Learning and the Size of the Government Spending Multiplier

Ewoud Quaghebeur

October 2013
2013/851
Learning and the Size of the Government Spending Multiplier

Ewoud QUAGHEBEUR∗
SHERPPA, Ghent University

October 3, 2013

Abstract

This paper examines the government spending multiplier when economic agents form their expectations based on an adaptive learning scheme. The learning mechanism is such that the agents forecast future values of forward-looking variables using a linear function of an information set that does not contain the fiscal shock. Our impulse response analysis shows that the effects of a government spending shock change substantially when the rational expectations hypothesis is replaced by this learning mechanism. In contrast to the dynamics under rational expectations, a government spending shock in a small-scale new Keynesian DSGE model with this adaptive learning mechanism crowds in private consumption and is associated with a positive comovement between real wages and hours worked. The learning model also relies less on consumption-leisure non-separability in utility and price stickiness to deliver high output multipliers, as opposed to the rational expectations benchmark. In the baseline calibration, the multiplier under learning is nearly twice as large as under rational expectations. These results are robust to a richer specification, irrespective of the financing strategy. An alternative adaptive learning model, where agents know the future path of taxes implied by the government spending shock, leads to results that differ to a large extent from those of the benchmark learning model and are largely incompatible with most of the empirical evidence.

JEL Classification: E62; D83; D84; E32; E37

Keywords: adaptive learning, DSGE, fiscal policy, fiscal multipliers, government spending

∗Correspondence to Ewoud.Quaghebeur@UGent.be. Sint-Pietersplein 6, B-9000 Ghent, Belgium. Phone +32 9 264.34.87.

I would like to thank Freddy Heylen, Tim Buyse, Julio Carrillo, Gerdie Everaert, Punnoose Jacob, Céline Poilly, and participants at the Conference on Computing in Economics and Finance 2012 and the Congress of the European Economic Association 2013 for helpful comments.
1 Introduction

Since the outbreak of the global financial crisis in 2008, countries around the world have tried to fight the recession with a series of fiscal policy measures. Many countries have adopted a broad range of measures such as large tax cuts, boosts in direct spending and various investment programs. More recently, substantial budget deficits and soaring public debt have raised concerns about the sustainability of fiscal policy over the longer term, especially in Europe. Policymakers are faced with the challenge to trade off the efforts to support global economic activity in the short run with a credible longer-term fiscal adjustment plan.

Recent contributions to the literature suggest that the impact of fiscal policy on economic activity can be substantially bigger than previously thought. A central issue in this debate is the size of the government spending multiplier. Although the empirical estimates are dispersed over a broad range, the estimates are in many cases higher than those found in theoretical business cycle models. Furthermore, Blanchard and Perotti (2002), Fatás and Mihov (2001), Gali et al. (2007), and Perotti (2008) find that government spending crowds in private consumption. This finding is also emphasized in Auerbach and Gorodnichenko (2012), Christiano et al. (2011), and Tagkalakis (2008), that focus on the impact of government spending during recessions. By contrast, standard business cycle models usually predict a large crowding out of private consumption, which leads to government spending multipliers that are typically smaller than one.

It is well-known that the rational expectations hypothesis is a key factor in explaining the small government spending multipliers in standard business cycle models. As an alternative to this hypothesis, we assume in this paper that agents form expectations using an adaptive learning mechanism. The motivation for using the adaptive learning approach is twofold. First, many authors have casted doubt upon the validity of the rational expectations hypothesis. The hypothesis presumes for instance that agents fully oversee the structure of the model and do not face any computational limitations in deriving the model-consistent expectations. The adaptive learning approach introduces a more plausible view of rationality. Second, the results of Orphanides and Williams (2005, 2007), Milani (2007), Slobodyan and Wouters (2009), and others, show that learning can improve the marginal likelihood and out-of-sample forecasts of a medium-scale DSGE model.

Our paper extends the existing literature by assessing the role of adaptive learning for the effects of government spending shocks in a new Keynesian DSGE model. In the baseline impulse response analysis we will assume that agents have no structural information about the fiscal rules or the government budget constraint, when forming expectations about the future. Hence, they do not fully anticipate the future fiscal consequences of a government spending increase. This is reflected in the data vector in the expectation formation mechanism, which does not include the fiscal shock. We believe that this is a plausible assumption in a context where fiscal policy changes are rare, and agents form expectations using beliefs that are based on recently observed variables. Especially when it comes to the macroeconomic effects of fiscal policy, it is hard to believe that agents have perfect knowledge on the laws of motion of aggregate variables as a function of the fiscal shock.
We find that, in contrast to the dynamics under rational expectations, government spending in a small-scale new Keynesian DSGE model with adaptive learning crowds in private consumption and is associated with a comovement between real wages and hours worked. Hence, we provide a theoretical argument for the large multipliers in the recent empirical literature. Our analysis shows that the multiplier can be bigger than one, even if price rigidity is only limited and the degree of non-separability of the utility function is small.

Our work is related to the analysis in Evans et al. (2009, 2012), where the effects of fiscal policy changes are investigated when agents combine limited structural information and an adaptive learning mechanism to form expectations about the future. In Evans et al. (2009) the effects are investigated in an endowment economy and the Ramsey model; Evans et al. (2012) consider a standard real business cycle model with lump-sum taxes. The starting point of this paper, however, is a new Keynesian DSGE model with commonly used model features such as imperfect competition, price rigidity, and capital adjustment costs. We will show that these model features crucially affect the impact of adaptive learning on the dynamics of a government spending shock, in particular when it comes to the degree of price rigidity.

The remainder of the paper is organized as follows. Section 2 provides a brief review of the existing empirical evidence on the impact of government spending shocks. Section 3 introduces the DSGE model that will be used throughout the paper. Section 4 sets out the adaptive learning mechanism used in the expectation formation. In Section 5, the effects of a government spending shock of the model with Adaptive Learning (AL) are compared with the effects under Rational Expectations (RE). A distinction is made between a neoclassical specification with fully flexible prices and a new Keynesian specification of the model. The role of learning for the government spending multipliers of output, private consumption, and investment is discussed in Section 6. In Section 7 we provide some extensions to the benchmark model and consider several robustness exercises. The last section concludes.

2 A brief review of existing empirical evidence

There exists a large empirical literature on the effects of government spending shocks on the business cycle. A central issue is the identification problem of fiscal shocks. Two main approaches have been used to solve this problem. Studies using an Structural Vector Autoregression (SVAR) approach typically identify government spending shocks by assuming that government spending is predetermined within the quarter. In contrast, the approach developed by Ramey and Shapiro (1998) identifies fiscal shocks by looking at narrative evidence of military buildups in the United States.\footnote{Originally, Ramey and Shapiro (1998) identified three episodes: the Korean War, the Vietnam War, and the Carter-Reagan buildup. Eichenbaum and Fisher (2004), Ramey (2011b), Perotti (2008) added the 9/11 terrorist attack as a fourth episode. Hall (2009) and Ramey (2011a) provide a comprehensive discussion of the empirical literature on government spending.}

Most studies find a positive effect of government spending on aggregate output, although the estimates are dispersed over a broad range. Table\[1\] shows the output multipliers of some prominent papers in the literature\[2\]. In a seminal paper, Blanchard and Perotti (2002) identify fiscal policy shocks in the
United States during the post-war period using an SV AR approach and find that an increase of government spending of 1% of GDP increases output by 0.84% to 0.90%. Using a similar identification strategy, Galí et al. (2007) find a multiplier of 0.68. Mountford and Uhlig (2009) achieve identification of an SV AR model by imposing sign restrictions on the impulse responses to the fiscal shock and find an impact multiplier of 0.65. Cross-country studies find evidence of considerable variation in the size government spending multiplier across countries. For instance, Ilzetzki et al. (2012) estimate the impact multiplier for high-income countries to be 0.39, whereas the multiplier for developing countries is not significantly different from zero. Similarly, narrative studies provide a wide range of estimates of impact of government spending on output. The estimated government spending multiplier in Ramey (2011b) ranges from 0.6 to 1.2 on impact. Using U.S. annual data, Barro and Redlick (2009) estimate the multipliers for temporary defense spending at 0.44–0.47 in the first year. There is very little evidence of negative multipliers (Mahfouz et al. 2002; IMF 2010), although Giavazzi and Pagano (1990) show that credible fiscal consolidations can have expansionary effects and Ilzetzki et al. (2012) find negative multipliers for high-debt countries. In the debate, virtually all empirical (and theoretical) contributions find a positive effect of government spending on hours worked.

