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Francesco Ferrante and Matthias Paustian

Household Debt and the Heterogeneous Effects of Forward Guidance *

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Abstract

We develop an incomplete-markets heterogeneous agent New-Keynesian (HANK) model in which households are allowed to lend and borrow, subject to a borrowing constraint. We show that, in this framework, forward guidance, that is the promise by the central bank to lower future interest rates, can be a powerful policy tool, especially when the economy is in a liquidity trap. In our model, the power of forward guidance is amplified by three redistributive channels, absent in a representative agent new-Keynesian model (RANK) or in a HANK model without private debt. First, expected lower rates imply a future transfer of wealth from savers to borrowers, reducing precautionary motives and stimulating current demand and inflation. Second, higher initial inflation lowers the path of the real rate increasing the wealth of borrowers, who have a higher marginal propensity to consume (MPC). Third, if debt is nominal, debt deflation generates also a wealth transfer towards high-MPC borrowing-constrained agents, further increasing aggregate consumption and inflation. These channels amplify each other in a liquidity trap, and can make forward guidance more powerful in a HANK model than in a RANK framework. These results contrast with previous research on HANK models, which focused on frameworks where agents were not allowed to borrow, and which found negligible effects of forward guidance.

Keywords: HANK model, zero lower bound, forward guidance, household debt

JEL Classification: E21, E32, E52, E58

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1 Introduction

In the aftermath of the financial crisis, while short-term interest rates were constrained at the zero lower bound, many central banks have used communication about a future lower path for the policy rate as a key alternative tool. The macroeconomic effects of such forward guidance (FG) in representative agent new Keynesian (RANK) models are particularly large, and are not decreasing in the horizon of the announced cut, see Carlstrom, Fuerst, and Paustian (2015) or Del Negro, Giannoni and Patterson (2012). At the heart of this so-called "forward guidance puzzle" in RANK models is the strong role for intertemporal substitution. The consumption Euler equation prescribes that aggregate demand depends on interest rates in all future periods without discounting. Hence, all else equal, interest rate changes in the very distant future have the same effect on consumption as interest rate changes today.

A growing recent literature has examined the transmission of this type of unconventional monetary policy in New Keynesian models with heterogeneous agents and incomplete markets, widely known as HANK models.[1] The seminal paper by McKay, Nakamura and Steinsson (2016) (MNS henceforth) documents that HANK models can considerably reduce the power of forward guidance. MNS explain that the key mechanism behind their results is that, when households may become borrowing constrained in the future, the resulting dynamics for aggregate consumption mimic that of a representative agent who discounts future interest rates, a "discounted Euler equation". As a result, movements in interest rates in the future have a smaller impact on current consumption in their HANK model than in the comparable RANK model, mitigating the forward guidance puzzle.

However, a number of authors have pointed out that the aggregate dynamics in response to future monetary policy shocks in HANK models depend crucially on various auxiliary assumptions, which can either dampen or amplify the power of forward guidance. For example, Werning (2015) and Hagedorn et al. (2019) show that the results in MNS are heavily influenced by assumptions on tax progressivity and on the distribution of dividends, which do not bear any consequence in a RANK model. These assumptions imply that, in MNS, forward guidance redistributes resources towards wealthier agents with lower marginal propensity to consume (MPC), which limits the effect on aggregate demand. Furthermore, several authors use tractable versions of HANK models, with a degenerate wealth distribution, to show analytically that the power of forward guidance depends on the cyclicality of income risk (Werning (2015), Acharya and Dogra (2019), Bilbiie (2019)), of liquidity (Werning (2015)) and of inequality (Bilbiie (2019)). Consequently, quantitative

[1] Several other papers have also studied the propagation of conventional monetary policy in HANK, see, for example, Kaplan and Violante (2018), and Auclert (2019).

HANK models, in which the wealth distribution is a relevant state variable, can give different answers to the question of whether forward guidance is still a powerful tool in heterogeneous agents frameworks. Hagedorn et al. (2019) introduce wage stickiness and nominal government bonds and taxes in their HANK model, in order to minimize the redistributive channels present in MNS, and find that the impact of forward guidance in a liquidity trap is still negligible, even weaker than in MNS. On the other hand, Werning (2015) shows that in a model with extreme market incompleteness, meaning no borrowing and no public debt, forward guidance has the same impact in RANK and HANK models, if individual income moves proportionally to aggregate income. Furthermore, Farhi and Werning (2019), show that one needs both a HANK framework and bounded rationality in order to solve the forward guidance puzzle.

In this paper, we revisit the effects of forward guidance in a HANK model where households are allowed to borrow. The role of household debt positions has received surprisingly little attention in HANK models in the context of forward guidance.[2][3] In fact, MNS, Hagedorn et al. (2019), and Farhi and Werning (2019) use models with a no-borrowing constraint, so that households are savers and the borrower is the government.[4] In our framework, households borrow and lend among each others. Furthermore, we make two additional assumptions in order to minimize the impact of the non-monetary redistributive channels operating in the model of MNS. First, we assume there is no government debt, so that bonds are in zero net supply. As a result, interest rates do not directly affect the government budget constraint, and hence there are no indirect redistributive effects of monetary policy operating through taxes and transfers. Second, we use a dividend distribution scheme that prevents fluctuations in aggregate profits to have redistributive effects. We believe that this approach allows us to abstract from indirect effects of forward guidance, operating through fiscal assumptions or unrealistic profit distributions, and to focus on the heterogeneous effects of forward guidance that work through borrowing and lending and through fluctuations in interest rates, which represent more direct channels of monetary policy propagation.

Our HANK framework introduces novel amplification mechanisms for forward guidance operating through three redistributive channels. First, in our model, the news of lower future rates at time T is associated with a future transfer from savers towards borrowers, some of which are at the borrowing constraint and behave like hand-to-mouth agents. This future transfer from low MPC agents to high MPC ones, immediately reduces

[2]The role of nominal positions has been studied in other contexts, see for example Doepke and Schneider (2006).

[3]To the best of our knowledge, the only exception is Werning (2015), who derives analytical results only for a simplified model with maximum borrowing proportional to aggregate income, log-utility and zero initial bondholdings. In any case, Werning (2015) abstracts from the redistributive channels we study in this paper.

[4]MNS claim, in a footnote, that their results are little changed once households are allowed to borrow. However, as mentioned above, the results in MNS are driven by counterfactual redistributive effects due to taxes and dividends distribution.

the precautionary motives of agents who are not at the constraint, but are likely to hit the constraint in the future, stimulating aggregate demand even for $t \leq T$. We call this effect a *transfer news channel*. Second, the standard intertemporal response by unconstained agents to FG causes inflation to rise on impact, and it implies a lower path for the real interest rate which generates a further transfer of wealth towards high MPC borrowers. This channel is very similar to what Auclert (2019) defines as the *interest rate exposure channel*, which also plays an important role in accounting for the redistributive effects of conventional monetary policy. Third, when debt is nominal, unexpected inflation created by forward guidance erodes the real value of borrowers' debt, particularly boosting the consumption of constrained agents through a *debt deflation channel*. Due to the interaction between redistribution, aggregate demand, inflation and the real rate, these three channels amplify each other, igniting a positive feedback loop which can magnify the effects of forward guidance in our HANK model compared to the RANK model, especially in a liquidity trap.

We quantify the effects of forward guidance in three classes of experiments, which are helpful to study the individual impact of the three channels described above. The first type of experiment considers forward guidance specified in terms of a constant path for the real interest rate prior to a loosening of the real rate in the future (*real rate forward guidance*). By keeping real rates fixed prior to the forward guidance date, we can focus on the anticipation effect of lower future rates, and we can single out the impact of the transfer news channel by using a "transfer news shock", which only captures the effects of the foreseen redistribution from savers to borrowers. In particular, we show that this channel is particularly strong for unconstrained borrowers, who are more likely to become constrained in the future, and it can result in the effect of FG being larger in HANK than in RANK, especially for shorter forward guidance horizons. The second type of experiment considers a constant path for the nominal interest rate prior to a loosening of the nominal rate in future (*nominal rate forward guidance*). In this exercise, higher inflation feeds back into a lower real rate also in the periods preceding the forward guidance date, stimulating consumption through an intertemporal substitution channel. In our model, this mechanism, which is at work also in the RANK model, is amplified by the interest rate exposure channel, which implies higher wealth for high-MPC borrowers and stronger aggregate demand. All the experiments are performed both with real and nominal bonds, in order to illustrate the impact of the debt deflation channel, which is particularly relevant for constrained agents. Finally, the third experiment considers a scenario in which adverse demand shocks bring the economy into a liquidity trap, and studies the effects of the central bank extending the stay at the ZLB for longer than predicated by a standard Taylor rule. The three channels amplify each other in a liquidity trap, making forward guidance a very powerful monetary tool in our framework, even more than in a comparable RANK model. This result is robust to the introduction of wage stickiness, which, by limiting fluctuations in real wages, can potentially reduce the response of hand-to-mouth agents.

Related Literature: This paper is related to a recent body of work studying the effects of conventional and unconventional monetary policy in models with heterogeneous agents and incomplete market. Compared to the representative agent canon, such models feature two new elements: i) heterogeneous MPCs and ii) precautionary motives.

As regards standard monetary policy, a number of papers have stressed the importance of MPC heterogeneity in shaping the aggregate response to monetary shocks. Kaplan et al. (2018) show how the transmission of monetary policy differs in a quantitative HANK model, with two assets with different liquidity, compared to a RANK one, because of the presence of a large fraction of wealthy hand-to-mouth agents. The behavior of these agents differs from the one of a representative agent, since they are very sensitive to changes in labor income but do no respond to interest rate changes through intertemporal motives. Auclert (2019) stresses that differences in marginal propensities to consume across agents imply that redistribution matters for the effect of monetary policy on aggregate quantities. In particular, he shows that the transmission of monetary policy operates via three redistributive mechanisms. First, an earnings heterogeneity channel reflecting that agents are affected differently by changes in labor and profit earnings. Second, a Fisher channel whereby unexpected inflation revalues net nominal debt positions, transfering resources from savers to borrowers. And finally, an interest rate exposure channel, since a monetary policy loosening redistributes away from agents with positive unhedged interest rate exposures (like the savers in our model) and towards those with negative interest rate exposures (like the borrowers in our model). Auclert (2019) shows that these re-distributive channels can amplify the effects of an expansionary monetary policy shock if the winners have a higher MPC than the losers, as it seems to be the case in the data.[5] Our main result of amplification via heterogeneity is consistent with the findings in Auclert (2019), as we show that the Fisher channel and the interest rate exposure channel, together with our novel transfer news channel, also strengthen the impact of forward guidance.

When we move to consider the question of whether forward guidance is a powerful monetary tool in HANK models, the literature offers a variety of answers, sometimes contrasting with each other. As we mentioned above, MNS were the first to consider HANK models for a possible solution to the forward guidance puzzle present in the canonical RANK model. Their intuition is that the likelihood of becoming constrained in the future effectively implies a shorter planning horizon, introducing discounting in the Euler

[5] Debortoli and Gali (2018), provide additional insights on the propagation of monetary shocks in HANK models by employing a more tractable two agent New Keynesian model (TANK), with constrained and unconstrained agents.

equation of unconstrained agents and hence dampening the strong intertemporal substitution motive at the heart of the strong power of FG in RANK frameworks.

On the other hand, Werning (2015) shows that for a simple HANK economy with no borrowing or lending and with household income proportional to aggregate income, the reaction of aggregate consumption to interest rates can be modeled according to a standard representative-agent Euler equation, "as if" markets were complete. In addition, Werning (2015) suggests that whether HANK models amplify or dampen the effect of forward guidance depends on the cyclicality of income risk, affecting precautionary motives, and on the cyclicality of liquidity, affecting households' ability to self-insure. In MNS, the assumptions on dividend distribution imply that income risk is procyclical, and the assumptions on government bonds supply and on the borrowing constraint imply that liquidity is countercyclical. As a result, aggregate consumption is less sensitive to interest rates. However, a model with countercyclical unemployment risk, or with procyclical liquidity, could potentially overturn this result. A related point is raised by Bilbiie (2019), in the context of a tractable two-agents HANK model (THANK), who shows that the impact of current and future monetary policy crucially depends on the cyclicality of inequality, that is the income difference between constrained and unconstrained agents, and on the cyclicality of risk, that is the probability of becoming constrained. Acharya and Dogra (2019) build a highly stylized and tractable heterogeneous agent framework, a pseudo representative agent New Keynesian model (PRANK), without differences in marginal propensities to consume, and focus on the role of the cyclicality of uninsurable risk in solving New Keynesian paradoxes. In line with Werning (2015), they find that forward guidance is less powerful than in the RANK model only if income risk is sufficiently procyclical. If instead, income risk is countercyclical heterogeneity exacerbates the forward guidance puzzle. Our findings are consistent with the analytical results obtained in the tractable models used in these papers. The redistributive channels introduced by household debt imply that income risk decreases with future expansionary monetary policy, as the gap between the total income of savers and borrowers narrows, reducing precautionary motives and strengthening the power of forward guidance. Our framework is directly comparable with the setting in MNS and it allows for a richer quantitative analysis than the analytical setting in Bilbiie (2019) or Acharya and Dogra (2019).

