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Monetary and fiscal policy under deep habits

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Allowing habits to be formed at the level of individual goods – deep habits - can radically alter the fiscal policy transmission mechanism as the counter-cyclicality of mark-ups this implies can result in government spending crowding-in rather than crowding-out private consumption in the short run. We explore the robustness of this mechanism to the existence of price discrimination in the supply of goods to the public and private sectors. We then describe optimal monetary and fiscal policy in our New Keynesian economy subject to the additional externality of deep habits and explore the ability of simple policy rules to mimic fully optimal policy. We find that the presence of deep habits at empirically estimated levels can imply large externalities that significantly affect the conduct of monetary and tax policy. However, despite the rise in government spending multipliers implied by deep habits, government spending is barely used as a stabilisation tool under the optimal policy.

1. Introduction

Deep habits (see Ravn et al., 2006, 2012), which occur at the level of the individual goods, rather than total household consumption, can improve the empirical performance of standard DSGE models in various dimensions. Aside from replicating the hump-shaped response of key variables to monetary policy shocks and adding inertial behavior more generally (as do other forms of habits), they also imply, consistently with the data, countercyclical markups and the crowding in of private sector consumption following increases in government spending. The latter property raises the government spending multiplier from well below one in the benchmark New Keynesian model, to above one.[1,2] The intertemporal nature of the pricing problem for firms, which face a dynamic demand curve as a result of deep habits, further implies that the transmission mechanism of monetary policy is altered too, with monetary policy affecting pricing

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[1] An alternative, commonly used extension to the benchmark model which is designed to achieve the crowding in of private consumption is to assume a proportion of households only consume out of current income and neither borrow nor save – see Gali et al. (2007) and Bilbiie (2009). We prefer to use the deep habits device for both theoretical and empirical reasons. While the assumption that some households are credit constrained may be justifiable, precluding the possibility of saving seems less so. Moreover, Colciago (2011) argues that the mechanism through which the crowding in occurs and the number of households that must be hand-to-mouth consumers for the crowding in effect to be achieved are not consistent with the data.

[2] Recent work looking at optimal monetary and fiscal policy in sticky-price New Keynesian models (see, for example, Schmitt-Grohe and Uribe, 2004a; Benigno and Woodford, 2003) typically finds that fiscal policy should be largely devoted to ensuring fiscal solvency, while monetary policy plays a demand management role. However, such models contain the usual crowding out effects from public consumption such that the efficacy of fiscal policy as a stabilization device may be thought to necessarily be limited.

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decisions directly. Finally, deep habits, which are of an external type, imply that the distortions present in the modelled economy, which effectively define the trade-offs facing the policy maker, are significantly different from those typically found in New Keynesian models. In this paper, we explore the implications for optimal monetary and fiscal stabilization policy of introducing this new distortion to policy making and the implied fundamental changes in the macroeconomic response to shocks. We now turn to motivate our exploration of the policy problem under deep habits more fully, before outlining the key results and plan of the rest of the paper.

Literature on deep habits: Empirical evidence generally finds that output, consumption and real wages increase in response to an unexpected increase in government spending, see inter alia (Fatas and Mihov, 2001; Blanchard and Perotti, 2002; Gali et al., 2007; Zubairy, 2010b, 2010c; Ravn et al., 2012). Contrary to this evidence, standard Real-Business Cycle models, for example Baxter and King (1993), and New Keynesian models, such as Fatas and Mihov (2001), find instead a crowding out effect: private consumption falls after a positive government spending shock. This result comes from the fact that after a government spending shock households face a negative wealth effect and inevitably lower their consumption and increase hours worked. The increase in labor supply also causes real wages to fall, another result at odds with the empirical evidence.

Ravn et al. (2006) show that the crowding in effect of public spending on private consumption can be induced in a standard RBC model where firms have some monopolistic power and agents' preferences contain deep habits in consumption of individual goods. Deep habits imply a downward-sloping demand function that depends on the lagged level of consumers' purchases of that specific good. Since firms take this demand function as a constraint in their optimal price-setting problem, deep habits have pronounced implications for aggregate supply. In particular, the inelastic part of the demand function due to the impact of consumers' past purchases of a specific good implies that, *ceteris paribus*, an increase in demand for the good generates an incentive for firms to lower markups. Hence, deep habits can successfully mimic the countercyclicality of firms' markups generally found in the data. Accordingly, an increase in government spending, which raises aggregate demand, leads to a decline in firms' markups. This shifts the labor demand curve outward, increasing real wages. In turn, the rise in wages induces households to substitute consumption for leisure. At plausible estimates of the degree of deep habits, this substitution effect may be strong enough to offset the negative wealth effect coming from the increase in public consumption, resulting in an equilibrium increase in private consumption, see Ravn et al. (2006, 2012) and Zubairy (2010b). When considering deep habits in an open economy context, Ravn et al. (2012) find that a two-country RBC model augmented with deep habits can not only provide a rationale for the countercyclical markup and increase in private consumption, but also for an initial depreciation in the real exchange rate following a government spending shock, a feature consistent with the empirical evidence. Moreover, deep habits share with their superficial counterpart[3] the same aggregate demand behavior, such that models featuring deep habits still retain the empirically desirable hump-shaped response of key aggregate variables after a monetary shock, see Ravn et al. (2010) and Leith et al. (2012).

Given that deep habits imply empirically appealing impulse responses to key macroeconomic shocks, it is not surprising that estimation of models with deep habits is typically preferred to their superficial counterparts. Ravn et al. (2010) introduce deep habits into a standard medium scale sticky-price/ sticky-wage model and estimate the key parameters using a limited information approach. They find that the model with deep habits provides a superior fit to the identified dynamic effects of monetary policy shocks compared with superficial habits. Moreover, the model with deep habits can account simultaneously for the persistent impact of monetary policy shocks on consumption, for the price puzzle, and inflation persistence. Similar evidence in favor of deep habits is found by Zubairy (2010a, 2010b). Lubik and Teo (2011) derive and estimate a New Keynesian Phillips curve (NKPC) in a model with deep habits and show that such habits alter the NKPC in a fundamental manner as it introduces expected and contemporaneous consumption growth, as well as the expected marginal value of future demand, as additional driving forces for inflation dynamics. Estimating the structural parameters of the model using a GMM technique, they find that the fit of the deep habits NKPC is much improved over the standard NKPC.

Motivation and plan: Aside from potentially raising the efficacy of government spending policy, as suggested by the evidence discussed above, the modelling of deep habits has further important implications for policy. Firstly, firms' current pricing decisions affect the stock of habits possessed by their customers and therefore future levels of demand for the good they produce. This intertemporal aspect to pricing decisions, on top of that implied by nominal inertia, means that monetary policy will have a direct effect on firms' pricing decisions and hence inflation. Secondly, the habits externality, whereby households do not take account of the impact of their consumption decisions on the welfare of others, implies that there is an additional distortion in the economy beyond those associated with monopolistic competition and nominal inertia. For standard estimates of the extent of habits formation, this distortion will dominate to such an extent that it implies a highly distorted economy, as in Levine et al. (2008). As a result, in an economy with deep habits, there is a potential role for fiscal stabilization policy, using government spending and/or tax instruments, alongside monetary policy, as we have moved a long-way from the special case implied by approximating an economy around an efficient steady-state.

The current paper explores the robustness of the crowding in result in the context of a New Keynesian model of optimal monetary and fiscal policy, where households possess deep habits in consumption. We also explore the ability of fiscal and monetary policy instruments to contribute to macroeconomic and fiscal stabilization in such an economy. To this end, we

[3] Superficial habits refer to habits that are formed at the level of the household's consumption basket, rather than at the level of individual items in the basket.

construct a sticky-price New Keynesian economy along the lines of Benigno and Woodford (2003), where households provide labor to imperfectly competitive firms who are subject to price adjustment costs. As in Benigno and Woodford (2003), taxes are distortionary. We begin exploring the fiscal policy transmission mechanism by varying the relative extent of habits in private and public goods consumption and by allowing firms to discriminate between pricing for private and public goods. In light of these results, we then assess the ability of fiscal policy to stabilize an economy with price-stickiness, monopolistic competition and deep habits in private and public consumption. In doing so, unlike Benigno and Woodford (2003), we also allow government spending to be used as a policy instrument, rather than treating it as an exogenous stream which needs to be financed.

In the next section, we describe our model. Section 3 then examines the fiscal policy transmission mechanism, before we explore optimal stabilization policy. We find that, government spending shocks can lead to a substantial crowding-in of private sector consumption in the short-run. However, despite the fact that government spending multipliers are now greater than one and that our benchmark calibration implies a large consumption externality as a result of the deep habits, when we turn to augment optimal monetary policy with the government spending instrument, we find that this instrument actually adds very little to stabilization policy in our model economy. The public consumption gap (the difference between the actual variable and the value that would be chosen by a benevolent social planner) is several orders of magnitude smaller than the corresponding consumption and output gaps. Moreover, it barely moves in response to either technology or mark-up shocks.[4] Nevertheless, the optimal monetary policy response to technology and mark-up shocks can be significantly different in the presence of deep habits, often resulting in a monetary policy stance which is the opposite of that without such habits effects.

Further enriching the policy problem to include government debt and consider distortionary taxation to be a policy instrument, we find that it remains optimal to allow steady-state government debt to follow a random walk.[5] At the same, time monetary policy essentially acts to stabilize the consumption gap in the face of technology shocks and tax policy deals with the mark-up shocks and the consumption externality, without generating significant inflation beyond the initial periods of the shock in either case. Therefore, although government spending contributes little to macroeconomic stabilization, tax policy is very useful in offsetting the consumption externality.

