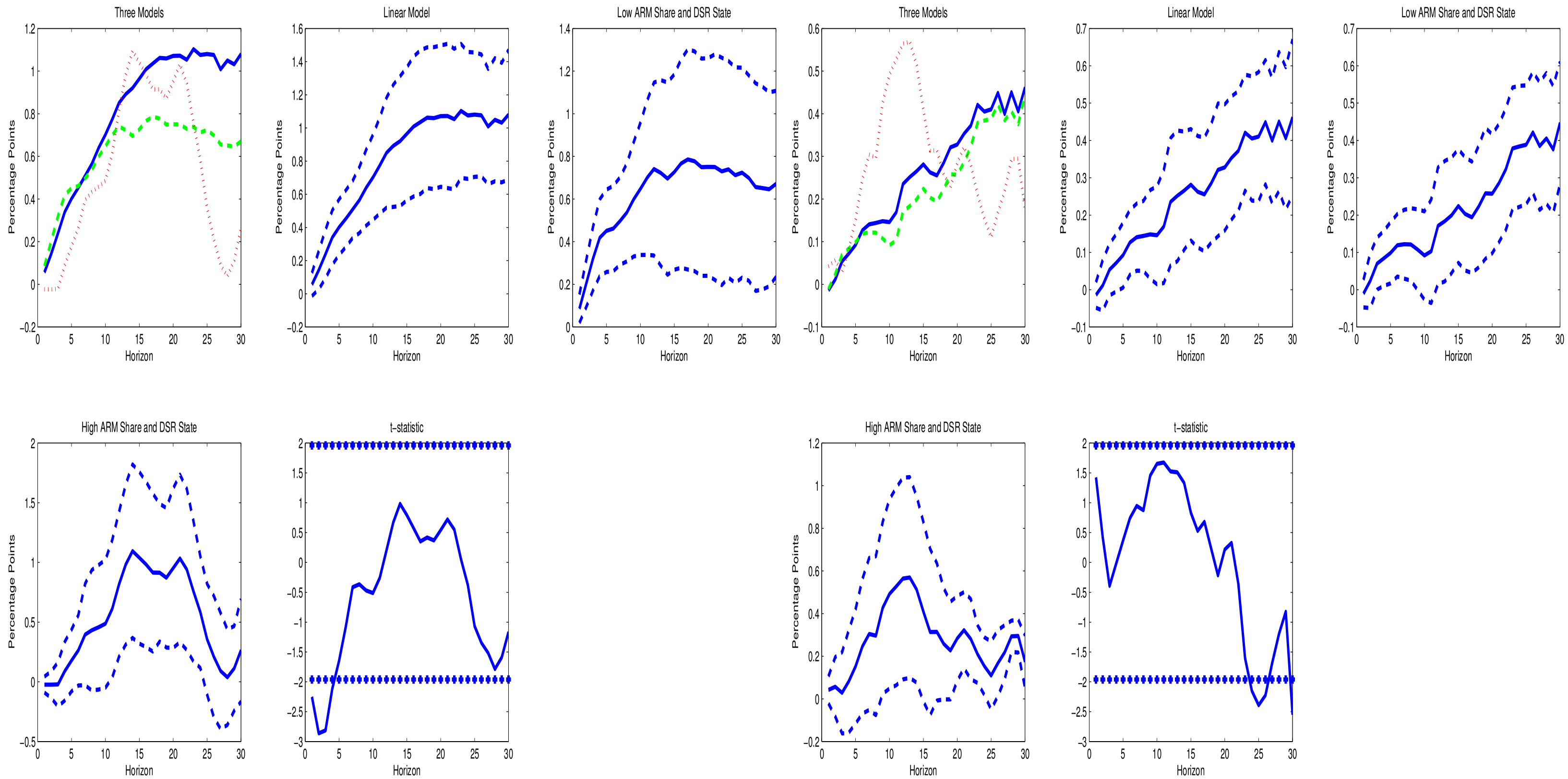


(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Consumer Price Index).

Notes: Panel (a): This figure presents the impulse responses of unemployment to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states. Panel (b): This figure presents the impulse responses of consumer prices to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states.

For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (±1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 3: **State-Dependent Effects of Credit Supply Shocks: (a) Federal Funds Rate; (b) 1-Year Adjustable-Rate Mortgage Rate**.



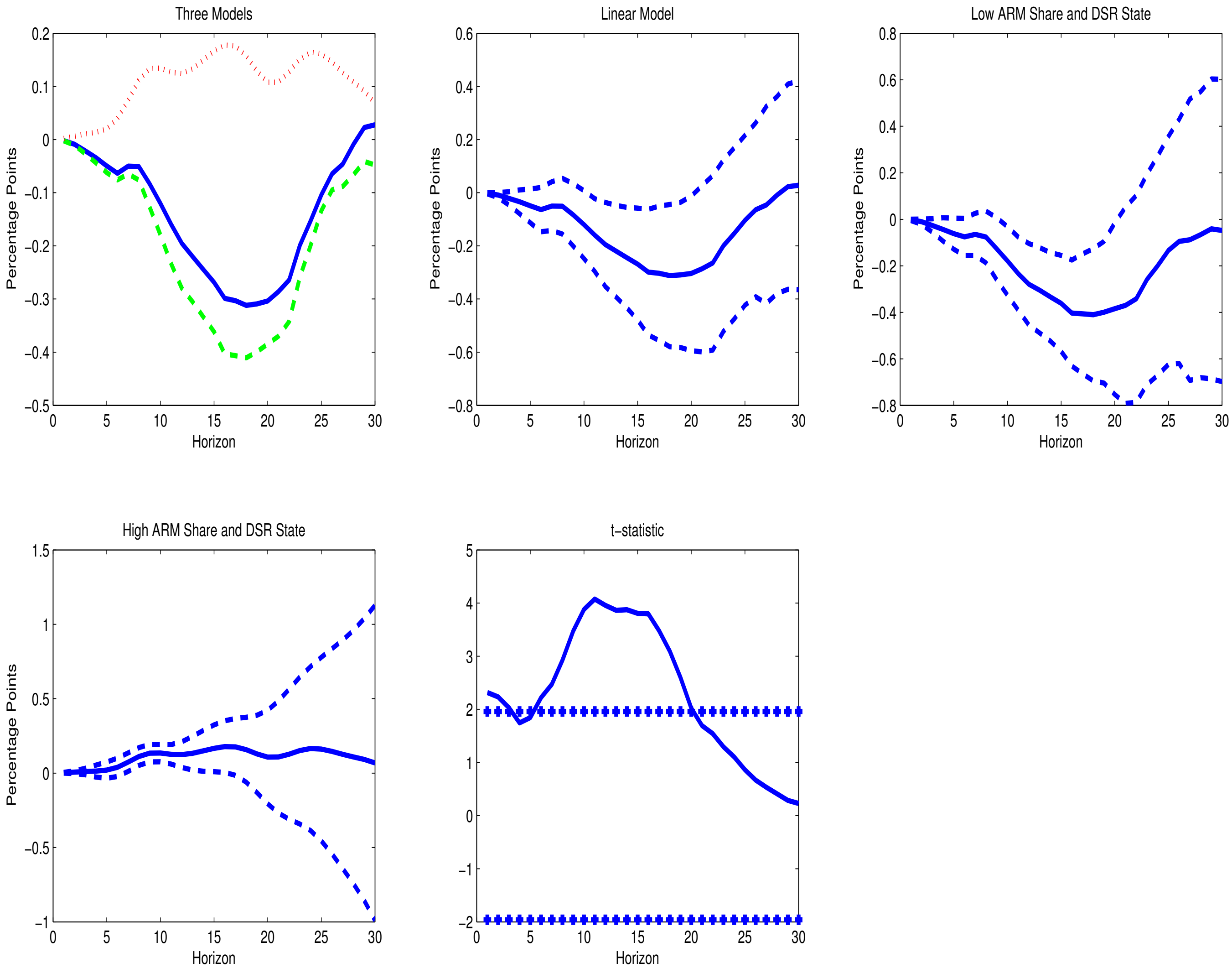
(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Federal Funds Rate).