Hagedorn et al. (2019) use a quantitative HANK model and maintain the assumption of a zero borrowing limit for households. They depart from MNS along two dimensions. First, they introduce wage stickiness in order to reduce the redistributive effect of fluctuations in profits. Second they assume that government debt, and taxes, are nominal. In their framework, the effect of forward guidance is negligible. This result is partially due to the fact that higher prices, induced by forward guidance, lower the real value of government bonds, which, for precautionary reasons, are considered net wealth by households, and depress aggregate demand. This channel counteracts the attempts of forward guidance to increase prices and results in relatively stable real interest rates, thereby preventing a strong intertemporal substitution effect.[6] The solution of the forward guidance puzzle proposed by Hagedorn et al. (2019) hence hinges on the fiscal assumptions regarding the supply of government debt, which play no role in our model. Furthermore, in the framework of Hagedorn et al. (2019), in which households are not allowed to borrow, debt deflation has an opposite effect compared to our model, since higher inflation reduces the real supply of government bonds, which are used for self-insurance purposes by households.[7] In the last part of our paper, we introduce wage rigidities as in Hagedorn et al. (2019), and we find that while the impact of FG in a liquidity trap is reduced both in the RANK and in the HANK model, the effect in HANK is still sizeable and larger than in RANK.

Another possible solution to the forward guidance puzzle is provided by Farhi and Werning (2019), who introduce bounded rationality, in the form of level-k thinking, in a HANK model. Their main message is that it is the interaction of market incompleteness and limited rationality which effectively mitigate the forward guidance puzzle, while each factor in isolation would not be enough. Compared to our paper, the work by Farhi and Werning (2019) abstracts from households' borrowing and does not study the power of FG in a liquidity trap.

To summarize, our paper shows that redistributive effects, linked to private debt holdings, are a key determinant of the aggregate impact of forward guidance in a HANK framework; and that taking into account these channels can make forward guidance in HANK models more powerful than in RANK models, in contrast to some previous literature. Hence, redistributive effects not only amplify the impact of conventional monetary policy, as highlighted by Auclert (2019), but they are also important for the transmission of unconventional policy actions.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 presents different types of forward guidance experiments. Section 4 concludes.

2 Model

Our modeling framework is very close to the one used by MNS, and features households' uninsurable income risk, borrowing constraints and nominal rigidities. The main difference between our model and the setup of MNS, where agents are subject to a no-borrowing constraint, is that we allow agents to borrow through one period risk-free debt, subject to a positive borrowing constraint.

[6] The implications of this mechanism are explained more in detail in Hagedorn (2018a, 2018b).

[7] Given that higher inflation reduces households' ability to self insure, one could interpret the result in Hagedorn et al. (2019) as an instance of countercyclical liquidity, as suggested by Werning (2015).

Furthermore, as we explain more in detail below, we depart from MNS also with respect to their assumptions regarding the aggregate availability of liquidity and the distribution of dividends. As pointed out by Werning (2015) and Hagedorn et al. (2019), the results in MNS are likely driven by the redistributive effects caused by fluctuations in taxes and profits in response to forward guidance. In particular, MNS assume: i) a fixed stock of government debt, financed by levying taxes only on high productivity agents; ii) profits, arising from monopolistic competition, equally distributed across agents in lump sums. Because of these assumptions, forward guidance produces a redistribution of wealth from high MPC agents towards low MPC households: lower interest rates imply lower returns on savings but also a lower debt servicing cost for the goverment and consequently lower taxes for low MPC agents; in addition, the positive effect of forward guidance on real wages implies a decline in dividends that hits disproportionately the agents with low productivity. As a result of these redistributive forces, forward guidance produces only small effects on aggregate demand in the MNS model.

In order to abstract from these confounding effects, we make assumptions aimed at minimizing indirect redistributive effects that can drive the relative power of forward guidance within an HANK model compared to its RANK counterpart. First, we assume that there is no supply of public debt, so that there is no role for fiscal policy in our model. Second, we assume that dividends are distributed lump sum but proportionally to agents' individual labor income.[8] As a result, fluctuations in aggregate income, wages plus dividends, have minimal impact on the distribution of individual non-financial income. Using the terminology of Werning (2015), we can think of household non-financial income risk as being "acyclical". Given these assumptions, we can focus on the redistributive channels of forward guidance that operate only through fluctuations in interest rates, which is the main tool of monetary policy.

2.1 Households

The economy is populated by a continuum of households deriving utility from consumption and leisure, according to

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_{j,t}, l_{j,t}\right) = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_{j,t}^{1-\sigma}}{1-\sigma} - \frac{l_{j,t}^{1+\varphi}}{1+\varphi}\right] \quad (1)$$

where $c_{j,t}$ is consumption of household j at time t and $l_{j,t}$ is labor supply. Households receive idiosyncratic labor productivity $z_{j,t}$ which follows a Markov chain with transition probabilities $P\left(z_{j,t+1}, z_{j,t}\right)$. Households can borrow and lend using a risk-free one-period bond, $b_{j,t+1}$, subject to a borrowing constraint. The

[8] A similar assumption is used in Fahri and Werning (2019).

value function of household j can be written recursively as

$$V_t(b_{j,t}, z_{j,t}) = \max_{c_{j,t}, l_{j,t}, b_{j,t+1}} \left\{ U(c_{j,t}, l_{j,t}) + \beta \sum_{z_{j,t+1}} \Pr(z_{j,t+1}, z_{j,t}) E_t V_{t+1}(b_{j,t+1}, z_{j,t+1}) \right\}$$

subject to

$$c_{j,t} + b_{j,t+1} \leq z_{j,t} l_{j,t} W_t + R_t^b b_{j,t} + \alpha_{j,t} D_t + \tau_t(z_{j,t}) \tag{2}$$

$$b_{j,t+1} \geq -\bar{b} \text{ with } \bar{b} \geq 0 \tag{3}$$

where W_t is the real wage and D_t are aggregate profits, and R_t^b is the realized gross real interest rate on bonds. In all our experiments we are going to compare the results obtained with either real bonds, for which $R_t^b = R_{t-1}$, the realized real rate; or with nominal bonds, in which case $R_t^b = \frac{i_{t-1}}{\pi_t}$, where i_t and π_t represent the gross nominal rate and inflation rate respectively. Equation (3) represents the borrowing constraint, which depends on the parameter $\bar{b}$. Each household receives a share $\alpha_{j,t}$ of aggregate profits and, as we will describe more in detail below, we will assume that this fraction is proportional to the household's labor income. Finally, $\tau_t(z_{j,t})$ represent lump sum taxes levied by the government, and potentially depending on households' individual productivity. As we mentioned above, and unlike the framework used by MNS, we will assume that bonds are in zero net supply, implying that taxes will play no role in our model.

The first order conditions for bond holdings and labor supply are given by

$$c_{j,t}(b_{j,t}, z_{j,t})^{-\sigma} = \mu_{j,t} + \beta E_t R_{t+1}^b \sum_{z_{j,t+1}} \Pr(z_{j,t+1}, z_{j,t}) c_{j,t+1}(b_{j,t+1}, z_{j,t+1})^{-\sigma} \tag{4}$$

$$z_{j,t} W_t (c_{j,t}(b_{j,t}, z_{j,t}))^{-\sigma} = (l_{j,t}(b_{j,t}, z_{j,t}))^{\varphi} \tag{5}$$

$$\mu_{j,t}\left(b_{j,t+1} + \bar{b}\right) = 0 \tag{6}$$

where $\mu_{j,t}$ is the multiplier on the borrowing constraint.

2.2 Production

The final good Y_t is produced from a continuum of intermediate inputs, indexed by $h \in [0, 1]$, according to the production function

$$Y_t = \left[\int_0^1 Y_t(h)^{(\varepsilon-1)/\varepsilon} dh\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{7}$$

where $Y_t(h)$ is the production of intermediate good h.

As a result the demand for intermediate good h will be given by

$$Y_t(h) = \left(\frac{P_t(h)}{P_t}\right)^{-\varepsilon} Y_t \tag{8}$$

where $P_t(h)$ represents the price of an individual variety, and the aggregate price level P_t satisfies

$$P_t = \left[\int P_t(h)^{1-\varepsilon} dz\right]^{\frac{1}{1-\varepsilon}} \tag{9}$$

Intermediate goods are produced by monopolistically competitive producers using only labor as input, according to

$$Y_t(h) = N_t(h) \tag{10}$$

Intermediate good producers are owned by a risk-neutral manager discounting the future at rate $1/R_t$.[9] As is standard in New-Keynesian models, they can reset prices only occasionally, with probability $(1-\gamma^p)$, as in Calvo (1983). As a result, their problem will consist in choosing the price P_t^*, in order to solve

$$\max_{P_t^*} E_t \sum_{s=0}^{\infty} \gamma_p^s \left[\prod_{i=0}^{s}\left(\frac{1}{R_{t+i}}\right)\right]\left[\frac{P_t^*}{P_{t+s}} - W_t\right] Y_{t+s}^*(h) \tag{11}$$

subject to

$$Y_{t+s}^*(h) = \left(\frac{P_t^*}{P_{t+s}}\right)^{-\varepsilon} Y_{t+s} \tag{12}$$

The solution to this problem satisfies

$$\pi_t^* = \frac{P_t^*}{P_t} = \frac{\varepsilon}{(\varepsilon-1)}\frac{g_{1,t}}{g_{2,t}} \tag{13}$$

where

$$g_{1,t} = p_t^m Y_t + \gamma_p \frac{1}{R_t} E_t g_{1,t+1} (\pi_{t+1})^{\varepsilon} \tag{14}$$

$$g_{2,t} = Y_t + \gamma_p \frac{1}{R_t} E_t g_{2,t+1} (\pi_{t+1})^{\varepsilon-1} \tag{15}$$

In addition, inflation $\pi_t = P_t/P_{t-1}$ can be written as

$$1 = (1-\gamma_p)\, \pi_t^{*(1-\varepsilon)} + \gamma_p \pi_t^{(\varepsilon-1)} \tag{16}$$

[9] This assumption is also used in Hagedorn et al. (2019). We have also tried an alternative specification in which managers discount at rate β as in MNS. The results are pretty similar.

2.3 Government

As in MNS, government is assumed to run a balanced budget to keep a constant level of debt each period, $\bar{B}$,

$$\int \tau_t(z)\, d\Gamma_t(b,z) = \bar{B}(R_t - 1) \tag{17}$$

where $\Gamma_t(b,z)$ represents the distribution of households over their bond holdings and labor productivity at time t. As mentioned before, in our baseline calibration we will set $\bar{B} = 0$ in order to abstract from the redistributive effects of fiscal assumptions.

Unless otherwise specified, monetary policy follows a simple Taylor rule

$$\log(i_t) = \log(R) + \phi_\pi \log(\pi_t) \tag{18}$$

where R represents the steady state real rate.

Finally, the real interest rate satisfies the Fisher relation

$$R_t = \frac{i_t}{\pi_{t+1}} \tag{19}$$

2.4 Equilibrium

Define $\Gamma_t(b,z)$ as the distribution of households over their bond holdings and labor productivity at time t. Then the equilibrium in the bond market requires

$$\int b_{t+1}(b,z)\, d\Gamma_t(b,z) = \bar{B} \tag{20}$$

Aggregate profits of intermediate firms are given by

$$D_t = Y_t - W_t N_t \tag{21}$$

where N_t represent aggregate labor demand.

