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RESEARCH ARTICLE

Deflationary traps, agents' beliefs and fiscal–monetary policies

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Abstract

We study the role of agents' limited cognitive capabilities, combined with fiscal and monetary policies, in the generation of a deflationary trap. In order to do so, we employ a heterogeneous expectations New Keynesian model in which the agents' forecasts are based on simple heuristics. Thanks to a learning mechanism, the model is able to generate endogenous changes in agents' beliefs that we prove to have a crucial role in the characterization of a deflationary trap. We show that the probability of hitting the zero lower bound on the interest rate, and potentially entering a deflationary trap, is not only affected by the inflation target set by the central bank. This probability is also influenced by the governments' focus on public debt stabilization and by the agents' memory and willingness to learn. We also show that the impact of these factors is very significant for inflation targets in the range 0–3%, while an inflation target of 4% isolates the system from the zero lower bound problem.

Keywords Monetary–fiscal policy · Agents' beliefs · Zero lower bound · Deflationary trap

JEL Classification E52 · E61 · F33 · F36

1 Introduction

In the years following the global financial crisis, the nominal interest rate in many advanced economies dropped and, also due to the coronavirus crisis, in some cases it reached its zero lower bound (hereafter ZLB). As a result, several studies have shown the peculiarities of the functioning of a system under this circumstance (Bondestein et al., 2012; Clarida 2012; Fernández-Villaverde et al. 2015; Aruoba et al. 2018).

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The main concern related to hitting the ZLB is that the economy can be caught in a liquidity trap and in a deflationary spiral (Svensson 2003). Although a first strand of literature has focused on the role of fundamental factors (Krugman 1998; Eggertsson and Woodford 2003; Eggertsson and Krugman, 2012; Guerrieri and Lorenzoni 2017; Le Riche et al. 2020), there has been an increasing interest in the shifts in agents' expectations as the main link between the ZLB and deflationary traps (Evans and Honkapohja 2005; Evans et al. 2008; Arseneau 2012; Benhabib et al. 2014; Mertens and Ravn 2014; Giraud and Pottier 2016; Benigno and Fornaro 2018; Kollmann 2021). In relation to this aspect, several economists have then argued that the design of monetary policy is crucial, as low inflation targets seem to facilitate entering a deflationary spiral (De Grauwe and Ji 2019; Hommes and Lustenhouwer 2019a, b; Andrade et al. 2021). Regarding the role of fiscal policy, the existing literature has mainly focused on its capabilities to drag the system out of a deflationary spiral and allow the economy to move away from a binding ZLB (Christiano et al. 2011; Woodford 2011; Benhabib et al. 2014; Schmidt 2017; Albonico et al. 2021).

In the present article, we study the impact of the ZLB in a tractable heterogeneous expectations New Keynesian model in which agents' forecasts are based on simple heuristics. Agents can be of two types: either fundamentalists or extrapolators. Fundamentalist agents base their output and government spending expectations on the steady-state values of the variables and their inflation expectations on the central bank's target, while extrapolative agents form their expectations according to the last observed value of the relevant macroeconomic variables. The model also includes a learning mechanism that allows agents to assess their adopted forecasting rule and to potentially change it (from fundamentalist to extrapolative and vice versa). This feature of the model generates endogenous waves of optimism and pessimism representing the agents' beliefs. The inclusion of such beliefs allows us to provide theoretical insights on aspects that have been largely ignored in the existing literature.

By using our measures of agents' beliefs, we show that they play a crucial role in the generation of a deflationary spiral. Specifically, we show how some features of the agents' beliefs can affect the likelihood of hitting the ZLB and entering a deflationary trap. In our model, this likelihood increases the lower is agents' memory and the higher is agents' willingness to learn.

Furthermore, we also show how the setting of fiscal policy affects the likelihood of hitting the ZLB and entering a deflationary spiral. The stronger the government's reaction to debt variations, the higher the probability of hitting the ZLB.

Finally, our model also confirms that the central bank's target affects the likelihood of hitting the ZLB and entering a deflationary trap. Increasing the inflation target from 0 to 4% progressively reduces the number of times the ZLB is binding despite the state of agents' beliefs. Hence, we conclude that progressively moving the inflation target towards 4% reduces the likelihood of entering a deflationary trap by sterilizing the impact of agent beliefs, as well as the influence of the governments' fiscal stance.

The rest of the paper is organized as follows. In Sect. 2, we derive the equations of the model, explain the expectations formation, define the agent's beliefs variables and discuss the model parametrization. In Sect. 3, we present the basic properties of the model. In Sect. 4, we study the functioning of the model when hitting the ZLB leads to a deflationary spiral. Sections 5 and 6 focus on the respective role of monetary and fiscal policies in relation to hitting the ZLB. Section 7 evaluates the importance of agents' memory and willingness to learn in the determination of the probability of hitting the ZLB. Section 8 concludes the paper.

2 The model

Our analysis is based on a heterogeneous expectations New Keynesian model. The characterization of the economy is the following. The private sector includes a unit mass of households and firms. Hence, by aggregating and linearizing the optimal choices of individual households and firms, we retrieve the equations of the aggregate demand and of the Phillips curve. As households are allowed to invest in government bonds, the representation of the economy also includes an equation for the evolution of public debt. The policy block is then specified with simple linear monetary and fiscal rules. In these we assume that the monetary policy instrument is the interest rate, while the fiscal policy instrument is government spending. The forecasts of output, inflation and government spending are based on two alternative simple heuristics (fundamentalist and extrapolative). The distribution of agents in the two heuristics is determined by a learning mechanism. Thanks to the learning mechanism, the model generates endogenous waves of optimism and pessimism that we summarize in two additional variables: animal spirits and fiscal beliefs.

2.1 The private sector

The characterization of the private sector is based on Hommes et al. (2018). In the model, time is infinite and households differ only in the way they form expectations. In particular, a household can be either extrapolator or fundamentalist (these expectations are explained in Sect. 2.4). These characteristics apply also to the problem of the individual firms.

2.1.1 Households

Each household $i \in [0, 1]$ seeks to maximize the following utility function defined over consumption (C_t^i) and labor (N_t^i)

$$\tilde{\mathbb{E}}_t^i \sum_{s=t}^{\infty} \beta^s \left[\frac{(C_s^i)^{1-\sigma}}{1-\sigma} - \frac{(N_s^i)^{1+\eta}}{1+\eta} \right], \tag{1}$$

in which C_t^i is an index defined, over the good variety $j \in [0, 1]$, by the following CES function, $C_t^i = (\int_0^1 C_t^i(j)^{\frac{\theta-1}{\theta}} dj)^{\frac{\theta}{\theta-1}}$. The parameters η and σ represent the inverses of the Frisch elasticity of labor supply and of the inter-temporal elasticity of consumption, respectively. Furthermore, $\tilde{\mathbb{E}}_t^i$ is the type-specific expectation operator of household i that can either be extrapolative or fundamentalist.

The utility maximization occurs subject to the following budget constraint

$$P_t C_t^i + \frac{D_{t+1}^i}{1+r_t} \leq D_t^i + (1-\tau)\Big[W_t N_t^i + P_t \Xi_t(j)\Big], \tag{2}$$

where W_t is the nominal wage rate, D_{t+1}^i is the nominal payoff of the one period risk-free government bonds held, r_t is the nominal interest rate, τ is the constant income tax rate. $\Xi_t(j)$ represents firm j's real profits and reflects the assumption that each firm in the economy is owned by one household. The aggregate price index in Eq. (2) is defined as $P_t = (\int_0^1 P_t(j)^{1-\theta} dj)^{\frac{1}{1-\theta}}$.

Combining the first order conditions with respect to consumption, labor and bonds holdings yields the following standard Euler and real wage ($w_t = \frac{W_t}{P_t}$) equations[1]

$$\frac{(C_t^i)^{-\sigma}}{1+r_t} = \beta \tilde{\mathbb{E}}_t^i \left[\frac{(C_{t+1}^i)^{-\sigma}}{\Pi_{t+1}}\right], \tag{3}$$

$$w_t = \frac{(N_t^i)^{\eta}(C_t^i)^{\sigma}}{1-\tau}. \tag{4}$$

These must hold in the equilibrium together with the budget constraint.

2.1.2 Firms

In our model there is a continuum of monopolistically competitive firms. Each firm $j \in [0, 1]$ produces a differentiated good with a linear technology represented by the following production function

$$Y_t(j) = AN_t(j), \tag{5}$$

where we assume that $A = 1$. Each firm maximizes its profit that is represented as

$$P_t \Xi_t(j) = P_t(j)Y_t(j) - mc_t Y_t(j) P_t - \frac{\phi}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - 1\right)^2 Y_t P_t, \tag{6}$$

in which mc_t is the marginal cost. Note that we have assumed that firms face a quadratic cost of adjusting nominal prices, that measured in terms of the final good is written as $\frac{\phi}{2}(\frac{P_t(j)}{P_{t-1}(j)} - 1)^2 Y_t$ (see Rotemberg 1982).[2] By using the price index, Eq. (6) can be written as

$$P_t \Xi_t(j) = P_t(j)^{1-\theta} P_t^{\theta} Y_t - mc_t P_t(j)^{-\theta} P_t^{1+\theta} Y_t - \frac{\phi}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - 1\right)^2 Y_t P_t. \tag{7}$$

[1] See the online Appendix I for further details.