The empirical literature remains divided on the response of private consumption and real wages to a government spending shock. On the one hand, SV AR methods usually find that an increase in government purchases leads to a rise in private consumption and the real wage. Blanchard and Perotti (2002), Fatás and Mihov (2001), Galí et al. (2007), and Perotti (2008), find that shocks in government spending are associated with increases in private consumption. Using a quarterly VAR for the U.S., Perotti estimate the U.S. consumption multiplier at 0.10 on impact and 0.40 after 8 quarters. The consumption multipliers in Galí et al. are 0.07 and 0.49, respectively. Moreover, the estimates of Galí et al. and Fatás and Mihov uncover a persistent increase the real wage. On the other hand, the narrative approach to identifying government spending shocks generally obtain a fall in both private consumption and real wages. Ramey and Shapiro (1998) simulate the responses to a U.S. military buildup and find that private consumption displays a significant decline after the shock. Edelberg et al. (1999) adopt an extended version of the Ramey and Shapiro approach and find that both consumption expenditures and real wages fall after a positive government spending shock. Similarly, Burnside et al. (2004) argue that an increase in government spending leads to persistent fall in real wages and an insignificant response of private consumption. Barro and Redlick (2009) estimate a consumption multiplier which is close to zero.
<table>
<thead>
<tr>
<th>Source</th>
<th>Methodology</th>
<th>Country</th>
<th>Fiscal instrument</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 quarter</td>
</tr>
<tr>
<td>Barro and Redlick (2009)</td>
<td>2SLS</td>
<td>United States</td>
<td>Temporary defense spending</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2SLS</td>
<td>United States</td>
<td>Permanent defense spending</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2SLS</td>
<td>United States</td>
<td>Tax</td>
<td></td>
</tr>
<tr>
<td>Blanchard and Perotti (2002)</td>
<td>SVAR, deterministic trend</td>
<td>United States</td>
<td>Government spending</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>SVAR, stochastic trend</td>
<td>United States</td>
<td>Government spending</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>SVAR, deterministic trend</td>
<td>United States</td>
<td>Tax</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>SVAR, stochastic trend</td>
<td>United States</td>
<td>Tax</td>
<td>0.70</td>
</tr>
<tr>
<td>Galí et al. (2007)</td>
<td>SVAR</td>
<td>United States</td>
<td>Government spending</td>
<td>0.68</td>
</tr>
<tr>
<td>Mountford and Uhlig (2009)</td>
<td>SVAR</td>
<td>United States</td>
<td>Government spending</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>SVAR</td>
<td>United States</td>
<td>Tax</td>
<td>0.28</td>
</tr>
<tr>
<td>Perotti (2008)</td>
<td>SVAR</td>
<td>United States</td>
<td>Government spending</td>
<td>0.70</td>
</tr>
<tr>
<td>Ramey (2011b)</td>
<td>Narrative approach</td>
<td>United States</td>
<td>Government spending</td>
<td>0.6-1.2</td>
</tr>
<tr>
<td>Romer and Romer (2010)</td>
<td>Narrative approach</td>
<td>United States</td>
<td>Tax</td>
<td>-</td>
</tr>
</tbody>
</table>

*a* For data samples that include WWII.

*b* Numbers taken from [Hall (2009)].

*c* Numbers taken from [Spilimbergo et al. (2009)].

Table 1: Survey of output multipliers in the empirical literature.
3 The Model Economy

This section briefly describes the new Keynesian DSGE model that we will use in this paper. The economy is populated by a representative household, a perfectly competitive final good producer, a continuum of monopolistically competitive intermediate good producers, a central bank, and a fiscal authority.3

Household The representative household maximizes expected lifetime utility. Preferences are defined over consumption, C_t, and hours worked, N_t, and described by the following utility function:

\[ E \sum_{t=0}^{\infty} \beta^t \left[ C_t^{\phi} (1 - N_t)^{1-\phi} \right]^{1-\sigma} - 1, \]

with \( \beta \in (0, 1) \), \( \sigma > 0 \), and \( \phi \in (0, 1) \). Here \( E_t^* (\cdot) \) denotes the subjective expectations of the household at time \( t \). We consider King, Plosser and Rebelo (1988) preferences, which is standard in business cycle analysis.

The household’s flow budget constraint is given by

\[ C_t + I_t + B_{t+1} \leq W_t N_t + r^t K_t + R_{t-1} \Pi_t^{-1} B_t + D_t - T_t, \]

where \( I_t, W_t, r^t, D_t, \) and \( T_t \) denote period \( t \) gross investment, real wage rate, real rental rate of capital, firms’ profits, and lump-sum taxes, respectively. In addition, the variable \( B_t \) represents the quantity of one-period bonds carried over from period \( t - 1 \). The variable \( R_{t-1} \) denotes the gross nominal interest rate on bonds purchased in period \( t - 1 \), and \( \Pi_t \) denotes the gross inflation rate. The stock of physical capital, \( K_t \), is owned by the household and accumulates according to

\[ K_{t+1} = (1 - \delta) K_t + I_t - \zeta \frac{I_t}{K_t} - K_t, \]

where \( \delta \) denotes the physical rate of depreciation, and \( \zeta > 0 \) is the Lucas and Prescott (1971) capital adjustment cost parameter.

Firms A representative, perfectly competitive firm bundles a continuum of intermediate goods into a final good using the following CES-technology:

\[ Y_t = \left( \int_0^1 Y_t(i)^{1-\epsilon} di \right)^{\frac{1}{\epsilon}}, \]

where \( \epsilon > 1 \), and \( Y_t(i) \) is the input of intermediate good \( i \in [0, 1] \). The firm chooses the quantities of inputs so as to maximize its profit, taking as given the final goods price \( P_t \) and the intermediate goods prices \( P_t(i) \), for all \( i \in [0, 1] \). Profit maximization implies the demand equation for intermediate good \( i \)

\[ Y_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon} Y_t. \]
There is a continuum of monopolistically competitive intermediate goods producers populating the unit interval. Facing the real factor prices \( W_t \) and \( r_k \), and the demand function (3.5), a typical intermediate goods firm \( i \in [0, 1] \) rents labour, \( N_t(i) \), and capital, \( K_t(i) \), in order to minimize costs. Its production function is given by

\[
Y_t(i) = Z_t K_t(i)^{\alpha} N_t(i)^{1-\alpha},
\]

where \( Z_t \) represents a technology shock that follows an exogenous process given by

\[
Z_t = Z_t^{\rho_Z} \exp(\varepsilon_t^Z), \quad \varepsilon_t^Z \sim \mathcal{N}(0, \sigma_Z^2),
\]

with \( \rho_Z \in (0, 1) \).

Following Calvo (1983), intermediate goods producers set nominal prices in a staggered fashion. Each period an intermediate goods producer can adjust its price with a constant probability \( 1 - \theta \). A firm \( i \) that is permitted to adjust prices at period \( t \), will choose a new optimal price, \( P_t^*(i) \), to maximize the expected present discounted value of future profits

\[
E_t^+ \sum_{k=0}^{\infty} (\beta \theta)^k \frac{U_{C,t+k}}{P_{t+k}} \left\{ P_t^*(i) Y_{t+k}(i) - MC_{t+k}Y_{t+k}(i) \right\},
\]

where \( U_{C,t+k} \) is the \( k \)-period ahead marginal utility of consumption. At the end of each period, the intermediate firm distributes its profits as a real dividend, \( D_t(i) \), to the representative household.

**Government Policies** The fiscal authority finances expenditure through lump-sum taxes and bond sales. The government budget constraint is given by

\[
T_t + B_{t+1} = G_t + R_t - 1 \Pi_t - 1 B_t.
\]

The budget constraint is supplemented with the following transversality condition for debt

\[
\lim_{t \to \infty} B_{t+1} \prod_t R_t \geq 0.
\]

Real expenditures, \( G_t \), evolves according to

\[
G_t = G_{t-1}^{\rho_G} \exp(\varepsilon_t^G), \quad \varepsilon_t^G \sim \mathcal{N}(0, \sigma_G^2),
\]

with \( \rho_G \in (0, 1) \). Here \( \varepsilon_t^G \) is a government spending shock.

The central bank sets the nominal interest rate according to the following Taylor rule:

\[
R_t = \Pi_t^{\rho_R} u_t^R
\]

with \( u_t^R = (u_{t-1}^R)^{\rho_R} \exp(\varepsilon_t^R) \), and \( \varepsilon_t^R \sim \mathcal{N}(0, \sigma_R^2) \). We assume the Taylor (1993) principle to hold, i.e. \( \rho_R > 1 \).

7
Market Clearing  Market clearing in the goods market and the markets of production factors requires
that the following conditions are met:

\[ Y_t = C_t + I_t + G_t \]  \hspace{1cm} (3.13)
\[ N_t = \int_0^1 N_t(i)di \]  \hspace{1cm} (3.14)
\[ K_t = \int_0^1 K_t(i)di \]  \hspace{1cm} (3.15)

4 Adaptive Learning

Traditionally, the model in the previous section is solved by assuming that agents form rational expec-
tations about forward-looking variables. By contrast, in this paper we follow the approach suggested by
Evans and Honkapohja (2001) and consider an adaptive learning mechanism where agents use past data
to estimate lead variables.

The model from the previous section can be approximated by the multivariate linear expectational
difference equation

\[ A_0 \begin{bmatrix} y_{t-1} \\ w_{t-1} \end{bmatrix} + A_1 \begin{bmatrix} y_t \\ w_t \end{bmatrix} + A_2 E^*_t y_{t+1} + B_0 \epsilon_t = 0, \]  \hspace{1cm} (4.1)

where \( y_t \) is the column vector of endogenous variables and \( w_t \) is the column vector of “shocks”. More
specifically, the vector \( y_t \) gathers the 13 endogenous variables of the model, and the vector \( w_t \) contains
the technology shock \( Z_t \), the fiscal shock \( G_t \), and the monetary shock \( u^R_t \).

