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Document de Travail n° 2023 – 14

Mai 2023

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Fiscal multipliers, public debt anchor and government credibility in a behavioural macroeconomic model*

Amélie BARBIER-GAUCHARD[†], Thierry BETTI[‡], Théo METZ [§]

May 4, 2023

Abstract: We develop a behavioural macroeconomic model to investigate the question of fiscal policy credibility and how agents' expectations about the output gap, public debt, expenditure and taxation affect the fiscal multiplier and debt stability. To do this, we model heterogeneous expectation-formation processes in a market populated by *fundamentalists* and *chartists*, agents being able to switch from one rule to another depending on the effective outcome in each period. This model produces waves of optimism and pessimism along the business cycle. We show in this article that when agents are optimistic about the future output gap and public debt, the fiscal multiplier tends to be larger whatever the nature of the fiscal shock. It also appears that fiscal expansion has less of a negative effect on public debt. Furthermore, agents' expectations about public debt and the fiscal credibility of the government affect indicators of government performance (the fiscal multiplier and public debt stability).

Keywords: public debt anchor, fiscal multipliers, fiscal credibility, behavioural macroeconomics.

JEL classification: E62, E7, H61, H68

*This paper was supported by the European Union. However, the views and opinions expressed are those of the authors alone and do not necessarily reflect those of the European Union. The European Union cannot be held responsible for them. The authors thank, Cars Hommes, the participants of the 10th UECE conference in Lisbon, the participants of the Tinbergen Insitute summer course on behavioural macroeconomics and complexity, the participants of the 1st International Workshop on Economic Growth and Dynamic Macroeconomics of the INFER Network, and the participants of the workshop on Scarring, hysteresis, and investment in Europe in the College of Europe for helpful comments.

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1 Introduction

In the context of the ongoing series of crises since the beginning of the 21st century (also called *the polycrisis* or *permacrisis*), fiscal rules are proving to be both insufficient and unsuitable to cushion economic shocks and stabilise public debt. Meanwhile, economic facts have highlighted the major role played by economic agents' expectations.

This contribution aims to fill a gap in the literature on fiscal credibility and government performance, both in terms of stabilising the economy (via fiscal multipliers) and of fiscal discipline. This paper offers an innovative theoretical insight into the role of fiscal credibility in terms of public debt and output stabilisation (by studying fiscal multipliers) in a framework where economic agents' expectations are based on "animal spirits". As such, this paper is located at the intersection of three areas of literature.

First, this paper borrows from the literature on fiscal discipline by focusing on the public debt path. Since the seminal paper of Kopits & Symansky (1998), the debate on fiscal discipline and government performance has regularly been reopened (see for instance Barbier-Gauchard, Baret & Debrun (2023) for a general overview of this debate). In the euro area, fiscal discipline has been a bone of contention between European authorities and member states (for a general overview, see Caselli et al. (2022)[1]). Widely criticised and several times reformed, the Stability and Growth Pact (1996) has failed to hold up the drift of public finance. In this respect, many studies, such as those by Barbier-Gauchard et al. (2021), have looked into the factors that affect fiscal rule compliance. In the same vein, Barbier-Gauchard, Baret & Papadimitriou (2023) try to predict future fiscal rule compliance.

Second, this paper provides new results on the determinants of fiscal multipliers. Since Auerbach & Gorodnichenko's 2012 seminal article, a vast literature has emerged on the state-dependence (or non-linearity) of fiscal multipliers. Empirically, fiscal multipliers have been shown to vary significantly over time and depending on the economic environment, and a number of theoretical articles have suggested various mechanisms to explain this variability. The main factors put forward based on DSGE models are variations in marginal utilities over the business cycle (Sims & Wolff (2018)), credit cycles and sovereign risk (Aloui & Eyquem (2019), Canzoneri et al. (2015), Ahmad et al. (2021) among others), or labour market mechanisms (Betti & Coudert (2022), Michaillat (2014)). In addition, studies bridge the gap between fiscal policy, debt dynamics and financial markets by highlighting the impact of sovereign risk on the effectiveness of fiscal policy (Badarau et al. (2014), Corsetti et al. (2013)).

Third, this paper fits into the literature on fiscal credibility, a fairly recent branch research. Most contributions to date are empirical studies dealing either with the determinants of fiscal credibility as analysed by ElBerry & Goeminne (2021) or Montes & de Hollanda Lima (2022), or with the effect of a fiscal credibility indicator on monetary and financial variables as in Montes & Acar (2020) and End & Hong (2022). Indeed, the credibility of fiscal plans influences government bond spread forecasts and then the evolution of the spreads themselves, as highlighted by Cimadomo et al. (2016). Also, Fève & Pietrunti (2016) and Ricco et al. (2016) demonstrate that fiscal policy communication affects agents' decisions and the fiscal multiplier.

To analyse the effects of agents' expectations on government performance (fiscal multipliers and public debt volatility), we use a behavioural macroeconomic model. This paper builds on the seminal work of De Grauwe (2012) and De Grauwe & Ji (2019) in behavioural macroeconomics to model non-rational expectations and allow for heterogeneous agents and waves of optimism and pessimism. De Grauwe & Foresti (2020) produce new insights into the short-run effects of fiscal policies, especially regarding the role of animal spirits over the business cycle on fiscal multipliers and the dynamics of government debt. Since the focus of this article is the credibility of fiscal policy, this type of model with heterogeneous expectations is relevant as a means of documenting the role of these mechanisms in fiscal policy shocks and debt sustainability.

[1] In this context, a recent strand of literature has focused on the quality or performance of public spending to better understand the reasons underlying public finance sustainability. For instance, Afonso & Coelho (2022) have evaluated the impact of so-called government spending efficiency scores (which efficiently indicate how governments can maintain their performance levels with fewer inputs) on fiscal sustainability. Larch et al. (2022) have described the necessary trade-off between discretionary public expenditure and public investment in the event of a major economic downturn.

This paper is therefore original in several ways. First of all, the behavioural macroeconomics approach offers a framework in which to analyse the role of agents' expectations on government performance, as initiated by De Grauwe & Ji (2019) and De Grauwe & Foresti (2020). Ricardian equivalence has been a central concept in modern macroeconomics to evaluate the effects on economic activity of fiscal shocks. This hypothesis holds in standard DSGE models with rational expectations. In this article, we verify the existence of this mechanism in a bounded rationality framework depending on the state of the economy.

We depart from De Grauwe & Foresti (2020) in several ways. First, our model considers an endogenous tax rate, thus allowing for possible Ricardian behaviour. Second, agents' have expectations regarding output-gap, inflation, public expenditure, but also about taxes and public debt. Finally, we propose an analysis of fiscal credibility and its impact on fiscal multipliers and public debt stability.

We show in this article that when agents are optimistic about the future output-gap and public debt, the fiscal multiplier tends to be larger whatever the nature of the fiscal shock. It also appears that fiscal expansion deteriorated, to a lesser extent, the public debt. Furthermore, agents' expectations about public debt and the fiscal credibility of the government turn out to affect government performance (the fiscal multiplier and public debt stability).

The rest of the paper is organised as follows. Section 2 reviews the literature. The behavioural macroeconomic model is described in section 3. Section 4 reports the results and section 5 concludes.

2 Literature review

Since the seminal work on Ricardian equivalence, trust in government has been considered crucial in governing the effectiveness of fiscal measures. As explained by Nguyen et al. (2022), trust in public institutions corresponds to "a person's belief that an institution will act consistently with their expectations of positive behaviour". However, this belief cannot be observed directly. Several measures of trust in government already exist[2]. Trust in government implies fiscal credibility. As proposed by End & Hong (2022), "fiscal credibility can be defined as the extent to which economic agents expect the government to try and fulfil its fiscal policy commitments. This covers two aspects: the intention and ability to achieve targets." The concept of credibility is very much related to the problem of time inconsistency introduced by Kydland & Prescott (1977)[3]. Fiscal credibility mainly rests on comparisons between budgetary forecasts (e.g., spending, budget balance, public debt, . . .) and budget outcomes.

Unlike the literature on central bank credibility, the literature on fiscal credibility[4] is fairly recent. The crucial questions are what the relevant indicators are to measure credibility and what impact the assessed degree of credibility has on the effectiveness of economic policy.[5] Montes & Acar (2020) have analysed disagreements in market expectations about fiscal results (public debt and primary budget balance) in Brazil between 2003 and 2017. Their findings indicate that increases in fiscal credibility (based on market expectations for the public debt to GDP ratio, but also on the primary surplus required to bring gross debt back to a value considered ideal) reduce expectation disparities. ElBerry & Goeminne (2021) empirically examine the determinants of deviations from budgetary forecasts, and hence of budget credibility, for 57 developing countries between 2006 and 2017. End & Hong (2022) develop different indicators of fiscal credibility that quantify the degree to which policy announcements anchor expectations, based on the deviation of private expectations from official targets, for 41 countries from 1989 to 2020. They also analyse the determinants of fiscal credibility and find that policy announcements partly re-anchor expectations and that fiscal rules and strong fiscal institutions, along with a good policy track record, magnify this effect, thereby improving fiscal credibility. Montes & de Hollanda Lima (2022) analyse the impact of fiscal credibility on the inflation risk premium in

[2] see for instance the OECD Trust Survey in Nguyen et al. (2022), offering food for thought on how to improve government outcomes and focus on what drives public trust in government.

[3] As an illustration, the time inconsistency problem lies in the possibility of altering previously announced policies due to changes in policymakers' preferences at another point in time, thus creating a time-inconsistent policy.

[4] also called "government credibility" or "budget credibility"

[5] For monetary policy, central bank credibility is traditionally assessed by the deviation of inflation expectations from the announced inflation target, the inflation target announced by the central bank. However, Bicchal (2022) discusses alternative measures of central bank credibility. For fiscal credibility, the question is more complex because unlike central banks, fiscal authorities do not commit to any particular macroeconomic objective.