Finally, we assess the ability of a set of simple policy rules to mimic the fully optimal Ramsey policy. In the appendix, we consider the determinacy properties of these rules and find that the usual classification of the determinate active and passive policy rules due to Leeper (1991) depends upon the extent of deep habits formation present. Our analysis shows that the combination of optimized simple, but inertial, monetary policy rules which respond to inflation and tax rules which respond to government debt can effectively achieve the level of welfare found under the Ramsey plan. However, the optimal coefficients of these rules are radically different whether or not the model includes habits effects, with a substantial fall in the monetary policy response to inflation and an associated rise in the response of taxation to government debt, when habits are present. This combination of interest rate and tax policy successfully manages the unwinding of the stock of habits following shocks, without generating significant inflation.

Sensitivity analysis indicates that the main results are generally robust to variations in the degree of labor supply elasticity and nominal inertia. The final section concludes.

2. The model

The economy consists of households, a monopolistically competitive production sector, and the government. Households derive utility from consumption of both private and public goods and they form external consumption habits at the level of the individual (private/public) goods in their baskets – Ravn et al. (2006) call this type of habits 'deep'. Furthermore, firms are subject to nominal inertia in the form of price adjustment costs and they may price discriminate between sales to households or the government.

2.1. Households

The economy is populated by a continuum of households, indexed by k and of measure 1. Households derive utility from consumption of composite private and public goods and disutility from hours spent working.

Deep habits: When habits are of the deep kind, each household's private consumption basket, X_t^k, is an aggregate of a continuum of habit-adjusted goods, indexed by i and of measure 1,

$$X_t^k = \left(\int_0^1 \left(C_{it}^k - \theta C_{it-1} \right)^{(\eta_t - 1)/\eta_t} di \right)^{\eta_t/(\eta_t - 1)},$$

[4] Note that the fact that the government spending gap does not move does not mean that government spending itself is not varied in response to shocks. In the case of positive technology shocks the social planner would choose to expand both public and private consumption, after correcting for the consumption externalities implied by habits. Therefore maintaining the public consumption gap in the face of such a shock implies that public consumption would increase.

[5] As in, for example, Benigno and Woodford (2003), Schmitt-Grohe and Uribe (2004a), and Leith and Wren-Lewis (2013).

where C_{it}^k is the household k's consumption of good i and $C_{it} \equiv \int_0^1 C_{it}^k \, dk$ denotes the cross-sectional average consumption of this good. η_t is the time-varying elasticity of substitution between habit-adjusted varieties, assumed to follow a stationary AR(1) process, as in Ireland (2004): $\ln \eta_t = (1-\rho_\eta) \ln \eta + \rho_\eta \ln \eta_{t-1} + \varrho_t^\eta$, with persistence parameter $\rho_\eta \in (0,1)$ and random shocks $\varrho_t^\eta \sim iidN(0, \sigma_\eta^2)$. The parameter θ measures the degree of external habit formation in consumption of each individual private good i. Setting θ to 0 returns us to the usual case of no habits in private consumption.

The composition of the consumption basket is chosen in order to minimize expenditures, and the resultant demand is

$$C_{it}^k = \left(\frac{P_{it}^C}{P_t^C} \right)^{-\eta_t} X_t^k + \theta C_{it-1}, \quad \forall i$$

where P_t^C represents the overall price index (or CPI), defined as an average of prices of private goods, $P_t^C \equiv (\int_0^1 (P_{it}^C)^{1-\eta_t} \, di)^{1/(1-\eta_t)}$. Aggregating across households yields the total private consumption demand for good i, $i \in [0,1]$,

$$C_{it} = \left(\frac{P_{it}^C}{P_t^C} \right)^{-\eta_t} X_t + \theta C_{it-1}. \tag{1}$$

Due to the presence of habits, this demand is dynamic in nature, as it depends not only on current period elements but also on the lagged value of consumption. This, in turn, will make the pricing/output decisions of the firms producing these goods, intertemporal.

Remainder of the household's problem: For the remainder of the households' problem, households choose the habit-adjusted private consumption aggregate, X_t^k, hours worked, N_t^k, and the portfolio allocation, D_{t+1}^k, to maximize expected lifetime utility,

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(X_t^k)^{1-\sigma}}{1-\sigma} - \frac{(N_t^k)^{1+\upsilon}}{1+\upsilon} + \chi^G \frac{(X_t^{G,k})^{1-\sigma}}{1-\sigma} \right]$$

subject to the budget constraint,

$$\int_0^1 P_{it}^C C_{it}^k \, di + E_t Q_{t,t+1} D_{t+1}^k = (1-\tau_t) W_t N_t^k + D_t^k + \Phi_t \tag{2}$$

and the usual transversality condition. E_t is the mathematical expectation conditional on information available at time t, β is the discount factor $(0<\beta<1)$, χ^G the relative weight on utility from consumption of public goods, and σ and υ are the inverses of the intertemporal elasticities of habit-adjusted consumption and work $(\sigma, \upsilon > 0;\ \sigma \neq 1)$. The household's period-t income includes the following: after-tax wage income from providing labor services $(1-\tau_t) W_t N_t^k$, dividends Φ_t, and payments on the portfolio of assets D_t^k. Financial markets are complete and $Q_{t,t+1}$ is the one-period stochastic discount factor for nominal payoffs. τ_t is the labor income tax rate. In the maximization problem, households take as given the processes for C_{t-1}, W_t, Φ_t, and τ_t, as well as the initial asset position D_{-1}^k.

The first-order conditions for labor and habit-adjusted consumption are

$$\frac{(N_t^k)^\upsilon}{(X_t^k)^{-\sigma}} = (1-\tau_t) w_t$$

and

$$Q_{t,t+1} = \beta \left(\frac{X_{t+1}^k}{X_t^k} \right)^{-\sigma} \frac{P_t^C}{P_{t+1}^C},$$

where $w_t \equiv W_t / P_t^C$ is the real wage. The Euler equation for consumption can be written as

$$1 = \beta E_t \left[\left(\frac{X_{t+1}^k}{X_t^k} \right)^{-\sigma} \frac{P_t^C}{P_{t+1}^C} \right] R_t,$$

where $R_t^{-1} = E_t[Q_{t,t+1}]$ denotes the inverse of the risk-free gross nominal interest rate between periods t and $t+1$, while $\pi_t^C \equiv P_t^C / P_{t-1}^C$ is inflation.

2.2. The government

Deep habits. We follow the literature (Ravn et al., 2006, 2007) and allow for deep habits effects in public consumption, but will assess how optimal policy varies as we alter the extent of such externalities, including the special case where there are no habits effects in government spending.

As with the consumption habits in private consumption, the government purchases individual goods so as to maximize the aggregate X_t^G that enters the representative household's utility function, given the allocated level of aggregate spending,

G_{it-1}, from the previous period,

$$\max_{\{G_{it}^k\}_i} X_t^G = \left(\int_0^1 (G_{it} - \theta^G G_{it-1})^{(\eta_t - 1)/\eta_t} \, di \right)^{\eta_t/(\eta_t - 1)}$$

$$\text{s.t.} \int_0^1 P_{it}^G G_{it}^k \, di \le P_t^G G_t^k.$$

That is, the government does not internalize the impact of its expenditure decisions on household habit formation over publicly funded consumption when deciding how much of an individual good to purchase. Since firms could potentially discriminate between sales to the private and the public sectors, we allow for a distinct set of public purchased goods prices, $\{P_{it}^G\}_i$, and a corresponding price index, P_t^G.[6] θ^G gives a measure of the level of habits formation in the consumption of public goods. In the maximization problem, the government takes as given the past consumption of individual public goods, as it respects the habits formation behavior of households. The demand for public goods i, $i \in [0,1]$, is

$$G_{it} = \left(\frac{P_{it}^G}{P_t^G} \right)^{-\eta_t} X_t^G + \theta^G G_{it-1}, \tag{3}$$

where $P_t^G = (\int_0^1 (P_{it}^G)^{1-\eta_t} \, di)^{1/(1-\eta_t)}$.

Government budget constraint: Combining the series of the representative consumer's flow budget constraints, (2), with borrowing constraints that rule out Ponzi schemes, gives the intertemporal budget constraint (see Woodford, 2003, Chapter 2, p. 69),

$$\sum_{T=t}^{\infty} E_t[P_T C_T] \le D_t + \sum_{T=t}^{\infty} E_t[Q_{t,T}(\Phi_T + W_T N_T(1-\tau_T))].$$

Noting the equivalence between factor incomes and national output,

$$P_t^C Y_t^C + P_t^G Y_t^G = W_t N_t + \Phi_T,$$

and the definition of aggregate demand, we can rewrite the private sector's budget constraint as

$$D_t = -\sum_{T=t}^{\infty} E_t[Q_{t,T}(P_T^G G_T - W_T N_T \tau_T)]$$

which implies that some combination of monetary accommodation, distortionary taxation and spending adjustments is required to service government debt as well as stabilize the economy.[7] Noting that, in aggregate, the households' net portfolio consists of government bonds $D_t = R_{t-1} B_{t-1}$ allows us to write the flow budget constraint as

$$B_t = R_{t-1} B_{t-1} + P_t^G G_t - \tau_t W_t N_t \tag{4}$$

or in real terms,

$$b_t = R_{t-1} (\pi_t^C)^{-1} b_{t-1} + \zeta_t G_t - \tau_t w_t N_t$$

where $b_t \equiv B_t / P_t^C$ is real value of debt and $\zeta_t \equiv P_t^G / P_t^C$ is the relative price of public goods in terms of private goods ($\zeta_t = 1$ when firms charge the same price to both households and the government).