When agents have rational expectations, the dynamics of the model are characterized by the following
Rational Expectations Equilibrium (REE):

\[ \begin{bmatrix} y_t \\ w_t \end{bmatrix} = T \begin{bmatrix} y_{t-1} \\ w_{t-1} \end{bmatrix} + \Psi \epsilon_t. \]  \hspace{1cm} (4.2)

This REE can be reformulated as a Minimum State Variable (MSV) solution of the form

\[ y_t = \begin{bmatrix} b_{MSV} & c_{MSV} \end{bmatrix} \begin{bmatrix} y^S_{t-1} \\ w_t \end{bmatrix}, \]  \hspace{1cm} (4.3)
\[ w_t = \rho w_{t-1} + \epsilon_t \]  \hspace{1cm} (4.4)

where \( y^S \) is the set of endogenous state variables (variables appearing with a lag).

When agents use a learning mechanism to form expectations, the law of motion of the model can be
derived in the following way. We assume that agents know the functional form of the MSV solution and
therefore use the following forecast rule:

\[ E^*_t y^f_{t+1} = \Psi_{t-1} \begin{bmatrix} \tilde{y}_t \\ E^*_t \tilde{w}_{t+1} \end{bmatrix} = \Psi_{t-1} \begin{bmatrix} \tilde{y}_t \\ \rho \tilde{w}_t \end{bmatrix}, \]  \hspace{1cm} (4.5)

with \( \Psi = \begin{bmatrix} b & c \end{bmatrix} \). It is the MSV solution forwarded one period and assuming that agents: (1) use
coefficients \( \Psi_{t-1} \) estimated in the previous period instead of the MSV coefficients \( b_{MSV} \) and \( c_{MSV} \), (2)
use only a limited set of endogenous variables $\bar{y}_t$ and shocks $\bar{w}_t$ in their expectation formation, and (3) know the processes of shocks $\bar{w}_t$. Notice that $E_t^* y_{t+1}^f$ are the period $t$ expectations on period $t+1$ values of forward-looking variables.

Agents estimate the coefficients $\Psi_t$ using a constant-gain variant of Recursive Least Squares:

$$
\Psi_t = \Psi_{t-1} + \gamma S^{-1}_{t-1} (y_{t-1}^f - \Psi_{t-1}^T X_{t-1})^T,
\quad S_t = S_{t-1} + \gamma (X_{t-1}X_{t-1}^T - S_{t-1}),
$$

where $X_t = (\bar{y}_{t-1}; \bar{w}_t)$ is the data vector used to estimate the beliefs, $S_t$ is the moment matrix for $X_t$, and $\gamma > 0$ is the gain parameter. Initial beliefs $\Psi_0$ are set to the corresponding MSV coefficients in $b_{MSV}$ and $c_{MSV}$.

Because the gain parameter is assumed to be a positive constant, the learning algorithm weighs recent data more heavily. Orphanides and Williams (2005, 2007) refer to this approach as “perpetual learning” because agents forget past data over time and hence learn permanently. The constant-gain recursive least squares algorithm is therefore widely used in the adaptive learning literature (see Eusepi and Preston, 2011; Milani, 2007; Slobodyan and Wouters, 2012, for example).

Now, we can insert the expression for $E_t^* y_{t+1}^f$ in the linear approximation of the model (4.1). This results in the following law of motion under learning

$$
\begin{bmatrix}
y_t \\
w_t
\end{bmatrix} = T_t \begin{bmatrix}
y_{t-1} \\
w_{t-1}
\end{bmatrix} + R_t \varepsilon_t,
$$

(4.7)

In contrast to the REE (see Equation (4.2)), the matrices $T_t$ and $R_t$ are time-dependent. In fact, they depend on the coefficient estimates $\Psi_{t-1}$. Equation (4.7) describes the dynamics of the model under learning.

In the benchmark model, agents have to form expectations on six forward-looking variables: consumption, investment, hours worked, inflation, Tobin’s $Q$, and the rental rate of capital. The impact of government spending on these variables depends on the parameters and underlying structure of the model. It is implausible to assume that agents have this structural knowledge and, hence, know the laws of motion of these forward-looking variables. In fact, as argued in the introduction, real-world decision makers are faced with cognitive and informational constraints in forming expectations about the future. Especially when it comes to the macroeconomic effects of fiscal policy, it is hard to believe that households and firms have perfect knowledge on how a fiscal policy shock affects aggregate variables in the next quarter. Therefore, the impulse response analysis in the following section will be executed under the assumption that the fiscal shock is not part of the data vector in the expectation formation. We believe that it is justifiable to assume this, in particular when agents were not confronted with a recent change in fiscal policy, because according to the learning approach, beliefs about the future are based on recently

---

4Tobin’s $Q$ is defined as $Q_t \equiv q_t / \lambda_t$, where $q_t$ is the Lagrangian multiplier with respect to the capital accumulation rule and $\lambda_t$ the Lagrangian multiplier with respect to the household’s budget constraint in the household’s optimization problem. See Appendix A for the derivations.
observed variable. In the benchmark model, our modus operandi implies that expectations on forward-looking variables are a linear function of the capital stock $K_t$, the technology shock $Z_t$, and the monetary shock $u_t^R$.

5 The role of expectations for the effects of government spending shocks

This section examines the effects of a government spending shock under different assumptions with respect to agents’ expectations. In particular, the macroeconomic effects of the shock under rational expectations are compared with those under adaptive learning. Because the role of price rigidity is of crucial importance, the benchmark model is examined in comparison with a neoclassical specification of the model where prices are fully flexible.

5.1 Calibration

We calibrate the model to quarterly periods. The parameters receive the values presented in Table 2. Most parameters are set to values that are typical in the business cycle literature. The elasticity of output with respect to capital, $\alpha$, is fixed to 1/3. The subjective discount factor, $\beta$, is calibrated to match an annualized steady state real interest rate of 4.0%. The value of $\delta$ is 0.025 so that the depreciation rate of capital is 2.5% per quarter. The elasticity of substitution between intermediate goods, $\varepsilon$, is such that the markup of price over marginal cost is equal to 20% in steady state. The Calvo (1983) parameter, $\theta$, is 0.75, implying an average frequency of price reoptimization of 4 quarters. The Taylor rule coefficients on inflation, $\rho_\Pi$, and output, $\rho_Y$, are set at 1.5 and 0.1 respectively, which are standard values in the literature. The AR(1) coefficients of technology, $\rho_Z$, and government expenditure, $\rho_G$, receive a value of 0.90. The coefficient of risk aversion, $\sigma$, is set to 2.0. Following Christiano et al. (2011), the capital adjustment cost parameter, $\varsigma$, is equal to 17. The share of government expenditure in GDP, $\bar{G}/\bar{Y}$, is set at 0.20 to match the postwar U.S. government spending share. The preference parameter $\phi$ is calibrated such that the share of time devoted to work in the steady state is fixed to 1/3. As a benchmark, the gain parameter, $\gamma$, is set to 0.02, which is a value well within the range of estimates reported in the literature. However, the particular value of the gain parameter is not crucial for our impulse response analysis. All error terms are assumed to have a standard deviation of 0.50. For simplicity, the AR(1) coefficient of the nominal interest rate, $\rho_R$, and the steady state debt-to-output ratio, $\bar{B}/\bar{Y}$, are assumed to be zero.

Table 3 shows the model values of some important macroeconomic aggregates. The calibration produces shares of private consumption and investment in GDP close to those observed in most industrialized countries. The steady-state labour’s share of total income is 0.56, a value roughly consistent with

---

Orphanides and Williams (2005, 2007) found that a gain parameter in the range 0.01–0.04 provides the best fit between the agents’ forecasts in the model and the expectations data from the Survey of Forecasters. Using a similar strategy, Branch and Evans (2006) obtain a value of 0.0345. The estimate of Milani (2007) equals 0.0183 and hence lies within the same range. However, the estimated gain of 0.0029 in Eusepi and Preston (2011) is much smaller. The estimation results from Slobodyan and Wouters (2012) provide values for $\gamma$ going from 0.001 to 0.06 depending on the particular learning scheme.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>Output elasticity with respect to capital</td>
<td>1/3</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Households subjective discount factor</td>
<td>$1.04^{-0.25}$</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Gain parameter</td>
<td>0.020</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Rate of physical capital depreciation</td>
<td>0.025</td>
</tr>
<tr>
<td>$\varepsilon$</td>
<td>Elasticity of substitution between intermediate goods</td>
<td>6.0</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Degree of nominal price rigidity</td>
<td>0.75</td>
</tr>
<tr>
<td>$\rho_G$</td>
<td>Government expenditure AR(1) coefficient</td>
<td>0.90</td>
</tr>
<tr>
<td>$\rho_{\Pi}$</td>
<td>Taylor rule inflation rate coefficient</td>
<td>1.5</td>
</tr>
<tr>
<td>$\rho_R$</td>
<td>Interest rate AR(1) coefficient</td>
<td>0.00</td>
</tr>
<tr>
<td>$\rho_Y$</td>
<td>Taylor rule output coefficient</td>
<td>0.10</td>
</tr>
<tr>
<td>$\rho_Z$</td>
<td>Technology shock AR(1) coefficient</td>
<td>0.90</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Coefficient of risk aversion</td>
<td>2.0</td>
</tr>
<tr>
<td>$\sigma_G$</td>
<td>Standard deviation of the fiscal disturbance $\varepsilon_G$</td>
<td>0.50</td>
</tr>
<tr>
<td>$\sigma_R$</td>
<td>Standard deviation of the interest rate disturbance $\varepsilon_R$</td>
<td>0.50</td>
</tr>
<tr>
<td>$\sigma_Z$</td>
<td>Standard deviation of the technology disturbance $\varepsilon_Z$</td>
<td>0.50</td>
</tr>
<tr>
<td>$\varsigma_I$</td>
<td>Capital adjustment cost parameter</td>
<td>17</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Preference parameter</td>
<td>0.35</td>
</tr>
<tr>
<td>$\bar{G}/\bar{Y}$</td>
<td>Steady state government expenditure to output ratio</td>
<td>0.20</td>
</tr>
</tbody>
</table>