(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (1-Year Adjustable-Rate Mortgage Rate).

Notes: Panel (a): This figure presents the impulse responses of the federal funds rate to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states. Panel (b): This figure presents the impulse responses of the 1-Year Adjustable-Rate Mortgage Rate to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states.

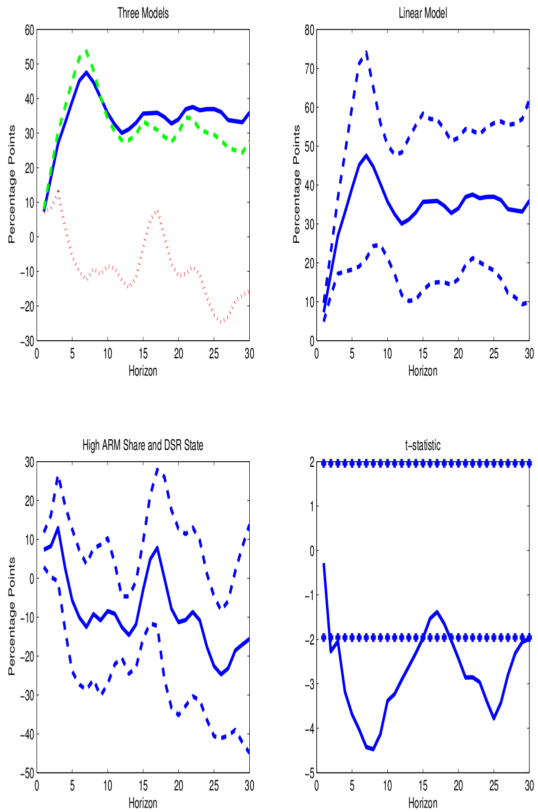
For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (±1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 4: **State-Dependent Effects of Credit Supply Shocks on Mortgage Default Rates**.

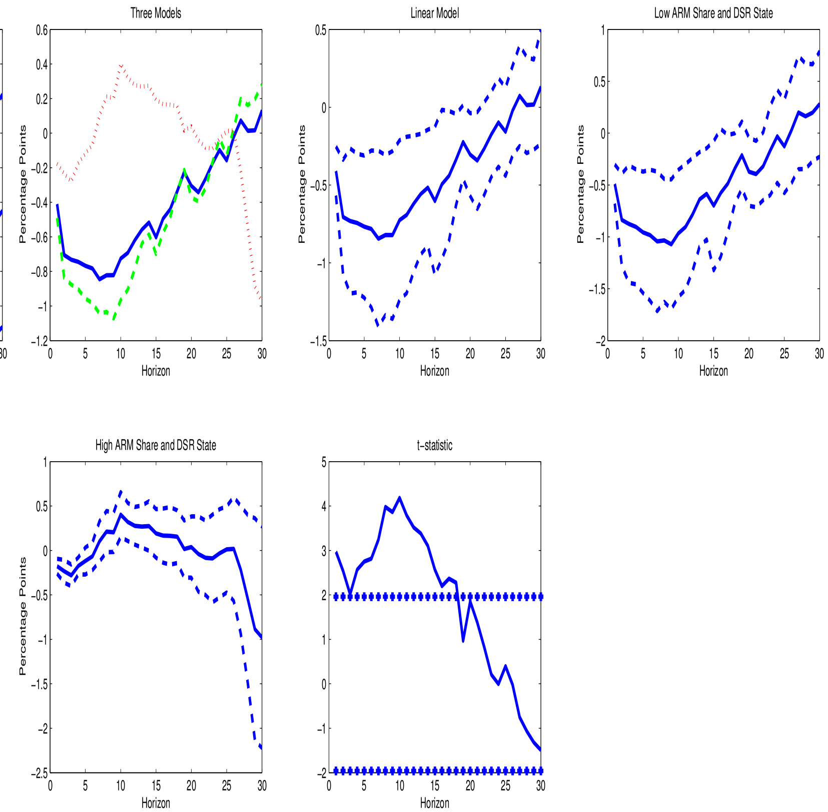


Notes: This figure presents the impulse responses of mortgage default rates to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states. In the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (±1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 5: **State-Dependent Effects of Credit Supply Shocks: (a) Primary Dealers' Market Value; (b) Financial Firms' Credit Spread**.



(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Primary Dealers' Market Value).

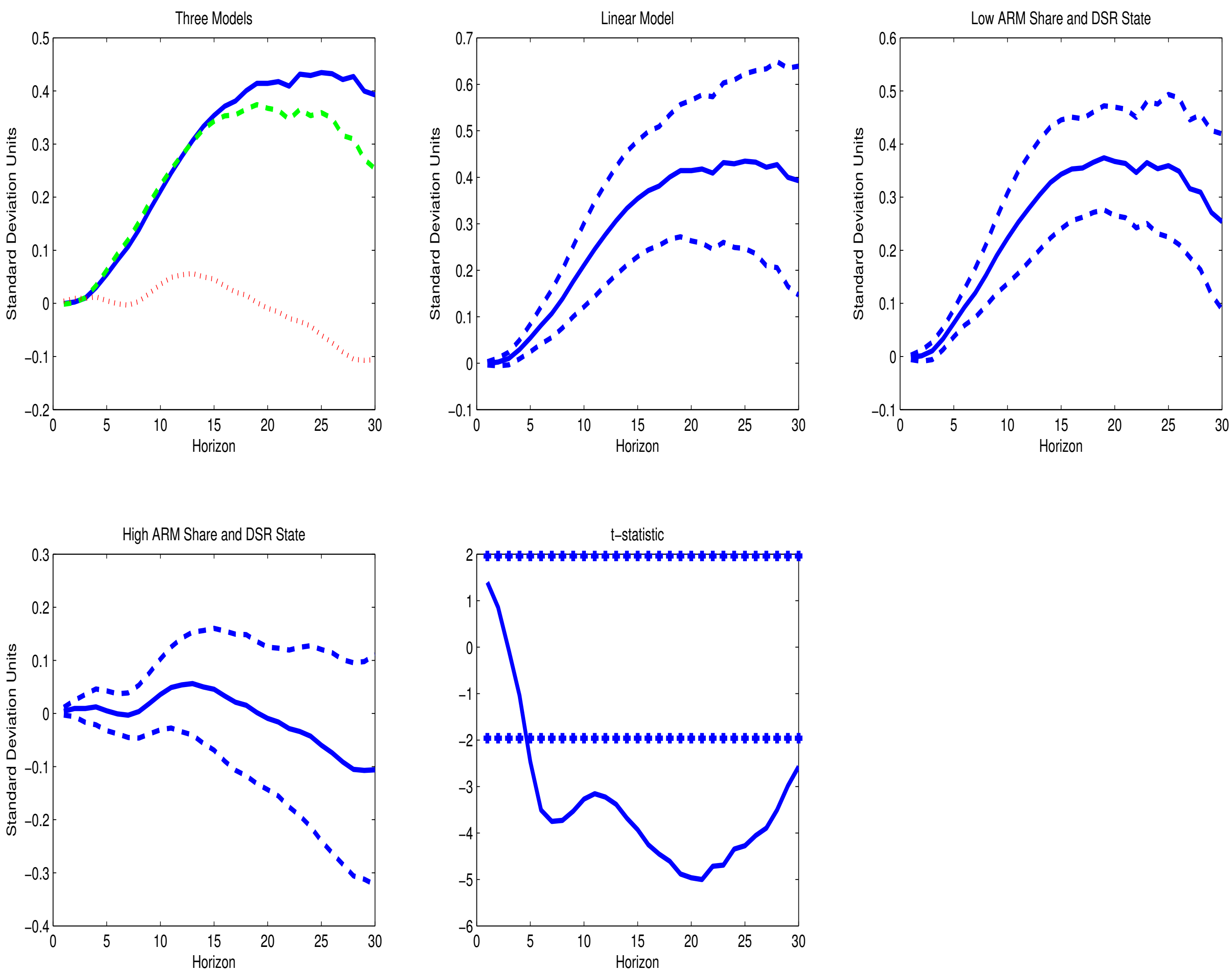


(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Financial Firms' Credit Spread).