Brazil from 2015 to 2018. They consider two different fiscal credibility indicators depending on the financial market expectations process (based either on primary surplus expectations, or on the deviation of expectations regarding government commitments to public debt sustainability following IMF recommendations). Their estimates indicate that fiscal credibility improvements reduce the inflation risk premium and, that these improvements mitigate the adverse effect of discretionary fiscal policies on the inflation risk premium. In addition, a dynamic analysis using impulse-response functions from VAR estimates reveals that the inflation risk premium is more sensitive to improvements in fiscal credibility than to improvements in monetary credibility. Unfortunately, the impact of fiscal credibility on government performance, particularly on fiscal multipliers, has scarcely been investigated to date in this literature.

This is despite the fact that, as underlined by Leeper (2009), agent expectations play an important role in the implementation of fiscal policies by policymakers, notably in predicting how policies will affect the economy and agents. It is now well established that fiscal multipliers depend on the state of the economy and on the development of a given country, its trade openness, its exchange rate regime and its level of debt Ilzetzki et al. (2013). Their impact may also depend on what predictions agents make about the fiscal stance of the government. In a frictionless real business cycle model for instance, Baxter & King (1993) find that the government spending fiscal multiplier is positive with respect to output but negative with respect to private consumption. In contrast, using an adaptive learning system in a RBC model, Mitra et al. (2019) demonstrate that short-term agent reactivity to public spending can lead to a larger positive fiscal multiplier. Fiscal multipliers can also be larger than those in a dynamic stochastic general equilibrium (DSGE) model Christiano et al. (2011) when the nominal interest rate is at or near zero. It is therefore clear that agents' expectations play a crucial role.

A new wave of macroeconomic behavioural models accommodates economic agents with bounded rationality, meaning that they have a limited understanding of the world around them. Thus, instead of optimising their utility function in infinite horizon, agents use simple rules/heuristics to forecast desirable variables. The agents are thus 'rational' in the sense that they learn from their mistakes and switch between the rules according to measures of performance (see the seminal work of Brock & Hommes (1997, 1998) and De Grauwe (2012), De Grauwe et al. (2012)). These changes between rules create non-linearity in the model and thus amplify the waves of business cycles. De Grauwe (2012), De Grauwe et al. (2012) refer to 'animal spirits' in reference to Keynes (1936) and Akerlof & Shiller (2010) because it is these waves of optimism and pessimism that create the business cycle. According to Keynes (1936), these 'animal spirits' represent uncertainty with respect to investment behaviour that is not always purely rational and predetermined. De Grauwe & Foresti (2020) present a three-equation new Keynesian model including a fiscal Taylor rule and a debt dynamic equation. Their results indicate that animal spirits drive the business cycle and thus affect the fiscal multiplier, which depends on the latter. These findings support Auerbach & Gorodnichenko's 2012 empirical evidence and the well-know state dependency of the fiscal multiplier Baum et al. (2012). This means that fiscal consolidation in periods of contraction, when agents are considered pessimistic, has a negative effect on output. The authors also find that the fiscal multiplier remains positive during expansion periods, when agents are optimistic, which implies that there is a noisy relationship between these two variables. This goes against Bentour (2021), for whom an expansionary period in which debt increases fits with Ricardian equivalence in that agents worry about a long-term rise in interest rates, thus decreasing the multiplier.

De Grauwe & Foresti (2020) use a similar model, except that they include an interest rate growth differential to capture each of the studied countries' fiscal space. This theoretical framework leads the authors to conclude that animal spirits are responsible for the negative correlation between public debt levels and the business cycle, thereby affecting policymakers' options. This model is also consistent with literature data on the state dependence of the multiplier. In his model, Gabaix (2020) introduces a new micro-founded "cognitive discounting" parameter that alters agents' expectations relative to rational expectations, while agents also use the steady state of the economy as a benchmark to forecast the future. He then defines the fiscal policy as transfers from the government to households and firms and assumes that there is no government consumption. Because of bounded rationality, agents are not longer considered Ricardian so the fiscal policy has a greater effect on the economy by decreasing taxes, especially when the zero lower bound is reached, where this policy is optimal. In this context, a tax cut increases households' consumption because they feel richer after the transfer, even in a two period model. Two more results of his behavioural model are that the monetary and fiscal policies can both be substitutes and that the multiplier for government spending (which is introduced in the consumer utility function) is greater than or equal to one. Gasteiger & Zhang (2014) analyse tax reforms in a learning process and find that volatility increases, leading to oscillatory dynamics similar to the waves created by pessimistic and optimistic behaviour in De Grauwe (2012), lowering the welfare gain after the reform compared with rational expectations. In the modelling vein of Brock & Hommes (1997), Hommes et al. (2018) study fiscal consolidation when agents are heterogeneous and have bounded rationality. They include a debt threshold in their model that characterises the time to consolidation if this threshold is reached. They find that agents' behaviours play an important role in the successful achievement of the fiscal plan whether the taxes-based or spending-based consolidations are anticipated or not. The time to consolidation is longer in a wave of pessimism if agents have not anticipated the correct type of consolidation (i.e. they anticipated a tax-based consolidation but a spending-based consolidation arose). Conversely, a wave of optimism reduces the time to consolidation if a tax-based plan is announced when agents had anticipated a spending-based plan.

Our aim is to fill a gap in the literature on fiscal credibility and government performance. This paper offers innovative theoretical insights into the role fiscal credibility plays in stabilising public debt and output-gap (*via* fiscal multipliers) in a framework where economic agents' expectations are based on "animal spirits".

3 Model

We develop a behavioural model in the spirit of De Grauwe (2012), De Grauwe & Ji (2019) and De Grauwe & Foresti (2020), where heterogeneous agents use heuristics to form their expectations. The model is a standard new-Keynesian model with an aggregate demand relationship, a new-Keynesian Phillips curve and a standard Taylor rule for the monetary policy. Also, a fiscal policy block is introduced with public expenditure and an endogenous consumption tax. The key element of the model is the expectation formation process, which allows us to introduce uncertainty about the future evolution of the macroeconomic variables, notably the public finance variables: public expenditure, the tax rate and public debt.

3.1 Description of the framework

The economy can be summarised by the following set of log-linearised equations:

$$y_t = a_1 \tilde{E}_t y_{t+1} + (1-a_1)y_{t-1} - a_2(r_t - \tilde{E}_t \pi_{t+1} + (\tau_t - \tilde{E}_t \tau_{t+1})) + a_3(g_t - \tilde{E}_t g_{t+1}) + \epsilon_t \tag{1}$$

$$\pi_t = b_1 \tilde{E}_t \pi_{t+1} + (1-b_1)\pi_{t-1} + b_2 y_t + \eta_t \tag{2}$$

$$r_t = c_1(\pi_t - \pi^*) + c_2 y_t + c_3 r_{t-1} + \mu_t \tag{3}$$

$$g_t = f_1 g_{t-1} + w_t \tag{4}$$

$$\tau_t = z_1 \tau_{t-1} + z_2(\tilde{E}_t b_{t+1} - b^*) + z_3 y_{t-1} + \delta_t \tag{5}$$

$$b_t = r_{t-1} + x_1(b_{t-1} - \pi_{t-1}) + x_2 g_t - x_3(y_t + \tau_t) + v_t \tag{6}$$

$\tilde{E}_t$ stands for the expectation operator described below.

Equation (1) is a standard aggregate demand relationship where the output-gap y_t is determined by its own expected future value, its past value and the real interest rate $(r_t - \tilde{E}_t \pi_{t+1})$, r_t defines the nominal interest rate set by the central bank and π_t is the inflation rate. In addition, the output-gap depends on public expenditure g_t, but also on the gap between the current consumption tax, τ_t, affecting household decisions, and the expected future tax rate (i.e. if $\tau_t < \tilde{E}_t \tau_{t+1}$, agents forecast a higher tax in the future, which reduces the output-gap, and conversely when $\tau_t > \tilde{E}_t \tau_{t+1}$). Equation (2) is a version of a new-Keynesian Phillips curve where the current inflation rate is explained by indexation on past inflation (with a degree $(1-b_1)$), which allows for inflation persistence in the model), the expected future inflation rate, the current output-gap, and white noise (η_t). Equation (3) is a standard Taylor rule with a degree of inertia measured by the parameter c_3. The central bank sets the nominal interest rate r_t to stabilise inflation around π^*, based on the output-gap.

In the fiscal block, we treat public expenditure in equation (4) as exogenous and defined by an AR(1) process with a persistence f_1 and white noise w_t. Equation (5) represents the simple rule for the tax rate on revenue. A degree of inertia z_1 is introduced here in the sense that the government's behaviour is smoothed when it sets the tax rate, depending on the deviation between the expected public debt and the public debt target, b^* and the output-gap, with respective weights z_2 and z_3. Finally, equation (6) gives the linearised version of the public debt dynamic following Kirsanova et al. (2007) and Rossi (2007).[6] The public debt b_t is given by the lagged public debt and the current primary deficit.

In this model, the output-gap, the inflation rate, the nominal and real interest rates, the public expenditure, the consumption tax and the public debt are interpreted as percentage deviations from their steady state values. $[\epsilon_t, \eta_t, \mu_t, w_t, v_t, \delta_t]$ is a vector of $i.i.d$ exogenous disturbances with zero mean and constant standard deviation, equal to 0.5, which represent a demand shock (ϵ_t), a cost-push shock (η_t), a monetary policy shock (μ_t), shocks on fiscal tools (w_t and δ_t) and a public debt shock (v_t).

Derivations of the micro-foundations and calculation details for the system of equations are presented in appendix (A).