[2] This cost relates the negative effects on the relationship between customer and firm of price changes. The cost is increasing in the size of the price change and in the overall scale of economic activity.

The profit maximization with respect to the price level yields the following solution[3]

$$
\begin{aligned}
&(\theta-1)\frac{P_t(j)Y_t(j)}{P_tY_t}+\phi\Pi_t(j)(\Pi_t(j)-1)\\
&\quad=\theta mc_t\frac{Y_t(j)}{Y_t}+\phi\beta\tilde{\mathbb{E}}_t^j\left[\left(\frac{C_{t+1}^j}{C_t^j}\right)^{-\sigma}\frac{Y_{t+1}}{Y_t}\Pi_{t+1}(j)(\Pi_{t+1}(j)-1)\right], \qquad (8)
\end{aligned}
$$

where $\tilde{\mathbb{E}}_t^j$ is the type-specific expectation operator of firm j that can either be extrapolative or fundamentalist. It is important to note that given the assumption that each firm is run by a household, firms' heuristics for predicting future variables correspond to the ones of their respective household.

2.2 The economy: aggregation and log-linearization

Given the assumption of the adjustment costs à la Rotemberg, the resource constraint of the economy is the following

$$
Y_t=C_t+G_t+\frac{\phi}{2}\left(\frac{P_t}{P_{t-1}}-1\right)^2Y_t=C_t+g_tY_t+\frac{\phi}{2}\left(\frac{P_t}{P_{t-1}}-1\right)^2Y_t, \qquad (9)
$$

in which G_t is total public spending and g_t represents spending as a percentage of income.

Finally, the representation of the economy requires the specification of an equation identifying the evolution of the total public debt. In this regard, we follow Kirsanova et al. (2007) and Blake and Kirsanova (2012) to write it as

$$
D_{t+1}=(1+r_t)(D_t+P_tG_t-\tau P_tY_t). \qquad (10)
$$

We can now aggregate the relevant equations and represent them in their log-linear form. To this aim, the model is log-linearized around a zero inflation steady state.

Use Eqs. (3) and (9) to retrieve the aggregate demand as[4]

$$
\hat{Y}_t=\tilde{\mathbb{E}}_t\hat{Y}_{t+1}-\frac{\bar{g}}{1-\bar{g}}(\tilde{\mathbb{E}}_t\hat{g}_{t+1}-\hat{g}_t)-\frac{1}{\sigma}(\hat{r}_t-\tilde{\mathbb{E}}_t\pi_{t+1})+\epsilon_t, \qquad (11)
$$

where $\bar{g}$ represents public spending in the steady state.

The aggregation and log-linearization of Eq. (8) yields the following Phillips curve equation

$$
\pi_t=\beta\tilde{\mathbb{E}}_t\pi_{t+1}+k(\sigma+\eta)\hat{Y}_t-k\sigma\frac{\bar{g}}{1-\bar{g}}\hat{g}_t+\xi_t, \qquad (12)
$$

[3] See the online Appendix I for further details.

[4] Further details on the aggregation and linearization are provided in the online Appendix III.

in which $k = \frac{\theta - 1}{\phi}$.

Finally, defining a measure of real debt as $d_{t+1} = \frac{D_{t+1}}{P_t}$, we log-linearize the government budget constraint (10) in order to obtain the following equation

$$\hat{d}_{t+1} = \hat{r}_t + (1 + \bar{r})\left[\hat{d}_t - \pi_t + \frac{\bar{g}}{\chi}\hat{g}_t + \left(\frac{\bar{g} - \tau}{\chi}\right)\hat{Y}_t\right] + \phi_t, \tag{13}$$

where $\bar{r}$ and χ are the interest rate and the ratio of real public debt to output in the steady state, respectively.[5]

Note that we have added demand (ϵ_t), supply (ξ_t) and public debt (ϕ_t) shocks to their respective equations. These shocks are all assumed to be independent and normally distributed with constant standard deviation and allow to include the impact on output, inflation and public debt of variables and events that are not formally accounted for in the model. Equations (11), (12) and (13) represent the evolution of the economy that needs to be completed by specifying the setting of the monetary and fiscal policy variables.

2.3 Policy setup

In the specification of the policy setup, we assume that policy makers interact non-cooperatively by using simple linear monetary and fiscal rules with feedback coefficients on variables of interest. The central bank performs monetary policy by controlling the interest rate,[6] while the government is assumed to perform fiscal policy by modifying public spending.

The monetary rule is written as

$$\hat{r}_t = c_3\hat{r}_{t-1} + (1 - c_3)[c_1(\pi_t - \pi^*) + c_2\hat{Y}_t] + \mu_t, \tag{14}$$

where μ_t represents a monetary shock.

The fiscal rule follows the same logic but we assume that the government reacts to the variables of interest with one lag as it needs one period to process and implement fiscal adjustments (see for instance, Muscatelli and Tirelli 2005). This reflects the fact that fiscal decisions are normally taken at a lower frequency and are the result of a longer decisional process when compared to monetary policies. Hence, we write the fiscal policy rule as

$$\hat{g}_t = f_1\hat{g}_{t-1} - (1 - f_1)[f_2\hat{Y}_{t-1} + f_3\hat{d}_{t-1}] + \upsilon_t, \tag{15}$$

in which υ_t indicates a fiscal policy shock.

The inclusion of the parameters c_3 in Eq. (14) and f_1 in Eq. (15) represent the possibility of considering instrument smoothing in the two policy rules. The range of

[5] Please refer to the online Appendix II for a derivation of the steady state relations.

[6] Whenever not specified, in the monetary rule we assume that the central bank targets a zero inflation rate ($\pi^* = 0$).

these parameters is between 0 and 1, with a value of 0 implying no policy instrument smoothing.

2.4 Expectations

In our model, we depart from the assumption of rational expectations and assume that agents use simple rules, heuristics, in order to forecast output, inflation and public spending. Specifically, we follow Brock and Hommes (1997) and De Grauwe and Foresti (2020, 2023) by assuming that agents can use two alternative forecasting rules. Extrapolators forecast the variable by using its most recent observation. Fundamentalists forecast output and spending by using their steady state value, while their inflation forecasts rely on the central bank's target. Hence, the forecasting rules can be written as follows

$$Fundamentalist \quad rules: \quad \tilde{\mathbb{E}}_t^f \hat{Y}_{t+1} = 0; \tilde{\mathbb{E}}_t^f \hat{g}_{t+1} = 0; \tilde{\mathbb{E}}_t^f \pi_{t+1} = \pi^*. \tag{16}$$

$$Extrapolative \quad rules: \quad \tilde{\mathbb{E}}_t^e \hat{Y}_{t+1} = \hat{Y}_{t-1}; \tilde{\mathbb{E}}_t^e \hat{g}_{t+1} = \hat{g}_{t-1}; \tilde{\mathbb{E}}_t^e \pi_{t+1} = \pi_{t-1}. \tag{17}$$

The aggregate output forecast is given by the weighted average between the two rules

$$\tilde{\mathbb{E}}_t \hat{Y}_{t+1} = \alpha_{f,t}^y \tilde{\mathbb{E}}_t^f \hat{Y}_{t+1} + \alpha_{e,t}^y \tilde{\mathbb{E}}_t^e \hat{Y}_{t+1}, \tag{18}$$

where $\alpha_{f,t}^y$ and $\alpha_{e,t}^y$ are the probabilities that agents use the fundamentalist and extrapolative rule when forecasting $\hat{Y}_{t+1}$ (then $\alpha_{f,t}^y + \alpha_{e,t}^y = 1$). Note that these weights also represent the fractions of agents using the two rules. However, these fractions are not constant as agents are able to revise their expectations and move from one rule to another. To this aim, they monitor the performance of the two forecasting rules by using their Mean Squared Forecasting Error as follows

$$L_{f,t}^y = -\sum_{k=0}^{\infty} \omega_k [\hat{Y}_{t-k-1} - \tilde{\mathbb{E}}_{t-k-2}^f \hat{Y}_{t-k-1}]^2, \tag{19}$$

$$L_{e,t}^y = -\sum_{k=0}^{\infty} \omega_k [\hat{Y}_{t-k-1} - \tilde{\mathbb{E}}_{t-k-2}^e \hat{Y}_{t-k-1}]^2. \tag{20}$$