**Table 2:** Model parameters.
Table 3: Steady-state values of main variables in the benchmark model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{C}{Y}$</td>
<td>0.601</td>
<td>$\frac{r^k}{T}$</td>
<td>0.277</td>
</tr>
<tr>
<td>$\frac{I}{Y}$</td>
<td>0.199</td>
<td>Annualized $r$</td>
<td>0.040</td>
</tr>
<tr>
<td>$\frac{W_N}{Y}$</td>
<td>0.555</td>
<td>Annualized $r^k$</td>
<td>0.147</td>
</tr>
</tbody>
</table>

the observed U.S. labour income share.\(^6\)

5.2 Impulse responses after a government spending shock

We consider an increase in government spending of 1% of GDP that is financed through an increase in lump-sum taxes.

**Neoclassical specification** Figure 1 shows the responses to the government spending shock when prices are fully flexible ($\theta \to 0.00$).\(^7\) The solid and dashed lines depict the impulse responses under Rational Expectations (RE) and Adaptive Learning (AL), respectively. Under rational expectations the effects of fiscal policy in a neoclassical model are well-understood – see for instance Baxter and King (1993). A temporary increase in government spending has a negative wealth effect, through additional taxes, resulting in a fall private consumption and leisure. As a consequence, labour supply increases which causes a fall in the real wage. The government absorption of resources reduces private investment. The fall in the capital-labour ratio raises the rental rate of capital $r^k_T$. The ratio converges to its steady-state value as investment recovers and both $W_t$ and $r^k_T$ return to their steady-state values.

Under the learning scheme we consider, agents fail to foresee the higher taxes in the future when they form expectations on forward-looking variables. The negative wealth effect is taken into account in the expectation formation only indirectly though the observed fall in the capital stock. That is why the change in agents’ expectations of consumption, employment, and other forward-looking variables is only limited. As a consequence, the adaptive learning mechanism diminishes the fall in consumption and reduces the increase in labour supply. The drop in disposable income is captured by a stronger contraction of investment. In the aggregate, the net impact of a government spending shock on output is slightly smaller under adaptive learning than under rational expectations.

Evans et al. (2012) also investigate the role of adaptive learning in an RBC model for different fiscal policy scenarios. In contrast with our approach, the authors assume that the policy change is announced credibly by policymakers, and agents have structural information on the fiscal rules or the government budget constraint and take this into account when forecasting the future path of taxes and expenditures. As an extension to the baseline impulse response analysis, we will discuss a similar learning mechanism in Section 7.2.

---

\(^6\) The U.S. labour income share in the industrial sector over the period 2000-2010 was on average 57% (OECD, 2013).

\(^7\) The impulse responses of all variables in the model are included in Section D of the Appendix.
**Figure 1:** Impulse responses to an increase in government spending of 1% of GDP in the neoclassical specification of the model. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters.
Figure 2: Impulse responses to an increase in government spending of 1% of GDP in the new Keynesian model. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters.

**New Keynesian specification** Figure 2 depicts the impulse responses after a government spending shock in the economy where prices are rigid. When agents have rational expectations, the effects of a fiscal expansion are similar to those under fully flexible prices. Quantitatively, however, the effect on hours worked is stronger because the rise in labour supply is accompanied by an outward shift in labour demand. As set forth by Rotemberg and Woodford (1991), Linnemann and Schabert (2003), Perotti (2008) and others, nominal rigidities generate a fall in the markup when the government boosts aggregate demand. This induces a rise in labour demand, which amplifies the increase in employment and reduces the fall in the real wage rate.

When agents form expectations using an adaptive learning mechanism, the effects of a government spending shock change substantially, especially with respect to the response of private consumption and real wages. In contrast to the neoclassical specification, government spending crowds in private consumption. This finding is particularly interesting since it is in accordance with the empirical evidence found in Auerbach and Gorodnichenko (2012), Blanchard and Perotti (2002), Fatás and Mihov (2001), Gali et al. (2007), Perotti (2008), and Tagkalakis (2008), for example.

There are several incentives engendering the representative household to increase its consumption. When preferences are non-separable, an increase in employment raises the marginal utility of consumption. Nominal price rigidity amplifies this effect because it strengthens the rise in employment caused
by the government spending shock. In spite of this, when agents have rational expectations the negative wealth effect of higher future taxes still dominates this mechanism leading to a net crowding out of private consumption in both the neoclassical and new Keynesian calibration of the model. Nonetheless, when agents form expectations by adaptive learning and prices are rigid, the net effect of government spending on consumption is positive. In that case, agents do not take the negative wealth effect of higher future taxes directly into account when forming beliefs about the future and the positive effect of higher employment is sufficiently strong to overrule the negative wealth effect. Hence, the expectation formation is of crucial importance in explaining the rise in private consumption.

The learning mechanism makes it possible to obtain the positive consumption response for a fairly low degree of non-separability of utility over consumption and leisure. Figure 3 shows the impulse responses of private consumption and output for different values of $\sigma$. The gray (light) shaded area in the right-hand plot shows that when economic agents have rational expectations, the impact of government spending on private consumption is negative for all considered values of $\sigma$. This is in sharp contrast with the impulse responses of the Adaptive Learning model depicted by the blue (dark) shaded area. It is clear that under the learning mechanism, the crowding in effect on consumption occurs even if $\sigma$ is small. However, in the limit case of $\sigma = 1$, when preferences are separable over leisure and consumption, this effect does not occur.

Another notable observation is the positive response of real wages under learning. Only when agents use the adaptive learning mechanism, the increase in aggregate hours after a positive government spending shock coexists with an increase in real wages. That is because the learning behaviour reduces the labour supply effect of the government spending shock, while price rigidity leads to a rise in labour demand. In the context of price rigidity it is optimal for a intermediate goods firm that cannot increase its price, to hire more production factors, including labour, which results in a net increase of the real wage rate. Considering this adaptive learning mechanism brings the theoretical impulse responses again in line with those observed empirically. Evidence on the comovement between real wages and hours worked after a government spending shock can be found in Rotemberg and Woodford (1992), Galí et al. (2007), and Fatás and Mihov (2001), for example. However, the empirical evidence is not entirely unambiguous (see, for instance, Ramey and Shapiro (1998), and Perotti (2008)). Another difference with the neoclassical specification, is the dampening effect of learning on the fall in investment.

6 Government Spending Multiplier

The question of the size of the government spending multiplier has been addressed by many authors in the literature. The growing empirical evidence that the size of the output multiplier can be much larger
than one, especially when the economy is in recession and the zero bound on the nominal interest rate binds, confronts the theoretical literature with an important challenge. In response to this, several authors have proposed different mechanisms such as alternative preference specifications (Linnemann, 2006), the existence of rule-of-thumb consumers (Galí et al., 2007), different kinds of rigidities, and the stance of monetary policy (Christiano et al., 2011; Coenen et al., 2012; Leeper et al., 2011).

Against that background, the discussion in the previous section shows that expectation formation too is a key factor for the impact of fiscal policy and that adaptive learning can amplify this impact substantially. Because in our learning mechanism agents do not account for the negative wealth effect of tax-financed government spending expansion in their expectation formation directly, private consumption can respond positively and in this way amplify the response of aggregate economic activity. An important result is that it is possible to achieve this outcome even if the degree of nonseparability between leisure and consumption in the utility function is weak, whereas in a model with rational expectations it is often necessary to assume (implausibly) high values for this parameter (see Linnemann, 2006; Bilbiie, 2009, 2011, for example).

In addition, adaptive learning provides a theoretical mechanism for generating government spending multipliers bigger than one, even if the price stickiness is relatively small. This is particularly relevant since the discussion in Nakamura and Steinsson (2008) points out that the extent of price rigidity is often overestimated. Figure 4 reports the multipliers for output, consumption, and investment for different degrees of price rigidity $\theta$. Moreover, the figure allows to compare the multipliers under rational expectations (RE) with those under adaptive learning (AL). The figure shows that for the benchmark case

![Image of Figure 3](image_url)
with \( \theta = 0.75 \), the output multiplier under learning is bigger than one and almost twice as large as the multiplier under rational expectations.