3.2 Matrix representation of the system of linear equations

Our model can be written in matrix form with a vector of endogenous variables, Y, parameter matrices, A, B and C, and smoothed vectors, V and X, joined to π^* and b^*, and an error vector, W. This system of matrices can be re written $AZ_t = B\tilde{E}_t Z_{t+1} + CZ_{t-1} + V\pi^* + Xb^* + W_t$, such that:

$$\begin{bmatrix} 1 & 0 & a_2 & -a_3 & a_2 & 0 \\ -b_2 & 1 & 0 & 0 & 0 & 0 \\ -c_2 & -c_1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ x_3 & 0 & 0 & -x_2 & x_3 & 1 \end{bmatrix} \begin{bmatrix} y_t \\ \pi_t \\ r_t \\ g_t \\ \tau_t \\ b_t \end{bmatrix} = \begin{bmatrix} a_1 & a_2 & 0 & -a_3 & a_2 & 0 \\ 0 & b_1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & z_2 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \tilde{E}_t y_{t+1} \\ \tilde{E}_t \pi_{t+1} \\ \tilde{E}_t r_{t+1} \\ \tilde{E}_t g_{t+1} \\ \tilde{E}_t \tau_{t+1} \\ \tilde{E}_t b_{t+1} \end{bmatrix} +$$
$$\begin{bmatrix} 1-a_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1-b_1 & 0 & 0 & 0 & 0 \\ 0 & 0 & c_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & f_1 & 0 & 0 \\ z_3 & 0 & 0 & 0 & z_1 & 0 \\ 0 & -x_1 & 1 & 0 & 0 & x_1 \end{bmatrix} \begin{bmatrix} y_{t-1} \\ \pi_{t-1} \\ r_{t-1} \\ g_{t-1} \\ \tau_{t-1} \\ b_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -c_1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \pi^* \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ -z_2 \\ 0 \end{bmatrix} b^* + \begin{bmatrix} \epsilon_t \\ \eta_t \\ u_t \\ w_t \\ \delta_t \\ v_t \end{bmatrix}$$

The system only has a solution if matrix A is non-singular.

3.3 Expectations: defining heuristic rules

As in Brock & Hommes (1997), economic agents behave according to simple rules (heuristics) and decide to switch between these rules depending on how well the rules perform in predicting the output-gap, inflation, public expenditure, tax revenue and public debt. For De Grauwe (2012), this switching to the best performing heuristic represents the agents' rationality. *Fundamentalist agents* predict the steady state value of the variable (normalised to zero here) or the value targeted by an institution, such as the central bank's inflation target or the government's public debt target. *Chartist agents* account for the last period of observation in their forecasts. We now define the public debt expectations of both types of agents.

[6]See Uhlig (1999) for details of the linearisation method

$$\tilde{E}_t b^f_{t+1} = b^* \quad (7)$$

$$\tilde{E}_t b^c_{t+1} = b_{t-1} \quad (8)$$

In equation (7), b^* is the steady state value of the government's public debt target. In equation (8), b_{t-1} is the last debt observation made by the chartist agents. We now sum the two expectations to determine the agents' total debt expectation.

$$\tilde{E}_t b_{t+1} = \alpha^f_{b,t}\tilde{E}_t b^f_{t+1} + \alpha^c_{b,t}\tilde{E}_t b^c_{t+1} \quad (9)$$

$$\tilde{E}_t b_{t+1} = \alpha^f_{b,t} b^* + \alpha^c_{b,t} b_{t-1} \quad (10)$$

We define $\alpha^f_{b,t}$ and $\alpha^c_{b,t}$ as the probabilities of following either of the two rules, i.e. of adopting either chartist or fundamentalist behaviour over a given period. In other words, these are the probabilities of being a chartist or a fundamentalist. We apply the same logic to the definitions of the output-gap, inflation, public expenditure and tax rate expectations. We assume that $\alpha^f_{i,t} + \alpha^c_{i,t} = 1$ for each i variable.

3.4 Selection of the forecasting rule

In our model, economic agents can learn over time and evaluate the performance of their forecasts. They learn from their mistakes as in De Grauwe (2012). This switching behaviour is based on a forecasting criterion, the *mean square forecast error* where U^f_t and U^c_t represent the utilities of fundamentalist and chartist agents. In the case of public debt for instance:

$$U^f_{b,t} = -\sum_{q=0}^{\infty} \omega_q (b_{t-q-1} - \tilde{E}_{t-q-2} b^f_{t-q-1})^2 \quad (11)$$

$$U^c_{b,t} = -\sum_{q=0}^{\infty} \omega_q (b_{t-q-1} - \tilde{E}_{t-q-2} b^c_{t-q-1})^2 \quad (12)$$

with :

$$U^f_{b,t} = \rho U^f_{b,t-1} - (1-\rho)(b_{t-1} - \tilde{E} b^f_{t-1})^2 \quad (13)$$

$$U^c_{b,t} = \rho U^c_{b,t-1} - (1-\rho)(b_{t-1} - \tilde{E} b^c_{t-1})^2 \quad (14)$$

These utilities are defined as the negative of the mean squared forecasting errors of the forecasting rules, $\omega_q = (1-\rho)\rho^q$ are the geometrically declining weights where ρ is a memory parameter as in Sargent et al. (1993). We will generally assume $0 < \rho < 1$. For public debt, the probability of choosing the fundamentalist rule $\alpha^f_{b,t}$ (and $\alpha^c_{b,t}$ for the chartist rule) is defined by:

$$\alpha^f_{b,t} = P(U^f_{b,t} + \varepsilon^f > U^c_{b,t} + \varepsilon^c) = \frac{exp(\lambda U^f_{b,t})}{exp(\lambda U^f_{b,t}) + exp(\lambda U^c_{b,t})} \quad (15)$$

$$\alpha^c_{b,t} = 1 - \alpha^f_{b,t} \quad (16)$$

Indeed, as explained by De Grauwe (2012) and Kahneman (2002), the probability of choosing a given rule depends on its utility but also on unpredictable factors given by ε^f and ε^c. This probability also gives the proportions of fundamentalist and chartist agents. The parameter λ measures the "intensity of choice" and is related to the variance of the random components. λ can also be interpreted as the willingness to learn from past performance.

3.5 Animal spirits

Once agents choose which rule to follow, this has a strong effect on their market sentiment. Basically, this can be represented by an index of so called 'animal spirits'[7], as suggested by De Grauwe (2012) , which reflects agents' degree of optimism or pessimism at a given time for a given variable. Our modelling of animal spirits for the fiscal block differs from that of De Grauwe & Foresti (2020) in two respects: i) the model includes expectation mechanisms for public debt and the tax rate (endogenous here), ii) the animal spirits for the fiscal tools (public expenditure and tax rate) are conditioned by a public debt indicator (the level of public debt in the preceding period compared with the government's target). For public debt, this "animal spirit" variable, $S_{b,t}$ can be defined as:

$$S_{b,t} = \begin{cases} -\alpha^c_{b,t} + \alpha^f_{b,t} & \text{if } b_{t-1} > b^* \\ \alpha^c_{b,t} - \alpha^f_{b,t} & \text{if } b_{t-1} < b^* \end{cases} \tag{17}$$

$S_{b,t}$ in equation (17) is thus the animal spirits index for public debt and varies from -1 when agents are at their most pessimistic to 1 when they are most optimistic. If $b_{t-1} > b^*$, chartist agents expect future public debt to increase. They are considered pessimistic and we assign a negative symbol to $\alpha^c_{b,t}$. Fundamentalist agents expect debt to return to the value targeted by the government. They are therefore considered optimistic and we assign a positive symbol to $\alpha^f_{b,t}$. If $b_{t-1} < b^*$, chartist agents expect future public debt to decrease. They are considered optimistic and we assign a positive symbol to $\alpha^c_{b,t}$. Fundamentalist agents expect debt to return to the value targeted by the government. They are thus considered pessimistic and we assign a negative symbol to $\alpha^f_{b,t}$.

Because $\alpha^f_{b,t} + \alpha^c_{b,t} = 1$, the animal spirit equations (15) and (16) can be rewritten as:

$$S_{b,t} = \begin{cases} 1 - 2\alpha^c_{b,t} & \text{if } b_{t-1} > b^* \\ -1 + 2\alpha^c_{b,t} & \text{if } b_{t-1} < b^* \end{cases} \tag{18}$$

The same reasoning can be applied to define the animal spirit indexes for the tax rate ($S_{\tau,t}$), the output-gap ($S_{y,t}$) public expenditure ($S_{g,t}$) and inflation ($S_{\pi,t}$).

The animal spirit indexes for the tax rate and public expenditure depend on the level of public debt in the previous period:

$$S_{\tau,t} = \begin{cases} 1 - 2\alpha^c_{\tau,t} & \text{if } b_{t-1} > b^* \\ -1 + 2\alpha^c_{\tau,t} & \text{if } b_{t-1} < b^* \end{cases} \tag{19}$$

$$S_{g,t} = \begin{cases} 1 - 2\alpha^c_{g,t} & \text{if } b_{t-1} < b^* \\ -1 + 2\alpha^c_{g,t} & \text{if } b_{t-1} > b^* \end{cases} \tag{20}$$

For the output-gap and inflation, the animal spirit indexes are given by :

$$S_{y,t} = \begin{cases} -1 + 2\alpha^c_{y,t} & \text{if } y_{t-1} > 0 \\ 1 - 2\alpha^c_{y,t} & \text{if } y_{t-1} < 0 \end{cases} \tag{21}$$

$$S_{\pi,t} = \begin{cases} 1 - 2\alpha^c_{\pi,t} & \text{if } \pi_{t-1} > \pi^* \\ -1 + 2\alpha^c_{\pi,t} & \text{if } \pi_{t-1} < \pi^* \end{cases} \tag{22}$$

For the output-gap, the index depends on the previous level of the variable: agents are optimist if the output-gap is larger than 0 and vice versa. For inflation, the index depends on the central bank's inflation target.

[7]See for instance Akerlof & Shiller (2010) following this Keynesian intuition.

3.6 Calibration

Values for the parameters were obtained from the literature: Galí (2008) for the demand and supply equations[8], Blattner & Margaritov (2010) for the Taylor rule. Parameters related to the expectation formation process (notably ρ and λ) were calibrated following De Grauwe (2012) and De Grauwe & Ji (2019). For the fiscal block, the f_1 parameter in the public expenditure rule was defined using De Grauwe & Foresti (2020). In the tax rule, we follow Forni et al. (2009) for parameters z_1 and z_2, and we set $z_3 = 0.4$. Parameters $[x_1, x_2, x_3]$ were calibrated following Rossi (2007), who derives a linear expansion of public debt around its steady-state value, as in Kirsanova & Wren-Lewis (2012).