We assume the weights assigned to each error in time (ω_k) as declining and define them as $\omega_k = (1-\rho)\rho^k$, with $0 \leq \rho \leq 1$. Under this specification of the weights, Eqs. (19) and (20) can be rewritten as

$$L_{f,t}^y = \rho L_{f,t-1}^y - (1-\rho)[\hat{Y}_{t-1} - \tilde{\mathbb{E}}_{t-2}^f \hat{Y}_{t-1}]^2, \tag{21}$$

$$L_{e,t}^y = \rho L_{e,t-1}^y - (1-\rho)[\hat{Y}_{t-1} - \tilde{\mathbb{E}}_{t-2}^e \hat{Y}_{t-1}]^2. \tag{22}$$

We can now verify why ρ can be interpreted as the measure of agents' memory. When $\rho = 1$, Eqs. (21) and (22) become $L_{f,t}^y = L_{f,t-1}^y$ and $L_{e,t}^y = L_{e,t-1}^y$ meaning that, given Eqs. (19) and (20), agents have infinite memory. On the contrary, if $\rho = 0$ agents have no memory. Then, following discrete choice theory (see Anderson et al. 1992; Branch and Evans 2011), the probability of choosing the two rules can be retrieved as

$$\alpha^{y}_{f,t} = \frac{exp(\gamma L^{y}_{f,t})}{exp(\gamma L^{y}_{f,t}) + exp(\gamma L^{y}_{e,t})}, \tag{23}$$

$$\alpha^{y}_{e,t} = \frac{exp(\gamma L^{y}_{e,t})}{exp(\gamma L^{y}_{f,t}) + exp(\gamma L^{y}_{e,t})} = 1 - \alpha^{y}_{f,t}. \tag{24}$$

These equations show how the fractions of agents using each rule are not constant and change according to their performance. According to Eqs. (23) and (24), the distribution of agents in the two rules is also determined by γ. This parameter measures the agents' willingness to learn (see De Grauwe 2012). Thus, the selection mechanism that we employ should be interpreted as a learning mechanism based on trial and error. When agents observe that the rule they use performs less well than the alternative one, they are willing to switch to the better performing rule.

There is ample evidence from laboratory experiments supporting the behavioral framework described in Eqs. (16–24). See Pfajfar and Zakelj (2011, 2014), Kryvtsov and Petersen (2013) and also Assenza et al. (2014) for a literature survey. Moreover, several experiments at CeNDEF University of Amsterdam (see Assenza et al. 2021; Hommes 2021) find that among different forecasting rules, the one that tends to become dominant in the consecutive rounds of an experiment is quite in accordance with the discrete choice principle we employ in our model.

The specification of the aggregate expectations of inflation and government spending follows the same logic adopted for the output

$$\tilde{\mathbb{E}}_t \pi_{t+1} = \alpha^{\pi}_{f,t} \tilde{\mathbb{E}}^{f}_t \pi_{t+1} + \alpha^{\pi}_{e,t} \tilde{\mathbb{E}}^{e}_t \pi_{t+1}, \tag{25}$$

$$\tilde{\mathbb{E}}_t \hat{g}_{t+1} = \alpha^{g}_{f,t} \tilde{\mathbb{E}}^{f}_t \hat{g}_{t+1} + \alpha^{g}_{e,t} \tilde{\mathbb{E}}^{e}_t \hat{g}_{t+1}. \tag{26}$$

The same learning mechanism reported in Eqs. (19–20) and (21–22) applies to the formation of inflation and government spending expectations. Hence, the probabilities of choosing the two inflation forecast rules are

$$\alpha^{\pi}_{f,t} = \frac{exp(\gamma L^{\pi}_{f,t})}{exp(\gamma L^{\pi}_{f,t}) + exp(\gamma L^{\pi}_{e,t})}; \quad \alpha^{\pi}_{e,t} = \frac{exp(\gamma L^{\pi}_{e,t})}{exp(\gamma L^{\pi}_{f,t}) + exp(\gamma L^{\pi}_{e,t})} = 1 - \alpha^{\pi}_{f,t}. \tag{27}$$

While the probabilities of choosing the two rules for the government spending expectations are

$$\alpha^{g}_{f,t} = \frac{exp(\gamma L^{g}_{f,t})}{exp(\gamma L^{g}_{f,t}) + exp(\gamma L^{g}_{e,t})}; \quad \alpha^{g}_{e,t} = \frac{exp(\gamma L^{g}_{e,t})}{exp(\gamma L^{g}_{f,t}) + exp(\gamma L^{g}_{e,t})} = 1 - \alpha^{g}_{f,t}. \tag{28}$$

It is worth noting that in our model the three predictions for output, inflation and government spending are made independently. This is a strong assumption and reflects the fact that agents in our model do not have a psychological predisposition to become fundamentalists or extrapolators. Although we employ a bounded rationality framework, agents are endowed with some capacity to decide what would be the best (in their own understanding and within the dichotomy between being fundamentalist or extrapolative) way to form their expectations. This is based largely on what they observe and experience over time. One agent is not fundamentalist or extrapolative by nature but it can decide based on experience, perception, observations and reflections on the evolution of individual indicators. For example, let's assume one household applies the fundamentalist rule to forecast all the three indicators and over the years this rule performs very well in forecasting output and government spending but performs very poorly in forecasting inflation. In our model, this household will be capable of retaining the fundamentalist rule to forecast output and spending, but it will be allowed to switch to the extrapolative one for inflation, hoping to improve the accuracy of its forecast. In a way, in this setup, households are able to recognize that different variables may have different patterns and determinants so that different forecasting rules may be applied to them. Assenza et al. (2021) provide experimental evidence of the fact that some agents are actually able to separate the formulation of expectations for output and inflation and apply, if needed, different forecasting rules. Furthermore, it is worth noting that our model does not exclude the possibility for agents to apply the same forecasting rule to all the variables as such an option is not ruled out. In fact, it is possible that despite the assumption of independence, the realized choices generated from our model are actually correlated due to the interactions between the different variables.[7]

2.5 Agents' beliefs

The specification of expectations allows us to define indices measuring agents' beliefs.

First, the fractions of output fundamentalists and extrapolators can be used to define a variable measuring the animal spirits. In defining our variable, we rely on the definition that is widely used in behavioural economics and market psychology, where animal spirits include the state of pessimism or confidence that can influence economic decision making and that, due to self-fulfilling mechanisms, can boost or impede economic growth (Akerlof and Shiller 2009; De Grauwe 2011; De Grauwe and Ji 2019). To this aim, our variable of animal spirits is defined as

$$AS_t = \begin{cases} \alpha^y_{e,t} - \alpha^y_{f,t} \; if \quad \hat{Y}_{t-1} > 0 \\ -\alpha^y_{e,t} + \alpha^y_{f,t} \; if \quad \hat{Y}_{t-1} < 0 \end{cases}, \tag{29}$$

where AS_t ranges between -1 (indicating the maximum level of pessimism) and $+1$ (indicating maximum level of optimism). When $\hat{Y}_{t-1} > 0$, a fraction $\alpha^y_{e,t}$ (extrapolators) of agents will forecast a positive output gap. Given their prediction of a positive change in output, these agents are defined as optimist. At the same time, the other

[7] We explore this in the online Appendix IV, where we report the realized correlations between the probabilities of being an extrapolator for the output, inflation and spending. We show that these are all positively correlated with each other.

fraction $\alpha^{y}_{f,t}$ (fundamentalists) will make a pessimistic forecast as these agents expect the positive gap to go back to zero. Given their prediction of a reduction in output, these agents are defined as pessimist. Hence, the shares of optimistic and pessimistic forecasts can be combined to see that when $\alpha^{y}_{e,t} > \alpha^{y}_{f,t}$ the economy is characterized by waves of optimism in animal spirits, while if $\alpha^{y}_{e,t} < \alpha^{y}_{f,t}$ the economy goes through a phase of pessimism. Clearly, the opposite reasoning applies when $\hat{Y}_{t-1} < 0$. In such a case, optimism is measured by $\alpha^{y}_{f,t}$ while pessimism by $\alpha^{y}_{e,t}$, and the magnitude of the waves of optimism and pessimism is measured by the difference between the two fractions as in Eq. (29). When $\alpha^{y}_{e,t} = \alpha^{y}_{f,t}$, market sentiments are neutral and optimism and pessimism cancel out, $AS_t = 0$, so that animal spirits do not affect the dynamics of the model.

A similar approach can be followed to define fiscal beliefs as

$$FB_t = \begin{cases} \alpha^{g}_{e,t} - \alpha^{g}_{f,t} \; if \quad \hat{g}_{t-1} > 0 \\ -\alpha^{g}_{e,t} + \alpha^{g}_{f,t} \; if \quad \hat{g}_{t-1} < 0 \end{cases}, \tag{30}$$

where also $-1 \leq FB_t \leq +1$ but its interpretation is slightly different. When $\hat{g}_{t-1} > 0$, extrapolators ($\alpha^{g}_{e,t}$) expect a fiscal expansion, while fundamentalists ($\alpha^{g}_{f,t}$) expect a restrictive fiscal policy. The opposite occurs when $\hat{g}_{t-1} < 0$. Fiscal beliefs in the economy are then generated by the difference between the fractions of the two agent types. When $FB_t > 0$, fiscal beliefs are characterized by an increase in government spending, while the opposite occurs when $FB_t < 0$. Again, the magnitude of such beliefs depends on the difference between $\alpha^{g}_{f,t}$ and $\alpha^{g}_{e,t}$. In the extreme cases, if $FB_t = 1$ all agents expect an increase in public spending, while when $FB_t = -1$ every agent expects a reduction in spending.