Notes: Panel (a): This figure presents the impulse responses of the He et al. (2016) primary dealers' market value series to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states. Panel (b): This figure presents the impulse responses of the Gilchrist and Zakrajsek (2011) financial firms' credit spread series to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states.

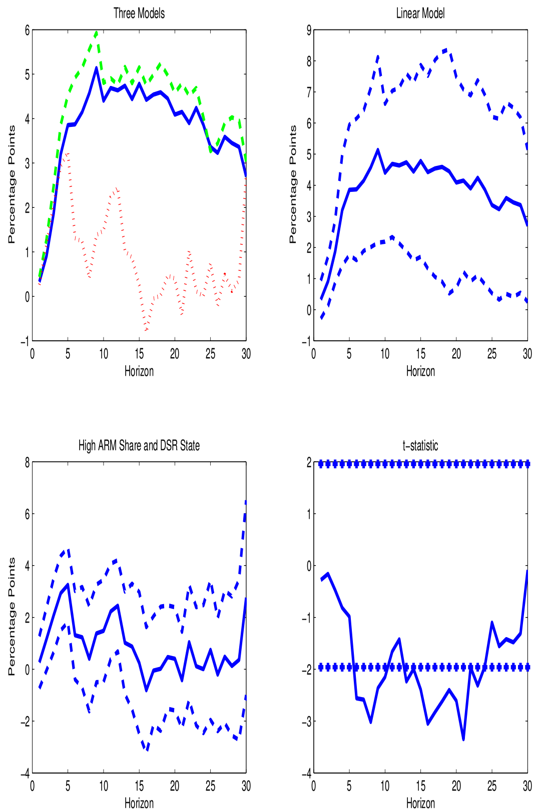
For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (±1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 6: **State-Dependent Effects of Credit Supply Shocks on Non-Financial Leverage**.

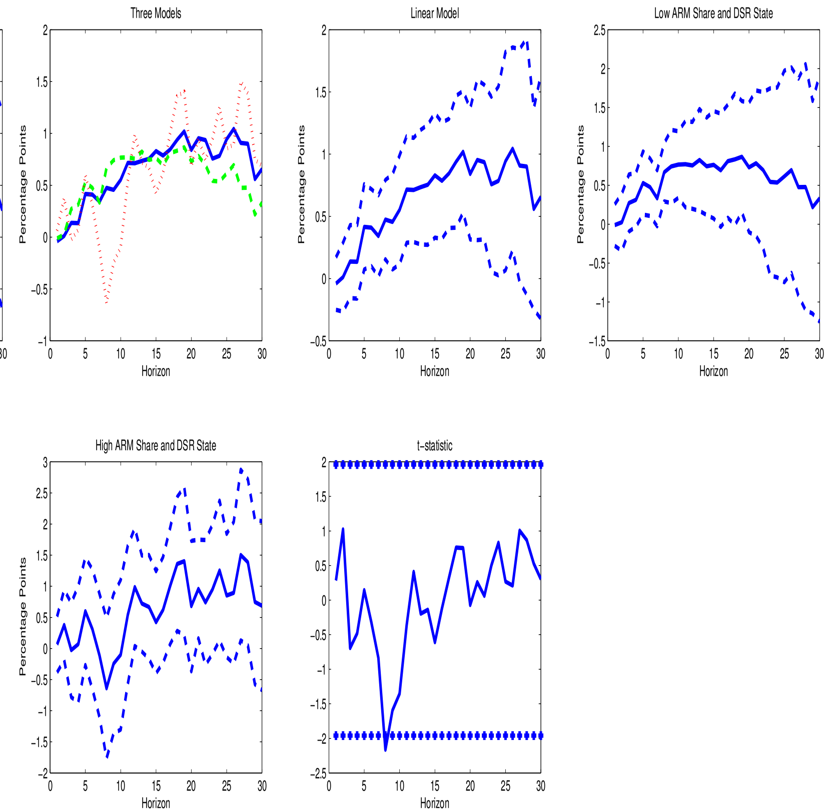


Notes: This figure presents the impulse responses of the Chicago Fed non-financial leverage subindex to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states. In the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (±1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 7: **State-Dependent Effects of Credit Supply Shocks: (a) Consumer Durable Goods; (b) Consumer Non-Durable Goods**.



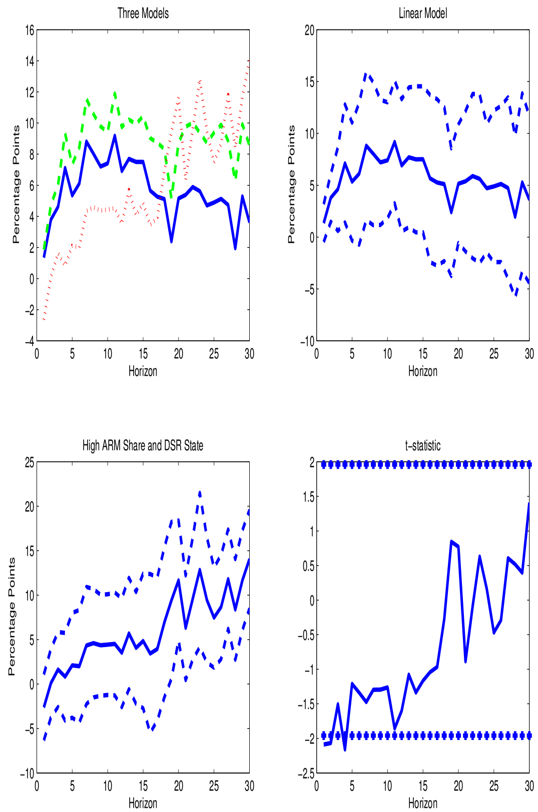
(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Consumer Durable Goods).



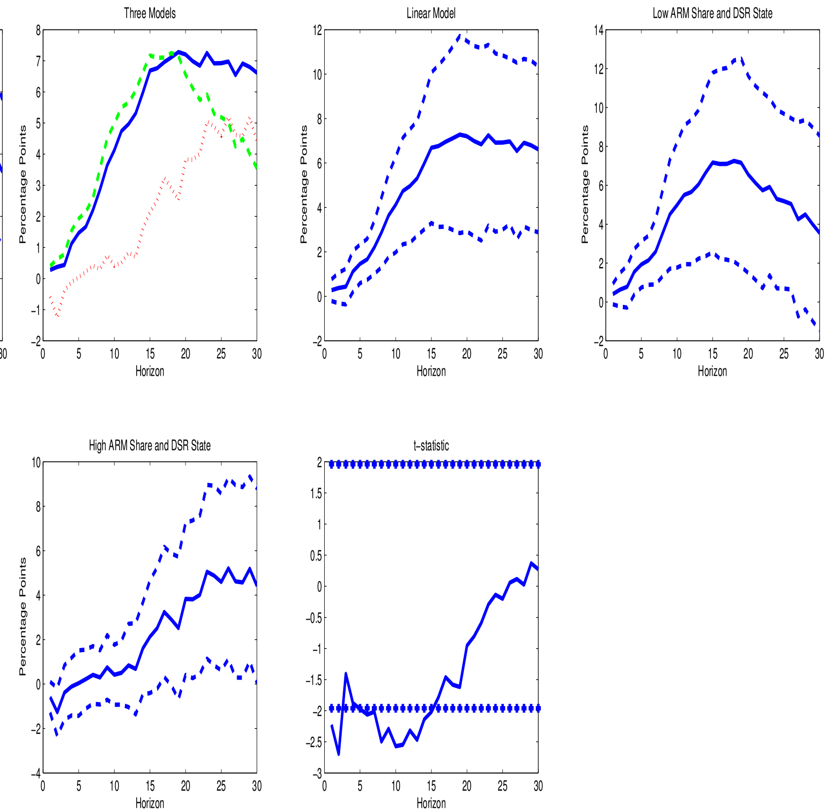
(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Consumer Non-Durable Goods).