The consumption multiplier is increasing with the degree of price rigidity. As noted earlier, it is optimal for an intermediate firm that cannot change its price, to hire more labour when the demand for its intermediate good increases. This amplifies the raise in employment after a government spending increase, and encourages the household to consumption more when preferences are non-separable. Figure 4 shows that government spending crowds in private consumption when prices are sufficiently rigid. For example, if \( \theta = 0.75 \) the consumption multiplier equals 0.14. Moreover, notice that the crowding out of investment becomes smaller as prices become more sticky. Nevertheless, the investment multiplier always remains negative.

Figure 4: Impact multipliers for different degrees of price rigidity in the Rational Expectations (RE) model and the Adaptive Learning (AL) model.
7 Extensions and Robustness Analysis

7.1 Alternative specification of fiscal policy

A rich specification of fiscal policy  In the baseline impulse response analysis, the increase in government spending was financed through an increase in lump-sum taxes. This makes the results comparable with the policy experiments typically considered in the literature. As an extension, we consider a richer specification of fiscal policy in which the fiscal authority finances expenditure, interest payments, and lump-sum transfers through the emission of one-period debt and through taxation on private consumption and capital and labor income. Like Leeper et al. (2010) we allow the fiscal instruments to react to the government debt level and output deviations from the steady state.

The government budget constraint is given by

\[ B_{t+1} + \tau_c^t G_t + \tau_w^t W_t N_t + \tau_k^t r_t K_t = G_t + R_{t-1} \Pi_{t-1}^{-1} B_t + T R_t, \quad (7.1) \]

where \( \tau_c^t, \tau_w^t, \) and \( \tau_k^t \) are the tax rates on private consumption, labor income, and capital income, respectively, and \( T R_t \) are lump-sum transfers.\(^{9}\) The budget constraint is supplemented with the standard transversality condition for debt.

Government expenditure and lump-sum transfers evolve according to the following policy rules:

\[ \dot{G}_t = -\eta_g \dot{Y}_t - \theta_g \dot{B}_t + \dot{u}_g^R, \quad \dot{u}_g^R = \rho_g \dot{u}_g^{R-1} + \epsilon_g^R, \quad (7.2) \]

\[ \dot{T R}_t = -\eta_{TR} \dot{Y}_t - \theta_{TR} \dot{B}_t + \dot{u}_{TR}^R, \quad \dot{u}_{TR}^R = \rho_{TR} \dot{u}_{TR}^{R-1} + \epsilon_{TR}^R, \quad (7.3) \]

where \( \epsilon_g^R, \epsilon_{TR}^R \sim \mathcal{N}(0, \sigma_e^2) \). Usually expenditure and transfers are assumed to follow AR processes (see Forni et al., 2007; Galí et al., 2007; Bilbiie et al., 2008, for example). In our model, as in Chung and Leeper (2007) and Leeper et al. (2010), we allow them to adjust to changes in output and the debt level. First, the parameters \( \eta_g, \eta_{TR} > 0 \) imply that expenditure and lump-sum transfers are countercyclical and hence work as automatic stabilizers. Second, both instruments negatively adjust to a change in the debt level, i.e. \( \theta_g, \theta_{TR} > 0 \). Generally it is assumed that only lump-sum transfers work as debt-stabilizing instruments. By permitting spending to have the same effect, we allow for so-called “spending reversals”. This is confirmed by Corsetti et al. (2009) who find that episodes of deficit spending are often followed by a fall in government expenditure. Galí and Perotti (2003) also find that government spending is sensitive to the debt level.

The policy rules for the tax rates in log deviations from the steady state are

\[ \dot{\tau}_c^t = \eta_c \dot{Y}_t + \theta_c \dot{B}_t + \dot{u}_c^c, \quad \dot{u}_c^c = \rho_c \dot{u}_c^{c-1} + \epsilon_c^c, \quad (7.4) \]

\[ \dot{\tau}_w^t = \eta_w \dot{Y}_t + \theta_w \dot{B}_t + \dot{u}_w^w, \quad \dot{u}_w^w = \rho_w \dot{u}_w^{w-1} + \epsilon_w^w, \quad (7.5) \]

\[ \dot{\tau}_k^t = \rho_k \dot{u}_k^{c-1} + \epsilon_k^c. \quad (7.6) \]

\(^{9}\)In contrast to the benchmark model, we consider a lump-sum transfer \( T R_t \) instead of a lump-sum tax \( T_t \), but this is just a matter of definition since \( T_t = -TR_t \). It is more natural to proceed in this way since, with this alternative fiscal policy specification, the parameterisation of the model implies a negative lump-sum tax rate.
where \( \varepsilon_t^c, \varepsilon_t^k, \varepsilon_t^w \sim \mathcal{N}(0, \sigma^2) \). Similar to expenditure and transfers, the tax rates on capital and labor income respond to changes in output and government debt. We assume the coefficients \( \eta_k, \eta_w, \theta_k \) and \( \theta_w \) to be positive so that the tax rates stabilize both output and debt whenever they exceed their steady state value. The consumption tax rate, however, is assumed to follow an exogenous process. Indeed, this is consistent with empirical work such as Giorno et al. (1995) and Van den Noord (2000). We also assume that the tax rates do not affect one another since in the estimation results from Leeper et al. (2010) the co-movement coefficient between both tax rates turned out not to be significant.

**Calibration** The parameters from this rich fiscal policy block receive the values indicated in Table 4 shows. We set the output elasticity of government expenditure, \( \eta_g \), to \(-0.09\), which is the average of the values provided in Blanchard and Perotti (2002), Chung and Leeper (2007), Giorno et al. (1995), Leeper et al. (2010), Perotti (2004) and Van den Noord (2000). The output elasticity of the labor tax rate, \( \eta_w \), is assumed to be 0.31. Blanchard and Perotti (2002) and Perotti (2004) report a value 0.26 while the average estimate of Leeper et al. (2010) is 0.36. The output elasticity of transfers, \( \eta_{TR} \), is valued at \(-0.16\), taking into account the choices of Blanchard and Perotti (2002), Chung and Leeper (2007), Leeper et al. (2010) and Perotti (2004). The AR coefficients of the fiscal policy shocks are all set to 0.90. Empirical studies usually find that government expenditure shocks are highly persistent with an AR coefficient close to that value (see Bilbiie et al., 2008; Fatás and Mihov, 2001, Leeper et al. 2010, for example). This is also true for the estimated AR coefficients for the tax rules provided by Leeper et al. (2010). The steady state tax rates are the marginal total tax wedge, the value added tax rate, and the corporate income tax rate retrieved from the OECD (2010b) database. The values are averages over 30 OECD countries taken over the period 2000–2010. For the debt coefficients we use the average of the estimates in Leeper et al. (2010). For the ratio \( B/Y \) we used the average general government gross financial liabilities provided in the OECD (2010a) database over the period 1995–2008 for the OECD total.

**Government spending multipliers** The rich specification of fiscal policy allows us to compare government spending multipliers for different financing strategies for the government spending increase. Table 5 includes the results for three financing strategies. “Strategy 1” corresponds to the baseline analysis of a government spending increase financed through lump-sum taxation, without a change in government

---

1. Blanchard and Perotti (2002), Perotti (2004) and Chung and Leeper (2007) set the elasticity of government expenditure to zero, Giorno et al. (1995) to \(-0.2\), Van den Noord, Giorno et al. (1995) to \(-0.3\) and Leeper et al. (2010) to \(-0.03\).
2. Blanchard and Perotti (2002) and Perotti (2004) assume the output elasticity of transfers to be \(-0.2\) and Chung and Leeper (2007) estimate it to be \(-0.15\). In Leeper et al. (2010) the estimate is \(-0.12\) if we take the average over the various models.
3. The labor income tax is the combined central and sub-central government income tax plus employee social security contribution, as a percentage of average gross wage earnings. The capital income tax rate is the basic combined central and sub-central (statutory) corporate income tax rate given by the adjusted central government rate plus the sub-central rate. The tax rates are averaged over the period 2000-2010 and over the following OECD countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey and the United Kingdom. See OECD (2010b) for explanatory notes.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta_g$</td>
<td>Government expenditure $Y$ coefficient</td>
<td>0.03</td>
</tr>
<tr>
<td>$\eta_w$</td>
<td>Labour income tax $Y$ coefficient</td>
<td>0.36</td>
</tr>
<tr>
<td>$\eta_{TR}$</td>
<td>Lump-sum transfer $Y$ coefficient</td>
<td>0.13</td>
</tr>
<tr>
<td>$\eta_k$</td>
<td>Capital income tax $Y$ coefficient</td>
<td>1.7</td>
</tr>
<tr>
<td>$\theta_g$</td>
<td>Government expenditure debt coefficient</td>
<td>0.23</td>
</tr>
<tr>
<td>$\theta_w$</td>
<td>Labour income tax debt coefficient</td>
<td>0.05</td>
</tr>
<tr>
<td>$\theta_{TR}$</td>
<td>Lump-sum transfer debt coefficient</td>
<td>0.50</td>
</tr>
<tr>
<td>$\theta_k$</td>
<td>Capital income tax debt coefficient</td>
<td>0.39</td>
</tr>
<tr>
<td>$\rho_c$</td>
<td>Consumption tax AR coefficient</td>
<td>0.90</td>
</tr>
<tr>
<td>$\rho_k$</td>
<td>Capital income tax AR coefficient</td>
<td>0.90</td>
</tr>
<tr>
<td>$\rho_{TR}$</td>
<td>Lump-sum transfer AR coefficient</td>
<td>0.90</td>
</tr>
<tr>
<td>$\rho_w$</td>
<td>Labour income tax AR coefficient</td>
<td>0.90</td>
</tr>
<tr>
<td>$\bar{\tau}_c$</td>
<td>Steady state consumption tax rate</td>
<td>0.18</td>
</tr>
<tr>
<td>$\bar{\tau}_w$</td>
<td>Steady state labour income tax rate</td>
<td>0.45</td>
</tr>
<tr>
<td>$\bar{\tau}_k$</td>
<td>Steady state capital income tax rate</td>
<td>0.29</td>
</tr>
<tr>
<td>$B/Y$</td>
<td>Steady state debt to output ratio</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Table 4: Parameters for the alternative fiscal policy specification.