In relation to the link between inflation and agent's beliefs, we follow De Grauwe (2011) by interpreting the inflation forecasting heuristics as a measure of how credible the central bank's inflation targeting is for the agents. This can be achieved by simply looking at the shares of inflation fundamentalists ($\alpha^{\pi}_{f,t}$) (or, alternatively, at the share of extrapolators, $\alpha^{\pi}_{e,t} = 1 - \alpha^{\pi}_{f,t}$). If the central bank's inflation target is very credible, using the announced inflation target will produce good forecasts and, as a result, the probability that agents will rely on the inflation target ($\alpha^{\pi}_{f,t}$) will be high. If, on the contrary, the inflation target does not produce good forecasts (compared to the extrapolative rule) the probability that agents will use it will be small (low $\alpha^{\pi}_{f,t}$) and we will observe higher concentration in the use of the extrapolative rule (high $\alpha^{\pi}_{e,t}$).

2.6 Summary of the model and parametrization

The complete model can be summarized as follows. It includes the aggregate demand (11), the Phillips curve (12), the monetary and fiscal policy rules (14) and (15), and the equation representing the evolution of public debt (13). The expectations evolve according to the principles enunciated in Eqs. (16–28). The model is completed by measuring animal spirits and fiscal beliefs with Eqs. (29) and (30).

Table 1 Parametrization

$\sigma = 2$	$\bar{g} = 0.21$	$\phi = 100$	$\theta = 6$	$\eta = 2$	$\beta = 0.99$
$c_1 = 1.5$	$c_2 = 0.125$	$c_3 = 0.5$	$f_1 = 0.5$	$f_2 = 0.5$	$f_3 = 0.2$
$\bar{r} = 0.01$	$\chi = 0.6$	$\gamma = 2$	$\rho = 0.5$	$SD_{shock} = 0.5^{\S}$	$M_{shock} = 0^{\S}$

§ Standard deviation and mean of the shocks

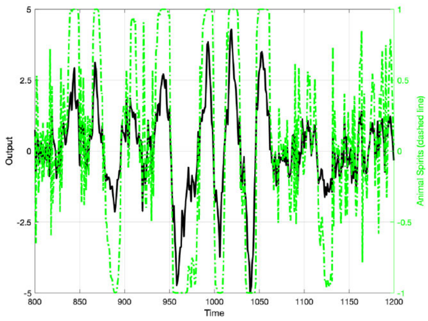
The model is then simulated according to the parametrization reported in Table 1. The parametrization is implemented by taking the relevant period to correspond to a quarter. The preference parameter is set as $\beta = 0.99$, which implies a yearly 4% return on financial assets in the steady state (see Galí, 2008). Hence, given the quarterly parametrization, $\bar{r} = 0.01$. For the aggregate demand, Phillips curve and public debt functions we set the parameters to match standard macroeconomic simulation results. This ensures any potential comparability with the baseline macroeconomic model. In the demand function, we set $\sigma = 2$ and $\bar{g} = 0.21$, while for the supply function we set $\eta = 2$ as well as $\phi = 100$ and $\theta = 6$ (Hommes et al. 2018). Based on these parameters, given that $k = \frac{\theta - 1}{\phi}$, we set $k = 0.05$. Finally, we assume that debt to output ratio in the equilibrium is 60%, so we set $\chi = 0.6$ (Kirsanowa et al, 2007; Kirsanova and Wren-Lewis 2012). Then, $\tau = 0.216$ is retrieved from the steady state equation of debt to income, $\tau = (1 - \beta)\chi + \bar{g}$ (see the online Appendix II). Also for the parametrization of the policy rules, we tried to be as consistent as possible with the intervening literature. We apply the Taylor principle and set $c_1 = 1.5$ in the monetary policy function (see Galí, 2008). In the prametrization of the fiscal policy rule, we set $f_2 = 0.5$ and $f_3 = 0.2$ (see De Grauwe 2012). Furthermore, we assume policy instruments smoothing and set $c_3 = 0.5$ and $f_1 = 0.5$ (Woodford, 2003; De Grauwe 2012). Finally, regarding the expectations equations, we set the parameter of the agents' willingness to learn as $\gamma = 2$ and the memory parameter as $\rho = 0.5$ (De Grauwe 2012).

3 Basic properties of the model

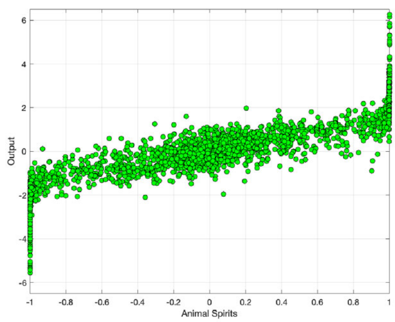
We first highlight the main features of the model by simulating it without imposing the ZLB. Figure 1 provides information on agent's beliefs, output and inflation from the simulation of the model over 2000 periods. The same, in relation to public debt and government spending, is done in Fig. 2.

Figure 1 panel (a) shows the simulated output and animal spirits in the time domain, while panel (b) reports the same variables in a scatter diagram.[8] First, panels (a) and (b) show the animal spirits variable in action. Our variable mimics the behaviour of confidence indices often used as proxies for animal spirits in empirical works oscillating between optimism and pessimism over time. This is due to the learning mechanism and the related definition of Eq. (29). Agents are not optimist or pessimist

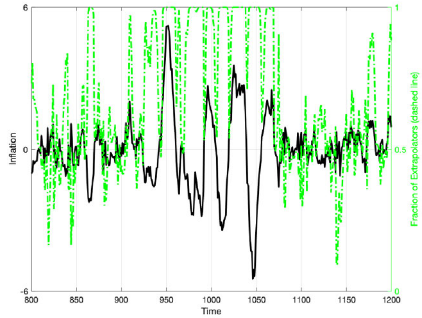
[8] The two panels complement each other. For the sake of clarity, panel (a) shows only a portion of the simulation in the time domain, so to show the time paths of the two variables and their links. Panel (b) allows to verify that what suggested by panel (a) holds throughout the entire simulation.



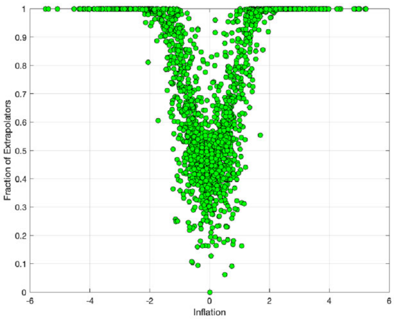
(a) Animal Spirits and Output {sample}



(b) Animal Spirits and Output {full}



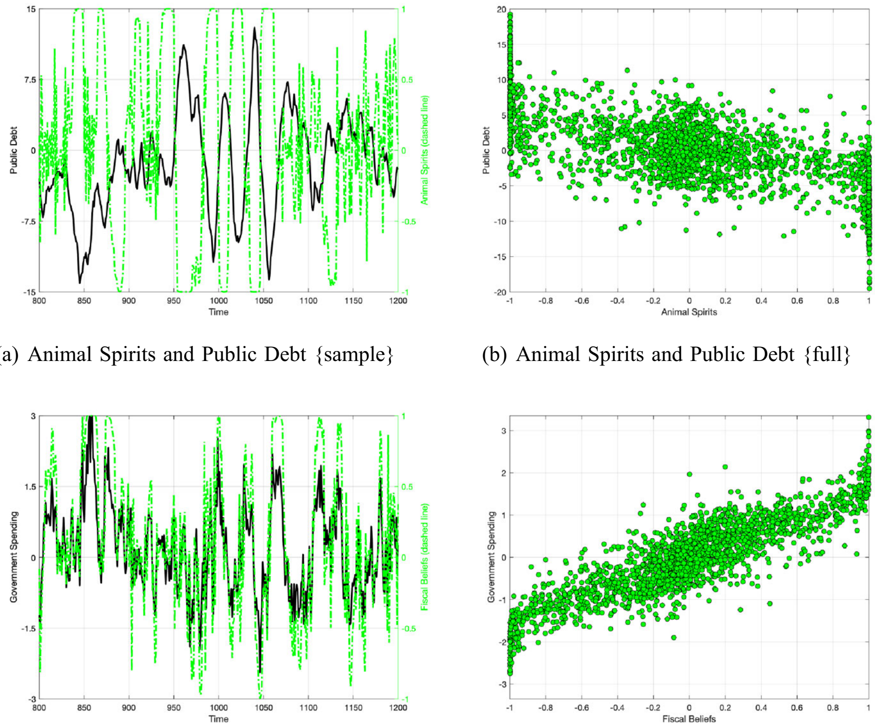
(c) Extrapolators and Inflation {sample}