2.3. Firms

Goods are produced by a continuum of monopolistically competitive firms (indexed by i and of measure 1), which are subject to nominal inertia in the form of quadratic price adjustment costs, as in Rotemberg (1982). Firms may also differentiate their output/pricing decisions according to the sector they are supplying, either private or public.

Each firm i produces a unique good using only labor as input in the production process

$$Y_{it}^{\mathcal{F}} = A_t N_{it}^{\mathcal{F}}, \tag{5}$$

with $\mathcal{F} = \{C, G\}$ denoting the specific sector goods are supplied to. Total factor productivity, A_t, affects all firms symmetrically and follows an exogenous stationary process, $\ln A_t = \rho_A \ln A_{t-1} + \varrho_t^A$, with persistence parameter $\rho_A \in (0,1)$ and random shocks $\varrho_t^A \sim iidN(0, \sigma_A^2)$.

The nominal profits from sales to the private sector are given as

$$\Phi_{it}^C \equiv P_{it}^C Y_{it}^C - W_t N_{it}^C - \frac{\varphi}{2} \left(\frac{P_{it}^C}{\pi^C P_{it-1}^C} - 1 \right)^2 P_t^C Y_t^C$$

[6] Ravn et al. (2006) and the rest of the literature on deep habits assume that there is no price discrimination between private and public customers.

[7] In Sections 3.1 and 3.2 below, we temporarily abstract from the fiscal financing needs of the government by allowing access to lump-sum taxation. We do so in order to explore the implications of removing government debt from the policy problem, before excluding lump-sum taxes and returning to the more realistic case where all taxes are distortionary.

while those from sales to the public sector are

$$\Phi_{it}^G \equiv P_{it}^G Y_{it}^G - W_t N_{it}^G - \frac{\varphi}{2}\left(\frac{P_{it}^G}{\pi^G P_{it-1}^G} - 1\right)^2 P_t^G Y_t^G$$

where the last term in each expression represents the nominal costs of price adjustment. Note that we distinguish between the prices charged for public goods and private goods to allow firms to price discriminate between the two sectors. We also consider what happens when such price discrimination is not possible.

We let $Z_t^{\mathcal{F}(i)}$ denote the price adjustment costs of firm i (in real terms) when supplying goods to sector $\mathcal{F} = \{C, G\}$,

$$Z_t^{\mathcal{F}(i)} \equiv \frac{\varphi}{2}\left(\frac{P_{it}^{\mathcal{F}}}{\pi P_{it-1}^{\mathcal{F}}} - 1\right)^2 Y_t^{\mathcal{F}}$$

and we assume that these adjustment costs are expressed in terms of a CES aggregate of the differentiated goods but which does not feature habits[8] (here we index the differentiated firms/goods by j to avoid confusion when aggregating),

$$Z_t^{\mathcal{F}(i)} = \left(\int_0^1 (Z_{jt}^{\mathcal{F}(i)})^{\frac{\eta_t - 1}{\eta_t}}\, dj\right)^{\eta_t/(\eta_t - 1)} \tag{6}$$

For any given level of $Z_t^{\mathcal{F}(i)}$, the demand for individual varieties j must be such that total expenditures $\int_0^1 P_{jt}^{\mathcal{F}} Z_{jt}^{\mathcal{F}(i)}\, dj$ are minimized, subject to the constraint (6). This then yields the individual demand

$$Z_{jt}^{\mathcal{F}(i)} = \left(\frac{P_{jt}^{\mathcal{F}}}{P_t^{\mathcal{F}}}\right)^{-\eta_t} Z_t^{\mathcal{F}(i)}$$

where $P_t^{\mathcal{F}} = (\int_0^1 (P_{jt}^{\mathcal{F}})^{1-\eta_t}\, dj)^{1/(1-\eta_t)}$ is the price index and the associated total expenses are $\int_0^1 P_{jt}^{\mathcal{F}} Z_{jt}^{\mathcal{F}(i)}\, dj = P_t^{\mathcal{F}} Z_t^{\mathcal{F}(i)}$. Aggregating across all firms, the demand for each differentiated good j associated with the price adjustment costs is

$$Z_{jt}^{\mathcal{F}} = \left(\frac{P_{jt}^{\mathcal{F}}}{P_t^{\mathcal{F}}}\right)^{-\eta_t} Z_t^{\mathcal{F}} \tag{7}$$

where $Z_{jt}^{\mathcal{F}} \equiv \int_0^1 Z_{jt}^{\mathcal{F}(i)}\, di$ and $Z_t^{\mathcal{F}} \equiv \int_0^1 Z_t^{\mathcal{F}(i)}\, di$.

Profit maximization: In providing goods to households or to the government, firms choose $P_{it}^{\mathcal{F}}$, $\mathcal{F}_{it}$, $Z_{it}^{\mathcal{F}}$, and $N_{it}^{\mathcal{F}}$ for $\mathcal{F} = \{C, G\}$ to maximize the present discounted value of profits, $E_t \sum_{s=0}^{\infty} Q_{t,t+s} \Phi_{it+s}^{\mathcal{F}}$, subject to the dynamic demand constraints (1) or (3), the constraint in (7), the production technology (5), and under the restriction that all demand be satisfied at the chosen price, $\mathcal{F}_{it} + Z_{it}^{\mathcal{F}} = Y_{it}^{\mathcal{F}}$. $Q_{t,t+s}$ is the s-step ahead stochastic discount factor for nominal payoffs

$$\left(Q_{t,t+s} = \beta^{t+s} \frac{u_{X,t+s}}{u_{X,t}} \frac{P_t^C}{P_{t+s}^C}\right).$$

The associated first-order conditions are

$$v_{it} = \left(P_{it}^C - MC_t\right) + \theta E_t\left[Q_{t,t+1} v_{it+1}\right]$$

$$v_{it}^G = \left(P_{it}^G - MC_t\right) + \theta^G E_t\left[Q_{t,t+1} v_{it+1}^G\right]$$

$$\begin{aligned} Y_{it}^C = \eta_t \left(\frac{P_{it}^C}{P_t^C}\right)^{-\eta_t - 1} (P_t^C)^{-1}\left[\left(P_{it}^C - MC_t\right) Z_t^C + v_{it} X_t\right] \\ + \varphi\left(\frac{P_{it}^C}{\pi^C P_{it-1}^C} - 1\right)\frac{P_t^C Y_t^C}{\pi^C P_{it-1}^C} - \varphi E_t\left[Q_{t,t+1}\left(\frac{P_{it+1}^C}{\pi^C P_{it}^C} - 1\right)\frac{P_{it+1}^C}{\pi^C (P_{it}^C)^2} P_{t+1}^C Y_{t+1}^C\right] \end{aligned}$$

and

$$\begin{aligned} Y_{it}^G = \eta_t \left(\frac{P_{it}^G}{P_t^G}\right)^{-\eta_t - 1} (P_t^G)^{-1}\left[(P_{it}^G - MC_t) Z_t^G + v_{it}^G X_t^G\right] \\ + \varphi\left(\frac{P_{it}^G}{\pi^G P_{it-1}^G} - 1\right)\frac{P_t^G Y_t^G}{\pi^G P_{it-1}^G} - \varphi E_t\left[Q_{t,t+1}\left(\frac{P_{it+1}^G}{\pi^G P_{it}^G} - 1\right)\frac{P_{it+1}^G}{\pi^G (P_{it}^G)^2} P_{t+1}^G Y_{t+1}^G\right] \end{aligned}$$

[8] While it seems natural to allow for habits formation by households in the consumption of private and public goods, a similar assumption does not appear particularly plausible when applied to firms.

Table 1
Parameter values used in simulations.

Parameter	Value	Description
$1/\beta$	$(1.04)^{1/4}$	Real interest rate
σ	2	Inverse of intertemporal elasticity of substitution
ϵ_{Nw}	1.3	Frisch labor supply elasticity
η	8.13	Elasticity of substitution between goods
φ	26.34	Price adjustment cost parameter
θ	0.86	Degree of habit formation in private goods consumption
θ^G	0.86	Degree of habit formation in public goods consumption
χ^G	0.143	Relative weight on utility from public goods consumption
π^C	$(1.035)^{1/4}$	Gross CPI inflation rate
B/GDP	0.55×4	Debt to GDP ratio
ρ_A	0.8556	Persistence of technology
ρ_η	0.9625	Persistence of markup shock process
ρ_G	0.87	Persistence of exogenous government spending
σ_A	0.006	Standard deviation of technology process
σ_η	$0.0012\times\varphi$	Standard deviation of markup shock process
σ_G	0.016	Standard deviation of exogenous government spending

where $MC_t = W_t/A_t$ represents the nominal marginal cost of production, while v_{it} and v_{it}^G are the Lagrange multipliers on the dynamic demand constraints and represent the shadow prices of producing private and public good i, respectively. These shadow values equal the marginal benefit of additional profits from each type of good, $P_{it}^C - MC_t$ and $P_{it}^G - MC_t$, respectively, plus the discounted expected payoffs from higher future sales, $\theta E_t[Q_{t,t+1}v_{it+1}]$ and $\theta^G E_t[Q_{t,t+1}v_{it+1}^G]$. In the presence of deep habits in consumption, increasing sales to the private (public) sector leads to an increase in sales of θ (θ^G) in the next period. The other first-order conditions indicate that an increase in price P_{it}^C (P_{it}^G) brings additional revenues of Y_{it}^C (Y_{it}^G), while simultaneously causing a decline in demand and affecting price adjustment costs.