debt and in the absence of other fiscal instruments. In “Strategy 2” the rich specification of fiscal policy is considered for which the fiscal instruments evolve according to the rules (7.2)–(7.6). Consequently, government spending, lump-sum taxes, the capital income tax rate, and the labour income tax rate stabilize output and debt. Hence, in this financing strategy, the government spending increase is financed through these fiscal instruments and through debt. In “Strategy 3” we consider the experiment where the lump-sum tax is the only debt-stabilizing instrument, and there is no output-stabilization by any of the fiscal instruments.\(^\text{13}\) Table 5 shows that the differences in the financing strategies only have a minor effect on the impact multipliers. Irrespective of the financing strategy, the multipliers under adaptive learning remain substantially bigger than under rational expectations. When distortionary taxes are used to finance the government expenditure increase (Strategy 2), the output multiplier is somewhat smaller for both expectation formation mechanisms, because the increase in the labour income tax rate and the capital income tax rate diminishes the raise in employment and affects private investment. For both the Adaptive Learning model and the Rational Expectations model, the multiplier is the biggest when the government spending increase is financed through lump-sum taxation and debt (Strategy 3). Under adaptive learning, the multiplier reaches a value of 1.16. The impulse responses for the different financing strategies are shown in the appendix.

\(^\text{13}\) Consequently, all output coefficients ($\eta_g$, $\eta_w$, $\eta_{TR}$, and $\eta_k$) and the debt coefficients in the fiscal rules for government expenditure, the labour income tax rate, the capital income tax rate ($\theta_g$, $\theta_w$, and $\theta_k$) are set to zero. The lump-sum transfer debt coefficient $\theta_{TR}$ retains the value of 0.50.
Impact multiplier Financing strategy

<table>
<thead>
<tr>
<th></th>
<th>Strategy 1 (T)</th>
<th>Strategy 2 (T, B, τ, τ')</th>
<th>Strategy 3 (T, B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RE</td>
<td>AL</td>
<td>RE</td>
</tr>
<tr>
<td>∆Y/∆G</td>
<td>0.62</td>
<td>1.07</td>
<td>0.66</td>
</tr>
<tr>
<td>∆C/∆G</td>
<td>−0.25</td>
<td>0.10</td>
<td>−0.22</td>
</tr>
<tr>
<td>∆I/∆G</td>
<td>−0.13</td>
<td>−0.03</td>
<td>−0.11</td>
</tr>
</tbody>
</table>

Table 5: Impact multipliers for different specifications of fiscal policy in the Rational Expectations (RE) model and the Adaptive Learning (AL) model. See main text for a description of the different financing strategies.

7.2 Alternative setup of the learning dynamics: heterogeneous expectations

In the previous sections, the adaptive learning setup was such that the government spending shock was not part of the information set in the expectation formation mechanism. We have argued that it is indeed more realistic to assume that agents have incomplete information about the effects of government spending shock, instead of having complete knowledge of the underlying structure and parameters of the economy. By doing so, the learning setup considered in this paper deviates from the one followed by Evans et al. (2009, 2012), where the authors assume that agents use an adaptive learning mechanism to forecast future aggregate variables, but have structural knowledge about the fiscal rules or the government budget constraint. In particular, agents have perfect knowledge on the effect of the government spending shock on future taxes, but have imperfect knowledge on the general equilibrium effects on other forward-looking variables. Indeed, according to Evans et al. (2012) it is plausible to assume that agents know the implications of an increase in government spending for (future) taxes, but lack knowledge on the structure of the economy to fully understand the effects of such policies on aggregate variables such as future interest rates and GDP.

Considering this, we adapt our learning approach to allow for this asymmetry in expectation formation. We follow a similar approach as Evans et al. (2012) and consider the following consumption function

\[ C_t = \beta R_t E_t \left[ \Pi_{t+1} (1 - N_t) (1 - \phi) (1 - \sigma) (1 - N_{t+1}) (1 - \phi) (1 - \sigma) \right] \]

instead of the typical Euler equation for consumption. This allows us to distinguish between the expectations on future taxes and those on other forward-looking variables. We translate this idea into our model, by replacing the forecast rule (4.5) by the following two rules:

See Section A of the Appendix for the full set of model equations.
\[ E_t^*T_{t+1} = \hat{b}_{1,1}K_t + \hat{\epsilon}_{1,1}\rho_1 Z_t , \quad (7.8) \]

\[
\begin{bmatrix}
E_t^*I_{t+1} & E_t^*N_{t+1} & E_t^*\Pi_{t+1} & E_t^*Q_{t+1} & E_t^*r_{t+1}^k & E_t^*Y_{t+1}
\end{bmatrix}^T = \hat{b}_{2,1}K_t + \hat{\epsilon}_{2,1}\rho_2 Z_t . \quad (7.9)
\]

The government spending shock \( G_t \) is part of the information set of the forecasting model for \( T_{t+1} \), but not for the other forward-looking variables. Consequently, the agents perfectly anticipate the path of future taxes implied by the government spending shock, but do not have structural knowledge on the general equilibrium effects of this shock on the other variables they need to forecast.

**Neoclassical specification**  Figure 5 shows the macroeconomic dynamics of a government spending increase under this alternative adaptive learning mechanism and under rational expectations when prices are fully flexible. At impact, agents that use the learning mechanism fully anticipate the future path of higher taxes but fail to correctly forecast the positive effect of government spending on future pre-tax income. This leads to an excessive fall in private consumption which induces an increase in savings that is reflected in an increase in private investment. The pessimistic forecasts of future income also boosts labour supply, which causes a fall in real wages. However, the increased capital stock leads to an upward revision of the output forecasts and an improvement of the capital-labour ratio from the next quarter onwards. Consequently, the recovery of private consumption and the wage rate occurs more rapidly than under rational expectations. In this neoclassical specification of the model, the learning mechanism enhances the output effect of a government spending increase.

**New Keynesian specification**  The impulse responses for the new Keynesian specification of the model are depicted in Figure 6. As in the neoclassical specification, the government spending shock, reduces both the wage rate and the cost of capital. This results in a fall of marginal costs, and hence, of the aggregate price level. Because of the Calvo lottery for the intermediate sector, a fraction of intermediate firms cannot reset its price and will lower demand for labour and capital instead. This explains why the net effect on employment is lower than under rational expectations and the decline in real wages is more pronounced. Moreover, the rise in investment is somewhat weakened. In the aggregate, the impact effect on output is lower under learning. In general, the alternative specification of the adaptive learning mechanism results in impulse responses that are in contrast with a large part of the literature. An increase in government spending is typically associated with an increase in marginal costs, and hence inflation (see Christiano et al., 2011; Hall, 2009; Monacelli and Perotti, 2008, for instance).
Figure 5: Impulse responses to an increase in government spending of 1% of GDP in the neoclassical specification of the model. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters.
Figure 6: Impulse responses to an increase in government spending of 1% of GDP in the new Keynesian model. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters.
8 Conclusion

This paper assesses the role of expectations for the macroeconomic effects of an increase in government spending and, in particular, the size of the government spending multiplier. There is no doubt that it is implausible to assume that agents have complete knowledge of the structure of the economy. Therefore, we consider a model where agents have to use an adaptive learning mechanism to form expectations about forward-looking variables. Especially when it comes to fiscal policy, we argue that agents do not know how a policy shock affects future aggregate variables such as the future interest rate, wage rate, or employment. Therefore, we consider an expectation formation mechanism where the fiscal shock is not part of the data vector. As a consequence, a rise in government spending is not taken into account directly by the agents when forming expectations. The impulse responses under this type of learning show that the effects of expansionary fiscal policy crucially depend on the agents’ beliefs about the future.

This paper provides a new explanation for a positive consumption response to a government spending boost. Indeed, when prices are rigid and preferences non-separable in consumption and leisure, government spending crowds in private consumption under learning. Moreover, this Adaptive Learning model relies less on non-separability in utility and price stickiness to deliver high output multipliers. Moreover, the learning mechanism induces a positive comovement between real wages and hours worked after a government spending shock in the new Keynesian model.