(d) Extrapolators and Inflation {full}

Fig. 1 Agents' beliefs, output and inflation

by nature and, although their rationality is bounded, their beliefs formation is a dynamic process that interacts with the surrounding economic scenario. As a result, our variable is able to replicate self-fulfilling waves of optimism and pessimism typical of animal spirits. Panel (a) also shows strong cyclical movements in output around its steady state that are closely linked to the waves of optimism and pessimism in the market as measured by animal spirits index (correlation between the two variables is $+0.87$). Therefore, as confirmed in panel (b), periods of pessimism are characterized by busts in economic activity, while periods of optimism correspond to booms. This link can be easily explained as follows. In a phase of intense optimism, agents expect positive output and behave accordingly, so that the boom in output is created via the aggregate demand. A peculiarity of this class of models is that the relation between animal spirits and output results in the latter not being normally distributed, with excess kurtosis and fat tails (De Grauwe 2012; Calvert Jump and Levine 2019). Our model confirms this result as the output kurtosis is 4.99. Panels (c–d) focus on the link between the inflation rate and agents' heuristics. Panel (c) shows how the fraction of inflation extrapolators fluctuates around 50% (and so does the fraction of fundamentalists) when the inflation rate is around the central bank's target. However, when the inflation rate moves away from the target, the fraction of fundamentalists sharply declines



(a) Animal Spirits and Public Debt {sample}

(b) Animal Spirits and Public Debt {full}

(c) Fiscal Beliefs and Spending {sample}

(d) Fiscal Beliefs and Spending {full}

Fig. 2 Agents' beliefs, public debt and government spending

and more and more agents rely on the extrapolative rule. As confirmed by panel (d), this occurs irrespective of the sign of the deviation. According to the results reported in panel (d), for deviations of the inflation bigger than $\pm 2\%$ inflation expectations become fully extrapolative. On the contrary, when the central bank is able to keep inflation around the target, a substantial fraction of agents is fundamentalist and uses the monetary authority's target as a reference point when forecasting inflation. Given that the fraction of fundamentalists can be considered as a measure of the central bank's credibility, we can then conclude that the less the central bank is able to keep inflation around its target, the lower its credibility.

In Fig. 2 panels (a–b), the link between public debt and animal spirits is presented. The simulated correlation between these two variables is -0.68 and this is reflected in the scatter diagram. Thus, periods of high public debt are characterized by pessimism in animal spirits, while optimism dominates in period of low public debt. Based on this result, we can also conclude that the government faces a trade-off between the stabilization of animal spirits and the stabilization of public debt and that it may not be able to stabilize booms and busts due to the debt constraint it faces.

To see this more clearly, suppose that an economy is hit by a strong wave of pessimism. Given the high correlation between animal spirits and output, the wave of pessimism translates into a phase of recession. The recession will lead to an automatic increase in the budget deficit and to an increasing public debt. This leads to a trade-off for the fiscal authorities: attempts at stabilizing the animal spirits by fiscal stimulus will increase the budget deficit and raise public debt. The same holds when the economy experiences a boom produced by strong optimism. Clearly, this is rooted in the definition of the fiscal rule (15) and in the strong correlation between output and animal spirits. Therefore, if the government follows a fiscal rule like in Eq. (15), it will have to choose between the stabilization of the animal spirits and the stabilization of public debt. Finally, Fig. 2 panels (c–d) show the link between government spending and fiscal beliefs (correlation is 0.88 between the two variables). By keeping in mind the definition of fiscal beliefs, the figure shows how the extrapolative rule tends to dominate in periods in which spending substantially deviates from its steady state (this applies to both positive and negative deviations). At the same time, heterogeneity in expectations is more pronounced when spending is around its long-run average. In periods of pessimistic (restrictive) fiscal beliefs, the latter will have a positive impact on output via the aggregate demand. This would allow governments to decrease spending and the pessimistic beliefs are then vindicated. Thanks to the learning mechanism, the increased performance of pessimism will attract other agents from the optimistic pool,[9] this cumulative phenomenon results in the fact that in our model also the fiscal beliefs are self-fulfilling.

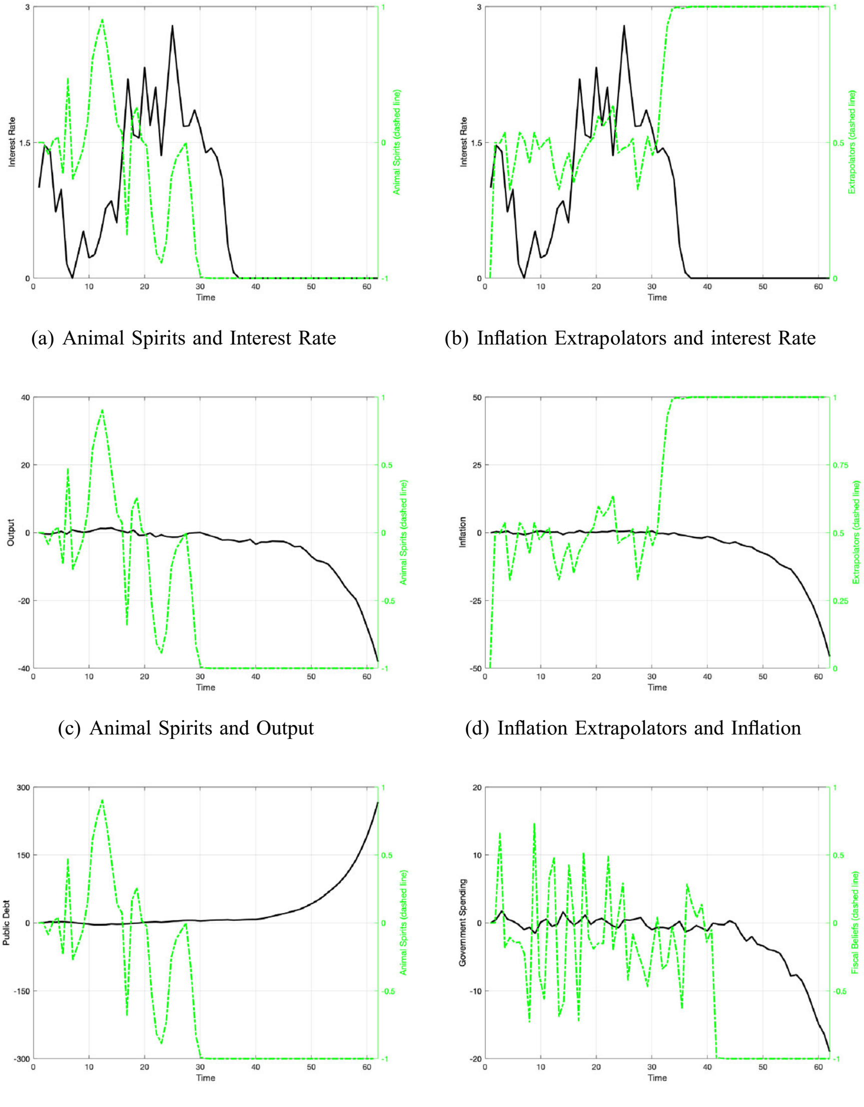
4 ZLB and deflationary traps

In this section, we look at the functioning of the model when we impose the ZLB on the interest rate. Specifically, we study how this situation can create a deflationary trap in which the agents' beliefs, generated within the model, play a crucial role. The results of the reported simulation imply that when the ZLB prevails, the economy can be trapped into a deflationary spiral that is dynamically unstable. Figure 3 shows the dynamics of the model under this circumstance.[10]

Panel (a) shows that animal spirits are characterized by extreme pessimism when the system hits the ZLB: when the interest rate is trapped at the ZLB, the animal spirits index collapses to -1. Furthermore, panel (b) shows that when the interest rate is trapped at the ZLB, the inflation expectations are dominated by the extrapolative rule. The explanation is the following. Once the interest rate is stuck at the ZLB, agents start realizing that the central bank is not capable of using its policy instrument to fulfil its target. Therefore, the credibility of the central bank drops and agents do not use the monetary authority's inflation target to form their expectations. A cumulative learning process is triggered and it results in the fact that extrapolators dominate the inflation expectations. Panel (d) shows how this mechanism is also reflected in the inflation dynamics. At the ZLB the central bank is not able to further reduce the nominal interest rate to stimulate inflation that is too low and below its target. Once agents realize this,

9 The opposite occurs when optimistic (expansionary) fiscal beliefs dominate.

10 In this figure, we report all the variables as represented in the log-linear version of the model, except for the interest rate that is expressed in levels.



