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Fiscal consolidations and heterogeneous expectations

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ABSTRACT

We analyze fiscal consolidations using a New Keynesian model where agents have heterogeneous expectations and are uncertain about the composition of consolidations. We look at spending-based and tax-based consolidations and analyze their effects separately. We find that the effects of consolidations and the output multipliers are sensitive to heterogeneity in expectations before and after implementation of a specific fiscal plan. Depending on the beliefs about the type of consolidation prior to implementation, we show that heterogeneity in expectations may lead to optimism in the economy, improving thus the performance of a specific fiscal plan, or can work towards the opposite direction leading to pessimism, amplifying the contractionary effects of the consolidation. In general, we find that spending-based consolidations last longer and lead to deeper recessions when agents are boundedly rational compared to the rational expectations benchmark, while the opposite holds for tax-based consolidations.

1. Introduction

The recent financial crisis gave rise to various types of government interventions. These interventions led to rising government debt levels in most advanced economies (see IMF, 2011). Consequently, the majority of governments of those economies started the implementation of consolidation policies. In the Eurozone, such policies are still pursued in an effort to overcome the debt crisis in the countries of the Periphery. This crisis reshaped the way governments, within and outside the Monetary Union, think in terms of fiscal policy. In particular, the necessity for fiscal sustainability has arisen. There is a vast empirical and theoretical literature focusing on fiscal consolidations (see Alesina and Ardagna, 1998; Alesina and Ardagna, 2010; Alesina et al., 2015; Ardagna, 2004; Bertola and Drazen, 1993; Bi et al., 2013 and Guajardo et al., 2014 among others). However, little attention has been paid to the analysis of fiscal consolidations when agents are boundedly rational and heterogeneous in the way they form expectations. In this paper, we build a framework that allows for these features and, given those, we provide further insights as regards the effects of fiscal consolidations in the economy.

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Most of the theoretical literature on consolidations, so far, has assumed that agents are fully rational. The failure of traditional rational expectations models to capture some key facts in the data, especially after the recent financial crisis, raises the need for a richer modeling of economic behavior. In fact, the analysis of the effects of fiscal consolidations, in theoretical models, when agents are not behaving fully rational at all times and are heterogeneous has not been very extensive. In this paper, we contribute to this literature by building a closed economy New Keynesian model with distortionary taxes, where agents are boundedly rational and heterogeneous in the way they form expectations, in the spirit of Brock and Hommes (1997). Our target is to provide a framework where we can analyze the anticipation effects of fiscal consolidations, be it tax-based or spending-based, and how heterogeneity in expectations can alter the way a given type of consolidation affects the economy both ex-ante and ex-post. In fact, we show that heterogeneity in expectations and uncertainty regarding the type of the upcoming consolidation are crucial in determining the effectiveness of consolidations in stabilizing debt and its effects on economic activity, both before and after implementation.

We assume that there are two types of agents in the economy, namely, the Fundamentalists and the Naive agents. The first type uses announced policy (e.g. monetary and fiscal) rules when it forms its expectations about inflation and output. In particular, Fundamentalists take into account the commitment of the central bank to price stability. Moreover, when forming their expectations, they take into account the commitment of the fiscal authority to stabilize debt-to-GDP when the latter exceeds a certain threshold. On the contrary, Naive agents ignore the commitments of the two authorities when forming their expectations, and use the last observations of economic variables as their forecast for the future. Notice that the Naive forecast would be optimal if inflation, output and other variables followed a random walk. The Naive forecast will therefore be nearly optimal when economic variables are highly persistent and can be described by a near unit root process. Agents can switch between the two forecasting types according to an endogenous fitness measure. Agents choose the type with the higher fitness measure (i.e. lower past forecast error). Moreover, we assume Euler equation learning (see Honkapohja et al., 2013), so that both types of agents need to form one period ahead expectations only. We believe that the assumption that agents use simple, two period trade-offs like the Euler equation, better fits in our bounded rationality framework than the assumption that agents are able to form expectations over an infinite horizon, and are additionally able to choose a fully optimal consumption, labor or pricing plan up to the infinite future, given these expectations. We acknowledge however, that an approach based on anticipated utility, where agents are behaving optimally given their expectations up to the infinite future is also appealing in many settings.[2] An advantage of such an infinite horizon approach would e.g. be that it makes it easier to model agents' responses to anticipated fiscal policy changes (as in e.g. Evans et al., 2009). However, in our framework with heterogeneous agents, the presence of forward-looking fundamentalists allows us to model anticipation effects also under Euler equation learning. Furthermore, by assuming uncertainty about the exact timing of consolidators, we are also able to model consolidations that are anticipated already several periods before their implementation.

We assume that the government implements tax-based consolidations by raising a distortionary labor income tax. Spending-based consolidations are implemented through cuts in spending that is wasteful. Following Bi et al. (2013), we introduce uncertainty about the nature of fiscal consolidations. In particular, agents may be uncertain or wrong about whether the consolidation will be tax-based or spending-based and assign a probability to the occurrence of each type of consolidation. Given that the fiscal authority implements consolidations with a certain lag, this type of uncertainty affects expectations of Fundamentalists before consolidations are actually implemented. This is due to the assumption that those agents are forward looking and take into account the future monetary/fiscal policy stance.

We find that the anticipation of spending-based consolidations leads to an increase in output ant that this can result in a wave of optimism in the economy in the spirit of De Grauwe (2012) and De Grauwe and Ji (2016), where naive agents keep expecting high output, and increase their consumption. On the other hand, the anticipation of upcoming tax-based consolidations can trigger a wave of pessimism. When consolidations are actually implemented however, spending cuts generally lead to deeper recessions than tax hikes, and to a slower decrease in the debt to GDP ratio. This is due to the bounded rationality of, and heterogeneity in, expectations, where especially naive agents do not adjust their consumption in the way that fully rational agents would.

Tax-based consolidations are especially successful in reducing debt when Fundamentalists anticipated the consolidations to be spending-based. In this case the wave of optimism that is triggered by the expected spending-based consolidations is reinforced by the fact that more agents switch to Naive expectations, as Fundamentalists turn out to be wrong about the anticipated type of consolidation (tax- rather than spending-based). In this case a considerable boom in output can persist even while the government is increasing taxes. Similarly, when spending-based consolidations were expected to be tax-based, they are less successful due to an increase in pessimism.

Finally, we find that optimism (pessimism) in the economy keeps rising when uncertainty about the timing of consolidations causes Fundamentalists to keep expecting spending-based (tax-based) consolidations during several periods before their implementation. This can then lead to a considerable decrease (increase) in the debt to GDP ratio before consolidations actually start.

Our findings contribute to the existing literature in several ways. To the best of our knowledge, this is the first study to analyze fiscal consolidations when agents are boundedly rational and switch to better performing heuristics over time.[3]

[2] See e.g. Branch and McGough (2018) for further discussion on the two approaches.

[3] Erceg and Linde (2013) analyze fiscal consolidations in a currency union model with boundedly rational and heterogeneous agents. However, in their model a fixed fraction of agents consume all their income in every period and do not solve any inter-temporal optimization problem. In our model on the

We highlight the importance of anticipation effects, first, and, second, the degree of heterogeneity towards improving or deteriorating the performance of the consolidation, during and after implementation. We distinguish between the short and long-run effects of fiscal consolidations in terms of their performance in stabilizing debt. In line with the existing literature, we show that the magnitude, the duration, the composition and the likelihood of consolidation matter in determining the extent to which a specific type of consolidation is successful in stabilizing debt and/or is expansionary. Our major contribution, though, is that the assumption of boundedly rational agents leads to policy implications that may differ to those under rational expectations (RE) substantially. For instance, we show that heterogeneity in expectations generates pessimism in the economy after spending-based consolidations have been implemented. Contractions last longer than under RE and make consolidations last longer as well. Under tax-based consolidations instead, pessimism after implementation evaporates more quickly. In this case, smaller tax hikes are needed compared to the RE case, and the consolidation lasts for less periods due to the quicker recovery in the tax base. We show that under RE, spending-based consolidations (anticipated and unanticipated) cause milder contractions on impact compared to tax-based consolidations. However, in our behavioral model this result is reversed.

The next section provides a brief overview of the existing empirical and theoretical literature on fiscal consolidations. Section 3 outlines the model and the fiscal consolidations that may occur, as well as the heterogeneity in the way agents form expectations. Sections 4 and 5 analyze the performance of the two types of consolidations under different private sector expectations, by means of theoretical results and impulse responses, respectively. In Section 6 we discuss the intuition of the differences between spending- and tax-based consolidations in our behavioral model, and Section 7 concludes.

2. Related literature

In the literature, there is substantial research on the effects of fiscal consolidations. In particular, there has been much research on the effects of different types of fiscal consolidations (e.g. spending-based and tax-based). A large empirical literature provides evidence supporting the expansionary fiscal consolidations hypothesis (see Alesina and Ardagna, 1998; Alesina and Ardagna, 2010; Alesina and Perotti, 1995; Ardagna, 2004; Perotti, 1996). In particular, the key finding is that fiscal consolidations are sometimes correlated with rapid economic growth, especially when implemented by spending cuts rather than tax increases. On the other hand, another strand of the empirical literature using narrative data to identify consolidations, initially introduced by Romer and Romer (2010), finds that output drops following both types of consolidations and that recessions are deeper after tax hikes (Guajardo et al., 2014).[4] Similarly, Alesina et al. (2015), using a richer structure for modeling fiscal consolidations which accounts for anticipation effects, find that spending-based consolidations are less costly, in terms of output losses than tax-based ones.[5] Finally, Wiese et al. (2015) find instead that the composition of fiscal adjustments is not related to their success in advanced economies. We find that tax-based consolidations cause milder recessions than spending-based ones when agents are boundedly rational. The opposite holds when agents have rational expectations. When it comes to debt stabilization though the differences between the two types of consolidations are marginal when agents are boundedly rational. The existing empirical literature does not use forecasts of agents nor does it account for potential heterogeneity in beliefs. In most studies instead ex-post data have been used.

Beetsma et al. (2015) analyze the confidence effects of fiscal consolidations, showing that consumer confidence deteriorates after revenue-based consolidation announcements in European countries.[6] Our model captures this fact. When agents expect tax-based consolidations to be more likely to happen, output contracts even before implementation owing to pessimism due to the drop in expected future disposable income. On the other hand, Beetsma et al. (2015) find that spending-based consolidation announcements are less harmful in terms of consumer confidence before implementation. In our model, we show that output expands one period before implementation of anticipated spending-based consolidations, owing to the lower future real interest rates that Fundamentalists expect. Consequently, Naive agents become gradually more optimistic expecting higher output in the next period which we interpret as an improvement in confidence (or optimism) in the economy.

In the theoretical literature, Bertola and Drazen (1993) develop a model where the government satisfies its intertemporal budget constraint by periodically cutting spending, where the latter is inherently unsustainable. A worsening of

other hand, all agents solve an inter-temporal optimization problem given their expectations, and switch to a different expectation formation heuristic, if that heuristic has better past performance. Another distinctive feature of our model compared to theirs is the short-sightedness of Fundamentalists who are not fully rational and do not form expectations over the infinite future.

[4] Earlier papers using the conventional approach to identify fiscal consolidations argued in favor of the expansionary effects of spending-based consolidations ("expansionary fiscal austerity"), see Alesina and Ardagna (2010); Alesina et al. (2002); Alesina and Perotti (1996) and Giavazzi and Pagano (1990) among others. However, their measure of identifying consolidations (i.e. the CAPB) suffers from problems like reverse causality or changes in fiscal variables due to non-policy changes correlated with other developments in output. Finally, as Romer and Romer (2010) point out, another approach, followed by Blanchard and Perotti (2002), using SVAR analysis and institutional information to identify consolidations, suffers from problems similar to those of the studies above.

[5] However, as Guajardo et al. (2014) argue, a drawback of contemporaneous estimates is that planned impacts on budgets may tend to be over-optimistic relative to the ex-post outcomes. Consequently, the negative effects of consolidations on output may be understated due to the induced bias. This is the case with spending cuts in many instances, where the announced cuts were stronger than those actually implemented (Beetsma et al., 2016).

[6] Beetsma et al. talk about improvements in consumer confidence which translate into boosts in private consumption and ultimately in output and vice versa when consumer confidence deteriorates.

the fiscal conditions can increase the probability of a beneficial fiscal consolidation which can thus be expansionary. Bi et al. (2013) augment the model of Bertola and Drazen (1993) with distortionary taxation and analyze the effects of different types of fiscal consolidations. Moreover, they look at the effects of persistence in those, as well as of the uncertainty of economic agents over the composition of the upcoming fiscal consolidation. Accounting for the monetary policy stance as well, they find that spending and tax-based consolidations can be equally successful in stabilizing government debt at low debt levels. Nevertheless, at high debt levels, spending-based consolidations are expected to be expansionary and more successful in stabilizing debt, especially when agents anticipate a tax-based consolidation. They however, do not account for heterogeneity in expectations.

Contrary to Bi et al., agents in our model do not have rational expectations, but are short-sighted and heterogeneous in their expectations about macro aggregates. Moreover, our comparison between the two types of consolidations is richer. Specifically, we find that both types of consolidations perform equally well in stabilizing the debt-ratio, at least in the medium- to long-run, when agents are certain and correct about the type and the timing of the consolidation. On the contrary, we show that the debt-ratio is stabilized faster after tax hikes when agents anticipate spending-based consolidations. Finally, we show that timing uncertainty about the implementation of the consolidations favors spending-based ones due to the anticipation effects which lead to a persistent expansion in the periods prior to implementation.

Finally, Erceg and Linde (2013) examine the effects of tax-based and spending-based consolidations in a two country DSGE model for a currency union. They assume agent heterogeneity by introducing fixed fractions of forward looking and “hand-to-mouth” households. They find that tax-based consolidations have less adverse output costs than spending-based ones in the short to medium-run. Moreover, they show that large spending-based consolidations can be counterproductive in the short-run when the zero lower bound in interest rate binds, while they argue in favor of a “mixed strategy” combining both types of consolidations.

Although little attention has been paid to heterogeneity in expectations,[7] the effects of fiscal policy changes when agents are boundedly rational have been analyzed in the literature. Evans et al. (2009) look at the effects of fiscal policy changes in an infinite horizon adaptive learning model, where agents consider future policy changes as credible, and use steady state learning for future interest rates. In this case, forecasts under learning give rise to dynamics in interest rates that are different from the rational expectation dynamics. After a credible announcement of a change in fiscal policy in a specific moment in the future, interest rates under learning tend to fluctuate many periods before implementation as opposed to the rational expectations case. In their approach though, when agents used Euler equation learning, they do not react to announced future policy changes (even one period before implementation). In our model instead, heterogeneity allows agents to react to announced future policy changes even with Euler equation learning. This is because of the existence of fundamentalists who trust the fiscal authorities and take into account the effect that the policy change will have on other variables one period before implementation.[8]

Mitra et al. (2013) using an RBC model where agents are fully aware of the imminent fiscal policy change but uncertain about the true law of motion of future wages and interest rates, show that systematic forecast errors can lead to periods of optimism and /or pessimism depending on the state of the economy. Specifically, optimism before implementation can lead to a gradual rise in private consumption and thereby output before and in some periods after implementation, due to the persistence in forecast errors. However, after implementation agents revise their forecasts downwards and this can lead to contractions and to periods of pessimism. Gasteiger and Zhang (2014) use a richer model with distortionary taxes and elastic labor supply and show that anticipated tax changes can lead to oscillatory dynamics due to waves of optimism or pessimism. Again, such waves arise from forecast errors. In our case pessimism or optimism arises for the same reason, but also depends on the degree of heterogeneity which is absent in the papers above. For instance, if Fundamentalists have been wrong about the type of the consolidation or about the path of inflation or output next period, they might switch to the naive rule which uses only past information. As the fraction of agents switching to that rule increases, pessimism or optimism in the economy also increases. This may either prolong expansions or contractions depending on the effects of the imminent consolidation in the periods prior to implementation.

3. The model

3.1. Households

In our model time is infinite and there is a continuum of households that differ only in the way they form expectations. In particular, a household can be either Naive or Fundamentalist. Households of the same type make identical decisions. The

[7] An exception is Gasteiger (2017), who provides a taxonomy of the alternative regimes and the equilibrium properties in a model where a fraction of agents is rational and a fraction is adaptive. He shows that conditions for determinacy and existence of an equilibrium can change compared to the benchmark where all agents are endowed with RE. In our paper on the other hand, the focus is on dynamic responses to fiscal policy changes in the form of consolidations. Moreover, in our framework expectations of agents are a function of observables and known parameters only, regardless of their type. Therefore, the properties of our model are not described by determinacy or indeterminacy, but instead by local stability of a fixed point, as determined by the eigenvalues of the Jacobian matrix of the resulting system of difference equations. In line with Gasteiger (2017) we find however that when we have both active fiscal and active monetary policy there is local divergence/explosiveness.

[8] Moreover, Evans et al. (2009) do not analyze fiscal consolidations but instead look at balanced budget changes in spending, while bonds are in zero net supply. They also consider lump-sum taxes abstracting thereby from the distortionary effects of taxation and its effects on agents expectations.

intra-temporal problem of each household $i \in [0.1]$, consists of choosing consumption over a continuum of different goods to minimize expenditure. The elasticity of substitution between the different goods is θ, so that households choose

$$C_t^i(j) = \left(\frac{p_t(j)}{P_t}\right)^{-\theta} C_t^i, \tag{1}$$

with C_t^i and P_t being total consumption of the household and the aggregate price level, respectively, defined by

$$C_t^i = \left(\int_0^1 C_t^i(j)^{\frac{\theta-1}{\theta}} dj\right)^{\frac{\theta}{\theta-1}}, \tag{2}$$

$$P_t = \left(\int_0^1 P_t(j)^{1-\theta} dj\right)^{\frac{1}{1-\theta}}. \tag{3}$$

Household i chooses consumption, C_t^i, labor, H_t^i, and nominal bond holdings, B_t^i, to maximize

$$\tilde{E}_t^i \sum_{s=t}^{\infty} \beta^s \left[\frac{\left(C_s^i\right)^{1-\sigma}}{1-\sigma} - \frac{\left(H_s^i\right)^{1+\eta}}{1+\eta}\right], \tag{4}$$

subject to its budget constraint

$$P_t C_t^i + B_t^i \;\le (1-\tau_t) W_t H_t^i + (1+i_{t-1}) B_{t-1}^i + P_t \int_0^1 \Xi_t(j) dj, \tag{5}$$

where W_t is the nominal wage rate, τ_t is the labor tax rate, and i_t is the nominal interest rate. $\Xi_t(j)$ represents firm j's real profits while $\tilde{E}_t^i$ is the type-specific expectation operator of household i (which can either be Naive or Fundamentalist).