Aggregate labor supply L_t is given by

$$L_t = \int z l_t(b,z)\, d\Gamma_t(b,z) \tag{22}$$

and labor market clearing requires that

$$N_t = L_t \tag{23}$$

Aggregate production will be given by

$$Y_t = N_t = L_t \tag{24}$$

Finally, aggregating over households' budjet constraints we can obtain the aggregate resource constraint

$$C_t = Y_t \tag{25}$$

where $C_t = \int c_t(b, z)\, d\Gamma_t(b, z)$, represents aggregate consumption.[10]

3 Forward Guidance Experiments

In order to highlight the redistributive channels of forward guidance in our model, we will perform several types of experiments. The first type of experiment, which we call *real rate forward guidance*, assumes that the central bank announces a decline in the real interest rate T periods in the future, while the real rate stays constant in the preceding periods. The second type of experiment, which we call *nominal rate forward guidance*, assumes that the central bank announces the same decline in the nominal rate in period t+T, but keeps only the nominal rate unchanged in preceding periods. Finally, the third type of experiment will focus on the impact of forward guidance in a liquidity trap, when current monetary policy is constrained by the zero lower bound. In all the experiments, we will compare the results obtained when using a version of the model with real bonds with one using nominal bonds.

3.1 Calibration and Solution

Apart from our assumptions on the supply of government bonds, on the distribution of dividends, and on the borrowing constraint, we calibrate the model exactly as in MNS, as shown in table 1. We use a value for the risk aversion parameter σ, equal to 2. The Frish elasticity of labor supply, $1/\varphi$, is set equal to 0.5. We choose a parameter for the elasticity of substitution of intermediate goods, ε, equal to 6, which implies a steady state markup of 20 percent. The Calvo parameter γ^p is set to 0.85, resulting in a 15 percent probability of resetting prices every quarter. We set the discount factor $\beta = 0.962$ in order to obtain a steady state value of the real interest rate of 2 percent annually. As in MNS, we calibrate the idiosyncratic wage

[10]Aggregate output could potentially depend also on price dispersion S_t, according to $Y_t = S_t L_t$, where S_t satisfies $S_t = \left[(1-\gamma_p)(\pi_t^*)^{-\varepsilon} + \gamma_p \pi_t^{\varepsilon} S_{t-1}\right]$. However, since we will be solving our model using linearization techniques, this second order term will not affect aggregate dynamics and we omit it in the main text. We checked that our solution approach delivers very similar results to the ones obtained in MNS, who employ a perfect-foresight nonlinear solution algorithm, for the FG experiments with a fixed path for the real rate. Small differences may appear in a liquidity trap, when price dispersion costs can become large relative to output. However, we follow Hagedorn et al. (2019), who abstract from the real impact of Rotemberg costs, in order to avoid that large price movements result in unrealistic resource costs in a liquidity trap.

risk to match the wage process estimated in Floden and Linde' (2001), by using an AR(1) process with an autoregressive coefficient of 0.966 and an innovation variance of 0.17. This process is approximated with a three states Markov chain using the Rouwenhorst (1995) method.[11] Unless otherwise specified, we use a standard Taylor rule to determine the nominal interest rate, according to $\log i_t = \log R + \phi \log \pi_t$, with $\phi = 1.5$.

As mentioned above, we depart from MNS with respect to three assumptions. First, we allow households to borrow, by setting a value for the borrowing constraint, $\bar{b} = 1.3$, that is equal to about 5 times average mothly labor income in the steady state equilibrium. This multiple was suggested by MNS as a reasonable approximation of the evidence provided by Kaplan, Violante and Weidner (2014) on the distribution of households' unsecured debt in the U.S. Second, we assume that bonds are in zero net supply, that is $\bar{B} = 0$, implying that the government does not need to levy any tax, that is $\tau_t(z) = 0$ for all z, t. As a result, we can abstract from redistributive effects linked to assumptions on tax progressivity, which are discussed by Hagedorn et al. (2019). Third, we assume that dividend distribution is proportional to labor income, that is $\alpha_{j,t} = z_{j,t} l_{j,t} / L_t$.[12] This assumption helps to avoid that fluctuations in aggregate profits might have unrealistic redistributive effects, possibly overcoming the direct effects of forward guidance, as pointed out by Werning (2015). In fact, substituting the values for $\alpha_{j,t}$, and $\tau_t(z_{j,t})$, and using the equilibrium value of dividends implied by eq. (21), we can rewrite the household's budget constraint of eq. (2) as

$$c_{j,t} + b_{j,t+1} \leq z_{j,t} l_{j,t} + R_t^b b_{j,t} \tag{26}$$

Equation (26) shows that, in our framework, the only aggregate variable directly affecting households' wealth is going to be the interest rate on bonds, R_t^b, while there is no redistributive impact from dividends or taxes.[13] As a consequence, we can abstract from assumptions on households' portfolio choices or on tax progressivity, and we can isolate the redistributive effects of forward guidance that operate only through fluctuations in interest rates, the main policy tool of the monetary authority. This calibration results in about 18 percent of agents being constrained in the model's steady state, a number close to the one obtained by MNS.[14]

We solve the model using by using the Reiter (2009) method, which combines a global solution, to determine the steady state distribution, with linearization around the steady state in order to determine the

[11] As pointed out by Hagedorn et al. (2019), MNS use values for their Markov chain that imply an aggregate productivity greater than one. We adjust slightly the values so that aggregate productivity is equal to 1 as in the complete market model.

[12] The shares $\alpha_{j,t}$ are normalized by total labor supply in order to sum up to one.

[13] Aggregate wage is still going to affect household wealth through the labor supply decision in eq. (5). Since dividends are assumed to be distributed in lump sum fashion, $\alpha_{j,t}$ does not affect households' labor supply.

[14] In addition, we obtain that in steady state 22% of agents are unconstrained borrowers and 60% of agents are savers.

dynamics of the aggregate economy. In particular, we approximate the distribution of agents over bond holdings and labor productivity, $\Gamma(b, z)$, by using a grid with 75 bins, obtained by combining 25 bins for bonds with 3 bins for productivities.[15][16]

Table 1: Calibration

Parameters	Description	Value	Target/Source
β	Discount Factor	0.96	2% annual real rate (MNS)
σ	Risk Aversion	2	MNS
φ	Inverse Frisch Elasticity	2	MNS
γ_p	Price Stickiness	0.85	MNS
ε	CES Elasticity	6	MNS
$\bar{B}$	Supply Governmnet Bonds	0	No Taxes
$\bar{b}$	Borrowing Limit	1.3	5 times avg. monthly income (MNS)
ϕ_π	Taylor rule coefficient on inflation	1.5	MNS

3.2 Real Rate Forward Guidance

In our first experiment we focus on the effects of an anticipated decline in the real interest rate in period $t+T$, with the real rate being at its steady state value in all the other periods (a similar experiment is used in MNS). For simplicity, we assume that monetary policy is characterized by an exogenous rule for the real interest rate, that is $R_t = i_t/E_t\pi_{t+1} + \varepsilon^r_{t,t-j}$, where $\varepsilon^r_{t,t-j}$ represents a shock to the real interest rate announced j periods in advance, a forward guidance shock. We consider an experiment in which the monetary authority promises a 50 basis points decline in the real interest rate T quarters in the future, that is a shock to $\varepsilon^r_{t,t-T}$.[17] We perform the experiment first with real bonds and then consider nominal monds.

[15]We have also tried to use a finer grid, which increased computational time but produced identical results. In addition, we have checked that the Reiter method allows to replicate the main results of MNS, who use a perfect-foresight nonlinear algorithm. Small differences might be present in the liquidity trap experiments, in which non-linearities can generate visible effects from price dispersion that are not captured by our solution method. However, we follow Hagedorn et al. (2019) in disregarding potentially unrealistic output effects arising from price dispersion.

[16]One advantage of this method is that it can be implemented in Dynare, sensibly reducing the computational time compared with non-linear perfect foresight algorithms. In addition, this method allows to solve for the ZLB in a relatively easy way by using, for example, the OccBin toolbox developed by Guerrieri and Iacoviello (2015).

[17]Alternatively, it is possible to replicate this experiment by using a standard Taylor rule, and by feeding a sequence of anticipated monetary policy shocks that delivers a constant path for the real interest rate until period $T-1$, and then produces a 50 basis points decline in period T. We have checked that this alternative approach delivers basically identical results.

3.2.1 Real Bonds

Figure 1 reports the response of our HANK model (solid blue line) and of the corresponding RANK model (red dotted line), to an anticipated shock one year in the future ($T = 4$), when bonds are real. As explained in detail in MNS, the Euler equation in the RANK model implies that the initial change in output is proportional, with a coefficient of $1/\sigma = 0.5$, to the expected sum of future real rate changes. As a result, output is 0.25% higher than in steady states for any period preceding $t+T$. The path of output in our HANK model, the solid blue line, is slightly higher than in the RANK model. To understand this result it is useful to look at the blue dashed line, which represents the contribution of the ”transfer news shock” implied by the forward guidance experiment in our HANK framework, that is the implied transfer, from savers to borrowers, generated by the decline in the realized real rate at time $t + T + 1$.[18] As we see from figure 1, the transfer from low MPC agents towards high MPC agents in the fifth quarter generates a spike in output. Furthermore, such transfer reduces agents precautionary motives at time 0, resulting in an increase in output also on impact and in the preceding periods. We call this mechanism amplifying the effects of forward guidance, which is absent in the RANK model or in HANK models without household debt, the *transfer news channel*. Figure 2, presents the same experiment for a forward guidance horizon of $T = 20$. In this case the path of output of HANK is slightly above the one for RANK after period 10, but the impact response in HANK is slightly smaller. The impact of the transfer news shock is fairly similar.

In figure 3, we extend this experiment to multiple horizons, and we report the impact responses of output and inflation. As was suggested by figure 1 and 2, the output response is larger for the HANK model at shorter horizons, but it becomes weaker than the RANK when forward guidance pertains horizons more than 10 quarters in the future. It has to be noted that forward guidance appears to be quite stronger in our model compared to the framework of MNS (green dotted line), both because of the absence of redistributive effects of dividends and taxes, negatively affecting poor households, and because of the presence of the transfer news channel. On the other hand, given that inflation depends on the sum of future marginal costs in both types of models, we have that its impact response is increasing in the forward guidance horizon. However, in this experiment the behavior of inflation has no bearing on output dynamics, since the path of the real rate is fixed in all the experiments.

In order to investigate further the determinants of the downward sloping blue line generated by our model, figure 4 presents the time zero impact on the aggregate consumption of constrained borrowers, unconstrained

[18] To implement this type of shock, we simply feed into the model a lump sum transfer, $\tilde{\tau}_{i,t}$, proportional to the value of agents' outstanding debt in order to capture each agent's exposure to the change in the realized real rate at time $t+T+1$, that is $\tilde{\tau}_{i,t+T+1} = \varepsilon^{T}_{t,t-T} b_{i,t+T}$, where $\varepsilon^{T}_{t,t-T}$ represents the change in the real rate implied by forward guidance.

borrowers and unconstrainted savers, when considering either the forward guidance shock or the transfer shock.[19] The left panel shows how the three groups react very differently to the FG shock for shorter horizons. Unconstrained borrowers react more than the RANK model. Savers' initial response is quite close to RANK, whereas the response of constrained agents is somewhere in the middle. To understand what drives the differential response of each group, it is useful to consider the impact of the implied transfer news shock, reported in the right panel of figure 4. In addition to the standard intertemporal motive, in our model, lower future interest rates stimulate the demand of unconstrained agents by reducing precautionary motives. In fact, lower real rates imply a future transfer from savers towards borrowers (constrained and unconstrained), who are the agents with a higher likelihood of becoming constrained and with a higher MPC. As a result, borrowers react more on impact, as they are more likely to benefit from the transfer, putting upward pressure on aggregate demand. The impact response of constrained agents is mainly driven by the positive general equilibrium effect on wages, which stimulates their labor supply. The total impact on aggregate output depends on the average MPC of each group and on their share of aggregate consumption, and the right panel of figure 4 shows that the transfer shock component has an aggregate effect on output of about 0.01%.[20]

As the FG horizon extends into the future, the initial response of unconstrained savers and borrowers becomes very similar, both for the FG shock and the transfer news shock. This result is due to the fact that as $T \to \infty$, agents expect to converge to the ergodic distribution, where the expected initial bond holding is zero. Consequently, the initial bond holdings play little role for a shock occurring far in the future. However, what might be surprising is that while the aggregate effect of the transfer news shock is still positive and stable for longer horizons, the total effect of FG in the HANK model declines below the effect in the RANK model. One possible explanation for this outcome is that in our framework, and in the MNS model, the amount of borrowing allowed to constrained agents is constant at $\bar{b}$. Using the terminology proposed by Werning (2015), we can say that the total amount of liquidity in the economy is countercyclical, since it expands and contracts less than output. As suggested by Werning (2015), countercyclical liquidity can hamper the effect of FG as some agents might not be able to smooth consumption in response to an expected future higher income, due to the future lower rates, because of the constant borrowing limit. Consequently, the expected probability of becoming constrained might increase, reducing the time zero consumption response of unconstrained agents. To check this intuition, we perform the same experiment in an alternative version of the model in which the borrowing constraint scales proportionally to aggregate income, that is where

[19] Savers and borrowers are classified according to their end of period bond holdings in steady state. Very similar results are obtained if we use the initial bond holdings instead.