(a) Animal Spirits and Interest Rate

(b) Inflation Extrapolators and interest Rate

(c) Animal Spirits and Output

(d) Inflation Extrapolators and Inflation

(e) Animal Spirits and Public Debt

(f) Fiscal Beliefs and Government Spending

Fig. 3 Agents' beliefs and macroeconomic variables in a deflationary trap

they quickly switch to the extrapolative rule. The dominance of the extrapolative rule, combined with low inflation and the ZLB, generates a self-fulfilling mechanism of deflation that cannot be contained by the monetary authority.[11] Moreover, given the link between animal spirits and output established in the previous section, we can

[11] In principle, the dominance of the extrapolative rule (also for output and spending) is at the heart of the deflationary spiral. Infact, given the trends in inflation expectations, animal spirits and fiscal beliefs

argue that the period of strong pessimism that characterizes the system at the ZLB should be reflected in decreasing output. This is confirmed in panel (c). One can easily observe that the simulated behavior of the interest rate, inflation and output clearly mimics a deflationary trap. At the same time, based on the links among the model variables established in the previous section, we can also expect that a period of chronic pessimism in animal spirits should be characterized by growing public debt. In fact, in panel (e) we show how the real public debt level explodes and that this dynamics is triggered by the system hitting the ZLB. The explosive path of public debt is the result of the falling inflation, decreasing tax income (due to the fall in output) and the impossibility to reduce the interest rate in order to lower the weight of past debt.[12] Finally, panel (f) highlights how the explosive debt dynamics and chronic pessimism are reflected in austerity measures that soon trigger self-fulfilling pessimism in fiscal beliefs.

5 ZLB and monetary policy

Most of the studies on the ZLB have focused on its links with monetary policy. A recurrent result in the literature is that the probability of hitting the ZLB (and then entering a deflationary spiral) is strongly linked to the inflation target set by the central bank (Evans et al. 2008; De Grauwe and Ji 2019; Hommes and Lustenhouwer 2019b). Our behavioral model confirms this result. This creates a basis on which we will develop the additional insights presented in the next two sections.

In Fig. 4 panel (a), we report the number of ZLB hits under different central bank's inflation targets. The figure shows that increasing the target progressively reduces the probability of hitting the ZLB. Very low inflation targets expose the system to higher probability of hitting the ZLB and then entering a deflationary trap. For instance, for an inflation target equal to 0, this probability is extremely high, but with a 2% inflation target, it sharply reduces. However, despite this reduction, under a 2% target the system still hits the ZLB in 29.9% of cases. Further increments bringing the target between 3% and 4% provide very significant reductions of the ZLB hits. According to our results, inflation targets between 3% and 4% seem to secure the system from the ZLB problem and, consequently, from the risk of deflationary traps.

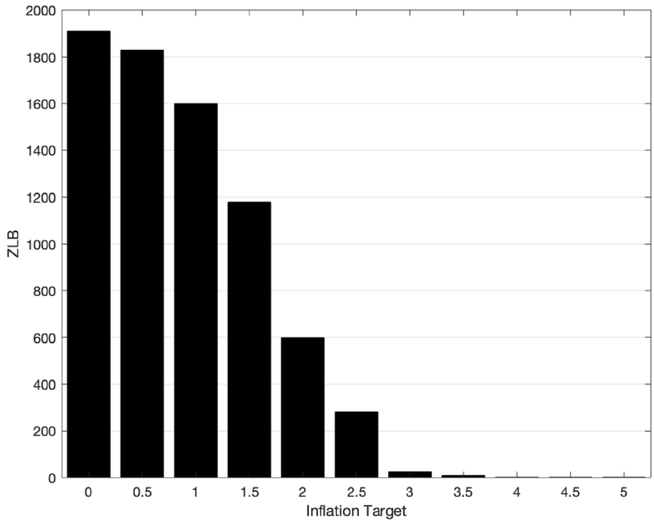
In this case, the hits number becomes negligible (i.e. for a 3% target the system hits the ZLB in 1.5% of the cases).[13] Finally, Fig. 4 panel (a) also shows that there are no marginal benefits deriving from inflation target values above 4%.

In panel (b) of Fig. 4, we report the mean values of the animal spirits and fiscal beliefs indices for different values of the inflation target. The figure shows that when the

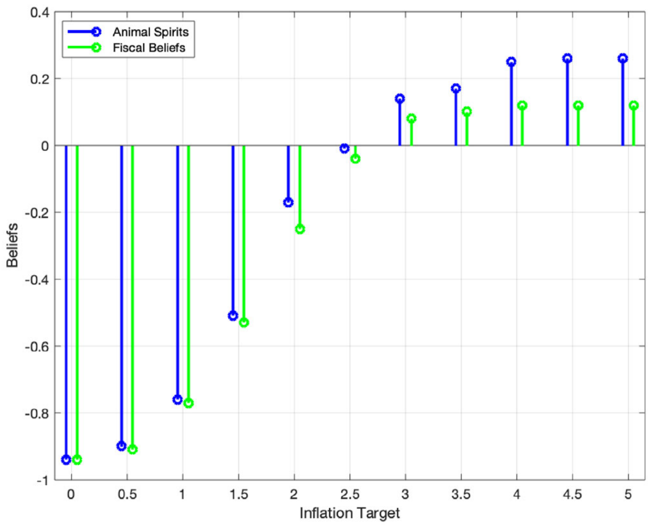
Footnote 11 continued
reported in Fig. 3, one can see that a potential shift towards the fundamentalist rule would help the system in fighting the destabilizing dynamics.

[12] This mechanism is similar to the debt-deflation theory pioneered by Fisher (1933).

[13] According to the data reported in De Grauwe and Ji (2019), the average ZLB hits experienced by countries with central banks' target of 2% (EMU, US, UK, CH and SE) is around 26%; while for countries with central banks' targets of 3% (CA, NO, AU and NZ), the recorded number of hits is 1.5%. Hence, the results provided by our model are in line with the existing evidence on the link between inflation targets and the ZLB.



(a) Inflation Target and ZLB



(b) Inflation Target and Beliefs

Fig. 4 Inflation target, ZLB and beliefs

inflation target increases, agents beliefs move towards more optimism in a non-linear way. Put differently, increasing the inflation target (starting from 0%) significantly reduces endemic pessimism. For targets below 2%, agents' beliefs are characterized by pronounced pessimism. Starting from a target of 2%, beliefs are characterized by more tranquillity. When the inflation target reaches 2.5%, both indices are around zero on average, so that periods of optimism and pessimism are equally probable. Starting from a target of 3%, beliefs are still tranquil with light optimism. The interpretation of such links is the following. When the inflation target is 0%, the cyclical movements in output and animal spirits inevitably lead to recessions that also drive inflation into negative territories. If the recession is deep and deflation intense, then the real interest rate is likely to increase significantly and so does the real public debt. Under this circumstance, the ZLB makes it impossible for the central bank to lower the nominal interest rate. At the same time, the government experiences a kind of policy trade-off as, given the fiscal rule (15), the decrease in output and the increase in public debt call for opposite spending policies. As the economic policy authorities loose their stabilizing capacity, and the economy gets stuck in recession and deflation, pessimism sets in. Such pessimism further amplifies the recession and a self-validating spiral develops. The higher the inflation target, the lower the probability that such a mechanism can take place. Hence, higher targets are associated with more optimism. As according to panel (b) no further changes in agents' beliefs seem to take place for targets above 4%, we have further support for the idea that there are no marginal benefits by rising the target above this threshold.

Thus, based on the results highlighted in this section, we conclude that very low inflation targets (below 2%) become a breeding ground for pessimism, recessions and deflationary spirals. The way out is to increase the inflation target. Our results suggest that an inflation target of $3-4\%$ is better than 2% in making sure that the economy does not get stuck in the chronic pessimism at the ZLB.

6 ZLB and fiscal policy

As previously discussed, most of the literature on the ZLB has focused on its links with monetary policy. The limited number of studies that have also considered the role of fiscal policy has mainly focused on its capabilities to drag the economy out of the ZLB, and of a deflationary trap, via expansionary policy shocks. However, it can be argued that also fiscal policy can affect the probability of hitting the ZLB. This involves investigating the impact of different values of the parameters in the fiscal rule.

Figure 5 presents the number of times the system has hit the ZLB under different values for the parameter of public debt (f_3) in the fiscal rule (combined with the central bank's inflation target). It can be seen that higher values of f_3 substantially increase the probability of hitting the ZLB. The interpretation of this result is the following. In periods in which public debt increases (i.e. due to strong shocks), the government reacts by reducing spending. If it is not fully anticipated by agents, the reduction in spending will trigger a reduction in both inflation and output. The reductions in inflation and output imply a decrease in the interest rate by the central bank. As a result, the stronger the reaction of the government to the debt increase, the stronger the related decrease in the interest rate that can therefore hit the ZLB with higher probability. Therefore, if the government is strongly focused on public debt stabilization, the chances of hitting the ZLB are higher.