In contrast, if we do not allow producers to discriminate between private and public sales of their products, then the first-order conditions reduce to

$$v_{it} = (P_{it}^C - MC_t) + \theta E_t[Q_{t,t+1}v_{it+1}]$$
$$v_{it}^G = (P_{it}^G - MC_t) + \theta^G E_t[Q_{t,t+1}v_{it+1}^G]$$

and

$$Y_{it} = \eta_t \left(\frac{P_{it}^C}{P_t^C}\right)^{-\eta_t - 1} (P_t^C)^{-1}\left[\left(P_{it}^C - MC_t\right)Z_t + v_{it}X_t + v_{it}^G X_t^G\right]$$
$$+\varphi\left(\frac{P_{it}^C}{\pi^C P_{it-1}^C} - 1\right)\frac{1}{\pi^C P_{it-1}^C}P_t^C Y_t - \varphi E_t Q_{t,t+1}\left(\frac{P_{it+1}^C}{\pi^C P_{it}^C} - 1\right)\frac{P_{it+1}^C}{\pi^C (P_{it}^C)^2}P_{t+1}^C Y_{t+1}$$

with the additional constraint that $P_{it}^G = P_{it}^C$. The combined first-order condition indicates that the common price should be increased until the extra revenue generated by selling to both sectors, $Y_{it} = Y_{it}^C + Y_{it}^G$, matches the value of the decline in demand and the changes in price adjustment costs.

2.4. Equilibrium

All households and firms in this economy are symmetric. The production of private and public goods amounts to $Y_t^C = A_t N_t^C$ and $Y_t^G = A_t N_t^G$, which can be aggregated to an economy-wide level of output

$$Y_t \equiv Y_t^C + Y_t^G = A_t N_t \tag{8}$$

where $N_t = N_t^C + N_t^G$ represents aggregate labor.

The markets for private and public goods must clear, so we have

$$C_t + \frac{\varphi}{2}\left(\frac{\pi_t^C}{\pi^C} - 1\right)^2 Y_t^C = Y_t^C \tag{9}$$

$$G_t + \frac{\varphi}{2}\left(\frac{\pi_t^G}{\pi^G} - 1\right)^2 Y_t^G = Y_t^G \tag{10}$$

which reduces to the usual aggregate resource constraint, when firms do not price discriminate between sales to households and the government,

$$C_t + G_t + \frac{\varphi}{2}\left(\frac{\pi_t^C}{\pi^C} - 1\right)^2 Y_t = Y_t \tag{11}$$

Note that we generally have two measures of aggregate prices – the usual consumer price index P_t^C and the index of the prices of goods supplied to the government P_t^G – and consequently two measures of inflation, $\pi_t^C \equiv P_t^C / P_{t-1}^C$ and $\pi_t^G \equiv P_t^G / P_{t-1}^G$. There are also two markups of price over marginal cost associated with sales to the private and public sector, $\mu_t^C \equiv P_t^C / MC_t$ and $\mu_t^G \equiv P_t^G / MC_t$, where μ_t^C is the inverse of the real marginal cost.

The symmetric equilibrium is characterized by Eqs. (8)–(11), together with the government budget constraint and the equilibrium conditions defining the households' and the firms' behavior (Appendix A.3 lists the entire set of equilibrium conditions), to which we add the monetary and fiscal policy specification (as detailed in Sections 3 and 4 below).

2.5. Solution method and model calibration

Since we are ultimately interested in assessing the welfare benefits of allowing fiscal policy to contribute to the stabilization of our New Keynesian economy featuring deep habits, we cannot rely on linear approximations to our model's equilibrium conditions when evaluating optimal policy. Kim and Kim (2003) have shown that such approximations can give rise to spurious welfare rankings amongst alternative policies. Instead, we employ the perturbation methods of Schmitt-Grohe and Uribe (2004b) to obtain a second-order accurate solution to the model which can be used to validly rank the welfare consequences of alternative policies.

In order to solve the model, we must select numerical values for some key structural parameters. Table 1 reports our choices. The bulk of our benchmark calibration comes from the estimation/calibration of Ravn et al. (2006). The model is calibrated to a quarterly frequency and, following Ravn et al. (2006), we assume an annual real rate of interest of 4%, which implies a discount factor β of 0.9902. From the same source, the risk aversion parameter σ is set at 2.0 and υ (the inverse of the Frisch labor supply elasticity) is equal to $1/1.3$.[9] The Rotemberg price adjustment parameter, $\varphi = 26.34$, is chosen to match the Calvo no-price change probability of 0.6 from Schmitt-Grohe and Uribe (2006) (which in turn is consistent with an average price contract length of 7.5 months), given the reduced-form equivalence between the two forms of nominal-inertia to a first-order approximation. Finally, our habits formation parameter, $\theta = 0.86$, is taken from the central estimate in Ravn et al. (2006) and we assume a similar benchmark for the habits in public consumption, θ^G. These values fall within the range of estimates identified in the literature.[10]

The remaining parameters are calibrated as follows. The weight attached to public consumption in utility, χ^G, is 0.143, such that the steady state under the Ramsey plan implies a government spending to GDP ratio of 0.2, consistent with the U.S. data average between 1947 and 2004. We set steady-state government consumption to be in line with the same level, when we assume G_t follows an exogenous process, rather than lying in the set of optimal policy instruments. The elasticity of substitution parameter η is set to 8.128, which implies a steady-state markup of 15%, as a central calibration relative to the typical values in the literature, which range from 10 to 20%. We further assume a steady state government debt to GDP ratio that corresponds to an annual average of 55%, again based on U.S. data from 1947 to 2004. Under the optimal Ramsey policy, the implicit steady state tax rate takes an empirically plausible value of 0.36 under no habits and 0.25 under the benchmark calibration of habits, reflecting primarily the fiscal financing role of taxes.[11] Technology shocks are assumed persistent with persistence parameter $\rho_A = 0.8556$ and standard deviation $\sigma_A = 0.006$. These values are taken from Schmitt-Grohe and Uribe (2006), who estimate the process jointly with a Taylor rule to match inflation and GDP moments over the post-war period. In the case of an exogenous government spending process, its characteristics are also taken from the estimates in Schmitt-Grohe and Uribe (2006) and are based on the estimation of an AR(1) process using HP-filtered data for government spending between 1947 and 2004, $\rho_G = 0.87$ and $\sigma_G = 0.016$. The mark-up shocks follow the estimated process in Ireland (2004), $\rho_\eta = 0.9625$ and $\sigma_\eta = 0.0012$. Finally, the steady-state inflation rate of 3.5% per year is based on the U.S. data average between 1947 and 2004, and implies that, under our various descriptions of policy, the nominal interest rate never breaches the zero-lower bound for plausible draws of the shocks.

3. Optimal ramsey policy

In this section, we consider the nature of optimal policy in response to exogenous shocks. The optimal policy problem can be set up in terms of a Lagrangian as

$$L_0 = \max_{\mathbf{y}_t} E_0 \sum_{t=0}^{\infty} \beta^t [U(\mathbf{y}_{t+1}, \mathbf{y}_t, \mathbf{y}_{t-1}, \mathbf{u}_t) - \lambda_t f(\mathbf{y}_{t+1}, \mathbf{y}_t, \mathbf{y}_{t-1}, \mathbf{u}_t)]$$

[9] Estimates of this elasticity vary quite widely and Section 5 below considers a sensitivity analysis with respect to this parameter.

[10] Macro-based estimates of habits formation of the deep kind range from relatively lower values of 0.53, as in Ravn et al. (2012), to very high values of 0.95–0.97, as reported by Ravn et al. (2006), Lubik and Teo (2011), and Zubairy (2010c).

[11] In the case where the government has access to lump-sum taxes to balance the budget, the optimal steady state tax rate would be −0.14 with no habits, reflecting the long-run inefficiency due to monopolistic competition, and a very large 0.83 under the benchmark value of habits, reflecting the consumption externality.

where $\mathbf{y}_t$ and $\mathbf{u}_t$ are vectors of the model's endogenous and exogenous variables, respectively,

$$U(\mathbf{y}_{t+1},\mathbf{y}_t,\mathbf{y}_{t-1},\mathbf{u}_t) = \frac{(X_t)^{1-\sigma}}{1-\sigma} - \frac{(N_t)^{1+\upsilon}}{1+\upsilon} + \chi^G \frac{(X_t^G)^{1-\sigma}}{1-\sigma},$$

$$f(\mathbf{y}_{t+1},\mathbf{y}_t,\mathbf{y}_{t-1},\mathbf{u}_t) = 0$$

are the model's equilibrium conditions (Eqs. (A.2)–(A.21)) in Appendix A.3, and $\boldsymbol{\lambda}_t$ is a vector of Lagrange multipliers associated with these constraints.

The optimization implies the following first-order conditions:

$$E_t\left[\frac{\partial U(\cdot)}{\partial \mathbf{y}_t} + \beta F \frac{\partial U(\cdot)}{\partial \mathbf{y}_{t-1}} + \beta^{-1}\boldsymbol{\lambda}_{t-1} F^{-1} \frac{\partial f(\cdot)}{\partial \mathbf{y}_{t+1}} + \boldsymbol{\lambda}_t \frac{\partial f(\cdot)}{\partial \mathbf{y}_t} + \beta \boldsymbol{\lambda}_{t+1} F \frac{\partial f(\cdot)}{\partial \mathbf{y}_{t-1}}\right] = 0 \tag{12}$$

where F is the lead operator, such that F^{-1} is a one-period lag. A second-order accurate solution to optimal policy then involves solving these first-order conditions in combination with the non-linear equilibrium conditions of the model, $f(\mathbf{y}_{s+1},\mathbf{y}_s,\mathbf{y}_{s-1},\mathbf{u}_s) = 0$, using the perturbation methods of Schmitt-Grohe and Uribe (2004b).