[20] With our calibration, in steady state constrained borrowers account for about 7% of total consumption, unconstrained borrowers account for about 18%, and savers account for the remaining 75%.

agents can borrow up to $\bar{b}\frac{Y_t}{Y_{ss}}$. Quoting again Werning (2015), this setup should correspond to a world in which liquidity is acyclical. The implied impact effects of FG on output and inflation are represented by the blue dash-dotted line in figure 3. In this case, the impact of FG is larger in HANK for all the horizons, and it is slightly increasing with T. These results are due to two new effects. First, when output expands, because of a higher demand by unconstrained agents, it also relaxes the borrowing constraint of high-MPC constrained agents, boosting their consumption for all the periods preceting $t + T$. Second, the larger T, the longer the expansion in output and the longer the period over which the borrowing constraint is being relaxed, generating an increasing attenuation in agents' precautionary motives.[21] In the rest of the paper, we will maintain the setup with a constant borrowing constraint, as it is standard in most Bewley-Ayagari models. It is beyond the scope of this paper to provide a realistic modeling of the cyclicality of liquidity. Furthermore, as shown in figure 3, eliminating countercyclical liquidity would only amplify our results.

The main objective of this section was to highlight the presence, especially at shorter horizons, of a transfer news channel in a HANK model with private debt, and to show that real rate FG is stil powerful in our setup. This new channel could be even more powerful in a model with larger income risk or with procyclical liquidity.[22]

3.2.2 Nominal Bonds

We now perform the same real rate FG experiment assuming that bonds are nominal. Figure 5 compares the horizon effect of forward guidance for real bonds (as reported in figure 3) and nominal bonds (the dashed black line). With nominal bonds the impact of FG becomes clearly increasing in the horizon of the announcement. This effect is due to the fact that the increasing impact of FG on inflation, a feature shared with MNS, now translates in an increasing transfer towards borrowers at time zero, through a *debt deflation channel*. Figure 6 decomposes the impact effect between savers and borrowers. In this instance, as it can be seen from the left panel of figure 6, the upward sloping behavior of output is driven by the increasing response of constrained borrowers, who have high MPC and whose consumption reacts strongly to the unexpected transfer. The right panel of figure 6 shows how also the response of unconstrained borrowers starts increasing with the FG horizon after period 10, as the influence of the transfer news channel wanes (as shown in figure 4).

[21] In addition, the transfer news channel is amplified as well, since the higher output resulting from the redistribution of resources feeds back into a higher consumption for constrained agents.

[22] We have experimented with alternative model calibrations in which income risk is larger than in the baseline. In this case, the transfer news channel becomes stronger, increasing the gap between the output effect in the HANK model and the RANK model for short horizons.

In fact, in this experiment, the transfer news channel is still active, and it amplifies the impact of the debt deflation channel. The key takeaway of this quantitative exercise is that with nominal debt the response of inflation to FG has positive spillovers for output that increase with the FG horizon, a feature that had not been documented in previous literature.

3.3 Nominal Rate Forward Guidance

In the previous experiments, the real rate was not allowed to move endogenously in the periods preceding the announced rate decline at time T. As a consequence, inflation did not play a role for output movements, apart from the debt deflation effect obtained with nominal bonds at time zero. We now assume that the central bank holds the nominal interest rate i fixed before time T, decreases the nominal interest rate by 50 basis points at time T, and then it allows i to react according to the Taylor rule specified above for the periods following T.[23]

Figure 7 reports the results of this experiment, with $T = 12$. The output response of output in the RANK model is much larger compared to the previous experiments. This result is due to the fact that the initial spike in inflation causes a decline in the real interest rate, which, unlike the previous experiments, stays below steady state for all periods before T, stimulating aggregate demand. This effect is amplified in our HANK model since the lower real rate implies a wealth transfer from savers to borrowers, who have a higher MPC in the model. This channel is similar to the *interest rate exposure channel* described by Auclert (2019) as one of the main redistributive channels of conventional monetary policy. As we will show in the next exercises, also in the context of forward guidance this mechanism is particularly relevant in HANK frameworks.

Figure 8 looks at how the effects of nominal rate forward guidance vary with the horizon of the decline in the interest rate. In the RANK model, the initial impact on output increases exponentially with the horizon, since, as explained above, the initial jump of inflation is increasing in the horizon of FG. Furthermore, higher consumption feeds back into higher inflation, amplifying the total effect. In our HANK model, the effect is even stronger, as the redistribution through lower real rates operates for a longer time period. The right panel of figure 8 shows that unconstrained borrowers are in fact the agents reacting more on impact. At the same time, the transfer news channel and the intertemporal amplification, present also in the RANK model, are also operating, boosting the consumption of all the agents.

Finally, figure 9 reports also the results for the same type of experiment when we consider nominal

[23] A similar experiment has been performed also by Calstrom et al. (2015) and Farhi and Werning (2019).

bonds. As expected, the output response is stronger than the case with real bonds, since the debt deflation channel augments the positive effects of low inflation. The channels discussed in this section are going to be helpful to interpret the results of our third type of experiment, in which the nominal rate is fixed at the zero-lower-bound for a certain number of periods and the central bank promises to keep it low even longer in order to stimulate the economy.

3.4 Forward Guidance in a Liquidity Trap

Forward guidance is a key policy tool when the current policy rate is constrained by the zero-lower-bound. In this section, we study the power of forward guidance in a liquidity trap. Figure 10 considers an experiment in which the discount factor β increases for a known number of periods, before reverting to its steady state value, causing the nominal interest rate to hit the ZLB.[24] In the baseline experiment, the nominal rate is governed by the standard "naive" Taylor rule, responding only to inflation, employed in the previous exercises. The path of the discount factor is calibrated to obtain a ZLB episode of eight quarters and a 4% decline in output both in the RANK model (solid red line), in the HANK model with real bonds (solid blue line), and in the HANK model with nominal bonds (solid black line).[25] The dashed line represents the behavior of the three models under an "extended" monetary policy rule which keeps the nominal rate to zero for four extra periods, as it can be see in the top left panel of figure 10.

In the RANK model, forward guidance reduces the decline in output and inflation by about two thirds. In our HANK model with real debt, the effect of the four extra periods of low rates is more powerful, with output declining only by about 0.5 percent, and inflation only by 0.25 percent. In our HANK model with nominal debt the recession is completely avoided. Hence, when private debt is introduced, in a liquidity trap forward guidance can be a powerful policy tool also in a HANK model, even more than in a standard RANK framework. This result is due to the three channels outlined above: i) a reduction in the precautionary motives of unconstrained agents, the transfer news channel, ii) a transfer of wealth towards high MPC agents through lower real rates, the interest rate exposure channel, and iii) when debt is nominal, a debt deflation channel. As the lower left panel of figure 10 shows, a key driver of the recession with the "naive" monetary policy is the spike in the real rate, which depresses aggregate demand. Through the redistributive channels present in our model, forward guidance is very effective at avoiding a large drop in inflation and at stimulating demand. Figure 11 delves deeper into the propagation of forward guidance policy in our model

[24]The same approach to study liquidity traps is used, among others, by MNS and Hagedorn et al. (2019).

[25]We exploit the linear solution of our model and we implement the ZLB by using the OccBin toolbox developed by Guerrieri and Iacoviello (2015).

by reporting the behavior of aggregate consumption for savers and borrowers. As expected, on impact the policy is particularly beneficial for borrowers' consumption, but also savers respond strongly because of the intertemporal channel operating through lower real rates.

Another indirect channel, through which monetary policy operates in a HANK model, is by affecting agents' wealth through real wages and dividends. In figure 10 we see how real wages experience large fluctuations in a liquidity trap. With flexible wages, dividends move in the opposite direction. As a result FG can cause a large decline in dividends by stimulating demand and real wages. When dividends are distributed lump sum, as in MNS, the negative impact of FG on profits can disproportionately affect high MPC agents, resulting in a much weaker effect of forward guidance in a liquidity trap (see Werning (2015)). As shown in eq. (26), our assumptions on dividends distribution imply that there is no direct redistributive effect of either profits or wages.[26] However, wage fluctuations still affect individual labor supply decisions (see eq. (5)). Potentially, the labor supply of constrained agents, who have high MPC, could be more responsive to changes in the real wage.[27] In the real rate FG experiments with real bonds, constrained agents benefit from lower future rates only because of the general equilibrium effect on wages. As a result, one might wonder whether the power of forward guidance in our HANK framework would be greatly reduced with the introduction of sticky wages. Hagedorn et al (2019) introduce sticky wages in their framework in order to reduce the redistributive effects of labor income and in order to minimize fluctuations in dividends. In particular, they assume that each household provides differentiated labor services to a union, which sells these services to a labor packer. The labor packer combines them into aggregate effective labor using a standard CES technology, with elasticity of substitution ε^w. Unions set the nominal wage for an effective unit of labor in order to maximize their profits subject to quadratic adjustment costs a la Rotemberg (1982). These costs are given by $\frac{\theta^w}{2}\left(\pi_t^w - \bar{\pi}^w\right)^2$, where π_t^w is wage inflation, and are proportional to aggregate hours. The solution to the unions' problem delivers a familiar wage Phillips curve[28]

$$\theta^w \left(\pi_t^w - \bar{\pi}^w\right) \pi_t^w = \left(1 - \varepsilon^w\right) W_t + \varepsilon^w \frac{L_t^{\varphi}}{C_t^{-\sigma}} + \theta^w E_t \frac{1}{R_t} \left(\pi_{t+1}^w - \bar{\pi}^w\right) \pi_{t+1}^w \frac{L_{t+1}}{L_t} \tag{27}$$

A key assumption in Hagedorn (2019) is that, when setting wages, unions take into account the aggregate marginal rate of substitution between aggregate labor and aggregate consumption, $\frac{L_t^{\varphi}}{C_t^{-\sigma}}$, implying that all households supply the same amount of labor at all times. Consequently, when we introduce wage stickiness

[26]Our assumptions essentially allow us to abstract from the direct redistributive effects of what Auclert (2019) defines the earnings heterogeneity channel. According to the empirical findings in Auclert (2019), this channel should amplify even more the impact of monetary policy in HANK models.

[27]On the other hand, one must keep in mind that these are also the agents with the lowest idiosyncratic labor productivity realization, potentially reducing the elasticity of labor supply to real wages.

[28]See Hagedorn et al. (2019) for a detailed solution of the union's problem.

in this fashion in a HANK model, we are not only affecting the dynamics of the model through the standard channels of a New-Keynesian RANK model, but, by eliminating labor supply heterogeneity, we are also eliminating agent's ability to self-insure by adjusting their labor choice.[29] Despite this importante caveat, we introduce wage stickiness in the same way as in Hagedorn et al. (2019), since it is a simple way to limit wage fluctuations.[30] We calibrate $\varepsilon^w = 6$ in order to have the same markup in wages and prices, ad set the adjustment cost parameter θ^w in order to obtain the same Philips curve slope implied by the Calvo setting for price stickiness used in the previous experiments.[31] Figure 12 replicates the experiment of figure 11, by targeting the same durations of ZLB and decline in output, while assuming that wages are sticky.[32] Forward guidance is now weaker in all the three models considered, but it is still more powerful in our HANK model, where it reduces the output decline by more than half, twice as much as in the RANK counterpart.[33] One reason why FG is weaker in this experiment is that inflation, and consequently the real rate, move less, dampening the the intertemporal channel of forward guidance. In the HANK model, smaller fluctuations in wages and inflation reduce the redistribution towards constrained agents that we have described in the previous quantitative exercises. The power of the three redistributive channels in our model is still non negligible, given that FG noticeably reduces the downturn. Furthermore, we have to keep in mind that, in the setup used in figure 12, high MPC agents are not allowed to adjust their labor supply in response to changes in their wealth and consumption, introducing an additional limitation to the impacf of FG that is unrelated to wage stickiness. Summing up, even when introducing, in a simplified way, frictions in wage adjustments forward guidance remains an effective tool at the ZLB in our HANK framework.

[29] As a result, in addition to the standard wedge introduced my monopolistic competition in the unions market, wage stickiness also affects the steady state distribution by equalizing labor supply across agents. For example, with our calibration, once we introduce wage stickiness, the share of constrained agents is slightly smaller, around 16%.