Expectations significantly influence the size of the multipliers of output, private consumption, and investment. In contrast to the Rational Expectations model, it is possible to have an output multiplier that is substantially larger than one for plausible degrees of price rigidity. When the Calvo parameter \( \theta \) equals 0.75 the new Keynesian Adaptive Learning model generates an output multiplier of 1.05, a value that is almost twice as large as the multiplier under rational expectations. The investment multiplier for this Adaptive Learning model is larger than for the Rational Expectations model, but remains negative for the degrees of price rigidity considered.

Evans et al. (2009, 2012) argue that agents may know the fiscal consequences of a change in fiscal policy. Therefore, we complement the benchmark learning setup with an alternative specification of learning where agents know the future path of taxes implied by the government spending shock. This alternative model predicts an excessive fall in private consumption in response to a government spending increase, because the negative wealth effect of future higher taxes is fully anticipated, whereas the positive impact on other (aggregate) variables, such as future pre-tax income and employment, is not. The implied increase in savings leads to an increase in private investment. Moreover, this excessive “pessimism” magnifies the rise in labour supply, resulting in a greater decline in real wages than under rational expectations. The responses of these variables seem at odds with contributions in the empirical literature that predict a crowding in of private consumption and a rise in real wages. Furthermore, the rise in government spending is associated with a fall in the inflation rate. Hence, the predictions of this alternative learning model seem incompatible with a large part of the literature, where an increase in government spending is typically associated with an increase in inflation. On the other hand, our benchmark learning setup yields responses that are largely consistent with this evidence.
Bibliography


Appendices

A Derivations of Model Equations

A.1 Household’s Optimization Problem

The Lagrangian associated with the household’s optimization problem is given by

\[ \mathcal{L} = E_0 \sum_{t=0}^\infty \beta^t \left\{ U(C_t, 1 - N_t) + \lambda_t \left[ W_t N_t + r_t^k K_t + R_{t-1} \Pi_t^{-1} B_t + D_t - T_t - C_t - I_t - B_{t+1} \right] + q_t \left[ (1 - \delta) K_t + I_t - \mathcal{J}(K_t, I_t, I_{t-1}) - K_{t+1} \right] \right\}. \]

The associated optimality conditions are

\[
\begin{align*}
\frac{\partial \mathcal{L}}{\partial C_t} &= 0 \quad \Leftrightarrow \quad U_{C,t} = \lambda_t, \\
\frac{\partial \mathcal{L}}{\partial (1 - N_t)} &= 0 \quad \Leftrightarrow \quad U_{1-N,t} = \lambda_t W_t, \\
\frac{\partial \mathcal{L}}{\partial B_{t+1}} &= 0 \quad \Leftrightarrow \quad \beta E^*_t \left( \lambda_{t+1} R_t \Pi_{t+1}^{-1} \right) = \lambda_t \Leftrightarrow R_t = E^*_t \left( \frac{\lambda_t \Pi_{t+1}}{\beta \lambda_{t+1}} \right), \\
\frac{\partial \mathcal{L}}{\partial I_t} &= 0 \quad \Leftrightarrow \quad \lambda_t = q_t (1 - \mathcal{J}_{t,t}) - \beta E^*_t \left( q_{t+1} \mathcal{J}_{t+1,t+1} \right), \\
\frac{\partial \mathcal{L}}{\partial q_t} &= 0 \quad \Leftrightarrow \quad W_t N_t + r_t^k K_t + R_{t-1} \Pi_t^{-1} B_t + D_t - T_t - C_t - I_t - B_{t+1} = 0, \\
\frac{\partial \mathcal{L}}{\partial \lambda_t} &= 0 \quad \Leftrightarrow \quad (1 - \delta) K_t + I_t - \mathcal{J}(K_t, I_t, I_{t-1}) - K_{t+1} = 0.
\end{align*}
\]

Combining conditions (A.1) and (A.2) yields the labor supply equation

\[ W_t = \frac{U_{1-N,t}}{U_{C,t}}. \quad \text{(A.6)} \]

Conditions (A.1) and (A.3) allow us to derive the following Euler equation for consumption

\[ U_{C,t} = \beta R_t E^*_t \left( \Pi_{t+1}^{-1} U_{C,t+1} \right). \quad \text{(A.7)} \]

Optimality conditions (A.4) and (A.5) can be further simplified using condition (A.3). We get that

\[
\begin{align*}
1 &= Q_t \left[ 1 - \mathcal{J}_{t,t} \right] - R_t^{-1} E^*_t \left[ \Pi_{t+1} Q_{t+1} \mathcal{J}_{t+1,t+1} \right], \\
Q_t &= R_t^{-1} E^*_t \left[ \Pi_{t+1} \left\{ r_{t+1}^k + Q_{t+1} (1 - \delta - \mathcal{J}_{t+1,t+1}) \right\} \right],
\end{align*}
\]

where Tobin’s \( Q_t \equiv q_t / \lambda_t \).
Functional Form Assumptions In the benchmark model we consider the following specification of preferences and the capital adjustment cost function:

\[ U(C_t, 1 - N_t) = \left[ \frac{C_t}{1 - N_t} \right]^{1-\phi} - 1, \]

\[ \mathcal{S}(\cdot) = \frac{\zeta}{2} \left( \frac{I_t}{K_t - \delta} \right)^2 K_t, \]

where \( \zeta > 0 \) is the Lucas and Prescott (1971) capital adjustment cost parameter. For these functional forms, the optimality conditions (A.6), (A.7), (A.8), and (A.9) become

\[ W_t = \frac{1 - \phi}{\phi} \frac{C_t}{1 - N_t}, \]

\[ C_t^{(1-\sigma)-1} (1 - N_t)^{\phi(1-\sigma)} = \beta R^* E_t \left[ \sum_{i=N_t+1}^{\infty} C_t^{(1-\sigma)-1} (1 - N_t)^{\phi(1-\sigma)} \right], \]

\[ 1 = Q_t \left[ 1 - \zeta \left( \frac{I_t}{K_t - \delta} \right) \right], \]

\[ Q_t = R_t^{-1} E_t \left[ \Pi_t \left[ r_{t+1} + Q_t \left( 1 - \delta - \zeta \left( \frac{I_t}{K_t - \delta} \right) \left( \frac{1}{2} \left( \frac{I_t}{K_t - \delta} \right) - \frac{I_t}{K_t \delta} \right) \right] \right] \].

A.2 Firms’ Optimization Problem

A.2.1 Final Good Sector

The profit maximization problem of the final good firm is represented as

\[ \max_{Y_t(i)} P_t Y_t - \int_0^1 P_t(j) Y_t(j) dj, \quad \forall i \in [0, 1], \]

where both the final good price \( P_t \) and the prices for the intermediate goods \( P_t(i), j \in [0, 1], \) are taken as given. Profit maximization yields the following demand schedule for intermediate good \( i \):

\[ Y_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t. \quad (3.5) \]

The final good producers are perfectly competitive. Thus, we have the following zero-profit condition

\[ P_t \left( \int_0^1 Y_t(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}} - \int_0^1 P_t(i) Y_t(i) di = 0. \]

This leads to the following expression for the final good price

\[ P_t = \left( \int_0^1 P_t(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}. \]

In the symmetric equilibrium all intermediate good producers set the same price. Therefore, the aggregate price \( P_t \) and the intermediate good prices \( P_t(i) \) for all \( i \) will be the same.
A.2.2 Intermediate Goods Sector

The Lagrangian for the expenditure minimization problem for the intermediate good producer $i$ is given by

$$ L = W_t N_t(i) + R^k_t K_t(i) + \mu_t(i) \left[ Y_t(i) - Z_t K_t(i) \alpha N_t(i) \right] , $$

and the corresponding first-order conditions

$$ W_t = \mu_t(i) (1 - \alpha) Z_t K_t(i) \alpha N_t(i) , $$

$$ R^k_t = \mu_t(i) \alpha Z_t K_t(i) \alpha N_t(i) 1 - \alpha . $$

Here the Lagrange multiplier is also the real marginal cost. Therefore we will define the real marginal cost of firm $i$ as $MC_t(i) = \mu_t(i)$. In the symmetric equilibrium real marginal cost is common to all firms and given by

$$ MC_t = \alpha^{-\alpha} (1 - \alpha)^{\alpha - 1} \left( R^\alpha_t \right)^{\alpha} W_t 1 - \alpha Z_t^{-1} . $$

Intermediate good producers choose the price $P^*_t(i)$ that maximizes discounted real profits

$$ E^*_t \sum_{k=0}^{\infty} \left( \beta \theta \right)^k \frac{UC_t + k}{UC_t} \left\{ \frac{P^*_t(i)}{P_{t+k}} Y_{t+k}(i) - MC_t Y_{t+k}(i) \right\} $$

subject to

$$ Y_{t+k}(i) = \left( \frac{P^*_t(i)}{P_{t+k}} \right)^{-\epsilon} Y_{t+k} . \quad (A.10) $$