Notes: Panel (a): This figure presents the impulse responses of industrial production of consumer durable goods to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states. Panel (b): This figure presents the impulse responses of industrial production of consumer non-durable Goods to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states. For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (± 1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 8: **State-Dependent Effects of Credit Supply Shocks: (a) Housing Starts; (b) Business Equipment Production**.



(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Housing Starts).

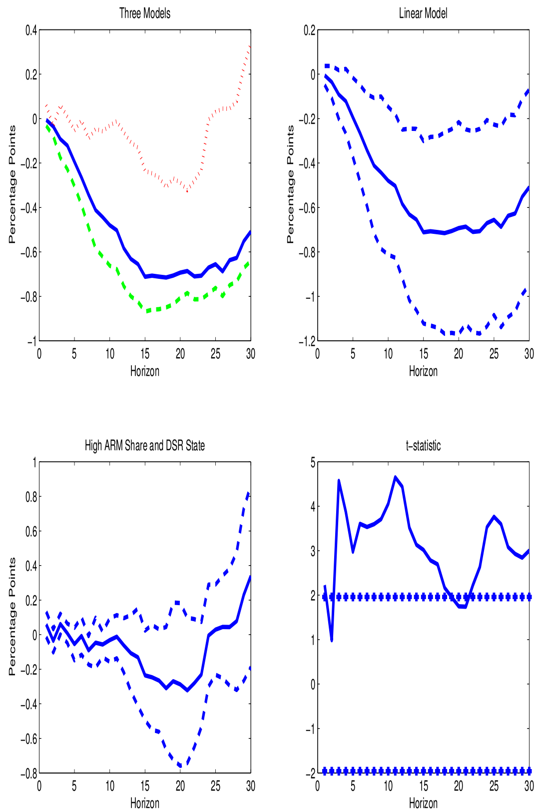


(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Business Equipment Production).

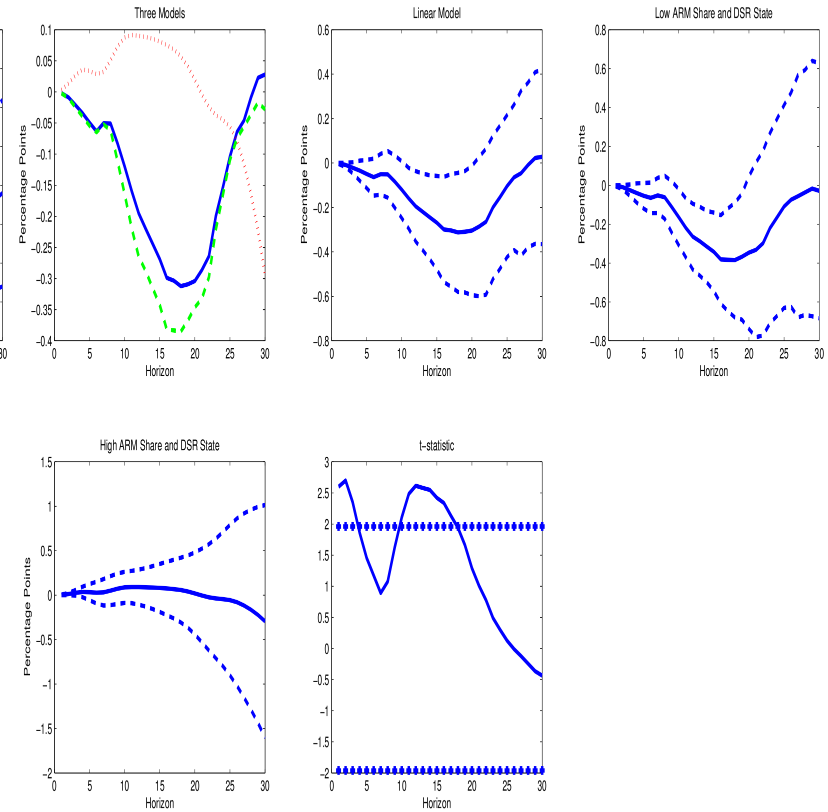
Notes: Panel (a): This figure presents the impulse responses of housing starts to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states. Panel (b): This figure presents the impulse responses of Business Equipment Production to a one standard deviation credit supply shock from the linear model and non-linear model, where in the latter the two states are the low and high ARM share and DSR level states.

For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (± 1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 9: **3-Months Lagged Moving Average of ARM Share Series: (a) Unemployment Rate; (b) Mortgage Default Rate**.



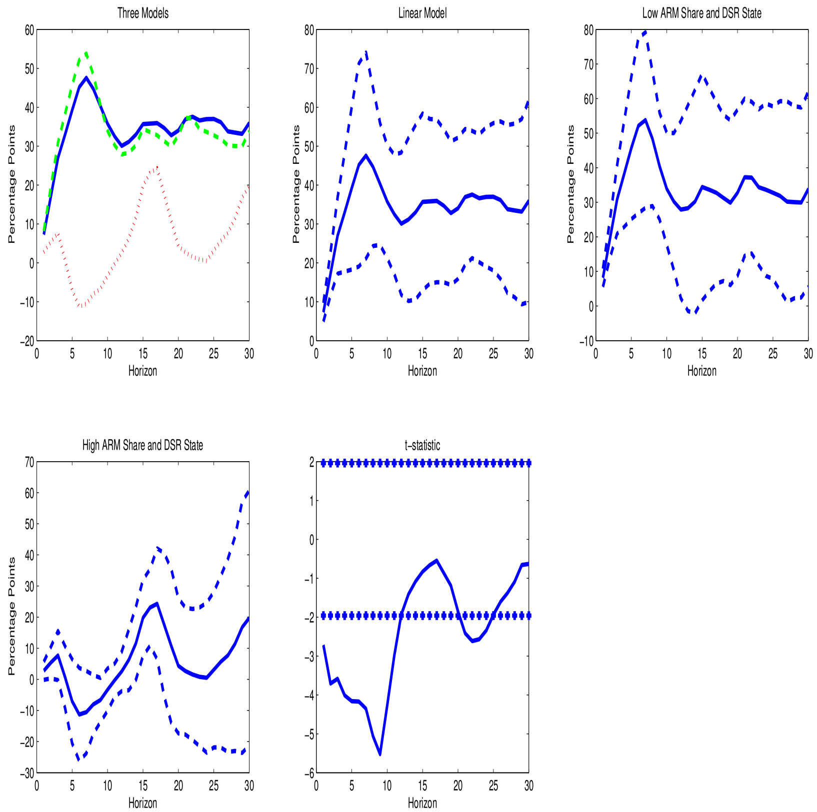
(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Unemployment Rate).