[30] A similar approach is used also in Auclert, Rognlie and Straub (2018).

[31] The implied Phillips curve slope for prices a la Calvo, is given by $\frac{(1-\gamma_p)(1-\gamma_p/R)}{\gamma_p}$ and is about 0.025. As a result, the implyed θ^w is around 200. In addition, we assume that also the price Phillips curve is determined with a Rotemberg (1982) approach, with the same parameters. As in Hagedorn et al. (2019), we assume that adjustment costs are non-pecuniary.

[32] With sticky wages, in order to obtain the same decline in output and the same duration of the ZLB we need to use a discount factor shock with a shorter duration than in the experiment in figure 10, 9 periods instead of 12.

[33] In addition to the different fiscal assumptions, the comparison of our liquidity trap experiment with the one presented in Hagedorn et al. (2019) is made difficult by other factors. First, Hagedorn et al. (2019), match a quite larger slope for the Phillips curve of 0.11. In addition, for their main liquidity trap experiment they use a Taylor rule coefficient on inflation of 0.5, which makes a comparison with the RANK model impossible because of indeterminacy.

4 Conclusions

The transmission of conventional monetary policy and of forward guidance has been extensively studied in standard New Keynesian models with a representative agent. In these type of models, monetary policy operates mainly through an intertemporal substitution channel, which makes forward guidance particularly potent (Carlstrom et al. (2015), MNS). The transmission of monetary policy in models with heterogeneous agents and incomplete markets is more complex, because of the presence of precautionary motives and of heterogeneity in agents' marginal propensity to consume. Recent papers have studied how these new elements affect the propagation of conventional (Kaplan et al. (2018), Auclert (2019)) and unconventional monetary policy. In particular, a set of papers has tried to answer the question of whether HANK models dampen or amplify, with respect to the RANK framework, the aggregate effects of forward guidance (MNS, Werning (2015), Hagedorn et al (2019), Bilbiie (2019), Acharya and Dogra (2019)). This debate has so far abstracted from the redistrubition arising from the interaction between household debt and forward guidance. This paper contributes to the literature by studying the role of redistributive channels for the propagation of news on future interest rates in HANK models in which households borrow and lend.

Our main finding is that household debt introduces three redistributive mechanisms that tend to amplify the power of forward guidance in a HANK model. First, lower future rates imply a future transfer from savers to borrowers, which decreases precautionary motives. Second, higher initial inflation results in a lower path of the real rate, increasing the wealth of borrowers, who have a higher marginal propensity to consume. Third, if debt is nominal, at the time of the policy announcement debt deflation generates also a wealth transfer towards high-MPC borrowing-constrained agents, further increasing aggregate consumption and inflation. These channels amplify each other in a liquidity trap, potentially making forward guidance a powerful monetary tool in a HANK model, even more than in a RANK framework. Auclert (2019), shows that the second and the third channel are important for the transmission of standard monetary policy, both from a theoretical and an empirical perspective. We show that redistribution, and its interaction with precautionary motives, can also play an important role for the transmission of forward guidance.

Hence, our work suggests that household debt should be taken into account when evaluating the effectiveness of unconventional monetary policy in incomplete markets models. Furthermore, our results could be even stronger if debt were subject to default, or if it were collateralized by a durable asset whose price reacts to monetary stimulus, like, for example, mortgages [34]. These are all interesting topics for future research.

[34] see, for example, Kaplan, Mitman and Violante (2019)

References

ACHARYA, S., AND K. DOGRA (2019): "Understanding HANK: Insights from a PRANK," Working paper, FRB of New York.

AIYAGARI, S. R. (1994): "Uninsured idiosyncratic risk and aggregate saving," *The Quarterly Journal of Economics*, 109(3), 659–684.

AUCLERT, A. (2019): "Monetary policy and the redistribution channel," *American Economic Review*, 109(6), 2333–67.

BAYER, C., R. LÜTTICKE, L. PHAM-DAO, AND V. TJADEN (2019): "Precautionary savings, illiquid assets, and the aggregate consequences of shocks to household income risk," *Econometrica*, 87(1), 255–290.

BILBIIE, F. O. (2019): "Monetary Policy and Heterogeneity: An Analytical Framework," Working paper.

CARLSTROM, C. T., T. S. FUERST, AND M. PAUSTIAN (2015): "Inflation and output in New Keynesian models with a transient interest rate peg," *Journal of Monetary Economics*, 76, 230 – 243.

COIBION, O., Y. GORODNICHENKO, L. KUENG, AND J. SILVIA (2017): "Innocent Bystanders? Monetary policy and inequality," *Journal of Monetary Economics*, 88, 70–89.

DEBORTOLI, D., AND J. GALÍ (2018): "Monetary policy with heterogeneous agents: Insights from TANK models," Working paper.

DEL NEGRO, M., M. GIANNONI, AND C. PATTERSON (2012): "The forward guidance puzzle," Staff Reports 574, Federal Reserve Bank of New York.

FARHI, E., AND I. WERNING (2019): "Monetary Policy, Bounded Rationality, and Incomplete Markets," Discussion Paper 11.

GORNEMANN, N., K. KUESTER, AND M. NAKAJIMA (2012): "Monetary policy with heterogeneous agents," .

GUERRIERI, L., AND M. IACOVIELLO (2015): "OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily," *Journal of Monetary Economics*, 70, 22–38.

GUERRIERI, V., AND G. LORENZONI (2017): "Credit crises, precautionary savings, and the liquidity trap," *The Quarterly Journal of Economics*, 132(3), 1427–1467.

HAGEDORN, M. (2018a): “A Demand Theory of the Price Level,” Working paper.

——— (2018b): “Prices and inflation when government bonds are net wealth,” .

HAGEDORN, M., J. LUO, I. MANOVSKII, AND K. MITMAN (2019): “Forward guidance,” *Journal of Monetary Economics*, 102, 1–23.

KAPLAN, G., K. MITMAN, AND G. L. VIOLANTE (2019): “The housing boom and bust: Model meets evidence,” *Journal of Political Economics*, forthcoming.

KAPLAN, G., B. MOLL, AND G. L. VIOLANTE (2018): “Monetary policy according to HANK,” *American Economic Review*, 108(3), 697–743.

KAPLAN, G., J. WEIDNER, AND G. VIOLANTE (2014): “The Wealthy Hand-to-Mouth,” Brookings papers on economic activity, Brookings Instiution.

LE GRAND, F., AND X. RAGOT (2018): “Optimal Fiscal Policy with Heterogeneous Agents and Aggregate Shocks,” Working paper.

MCKAY, A., E. NAKAMURA, AND J. STEINSSON (2016): “The Power of Forward Guidance Revisited,” *American Economic Review*, 106(10), 3133–58.

RAGOT, X. (2018): “Chapter 4 - Heterogeneous Agents in the Macroeconomy: Reduced-Heterogeneity Representations,” in *Handbook of Computational Economics*, ed. by C. Hommes, and B. LeBaron, vol. 4 of *Handbook of Computational Economics*, pp. 215 – 253. Elsevier.

RAVN, M. O., AND V. STERK (2017): “Job uncertainty and deep recessions,” *Journal of Monetary Economics*, 90, 125–141.

REITER, M. (2009): “Solving heterogeneous-agent models by projection and perturbation,” *Journal of Economic Dynamics and Control*, 33(3), 649–665.

WERNING, I. (2015): “Incomplete Markets and Aggregate Demand,” Working paper, MIT.