Dividing the budget constraint by $P_t Y_t$ and writing bonds in real terms as a share of GDP $b_t^i = \frac{B_t^i}{P_t Y_t}$ gives

$$\frac{C_t^i}{Y_t} + b_t^i \le (1-\tau_t) w_t \frac{H_t^i}{Y_t} + \frac{(1+i_{t-1}) b_{t-1}^i Y_{t-1}}{\Pi_t Y_t} + \frac{\Xi_t}{Y_t}, \tag{6}$$

where $\Xi_t = \int_0^1 \Xi_t(j) dj$ are aggregate real firm profits, $\Pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate, and $w_t = \frac{W_t}{P_t}$ is the real wage rate.

The first order conditions with respect to C_t^i, H_t^i and b_t^i lead to the usual Euler equation and to an expression for the real wage, which, together with the budget constraint (6), must hold in equilibrium:

$$(C_t^i)^{-\sigma} = \beta \tilde{E}_t^i \left[\frac{(1+i_t)(C_{t+1}^i)^{-\sigma}}{\Pi_{t+1}}\right], \tag{7}$$

$$w_t = \frac{(H_t^i)^{\eta} (C_t^i)^{\sigma}}{(1-\tau_t)}. \tag{8}$$

3.2. Firms

There is a continuum of monopolistically competitive firms, producing the final differentiated goods. Each firm is run by a household and follows the same heuristic for prediction of future variables as the household it is run by. We assume Rotemberg pricing. Each monopolistic firm $j \in [0, 1]$ faces a quadratic cost of adjusting nominal prices, which can be measured in terms of the final good, and is given by

$$\frac{\phi}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - 1\right)^2 Y_t, \tag{9}$$

where ϕ measures the degree of nominal price rigidity. As stressed by Rotemberg (1982) the adjustment cost accounts for the negative effects of price changes on the customer-firm relationship and is increasing in the size of the price change and in the overall scale of economic activity. Each firm has a linear technology with labor as its only input

$$Y_t(j) = A H_t(j), \tag{10}$$

where A is an aggregate productivity which we assume to be constant.[9] The problem for firm j is then

$$\max_{\{Y_t(j), P_t(j)\}_{t=0}^{\infty}} \tilde{E}_t^i \sum_{s=0}^{\infty} Q_{t,t+s}^j P_{t+s} \Xi_{t+s}(j), \tag{11}$$

[9] Since our focus is on the effects of fiscal consolidations following a drop in the debt threshold we decide to shut down all shocks in order to keep the analysis simple. However, our results hold when debt rises above an unchanged threshold due to shocks hitting the economy other than an unanticipated fall in the debt threshold.

subject to the demand for its product. In the expression above, the term $Q^j_{t,t+s}$ represents the stochastic discount factor of the household that runs firm j, while the term $P_t \Xi_t(j)$ denotes firm j's nominal profits defined as

$$P_t \Xi_t(j) = P_t(j)Y_t(j) - mc_t Y_t(j) P_t - \frac{\phi}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - 1\right)^2 Y_t P_t$$
$$= P_t(j)^{1-\theta} P_t^{\theta} Y_t - mc_t P_t(j)^{-\theta} P_t^{1+\theta} Y_t - \frac{\phi}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - 1\right)^2 Y_t P_t. \quad (12)$$

The first order condition of the maximization problem of the firm with respect to $P_t(j)$ is

$$(1-\theta)Y_t(j) + \theta mc_t \frac{P_t}{P_t(j)} Y_t(j) - \phi\left(\frac{P_t}{P_{t-1}(j)}\right)(\Pi_t(j) - 1)Y_t + \phi \tilde{E}^j_t\left[Q^j_{t,t+1} Y_{t+1} \frac{P_{t+1}}{P_t(j)} \Pi_{t+1}(j)(\Pi_{t+1}(j) - 1)\right] = 0, \quad (13)$$

where $\Pi_t(j)$ is the (gross) price inflation of the good produced by firm j. mc_t denotes the marginal cost of the firm and is equal to $mc_t = \frac{w_t}{A}$. Finally, multiplying (13) by $\frac{P_t(j)}{P_t Y_t}$ and plugging in the stochastic discount factor gives

$$(\theta - 1)\frac{P_t(j)Y_t(j)}{P_t Y_t} + \phi \Pi_t(j)(\Pi_t(j) - 1) = \theta mc_t \frac{Y_t(j)}{Y_t} + \phi\beta \tilde{E}^j_t\left[\left(\frac{C^j_{t+1}}{C^j_t}\right)^{-\sigma} \frac{Y_{t+1}}{Y_t} \Pi_{t+1}(j)(\Pi_{t+1}(j) - 1)\right]. \quad (14)$$

3.3. Government and market clearing

The government issues one period bonds and levies labor taxes, τ, to finance its spending, G_t. Its budget constraint is given by

$$B_t = P_t G_t - \tau_t W_t H_t + (1 + i_{t-1})B_{t-1}, \quad (15)$$

with $H_t = \int H^i_t di$ and $B_t = \int B^i_t di$ aggregate labor and aggregate bond holdings, respectively. Dividing by $Y_t P_t$ gives

$$b_t = g_t - \tau_t w_t \frac{H_t}{Y_t} + \frac{(1 + i_{t-1})b_{t-1}}{\Pi_t}\frac{Y_{t-1}}{Y_t} = g_t - \tau_t mc_t + \frac{(1 + i_{t-1})b_{t-1}}{\Pi_t}\frac{Y_{t-1}}{Y_t}, \quad (16)$$

where $b_t = \frac{B_t}{P_t Y_t}$ and $g_t = \frac{G_t}{Y_t}$ are the real debt to GDP ratio and government expenditure to GDP, respectively.

The government adjusts spending and taxes according to the following rules:

$$g_t = g_1 - \zeta \gamma_1 \max(0, b_{t-2} - DT_{t-2}), \quad (17)$$

and

$$\tau_t = \tau_1 + (1 - \zeta)\gamma_2 \max(0, b_{t-2} - DT_{t-2}). \quad (18)$$

where DT_t is the debt threshold set by the government. When the debt ratio is above this threshold the government uses spending and/or taxes to stabilize the debt ratio. The parameter ζ determines whether the government uses spending, taxes, or a mixture of both to stabilize debt. For expositional clarity, we will only consider the two extreme cases where either spending is the only instrument ($\zeta = 1$) or taxes are the only instrument to stabilize debt ($\zeta = 0$). When the debt ratio is below the threshold, spending and taxes are set equal to their steady state values, τ_1 and g_1. This means that below the threshold the government is not stabilizing debt. It only does so as long as debt exceeds the threshold.[10] The debt threshold is set by the government to make sure that it will always have fiscal space. That is, the government wants to prevent the debt to GDP ratio from rising to a level close to the fiscal limit of the economy. If the debt to GDP ratio is far from this fiscal limit the government is not worried about the debt to GDP ratio in the economy and does not respond to it with fiscal variables. When the debt to GDP ratio rises above the threshold, the government starts to get concerned about its fiscal space, and adjusts spending or taxes proportional to how far the debt ratio has risen above the threshold.

Note that taxes and spending respond with a two period lag to deviations of the debt ratio from its threshold. This captures two features of the model. First, variables are not observed contemporaneously, neither by the agents nor by the government. Secondly, we assume that the government needs one period to process and implement fiscal adjustments.[11]

[10] Even though fiscal policy is active when the debt ratio lies below the threshold, fiscal policy will become passive once the threshold is crossed. This implies that under active monetary policy the debt ratio can temporarily enter an explosive path, but that it will be stabilized eventually. Therefore, the transversality condition will be satisfied, and the model will be globally stable under rational expectations (RE). In the literature on the monetary/fiscal policy mix, it has been shown that a RE model can be globally stable even though the economy might spend periods in which both policies are active. This the case as long as agents are aware of the fact that an active monetary/passive fiscal policy regime exists and is the most recurrent one (see Bianchi, 2012; Bianchi and Ilut, 2017 and Davig et al., 2007 among others). In our model, this regime will occur endogenously because of a rising debt ratio when both policies are active.

[11] The implementation we assume is motivated by Alesina et al. (2016) who argue that fiscal plans consist of a sequence of actions, some of which are designed to be implemented in the future. Gasteiger and Zhang (2014) also refer to legislation and implementation lags in fiscal policy and they model the latter. Finally, Leeper (2009) discusses empirical evidence for anticipated fiscal policy (e.g. fiscal foresight), while Leeper et al. (2013) provide empirical evidence of it.

As a robustness check, we present in Appendix C.3, what would happen without the implementation lag in our benchmark case of correctly anticipated consolidations.

The threshold, DT_t, may change over time for two reasons. First of all, the government's preference for its desired fiscal space may change for e.g. political reasons. It may therefore increase (lower) its threshold to start consolidations farther from (closer) to the economy's fiscal limit. Secondly, the economy's fiscal limit my change due to market pressures, and the government may adjust its threshold accordingly to keep the same amount of fiscal space. In this paper, we do not model these market pressures nor the fiscal limit. Instead, we consider exogenous changes in the debt threshold as a trigger for consolidations, without specifying for what reason the government decides to change this threshold.

We consider both anticipated and unanticipated consolidations. We model anticipated consolidations as follows. We assume that the economy initially lies in a state slightly above the debt threshold where the government uses either spending or taxes to stabilize debt.[12] Agents are fully aware of the fiscal instrument used and of the structure of the feedback rule. At date t the government lowers the debt threshold and announces the new debt threshold to the public. At date $t+1$ the government observes the realization of b_t and compares it to the new debt threshold, DT_t. If $b_t > DT_t$, the government cuts spending or increases taxes, as in (17) or (18), depending on the value of ζ. Given the structure of the feedback rules, the consolidation starts two periods after the drop in the debt threshold (i.e. $t+2$), as long as $b_t > DT_t$. In our benchmark case of correctly anticipated consolidations, the instrument used to consolidate is the same as the one that was used initially before the drop in the debt threshold, i.e., the value of ζ does not change. The size of the consolidation is determined by the distance of b_t from the new debt threshold, DT_t, and the policy parameter γ_1, in the case of spending-based, or γ_2 in the case of tax-based consolidations. Fundamentalists trust the government fully and adjust their expectations accordingly one period before implementation.

Unanticipated consolidations are triggered in the same way with the difference that the lowering of the debt threshold by the government is not announced to the public. As such, Fundamentalists do not anticipate a spending cut or a tax hike.

In addition to anticipated and unanticipated consolidations we also consider different scenarios regarding changes in, and uncertainty about, the composition of the consolidation. In particular, we will consider cases where the value of parameter ζ is suddenly changed by the government on the day that consolidations start. This will not be announced to the public, and hence come as a surprise to agents.

Our classification of the alternative forms of consolidations is similar to Alesina et al. (2016), adjusted though to the specifics of our model. Alesina et al. (2016) classify anticipated consolidations as measures written in the legislation whose implementation was different from subsequent years, or measures implemented in a given year but already announced in the years before implementation (i.e. part of legislation adopted in previous years). They do not model those using a debt threshold as we assume in our model. In our case, incorporating a political process would complicate the analysis a lot. However, an announced drop in the debt threshold two periods before implementation leads to anticipation effects similar to those that Alesina et al. have in mind. As regards unanticipated consolidations, Alesina et al. classify those as measures that were immediately implemented. In our case instead, we stick with our framework of anticipated consolidations, but assume that the drop in the debt threshold is not announced so that the imminent consolidation is not expected. Finally, Alesina et al. account also for fiscal plans revised along the way and they model modifications of announced measures as unexpected shifts in fiscal policy. Our modeling of composition uncertainty is close to theirs. Specifically, in our case agents are aware of the drop in the debt threshold and think they know the fiscal instrument to be used two periods later. However, when the implementation day arrives the government changes the instrument used and this is a surprise to the agents. So, there are anticipation effects in the periods before implementation but about the wrong type of instrument.

The aggregate resource constraint of the economy is summarized as

$$Y_t = C_t + G_t + \frac{\phi}{2}\left(\frac{P_t}{P_{t-1}} - 1\right)^2 Y_t = C_t + g_t Y_t + \frac{\phi}{2}\left(\frac{P_t}{P_{t-1}} - 1\right)^2 Y_t. \tag{19}$$

3.4. Log-linearization and aggregation

We log-linearize the model around the zero inflation steady state.[13] The Euler equation, (7), can be log-linearized to get[14]

$$\hat{C}_t^i = \tilde{E}_t^i[\hat{C}_{t+1}^i] - \frac{1}{\sigma}(\hat{i}_t - \tilde{E}_t^i[\pi_{t+1}]). \tag{20}$$

Since our agents are boundedly rational, they are not able to fully optimize over an infinite horizon, taking account of all model equations and expectations about all variable up to infinity. Instead, we assume as in Branch and McGough (2009), that our boundedly rational agents use Euler equation learning (see Honkapohja et al., 2013), implying that they use the marginal costs versus marginal benefits trade-off of the Euler Eq. (20) to make decisions given their budget constraint, and given their subjective forecasts of aggregate variables.

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[12] This initial state corresponds to a high debt fixed point, specified in Section 4.3, consistent with a higher threshold.

[13] We specify the zero inflation steady state in Appendix A.1

[14] In what follows, for all the variables normalized with respect to GDP (debt, government purchases, federal expenditure, tax revenues) $\tilde{x}_t$ denotes a linear deviation ($\tilde{x}_t = X_t - \bar{X}$) from its steady state. Instead, for all other variables $\hat{x}_t$ denotes a percentage deviation ($\hat{x}_t = \log(X_t/\bar{X})$) from its steady state. This distinction avoids having the percentage change of a percentage. As regards inflation, we denote the log-linearized gross inflation Π_t as π_t.

Assuming that the law of iterated expectations holds at the individual level, we can iterate (21) forward to express household i's consumption decision as

$$\hat{C}_t^i = \tilde{E}_t^i \hat{C}_\infty^i - \frac{1}{\sigma} \tilde{E}_t^i \sum_{k=0}^{\infty} (\hat{i}_{t+k} - \pi_{t+k+1}), \tag{21}$$

where $\hat{C}_\infty^i = \lim_{k\to\infty} \hat{C}_{T+k}^i$.

Next, we assume that agents know that market clearing must hold. Log-linearizing (19) gives

$$\hat{Y}_t - \frac{\tilde{g}_t}{1-\bar{g}} = \hat{C}_t = \int \hat{C}_t^l dl, \tag{22}$$

where we now index the continuum of households $l \in [0, 1]$, to distinguish it from the particular household i that we are considering. Using (22), household i's expectations about next periods output, government spending and consumption satisfy

$$\tilde{E}_t^i \hat{Y}_{t+1} - \frac{\tilde{E}_t^i \tilde{g}_{t+1}}{1-\bar{g}} = \tilde{E}_t^i \hat{C}_{t+1} = \tilde{E}_t^i \int \hat{C}_{t+1}^l dl \tag{23}$$

We further assume that agents know that the consumption of other agents will satisfy their individual Euler equations. Using (21) we can therefore write

$$\tilde{E}_t^i \hat{Y}_{t+1} - \frac{\tilde{E}_t^i \tilde{g}_{t+1}}{1-\bar{g}} = \tilde{E}_t^i \int \tilde{E}_{t+1}^l \hat{C}_\infty^l dl - \tilde{E}_t^i \int \tilde{E}_{t+1}^l \frac{1}{\sigma} \sum_{k=1}^{\infty} (\hat{i}_{t+k} - \pi_{t+k+1}) dl \tag{24}$$

As in Branch and McGough (2009), we now assume that the law of iterated expectations holds at the aggregate level, so that $E_t^i E_{t+k}^l x_{t+k} = E_t^i x_{t+k}$. Under that assumption the above reduces to

$$\tilde{E}_t^i \hat{Y}_{t+1} - \frac{\tilde{E}_t^i \tilde{g}_{t+1}}{1-\bar{g}} = \tilde{E}_t^i \int \tilde{E}_{t+1}^l \hat{C}_\infty^l dl - \tilde{E}_t^i \frac{1}{\sigma} \sum_{k=1}^{\infty} (\hat{i}_{t+k} - \pi_{t+k+1}) \tag{25}$$

Agents use this relation to form expectations about the sum of future real interest rates when they make their consumption decision according to Eq. (21). Therefore, instead of having to come up with expectations about nominal interest rates and inflation up to the infinite future, they can make their consumption decision based on expectations about next periods output, government spending and inflation, and about limiting consumption.[15] In particular, using (25) to substitute for expected future real interest rates and inflation in Eq. (21), we can write agents' i consumption decision as

$$\hat{C}_t^i = \tilde{E}_t^i \hat{C}_\infty^i - \tilde{E}_t^i \int \tilde{E}_{t+1}^l \hat{C}_\infty^l dl + \tilde{E}_t^i \hat{Y}_{t+1} - \frac{\tilde{E}_t^i \tilde{g}_{t+1}}{1-\bar{g}} - \frac{1}{\sigma} (\hat{i}_t - \tilde{E}_t^i \pi_{t+1}). \tag{26}$$

Aggregating this consumption decision over all agents gives

$$\hat{C}_t = \int \tilde{E}_t^i \hat{C}_\infty^i di - \bar{E}_t \int \tilde{E}_{t+1}^l \hat{C}_\infty^l dl + \bar{E}_t \hat{Y}_{t+1} - \frac{\bar{E}_t \tilde{g}_{t+1}}{1-\bar{g}} - \frac{1}{\sigma} (\hat{i}_t - \bar{E}_t \pi_{t+1}), \tag{27}$$

where $\bar{E}_t$ is the aggregate expectation operator defined by $\bar{E}_t[X_{t+1}] = \int \tilde{E}_t^i [X_{t+1}] di = n_t^N \tilde{E}_t^N [X_{t+1}] + (1 - n_t^N) \tilde{E}_t^F [X_{t+1}]$, with n_t^N the fraction of Naive agents.

Finally, again as in Branch and McGough (2009), we assume that agents agree on terminal wealth and consumption of all agents, so that $\int \tilde{E}_t^i \hat{C}_\infty^i di - \bar{E}_t \int E_{t+1}^i \hat{C}_\infty^i di = 0$ and the first two terms in (27) drop out. Using Market clearing we can then obtain the aggregate IS equation

$$\hat{Y}_t = \bar{E}_t \hat{Y}_{t+1} - \frac{1}{\sigma} (\hat{i}_t - \bar{E}_t \pi_{t+1}) + \frac{1}{1-\bar{g}} \left(\tilde{g}_t - \bar{E}_t \tilde{g}_{t+1} \right). \tag{28}$$

Log-linearizing the optimal pricing Eq. (14) and combining it with the market clearing condition and the marginal cost equations in their log-linearized form we end up with the inflation equation

$$\pi_t = \beta \bar{E}_t [\pi_{t+1}] + \kappa (\sigma + \eta) \hat{Y}_t - \kappa \sigma \frac{\tilde{g}_t}{1-\bar{g}} + \kappa \frac{\tilde{\tau}_t}{1-\bar{\tau}}, \tag{29}$$

where $\kappa = \frac{\theta - 1}{\phi}$.