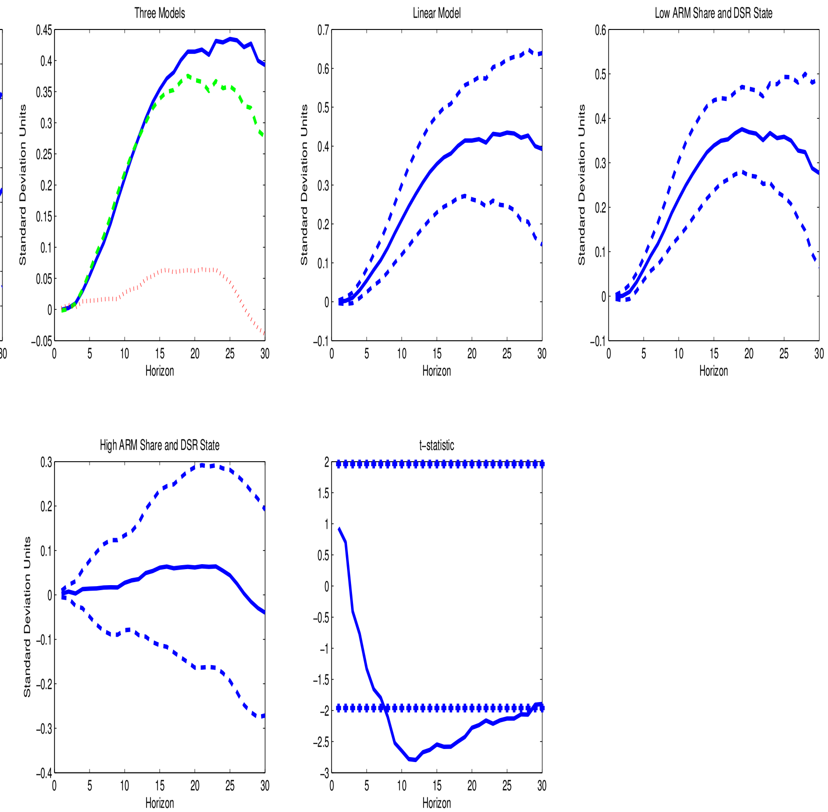
(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Mortgage Default Rate).

Notes: Panel (a): This figure presents the impulse responses of the unemployment rate to a one standard deviation credit supply shock from the linear model and non-linear model, where I_{t-1}^{ARM} takes on the value of one if the lagged 3-months moving average of the ARM share is above it median level. Panel (b): This figure presents the impulse responses of mortgage default rates to a one standard deviation credit supply shock from the linear model and non-linear model, I_{t-1}^{ARM} takes on the value of one if the lagged 3-months moving average of the ARM share is above it median level.
For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (±1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 10: **3-Months Lagged Moving Average of ARM Share Series: (a) Primary Dealers' Market Value; (b) Non-Financial Leverage**.



(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Primary Dealers' Market Value).

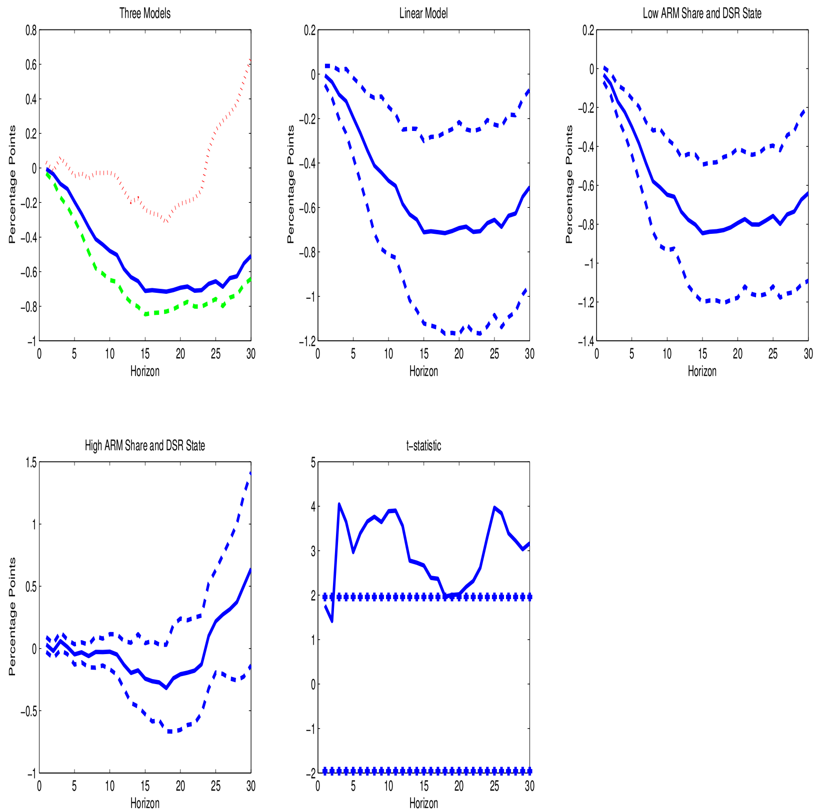


(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Non-Financial Leverage).

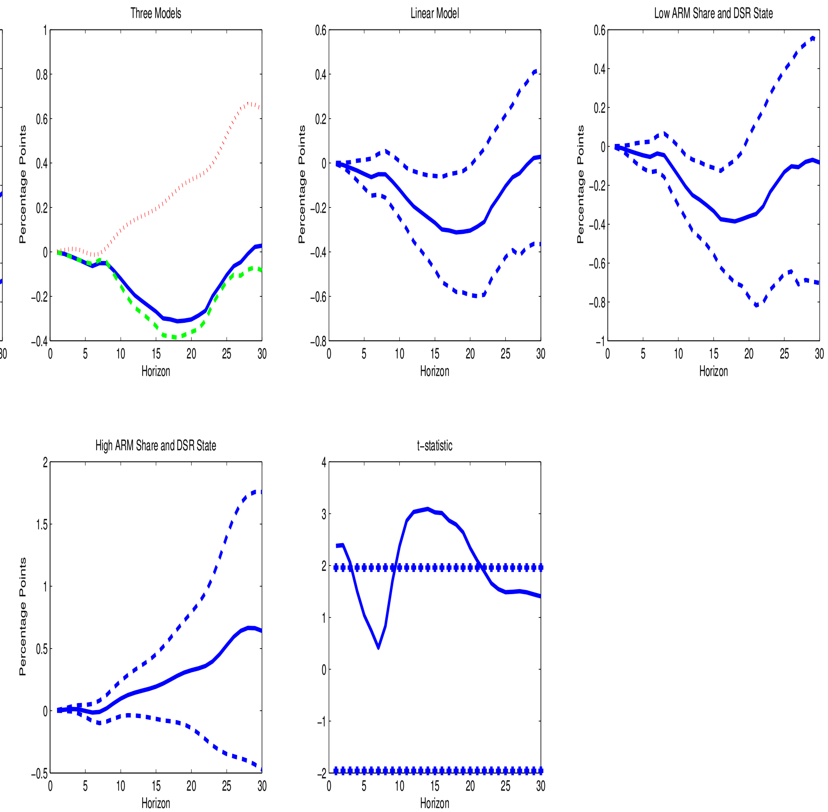
Notes: Panel (a): This figure presents the impulse responses of the He et al. (2016) primary dealers' market value series to a one standard deviation credit supply shock from the linear model and non-linear model, where I_{t-1}^{ARM} takes on the value of one if the lagged 3-months moving average of the ARM share is above it median level. Panel (b): This figure presents the impulse responses of Chicago Fed non-financial leverage subindex to a one standard deviation credit supply shock from the linear model and non-linear model, where I_{t-1}^{ARM} takes on the value of one if the lagged 3-months moving average of the ARM share is above it median level.

For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (±1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 11: **6-Months Lagged Moving Average of ARM Share Series: (a) Unemployment Rate; (b) Mortgage Default Rate**.