Table 1: Calibration of the model

β	0.99	Discount factor
σ	2	Relative risk aversion
π^*	2 %	Central bank's inflation target
b^*	0 %	Government's public debt target
ρ	0.5	Memory parameter
λ	2	Switching parameter in heuristic rules
a_1	0.5	Coefficient of expected output in demand equation
a_2	0.2	Interest rate elasticity of output demand
a_3	0.25	Public expenditure coefficient in the demand equation
b_1	0.1	Expected inflation coefficient in the Phillips curve
b_2	0.05	Output coefficient in the Phillips curve
c_1	1.25	Inflation coefficient in the Taylor rule
c_2	1	Output coefficient in the Taylor rule
c_3	0.9	Interest rate smoothing parameter in the Taylor rule
f_1	0.6	Public expenditure smoothing parameter in the public expenditure rule
z_1	0.9	Tax rate smoothing parameter in the tax rule
z_2	0.05	Expected public debt coefficient in the tax rule
z_3	0.4	Lagged output-gap coefficient in the tax rule
x_1	1.01	Lagged public debt and lagged inflation coefficient in the public debt accumulation equation
x_2	0.4	Current public expenditure coefficient in the public debt accumulation equation
x_3	0.33	Current output-gap and tax rate coefficient in the public debt accumulation equation

4 Results of the model

4.1 Macroeconomic impact of fiscal shocks

We first present the basic response of our model to one standard deviation fiscal shocks (on expenditure and tax) in the 100^{th} period. Throughout this section, we simulate the model with the whole set of structural shocks over 1000 periods and observe the reaction of the economy when an additional public expenditure shock is introduced in the 100^{th} period. We repeat this simulation 2000 times so that when the public expenditure shock occurs, the economy is each time in a different state.[9]

Figure (1) shows the impulse reaction functions (IRFs) of the key variables following a positive government expenditure shock while Figure (2) presents the IRFs in the case of a decrease in the tax rate. Output increases in both cases while the fiscal multiplier is relatively low (peaking at between 0.15 and 0.22 depending on the nature of the fiscal shock), due to the adjustment of the tax rate subsequent to the increase in public debt a few periods later. Both fiscal shocks are inflationary but less so in the case of an increase in public expenditure. Indeed, when the consumption tax rate decreases, the increase in household consumption amplifies the increase in prices, leading the central bank to increase its interest rate.

[8]The parameters in the demand equation and the new-Keynesian Phillips curve (a_1, a_2, a_3, b_1 and b_2) are defined in Appendix (A), which outlines the micro-foundations of the model.

[9]In order to focus mainly on the impact of tax and public debt expectations, for the sake of simplicity, the figures presented below were prepared with $\alpha_g^c = \alpha_g^f = 0.5$, meaning that agents are neither optimistic nor pessimistic about future public spending.

Figure 1: Impulse response functions of the variables after an increase in public expenditure

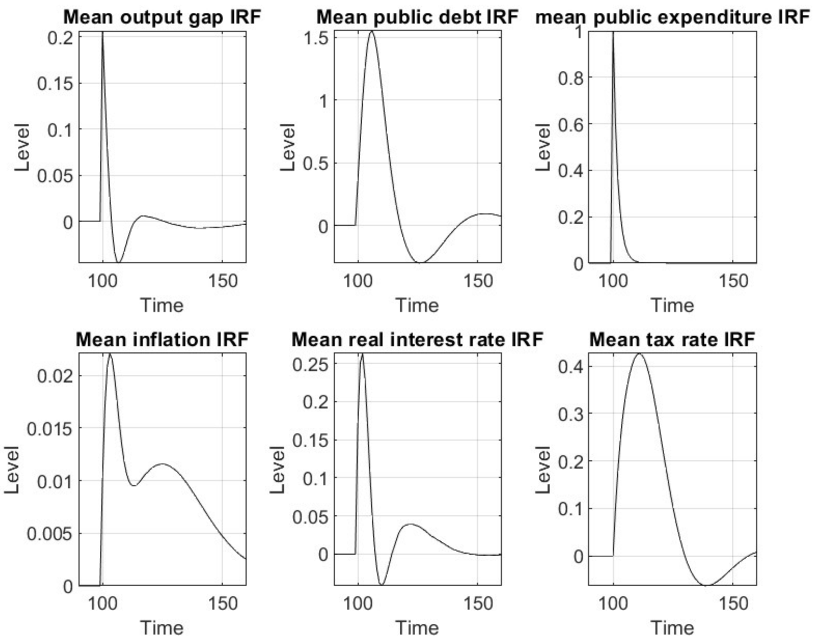
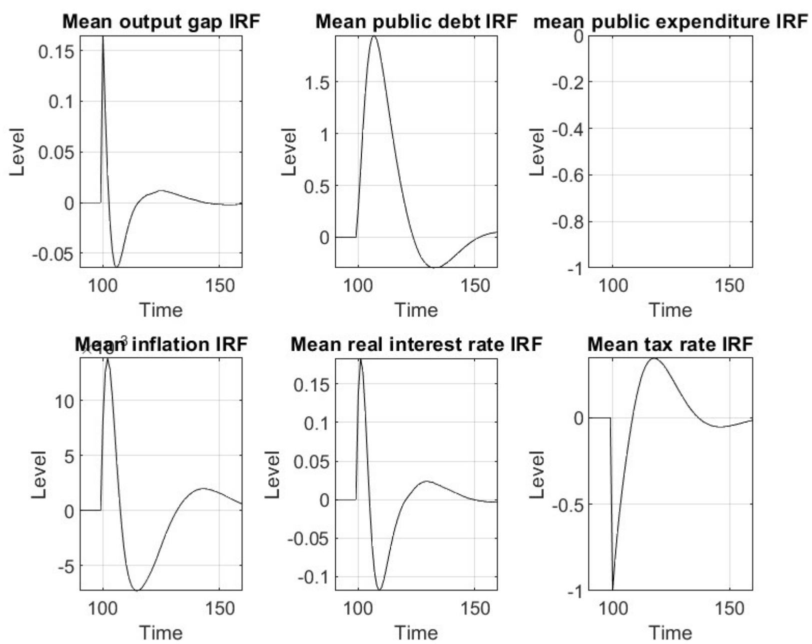
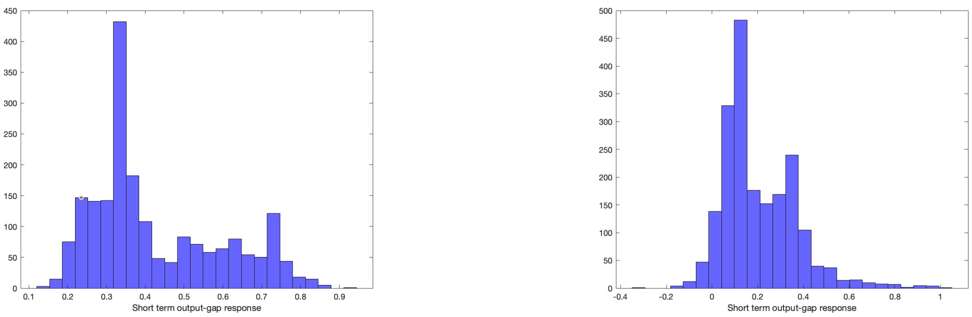


Figure 2: Impulse response functions of the variables after a decrease in consumption tax



While the results of the model for the output-gap, inflation and real interest rates are as expected, the more interesting point is the considerable state-dependency of the responses to the fiscal shocks. The histograms in Figure (3) show the distribution of fiscal multipliers for the 2000 simulations of the model. For public expenditure shocks for instance, the fiscal multiplier ranges from 0.1 to 1. The modal multiplier is around 0.35 for public expenditure shocks and around 0.1 for tax shocks. As already highlighted by De Grauwe & Foresti (2020), these histograms illustrate the uncertainty about the quantitative effects of fiscal shocks. Note that we use a linear version of the model so that the state dependence of the model comes only from the expectation formation process.

Figure 3: State dependence of the fiscal multiplier



(a) Public expenditure shock (b) Tax rate shock

4.2 Optimism/pessimism about output-gap and fiscal multipliers

These simulations indicate to what extent fiscal multipliers are state-dependent and in particular whether they depend on two key elements in the expectation formation process: 1) the agents' degree of optimism/pessimism regarding the expected output-gap and 2) the agents' optimism/pessimism about the expected public debt level.

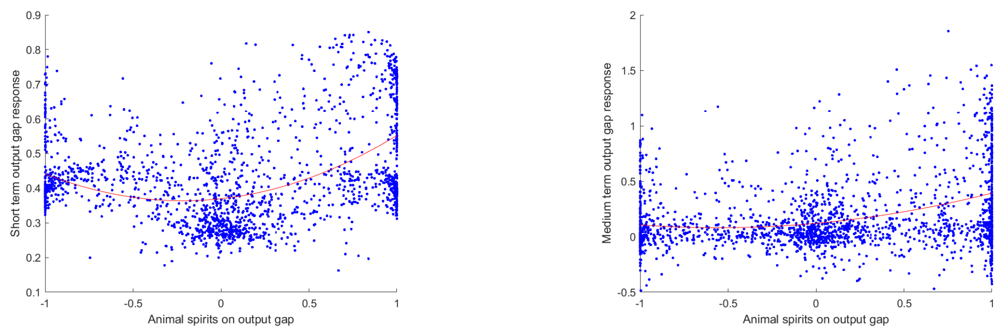
Figures (4) and (5) plot the short and medium-run fiscal multipliers (respectively 4 and 12 periods after the shock) as a function of the distribution of animal spirits regarding the output-gap for both types of fiscal shock (public expenditure and tax rate). On the x-axis, the animal spirit index varies from -1 to 1, i.e. from total pessimism (-1) to total optimism ($+1$), as given by equation (18). When the animal spirit index is equal to 0, the agents are considered neutral.