Next, we can log-linearize the government budget constraint, Eq. (16), to get

$$\tilde{b}_t = \frac{1}{\beta} \tilde{b}_{t-1} + \tilde{g}_t - \frac{\theta - 1}{\theta} (\tilde{\tau}_t + \bar{\tau} \hat{mc}_t) + \frac{\bar{b}}{\beta} (\hat{i}_{t-1} - \pi_t - \hat{Y}_t + \hat{Y}_{t-1}), \tag{30}$$

[15] Note that we have not specified yet how agents form their expectations about these variables. When agents form expectations about next period's output they could e.g. take account of what they think next periods taxes will be. They could however also completely ignore fiscal commitments of the government, as well as the government budget constraint. The expectation formation of our two types of agents are presented in Section 3.5.

with

$$\hat{mc}_t = (\sigma + \eta)\hat{Y}_t - \sigma\frac{\tilde{g}_t}{1-\bar{g}} + \frac{\tilde{\tau}_t}{1-\bar{\tau}} \quad (31)$$

Linearizing (17) and (18) gives

$$\tilde{g}_t = -\zeta\gamma_1 \max(0, \tilde{b}_{t-2} - \tilde{DT}_{t-2}), \quad (32)$$

$$\tilde{\tau}_t = (1-\zeta)\gamma_2 \max(0, \tilde{b}_{t-2} - \tilde{DT}_{t-2}). \quad (33)$$

We assume the central bank targets only inflation and that the inflation target is zero (which is consistent with the assumption of a zero inflation steady state that was assumed in the log-linearization in the previous section). We furthermore assume a forward looking Taylor (1993) type rule, where the central bank responds to inflation expectations. We consider a forward looking rather than a contemporaneous Taylor rule in order te maintain the behavioral assumption that agents in the economy (including the monetary and fiscal authority) cannot observe endogenous variables contemporaneously. McCallum (1999) also argue that a monetary policy rule where the central bank responds to contemporaneous prices is not operational. Moreover, forward looking Taylor rules perform well empirically (see e.g. Clarida et al., 1998). We note however that the results in this paper are qualitatively robust to the choice of this form of the interest rate rule, as we discuss in more detail in footnote 27. The log-linearized forward looking Taylor rule is given by

$$\hat{i}_t = \phi_\pi \bar{E}\pi_{t+1}. \quad (34)$$

3.5. Expectations formation

As discussed in the previous section, agents make their consumption, labor, and pricing decisions based on their expectations about next period's inflation, next period's output gap, and next period's government spending. We assume private sector beliefs are formed by two heuristics: Fundamentalists and Naive. Naive agents comprise a fraction n_t^N of the population and believe future inflation, output and government spending to be equal to their last observed values: $E_t^N\pi_{t+1} = \pi_{t-1}, E_t^N\hat{Y}_{t+1} = \hat{Y}_{t-1}, E_t^N\tilde{g}_{t+1} = \tilde{g}_{t-1}$.

Fundamentalists comprise a fraction $1 - n_t^N$ of the population. These agents trust to commitments of the monetary and fiscal authority and use the monetary and fiscal policy rules when they form expectations. However, because of surprise policy changes, Fundamentalists may be wrong, or uncertain, regarding the composition of fiscal adjustments (i.e. the value of ζ). In any period t, they believe government spending to be the fiscal instrument (i.e. $\zeta = 1$) with probability α_t, and taxes to be the fiscal instrument (i.e. $\zeta = 0$) with probability $1 - \alpha_t$. In line with the fiscal rule of the government, Fundamentalists expectations about next periods government are therefore given by

$$E_t^F\tilde{g}_{t+1} = -\alpha_t\gamma_1 \max(0, \tilde{b}_{t-1} - \tilde{DT}_{t-1}). \quad (35)$$

After they have observed a period of consolidations, Fundamentalists update their value of α_t. Throughout the paper we will assume that ζ has a fixed value, up until the point an unexpected composition change is announced or implemented. Fundamentalists do not anticipate that such surprise policy changes might arise. For this reason, after observing a period of spending-based consolidations Fundamentalists update their belief to $\alpha_t = 1$, and after observing a period of tax-based consolidations they update their belief to $\alpha_t = 0$.

Next we turn to Fundamentalists expectations about inflation and output. When forming these expectations, they take account of their beliefs about upcoming monetary and fiscal policy. Fundamentalists are furthermore aware of the model Eqs. (28)–(30). They are however boundedly rational and are not sophisticated enough to calculate perfect foresight paths until infinity and to base their expectations on such calculations. Instead they use a relatively simple heuristic to approximate the values of variables in the next period.

Unless very extreme consolidations occur, the debt ratio will be a highly persistent variable in our model. Furthermore, if the debt ratio remained constant over time, fiscal variables would remain constant as well, implying that also inflation and output would remain constant. Fundamentalists use these two features of the model to form expectations about next periods inflation and output.[16] Assuming that debt stays constant at its last observed value, they calculate the values of inflation and output that are consistent with that value of debt. They do this, by assuming that all agents form the same expectations as them.[17] As long as this is the case, and as long as the debt ratio, and therefore government spending and

[16] Since Fundamentalists are aware of the government budget constraint, they could also calculate the perfect foresight fixed point were it is fully correct that all variables remain constant. However, since agents need to form expectations about next period's variables only, and since debt is highly persistent, it is not a good heuristic to assume that debt will suddenly jump to its fixed point value. In absence of the cognitive ability to calculate the converging perfect foresight path towards this fixed point, it is instead better to approximate next period's dynamics by assuming that debt does not change in the short run.

[17] Note that this is consistent with the law of iterated expectations at the aggregate level, that was assumed in the previous section.

taxes, do not change too much from period to period, this heuristic gives a good approximation for next periods inflation and output. That said, Fundamentalists' expectations about inflation and output at date t about $t+1$ are as follows:[18]

$$E_t^F \pi_{t+1} = 0, \tag{36}$$

$$E_t^F \hat{Y}_{t+1} = -\left(\frac{\sigma}{\eta+\sigma}\frac{1}{1-\bar{g}}\alpha_t \gamma_1 + \frac{1}{\eta+\sigma}\frac{1}{1-\bar{\tau}}(1-\alpha_t)\gamma_2\right)\max(0, \tilde{b}_{t-1} - \tilde{DT}_{t-1}). \tag{37}$$

Since Fundamentalists make a joint prediction about all variables, the fractions of agents following this heuristic must be based on the relative performance of all predictions that are used by agents to make decisions (i.e. government spending, inflation and output). The most natural fitness measure then would be

$$U_{t-1}^i = -(\tilde{g}_{t-1} - E_{t-2}^i \tilde{g}_{t-1})^2 - (\pi_{t-1} - E_{t-2}^i \pi_{t-1})^2 - (\hat{Y}_{t-1} - E_{t-2}^i \hat{Y}_{t-1})^2, \tag{38}$$

where $i = F, N$. Following the fitness measure above, the fraction of Naive agents evolves as in Brock and Hommes (1997), according to

$$n_t^N = \frac{e^{\omega U_{t-1}^N}}{e^{\omega U_{t-1}^N} + e^{\omega U_{t-1}^F}}, \tag{39}$$

with U_{t-1}^N and U_{t-1}^F given by (38) evaluated at the Naive predictions and Fundamentalist predictions respectively. ω is the intensity of choice parameter that determines how sensitive agents are to past performance of heuristics and how fast they switch between heuristics.

Aggregate expectations about government spending, inflation and output are given by

$$\bar{E}_t \tilde{g}_{t+1} = n_t^N \tilde{g}_{t-1} - (1-n_t^N)\alpha_t \gamma_1 \max(0, \tilde{b}_{t-1} - \tilde{DT}_{t-1}). \tag{40}$$

$$\bar{E}_t \pi_{t+1} = n_t^N \pi_{t-1}, \tag{41}$$

$$\bar{E}_t \hat{Y}_{t+1} = n_t^N \hat{Y}_{t-1} - (1-n_t^N)\left(\frac{\sigma}{\eta+\sigma}\frac{1}{1-\bar{g}}\alpha_t \gamma_1 + \frac{1}{\eta+\sigma}\frac{1}{1-\bar{\tau}}(1-\alpha_t)\gamma_2\right)\max(0, \tilde{b}_{t-1} - \tilde{DT}_{t-1}). \tag{42}$$

Above we assumed that agents know the model equations and that Fundamentalists try to form expectations that are consistent with these equations. This however does not mean that Fundamentalists will always turn out to have better predictions than Naive agents. Due to heterogeneity in expectations formation, the expectations of Fundamentalists will not necessarily come true, even if when debt would remain unchanged. Instead, it is possible that the presence of Naive predictors in combination with shocks to the economy causes completely different dynamics. Naive predictors may then perform better than Fundamentalists. This would cause more Fundamentalists to abandon their model, since this model turned out not to be good enough to make adequate predictions about the actual law of motion of the economy. The fraction of Naive agents would then increase and waves of optimism or pessimism could arise.

3.6. Complete model

Our piecewise linear model is now given by The IS and Phillips curve, (28) and (29); the equations governing expectations, (38)–(42); the monetary and fiscal policy equations equations, (32)–(34); and the evolution of the debt ratio, (30) and (31). A detailed summery of the model equations governing expectations and output and inflation dynamics above and below the debt threshold is presented in Appendix A.3.

4. Consolidations

Suppose that the government lowers the debt threshold. Suppose furthermore that the debt threshold is positive and that the debt ratio is above the threshold.[19] The government will then start planning consolidations proportional to the magnitude of the shock to the debt threshold, either in the form of spending cuts, or in the form of tax increases. If the government announces that it has lowered the debt threshold, then, in the period before the consolidations are implemented, fundamentalists will incorporate the anticipated consolidations into their expectations.

Below, we analyze the dynamics that arise when the upcoming consolidation are anticipated, and how these dynamics depend on the type of consolidation (spending or tax-based), the strength of consolidations, γ_1 and γ_2, and agents' initial beliefs. The latter consists of the fraction of agents that are Naive, n_t^N, and the *initial* probability Fundamentalists place on consolidations being spending-based, which we call α^*.

[18] Full derivation of these expectations are shown in Appendix A.2.

[19] Either because debt was already above the threshold, or because the lowering of the threshold has resulted in debt being above the threshold.

Table 1
Parameter values.

Parameter	Name	Value
β	Discount factor	0.99
σ	Relative risk aversion	2
$\frac{1}{\eta}$	Frisch elasticity of labor supply	0.5
θ	Elasticity of substitution	6
ϕ_π	Coefficient on inflation in Taylor rule	1.5
ω	Intensity of choice	10,000
ϕ	Price adjustment costs	100
$\bar{g}$	Steady state government spending	0.21
$\bar{\tau}$	Steady state taxes	0.26
$\bar{b}$	Steady state debt	0.66
DT_t	Deviation of debt threshold from steady state	0.14

More specifically, the following quantities are affected: the levels of variables in the period where Fundamentalists expect a consolidation, but where it is not yet implemented (Section 4.1); the levels of variables during the implementation of consolidations (Section 4.2); and finally, the existence and stability (largest eigenvalue) of a fixed point above the debt threshold, as well as the debt ratio corresponding to that fixed point (Section 4.3). The first two subsections thus study short run dynamics, while the latter studies medium to long run dynamics. Short run dynamics are affected by initial beliefs (n_t^N and α^*), while the effect of these initial conditions die out in the long run.

4.1. Effects of expected consolidations due to a shock to debt or the debt threshold

If, in period t, a lowering of the debt threshold has led the debt to GDP ratio to be suddenly considerably above this threshold, then in period $t+1$, consolidations are expected by Fundamentalists, but not yet implemented. The actual type of consolidation then does not matter yet, but instead dynamics are driven by the type of consolidation that Fundamentalists expect. Depending on what type Fundamentalists expect, a consolidation can lead to either an expansion or a contraction in output. Furthermore, if the expansion is large enough, expected consolidations lead to a reduction in debt. We formalize this result in Proposition 1.

Proposition 1. *Assume that in period t an announcement of a lowering of the debt threshold is made, and that it holds that $\tilde{b}_t > \tilde{DT}_t$. This shock to the debt threshold affects next period's output (and thereby also inflation and debt) through Fundamentalists' expectations about future government spending and future output. The effect of a lowing of the debt threshold on next period's output is given by*

$$-\frac{\partial \hat{Y}_{t+1}}{\partial \tilde{DT}_t} = (1-n_{t+1}^N)\left(\frac{\eta}{\sigma+\eta}\alpha^*\frac{\gamma_1}{1-\bar{g}} - \frac{1}{\sigma+\eta}\frac{1}{1-\bar{\tau}}(1-\alpha^*)\gamma_2\right). \tag{43}$$

This implies that the effect of expected consolidations on output and inflation is positive, if and only if

$$\alpha^* > \frac{\gamma_2(1-\bar{g})}{\gamma_1(1-\bar{\tau})\eta + \gamma_2(1-\bar{g})}. \tag{44}$$

When this condition does not hold and the expectations lead to a contraction, then expected consolidation results in an increase in debt. When Condition (44) holds, the expected consolidation reduces debt.

Proof. In Appendix B.1. □

It follows from Proposition 1 that it is desirable that agents mainly expect spending-based consolidations. The higher the probability Fundamentalists place on spending-based consolidations, the larger the expansion of output, and the lower the debt to GDP ratio in the period before the consolidation is actually implemented. Throughout the paper we use the parameter values given in Table 1, unless otherwise stated. Under this calibration, anticipated consolidations lead to an expansion in output if Fundamentalists expect consolidations to be spending-based with a probability of at least 56%. Moreover, as can be seen in Eq. (43), when Fundamentalists do mainly expect spending-based consolidations, the expansion in output and the reduction in the debt ratio are increasing in the fraction of Fundamentalists, $1-n_{t+1}^N$.

4.2. Effects of implemented consolidations

If, after one period, debt still is above the debt threshold, the expectational effects analyzed above are still present two periods after the shock. However, additionally there now are direct effects of implemented consolidations on output, inflation and debt. Below we analyze the total effects (including both the expectational and direct effects) of consolidations in the period that they are implemented for the first time, i.e., two periods after the shock. Proposition 2 states that in this period, a tax-based consolidation is always more effective than a spending-based consolidation.

Proposition 2. *For tax-based and spending-based consolidations of equal direct impact on the government budget deficit ($\gamma_1 = \frac{\theta-1}{\theta}\gamma_2$), a tax-based consolidation always results in lower debt than a spending-based consolidation in the first period of implementation. Moreover, the difference on debt on impact, $-\frac{\partial \tilde{b}_{t+2}}{\partial \tilde{DT}_t}$, between spending-based and tax-based consolidations is given by*

$$\gamma_1\left((\bar{\tau}\frac{\theta-1}{\theta}+\frac{\bar{\tau}\frac{\theta-1}{\theta}-\bar{g}}{1-\beta}\kappa)\left(\frac{\theta}{(\theta-1)(1-\bar{\tau})}+\frac{\eta}{1-\bar{g}}\right)+\frac{\bar{\tau}\frac{\theta-1}{\theta}-\bar{g}}{1-\beta}\frac{1}{1-\bar{g}}\right) \tag{45}$$

Proof. In Appendix B.2. □

Expression (45) is always positive, so that, in the period where it is implemented for the first time, the debt ratio falls faster following a tax-based consolidation than a spending-based one. Under the calibration in Table 1, we get that for $\gamma_1 = 0.2$ the difference in the impact on debt between tax-based and spending-based consolidations amounts to 0.11% approximately. Moreover, it can immediately be seen that the difference in the debt ratio is increasing in the magnitude of consolidations, γ_1. We consider such difference as non-negligible. Note furthermore, that the difference in reducing debt under the two types of consolidations does not depend on initial expectations (n_t^N and α^*). The reason for this is that these expectations affect the evolution of variables in the economy equally under both types of *implemented* consolidations.

4.3. Medium and long run dynamics

Above we explicitly analyzed the levels of variables in the first two periods after the debt threshold shock. This gives clear insights in the short run dynamics that result form such a shock. Medium to long run dynamics will be determined by the existence and stability of a fixed point in the high debt region of the model. In this section, we investigate under what conditions this fixed point exists and how its stability is affected by the strength of consolidation, γ_1 and γ_2. One period after the first implementation of consolidations, Fundamentalists have learned the type of consolidation and update their belief to $\alpha_t = 1$ or to $\alpha_t = 0$. For long run dynamics the value of α^* (their initial belief) therefore does not matter. Furthermore, the initial fraction of Naive agents, n_t^N, does not matter either for long run dynamics, because in a fixed point both types of agents will perform equally well, and the fractions will converge to 0.5 each.

4.3.1. Existence high debt fixed point

Proposition 3 states the condition for a fixed point with high debt to exist, in case of spending-based consolidations.

Proposition 3. *When consolidations are spending-based, a fixed point above the debt threshold exists if and only if*

$$\gamma_1 > \frac{1}{\beta} - 1. \tag{46}$$

Proof. In Appendix B.3. □

Proposition 4 states that in case of tax-based consolidations, the condition for existence of the high debt fixed point is the same as in case of spending-based consolidations, but with γ_1 replaced by $\gamma_2\frac{\theta-1}{\theta}$. This is intuitive because if we let $\gamma_1 = \gamma_2\frac{\theta-1}{\theta}$, tax-based and spending-based consolidation are of equal magnitude in their effect on the budget deficit.

Proposition 4. *When consolidations are tax-based, a fixed point above the debt threshold exist if and only if*

$$\gamma_2\frac{\theta-1}{\theta} > \frac{1}{\beta} - 1. \tag{47}$$

Proof. In Appendix B.4. □

We can conclude from Propositions 3 and 4 that when consolidations are strong enough (making fiscal policy "passive" above the debt threshold in the terminology of Leeper, 1991), an extra fixed point exists above the debt threshold, in addition to the fixed point below the debt threshold where all variables are at the steady state levels of Appendix A.1.[20] In this fixed point above the debt threshold taxes or spending are constantly responding to debt. These higher taxes or lower spending are needed to finance the higher interest payments caused by the higher debt ratio that is consistent with the positive debt threshold.