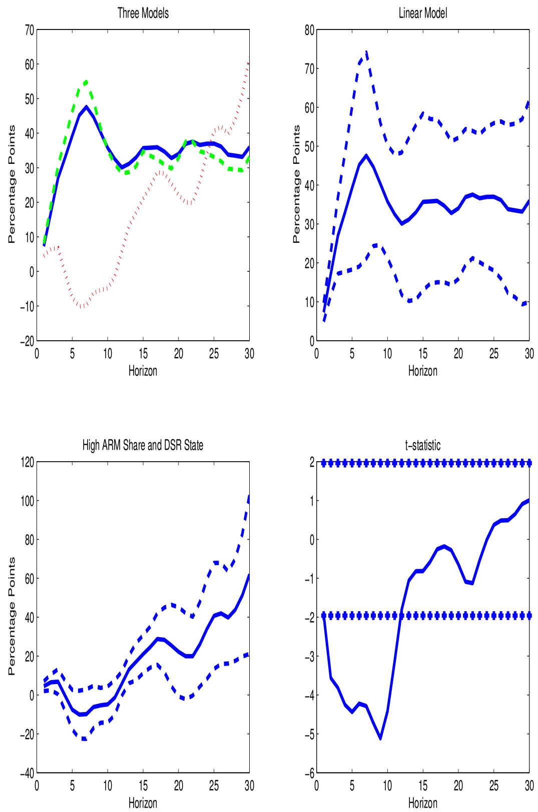
(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Unemployment Rate).



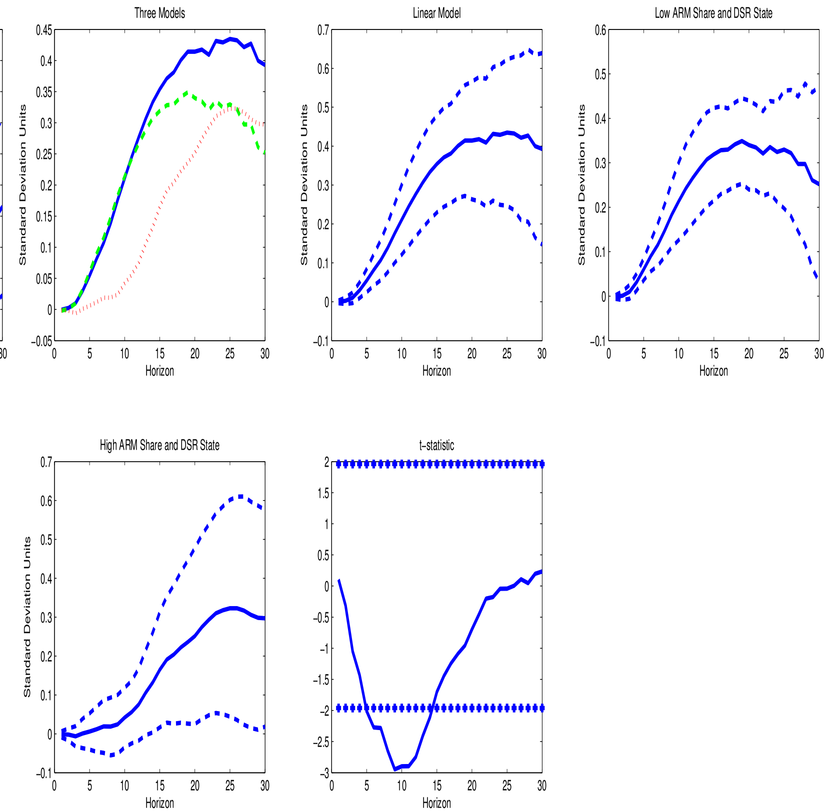
(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Mortgage Default Rate).

Notes: Panel (a): This figure presents the impulse responses of the unemployment rate to a one standard deviation credit supply shock from the linear model and non-linear model, where I_{t-1}^{ARM} takes on the value of one if the lagged 3-months moving average of the ARM share is above it median level. Panel (b): This figure presents the impulse responses of mortgage default rates to a one standard deviation credit supply shock from the linear model and non-linear model, I_{t-1}^{ARM} takes on the value of one if the lagged 3-months moving average of the ARM share is above it median level.
For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (± 1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 12: **6-Months Lagged Moving Average of ARM Share Series: (a) Primary Dealers' Market Value; (b) Non-Financial Leverage**.



(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Primary Dealers' Market Value).

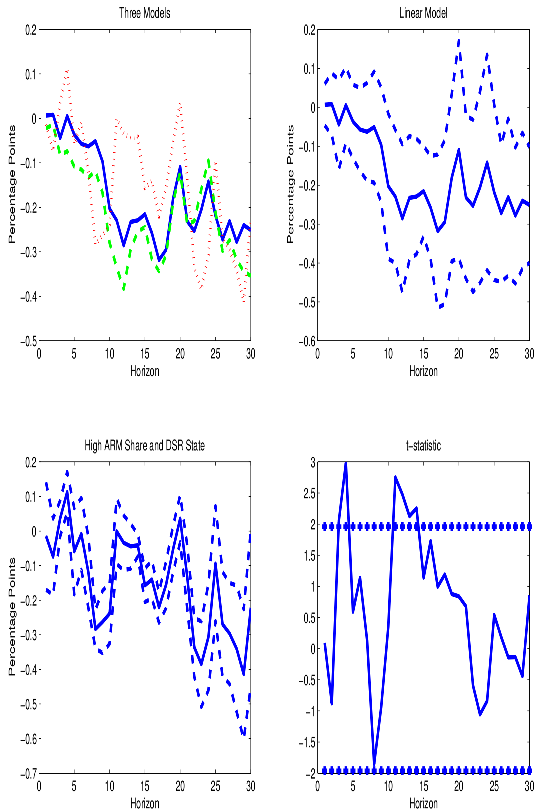


(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Non-Financial Leverage).

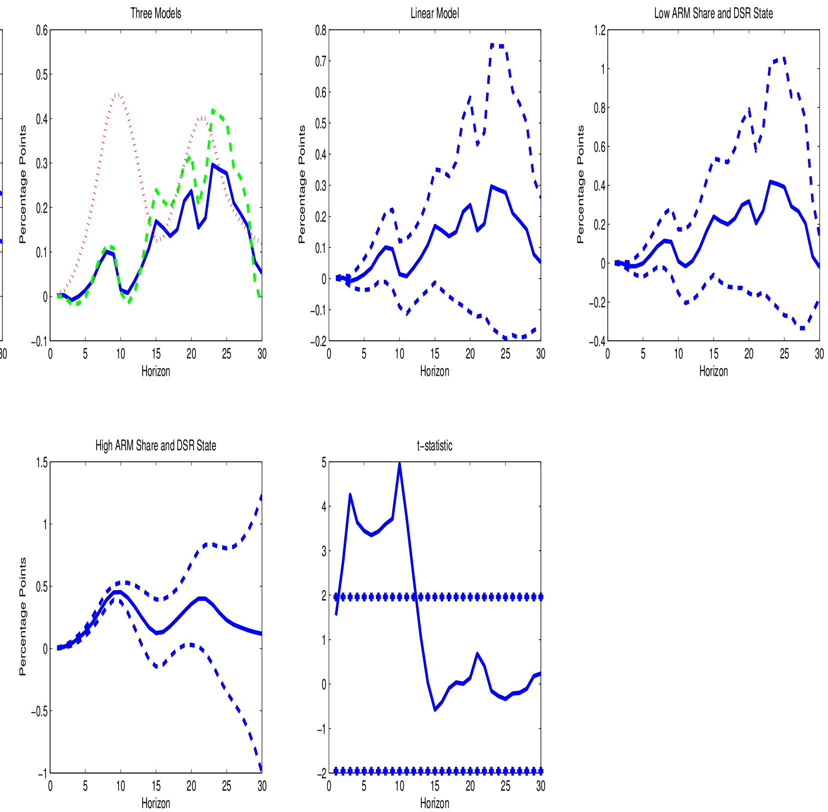
Notes: Panel (a): This figure presents the impulse responses of the He et al. (2016) primary dealers' market value series to a one standard deviation credit supply shock from the linear model and non-linear model, where I_{t-1}^{ARM} takes on the value of one if the lagged 3-months moving average of the ARM share is above it median level. Panel (b): This figure presents the impulse responses of Chicago Fed non-financial leverage subindex to a one standard deviation credit supply shock from the linear model and non-linear model, where I_{t-1}^{ARM} takes on the value of one if the lagged 3-months moving average of the ARM share is above it median level.