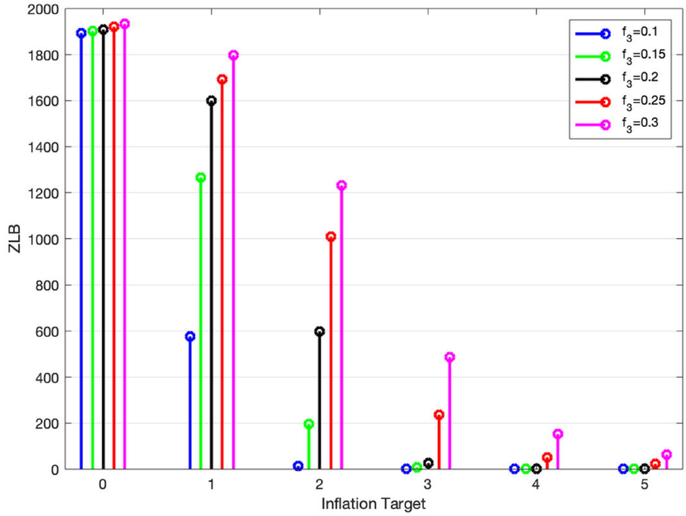


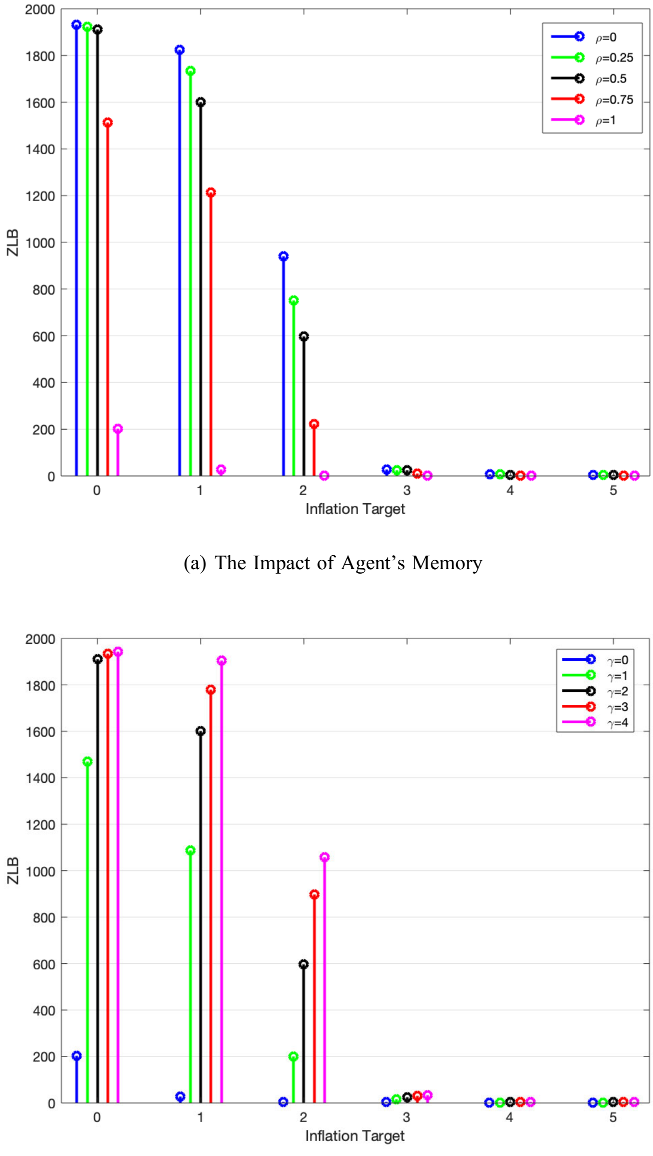
Fig. 5 Inflation target, ZLB and fiscal policy

Figure 5 also shows that this occurs irrespective of the inflation target set by the central bank. However, it is also shown that the magnitude of this effect changes for different values of the inflation target. When the inflation target is 0, the system will be strongly exposed to hitting the ZLB for any value of f_3. Nonetheless, as soon as the inflation target increases, the impact of debt stabilization in the fiscal rule becomes very important. The figure shows that higher values of f_3 increase the likelihood of hitting the ZLB also when the central bank sets a higher inflation target. In this sense, the conduct of fiscal policy can substantially reduce the positive effects of higher inflation targets. However, it is very important to note that this effect seems to be relevant only for inflation targets below 4%.

Given these results, we can now enrich our discussion of the previous section with the following conclusion. The combination of low inflation targets in the monetary rule and strong focus on debt stabilization in the fiscal rule dramatically increases the probability of hitting the ZLB and is a breeding ground for deflationary traps.

7 ZLB, memory and willingness to learn

As shown in Sect. 4, agents' beliefs play a crucial role in propagating a deflationary trap. One can then argue that the way in which these beliefs are formed also affects the probability of hitting the ZLB. In this section we look at the importance of the two main parameters involved in the learning mechanism of agents: the agents' memory (ρ) and willingness to learn (γ). To this aim, the model has been simulated under different values for these parameters in relation to different inflation targets. The results are reported in Fig. 6.



(a) The Impact of Agent's Memory

(b) The Impact of Agent's Willingness to Learn

Fig. 6 Inflation target, ZLB, memory and willingness to learn

Panel (a) focuses on the role of agents' memory. It shows that higher values of ρ (more memory) reduce the probability of hitting the ZLB and then to enter a deflationary trap. It can be argued that less memory implies more focus on recent information by agents and, therefore, stronger impact of recent observations on their expectations. Hence, once the system is on a decreasing nominal interest rate path, shorter agent's memory will imply expectations that strengthen the current macroeconomic dynamics. As a result, the interest rate will go further down and this increases the probability of hitting the ZLB. In contrast, longer agents' memory will reduce the impact of recent trends in macroeconomic variables on agents' expectations. As a result, longer memory allows agents to form expectations on a longer set of information and, therefore, it avoids an expectation-driven self-reinforcing downward trend in the economy. Figure 6 panel (a) also shows that the negative link between ρ and the probability of hitting the ZLB is observed independently from the inflation target set by the central bank. Even when the central bank sets the target at 0, if agents have infinite memory ($\rho = 1$) the impact of the ZLB is substantially reduced.

Figure 6 panel (b) reports the results of the same exercise when the sensitivity analysis involves the agents' willingness to learn (γ). It shows that higher values of γ (more willingness to learn) increase the probability of hitting the ZLB and then to enter a deflationary trap. In our model, a greater willingness to learn implies a higher agents' capability to switch from one forecasting rule to the other and, therefore, a stronger reaction of agents' expectations to steady trends and shocks. Hence, once the system is on a persistent decreasing nominal interest rate path, more agents will be willing and able to switch to the extrapolative rule. The increase in the fraction of extrapolators will imply a reinforcement of the current macroeconomic dynamics that pushes the interest rate further down. This raises the probability of hitting the ZLB. It can be noted that also the positive link between γ and the probability of hitting the ZLB is observed independently from the inflation target set by the central bank. When the central bank sets the target at zero, if agents have no willingness to learn ($\gamma = 0$) the problem of the ZLB is substantially less severe due to the absence of learning. In general, the reduction of learning substantially reduces the likelihood of hitting the ZLB as agents will be less and less able to change their forecasting rule.

Finally, as a general result, Fig. 6 shows that the impact of the behavioral parameters is very important for inflation targets below 4%. Once the central bank sets its inflation target at values equal or above 4%, the impact of these parameters tends to be negligible. Hence, an inflation target of 4% allows the central bank to keep the system away from deflationary paths and to avoid the nominal interest rate hitting the ZLB. This, in turn, prevents the agents' beliefs from being an important factor in leading the system to hit the ZLB.

8 Conclusion

In this article we have employed a New Keynesian behavioral model to study the impact of the ZLB on an economic system under the assumption that agents have limited cognitive capabilities. This model generates waves of optimism and pessimism (agents' beliefs).

We have studied how the system can be gripped in a deflationary spiral and, by making use of the endogenous waves of optimism and pessimism, we have proved that agents' beliefs play a crucial role in the generation of this dynamically unstable phenomenon. Within this framework, we have also investigated the role of macroeconomic policies and their links with agents' beliefs.

We have shown that increasing the inflation target from 0 to 4% progressively reduces the likelihood of hitting the ZLB. The interpretation provided by our framework is the following. Inflation targets below 2% are characterized by strong pessimism in agents' beliefs and expose the system to frequently hit the ZLB, leading to a deflationary spiral. Simulations of the model with inflation targets in the range of 2–3% are characterized by substantial changes in agents' beliefs that move away from chronic pessimism, resulting in a much lower number of ZLB hits. A target equal to 4% marginalizes the ZLB problem and stabilizes agents' beliefs. No further benefits are obtained when the inflation target is increased above 4%.

Our analysis has shown how also the conduct of fiscal policy can affect the likelihood of hitting the ZLB. According to our simulations, more focus on pubic debt stabilization by the fiscal authority increases the likelihood of hitting the ZLB. The impact of the fiscal stance is particularly relevant for inflation targets between 1 and 3%. Thus, the combination of low inflation targets and strong focus on public debt stabilization creates breeding grounds for deflationary traps. Our results also suggest that the impact of the fiscal stance is negligible for inflation targets equal, or above, 4%.