[20] Note that in the fixed point below the debt threshold, where all variables are at the steady state levels of Appendix A.1, both monetary and fiscal policy are "active". This fixed point therefore always is unstable. The high debt fixed point on the other hand, will typically be locally stable, so that the economy can converge to this fixed point. This is shown in Section 4.3.2.

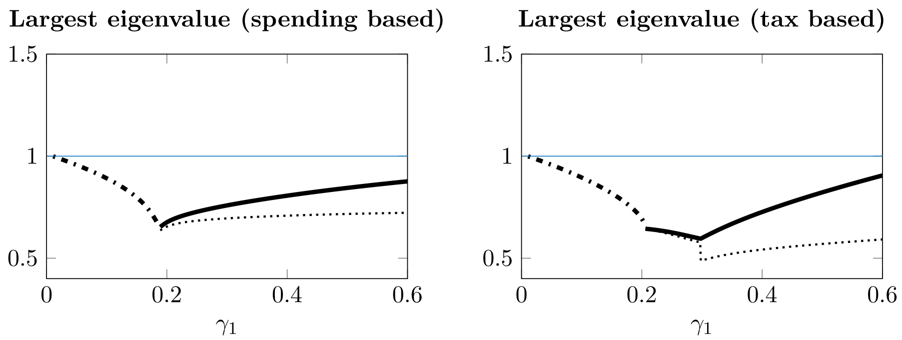

Fig. 1. Absolute values of largest eigenvalue in high debt fixed point for spending and tax-based consolidations. The dashed-dotted segment depicts a real and positive eigenvalue, while a solid segment depicts complex eigenvalues. The real part of the complex eigenvalues is plotted as a dotted curve. In case of tax-based consolidations it holds that $\gamma_2 = \frac{\theta}{\theta-1}\gamma_1$.

4.3.2. Stability of the high debt fixed point

When the fixed point above the debt threshold exists, dynamics in this region of the model are determined by the stability properties of the fixed point. When it is locally stable, convergence to the fixed point may occur, while otherwise debt will move away from the fixed point. Both convergence and divergence can happen monotonically or in an oscillatory fashion, depending on whether the eigenvalues are real and positive, or complex/negative. In order to get insight in dynamics when the debt ratio is above the threshold, we calculate the eigenvalues in the fixed point numerically. For this, we use the parameter values given in Table 1.

In Fig. 1 the absolute value of the largest eigenvalues in the high debt fixed point for spending-based (left panel) and tax-based (right panel) are plotted as a function of $\gamma_1 = \frac{\theta-1}{\theta}\gamma_2$ (the strength of consolidations). In the dashed-dotted part of the curves, the largest eigenvalue is real and positive. From the previous section we know that for very low values of γ_1 and γ_2, the fixed point above the debt threshold does not exist. For this reason we do not plot the largest eigenvalue for $\gamma_1 < \frac{1}{\beta} - 1$. It can be seen in Fig. 1, that under both types of consolidations the largest eigenvalue is real and equal to unity for the lowest allowed value of γ_1. As γ_1 (and γ_2) go up, this real eigenvalue decreases and the fixed point becomes more and more stable, implying faster monotonic convergence to the fixed point. Around $\gamma_1 = 0.2$ the eigenvalues are quite low in absolute value under both spending-based and tax-based consolidations.

In the solid part of the eigenvalue curves, the largest eigenvalues (in absolute value) are complex. Here, the dotted line depicts the real part of these largest eigenvalues. When eigenvalues are complex, cyclical dynamics arise.[21] This implies for our model that when the debt ratio is above the debt threshold, it will first decrease towards the fixed point, and then overshoot this debt ratio level and possibly also the debt threshold. When this happens, consolidations have been successful and no further spending cuts or tax increases are necessary up until the point that the debt ratio increases above the debt threshold again.[22]

In Appendix C.1 we show that the qualitative results from Fig. 1 are robust to the specification of monetary policy, and to the parameterization of price adjustment costs, ϕ. and relative risk aversion, σ.

4.3.3. Debt ratio in the high debt fixed point

When the high debt fixed point is stable, the level of the debt ratio in this fixed point is of crucial importance. When this debt ratio lies very close to the debt threshold, the government might be content with convergence to the fixed point. However, if the debt ratio lies considerably above the threshold, convergence to the fixed point is not desirable.

From the proofs of Propositions 3 and 4 it follows that, when the high debt fixed point exists and is stable, a more aggressive policy (higher γ_1, γ_2) leads to a lower debt ratio in the fixed point. Combining this with the results of the previous section, we can conclude that the government should respond strongly enough to debt. If it responds too weakly, slow monotonic convergence to a debt ratio significantly above the government's threshold will occur.

5. Impulse responses to a debt threshold shock

In this section we analyze the effects of a one time permanent drop to the debt threshold, both in the short run and in the long run, by means of simulated impulse responses. We show the difference between spending-based and tax-based

[21] Gasteiger (2017) using a model with heterogeneous expectations shows that oscillatory dynamics arise as the weight that agents with adaptive expectations attach to past information increases. In his model endogenous persistence increases in this case, which explains the oscillatory dynamics of the model. However, in our model oscillatory dynamics do not arise because of the presence of Naive agents, but instead because of the strength of consolidations.

[22] The time it takes before the debt ratio increases above the threshold again does not depend on the dynamical system analyzed in this section. Instead, it depends on the system in case 1 of Appendix A.3. Here fiscal policy is active (taxes and spending do not respond to debt) and debt will always monotonically increase as long as $\tilde{b}_t > 0$.

consolidations and distinguish between anticipated and unanticipated consolidations (Section 5.1). We also look at how these results depend on whether agents correctly anticipate the composition of the upcoming consolidations (Section 5.2). Finally, in Section 5.3, we study uncertainty about the timing of consolidations.

We compute the impulse responses as follows. We first simulate 100 initial periods, in which the economy converges to its only stable fixed point (see footnote 19 above). That is, after the initialization periods, the economy starts out at the high debt fixed point consistent with the initial value of the debt threshold. We then let the government drop the debt threshold, and plot the paths of our variables towards the new high debt fixed point that corresponds to the permanently lower debt threshold.

In the high debt fixed point, both Fundamentalists and Naive expectations are correct. Given the logistic distribution of the stochastic component in utility (see Eq. (39)), this implies that fractions are equal (i.e. 50–50) in this fixed point. Following a consolidation, the time lag in the performance measure governing the way fractions fluctuate (see Eqs. (38) and (39)) implies that agents realize whether they have been correct in their expectations about macro variables one period after the consolidation is implemented. This implies that under anticipated consolidations, the fractions will only start changing endogenously one period after the consolidations have started. This is our benchmark scenario regarding the way fractions behave and is captured by the black solid lines in all the figures in this section. In order to give more insight in the role of expectations, we also display the impulse responses that arise when we exogenously impose that all agents are Naive at the initial fixed point and the impulse responses where all agents are initially fundamentalists.[23] These cases will be plotted in dashed-dotted red and dashed blue, respectively. Finally, for comparison, in the benchmark cases of Section 5.1 we also plot the responses under rational expectations in green.

5.1. No composition uncertainty

We start with the benchmark cases where consolidations are either always spending-based or always tax-based, and where there is no uncertainty about this composition.

5.1.1. Anticipated consolidations

First, consider the case where the government makes credible announcements about the current debt threshold in every period, so that fundamentalists always see consolations coming. In particular, we calculate impulse responses for the case where the economy starts out at the high debt fixed point corresponding to a debt threshold of 80% of GDP ($\widehat{DT}_t = 0.8 - 0.66 = 0.14$), and where in period 0 the government lowers the debt threshold to 70% of GDP ($\widehat{DT}_t = 0.04$).[24]

Fig. 2 presents impulse responses of correctly anticipated spending-based consolidations. That is, in this figure, the government responds to debt with government spending only, $\zeta = 1$, and when the drop in the debt threshold is announced, Fundamentalists anticipate spending-based consolidations, $\alpha^* = 1$. The reaction coefficient to debt is given by $\gamma_1 = 0.2$. In Appendix C.2, we discuss what happens when the government implements stronger consolidations, and instead sets $\gamma_1 = 0.5$.

First focusing on the benchmark behavioral model we see in the top left panel of Fig. 2 that in period 1, the period that consolidation is expected by Fundamentalists but not yet implemented, an expansion in output occurs (black solid line). This is in line with Proposition 1, since we are considering $\alpha^* = 1$. As can be seen in Eq. (43), the effect of the shock on output in period 1 is scaled by the fraction of Fundamentalists. When all agents are Naive in period 1, nobody expects consolidations to occur in period 2 and output stays unaffected initially (red dash-dotted line). When all agents are initially Fundamentalists (blue dashed line), they all expect consolidations, which results in a larger expansion in output. Under rational expectations (green) output jumps already in period 0, since fully rational agents better take account of the future evolution of debt and government spending than Fundamentalists and hence immediately adjust their expectations when the debt threshold is lowered.

Considering all 15 periods, it is clear that the initial expansion upon anticipating future consolidations plays an important role in determining how deep the recession will be when consolidations are implemented. When everybody is Naive up to period 2, and no initial expansion occurs, output falls to a considerably lower level than in the other cases. In the rational expectation case on the other hand, where output was booming for two periods, the recession is not so deep.[25]

The top right panel shows that the effect on inflation is qualitatively similar to that on output, which also is in line with the theoretical results of Section 4.1. However, under rational expectations, inflation is substantially more volatile than in all cases of our behavioral model. This is because both Naive agents and Fundamentalists initially expect inflation to remain on target.[26] Since actual inflation largely depends on expected inflation, zero expected inflation results in a muted inflation

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[23] Note that since Fundamentalists and Naive agents have the same expectations in the high debt fixed point, exogenously changing the fractions of the two types does not alter aggregate expectations. All other variables therefore remain at their high debt fixed point values when we do this.

[24] Note that $\widehat{DT}_t$ is measured in deviation from the steady state around which the model has been log-linearized. The assumed parametrization results in a steady state debt ratio (and thereby debt threshold) of 0.66.

[25] We also simulated the model for the case where fully rational agents only anticipate upcoming consolidations in period 1. In that case the impulse response of output looks very similar to that of the behavioral models where initially all agents are fundamentalists (dashed blue curve). We can therefore conclude that the milder recession under RE observed in Fig. 2 is largely driven by the extra period of anticipation.

[26] As discussed in Section 3.5, Fundamentalists expect zero inflation because they do not take account of the future evolution of fiscal variables.

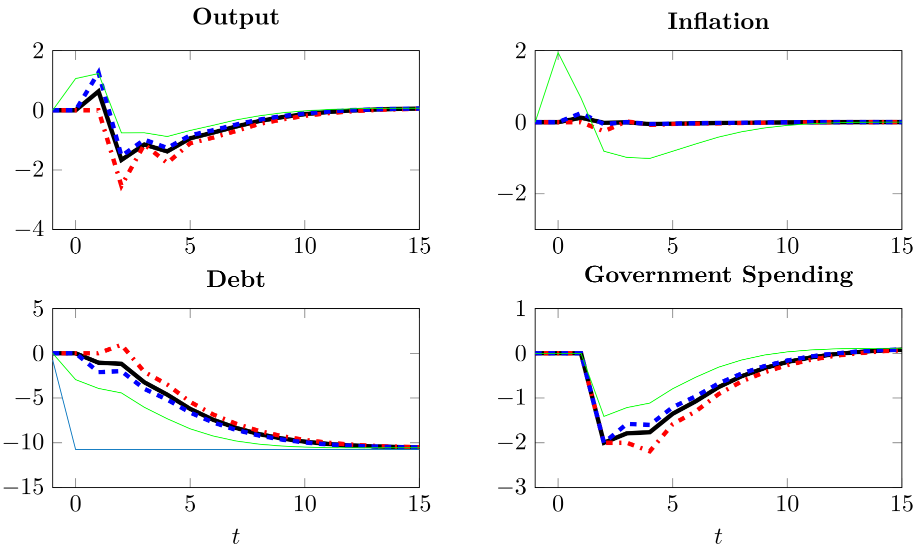

Fig. 2. Impulse responses to debt threshold shock for correctly anticipated spending-based consolidations. The benchmark behavioral model is plotted in black, the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive, and the case of rational expectations is plotted in green. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

response in our behavioral model. Under RE instead, the future debt and spending dynamics that agents account for, reflect on firms' inflation expectations, and thereby on firms' expected marginal costs, resulting in a more volatile response of inflation.

The anticipation-induced expansion in the period before implementation, under RE, in our benchmark case or when all agents are Fundamentalists, leads to a drop in the debt-ratio. This happens even before the government has initiated its spending cuts. In period 2 though, government spending is lowered, which leads to a sharp decline in output in all those three cases, which puts upward pressure on the debt to GDP ratio. Under RE, this pressure is offset by the reduction in debt service costs that follows from the drop in inflation and an active monetary policy. It can therefore be seen in the bottom left panel of Fig. 2, that debt under the green curve keeps falling rapidly. On the other hand, when all agents are initially Naive (red), debt initially rises because of the deeper recession (caused by the lack of an initial boom in output) and because of the more moderate response of inflation. However, as spending is cut even further, the debt ratio starts to drop towards its new fixed point value, also in this case.

From Section 4.3 we know that for spending-based consolidations with moderately low values of γ_1, the largest eigenvalue in the high debt fixed point is real and positive. In the bottom left panel of Fig. 2 we indeed see that debt converges monotonically to its fixed point value in all cases, and that it does not cross the debt threshold. Therefore, even though debt is considerably reduced after 10 quarters, the government will keep responding to debt.

Next, we turn to the case of tax-based consolidations. In Fig. 3 we present impulse responses for the case of $\zeta = \alpha^* = 0$. First, as formalized in Proposition 1, there is now a contraction instead of an expansion in output in period 1 (i.e. before implementation) in our benchmark scenario, in the case where initially all agents are Fundamentalists, and in the RE model. This pushes the debt ratio upward. Secondly, in Period 2, when the tax-based consolidations are implemented, the debt ratio decreases more than under spending-based consolidations, in line with Proposition 2. Again the initial impact on output, owing to anticipation effects, is stronger under RE, and inflation is more volatile in this case.

Contrary to the case of spending-based consolidations, contractions in our behavioral model are milder under tax-based consolidations compared to the RE case. This also allows the debt ratio to fall faster in the behavioral model. The abrupt increase in marginal costs - and hence in inflation - in the RE model causes a strong increase in debt service costs, which amplify contractions and delay the drop of the debt ratio. This makes higher tax hikes necessary and causes the consolidation to last longer.

In order to further explore the effects of the two types of consolidations both in short-run and the longer-run, we compute the impact and the present value output multipliers.[27] The reported multipliers correspond to the parametrization presented in Table 1 and to our benchmark scenario regarding the behavior of fractions of agents in the periods before

[27] We compute the present value fiscal multipliers as in Mountford and Uhlig (2009) and Bi et al. (2013): $\Gamma^y_{t+k} = \sum_{j=0}^{k} \left(\prod_{i=0}^{j} r^{-1}_{t+i}\right) \left(Y^{shock}_{t+j} - Y^{no}_{t+j}\right) / \sum_{j=0}^{k} \left(\prod_{i=0}^{j} r^{-1}_{t+i}\right) \left(x^{shock}_{t+j}\right)$, where r_t is the real interest rate, and x denotes the type of fiscal consolidation: $x_t = \tau_t \bar{H}\bar{w}$ (change in tax income due to tax rate change) for tax-based consolidations and $x_t = -G_t$ for spending-based ones. With our log-linear approximations these multipliers reduce to $\Gamma^y_{t+k} = \sum_{j=0}^{k} \left(\prod_{i=0}^{j} r^{-1}_{t+i}\right) \left(\hat{Y}^{shock}_{t+j}\right) / \sum_{j=0}^{k} \left(\prod_{i=0}^{j} r^{-1}_{t+i}\right) \left(\bar{w}\tilde{\tau}^{shock}_{t+j}\right)$ for tax-based and $\Gamma^y_{t+k} = \sum_{j=0}^{k} \left(\prod_{i=0}^{j} r^{-1}_{t+i}\right) \left(\hat{Y}^{shock}_{t+j}\right) / \sum_{j=0}^{k} \left(\prod_{i=0}^{j} r^{-1}_{t+i}\right) \left(\tilde{g}^{shock}_{t+j} + \bar{g}\hat{Y}^{shock}_{t+j}\right)$ for spending-based consolidations.

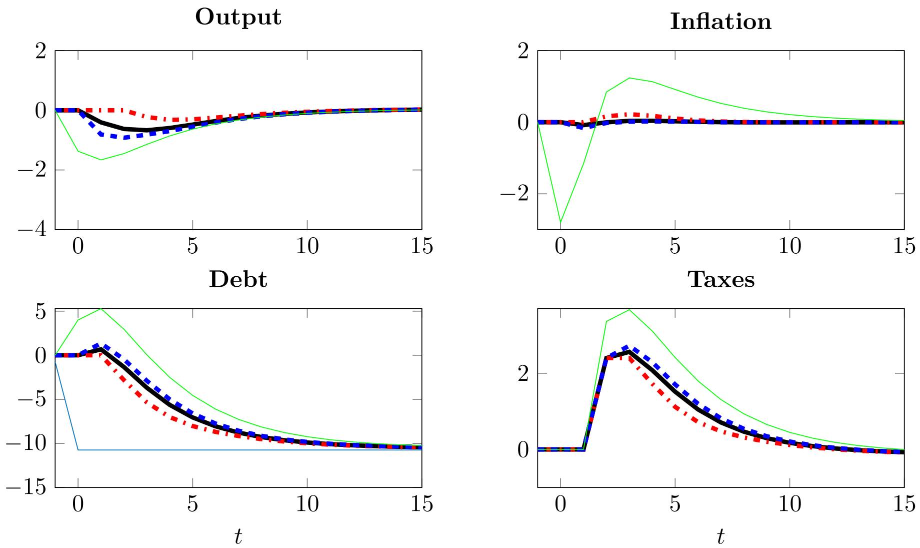

Fig. 3. Impulse responses to debt threshold shock for correctly anticipated tax-based consolidations. The benchmark behavioral model is plotted in black, the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive, and the case of rational expectations is plotted in green. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Output multipliers for benchmark behavioral model.