The corresponding first-order condition is

$$ E^*_t \sum_{k=0}^{\infty} \left( \beta \theta \right)^k \frac{UC_t + k}{UC_t} P^*_t Y_{t+k} \left\{ (1 - \epsilon)(P^*_t(i))^{-\epsilon} P_{t+k}^{-1} + \epsilon MC_t Y_{t+k} (P^*_t(i))^{-\epsilon - 1} \right\} = 0 $$

$$ \Leftrightarrow P^*_t(i) = \frac{\epsilon}{\epsilon - 1} \frac{E^*_t \sum_{k=0}^{\infty} \left( \beta \theta \right)^k \frac{UC_t + k}{UC_t} P^*_t Y_{t+k} MC_t + k P_{t+k}^{-1} Y_{t+k}}{E^*_t \sum_{k=0}^{\infty} \left( \beta \theta \right)^k \frac{UC_t + k}{UC_t} P^*_t Y_{t+k} } \quad (A.11) $$

Given Calvo pricing, the price index (A.2.1) can be written as

$$ P_{t+k}^{1-\epsilon} = (1 - \theta) (P^*_t(i))^{1-\epsilon} + \theta P_{t-1}^{1-\theta} \quad (A.12) $$

Log-linearization of the equilibrium conditions (A.11) and (A.12) around the zero inflation steady state yields the familiar new Keynesian Phillips curve.
B Steady State Analysis

\[ MC = \frac{\varepsilon - 1}{\varepsilon} \quad \bar{Y} = \text{given} \quad \bar{N} = \text{given} \]
\[ R = \frac{1}{\beta} \quad \bar{r}^k = \bar{R} - 1 + \delta \quad \bar{K} = \frac{\alpha \bar{Y} MC}{\bar{r}^k} \]
\[ I = \delta \bar{K} \quad Z = \frac{\bar{Y}}{K^\alpha \bar{N}^{1 - \alpha}} \quad \bar{G} = \frac{\bar{Y}}{\bar{Y}} \]
\[ T = \bar{G} \quad \bar{C} = \bar{Y} - I - \bar{G} \quad W = (1 - \alpha) MC \frac{\bar{Y}}{\bar{N}} \]
\[ \bar{Q} = 1 \quad \bar{\Pi} = 1 \]

C Log-linearization

C.1 New Keynesian specification

For the new Keynesian model we have the following log-linearized equilibrium conditions:

\[ \hat{Y}_t = \left( 1 - \frac{\bar{G}}{\bar{Y}} - \frac{I}{\bar{Y}} \right) \hat{C}_t + \frac{\bar{G}}{\bar{Y}} \hat{G}_t + \frac{I}{\bar{Y}} \hat{I}_t, \]
\[ \hat{Y}_t = \hat{Z}_t + \alpha \hat{K}_t + (1 - \alpha) \hat{N}_t, \]
\[ \hat{\Pi}_t = \frac{(1 - \theta)(1 - \beta \theta)}{\theta} \frac{MC_t + \beta \Pi_{t+1}}{\bar{Y}}, \]
\[ \hat{W}_t = \alpha \hat{K}_t + \hat{Z}_t + MC_t + \hat{K}_t (\alpha - 1), \]
\[ \hat{r}_t = (1 - \alpha) \hat{N}_t + \hat{Z}_t + MC_t + \hat{K}_t (\alpha - 1), \]
\[ \hat{K}_{t+1} = \hat{K}_t (1 - \delta) + \hat{I}_t \hat{\delta}, \]
\[ \hat{R}_t = \rho_n \hat{\Pi}_t + \hat{u}_t^R, \]
\[ \hat{u}_t^R = \rho_R \hat{u}_{t-1}^R + \varepsilon_t^R, \]
\[ \hat{Z}_t = \rho_Z \hat{Z}_{t-1} + \varepsilon_t^Z, \]
\[ \hat{G}_t = \rho_G \hat{G}_{t-1} + \varepsilon_t^G, \]
\[ \hat{I}_t = \hat{G}_t, \]
\[ \hat{C}_t + \hat{\Pi}_t \frac{\bar{N}}{1 - \bar{N}} = \hat{W}_t, \]
\[ \hat{C}_t (\phi (1 - \sigma) - 1) - \frac{\hat{N}_t (1 - \sigma) (1 - \phi)}{1 - \bar{N}} = \hat{R}_t - \hat{\Pi}_{t+1} + (\phi (1 - \sigma) - 1) \hat{C}_{t+1} - \frac{(1 - \sigma) (1 - \phi) \bar{N} \hat{N}_{t+1}}{1 - \bar{N}}, \]
\[ \hat{Q}_t = -\hat{R}_t + \hat{\Pi}_{t+1} + \beta \left( \hat{r}_t^k + (1 - \delta) \hat{Q}_{t+1} + \zeta_t \delta^2 (\hat{I}_t + \hat{\Pi}_{t+1}) \right), \]
\[ \hat{Q}_t = \delta \zeta_t (\hat{I}_t - \hat{\Pi}_t), \]

where a circumflex denotes log-deviations from the steady state. Hence, the dynamics of the model are characterized by a set of 15 log-linearized equilibrium conditions in 15 variables.
C.2 Neoclassical specification

The log-linearized equilibrium conditions characterizing the dynamics of the neoclassical specification of the model are the following:

\[
\dot{Y}_t = \left(1 - \frac{\bar{G}}{\bar{Y}} - \frac{\bar{I}}{\bar{Y}}\right) \dot{C}_t + \frac{\bar{G}}{\bar{Y}} \dot{G}_t + \frac{\bar{I}}{\bar{Y}} \dot{I}_t,
\]

\[
\dot{Y}_t = \dot{Z}_t + \alpha \dot{K}_t + (1 - \alpha) \dot{N}_t,
\]

\[
\dot{W}_t = \alpha \dot{K}_t + \dot{Z}_t - \alpha \dot{N}_t,
\]

\[
\dot{r}_t^k = (1 - \alpha) \dot{N}_t + \dot{Z}_t + \dot{K}_t (\alpha - 1),
\]

\[
\ddot{K}_{t+1} = \dot{K}_t (1 - \delta) + \dot{I}_t \delta,
\]

\[
\dot{Z}_t = \rho Z_{t-1} + \epsilon^Z_t,
\]

\[
\dot{G}_t = \rho_G G_{t-1} + \epsilon^G_t,
\]

\[
\dot{T}_t = \dot{G}_t,
\]

\[
\dot{C}_t + \frac{\bar{N}}{1 - \bar{N}} = \dot{W}_t,
\]

\[
\dot{C}_t (\phi (1 - \sigma) - 1) - \frac{\bar{N}_t (1 - \sigma) (1 - \phi) \bar{N}}{1 - \bar{N}} = \dot{R}_t + (\phi (1 - \sigma) - 1) \dot{C}_{t+1} - \frac{(1 - \sigma) (1 - \phi) \bar{N} \bar{N}_{t+1}}{1 - \bar{N}},
\]

\[
\dot{Q}_t = -\dot{R}_t + \beta \left[\frac{\bar{r}_t^k r_{t+1}^k + (1 - \delta) \dot{Q}_{t+1} + \varphi \delta^2 (\dot{I}_{t+1} - \dot{K}_{t+1})}{\bar{r}_t^k + (1 - \delta) \dot{Q}_{t+1} + \varphi \delta^2 (\dot{I}_{t+1} - \dot{K}_{t+1})}\right],
\]

\[
\dot{Q}_t = \delta \varphi \left(\dot{I}_t - \dot{K}_t\right).
\]

D Extensions and Robustness Exercises

D.1 Alternative specification of fiscal policy

In Section 7.1 we extend the benchmark model with a rich fiscal policy block and distinguish between three financing strategies. Figure 7 shows the impulse responses to an increase in government spending of 1% of GDP for these different specifications of fiscal policy. Figure 8 shows the expectations of forward-looking variables for these two models.

D.2 Alternative setup of the learning dynamics: heterogeneous expectations

For the new Keynesian specification of the model economy, the impulse responses after a government spending increase for the benchmark model and the model with heterogeneous expectations are shown in Figure 9. The expectations on forward-looking variables are depicted in Figure 10. For the neoclassical specification, the corresponding impulse responses are shown in Figure 11 and Figure 12.
Benchmark (T-financed G-shock)
- Debt- and output-stabilization by G, TR, τ^k, and τ^w
- Debt-stabilization by TR only; no output-stabilization

Figure 7: Impulse responses to an increase in government spending of 1% of GDP of the new Keynesian
model for different fiscal policy specifications. The impulse response functions are measured
in percentage deviations from steady-state. The horizontal axis measures quarters.
Figure 7: Impulse responses to an increase in government spending of 1% of GDP of the new Keynesian model for different fiscal policy specifications. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters. (continued)
Figure 8: Expectations on forward-looking variables after a government spending shock of 1% of GDP of the new Keynesian model for different fiscal policy specifications. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters.
Figure 9: Impulse responses to an increase in government spending of 1% of GDP of the new Keynesian model under different expectation formation mechanisms. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters.
Figure 10: Expectations on forward-looking variables after a government spending shock of 1% of GDP in the new Keynesian model under different expectation formation mechanisms. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters.
Figure 11: Impulse responses to an increase in government spending of 1% of GDP for the neoclassical specification of the model under different expectation formation mechanisms. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters.
Figure 12: Expectations on forward-looking variables after a government spending shock of 1% of GDP in the neoclassical specification of the model under different expectation formation mechanisms. The impulse response functions are measured in percentage deviations from steady-state. The horizontal axis measures quarters.