Figure 1: **Real Rate Forward Guidance for T=4: Real Bonds**

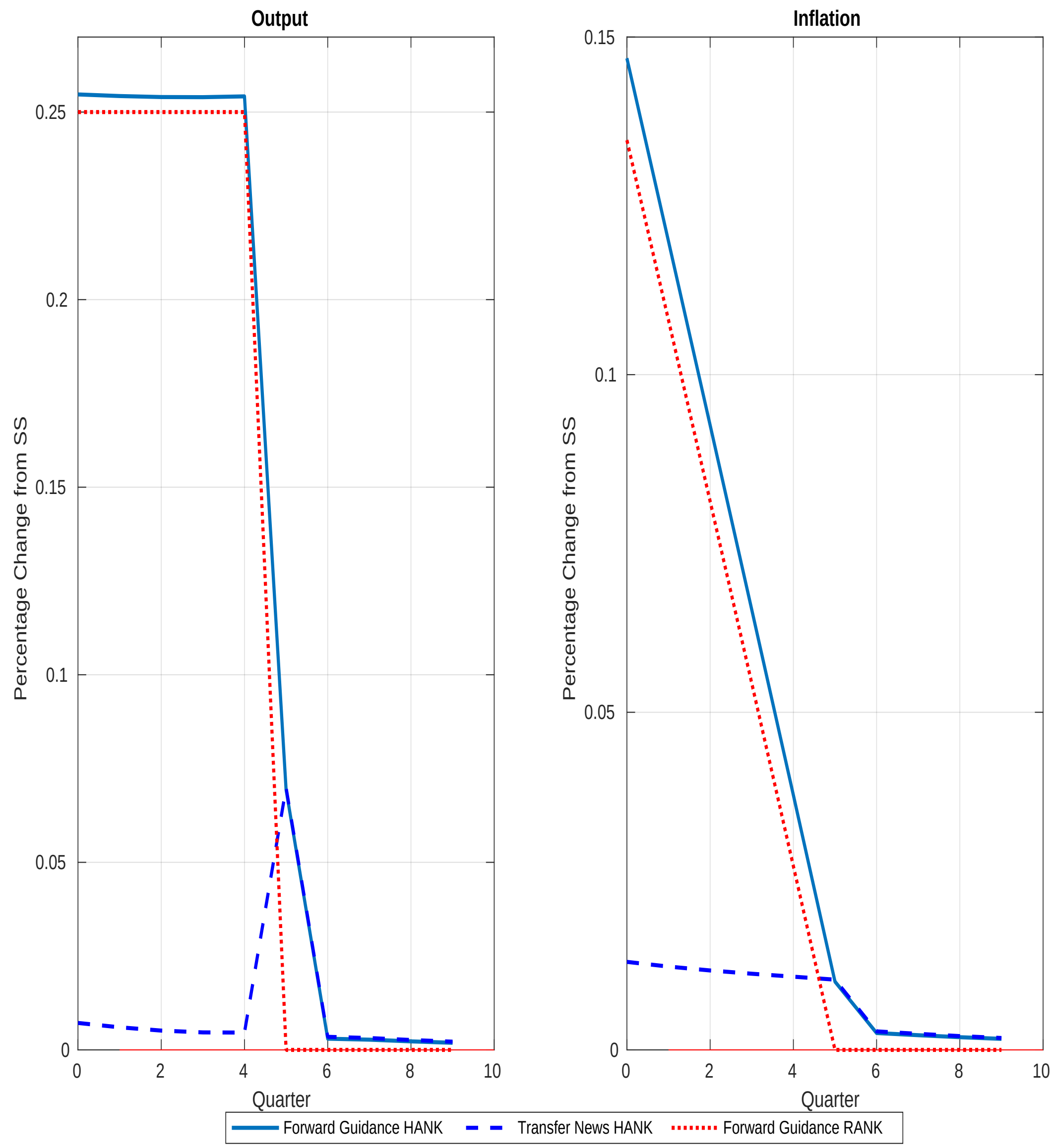

Figure 2: **Real Rate Forward Guidance for T=20: Real Bonds**

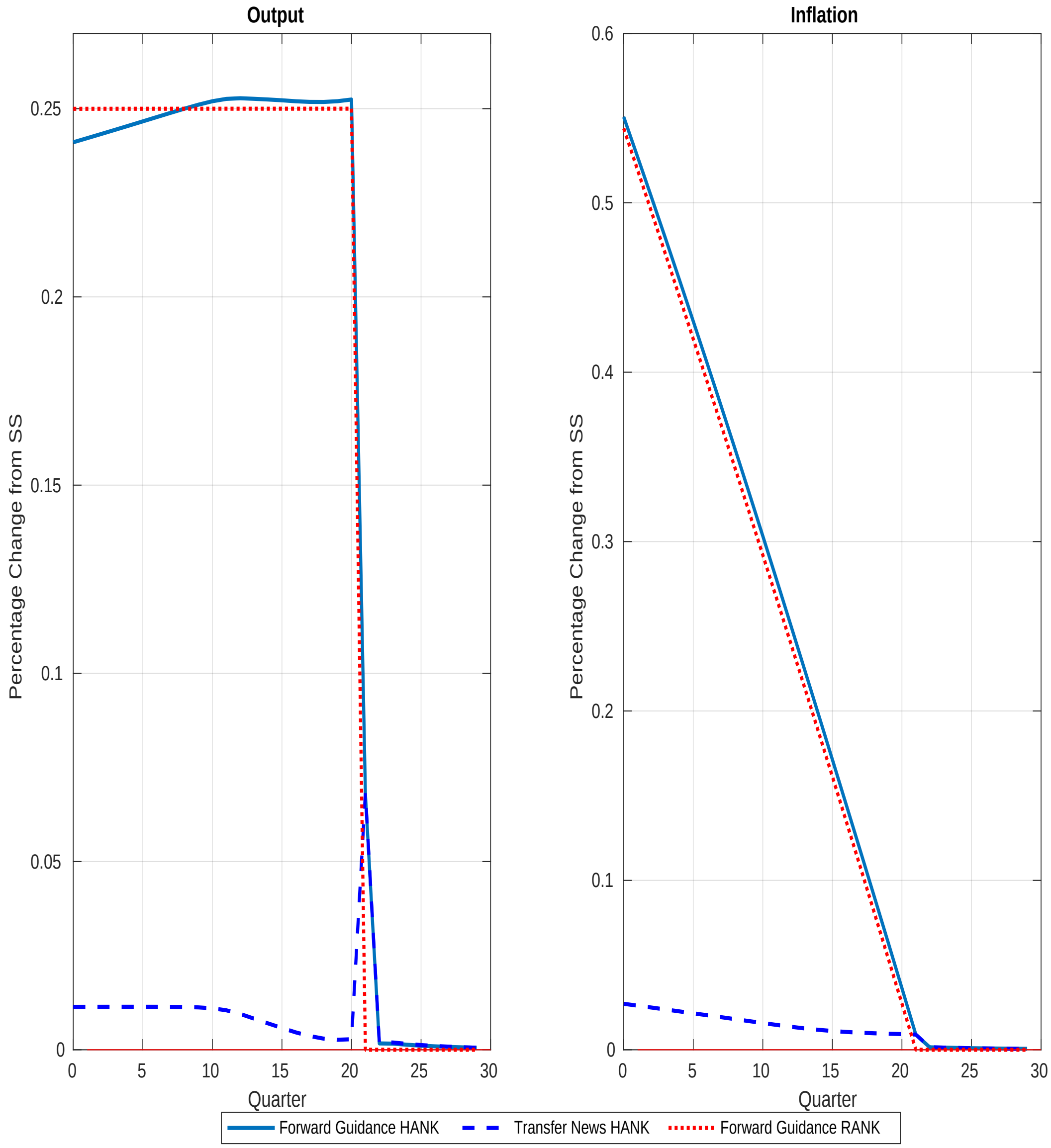

Figure 3: **Real Rate Forward Guidance for different horizons: Real Bonds**

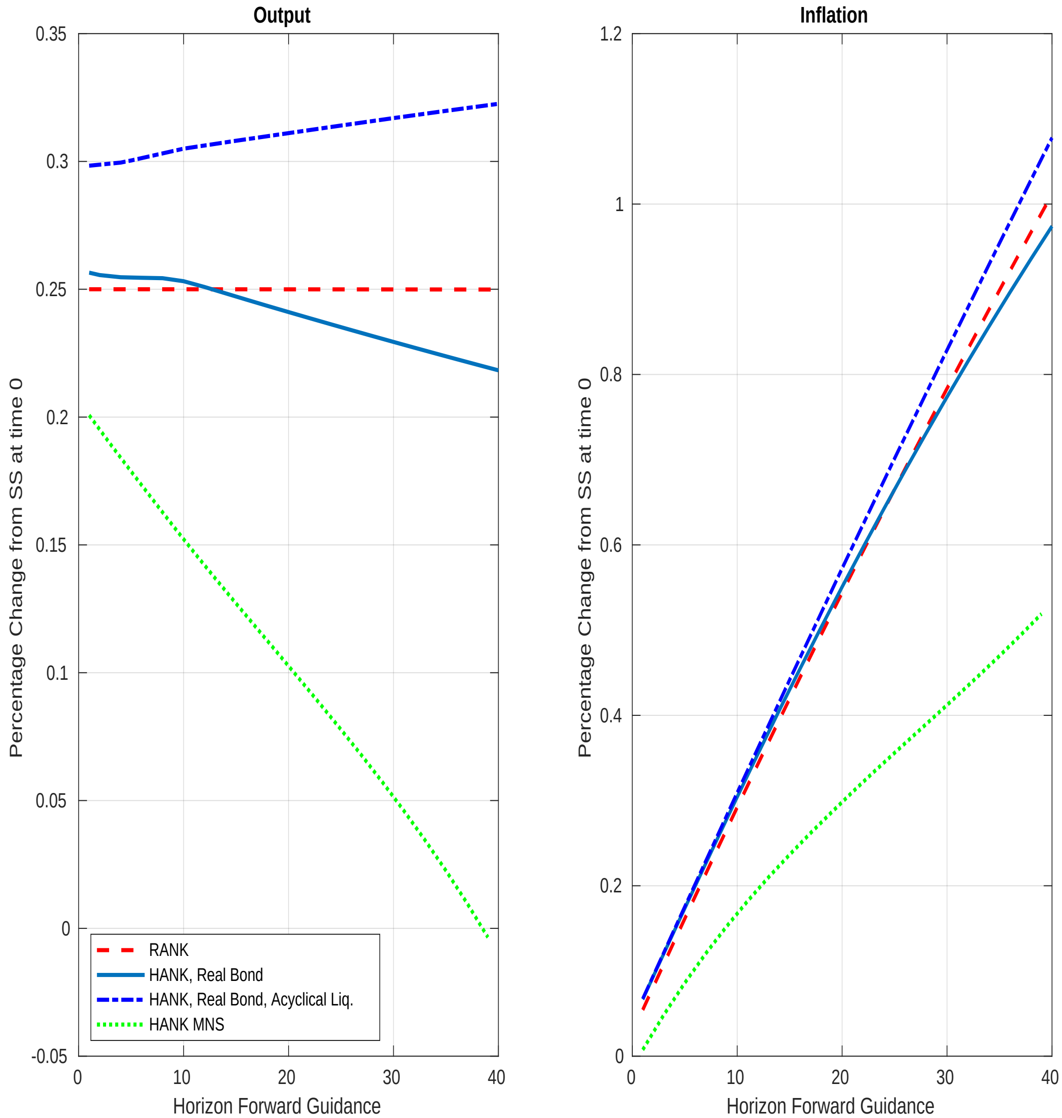

Figure 4: **Real Rate FG for different horizons: Real Bonds, Savers vs Borrowers**

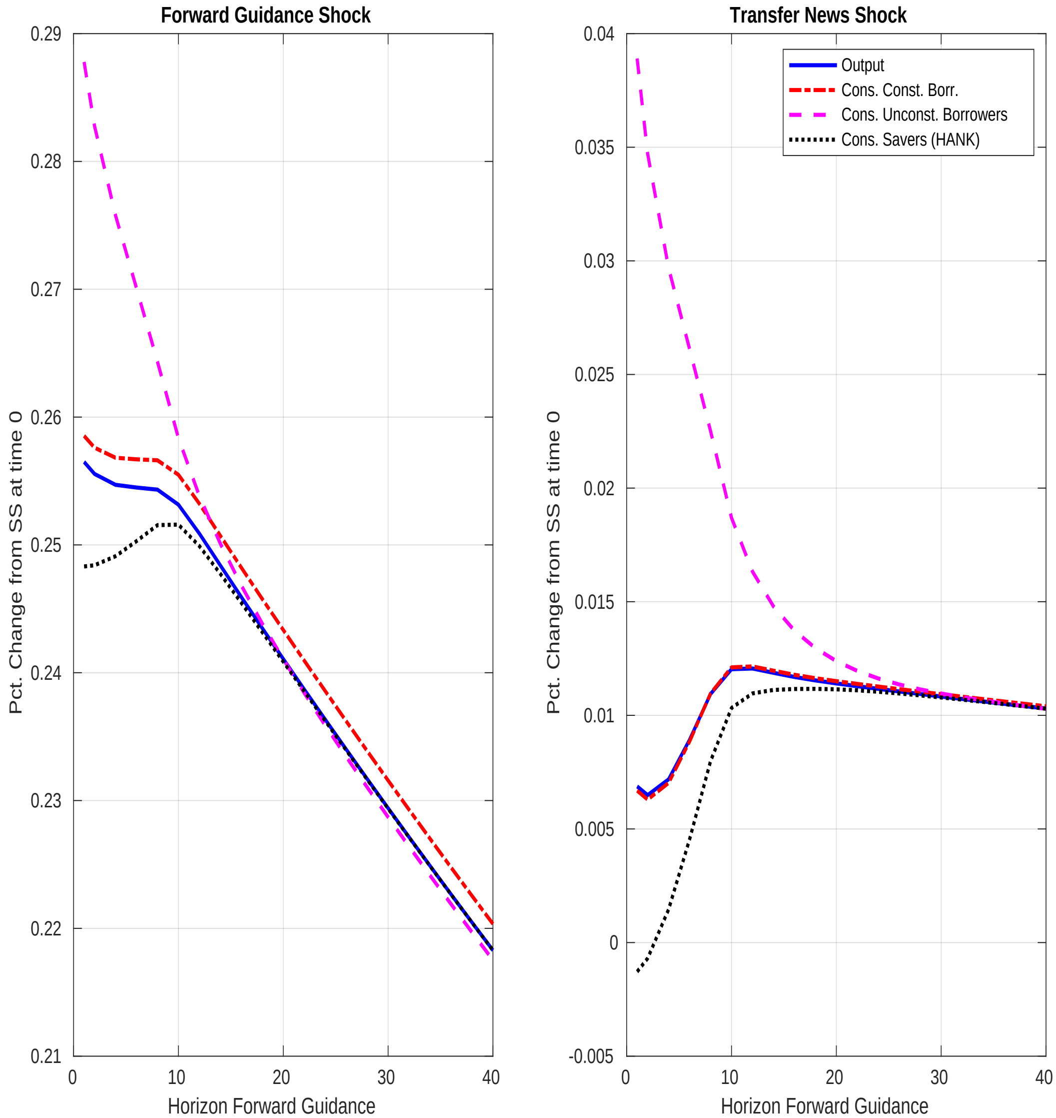

Figure 5: **Real Rate Forward Guidance for different horizons: Real vs Nominal Bonds**

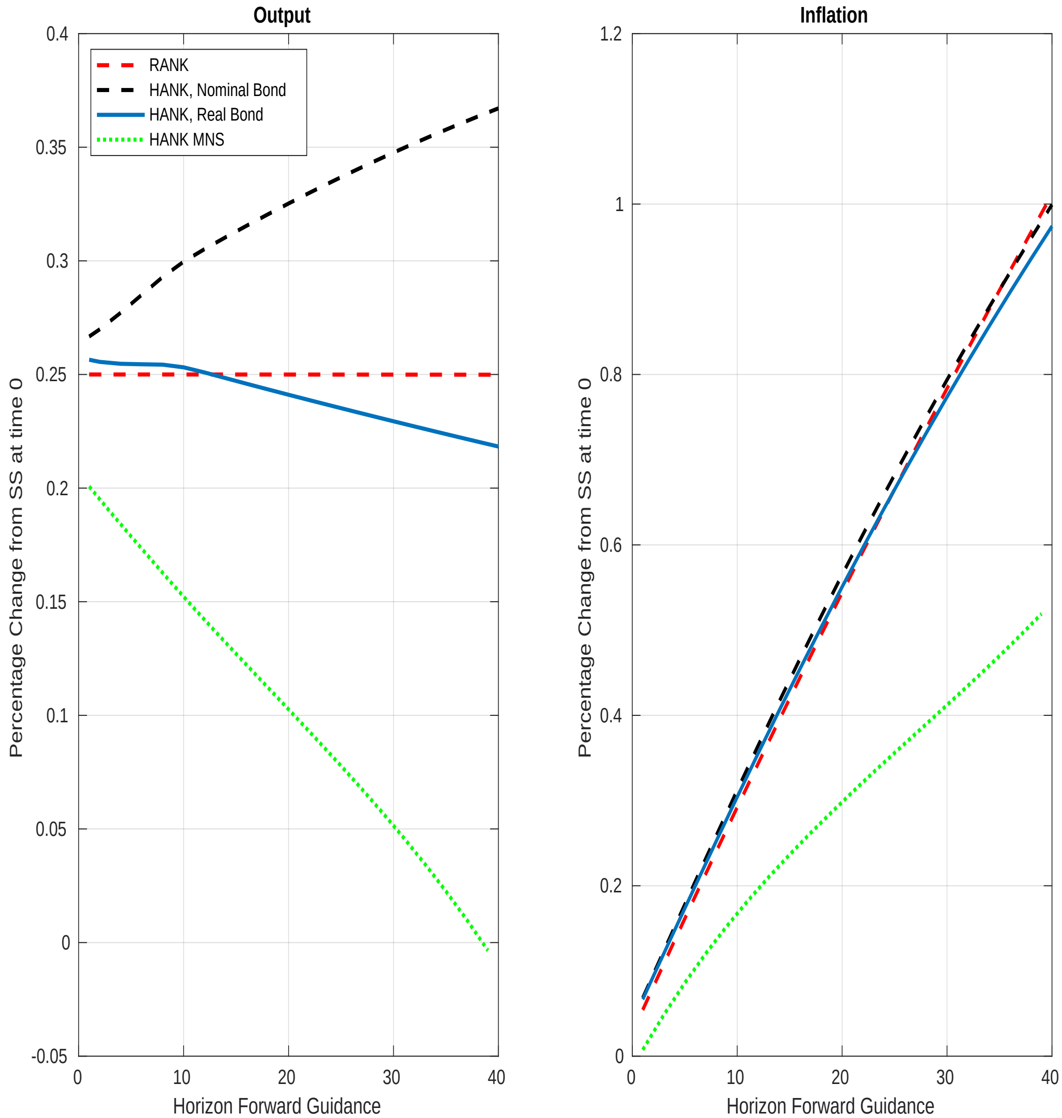

Figure 6: **Real Rate FG for different horizons: Nominal Bonds, Savers vs Borrowers**