Figure (4a) shows that the short-term fiscal multiplier is higher in periods of high optimism regarding the output-gap, compared with periods of pessimism. When the agents are completely pessimistic indeed, the average short-term fiscal multiplier is around 0.45, compared with about 0.55 when the agents are completely optimistic. The average multiplier is smaller (around 0.35) when the agents are neutral. The results therefore describe an asymmetric U-shaped curve. Our results, as do De Grauwe & Foresti (2020), show that fiscal multipliers depend on animal spirits regarding the output-gap. However, the outcomes with our model depend on the agents' degree of optimism or pessimism. In our economy indeed, when the agents are optimistic, an increase in demand due to an increase in public expenditure reinforces the expectation of a better output-gap in the future. As a result, the rise in public expenditure generates a sell-fulfilling expansion of the output-gap for a certain number of periods. In addition, and contrary to De Grauwe & Foresti (2020) where the multipliers are of the same magnitude for extreme levels of optimism and pessimism, expectations regarding future public debt (and thus, by extension, regarding future tax rates) play an important role in explaining why the largest fiscal multipliers are obtained in periods of high optimism regarding the output-gap. Because the tax rate is endogenous, and is adjusted to stabilise the public debt path, the agents' behaviour is also driven by expectations regarding future public debt. In particular, the fiscal multiplier following a public expenditure shock tends to be larger when agents are optimistic about a future decrease in public debt. Indeed, if agents are optimistic about public debt, a rise in public expenditure, which increases public debt, will not be interpreted by the agents as meaning the government will need to increase the tax rate in the near future. This means that Ricardian equivalence, in particular the amplitude of this mechanism, depends on agents' levels of optimism/pessimism about future public debt when a fiscal policy is implemented. Optimism regarding future public debt therefore has a sell-fulfilling consequence: a weak Ricardian equivalence effect produces a larger fiscal multiplier which, in turn, leads to a lower increase in public debt following the public expenditure shock due to the high correlation between animal spirits regarding the output-gap and public debt (0.6976 for a representative simulation). In addition, our results also reveal a positive relationship between the fiscal multiplier and the animal spirits regarding public debt, as highlighted by the OLS linear regression results in table (2), which are significant at the 1 % threshold.

Figure (5a) shows the same results for a negative tax rate shock. As is traditionally described, the short-term fiscal multiplier is lower (between 0.2 and 0.3) than in the case of a government spending shock. As shown in Figures (4b) and (5b), these conclusions are confirmed for the medium-term multipliers, but to a lesser extent (the multiplier effect decreases over time).

These results have a direct impact on the effects of the two types of fiscal shock on public debt. Following a positive fiscal shock (an increase in public expenditure or a decrease in the tax rate), Figure (6a) shows the cumulative response of public debt depending on the degree of optimism/pessimism regarding the output-gap following a public expenditure shock. The public debt response appears to decrease as the level of optimism about the output-gap increases. This means that the more optimistic the agents are, the less of a public debt adjustment is required because the fiscal multiplier is larger. Consequently, fiscal expansions are less detrimental to public finances in the context of optimistic market beliefs regarding the future output-gap and future public debt. Figure (6b) confirms the role of optimism / pessimism about output-gap on cumulative response of public debt following a tax shock.

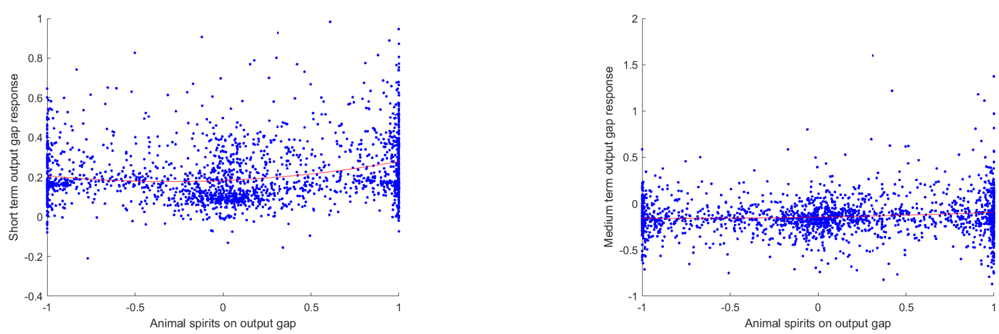
Figure 4: Fiscal multipliers and animal spirits on output-gap: the case of a one standard deviation increase in public expenditure



(a) Short-term fiscal multiplier

(b) Medium-term fiscal multiplier

Figure 5: Fiscal multipliers and animal spirits on output-gap: the case of a one standard deviation decrease in the tax rate



(a) Short-term fiscal multiplier

(b) Medium-term fiscal multiplier

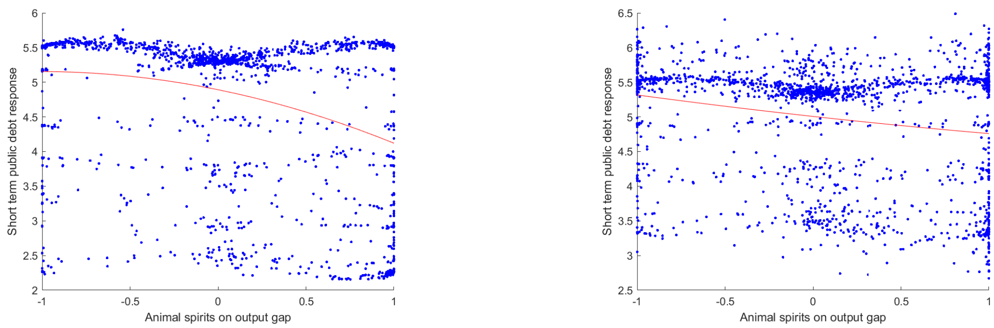
Table 2: OLS regression results for a representative simulation of the model

	Short-term output-gap response		Short-term public debt respons	
	(1)	(2)	(3)	(4)
(Intercept)	0.21***	0.21***	5.0203***	5.03***
	(0.003)	(0.003)	(0.01)	(0.01)
$S_{b,t}$	0.023***		−0.15***	
	(0.003)		(0.01)	
$S_{y,t}$		0.043***		−0.37***
		(0.0004)		(0.02)
Observations	2000	2000	2000	2000
R-squared	0.02	0.04	0.03	0.1

Notes: Standard deviation in parentheses; $^{*}\, p < 0.1$; $^{**}\, p < 0.05$; $^{***}\, p < 0.01$

$S_{b,t}$ and $S_{y,t}$ respectively stand for the animal spirit indexes regarding public debt and the output-gap.

Figure 6: Cumulative response of public debt and animal spirits on output-gap



(a) Public expenditure shock (b) Tax rate shock

4.3 Government credibility and fiscal multipliers

The notion of fiscal policy credibility is gradually gaining attention, as reflected by the growth in the associated literature. As proposed by End & Hong (2022), "fiscal credibility can be defined as the extent to which economic agents expect the government to try and fulfil its fiscal policy commitments. This covers two aspects: the intention and ability to achieve targets." Fiscal credibility or government credibility mainly rests on comparisons between budgetary forecasts (e.g., spending, budget balance, public debt, …) and budget outcomes. In this section, we analyse the impact of the government's credibility degree when implementing a public spending or taxation shock on the size of the fiscal multiplier and on the public debt response to the shock.

We partially follow End & Hong (2022) to calculate a credibility index in the model. A first possibility, which we call *private bias*, would be to express credibility as the absolute value of the difference between the expected debt in period $t-1$ for period t minus the actual level of debt in t, such that

$$PrivBias_t = |\tilde{E}_{t-1} b_t - b_t| \tag{23}$$

A value close to 0 indicates that the agents' expectations are in line with the actual level of debt that arises, and can be interpreted as a good anchoring of expectations by the agents.

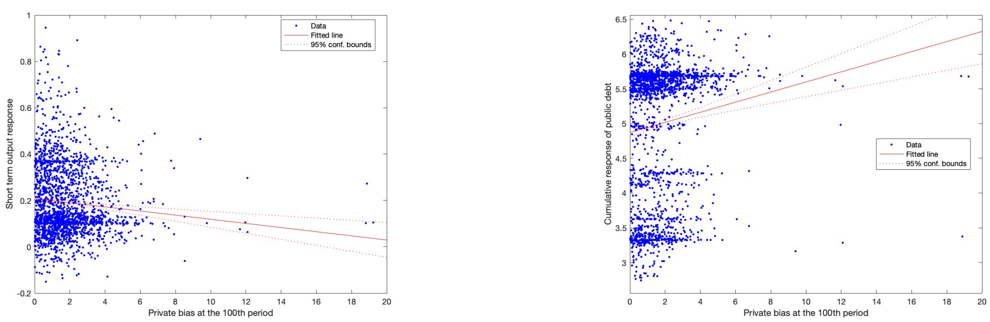
An alternative measure, called *announce bias*, would be to quantify credibility as the difference between the agents' expectations and those announced by the government. In the Eurozone for example, each member state announces its public deficit and public debt objectives to the European Commission as part of the European Semester. In our model, however, market expectations cannot easily be separated from government perspectives. The government only announces a target, b^*, which can be considered a long-term target. In this case, a potential credibility index would be:

$$AnnounceBias_t = |\tilde{E}_{t-1} b_t - b^*| \tag{24}$$

This credibility index is mainly driven by the share of targeters, i.e. the proportion of agents in the market who believe that the government will hit its debt target in the near future (see equation (7)). If targeters predominate, this means that targeters' expectations in the previous period were more accurate than the chartists'. In our view, this measure is somewhat less appropriate insofar as governments do not commit to reaching long-term targets within a time frame of a few quarters. In this sense, we favour the *private bias* measure described above.