For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (± 1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 13: **Excluding the ZLB period: (a) Unemployment Rate; (b) Mortgage Default Rate**.



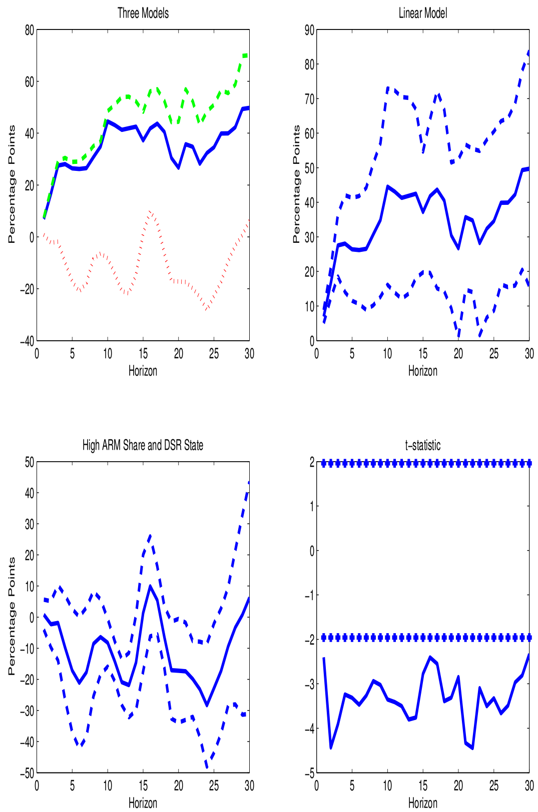
(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Unemployment Rate).



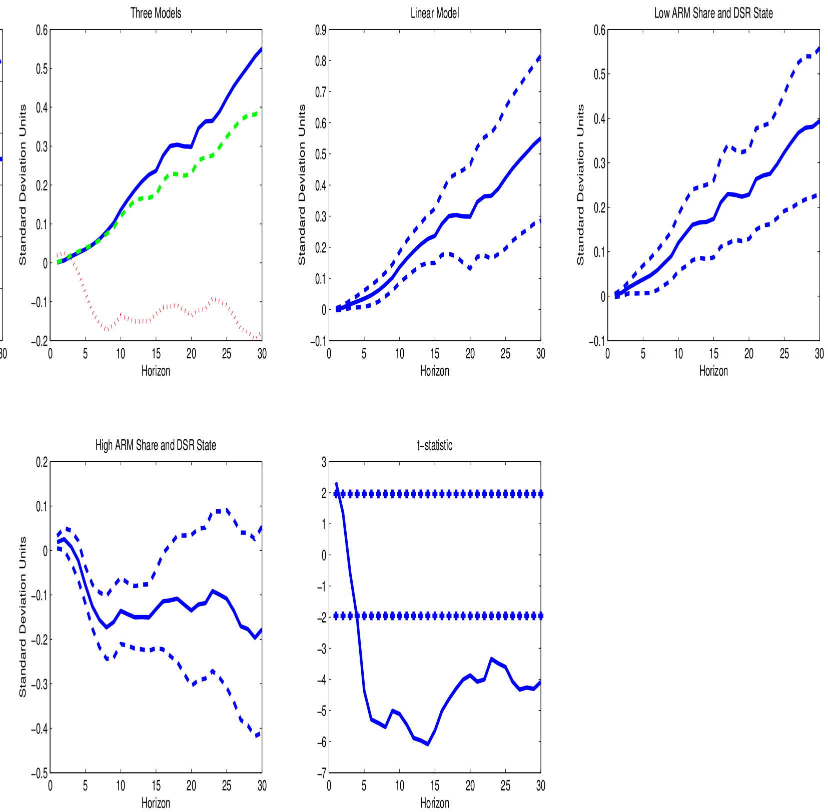
(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Mortgage Default Rate).

Notes: Panel (a): This figure presents the impulse responses of the unemployment rate to a one standard deviation credit supply shock from the linear model and non-linear model for the 1992-2008 sub-sample (2009-2013 period is excluded). Panel (b): This figure presents the impulse responses of mortgage default rates to a one standard deviation credit supply shock from the linear model and non-linear model for the 1992-2008 sub-sample (2009-2013 period is excluded).
For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (± 1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 14: **Excluding the ZLB period: (a) Primary Dealers' Market Value; (b) Non-Financial Leverage**.



(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Primary Dealers' Market Value).

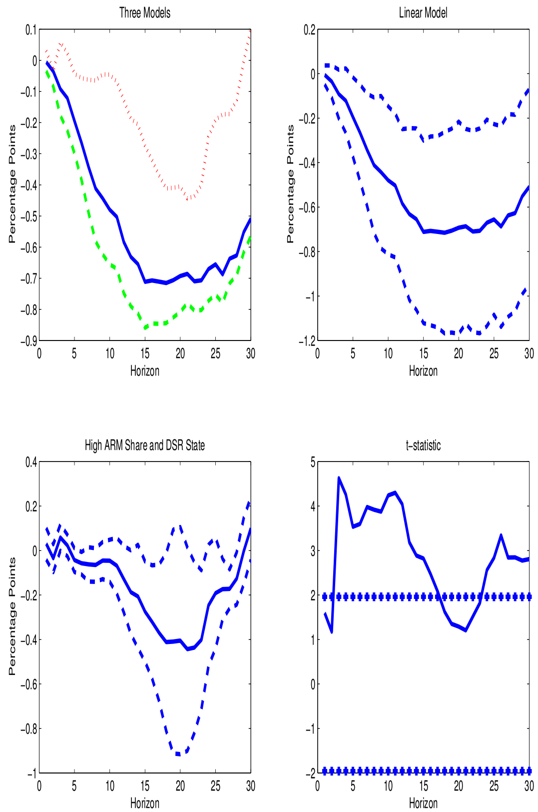


(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Non-Financial Leverage).