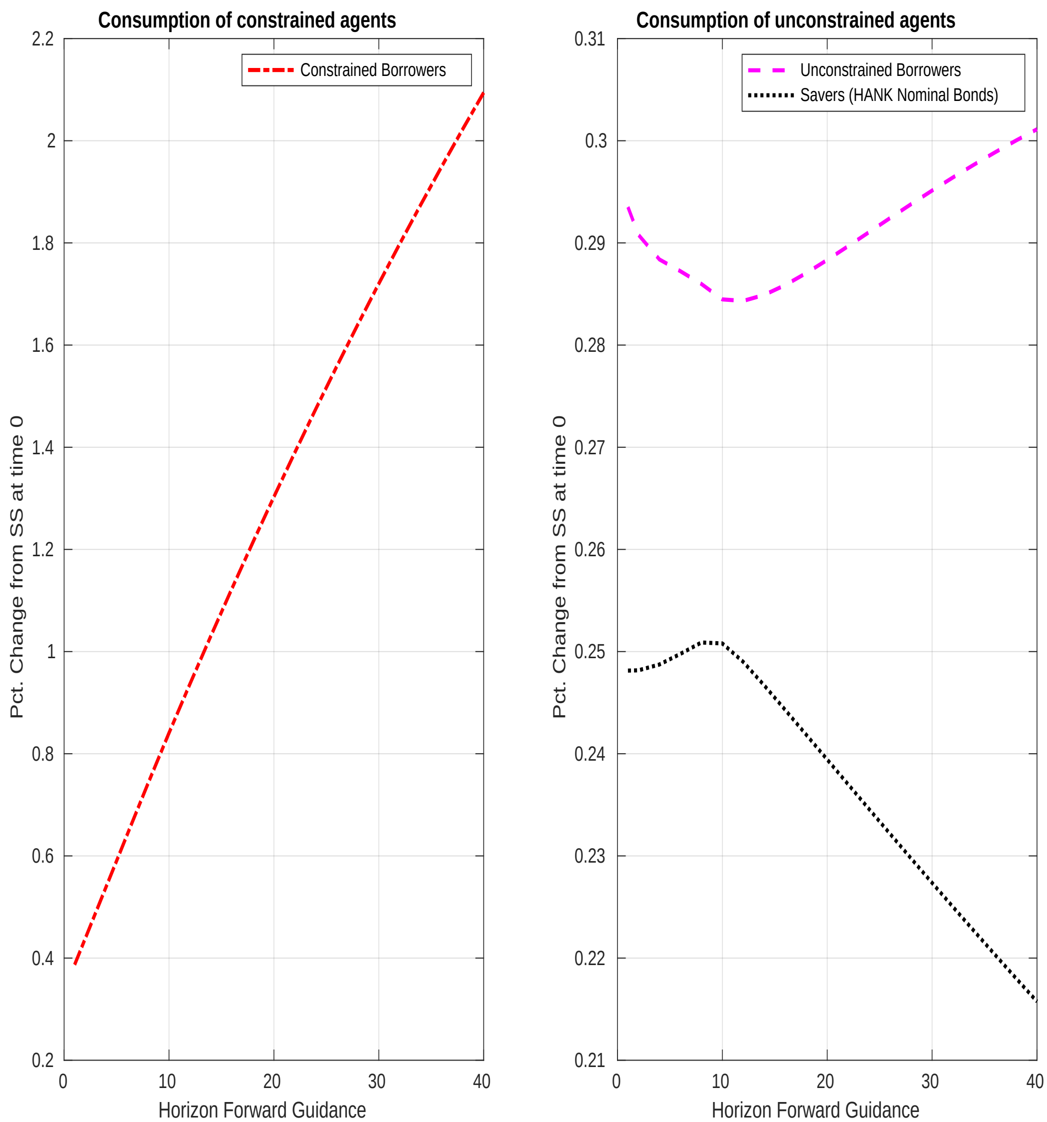

Figure 7: **Nominal Rate Forward Guidance for T=12: Real Bonds**

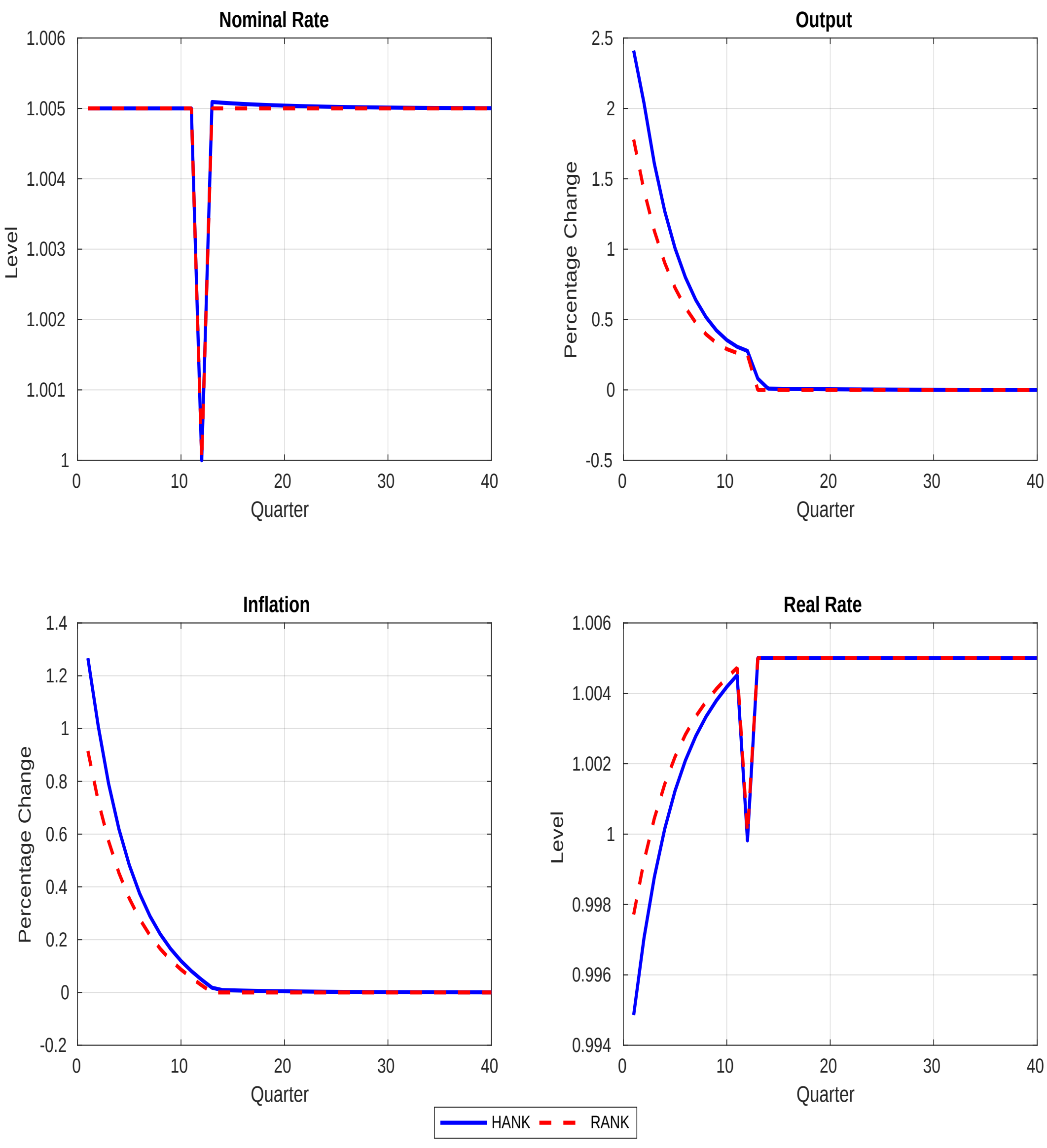

Figure 8: **Nominal Rate Forward Guidance for different horizons: Real Bonds**

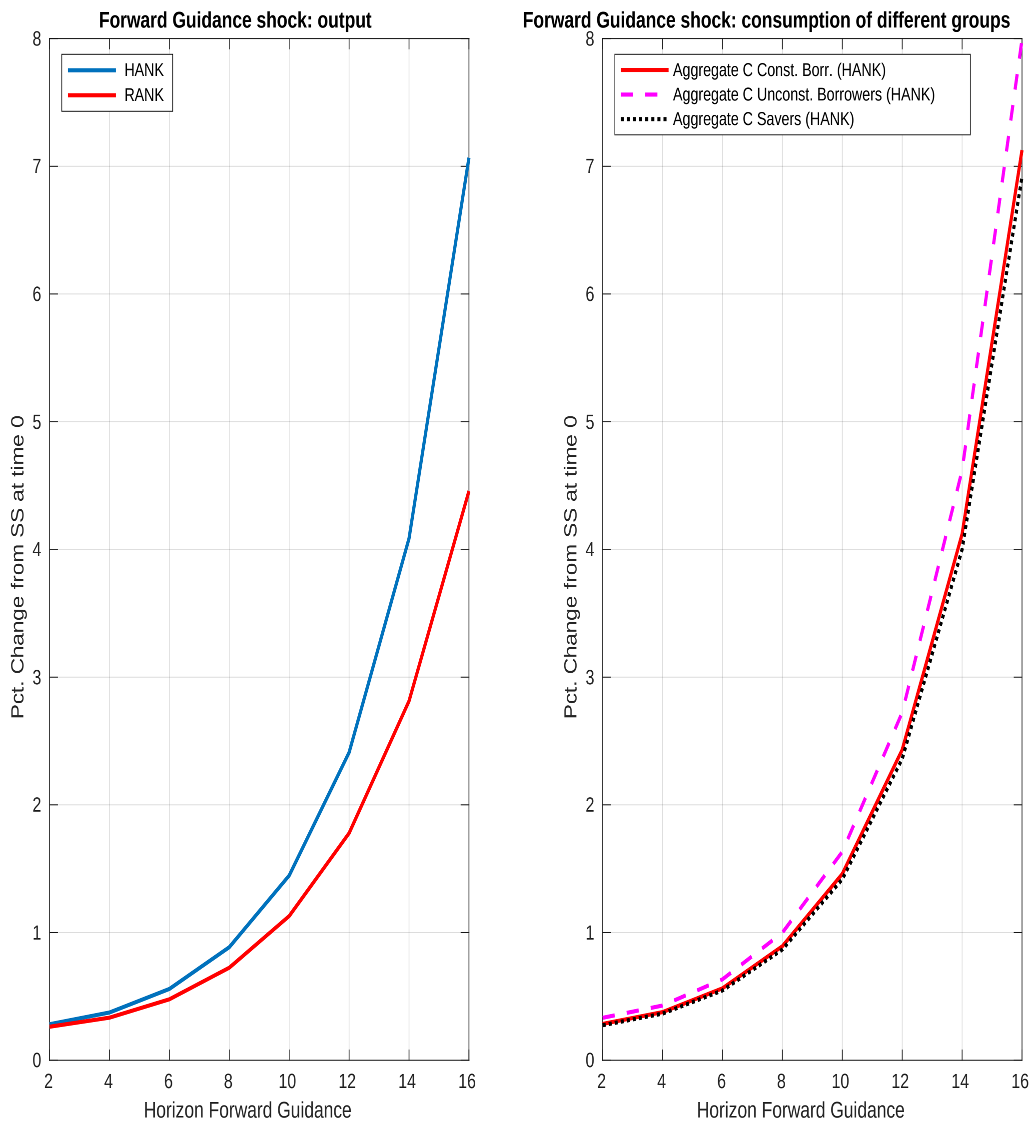

Figure 9: **Nominal Rate Forward Guidance for different horizons: Real vs Nominal Bonds**