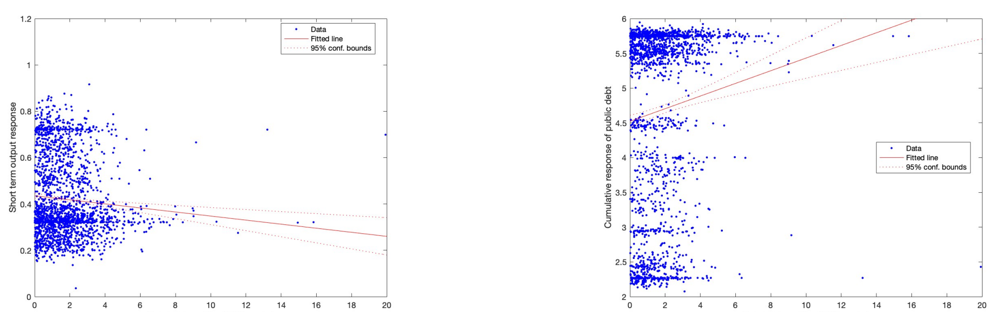
Figures (7) and (8) show the evolution of the short term fiscal multiplier and the cumulative response of public debt depending on the level of *private bias*, in the case respectively of a tax rate shock and of an expenditure shock. In particular, it appears that the closer to 0 the *private bias* is, *i.e.* the more credible the government is considered to be, the higher the fiscal multiplier is following a positive fiscal shock (see Figures (7a) and (8a)). Thus, trust in government prevents Ricardian behaviour. Consequently, the cumulative response of public debt is also affected positively by agents' *private bias* (see Figures (7b) and (8b)). In addition, Figure (9) confirms that a *private bias* close to 0 is associated with smaller public debt deviations whatever the nature of the fiscal shock.[10]

Figure 7: Evolution of the short term fiscal multiplier and of the cumulative response of public debt depending on the level (magnitude) of government credibility: the case of a decrease in the tax rate



(a) Evolution of the short term fiscal multiplier (b) Cumulative response of public debt

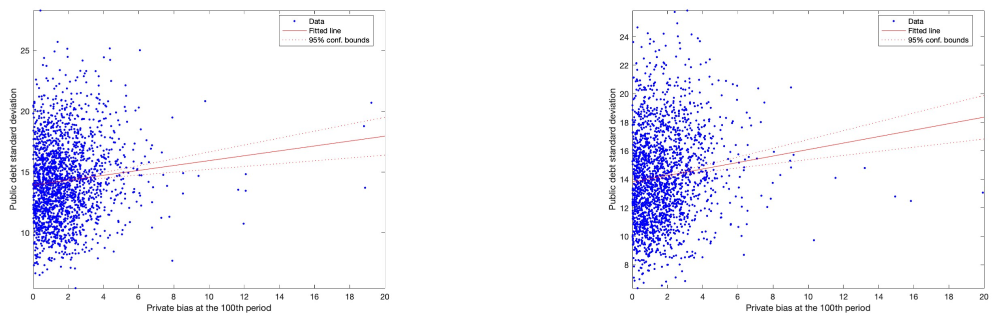
Figure 8: Evolution of the short term fiscal multiplier and of the cumulative response of public debt depending on the level (magnitude) of government credibility: the case of an increase in public expenditure



(a) Evolution of the short term fiscal multiplier (b) Cumulative response of public debt

[10]Note: in addition to all the scatter plots, we perform an OLS linear regression represented by the red line in each figure.

Figure 9: Credibility index (in absolute value) and public debt volatility

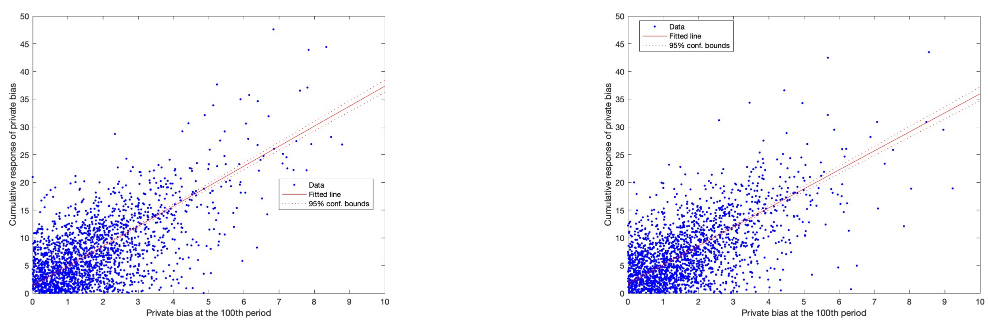


(a) Tax rate shock

(b) Public expenditure shock

Furthermore, Figure (10) illustrates the extent to which a fiscal shock affects future credibility as a function of the level of credibility at the time of the shock. We calculate the cumulative response of credibility for 4 periods after the fiscal shock. It is significant that credibility decreases less when the level of credibility was high at the time of the fiscal expansion than when it was already low.

Figure 10: Cumulative response of the credibility index (in absolute value) as a function of the value of the index at the time of the shock



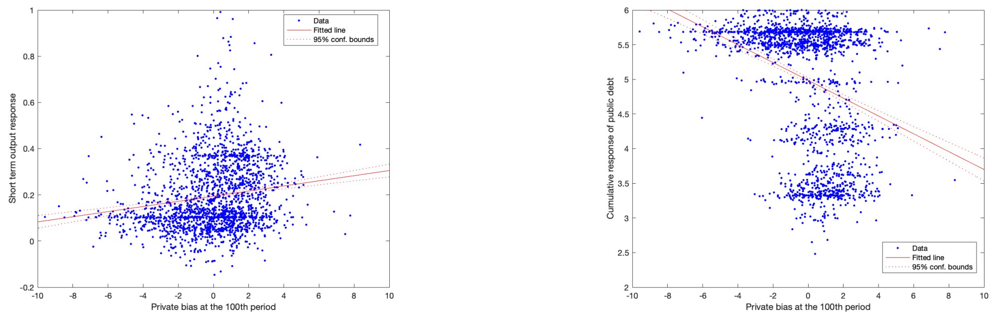
(a) Tax rate shock

(b) Public expenditure shock

So far, we have measured *private bias* in absolute terms, i.e. with positive and negative discrepancies between market expectations and the actual debt considered in the same way. The sign of the credibility index is also interesting however. Indeed, a positive value of $\tilde{E}_{t-1}b_t - b_t$ indicates that the agents had anticipated public debt to be higher than has come to pass, and therefore that the agents were over-pessimistic about the government's ability to stabilise public debt. Conversely, a negative value of $\tilde{E}_{t-1}b_t - b_t$ indicates over-optimism on the part of the agents. Figures (11), (12) and (13) show the results obtained when accounting for the sign of $\tilde{E}_{t-1}b_t - b_t$.

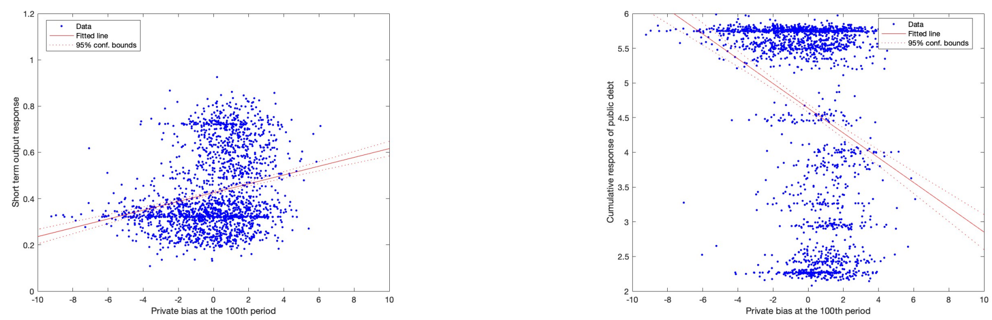
When the bias is positive at the time of the shock (meaning that agents overestimate the future level of public debt), the associated multiplier is higher in the case of both types of fiscal shock (Figures (11) and (12)). The mechanism is as follows: when agents realise that they have overestimated the level of public debt, they revise their expectations for the next period regarding public debt and therefore also for the level of taxation. The agents now anticipate a smaller future tax increase, producing a lower Ricardian equivalence effect. In consequence, the effect of fiscal expansion on public debt is also reduced. In contrast with the previous analysis based on absolute values, when the sign of the credibility index is taken into account, the effect on the fiscal multiplier is stronger in the case of a public spending shock. In addition, Figure (13) shows that when the *private bias* is positive at the time of the shock, debt fluctuations following the fiscal shock are less volatile.

Figure 11: Evolution of the short term fiscal multiplier and of the cumulative response of public debt depending on the level (positive or negative) of government credibility: the case of a decrease in the tax rate



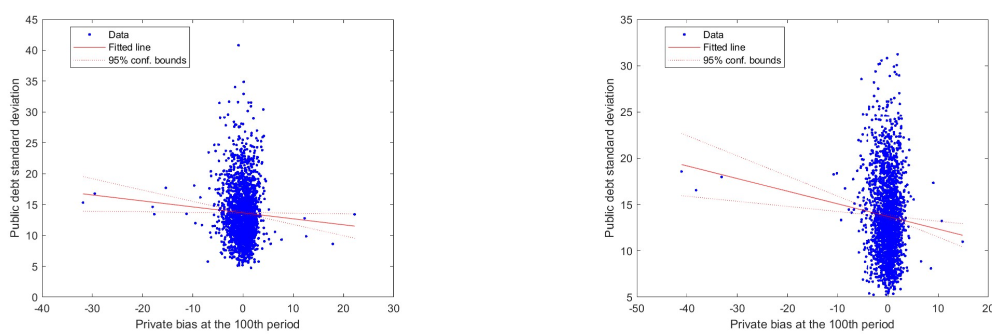
(a) Short term fiscal multiplier (b) Cumulative response of public debt

Figure 12: Evolution of the short term fiscal multiplier and of the cumulative response of public debt depending on the level (positive or negative) of government credibility: the case of an increase in public expenditure



(a) Short term fiscal multiplier (b) Cumulative response of public debt

Figure 13: Credibility index (in relative value) and public debt volatility



(a) Tax rate shock (b) Public expenditure shock

5 Conclusion

This paper offers several original contributions. The introduction of heterogeneous expectations in our model makes it suitable to analyse public debt anchor and how expectations about future debt evolve depending on the evolution of public debt and the output-gap over the business cycle. In addition, expectations regarding future public debt affect the output-gap through various channels. We also compute a fiscal credibility indicator based on the *private bias* of agents, which accounts for the level of trust in government in the model.