In order to explore the contribution of fiscal policy instruments to optimal stabilization in a sticky price economy featuring deep habits, we gradually introduce fiscal considerations to the policy problem. To begin with, we consider the nature of the fiscal policy transmission mechanism by introducing exogenous government spending shocks to a model variant where monetary policy is optimal. This allows us to explore the crowding-in results of Ravn et al. (2006) in an economy where monetary policy is conducted optimally and where we can make different assumptions about the pricing of private and public goods. We then allow government spending to be varied as part of optimal policy, to assess whether or not government spending (as a proxy for the manipulation of aggregate demand through fiscal policy) contributes to stabilization policy. In both cases, we temporarily abstract from fiscal solvency issues by assuming that the policy maker has access to a lump-sum tax through which to balance the budget. We then relax this assumption and consider the optimal policy response to technology and cost-push shocks, when taxes are distortionary and Ricardian equivalence no longer holds. In all cases, we consider optimal policies with commitment. Finally, in Section 4 we explore the ability of a set of simple (linear) policy rules to replicate the Ramsey policy.

3.1. *Exogenous government spending and optimal monetary policy*

We first consider the case when fiscal policy is exogenous, while monetary policy is set optimally under commitment, and the government has access to lump-sum taxes to balance its budget. We assume that government spending follows an exogenous stationary process, $\ln G_t = (1-\rho_G)\ln G + \rho_G \ln G_{t-1} + \varrho_t^G$, with persistence parameter $\rho_G \in (0,1)$ and random shocks $\varrho_t^G \sim iidN(0,\sigma_G^2)$. Even though government spending is exogenous, households still derive utility from the consumption of public goods and form habits accordingly. The monetary authority sets the nominal interest rate to maximize households' welfare subject to the private sector's response and given the exogenous processes. We analyze the implications of this policy in terms of impulse responses to a government spending shock since this allows us to explore the nature of the fiscal policy transmission mechanism in a model with deep habits.

A positive government spending shock: Fig. 1 details the impulse responses to a positive government spending shock in three cases – no habits, habits of $\theta = \theta^G = 0.86$ and common pricing across private and public goods and, finally, the same degree of habits, but with price discrimination across public and private goods. Consider the case without habits: the increase in government spending results in an increase in aggregate demand which the monetary authority offsets by raising real interest rates and discouraging household consumption. The policy maker does this until consumption falls by enough that labor supply increases essentially match the increase in labor demand and the marginal costs of production are largely unchanged (although they actually fall slightly in the initial period, as does inflation). Therefore, the essence of the optimal policy in the absence of habits lies in ensuring the inflationary consequences of the increase in government spending are largely negated.

Within this policy response, there is actually a feature of optimal policy under commitment which is not easy to discern from the plots of the impulse response functions – the presence of price level control. As noted by Woodford (2003), under commitment, a policy maker facing the constraint implied by the New Keynesian Phillips curve will find it optimal to not only stabilize inflation following shocks, but will also seek to stabilize the price level itself. Accordingly, the policy maker actually matches the initial fall in inflation with a prolonged period of slightly positive inflation. This mitigates the inflationary consequences of the government spending shock while achieving the best balance between private and public consumption. This feature of optimal policy will be more apparent when we consider the same shock in the presence of deep habits.

We then consider the case where household preferences include deep habits over both private and public goods ($\theta = \theta^G = 0.86$) and where the suppliers of these goods are constrained to supply to the private and public sectors at the same price. Here, the increased demand for goods tempts firms to reduce their mark-ups in order to capture a larger share of the increased overall product demand. Ceteris paribus, this will tend to stimulate consumption. The policy maker wishes to discourage the formation of such habits effects and so aggressively raises interest rates at the start of the simulation, which

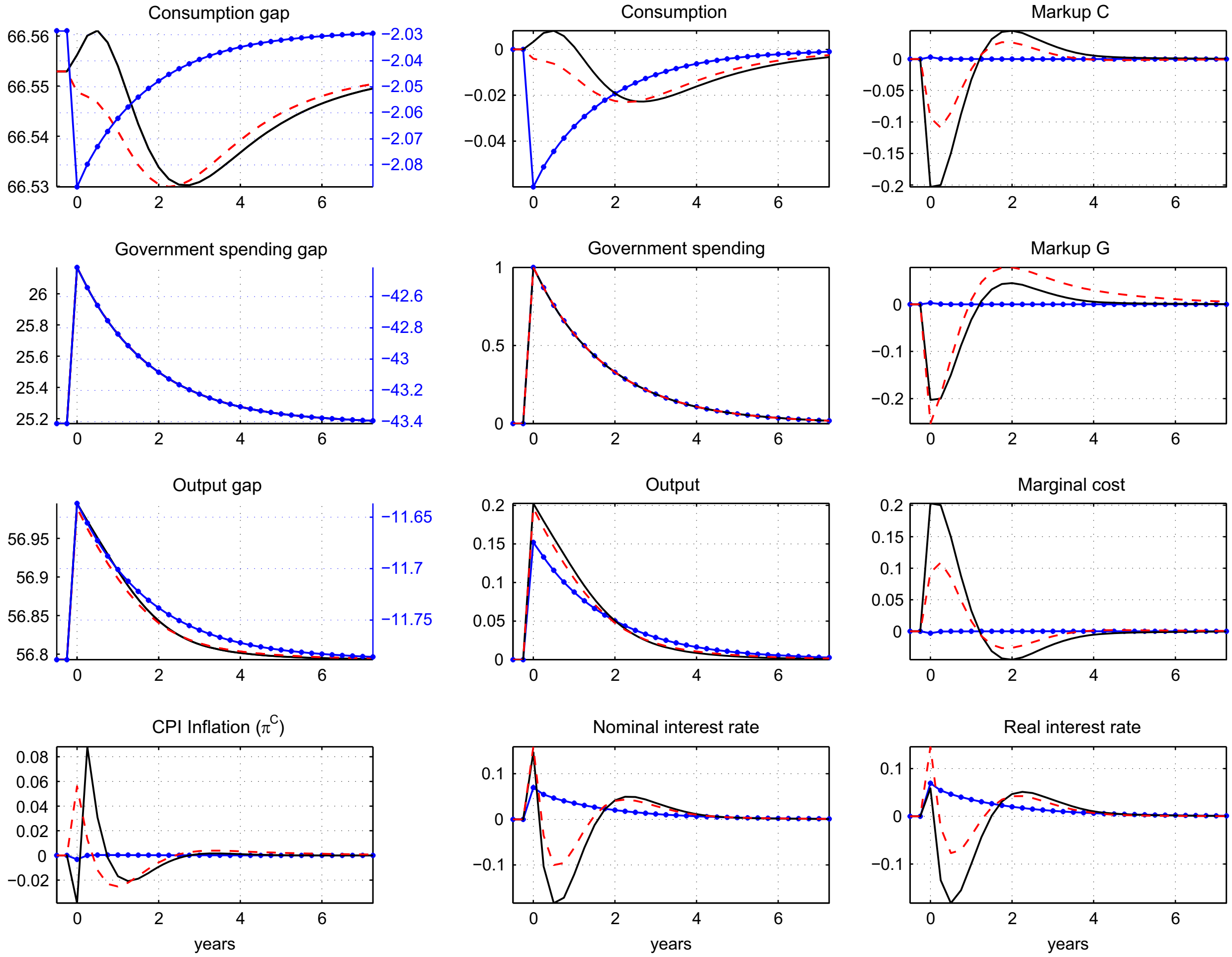

Fig. 1. Impulse responses to a +1% government spending shock with optimal monetary policy: no habits (dots) and deep habits ($\theta = \theta^G = 0.86$) with common pricing (solid line) and with discriminating pricing (dash lines). The inflation and interest rate variables are expressed in annualized terms. Gap variables under no habits read off the right *y*-axis.

encourages households to save rather than consume and reduces the discounted value of the sales generated by price cuts offered by firms. Despite this, the desire to gain market share is so great that the increase in government spending crowds in private consumption. As the shock passes, the policy maker wishes to mitigate the costs of falling habits-adjusted consumption and so relaxes policy for a time, before ultimately tightening it again. This cyclical behavior in policy making reflects the combined effects of the dynamics of habits-adjusted consumption and the implementation of a policy of price level control.

Finally, we consider a variant with the same degree of habits but where the producers can charge different prices to the private and public sectors. Here, the markup charged to the public sector is substantially reduced, but the government spending shock does not have a direct impact on the markup charged to the private sector's consumption goods, and private consumption is crowded out. The increase in aggregate demand due to the increase in public consumption does raise marginal costs and consumer price inflation. In the presence of nominal inertia, this implies that markups in the production of the private consumption goods fall. However, this decline is significantly smaller than the corresponding fall in the markup charged to the public sector. Also, in order to reduce the inflationary effect, monetary policy is tightened by more in the initial period than it would be under common pricing, which further discourages private consumption. There is then the same relaxation and subsequent tightening of policy which minimizes the costs of inflation and habits-adjusted consumption gaps, partly by relying on the expectational benefits of price-level control.

The crowding-in effects are effectively the result of the common pricing behavior by firms, combined with sufficient degrees of habits formation in private and public goods consumption.[12] Fig. 2 shows the response of consumption under different combinations of habits. For common levels of habits across private and public goods, the existence of crowding-in effects when

[12] Our results also differ from early studies in that we are assuming an optimal monetary policy.