Panel (a): no composition uncertainty					
		1qr	4qr	8qr	12qr
$\frac{\Delta Y}{\Delta G}$	Anticipated	−0.71	−0.64	−0.63	−0.63
	Unanticipated	−1.00	−0.78	−0.74	−0.73
$\frac{\Delta Y}{\Delta \tau}$	Anticipated	−0.31	−0.33	−0.36	−0.36
	Unanticipated	0	−0.16	−0.21	−0.22
Panel (b): composition change					
		1qr	4qr	8qr	12qr
$\frac{\Delta Y}{\Delta G}$	Anticipated	−1.17	−0.73	−0.68	−0.66
	Unanticipated	−1.00	−0.77	−0.71	−0.68
$\frac{\Delta Y}{\Delta \tau}$	Anticipated	0.49	0.58	0.62	0.56
	Unanticipated	0.09	−0.08	−0.12	−0.10

Table 3
Output multipliers for rational expectations model with no composition uncertainty.

		1qr	4qr	8qr	12qr
$\frac{\Delta Y}{\Delta G}$	Anticipated	−0.49	−0.56	−0.63	−0.64
	Unanticipated	−0.41	−0.54	−0.61	−0.62
$\frac{\Delta Y}{\Delta \tau}$	Anticipated	−0.51	−0.38	−0.37	−0.38
	Unanticipated	−0.46	−0.38	−0.37	−0.38

implementation. Looking at anticipated consolidations in panel (a) of Table 2, it is clear that spending-based consolidations cause deeper and more persistent recessions in our behavioral model. In Table 3 it can further be seen that in the long run the same holds under rational expectations, but that the impact multiplier under tax-based consolidations is more negative than the impact multiplier under spending-based consolidations in that case.

5.1.2. Unanticipated consolidations

Let us now consider the case of *unanticipated* consolidations. This will help highlight the anticipation effects of the previous subsection. We model unanticipated consolidations by a drop in the debt threshold that is not only unanticipated, but also unannounced. More specifically, we let our model again start in the high debt fixed point and let the government lower its debt threshold from 80% of GDP to 70% of GDP in period 0. However, the lowering of the debt threshold is not

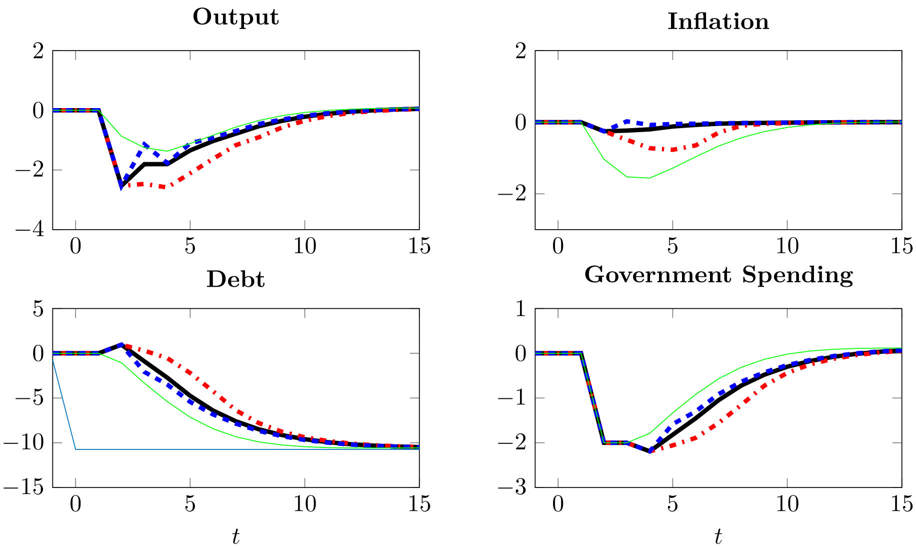

Fig. 4. Impulse responses to debt threshold shock for unanticipated spending-based consolidations. The benchmark behavioral model is plotted in black, the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive, and the case of rational expectations is plotted in green. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

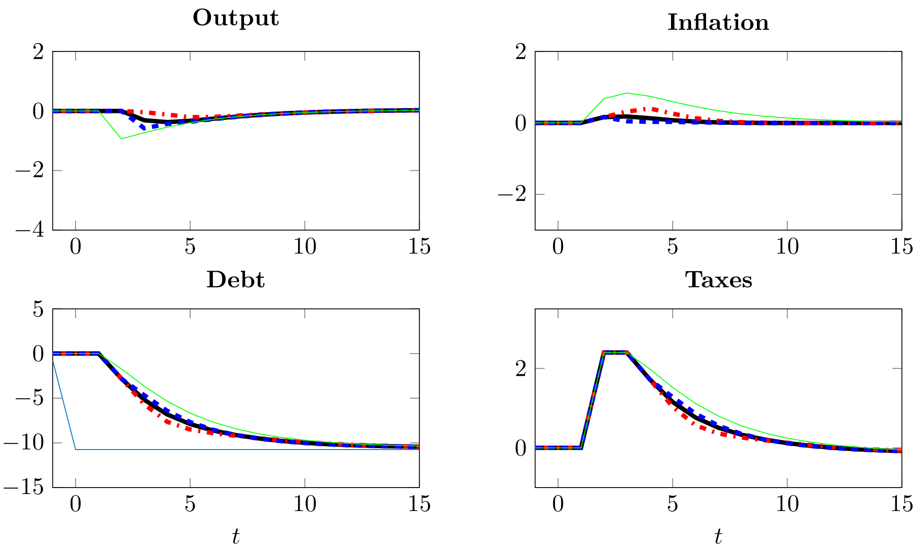

Fig. 5. Impulse responses to debt threshold shock for unanticipated tax-based consolidations. The benchmark behavioral model is plotted in black, the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive, and the case of rational expectations is plotted in green. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

announced, so that fundamentalists only become aware of the lower debt threshold after consolidations are implemented in period 2.

In Figs. 4 and 5 we plot impulse responses of unanticipated spending-based and tax-based consolidations, respectively. It can be seen here, that since consolidations are unanticipated, the anticipation affects described in Proposition 1, are absent. Instead, the model remains at the high debt fixed point corresponding to the old debt threshold in period 1. In period 2, consolidations are implemented, but still not expected, so that all variables initially follow the paths of the red dashed lines in Figs. 2 and 3 that correspond to all naive initial expectations.

In the next periods, both Fundamentalists and Naive agents start adjusting their expectations. The impulse responses then depend on the fraction of Naive agents in the economy as can be seen by comparing the red, black, and blue curves of the behavioral model. Note that since under unanticipated consolidations the economy is shocked in period 2, rather than period 0, we correspondingly adjust the periods for which we exogenously fix the fractions at all Naive or all Fundamentalist to obtain the dashed-dotted red and dashed blue curves.

First, consider the case of spending-based consolidations (Fig. 4). Here, our Benchmark case (black), and the case where initially all agents are Fundamentalists (dashed blue) closely follow the case where fundamentalists would have anticipated consolidations, but where all agents where naive in the two periods following the announcement (dashed-dotted red curves in Fig. 2). However, when all agents are Naive during the initial periods of consolidations (dashed-dotted red curves), an even larger wave of pessimism in output arises, that causes slower debt reduction. Finally, considering the green curves of rational expectations, it can be seen that output falls much less in the initial period of consolidation. This is because rational agents realize already in this period that the debt threshold must have dropped, and adjust their expectations and consumption accordingly. However, in the next period their consumption is very close to that of fundamentalists (dashed blue) who then also anticipate consolidations to continue. The more moderate initial recession under rational expectations has however led to a reduction rather than an increase in debt in period 2, so that in later periods smaller spending cuts are required.

Comparing the multipliers for the case of unanticipated consolidations with the case of anticipated spending-based consolidation in panel (a) in Table 2, it is clear that when spending cuts are not anticipated the contraction in output is deeper. This delays the drop in the debt ratio which makes further spending cuts necessary and increases pessimism in the economy.

Next we turn to tax-based consolidations (Fig. 5). In the first period of consolidations (period 2), again only agents with rational expectations (green) change their expectations and consumption, while output remains at its fixed point level for one more period in our boundedly rational model, where agents do not realize the debt threshold has dropped yet.[28] In later periods, the severity of the recession and the rise in inflation again depends on the initial fractions of Naive agents and Fundamentalists. In general however, unanticipated tax-based consolidations imply a less severe recession and faster debt reduction than the anticipated ones in Fig. 3.

Contrary to the case of spending-based consolidations, our results therefore show that unanticipated tax-based consolidations are preferable to anticipated ones. This is also reflected in the multipliers in panel (a) in Table 2. Here it can be seen the induced contraction in output after unexpected tax hikes is smaller than the contraction under anticipated tax hikes. The intuition is that when tax hikes are not expected, agents do not decrease their labor supply neither before, nor upon implementation. The same holds for their consumption. In the following periods the existence of Naive agents leads to a muted decrease in labor supply and in consumption. Consequently, the induced contraction is milder than under anticipated tax hikes, which allows for a faster drop in the debt ratio and, ultimately, for shorter consolidations.

The above is in line with the result of Proposition 1 that anticipated spending-based consolidations positively affect output and help to reduce debt, while anticipated tax-based consolidations do the opposite. Looking at anticipated and unanticipated consolidations under rational expectations, in Table 3, it can be seen that for tax-based consolidations, the anticipation effect only matters for the impact multiplier, and that for spending-based consolidations anticipation effects actually imply slightly more negative multipliers. The more moderate recession under rational expectations observed in Fig. 3 is therefore due to the fact that the reduction in debt during the anticipation periods implies lower future spending cuts, and not because the multipliers were positively affected by the anticipation of consolidations.

5.2. Composition surprise

In this subsection we investigate the effect of uncertainty about the composition of consolidations. We do this by calculating impulse responses for the case where, as in Section 5.1, the debt threshold is dropped 2 periods before the consolidation, but where the composition of the consolidation, ζ, is changed in the period where the consolidation first starts. As described in Section 3.3, the change in the composition is not announced and comes as a surprise to all agents in the economy.

5.2.1. Anticipated consolidations

We first study surprise changes in the composition of consolidations in the case of anticipated consolidations. That is, Fundamentalists know that the debt threshold has dropped, and that consolidations will be implemented, but they turn out to be wrong about the composition they expect the consolidation to have. In particular, we first let the economy start out in the high debt fixed point where taxes are the main instrument of the government ($\zeta = 0$). In period 0 it announces that it will drop the debt threshold from 80% to 70% of GDP, and that in two periods from now the consolidation will be tax-based. However, in period 2, where consolidations are implemented for the first time, the government suddenly changes the composition to $\zeta = 1$, and actually implements spending-based consolidations. The impulse responses are displayed in Fig. 6. Second, we perform the same exercise but now assuming that spending was initially the main instrument. In

[28] Note that the result that output does not change as unexpected tax hikes are implemented for the first time depends on the specification of the interest rate rule. As a robustness check, we have also simulated our model with a contemporaneous Taylor rule, where the nominal interest rate responds to contemporaneous inflation. In that case the increase in inflation caused by the tax increase results in an increase in the nominal interest rate and hence in an immediate drop in output. Because of the moderate response of inflation in our behavioral model, this effect is however not very large. Furthermore,

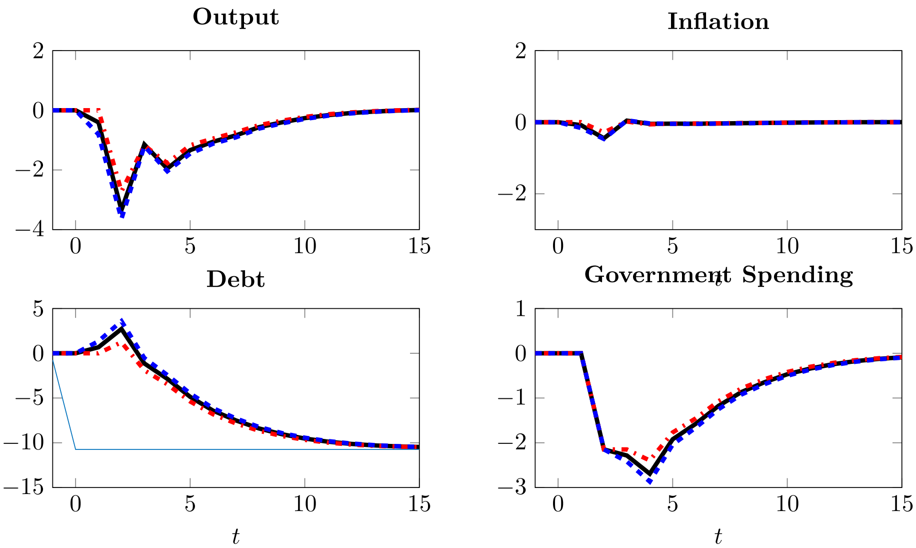

Fig. 6. Impulse responses to debt threshold shock for spending-based consolidations that were anticipated to be tax-based ($\alpha^* = 0$). The benchmark behavioral model is plotted in black, and the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

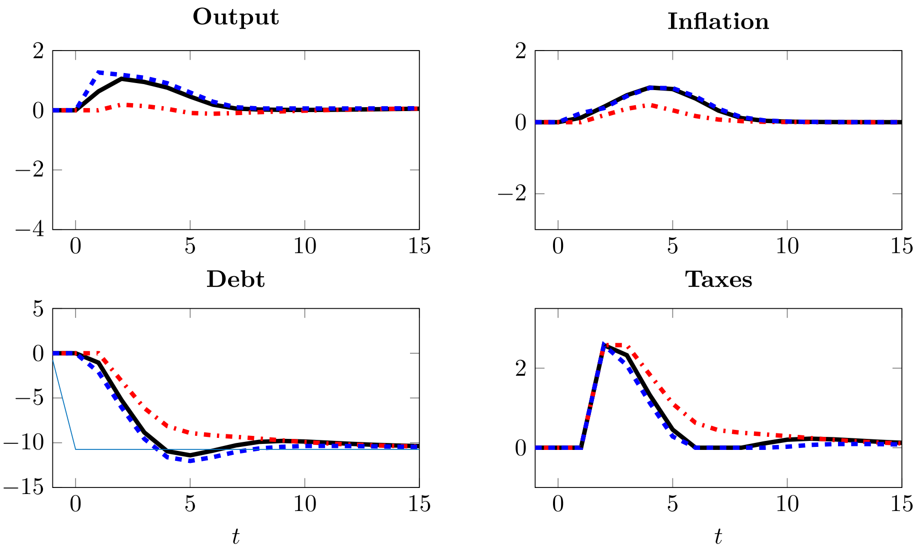

Fig. 7. Impulse responses to debt threshold shock for tax-based consolidations that were anticipated to be spending-based ($\alpha^* = 1$). The benchmark behavioral model is plotted in black, and the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

this case, Fundamentalists anticipated consolidations to be spending-based, but when the implementation day arrives, the government surprises agents in the economy by increasing taxes instead. The impulse responses are plotted in Fig. 7.

Let us now compare the differences between the case where agents turn out to have anticipated correctly the composition of the consolidation with the case where they have anticipated wrongly the nature of the upcoming consolidation. Take the case where agents anticipate spending-based consolidations and where the government then either implements spending-based consolidations (Fig. 2) or instead implements tax-based consolidations (Fig. 7). In period 1, no consolidations are implemented yet, but Fundamentalists expect spending-based consolidation both in Fig. 2 and in Fig. 7. During the anticipation period (i.e. period 1, before implementation) the dynamics are thus the same. Comparing the dy-

as in later periods inflation expectations become aligned with actual inflation because of the presence of Naive agents, the differences between the forward-looking and contemporaneous Taylor rule start to disappear.

namics in period 2, we see that when the consolidation is implemented, debt is reduced by more in Fig. 7. This is in line with Proposition 2, which says that for a given α^*, *initially*, tax-based consolidations always lead to lower debt than spending-based consolidations. The same intuition carries when agents always anticipate tax hikes. This is illustrated in Figs. 3 and 6.

We further observe that when the government implements spending-based consolidations while agents were expecting tax-based consolidations (Fig. 6) a severe recession arises (that is deeper then when agents would have expected spending-based consolidations). This is so because when Fundamentalists turn out to be wrong about the consolidations that they were expecting, more agents switch to the naive rule, coordinating on a wave of pessimism. On the other hand, when the government implements tax-based consolidations while agents were expecting spending-based consolidations (Fig. 7), a boom in output arises that causes fast debt reduction. Wrong beliefs in this case create optimism in the economy after implementation and lead to an increase in the tax base. As a, result debt drops faster and consolidations last for less periods. Therefore, temporary output gains can arise if the government temporarily surprises agents by raising taxes instead of cutting spending. However, it is important to note that such policy may come at a cost if the government consistently deviates from its previous announcements, and thereby harms its credibility.

Looking at the multipliers of anticipated consolidations with composition change in panel (b) of Table 2, we see that spending-based consolidations, when Fundamentalists anticipate tax hikes instead, are more contractionary than in the case where they correctly anticipate spending cuts (panel (a)). Looking at tax-based consolidations when Fundamentalists anticipate spending cuts, the multipliers indicate that in this case consolidations are in fact expansionary, as also observed in Fig. 7.

5.2.2. Unanticipated consolidations

Just as in the case of no composition uncertainty, graphs of unanticipated consolidations look similar to those of anticipated consolidations where initially all agents were naive (dashed-dotted red curves in Figs. 6 and 7). For the sake of brevity we therefore do not plot these graphs, but instead comment on the multipliers of unanticipated consolidations in case of a composition surprise, presented in panel (b) of Table 2. Comparing these multipliers with the multipliers obtained with no composition change, in panel (a), we see that multipliers are much less affected by the composition change than in case of anticipated consolidators. This confirms the discussion above, that the changes in multipliers under anticipated consolidations with composition surprises mainly come from anticipation effects and subsequent waves of optimism and pessimism, and not so much from the composition change itself.

5.3. Uncertainty about timing of consolidation

In the previous sections, we assumed that consolidations were either anticipated by fundamentalists or unanticipated. In this section, we study the in between case, where the government is not perfectly transparent about its current debt threshold, but where Fundamentalists are aware that the government is considering to drop the debt threshold either in the current period or in the near future. This can be thought of as speculation in the media that the debt ratio is too high and consolidations are necessary, but where it is not clear exactly when the government will start these consolidations.

In particular, we model the case where Fundamentalists believe from period 1 onward that the debt threshold might have dropped in the previous period with a 50% probability. That is, they put 50% weight on the possibility that everything remains as it was before, and 50% weight on the possibility that consolidations will start tomorrow. However, consolidations only actually start in period 5 (i.e. the debt limit dropped in period 3).

In Fig. 8 we plot the case of spending-based consolidations. Comparing this figure with Fig. 2 we see that the initial anticipation effects in period 1 are milder. This is because fundamentalists now expect consolidations only with a 50% probability rather than with certainty. However, the initial boom in output slowly grows larger as Fundamentalists keep expecting consolidations that are still not implemented. Additionally, so long as consolidations are postponed further, fundamentalists are wrong in their expectations. Hence, more and more agents become Naive and thus optimistic about output. This rise in output leads the debt to GDP ratio to keep going down, and even fall below the debt threshold. For this reason, government spending is increased rather than decreased in period 3 and 4, amplifying the rise in output.