Finally, we have also analyzed the role played by some attributes of agents' expectations formation. Specifically, we have shown that the likelihood of hitting the ZLB progressively increases for decreasing agents' memory and for increasing agents' willingness to learn. However, when the central bank's inflation target is set above 3%, the impact of agents' beliefs is reduced considerably.

The key takeaway of this paper is the following. Although the inflation target set by the central bank is crucial to avoid hitting the ZLB, other factors like the governments' focus on public debt stabilization and agents' beliefs are vey important in determining the strength of the ZLB problem for an economy. These factors are especially relevant for values of inflation targets that are commonly used in contemporary central banking (2–3%). However, their impact can be marginalized by setting an inflation target of 4%. In that case, the central bank is able to shield the system from the problems that arise when the economy hits the ZLB.

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References

Akerlof, G.A., Shiller, R.J.: Animal Spirits: How Human Psychology Drives the Economy, and Why it Matters for Global Capitalism. Princeton University Press (2009)

Albonico, A., Ascari, G., Gobbi, A.: The public debt multiplier. J. Econ. Dyn. Control. **132** (2021)

Anderson, S., de Palma, A., Thisse, J.F.: Discrete Choice Theory of Product Differentiation. MIT Press, Cambridge, MA (1992)

Andrade, P., Galí, J., Le Bihan, H., Matheron, J.: Should the ecb adjust its strategy in the face of a lower r^*? J. Econ. Dyn. Control. **132** (2021)

Arseneau, D.M.: Expectation traps in a new Keynesian open economy model. Econ. Theor. **49**, 81–112 (2012)

Aruoba, S.B., Cuba-Borda, P., Schorfheide, F.: Macroeconomic Dynamics Near the ZLB: A Tale of Two Countries. Rev. Econ. Stud. **85**, 87–118 (2018)

Assenza, T. Bao, T., Hommes, C., Massaro, D.: Experiments on Expectations in Macroeconomics and Finance. In: Duffy, J. (ed) Experiments in Macroeconomics (Research in Experimental Economics). 17, Emerald Group Publishing Limited, Bingley, West Yorkshire, pp. 11-70 (2014)

Assenza, T., Heemeijer, C.H., Hommes, C., Massaro, D.: Managing self-organization of expectations through monetary policy: a macro experiment. J. Monet. Econ. **117**, 170–186 (2021)

Benhabib, J., Evans, G.W., Honkapohja, S.: Liquidity traps and expectation dynamics: fiscal stimulus or fiscal austerity? J. Econ. Dyn. Control **45**, 220–238 (2014)

Benigno, G., Fornaro, L.: Stagnation Traps. Rev. Econ. Stud. **85**, 1425–1470 (2018)

Blake, W.P., Kirsanova, T.: Discretionary policy and multiple equilibria in LQ RE models. Rev. Econ. Stud. **79**(4), 1309–1339 (2012)

Bodenstein, M., Hebden, J., Nunes, R.: Imperfect credibility and the zero lower bound. J. Monet. Econ. **59**, 135–149 (2012)

Branch, W.A., Evans, G.W.: Monetary policy and heterogeneous expectations. Econ. Theor. **47**, 365–393 (2011)

Brock, W.A., Hommes, C.: A rational route to randomness. Econometrica **65**(5), 1059–1096 (1997). (**September**)

Calvert Jump, R., Levine, P.: Behavioural new Keynesian models. J. Macroecon. **59**, 59–77 (2019)

Christiano, L., Eichenbaum, M., Rebelo, S.: When is the government spending multiplier large? J. Polit. Econ. **119**(1), 78–121 (2011). (**February**)

Clarida, R.H.: What Has - and Has Not - been learned about monetary policy in a low-inflation environment? A review of the 2000s. J. Money Credit Bank **44**, 123–140 (2012). (**February**)

De Grauwe, P.: Animal spirits and monetary policy. Econ. Theor. **47**(2–3), 423–457 (2011)

De Grauwe, P.: Lectures on Behavioral Macroeconomics. Princeton University Press (2012)

De Grauwe, P., Foresti, P.: Animal spirits and fiscal policy. J. Econ. Behav. Org. **171**, 247–263 (2020)

De Grauwe, P. Foresti, P.: Interactions of fiscal and monetary policies under waves of optimism and pessimism. J. Econ. Behav. Org. **212**(C), 466–481 (2023)

De Grauwe, P., Ji, Y.: Inflation targets and the zero lower bound in a behavioural macroeconomic model. Economica **86**(342), 262–299 (2019). (**April**)

Eggertsson, G., Krugman, P.: Debt deleveraging, and the liquidity trap: a fisher-minsky-koo approach. Quart. J. Econ. **127**(3), 1469–1523 (2011)

Eggertsson, G., Woodford, M.: The zero bound on interest rates and optimal monetary policy. Brook. Papers Econ. Activity. **1**, 139–211 (2003)

Evans, G.W., Guse, E., Honkapohja, S.: Liquidity traps, learning and stagnation. Eur. Econ. Rev. **52**, 1438–1463 (2008)

Evans, G.W., Honkapohja, S.: Policy interaction, expectations and the liquidity trap. Rev. Econ. Dyn. **8**, 303–323 (2005)

Fernández-Villaverde, J., Gordon, G., Guerrón-Quintana, P., Rubio-Ramírez, J.F.: Nonlinear adventures at the zero lower bound. J. Econ. Dyn. Control **57**, 182–204 (2015)

Fisher, I.: The debt-deflation theory of great depressions. Econometrica **1**(4), 337–357 (1933)

Giraud, G., Pottier, A.: Debt-deflation versus the liquidity trap: the dilemma of nonconventional monetary policy. Econ. Theor. **62**, 383–408 (2016)

Guerrieri, V., Lorenzoni, G.: Credit crises, precautionary savings, and the liquidity trap. Quart. J. Econ. **132**, 1427–1467 (2017)

Hommes, C.: Behavioral and experimental macroeconomics and policy analysis: a complex systems approach. J. Econ. Literature **59**(1), 149–219 (2021)

Hommes, C., Lustenhouwer, J.: Managing unanchored, heterogeneous expectations and liquidity traps. J. Econ. Dyn. Control **101**, 1–16 (2019)

Hommes, C., Lustenhouwer, J.: Inflation targeting and liquidity traps under endogenous credibility. J. Monet. Econ. **107**, 48–62 (2019)

Hommes, C., Lustenhouwer, J., Mavromatis, K.: Fiscal consolidations and heterogeneous expectations. J. Econ. Dyna. Control **87**(C), 173–205 (2018)

Kirsanova, T., Satchi, M., Vines, D., Wren-Lewis, S.: Optimal fiscal policy rules in a monetary union. J. Money Credit Bank **39**(7), 1759–1784 (2007). (**October**)

Kirsanova, T., Wren-Lewis, S.: Optimal fiscal feedback on debt in an economy with nominal rigidities. Econ. J. **122**(559), 238–264 (2012)

Kollmann, R.: Liquidity traps in a world economy. J. Econ. Dyn. Control. **132** (2021)

Krugman, P.: It's Baaack: Japan's slump and the return of the liquidity trap. Brook. Pap. Econ. Act. **29**(2), 137–206 (1998)

Kryvstov, O., Petersen, L.: Expectations and Monetary Policy: Experimental Evidence, pp. 2013–44. Bank of Canada, No (2013)

Le Riche, A., Magris, F., Onori, D.: Monetary rules in a two-sector endogenous growth model. Econ. Theor. **69**, 1049–1100 (2020)

Mertens, K., Ravn, M.: Fiscal policy in an expectations-driven liquidity trap. Rev. Econ. Stud. **81**, 1673–1677 (2014)

Muscatelli, V.A., Tirelli, P.: Analyzing the interaction of monetary and fiscal policy: does fiscal policy play a valuable role in stabilisation? CESifo Econ. Stud. **51**(4), 549–85 (2005)

Pfajfar, D., Zakelj, B.: Inflation expectations and monetary policy design: evidence from the laboratory. Tilburg University, CentER Discussion Paper 2011-091 (2011)

Pfajfar, D., Zakelj, B.: Experimental evidence on inflation expectation formation. J. Econ. Dyn. Control **44**, 147–168 (2014)

Rotemberg, J.J.: Monopolistic price adjustment and aggregate output. Rev. Econ. Stud. **49**(4), 517–531 (1982)

Schmidt, S.: Fiscal activism and the zero nominal interest rate bound. J. Money Credit Bank **49**(4), 695–732 (2017). (**June**)

Svensson, L.: Escaping from a liquidity trap and deflation: the foolproof way and others. J. Econ. Persp. **17**(4), 145–166 (2003)

Woodford, M.: Simple analytics of the government expenditure multiplier. Am. Econ. J. Macroecon. **3**(1), 1–35 (2011)