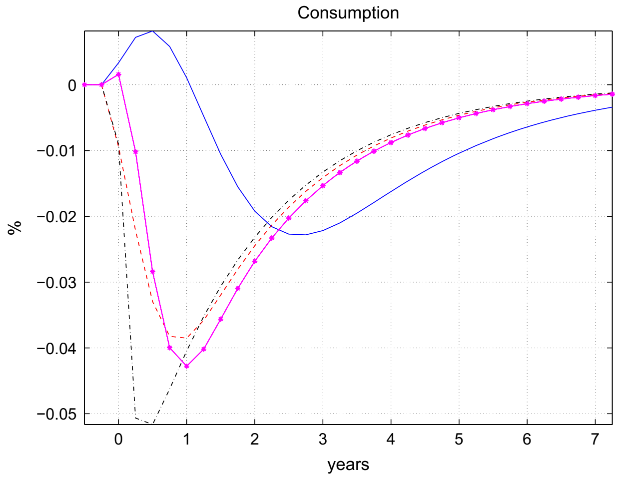

Fig. 2. Consumption responses to a +1% government spending shock under optimal monetary policy, with common pricing of private and public goods: $\theta = \theta^G = 0.86$ (solid line), $\theta = \theta^G = 0.6$ (dashed line), $\theta = 0$ and $\theta^G = 0.86$ (dash-dot line), $\theta = 0.5$ and $\theta^G = 0.86$ (stars).

monetary policy is optimal requires a degree of habits in excess of 0.72. However, for differing levels of habits in public and private goods consumption, a higher degree of habits in one can compensate, to varying degrees, for a lower degree of habits in the other and still support the crowding-in of private consumption. The crowding-in effects disappear if, for example, private goods consumption habits are at their benchmark level, $\theta = 0.86$, but there are no habits in public goods consumption, $\theta^G = 0$, or vice versa (the latter is shown by the dash-dot lines in Fig. 2). However, as the markup effects on private consumption are important in generating these results, higher degrees of habits formation in private consumption can restore the crowding-in effects, as is the case when $\theta^G = 0$ but $\theta = 0.96$ (which is the upper bound of the estimates in Ravn et al., 2006). Similarly, maintaining habits in public consumption at their benchmark level of 0.86 will result in crowding-in effects, provided the level of habits in private goods θ is of at least 0.4 (the stars impulse response in Fig. 2 illustrate such a case).

3.2. Endogenous government spending and optimal monetary policy

In this subsection, we analyze the optimal policy response to technology and mark-up shocks, where the nominal interest rate and government spending serve as policy instruments. We continue to ignore the budgetary consequences of policy by assuming fiscal authorities have access to a lump-sum tax with which to balance the budget.

A technology shock: Fig. 3 analyses the response to a positive technology shock and includes three cases – no habits effects and the case of deep habits with either common or discriminatory pricing across private and public goods. In the absence of habits effects, policy seeks to eliminate the inflationary consequences of the shock, leaving consumption, government spending and output suboptimally low due to the distortionary effects of monopolistic competition. If the policy maker were forced to behave in a time consistent manner, then this permanent distortion would result in an inflationary bias, but under commitment the policy maker is able to resist the temptation to introduce policy surprises in order to offset this distortion. Therefore, the policy maker raises public consumption and relaxes monetary policy to boost private consumption. These policies exactly balance the reduction in marginal costs that would otherwise arise as a result of the technology shock, so that inflation is zero throughout the simulation.

When we introduce significant deep habits effects, the nature of the distortion changes as households now over-consume, due to the habits externality, thus implying significant consumption and output gaps (the difference between actual output and the efficient level of output, as a percentage of the efficient level[13]) of 68% and 52%, respectively.[14] In the face of this enormous externality, monetary policy no longer seeks to solely stabilize inflation. Real interest rates are initially tightened to prevent the formation of such damaging habits externalities, while inflation falls initially. As the shock dissipates, policy is slowly relaxed to support the slow unwinding of increased stock of consumption habits. Given the expectational benefits of price level control in a forward looking model, monetary policy actually switches from its initial tightened stance to a more accommodative stance and the initial fall in inflation is offset by a subsequent rise. Therefore, we can see that the conduct of monetary policy has been significantly affected by the introduction of deep habits. In contrast, it is interesting to note that the government spending gap is small relative to the very large consumption and output gaps. Therefore, despite the fact that introducing deep habits implies that the economy faces a massive distortion and the output

[13] See Appendix A.5 for the details of the social planner's problem.

[14] In the absence of habits, the monopolistic competition and tax distortions would imply that output is sub-optimally low. However, as the degree of habits increases, the consumption externality begins to dominate rendering output inefficiently high.

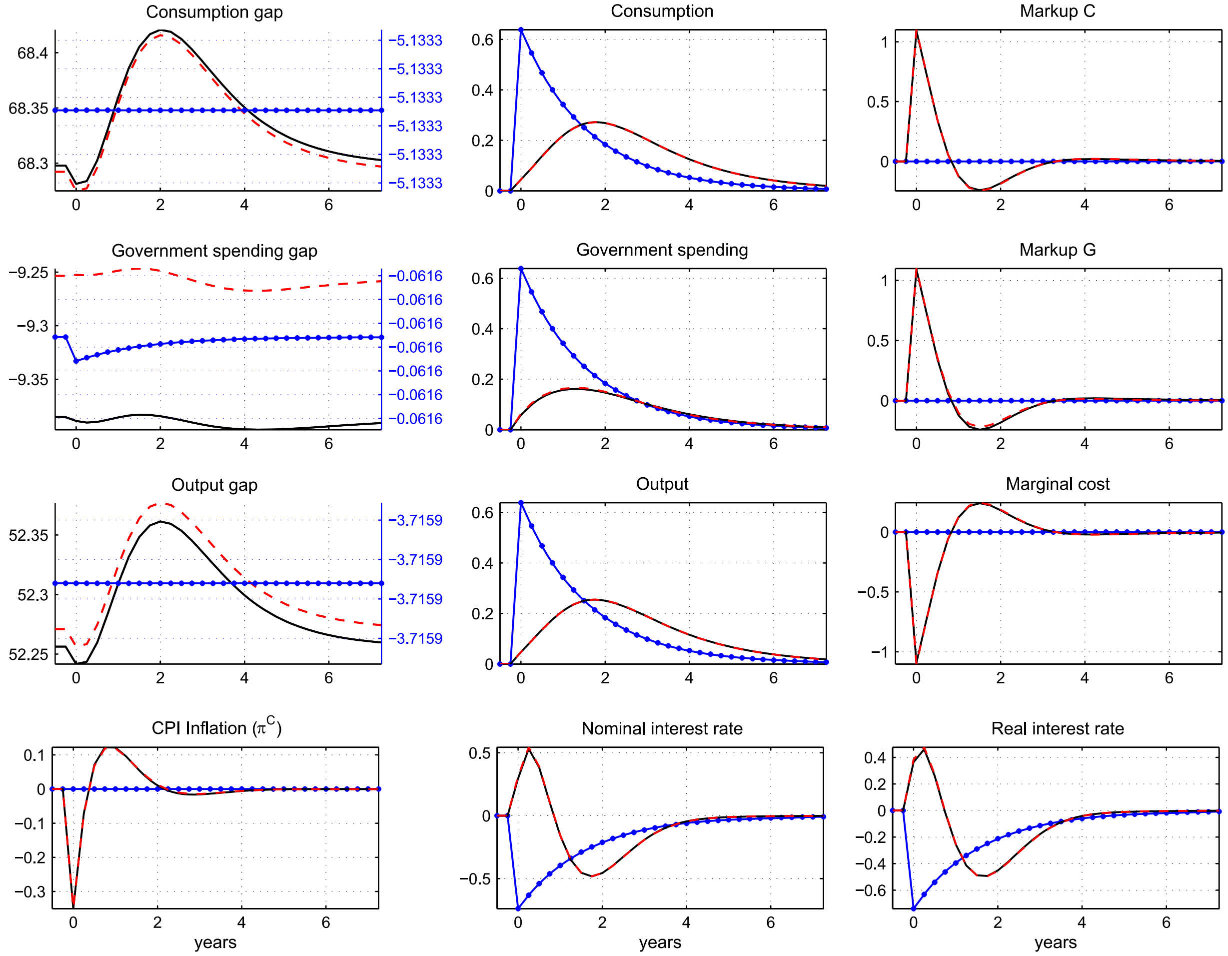

Fig. 3. Impulse responses to a +1% technology shock with optimal monetary and fiscal policy, the case of *lump-sum taxes*: no habits (dots) and deep habits ($\theta = \theta^G = 0.86$) with common pricing (solid line) and with discriminating pricing (dash lines). The inflation and interest rate variables are expressed in annualized terms. Gap variables under no habits read off the right y-axis.

multipliers associated with the government spending instrument rise from significantly below to above one, there is still little reliance on the government spending gap as a tool of stabilization policy. This is a pattern that will re-emerge throughout our simulations.[15]

A mark-up shock: We then consider the response of policy to a markup shock, taken as a 1% increase in η_t, which represents a decrease in the firms' desired markup. In this case, the policy maker faces a trade-off between inflation and output stabilization even in the absence of habits, as inflation falls while output rises. With little change in government spending, interest rates are initially raised in order to reduce aggregate demand and the size of the output gap, while allowing for additional deflation. This is illustrated by the dotted lines in Fig. 4. Again, the initial deflation is offset by a subsequent period of slightly lower interest rates and raised inflation, which is difficult to discern in the figure, and the government spending gap is negligible in comparison to the output and consumption gaps, which bear the brunt of the economic adjustment to the shock.