Looking at tax-based consolidations in Fig. 9, it can be seen that timing uncertainty regarding their implementation causes a persistent contraction in output in the periods before the consolidations are in fact implemented. This is for reasons mentioned in the sections above and which relate to a decrease in the consumption of Fundamentalists. As Fundamentalists continue to be wrong about the implementation of consolidations, the fraction of Naive agents increases and thereby pessimism in the economy. As a consequence, the debt to GDP ratio rises during the periods of anticipation.

In Table 4, we present the present value multipliers corresponding to Figs. 8 and 9. Comparing these with the multiplier of correctly anticipated consolidations in panel (a) of Table 2, we see that multipliers in case of spending-based consolidations become more negative under timing uncertainty. However, as mentioned above, smaller spending cuts are needed because of the initial fall in debt caused by the expansion in output due to the anticipation effects in the periods prior to implementation. In case of tax-based consolidations, it can be seen that multipliers become more negative as well under timing-uncertainty. This is because of the adverse effects that the longer lasting anticipation has on confidence in the economy. Moreover, under tax-based consolidations the anticipation of tax-hikes with uncertainty about the timing of implementation lead to a persistent recessions in the periods before implementation. This persistent recession puts upward

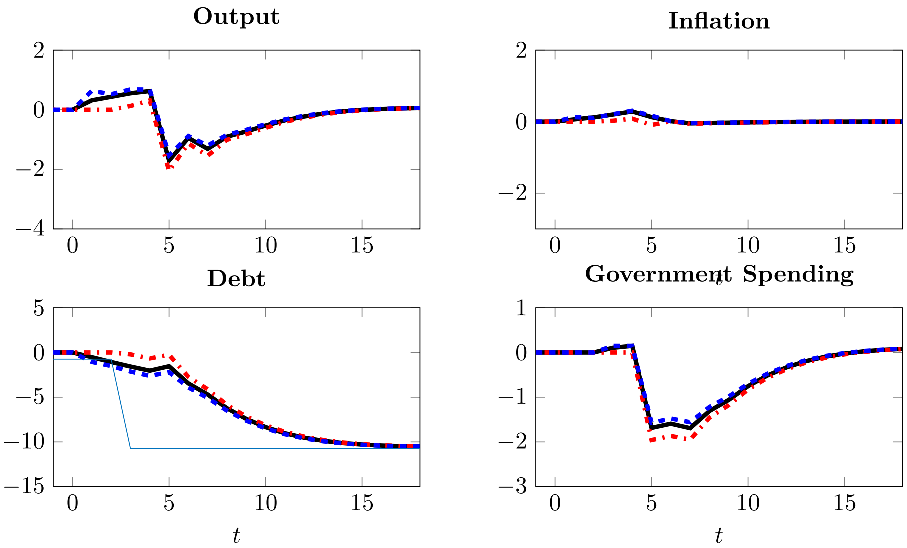

Fig. 8. Impulse responses to debt threshold shock for correctly anticipated spending-based consolidations. In the figure $\gamma_1 = 0.5$ instead of 0.2. The benchmark behavioral model is plotted in black, and the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

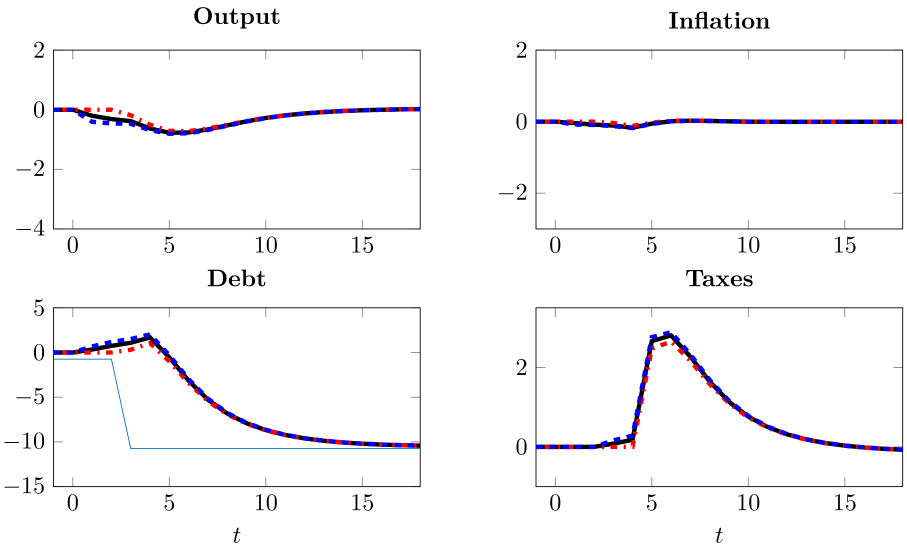

Fig. 9. Impulse responses to debt threshold shock for correctly anticipated strong tax-based consolidations. In the figure $\gamma_1 = 0.5$ instead of 0.2. The benchmark behavioral model is plotted in black, and the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
Output multipliers in case of uncertainty about the time of implementation of consolidations. From period 1 onwards fundamentalists expect that the debt threshold might have been dropped in the previous period with a 50% probability, while the actual drop only takes place in period 3.

	1qr	4qr	8qr	12qr
$\frac{\Delta Y}{\Delta G}$	−0.83	−0.67	−0.65	−0.65
$\frac{\Delta Y}{\Delta \tau}$	−0.35	−0.35	−0.37	−0.37

pressures on the debt-ratio necessitating bigger tax hikes than when agents are certain about the timing of implementation. Therefore, we conclude that timing uncertainty can be beneficial in case of anticipated spending-based consolidations, while timing uncertainty harms the economy in case of anticipated tax-based consolidations.

6. Spending-based vs tax-based consolidations: discussion

The impulse response analysis discussed in the sections above shows that, in our behavioral model, tax-based consolidations lead to milder contractions than spending-based consolidations. This is a robust result holding regardless whether consolidations are anticipated or not, or whether agents are certain about the timing and composition of an imminent consolidation or not. As argued above, spending-based consolidations lead to deeper and more persistent recessions and as such they tend to last longer. Under rational expectations though, tax-based consolidations cause deeper recessions on impact than spending-based ones.

In our behavioral model, the milder contractions under tax-based consolidations are mainly due to the bounded rationality of and heterogeneity in expectations, and their implications for each type's consumption and labor supply decisions (due to distortionary taxes). When the government increases taxes, Naive agents do not necessarily decrease their consumption as Fundamentalists do, nor do they decrease their labor supply. They will only do so to the extent that they are already observing a drop in output. Hence naive agents will not initiate the recession. If all agents are Fundamentalists when consolidations are implemented, a cut in consumption and labor does occur. However, since Fundamentalists are also boundedly rational and do not fully account for the future paths of debt and taxes and corresponding wealth effects, they also do not decrease their consumption by as much as fully rational agents would.[29] Given that in our behavioral model the initial contraction in output is milder, the tax base is not decreased substantially. This implies faster debt reduction and a quicker reversal (drop) in taxes. This allows for an increase in consumption and a faster recovery.

Under anticipated spending-based consolidations instead, the spending cuts lead to an immediate drop in output upon implementation that is only to a small extent offset by an increase in consumption. This is again first of all because naive agents do not respond at all initially, and secondly, because Fundamentalists do not fully take account of the future paths of fiscal variables either. The existence of Naive agents, who expect output to stay low, furthermore increases pessimism in the economy slowing down the recovery and forcing consolidations to last longer. Moreover, inflation and expected inflation remain relatively close to zero given that both types have initially been expecting zero inflation. This means that the real interest rate does not fall as much in response to the spending cuts as it would have with fully rational agents. Consequently, this channel does not significantly induce agents to increase their consumption, and pessimism in output remains. This causes the debt ratio to fall at a slower pace than under tax-based consolidations.

7. Conclusions

In this paper we have explored the effects of fiscal consolidations when agents are boundedly rational an have heterogeneous expectations in the spirit of Brock and Hommes (1997). Agents can switch between two types, namely, the Fundamentalist and the Naive. The former type consisted of forward looking agents that trust the commitments of the government, whereas the latter consisted of backward looking agents.

The fiscal authority was assumed to engineer a consolidation once the debt ratio exceeds an announced debt threshold, with a lag. Consolidations were implemented either through spending cuts or tax increases. We have explored what happens when prior to the consolidation, agents were uncertain or wrong about the timing and composition of the consolidations.

Our first finding was that in our behavioral model tax-based consolidations generally outperform spending-based ones. We showed that the type of consolidation that was anticipated was crucial in determining whether the consolidation would trigger expansions or abrupt contractions in output so long as it lasts. Moreover, whether the type of consolidation anticipated was correct or not, determined its duration. Consolidations last longer when agents wrongly anticipate them to be tax-based, but they turn out to be spending-based. This is due to the persistent contraction in output triggered by the implemented spending cuts and expected tax hikes and a subsequent wave of pessimism. On the contrary, when agents expect spending cuts but the government implements tax increases, a wave of optimism can arise that results in a boom in output that persists even during the periods of higher taxes.

The model was complex in its dynamics and we kept the analysis as simple as possible. Cases like the effect of the zero lower bound on the potential of a consolidation to be expansionary and/or successful in stabilizing debt, in a heterogeneous agents model, deserve further research.

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[29] In the literature, there is evidence in favor of agents' myopic behavior and against the permanent income hypothesis, implying that agents discount a lot their future wealth while placing higher weight on the fluctuations of their current disposable income. Galí et al. (2007) construct a New-Keynesian model with forward-looking and rule-of-thumb households, where the latter type of agents decides upon its consumption on the basis of their current disposable income only, since it is excluded from financial markets. They test the empirical validity of this assumption and find supporting evidence. Along the same lines (Parker, 1999) finds evidence of a high sensitivity of consumption to variations in after-tax income due to anticipated changes in social security taxes, while Souleles (1999) finds evidence of excess sensitivity of households' consumption to predictable tax refunds. Finally, Campbell and Mankiw (1989) reject the permanent income hypothesis in favor of a model with borrowing constraints or myopic behavior.

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Appendix A. Model

A.1. Zero inflation steady state

In this section, we derive the steady state of the non-linear model, where gross inflation equals 1, and where we normalize technology to $A = 1$.

Evaluating (14) at the zero inflation steady state gives

$$\bar{mc} = \frac{\theta - 1}{\theta}. \tag{A.1}$$

From (7) it follows that in this steady state we must have

$$1 + \bar{i} = \frac{1}{\beta}. \tag{A.2}$$

Furthermore, from (10) it follows that

$$\bar{H} = \bar{Y}. \tag{A.3}$$

Next, we solve the steady state aggregate resource constraint, (19), for consumption, and write

$$\bar{C} = \bar{Y}(1 - \bar{g}). \tag{A.4}$$

Plugging in these steady state labor and consumption levels in the steady state version of (8) gives

$$\bar{w} = \frac{\bar{Y}^{\eta}(\bar{Y}(1 - \bar{g}))^{\sigma}}{1 - \bar{\tau}} = \frac{\bar{Y}^{\eta+\sigma}(1 - \bar{g})^{\sigma}}{1 - \bar{\tau}} = \frac{\theta - 1}{\theta}, \tag{A.5}$$

where the last equality follows from the fact that $\bar{w} = \bar{mc}$ and from (A.1). We can thus write

$$\bar{Y} = \left(\frac{\theta - 1}{\theta}\frac{1 - \bar{\tau}}{(1 - \bar{g})^{\sigma}}\right)^{\frac{1}{\eta+\sigma}}. \tag{A.6}$$

Then we turn to the government budget constraint. In steady state (16) reduces to

$$\bar{b} = \bar{g} - \bar{\tau}\frac{\theta - 1}{\theta} + (1 + \bar{i})\bar{b}, \tag{A.7}$$

which gives

$$\bar{b} = \beta\frac{(\bar{\tau}\frac{\theta-1}{\theta} - \bar{g})}{1 - \beta}, \tag{A.8}$$

where we used (A.2) to substitute for the interest rate.

Steady state government spending and taxes are given by

$$\bar{g} = g_1 - \zeta\gamma_1 \max(0, \bar{b} - \bar{DT}), \tag{A.9}$$

and

$$\bar{\tau} = \tau_1 + (1 - \zeta)\gamma_2 \max(0, \bar{b} - \bar{DT}). \tag{A.10}$$

Assuming that the steady state debt threshold equals steady state debt, this reduces to

$$\bar{g} = g_1, \tag{A.11}$$

and

$$\bar{\tau} = \tau_1. \tag{A.12}$$

A.2. Fundamentalists' expectations about output and inflation

Fundamentalists form expectations by making the approximation that debt stays constant over time. When all agents form expectations in the same way as Fundamentalists, then constant debt implies that all variables remain constant. Fundamentalists use the Phillips curve and IS curve and monetary and fiscal policy rules to calculate the values of inflation and output that are consistent with any given level of debt. From (34) it follows that when all variables remain constant over time, we must have

$$i = \phi_\pi \pi. \tag{A.13}$$

Furthermore, (28) then reduces to

$$Y = Y - \frac{1}{\sigma}(i - \pi) - \frac{1}{1-\bar{g}}(g - g), \tag{A.14}$$

from which it follows that

$$\pi = i. \tag{A.15}$$

(A.13) and (A.15) can only both hold (assuming $\phi_\pi \neq 1$) if

$$\pi = i = 0. \tag{A.16}$$

Therefore, Fundamentalists inflation expectations satisfy $E_t^f \pi_{t+1} = 0$. Using this in (29), it follows that

$$0 = \kappa(\sigma + \eta)Y - \sigma\kappa\frac{g}{1-\bar{g}} + \kappa\frac{\tau}{1-\bar{\tau}}. \tag{A.17}$$

Output expectations of Fundamentalists therefore satisfy

$$E_t^F \hat{Y}_{t+1} = \frac{\sigma}{\sigma+\eta}\frac{g}{1-\bar{g}} - \frac{1}{\sigma+\eta}\frac{\tau}{1-\bar{\tau}}. \tag{A.18}$$

Using Fundamentalists perception of the fiscal rules (Eq. (35) for government spending and a similar expression for taxes), we arrive at

$$E_t^F \hat{Y}_{t+1} = -\left(\frac{\sigma}{\eta+\sigma}\frac{1}{1-\bar{g}}\alpha_t\gamma_1 + \frac{1}{\eta+\sigma}\frac{1}{1-\bar{\tau}}(1-\alpha_t)\gamma_2\right)\max(0, \tilde{b}_{t-1} - \tilde{DT}_{t-1}). \tag{A.19}$$

A.3. Model summary

Our system is piece-wise linear. The equation for inflation and output depend on the level of the debt to GDP ratio in the last two periods, even though the debt ratio does not show up in the equations explicitly. Below we give a summary of the equations governing inflation and output in the four regions of our model.

1. When debt is low ($\tilde{b}_{t-2} < \tilde{DT}_{t-2}$ and $\tilde{b}_{t-1} < \tilde{DT}_{t-1}$) we obtain, by plugging in monetary and fiscal policy in (28) and (29), the following system for inflation and output

$$\hat{Y}_t = \bar{E}_t[\hat{Y}_{t+1}] - \frac{\phi_\pi - 1}{\sigma}\bar{E}_t[\pi_{t+1}] - \frac{1}{1-\bar{g}}\bar{E}_t[\tilde{g}_{t+1}], \tag{A.20}$$

$$\pi_t = \beta\bar{E}_t[\pi_{t+1}] + \kappa(\sigma+\eta)\hat{Y}_t. \tag{A.21}$$

In this region of low debt, Fundamentalists expect all variables to be at their steady state value of 0, so that aggregate expectations are given by

$$\bar{E}_t\tilde{g}_{t+1} = n_t^N\tilde{g}_{t-1}, \tag{A.22}$$

$$\bar{E}_t\pi_{t+1} = n_t^N\pi_{t-1}, \tag{A.23}$$

$$\bar{E}_t\hat{Y}_{t+1} = n_t^N\hat{Y}_{t-1}. \tag{A.24}$$

2. When debt has just crossed the critical boundary, but consolidation is not yet implemented ($\tilde{b}_{t-2} < \tilde{DT}_{t-2}$, but $\tilde{b}_{t-1} > \tilde{DT}_{t-1}$), then (A.20), (A.21) and (A.23) still hold, while for aggregate government spending expectations we then have

$$\bar{E}_t\tilde{g}_{t+1} = n_t^N\tilde{g}_{t-1} - (1-n_t^N)\alpha_t\gamma_1(\tilde{b}_{t-1} - \tilde{DT}_{t-1}). \tag{A.25}$$

This is because Fundamentalists expect a consolidation to start in the next period. As regards aggregate expectations about output, they are formed as follows

$$\bar{E}_tY_{t+1} = n_t^NY_{t-1} - (1-n_t^N)\frac{1}{\sigma+\eta}\left(\frac{\sigma}{1-\bar{g}}\alpha_t\gamma_1 + \frac{1}{1-\bar{\tau}}(1-\alpha_t)\gamma_2\right)(\tilde{b}_{t-1} - \tilde{DT}_{t-1}). \tag{A.26}$$

3. When both $\tilde{b}_{t-2} > \tilde{DT}_{t-2}$ and $\tilde{b}_{t-1} > \hat{DL}_{t-1}$ expectations are again given by (A.23), (A.25) and (A.26), respectively. However, current output and inflation are now equal to

$$\hat{Y}_t = \bar{E}_t[\hat{Y}_{t+1}] - \frac{\phi_\pi - 1}{\sigma}\bar{E}_t[\pi_{t+1}] - \frac{1}{1-\bar{g}}\Big(\bar{E}_t[\tilde{g}_{t+1}] + \zeta\gamma_1(\tilde{b}_{t-2} - \tilde{DT}_{t-2})\Big), \tag{A.27}$$

$$\pi_t = \beta\bar{E}_t[\pi_{t+1}] + \kappa(\sigma+\eta)\hat{Y}_t + \kappa\left(\zeta\frac{\sigma\gamma_1}{1-\bar{g}} + (1-\zeta)\frac{\gamma_2}{1-\bar{\tau}}\right)(\tilde{b}_{t-2} - \tilde{DT}_{t-2}). \tag{A.28}$$

4. At some point, the consolidation has worked through, and the debt to GDP ratio falls again below the critical threshold. One period later, a consolidation is no longer expected for the future, but still implemented in the current period (since $\tilde{b}_{t-2} > DT_{t-2}$ but $\tilde{b}_{t-1} < DT_{t-1}$). In that case, expectations are given by (A.22), (A.23) and (A.24), while current output and inflation are given by (A.27) and (A.28).