We show in this article that when agents are optimistic about the future output-gap and public debt, fiscal multipliers tend to be larger whatever the nature of the fiscal shock (on tax or public expenditure). It also appears that fiscal expansion has less of a negative effect on public debt. Moreover, agents' expectations regarding public debt and the government's fiscal credibility are factors that impact government performance (the fiscal multiplier and public debt stability). In other words, we underline in this paper that uncertainty about future public finance is crucial in analysing the effects of fiscal policy shocks over the business cycle. This provides a new and interesting explanation for the state-dependence of fiscal multipliers based on economic agents' decisions when faced with uncertainty.

Following the work of Montes & Acar (2020) and Montes & de Hollanda Lima (2022), this model could be extended to analyse the interactions between fiscal credibility and monetary policy, in particular Central Banks' ability to stabilise inflation. Moreover, based on the studies of Larch & Braendle (2018), Beetsma et al. (2019) and Beetsma et al. (2022), it would be interesting to introduce an independent fiscal institution (IFI) which could commit to a public debt target to reach within a given time depending on the structural characteristics of the economy.

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Appendix A Micro foundations

A.1 Consumer problem

Our economy is based on the micro-founded heterogeneous expectations new-Keynesian model of Hommes et al. (2018) and De Grauwe & Foresti (2022).[11]

Each household $i \in [0,1]$ maximises the following utility function defined in terms of consumption (C_t^i), labour (N_t^i) and bond holdings (B_t^i):

$$\tilde{E}_t^i \sum_{s=t}^{\infty} \beta^s \left[\frac{(C_s^i)^{1-\sigma}}{1-\sigma} - \frac{(N_s^i)^{1+\eta}}{1+\eta} \right] \tag{IA.25}$$

subject to the following budget constraint:

$$(1+\tau_t) P_t C_t^i + B_t^i = W_t N_t^i + (1+r_{t-1}) B_{t-1}^i + P_t \int_0^1 \Xi_t(j) dj \tag{IA.26}$$

Where W_t is the nominal wage rate, τ_t is the consumption tax rate and r_t is the nominal interest rate. Dividing equation (IA.26) by the nominal GDP, $P_t Y_t$, yields:

$$(1+\tau_t)\frac{C_t^i}{Y_t} + b_t^i = w_t \frac{N_t^i}{Y_t} + \frac{(1-r_{t-1}) b_{t-1}^i Y_{t-1}}{\Pi_t Y_t} + \frac{\Xi_t}{Y_t} \tag{IA.27}$$

with $w_t = \frac{W_t}{P_t}$, the real wage, $\Pi_t = \frac{P_t}{P_{t-1}}$, the gross inflation rate, $b_t^i = \frac{B_t}{P_t Y_t}$, the real bond holdings as a percentage of income and $\Xi_t = \int_0^1 \Xi_t(j) dj$, aggregate corporate profits.

The first order conditions with respect to C_t^i, N_t^i and b_t^i lead to:

$$\lambda_t = \frac{\beta_t (C_t^i)^{-\sigma}}{(1+\tau_t) P_t} \tag{IA.28}$$

$$\frac{\beta_t (C_t^i)^{-\sigma}}{(1+\tau_t) P_t} \frac{1}{1+r_t} - \frac{\beta_{t+1} (\tilde{E}_t C_{t+1}^i)^{-\sigma}}{(1+\tilde{E}_t \tau_{t+1}) P_{t+1}} = 0 \tag{IA.29}$$

$$\beta \left(\frac{\tilde{E}_t C_{t+1}}{C_t} \right)^{-\sigma} = \frac{1}{1+r_t} \frac{(1+\tilde{E}_t \tau_{t+1}) \tilde{E}_t P_{t+1}}{(1+\tau_t) P_t} \tag{IA.30}$$

$$\beta \left(\frac{\tilde{E}_t C_{t+1}}{C_t} \right)^{-\sigma} = \frac{1}{1+r_t} \frac{(1+\tilde{E}_t \tau_{t+1})}{(1+\tau_t)} \Pi_{t+1} \tag{IA.31}$$

$$\frac{C_t}{\tilde{E}_t C_{t+1}} = \left[\frac{1}{1+r_t} \frac{(1+\tilde{E}_t \tau_{t+1})}{(1+\tau_t)} \tilde{E}_t \Pi_{t+1} \frac{1}{\beta_t} \right]^{\frac{1}{\sigma}} \tag{IA.32}$$

$$C_t = C_{t+1} \left[\frac{1}{1+r_t} \frac{(1+\tilde{E}_t \tau_{t+1})}{(1+\tau_t)} \tilde{E}_t \Pi_{t+1} \frac{1}{\beta_t} \right]^{\frac{1}{\sigma}} \tag{IA.33}$$

The equations can be aggregated and log-linearised following De Grauwe & Foresti (2022) and Hommes et al. (2018).

Starting with the aggregate demand equation (1), we first linearise the Euler equation (IA.33):

$$\hat{C}_t^i = \hat{C}_{t+1}^i + \frac{1}{\sigma} \left[-\hat{r}_t + \tilde{\tau}_{t+1} - \tilde{\tau}_t + \pi_{t+1} + ln \frac{1}{\beta} \right] \tag{IA.34}$$

$$\hat{C}_t^i = \tilde{E}_t^i \hat{C}_{t+1}^i - \frac{1}{\sigma} \left[\hat{r}_t - \tilde{E}_t \pi_{t+1} + (\tau_t - \tilde{E}_t \tau_{t+1}) - \rho \right] \tag{IA.35}$$

with $\rho = ln \frac{1}{\beta}$

[11] $\bar{x}$ is the steady state value of a variable
$\tilde{x}$ is a linear deviation from the steady state
$\hat{x}$ is a percentage deviation from the steady state

Given their non-rationality, agents do not optimise over an infinite horizon but instead use Euler learning (Honkapohja et al. 2013). Agents thus use the market-cost and marginal benefits trade-off of the Euler equation to make their decisions based on their budget constraint and their subjective forecasts for the aggregate variables. [12]

$$\hat{C}_t^i = \tilde{E}_t^i \hat{C}_\infty^i - \frac{1}{\sigma}\tilde{E}_t^i \sum_{k=0}^{\infty} \left[\hat{r}_{t+k} + (\tilde{\tau}_{t+k} - \tilde{E}_t \tilde{\tau}_{t+k+1}) - \tilde{E}\pi_{t+k+1} - \rho\right] \tag{IA.36}$$

Log-linearising the market clearing equation then yields:

$$Y_t = C_t + G_t + \frac{\phi}{2}(\frac{P_t}{P_{t-1}} - 1)^2 Y_t = C_t + g_t Y_t + \frac{\phi}{2}(\frac{P_t}{P_{t-1}} - 1)^2 Y_t \tag{IA.37}$$

with G_t the government's public expenditure expressed in percentage of GDP.
We have:

$$\hat{y} = (1-\bar{g})\hat{c} + \bar{g}(\tilde{g} + \hat{y}) \tag{IA.38}$$

$$(1-\bar{g})\hat{y} = (1-\bar{g})\hat{c} + \bar{g}\tilde{g} \tag{IA.39}$$

$$\hat{y}_t = \hat{c}_t + \frac{\bar{g}}{1-\bar{g}}\tilde{g}_t \tag{IA.40}$$

$$\hat{c}_t = \hat{y}_t - \frac{\bar{g}}{1-\bar{g}}\tilde{g}_t \tag{IA.41}$$

At $t+1$ we get:

$$\tilde{E}_t \hat{c}_{t+1} = \tilde{E}_t \hat{y}_{t+1} - \frac{\bar{g}}{1-\bar{g}}\tilde{E}_t \tilde{g}_{t+1} \tag{IA.42}$$

Equations (IA.41) and (IA.42) can be rewritten as:

$$\tilde{E}_t \hat{y}_{t+1} - \frac{\bar{g}}{1-\bar{g}}\tilde{E}_t^i \tilde{g}_{t+1} = \tilde{E}_t^i \int \tilde{E}_{t+1}^l \hat{C}_\infty^l dl - \tilde{E}_t^i \int \tilde{E}_{t+1}^l \frac{1}{\sigma}\sum_{k=1}^{\infty}(\hat{r}_{t+k} + (\tilde{\tau}_{t+k} - \tilde{\tau}_{t+k+1}) - \pi_{t+1}) \tag{IA.43}$$

Adding $+\frac{1}{\sigma}\sum_{k=1}^{\infty}(\hat{r}_{t+k} + (\tilde{\tau}_{t+k} - \tilde{\tau}_{t+k+1}) - \pi_{t+1})$ on both sides of the last equation and substituting it into equation IA.36 gives:

$$\hat{C}_t = \int \tilde{E}_t^i \hat{C}_\infty di - \tilde{E}_t \int \tilde{E}_{t+1}^l \hat{C}_\infty^l dl + \tilde{E}_t \hat{y}_{t+1} - \frac{\bar{g}}{1-\bar{g}}\tilde{E}_t^i \tilde{g}_{t+1} - \frac{1}{\sigma}(\hat{r}_{t+k} + (\tilde{\tau}_{t+k} - \tilde{\tau}_{t+k+1}) - \pi_{t+1}) \tag{IA.44}$$

Finally, substituting equation (IA.44) into (IA.41) yields the aggregate demand equation (1):

$$\hat{y}_t = \tilde{E}_t \tilde{y}_{t+1} - \frac{1}{\sigma}(\hat{r}_{t+k} - \pi_{t+1} + (\tilde{\tau}_{t+k} - \tilde{\tau}_{t+k+1})) + \frac{\bar{g}}{1-\bar{g}}(\tilde{g}_t - \tilde{E}_t \tilde{g}_{t+1}) \tag{IA.45}$$

[12] See Hommes et al. (2018).