In the presence of deep habits, the reduction in markup reduces the value of retaining market share and firms seek to raise the prices of their goods, and we observe a rise in inflation. As a result the initial tightening of monetary policy is even stronger, as the policy maker attempts to curb the large output gap that can ensue due to over-consumption effects. Following this initial tightening of policy, there is the now familiar relaxation of policy which supports habits-adjusted consumption as the mark-up shock fades away. This relaxation of policy is later moderated to achieve a slight fall in

[15] It should be noted that even though the government spending gap is often small, this need not imply that government spending itself does not respond to shocks. The government spending gap is measured relative to the efficient level of public goods consumption and this responds to technology shocks but not to markup shocks. Hence, under the Ramsey policy, there will be relatively significant movements in the level of government spending in the former case.

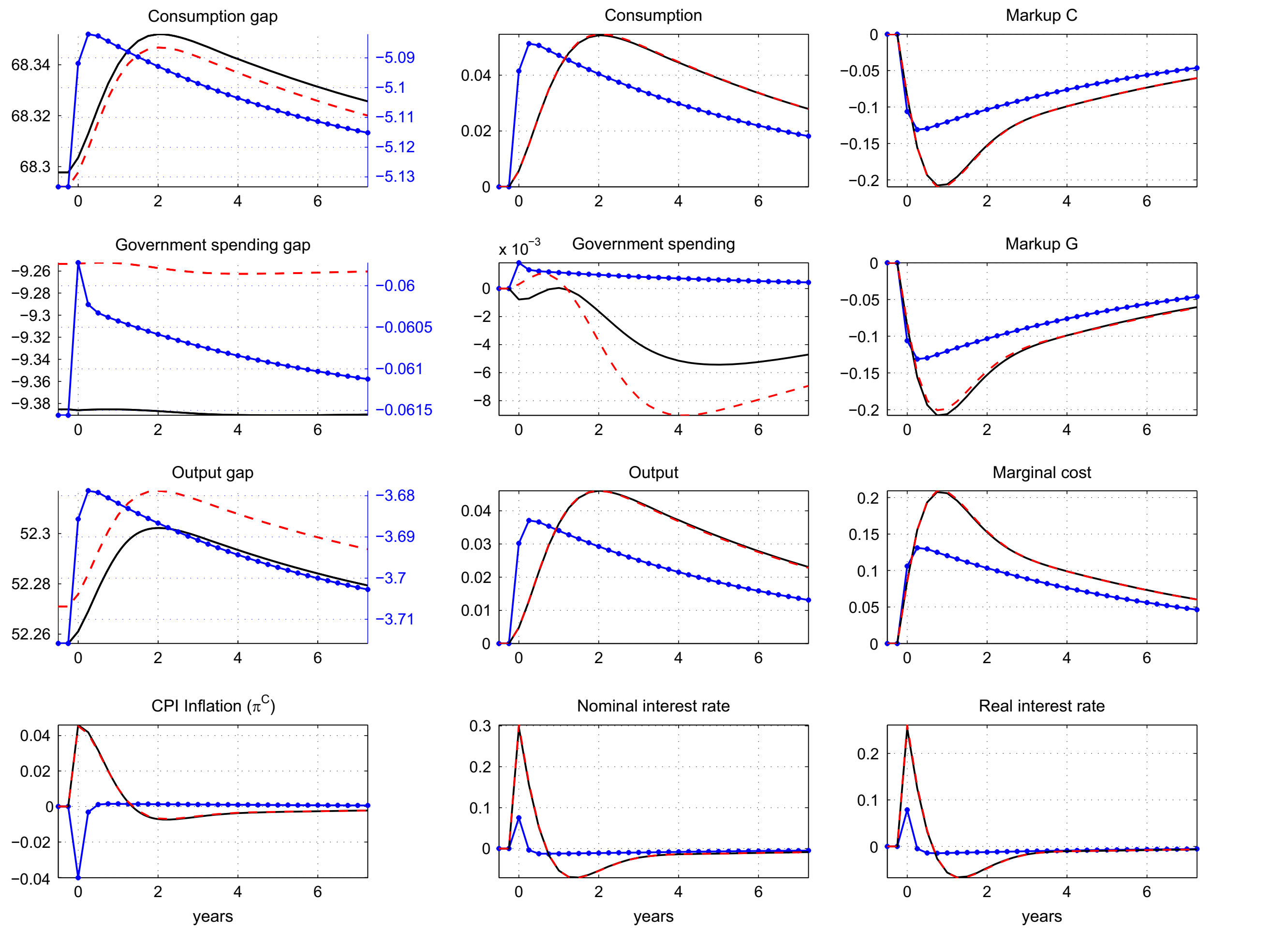

Fig. 4. Impulse responses to a negative markup shock (+1% change in η_t) under optimal monetary and fiscal policy, the case of *lump-sum taxes*: no habits (dots) and deep habits ($\theta=\theta^G=0.86$) with common pricing (solid line) and with discriminating pricing (dash lines). The inflation and interest rate variables are expressed in annualized terms. Gap variables under no habits read off the right *y*-axis.

inflation, expectations of which reduce the initial rise in inflation and is a feature of the ability to make credible policy promises under commitment. While the ability to price discriminate across private and public goods does not have much bearing on the results,[16] the time-varying markups that arise under deep habits are shown to play an important role in the optimal policy response to cost-push shocks.

3.3. *Optimal monetary and fiscal policy*

We now turn to the analysis of optimal Ramsey policy when policy makers have control over monetary policy and both fiscal policy instruments – government spending and income taxes, but where they no longer have access to lump-sum taxes to satisfy the government's budget constraint. It is important to note that if we did continue to remove the need to adjust either government spending or distortionary taxes to satisfy the intertemporal budget constraint, then the policy maker can achieve the first best allocation using the income tax instrument to offset the consumption externality and the mark-up shocks, while using the interest rate to offset the nominal inertia costs of technology shocks.

Before considering the response to technology and mark-up shocks, it is interesting to consider the initial steady-state of the Ramsey policy. This is computed by solving the steady-state of the Ramsey first-order conditions and the equilibrium conditions describing our New Keynesian economy, conditional on an initial government debt to GDP ratio. In the case of our model without habits, the combination of the monopolistic competition and tax distortions suppresses output below its socially efficient level. Interestingly, the optimal policy implies that the absolute size of the government spending gap is significantly smaller than the consumption gap. The intuition for this pattern lies in the desire to support the debt stock with the optimal combination of efficiency gaps in variables without generating any steady-state inflation. In the case of

[16] Impulse responses across the two types of pricing behavior are virtually the same.

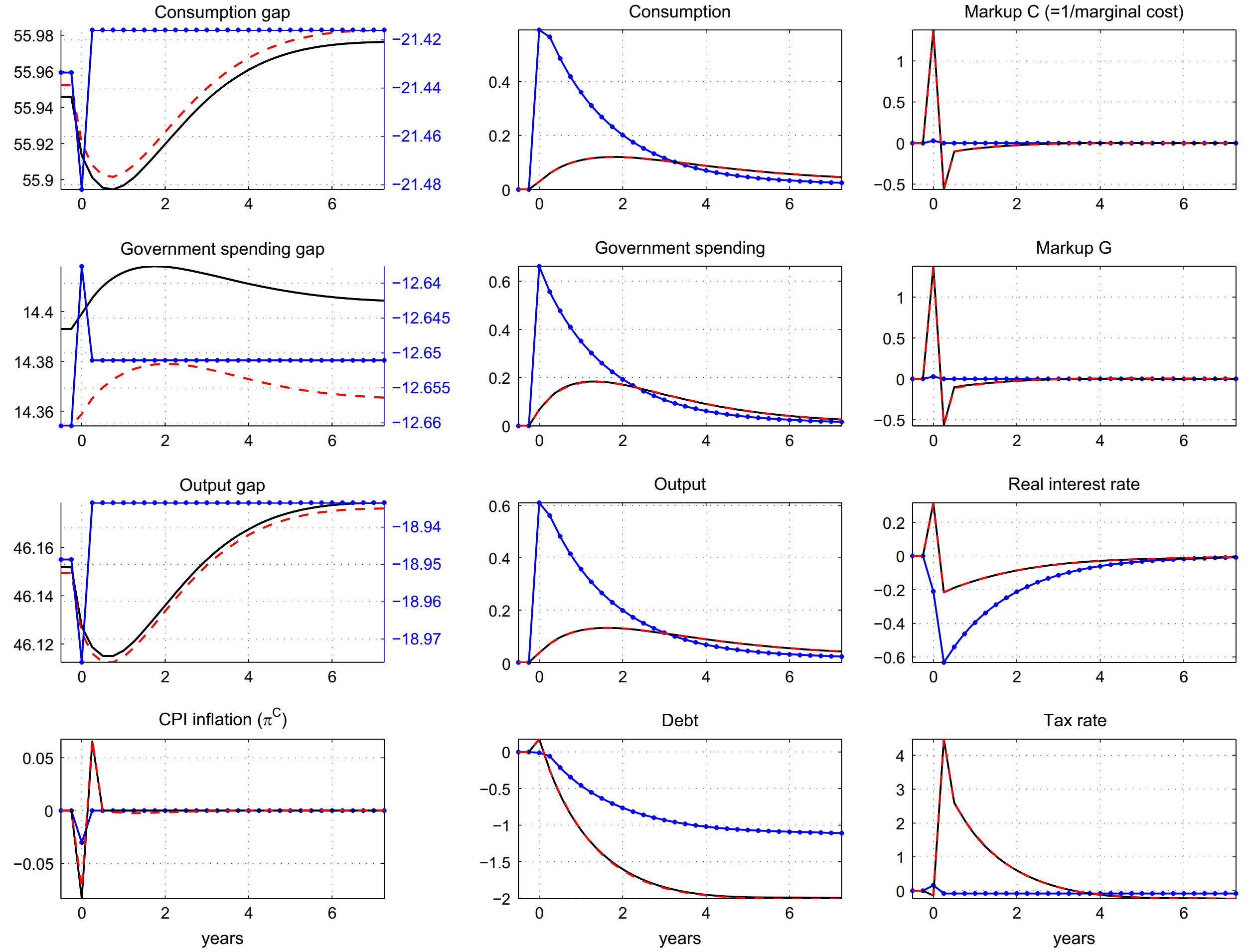

Fig. 5. Impulse responses to a +1% technology shock under optimal monetary and fiscal policy: no habits (dots) and deep habits ($\theta = \theta^G = 0.86$) with common pricing (solid lines) and with discriminating pricing (dash lines). The inflation and interest rate variables are expressed in annualized terms. Gap variables under no habits read off the right *y*-axis.

habits, the consumption externality renders the level of output too high despite the presence of monopolistic competition and distortionary taxation. As a result the consumption and government spending gaps are positive, but the consumption gap is four times the size of the government spending gap.