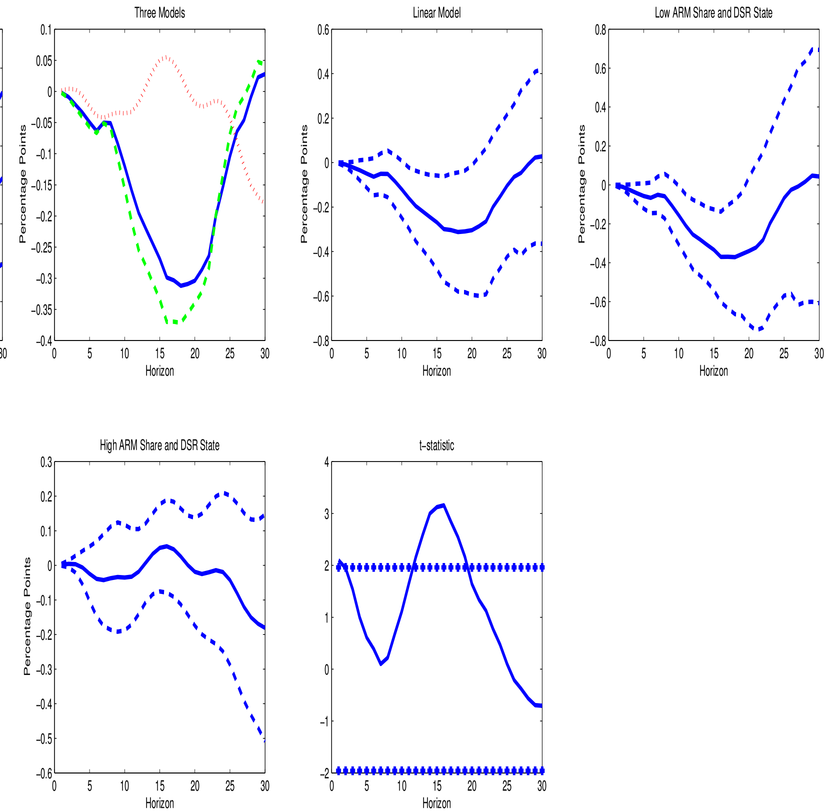
Notes: Panel (a): This figure presents the impulse responses of the He et al. (2016) primary dealers' market value series to a one standard deviation credit supply shock from the linear model and non-linear model for the 1992-2008 sub-sample (2009-2013 period is excluded). Panel (b): This figure presents the impulse responses of Chicago Fed non-financial leverage subindex to a one standard deviation credit supply shock from the linear model and non-linear model for the 1992-2008 sub-sample (2009-2013 period is excluded).

For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (± 1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 15: **1-Year ARM Share: (a) Unemployment Rate; (b) Mortgage Default Rate**.



(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Unemployment Rate).

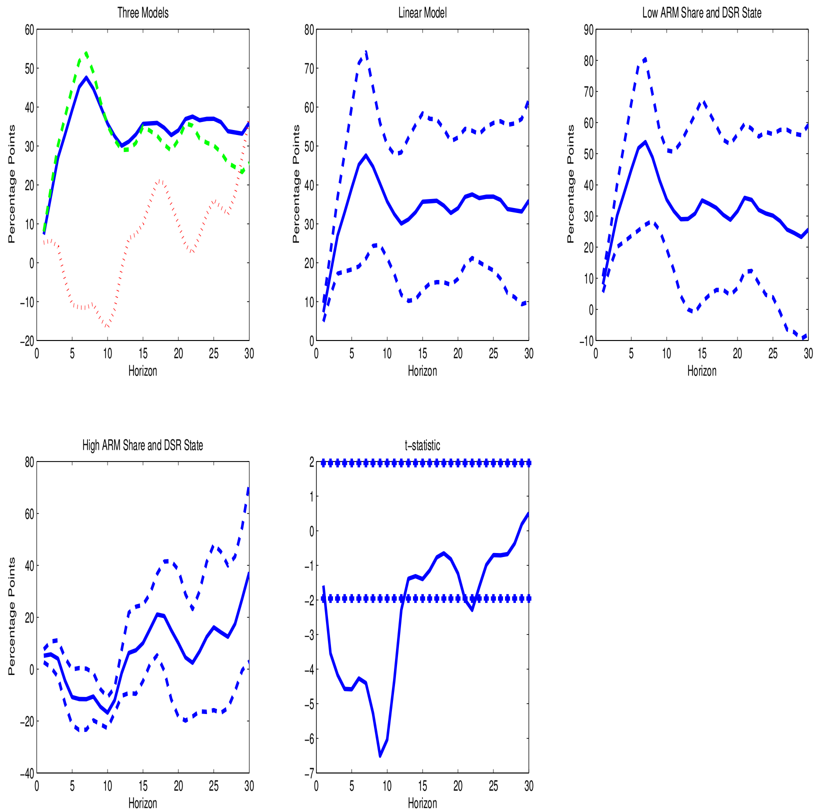


(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Mortgage Default Rate).

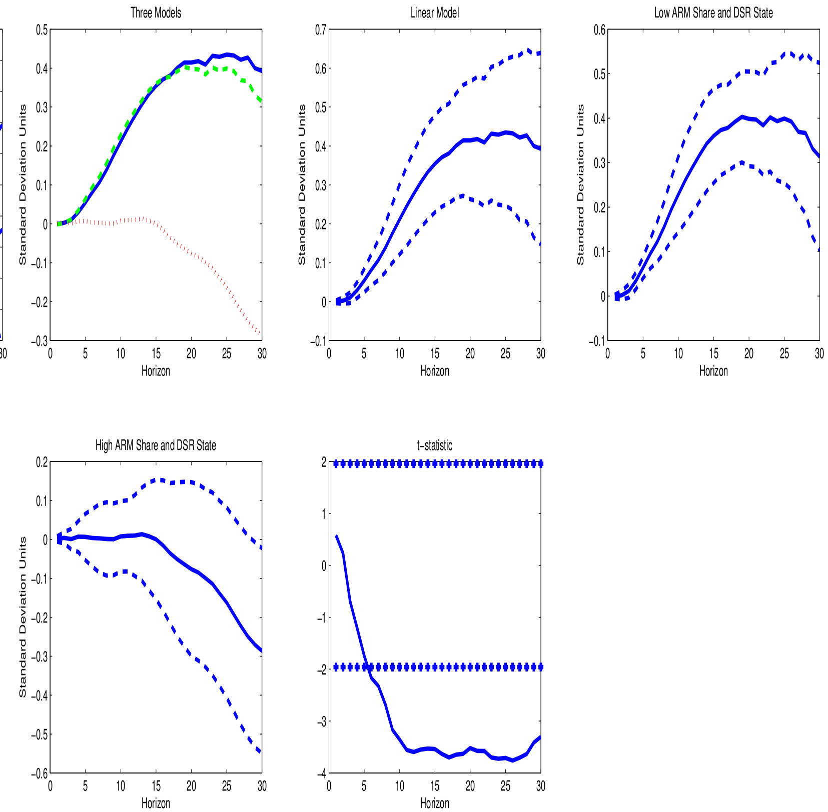
Notes: Panel (a): This figure presents the impulse responses of the unemployment rate to a one standard deviation credit supply shock from the linear model and non-linear model, where the ARM share series is based only on mortgages whose interest rate is set to reset within one year in accordance with market interest rates. Panel (b): This figure presents the impulse responses of mortgage default rates to a one standard deviation credit supply shock from the linear model and non-linear model, where the ARM share series is based only on mortgages whose interest rate is set to reset within one year in accordance with market interest rates.

For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (± 1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.

Figure 16: **1-Year ARM Share: (a) Primary Dealers' Market Value; (b) Non-Financial Leverage**.



(a) Impulse Responses to a One Standard Deviation Credit Supply Shock (Primary Dealers' Market Value).



(b) Impulse Responses to a One Standard Deviation Credit Supply Shock (Non-Financial Leverage).

Notes: Panel (a): This figure presents the impulse responses of the He et al. (2016) primary dealers' market value series to a one standard deviation credit supply shock from the linear model and non-linear model, where the ARM share series is based only on mortgages whose interest rate is set to reset within one year in accordance with market interest rates.
Panel (b): This figure presents the impulse responses of Chicago Fed non-financial leverage subindex to a one standard deviation credit supply shock from the linear model and non-linear model, where the ARM share series is based only on mortgages whose interest rate is set to reset within one year in accordance with market interest rates.
For both panels, in the first sub-figure the solid lines show the responses from the linear model, the dashed lines depict the responses in the low ARM share and DSR state, and the dotted lines are the responses in the high ARM share and DSR state. The next three sub-figures present the impulse responses from the linear model and the two states along with 95% confidence bands. The last sub-figure shows the t-statistic of the difference between the responses in the high ARM share and DSR state and the low one, where for convenience the 2.5% significance levels (± 1.96) are added. The responses are shown in terms of percentage deviations from pre-shock values. Horizon is in months.