A.2 Firm problem

We consider a continuum of monopolistically competitive firms producing the final differentiated goods. Each firm is run by a household and follows the same heuristic to predict future variables as the household it is run by. We assume Rotemberg pricing. Each monopolistic firm $j \in [0,1]$ has a production function given by:

$$Y_t^j = A_t N_t^{j,1-\alpha} \tag{IA.46}$$

We introduce a "new-Keynesian" feature in the model which is that prices are sticky. It is customary to assume so-called Calvo pricing. The behavioural model can be micro-founded under the same assumptions about price rigidity as in standard DSGE models. The assumption with Calvo pricing is that firms reset their prices in a period t with probability $1-\theta$, where θ is the fraction of firms that keep their prices fixed. θ can thus be considered a measure of price stickiness. In each period, firms that have drawn the "Calvo lottery ticket", i.e. are allowed to change their price, will set the price P_t^* that maximises the firms' current profits while that price remains effective. Firms maximise expected profits with respect to P_t^* :

$$\sum_{k=0}^{\infty}(\beta\theta)^k \tilde{E}_t^j \left[P_t^{*,j} Y_{t+\frac{k}{t}}^j - \Psi_{t+k}(Y_{t+\frac{k}{t}}^j)\right] \tag{IA.47}$$

subject to the demand constraints:

$$Y_{t+\frac{k}{t}}^j = (\frac{P_t^*}{P_{t+k}})^{-\epsilon} C_{t+k}^j \tag{IA.48}$$

where $\Psi_{t+k} Y_{t+\frac{k}{t}}^j$ is the cost function, and $Y_{t+\frac{k}{t}}^j$ is the output of the firm that last reset its price in period t. The first order condition for an optimum is:

$$\sum_{k=0}^{\infty}(\beta\theta)^k \tilde{E}_t^j \left[Y_{t+\frac{k}{t}}^j (P_t^{*,j} - M\psi_{t+\frac{k}{t}}^j)\right] = 0 \tag{IA.49}$$

where $\psi_{t+\frac{k}{t}}^j$ is the marginal cost in period t+k for a firm that last reset its price in period t, and M is the markup, i.e.

$$M = \frac{\epsilon}{\epsilon - 1} \tag{IA.50}$$

Log-linearising and solving for the price yields:

$$p_t^{j,*} = \mu + (1-\beta\theta)\sum_{k=0}^{\infty}{}^k \tilde{E}_t^j \left[mc_{t+\frac{k}{t}}^j + p_{t+k}^j\right] \tag{IA.51}$$

where μ is the desired markup, $mc_{t+\frac{k}{t}}^j$ is the (real) marginal cost. Note that $mc_{t+\frac{k}{t}}^j + p_{t+k}^j$ is the nominal marginal cost. Equation (IA.50) says that firms that reset their price set a price equal to the desired (equilibrium) markup plus the marginal costs expected to prevail as long as the price remains unchanged. Using

$$\pi_t = (1-\theta)(p_t^* - p_{t-1}) \tag{IA.52}$$

we obtain

$$\pi_t^j = \lambda \sum_{k=0}^{\infty} \beta^k \tilde{E}_t^j \left[\widehat{mc}_{t+k}^j\right] \tag{IA.53}$$

where $b_2 = \frac{(1-\theta)(1-\beta\theta)}{\theta}\frac{1-\alpha}{1-\alpha\epsilon}$ and $\widehat{mc}^j_{t+k}$ is the marginal cost expressed as a deviation from the steady state. Thus, when the marginal cost deviation from the steady state is positive, a fraction of prices is adjusted upwards, leading to more inflation. Just as for the demand equation, the discrete choice model for the selection of forecasting rules implies that:

$$\tilde{E}^j_t\left[\widehat{mc}_{t+k}\right] \tag{IA.54}$$

Finally we can rewrite

$$\pi^j_t = \beta\hat{E}^j_t\left[\pi_{t+1}\right] + \lambda\widehat{mc}_t \tag{IA.55}$$

Aggregating over all firms j (see Hommes and Lustenhouwer(2016)), we obtain

$$\pi^j_t = \beta\tilde{E}t\left[\pi_{t+1} + \lambda\widehat{mc}_t\right] \tag{IA.56}$$

The last step consists in relating the marginal cost to the output gap:

$$\pi^j_t = \beta\tilde{E}t\left[\pi_{t+1}\right] - \lambda\hat{\mu}_t \tag{IA.57}$$

where $\hat{\mu}_t = \mu_t - \mu = -\hat{m}c_t$ and $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}\frac{1-\alpha}{1-\alpha+\alpha\epsilon}$.

Analogously to the assumptions for firms' price-setting constraints, we assume that in each period only a fraction $1-\theta_w$ of households drawn randomly from the population re-optimise their posted nominal wage. We now consider how these re-optimising households set the wage for their labour. The households will choose w_t in period t to maximise:

$$\tilde{E}^i_t\left[\sum_{t=0}^{\infty}(\beta\theta_w)^k U(C^i_{t+k|t}, N^i_{t+k|t})\right] \tag{IA.58}$$

where $C^i_{t+k|t}$ and $N^i_{t+k|t}$ respectively denote the consumption and labour supply in period t+k of a household I that last reset its wage in period t. Note that the utility generated by any future wage is irrelevant in the context of the optimal setting of the current wage, and thus can be ignored in (IA.57). Given the utility function specified in (IA.25), the first-order condition associated with the above problem is:

$$\sum_{k=0}^{\infty}(\beta\theta_w)^k\tilde{E}^i_t\left[N_{t+k|t}U_c(C^i_{t+k|t}, N^i_{t+k|k})(\frac{w_t}{p_{t+k}} - M_w MRS_{t+k|t})\right] = 0 \tag{IA.59}$$

$MRS^i_{t+k|t} = -\frac{U_n(C^i_{t+k|t}, N^i_{t+k|k})}{U_c(C^i_{t+k|t}, N^i_{t+k|k})}$ denotes the marginal rate of substitution between consumption and labour in period t+k for a household that resets its wage in period t and $M_w = \frac{\epsilon_w}{1-\epsilon_w}$. Note that ϵ_w measures the elasticity of substitution between types of labour. Log-linearising (IA.59) around the steady state (zero inflation) yields the following approximate wage setting rule:

$$w^*_t = \mu^w + (1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k\tilde{E}^i_t\left[mrs_{t+k|t} + p_{t+k}\right] \tag{IA.60}$$

Where μ^w is household markup and $mrs_{t+k|t}$ is the (log) marginal rate of substitution in period t+k for a household that reset its wage in period t. Using $\pi^w_t = (1-\theta_w)(w_t - w_{t-1})$ we obtain:

$$\pi^w_t = \beta\tilde{E}^i_t(\pi^w_{t+1}) - \lambda_w\hat{\mu}^w_t \tag{IA.61}$$

where $\lambda_w = \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\varphi)}$ and $\hat{\mu}^w_t = \mu^w_t - \mu^w$.
Just as for the demand equation and the price setting equations, the discrete choice model for the

selection of forecasting rules (concerning wage inflation) makes it feasible to aggregate over all households i, hence:

$$\pi_t^w = \beta \tilde{E}_t(\pi_{t+1}^w) - \lambda_w \hat{\mu}_t^w \tag{IA.62}$$

To obtain the Philips curve used in our model, we follow Gali (2008):
Defining a real wage $\omega_t = w_t - p_t$, a real natural wage $\omega_t^n = w_t^n - p_t^n$, and a real wage gap $\tilde{\omega}_t = \omega_t - \omega_t^n$,

$$\begin{gathered}\hat{\mu}_t^w = \tilde{\omega}_t - (\sigma + \tfrac{\varphi}{1-\alpha})y_t \\ \hat{\mu}_t = -\tilde{\omega}_t - \tfrac{\alpha}{1-\alpha}y_t\end{gathered}$$

Referring to Equation (IA.55), the new-Keynesian Philips curve is:

$$\begin{gathered}\pi_t = \beta \tilde{E}_t(\pi_{t+1}) - \lambda \hat{\mu}_t \\ \pi_t = \beta \tilde{E}_t(\pi_{t+1}) + \lambda(\tilde{\omega}_t + \tfrac{\alpha}{1-\alpha}y_t) \\ \pi_t = \beta \tilde{E}_t(\pi_{t+1}) + \lambda(\hat{\mu}_t^w + \tfrac{\varphi}{1-\alpha})y_t + \tfrac{\alpha}{1-\alpha}y_t) \\ \pi_t = \beta \tilde{E}_t(\pi_{t+1}) + \lambda(\tfrac{\sigma(1-\alpha)+\varphi+\alpha}{1-\alpha})y_t + \lambda\hat{\mu}_t^w) \\ \pi_t = \beta \tilde{E}_t(\pi_{t+1}) + b_2 y_t + \lambda \hat{\mu}_t^w\end{gathered}$$

where $b_2 = \frac{(1-\theta)(1-\beta\theta)}{\theta} \frac{\sigma(1-\alpha)+\varphi+\alpha}{1-\alpha+\alpha\epsilon}$.

To obtain an aggregate supply equation with lagged inflation as in the main text, an indexation scheme has to be introduced. This involves indexing the non-Calvo-optimised prices in period t to inflation in period t-1, as done in Smets & Wouters (2003), where it is shown that with indexation, the aggregate supply curve is of the form:

$$\pi_t = \frac{\beta}{1+\beta\wedge}\tilde{E}_t(\pi_{t+1}) + \frac{\xi}{1+\beta\wedge}\pi_{t-1} + b_2 y_t + \lambda\hat{\mu}_t^w \tag{IA.63}$$

where $\wedge$ expresses the degree of indexation. When $\wedge = 0$, there is no indexation and no lagged inflation in the aggregate supply curve. When $\wedge = 1$ there is full indexation and the aggregate supply curve is as presented in the main text. In that case the coefficients on the forward-looking and lagged inflation add up to 1. This leads to equation (2) in the main text with: $b_1 = \frac{\beta}{1+\beta\wedge}$ and $1 - b_1 = \frac{\xi}{1+\beta\wedge}$.