Appendix B. Proofs of propositions

B.1. Proof Proposition 1

Leading (A.25) one period, it follows that

$$-\frac{\partial\bar{E}_{t+1}\tilde{g}_{t+2}}{\partial\tilde{DT}_t} = -(1-n^N_{t+1})\alpha^*\gamma_1. \tag{B.1}$$

Similarly it follows from (A.26) that

$$-\frac{\partial\bar{E}_{t+1}\hat{Y}_{t+2}}{\partial\tilde{DT}_t} = -(1-n^N_{t+1})\frac{1}{\sigma+\eta}\left(\frac{\sigma}{1-\bar{g}}\alpha^*\gamma_1 + \frac{1}{1-\bar{\tau}}(1-\alpha^*)\gamma_2\right) < 0. \tag{B.2}$$

Meanwhile, leading (A.20) one period, we obtain

$$\begin{aligned}-\frac{\partial\hat{Y}_{t+1}}{\partial\tilde{DT}_t} &= -\left(\frac{\partial\bar{E}_{t+1}\hat{Y}_{t+2}}{\partial\tilde{DT}_t} - \frac{1}{1-\bar{g}}\frac{\partial\bar{E}_{t+1}\tilde{g}_{t+2}}{\partial\tilde{DT}_t}\right)\\ &= (1-n^N_{t+1})\left(\frac{\eta}{\sigma+\eta}\alpha^*\frac{\gamma_1}{1-\bar{g}} - \frac{1}{\sigma+\eta}\frac{1}{1-\bar{\tau}}(1-\alpha^*)\gamma_2\right).\end{aligned} \tag{B.3}$$

It follows that the effect of a lowering of the debt threshold on next periods output is positive, if and only if

$$\eta\alpha^*\gamma_1\frac{1}{1-\bar{g}} > \frac{1}{1-\bar{\tau}}(1-\alpha^*)\gamma_2.$$

When $\alpha^* = 1$ this will always hold and when $\alpha^* = 0$ it will never hold. Solving for α^* gives

$$\alpha^* > \frac{\gamma_2(1-\bar{g})}{\gamma_1(1-\bar{\tau})\eta + \gamma_2(1-\bar{g})}. \tag{B.4}$$

Next we turn the effect of a lowering of the debt threshold on debt on the other variables of the model. Using (A.21), we have

$$-\frac{\partial\pi_{t+1}}{\partial\tilde{DT}_t} = \kappa(\sigma+\eta)\left(-\frac{\partial\hat{Y}_{t+1}}{\partial\tilde{DT}_t}\right). \tag{B.5}$$

Therefore, the effect on inflation is positive, if and only the effect of the lowering of the debt threshold on output is positive.

For debt we have, using (30),

$$\begin{aligned}-\frac{\partial\tilde{b}_{t+1}}{\partial\tilde{DT}_t} &= -\bar{\tau}\frac{\theta-1}{\theta}(\sigma+\eta)\left(-\frac{\partial\hat{Y}_{t+1}}{\partial\tilde{DT}_t}\right) - \frac{\bar{b}}{\beta}\left(-\frac{\partial\hat{Y}_{t+1}}{\partial\tilde{DT}_t}\right) - \frac{\bar{b}}{\beta}\left(-\frac{\partial\hat{\pi}_{t+1}}{\partial\tilde{DT}_t}\right)\\ &= -\left((\bar{\tau}(\sigma+\eta))\frac{\theta-1}{\theta} + \frac{\bar{b}}{\beta}(1+\kappa(\sigma+\eta))\right)\left(-\frac{\partial\hat{Y}_{t+1}}{\partial\tilde{DT}_t}\right).\end{aligned} \tag{B.6}$$

We can conclude that if (B.4) is satisfied, and the lowering of the debt threshold shock leads to a lower output level, then this shock increases debt. When on the other hand (B.4) is satisfied is satisfied, then the lowering of the debt threshold reduces debt before consolidations are implemented, relative to the case of no expected consolidations.

B.2. Proof Proposition 2

We first assume spending-based consolidation. Leading (A.20) and taking the derivative, we can write

$$-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t} = \frac{\partial \hat{Y}_{t+2}}{\partial \tilde{b}_{t+1}}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) - \frac{1}{1-\bar{g}}\gamma_1 + n^N_{t+2}\left(-\frac{\partial \hat{Y}_{t+1}}{\partial \tilde{DT}_t}\right) - \frac{\phi_\pi - 1}{\sigma} n^N_{t+2}\left(-\frac{\partial \hat{\pi}_{t+1}}{\partial \tilde{DT}_t}\right). \tag{B.7}$$

Here, the first term represents the effect of the expectation of fundamentalists, taking account of the fact that these are only effected by the most recent value of the debt ratio. The second term embodies the direct effect of implemented consolidations. The third and fourth term contain the effect that the changes in output and inflation in the anticipation period have on Naive expectations one period later.

Similarly, we obtain for inflation

$$-\frac{\partial \pi_{t+2}}{\partial \tilde{DT}_t} = \frac{\partial \pi_{t+2}}{\partial \tilde{b}_{t+1}}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) + \frac{\sigma\kappa\gamma_1}{1-\bar{g}} + \beta n^N_{t+2}\left(-\frac{\partial \hat{\pi}_{t+1}}{\partial \tilde{DT}_t}\right) + \kappa(\sigma+\eta)\left(-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t}\right). \tag{B.8}$$

$\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{b}_{t+1}}$ can be obtained by replacing n^N_{t+1} by n^N_{t+2} in (B.3) (since $\tilde{b}_{t+1}$ shows up in the same way in Eq. (A.20) as $-\tilde{D}T_{t+1}$). Updating (B.5) analogously gives $\frac{\partial \hat{\pi}_{t+2}}{\partial \tilde{b}_{t+1}}$.

Finally, we have

$$-\frac{\partial \tilde{b}_{t+2}}{\partial - \tilde{DT}_t} = -\gamma_1 + \frac{1}{\beta}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) - \bar{\tau}\frac{\theta-1}{\theta}\left(-\frac{\partial \hat{mc}_{t+2}}{\partial \tilde{DT}_t}\right) + \frac{\bar{b}}{\beta}\left(\left(-\frac{\partial \hat{Y}_{t+1}}{\partial \tilde{DT}_t}\right) - \left(-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t}\right) - \left(-\frac{\partial \hat{\pi}_{t+2}}{\partial \tilde{DT}_t}\right)\right), \tag{B.9}$$

with

$$-\frac{\partial \hat{mc}_{t+2}}{\partial \tilde{DT}_t} = (\sigma+\eta)\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{b}_{t+1}}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) + \frac{\sigma\gamma_1}{1-\bar{g}} + (\sigma+\eta)\left(-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t}\right). \tag{B.10}$$

We can therefore write

$$\begin{aligned}
-\frac{\partial \tilde{b}_{t+2}}{\partial \tilde{DT}_t} =& -\gamma_1 + \frac{1}{\beta}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) - \left(\bar{\tau}\frac{\theta-1}{\theta} + \frac{\bar{b}}{\beta}\kappa\right)\frac{\sigma\gamma_1}{1-\bar{g}} \\
& - \left(\bar{\tau}\frac{\theta-1}{\theta}(\sigma+\eta) + \frac{\bar{b}}{\beta}\kappa(\sigma+\eta)\right)\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{b}_{t+1}}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) \\
& - \left((\bar{\tau}(\sigma+\eta))\frac{\theta-1}{\theta} + \frac{\bar{b}}{\beta}(1+\kappa(\sigma+\eta))\right)\left(-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t}\right) \\
& + \frac{\bar{b}}{\beta}\left(1-\beta n^N_{t+2}\kappa(\sigma+\eta)\right)\left(-\frac{\partial \hat{Y}_{t+1}}{\partial \tilde{DT}_t}\right).
\end{aligned} \tag{B.11}$$

In case of tax-based consolidation we get

$$-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t} = \frac{\partial \hat{Y}_{t+2}}{\partial \tilde{b}_{t+1}}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) + n^N_{t+2}\left(-\frac{\partial \hat{Y}_{t+1}}{\partial \tilde{DT}_t}\right) - \frac{\phi_\pi - 1}{\sigma} n^N_{t+2}\left(-\frac{\partial \hat{\pi}_{t+1}}{\partial \tilde{DT}_t}\right) \tag{B.12}$$

$$-\frac{\partial \pi_{t+2}}{\partial \tilde{DT}_t} = \frac{\partial \pi_{t+2}}{\partial \tilde{b}_{t+1}}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) + \frac{\kappa\gamma_2}{1-\bar{\tau}} + \beta n^N_{t+2}\left(-\frac{\partial \hat{\pi}_{t+1}}{\partial \tilde{DT}_t}\right) + \kappa(\sigma+\eta)\left(-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t}\right), \tag{B.13}$$

and

$$\begin{aligned}
-\frac{\partial \tilde{b}_{t+2}}{\partial \tilde{DT}_t} =& -\frac{\theta-1}{\theta}\gamma_2 + \frac{1}{\beta}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) - \bar{\tau}\frac{\theta-1}{\theta}\left(-\frac{\partial \hat{mc}_{t+2}}{\partial \tilde{DT}_t}\right) \\
& + \frac{\bar{b}}{\beta}\left(\left(-\frac{\partial \hat{Y}_{t+1}}{\partial \tilde{DT}_t}\right) - \left(-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t}\right) - \left(-\frac{\partial \hat{\pi}_{t+2}}{\partial \tilde{DT}_t}\right)\right),
\end{aligned}$$

with

$$-\frac{\partial \hat{mc}_{t+2}}{\partial \tilde{DT}_t} = (\sigma+\eta)\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{b}_{t+1}}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) + \frac{\gamma_2}{1-\bar{\tau}} + (\sigma+\eta)\left(-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t}\right). \tag{B.14}$$

So that we can write

$$-\frac{\partial \tilde{b}_{t+2}}{\partial \tilde{DT}_t} = -\frac{\theta-1}{\theta}\gamma_2 + \frac{1}{\beta}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right) - \left(\bar{\tau}\frac{\theta-1}{\theta} + \frac{\bar{b}}{\beta}\kappa\right)\frac{\gamma_2}{1-\bar{\tau}}$$
$$-\left(\bar{\tau}\frac{\theta-1}{\theta}(\sigma+\eta) + \frac{\bar{b}}{\beta}\kappa(\sigma+\eta)\right)\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{b}_{t+1}}\left(-\frac{\partial \hat{b}_{t+1}}{\partial \tilde{DT}_t}\right)$$
$$-\left((\bar{\tau}(\sigma+\eta))\frac{\theta-1}{\theta} + \frac{\bar{b}}{\beta}(1+\kappa(\sigma+\eta))\right)\left(-\frac{\partial \hat{Y}_{t+2}}{\partial \tilde{DT}_t}\right)$$
$$+\frac{\bar{b}}{\beta}\left(1-\beta n^N_{t+2}\kappa(\sigma+\eta)\right)\left(-\frac{\partial \hat{Y}_{t+1}}{\partial \tilde{DT}_t}\right). \tag{B.15}$$

Subtracting the tax-based debt derivative, (B.15), from the spending-based debt derivative, (B.11), results in

$$-\left(\gamma_1 - \frac{\theta-1}{\theta}\gamma_2\right) - \left(\bar{\tau}\frac{\theta-1}{\theta} + \frac{\bar{b}}{\beta}\kappa\right)\left(\frac{\sigma\gamma_1}{1-\bar{g}} - \frac{\gamma_2}{1-\bar{\tau}}\right) + \left((\bar{\tau}(\sigma+\eta))\frac{\theta-1}{\theta} + \frac{\bar{b}}{\beta}(1+\kappa(\sigma+\eta))\right)\frac{\gamma_1}{1-\bar{g}}.$$

Assuming consolidations of equal impact on the budget deficit ($\gamma_1 = \frac{\theta-1}{\theta}\gamma_2$), this reduces to

$$\gamma_1\left((\bar{\tau}\frac{\theta-1}{\theta} + \frac{\bar{b}}{\beta}\kappa)\left(\frac{\theta}{(\theta-1)(1-\bar{\tau})} + \frac{\eta}{1-\bar{g}}\right) + \frac{\bar{b}}{\beta}\frac{1}{1-\bar{g}}\right). \tag{B.16}$$

This implies that a spending-based consolidation leads to a higher debt then a tax-based consolidation after two periods. Substituting for steady state debt we get

$$\gamma_1\left((\bar{\tau}\frac{\theta-1}{\theta} + \frac{\bar{\tau}\frac{\theta-1}{\theta}-\bar{g}}{1-\beta}\kappa)\left(\frac{\theta}{(\theta-1)(1-\bar{\tau})} + \frac{\eta}{1-\bar{g}}\right) + \frac{\bar{\tau}\frac{\theta-1}{\theta}-\bar{g}}{1-\beta}\frac{1}{1-\bar{g}}\right). \tag{B.17}$$

B.3. Proof Proposition 3

We assume steady state levels and we assume a spending-based consolidation is implemented. In a fixed point where Fundamentalists have correctly updated their belief to $\alpha_t = 1$ inflation and output satisfy

$$\pi(1-\beta n^N) = \kappa(\sigma+\eta)Y + \kappa\sigma\frac{\gamma_1(b-DT)}{1-\bar{g}}, \tag{B.18}$$

$$(1-n^N_t)Y = -(1-n^N_t)\frac{1}{\eta+\sigma}\sigma\frac{\gamma_1(b-DT)}{1-\bar{g}} - \frac{\phi_\pi - 1}{\sigma}n^N_t\pi. \tag{B.19}$$

Solving this two equations shows that fixed point inflation and marginal cost are zero and fixed point output is given by the Fundamentalists expected value:

$$Y = -\frac{1}{\eta+\sigma}\sigma\frac{\gamma_1(b-DT)}{1-\bar{g}}. \tag{B.20}$$

For debt we have in the fixed point where marginal cost and inflation are zero:

$$b = -\gamma_1(b-DT) + \frac{1}{\beta}b. \tag{B.21}$$

The fixed point debt ratio therefore is

$$b = \frac{DT\gamma_1}{1-\frac{1}{\beta}+\gamma_1}. \tag{B.22}$$

This is indeed a fixed point when the fixed point debt ratio lies above the debt threshold. This is the case if and only if

$$\gamma_1 > \frac{1}{\beta} - 1. \tag{B.23}$$

B.4. Proof Proposition 4

In tax case of tax-based consolidations that are fully expected by Fundamentalists ($\alpha_t = 0$) we again have a fixed point where marginal cost and inflation are zero. Output is now given by

$$Y = -\frac{1}{\eta+\sigma}\left(\frac{\gamma_2(b-DT)}{1-\bar{\tau}}\right).$$

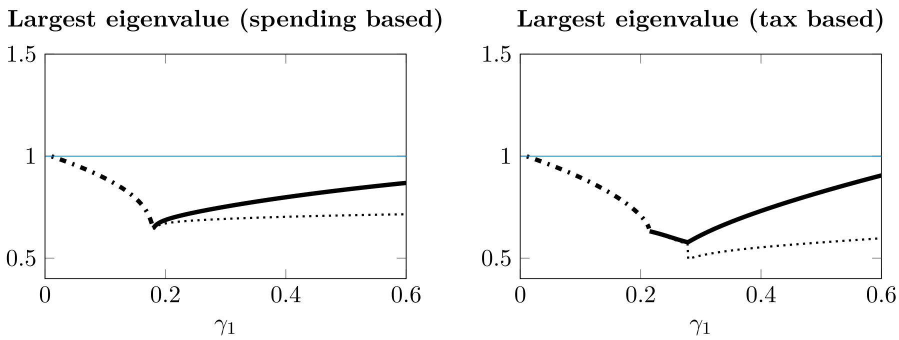

Fig. 10. Absolute values of largest eigenvalue in high debt fixed point for spending and tax-based consolidations. The dashed-dotted segment depicts a real and positive eigenvalue, while a solid segment depicts complex eigenvalues. The real part of the complex eigenvalues is plotted as a dotted curve. In case of tax-based consolidations it holds that $\gamma_2 = \frac{\theta}{\theta-1}\gamma_1$. In the figure, the benchmark calibration is used, but with $\phi_\pi = 1.1$ instead of $\phi_\pi = 1.5$.

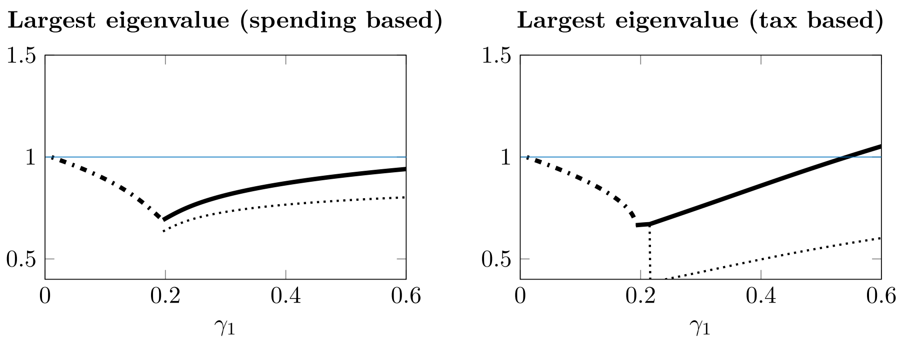

Fig. 11. Absolute values of largest eigenvalue in high debt fixed point for spending and tax-based consolidations. The dashed-dotted segment depicts a real and positive eigenvalue, while a solid segment depicts complex eigenvalues. The real part of the complex eigenvalues is plotted as a dotted curve. In case of tax-based consolidations it holds that $\gamma_2 = \frac{\theta}{\theta-1}\gamma_1$. In the figure, the benchmark calibration is used, but with $\phi = 10$ instead of $\phi = 100$.

For debt we now have

$$b = \frac{DT\gamma_2\frac{\theta-1}{\theta}}{1 - \frac{1}{\beta} + \gamma_2\frac{\theta-1}{\theta}}. \tag{B.24}$$

This is indeed a fixed point when this debt ratio lies above the debt threshold

The condition now becomes

$$\gamma_2\frac{\theta-1}{\theta} > \frac{1}{\beta} - 1. \tag{B.25}$$

Appendix C. Robustness

C.1. Largest eigenvalues

In this section, we look at the robustness of the largest eigenvalue results of Section 4.3 to the chosen parametrization. In Fig. 10, we plot the case of weaker monetary policy, where $\phi_\pi = 1.1$ instead of $\phi_\pi = 1.5$. This figure looks very similar to Fig. 1, so monetary policy does not seem to have a big impact on dynamics. This is because agents are short-sighted, heterogeneous and form expectations for one period ahead only. As such, changes in the commitment of the central bank to a specific rule have a smaller effect on expectations and thereby on the dynamics of the model. In Bi et al. (2013) instead, agents forecast over an infinite horizon and there is no heterogeneity in expectations. There, a less active monetary policy makes tax increases more expansionary after the consolidation, while it makes spending cuts much more contractionary.