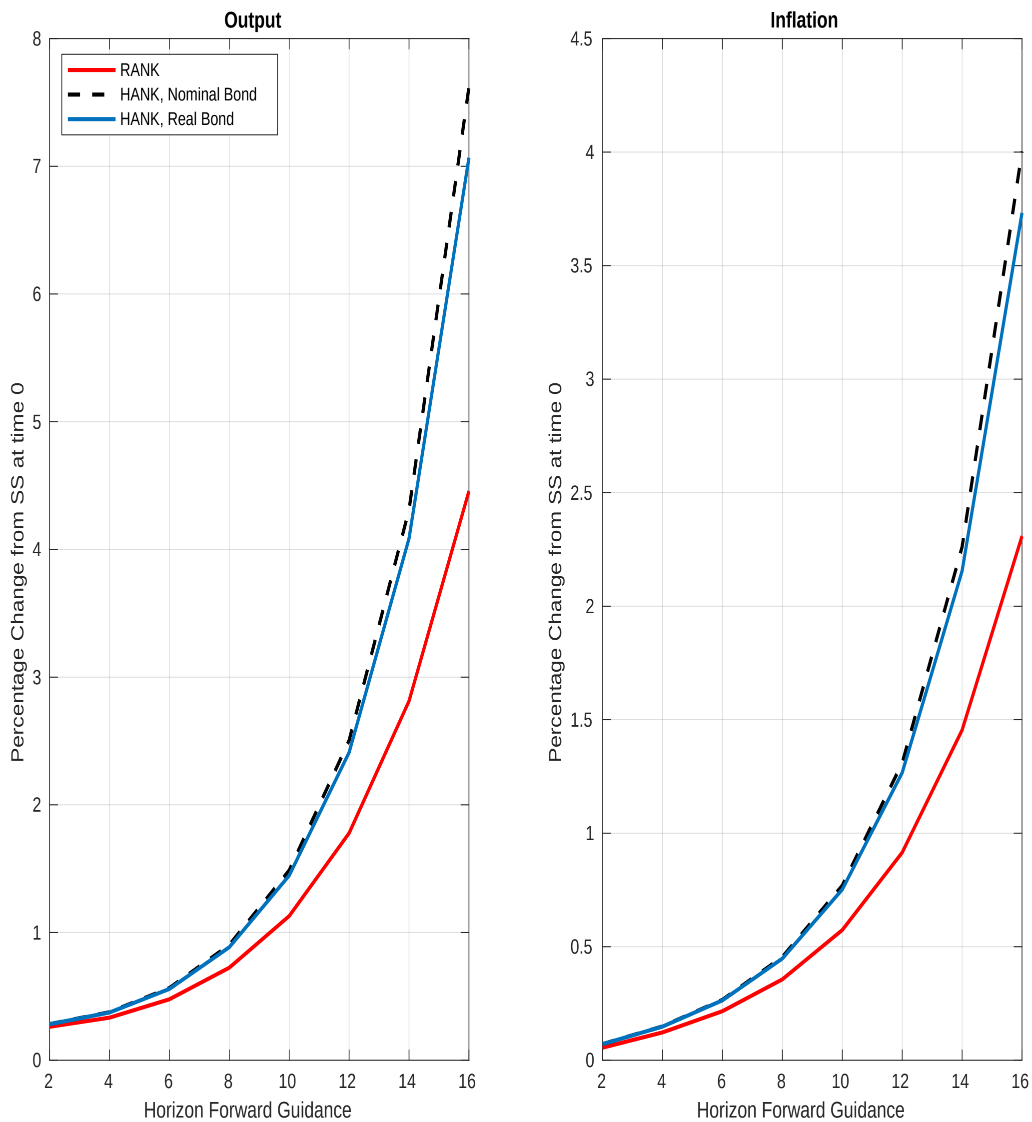

Figure 10: **Forward Guidance in a Liquidity Trap**

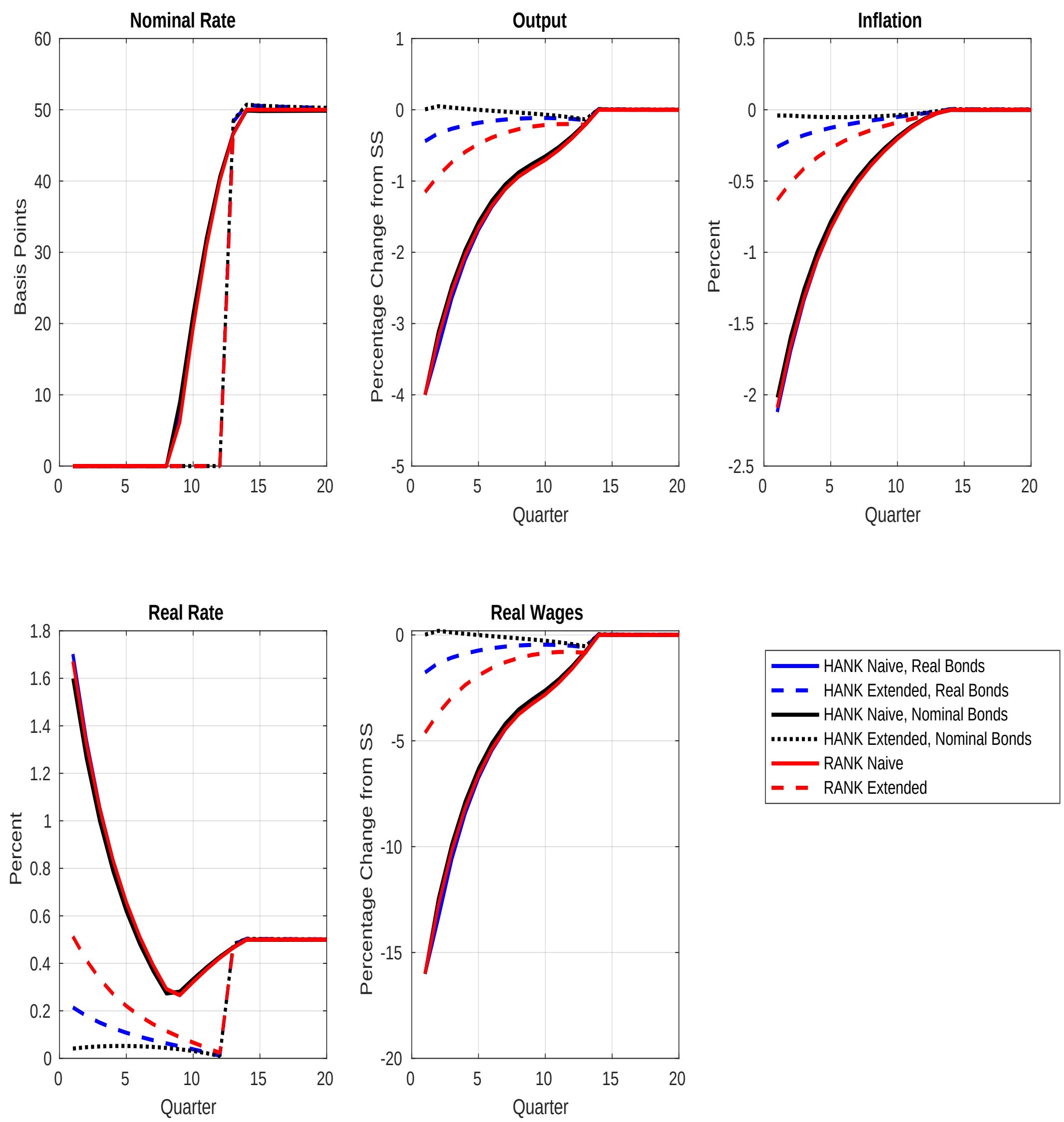

Figure 11: **Forward Guidance in a Liquidity Trap: Savers vs Borrowers**

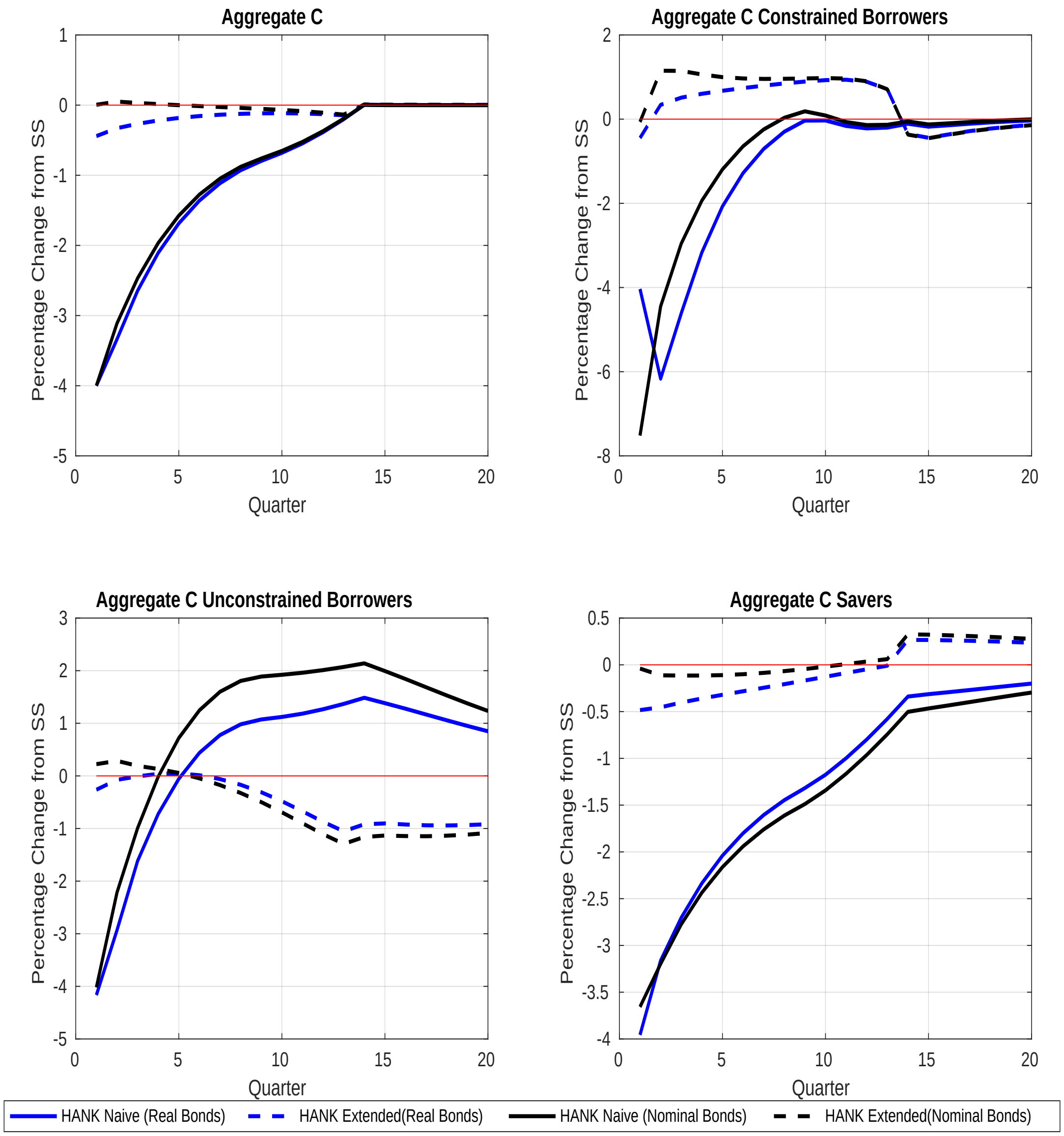

Figure 12: **Forward Guidance in a Liquidity Trap with Sticky Wages**