In Fig. 11, we plot the case where price adjustment costs are equal to $\phi = 10$ rather than $\phi = 100$. This leads to a much flatter Phillips curve. Similarly, Fig. 12 plots the case where the relative risk aversion parameter is $\sigma = 0.157$ instead of $\sigma = 2$.

In both Figures, qualitative results for reasonable values of γ_1 are the same as in Section 4.3. That is, for low values of γ_1 slow monotonic convergence occurs for both spending and tax-based consolidations due to a large positive eigenvalue. As γ_1 decreases, the eigenvalue becomes smaller and eventually the largest eigenvalues are complex.

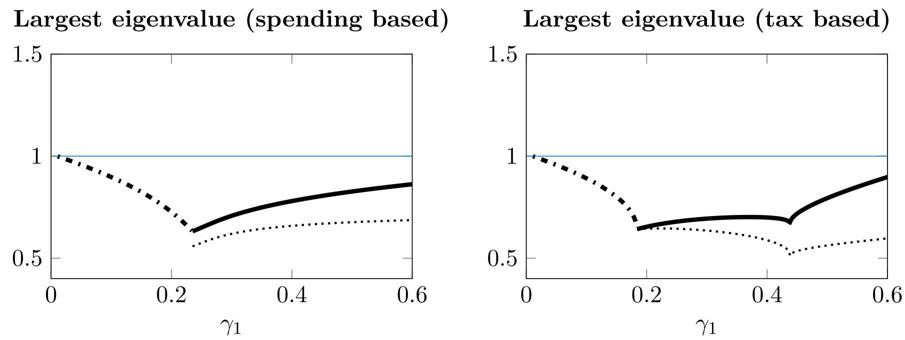

Fig. 12. Absolute values of largest eigenvalue in high debt fixed point for spending and tax-based consolidations. The dashed-dotted segment depicts a real and positive eigenvalue, while a solid segment depicts complex eigenvalues. The real part of the complex eigenvalues is plotted as a dotted curve. In case of tax-based consolidations it holds that $\gamma_2 = \frac{\theta}{\theta-1}\gamma_1$. In the figure, the benchmark calibration is used, but with $\sigma = 0.157$ instead of $\sigma = 2$.

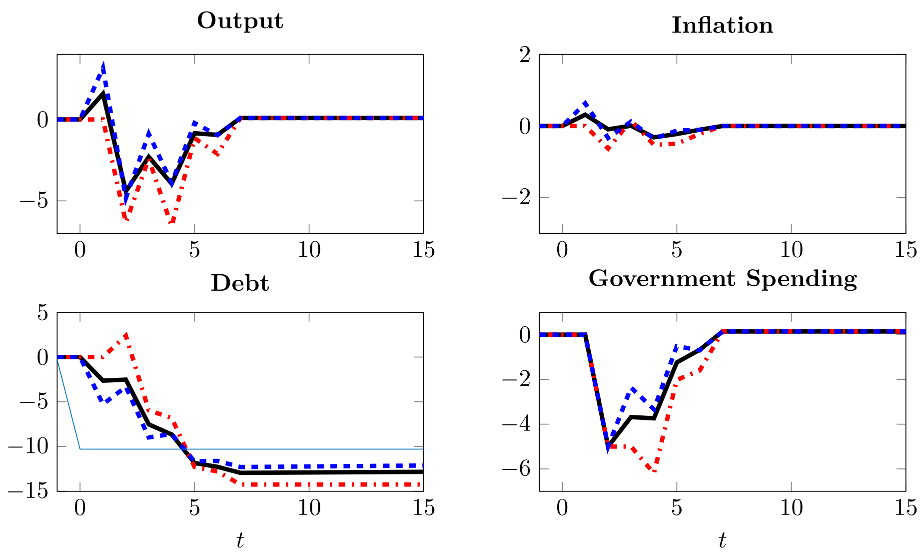

Fig. 13. Impulse responses to debt threshold shock for correctly anticipated tax-based consolidations. In the figure $\gamma_1 = 0.5$ instead of 0.2. The benchmark behavioral model is plotted in black, and the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

C.2. Stronger consolidations

In this section, we consider what happens to our benchmark impulse responses of Section 5.1 when the government implements stronger consolidations. We now set $\gamma_1 = 0.5$ instead of $\gamma_1 = 0.2$. Results of the benchmark case of anticipated consolidations with no composition uncertainty are presented in Figs. 13 and 14 for respectively spending-based and tax-based consolidations.

In Fig. 13 we see that debt overshoots both its fixed point value and the debt threshold in period 5. This is in line with the finding of Section 4.3 that the largest eigenvalue now is complex. Even though the debt ratio is eventually reduced faster and to a lower level, debt could considerably increase in the first period of implementation if all agents are initially Naive (red curves). The intuition for the larger difference between the 3 specifications of our behavioral model is that the stronger consolidations magnify expectation effects caused by Naive and Fundamentalists, both prior and during the consolidations. Furthermore, in the top left panel, it can be seen that the contraction in output is deeper due to the stronger spending cuts.

We present the multipliers in Table 5. First focusing on spending-based consolidations and comparing with panel (a) of Table 2, it can be seen that even though, stronger spending-based consolidations are more successful in reducing debt, they lead to more negative multipliers. On the other hand, stronger tax-based consolidations only lead to a more negative impact multiplier, but to less negative long run multipliers. In Fig. 14 we plot the case of correctly anticipated stronger tax-based consolidations. Again, the differences between the three specifications of initial conditions are amplified compared to the case of weaker consolidations, with the possibility of a significantly larger recession. However, debt is reduced faster and

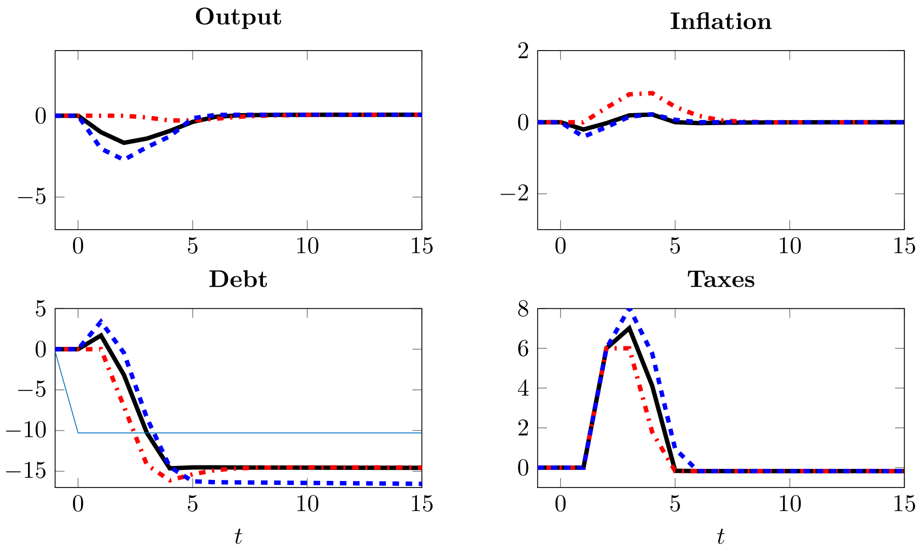

Fig. 14. Impulse responses to debt threshold shock for correctly anticipated strong spending-based consolidations. In the figure $\gamma_1 = 0.5$ instead of 0.2. The benchmark behavioral model is plotted in black, and the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 5
Output multipliers in case of stronger consolidations with $\gamma_1 = 0.5$ instead of 0.2.

	1qr	4qr	8qr	12qr
$\frac{\Delta Y}{\Delta G}$	−0.74	−0.72	−0.74	−0.75
$\frac{\Delta Y}{\Delta \tau}$	−0.33	−0.31	−0.32	−0.32

to a level significantly below the debt level. Finally, we can conclude that also under stronger consolidations, tax-based consolidations are more effective in reducing debt, and lead to less negative multipliers.

C.3. Implementation lag

Throughout the paper, we have assumed that fiscal adjustments take one period to be implemented. That is, in period t the government compares that last observed debt ratio, $\tilde{b}_{t-1}$, with the debt threshold, $\tilde{DT}_{t-1}$, and based on this determines next periods government spending and taxes, $\tilde{g}_{t+1}$ and $\tilde{\tau}_{t+1}$. In this appendix we study robustness to this specification. We now assume that the government makes its decision about government spending and taxes of period t, $\tilde{g}_t$ and $\tilde{\tau}_t$, based on b_{t-1} rather than b_{t-2}. Below we first show that effects of upcoming coming consolidations on expectations of Fundamentalists do not depend on the length of the implementation lag an on whether Fundamentalists can observer contemporaneous endogenous variables or not. In particular, we show that the results of Proposition 1 (containing the expectation effects of consolidations) still hold. Next, we show impulse responses for the case where we keep the behavioral assumption that Fundamentalists do not observe endogenous variables contemporaneously and have to form their expectations in period t using $t-1$ information of endogenous variables.

Without the 2-period implementation lag, the fiscal rules become

$$\tilde{g}_t = -\zeta\gamma_1 \max(0, \tilde{b}_{t-1} - \tilde{DT}_{t-1}), \tag{C.1}$$

and

$$\tilde{\tau}_t = (1-\zeta)\gamma_2 \max(0, \tilde{b}_{t-1} - \tilde{DT}_{t-1}). \tag{C.2}$$

This implies that $\tilde{g}_{t+1}$ and $\tilde{\tau}_{t+1}$ will depend on $\tilde{b}_t$. Since fundamentalists need to form expectations about $\tilde{g}_{t+1}$ and $\tilde{\tau}_{t+1}$ in period t, when the endogenous variable $\tilde{b}_t$ is not observed yet, it now matters whether Fundamentalists contemporaneous endogenous variables or not. If they could, then their expectations about government spending would become

$$E_t^F \tilde{g}_{t+1} = -\alpha_t\gamma_1 \max(0, \tilde{b}_t - \tilde{DT}_t), \tag{C.3}$$

If they cannot, they must first form a belief about the value of $\tilde{b}_t$. Since fundamentalists form expectations by assuming that debt remains constant over time (making use of the high persistence in this variable) we assume that they also do this here

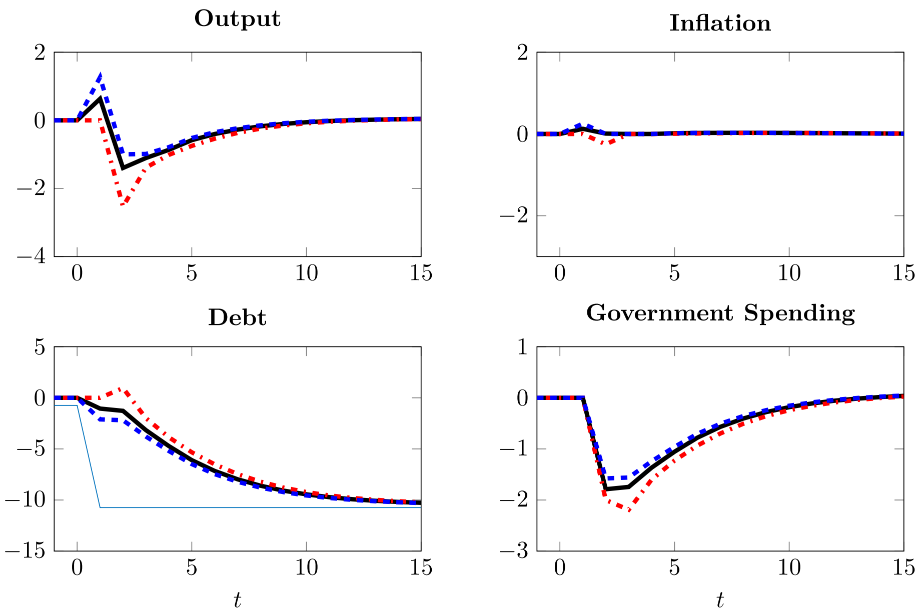

Fig. 15. Impulse responses to debt threshold shock for correctly anticipated tax-based consolidations in case of no implementation lag for fiscal adjustments. The benchmark behavioral model is plotted in black, and the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and approximate the current debt ratio by $\tilde{b}_t \approx \tilde{b}_{t-1}$. Since Fundamentalists do observe the exogenously announced debt threshold contemporaneously, their expectations about government spending then satisfy

$$E_t^F \tilde{g}_{t+1} = -\alpha_t \gamma_1 \max(0, \tilde{b}_{t-1} - \tilde{DT}_t). \tag{C.4}$$

Fundamentalists' expectations about output are adjusted in a similar fashion.

For a more convenient compatibility with Proposition 1, assume now that consolidations start again in period $t+2$. This means that there must have been a shock to the debt threshold in period $t+1$. We are now interested in how expectations, and hence endogenous variables in period $t+1$ (the period before implementation of the consolidation) are affected by this lowering of the debt threshold. Leading either (C.3) or (C.4) one period, and combining with naive expectations, it follows in both cases that

$$-\frac{\partial \bar{E}_{t+1}\tilde{g}_{t+2}}{\partial \tilde{DT}_{t+1}} = -(1-n_{t+1}^N)\alpha^* \gamma_1, \tag{C.5}$$

which is equal to (B.1). In a similar fashion it follows that, under the alternative fiscal rules and assumptions about the observation of endogenous variables, aggregate output expectations about period $t+2$ are affected as follows by the shock to $\tilde{DT}_{t+1}$

$$-\frac{\partial \bar{E}_{t+1}\hat{Y}_{t+2}}{\partial \tilde{DT}_{t+1}} = -(1-n_{t+1}^N)\frac{1}{\sigma+\eta}\left(\frac{\sigma}{1-\bar{g}}\alpha^*\gamma_1 + \frac{1}{1-\bar{\tau}}(1-\alpha^*)\gamma_2\right). \tag{C.6}$$

This expression is equal to (B.2). Therefore, the subsequent steps in the proof of Proposition 1 can be followed exactly, with now each time taking the derivative to $\tilde{DT}_{t+1}$ instead of to $\tilde{DT}_t$. It then follows that the effect of a debt threshold shock (that implies fiscal adjustments in the next period) on current periods output is positive, if and only if (B.4) holds. The expectational effects in the period before consolidations start are therefore robust to the specification of the implementation lag.

Next we turn to impulse responses for the case where government spending and taxes are given by (C.1) and (C.2), while keeping the behavioral assumption that Fundamentalists do not observe endogenous variables contemporaneously, so that their expectation about government spending are given by (C.4). In Figs. 15 and 16 we plot these impulse responses for the benchmark cases of correctly anticipated spending-based and tax-based consolidations, respectively. Comparing these figures with Figs. 2 and 3, it can be seen that without the implementation lag, dynamics are slightly more monotonic. In case of tax-based consolidations, it can further be seen that the largest tax hikes now take place in the first period of implemented consolidations (period 2), rather than one period later (it is period 3 in Fig. 3). This is because the highest debt level is still reached in the anticipation period (period 1), and without an implementation lag the period where taxes are based on this debt level is now period 2, rather than period 3.

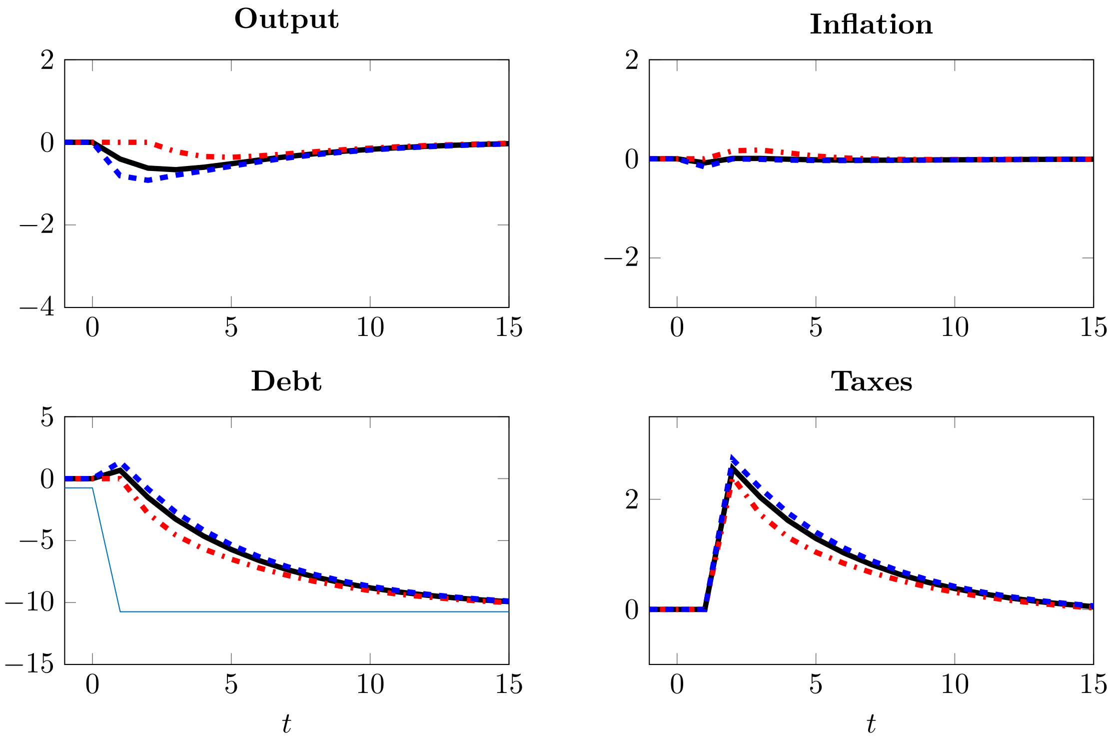

Fig. 16. Impulse responses to debt threshold shock for correctly anticipated spending-based consolidations in case of no implementation lag for fiscal adjustments. The benchmark behavioral model is plotted in black, and the dashed blue and dashed-dotted red curves depict the cases where in the initial fixed point all agents where respectively Fundamentalists and Naive. The debt threshold is plotted in blue in the bottom left panel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Overall, however, the dynamics in Figs. 15 and 16 are qualitatively very similar to those in Figs. 2 and 3, and our main results are robust to the assumption of a fiscal implementation lag.

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