We now consider the nature of the policy response to technology and cost-push shocks, in this highly distorted environment. Fig. 5 details the response to a 1% positive technology shock. A key element of the policy response is that the steady-state of government debt follows a random walk as in Benigno and Woodford (2003), Schmitt-Grohe and Uribe (2004a), and Leith and Wren-Lewis (2013). The basic intuition for this is that in a sticky-price environment adjusting fiscal instruments to offset fiscal shocks is costly, such that policy makers ensure that policy instruments are adjusted to service the new steady-state debt that emerges following shocks, but the policy maker commits to not attempting to do more. In the absence of habits, gap variables are adjusted to their new steady-state values from the second period onwards, and debt slowly evolves to its new steady-state consistent with those variables. Real interest rates are adjusted in the face of the technology shock to maintain consumption at its new constant gap value. With a positive technology shock, tax rates fall and government spending, consumption and output rise to support the lower steady-state debt stock without affecting inflation. As shown in Leith and Wren-Lewis (2013), the behavior in the initial period is slightly different as the policy maker exploits the fact that expectations are given to reduce the impact of the shock on debt. Accordingly, in the initial period the fall in real interest rates is moderated (to mitigate the fall in debt service costs and offset the increase in the tax base) and encourage a surprise deflation in the initial period (although taxes rise to partially offset this deflation) – the combined impact of this is to reduce the eventual decline in debt that would otherwise emerge.[17]

[17] Leith and Wren-Lewis (2013) show that the combination of instruments used in the initial period depends crucially upon the degree of price stickiness and the steady state debt-GDP ratio. In our benchmark calibration, debt service costs and inflationary surprises are particularly effective in influencing the level of government debt.

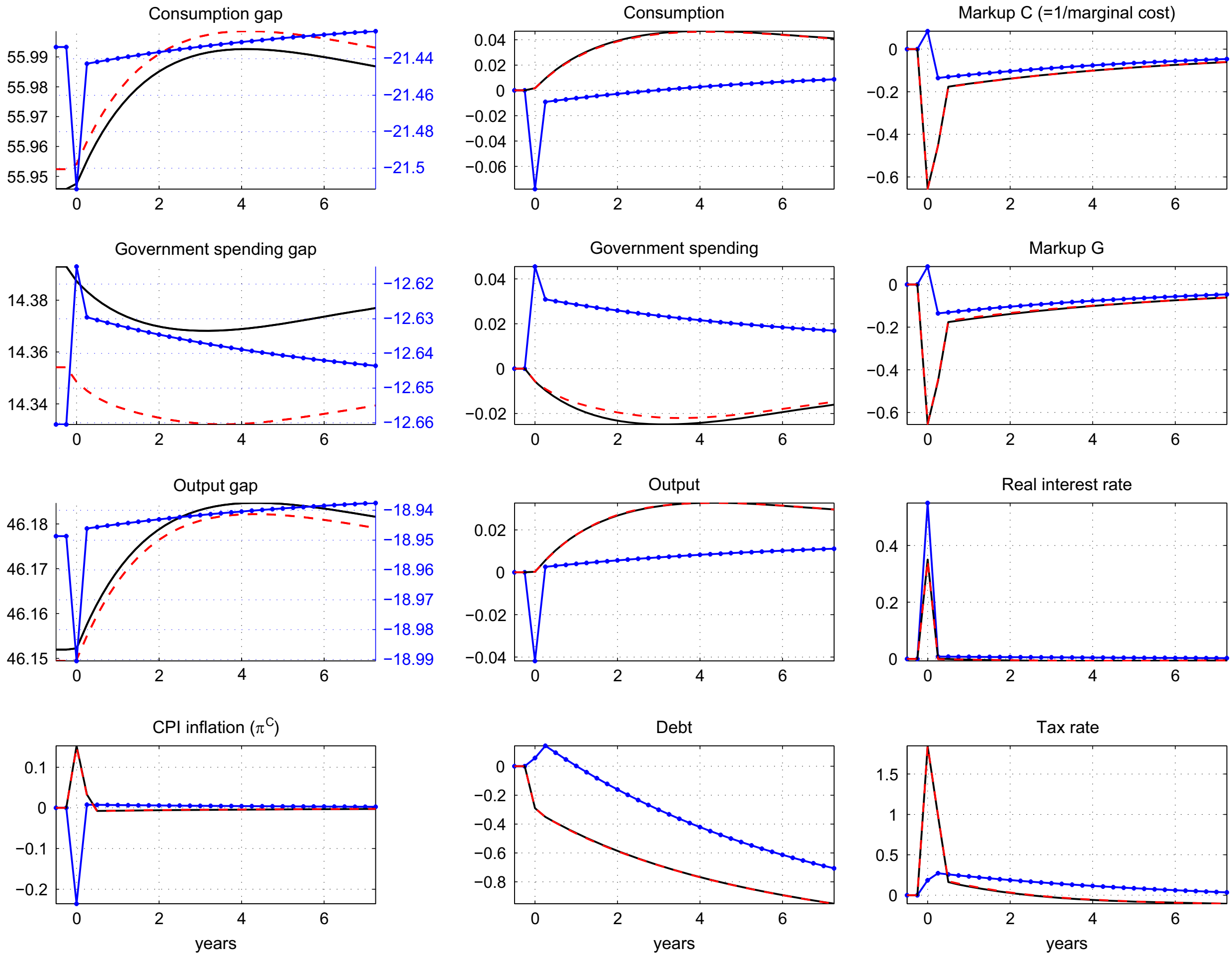

Fig. 6. Impulse responses to a negative markup shock (+1% change in η_t) under optimal monetary and fiscal policy: no habits (dots) and deep habits ($\theta = \theta^G = 0.86$) with common pricing (solid lines) and with discriminating pricing (dash lines). The inflation and interest rate variables are expressed in annualized terms. Gap variables under no habits read off the right y-axis.

When there are deep habits in consumption, the policy maker needs to minimize both the consumption externality and the costs of nominal inertia. Despite this additional trade-off, the assignment of instruments remains similar, although the stabilization of gap variables at their new long-run levels is no longer immediately after the initial period (it should be noted that the transition to the new steady-state still retains the property that inflation is effectively zero beyond the first two periods). Monetary policy adjusts interest rates to help stabilize the consumption gap in the face of the technology shock, and tax rates are adjusted to largely offset the extra consumption generated by the technology shock in the presence of habits, while together ensuring that inflation is near zero from the third period onwards. The pattern of adjustment in the first two periods is interesting and captures the essence of the trade-off facing the policy maker. In the first period, the policy maker tightens monetary policy to reduce the formation of undesirable habits effects, which tends to reduce inflation (it amounts to a negative inflation surprise in the first period), while the tax rate is slightly reduced. The combined effects of these changes are to actually increase the real value of government debt initially, despite the positive technology shock resulting in an increase in the tax base. This initial increase in debt then reduces the size of the steady-state fall in debt which ultimately emerges once the shock has passed. In the next period, there is a slight switch in the assignment of policy instruments as monetary policy is relaxed and higher taxation is used to discourage over-consumption. Anticipation of this second period tax increase mitigates the initial fall in inflation which is costly given the price adjustment costs. Using taxation in this way in the initial period is undesirable as the inflationary consequences of the tax increase would have reduced the initial debt level and implied greater adjustment to support the new lower steady-state debt level that would have implied.

We now consider the mark-up shock, detailed in Fig. 6. In the absence of habits, the tax rate is employed to mitigate the impact of the mark-up shock while maintaining the consumption, government spending and output gaps close to their new steady-state values. In the initial period, there is an attempt to offset the long-run reduction in government debt following the negative mark-up shock, primarily through tightening monetary policy (which increases debt service costs, reduces the size of the tax base and supports a surprise deflation). When we introduce deep habits, the policy maker has to consider both the consumption externality and the mark-up shock. As a result, the tax rate is raised more aggressively than in the absence of habits and inflation rises rather than falls. This reduces the initial stock of debt, which is undesirable, but helps reduce the initial increase in the stock of consumption habits. Nevertheless, gap variables are driven to their new steady-state values, which support the new steady-state value of debt without, subsequently, generating inflation.

We note that an economy where firms can price discriminate between private and public consumption is very similar to the one in which they are constrained to a common price policy. The responses to technology and mark-up shocks under optimal Ramsey policies are almost identical across the two types of pricing behavior. This is largely because the policy maker does not rely on government spending as a stabilization tool even when it can potentially have a large impact on aggregate demand through its ability to crowd-in private consumption.

In summary, the presence of deep habits, calibrated at empirically plausible levels, radically alters some aspects of the optimal policy problem. In particular, the evolution of monetary policy in response to government spending, technology and markup shocks seeks to balance the optimal path of habits-adjusted consumption with the need to minimize the costs of nominal inertia. Here the impact of monetary policy on the endogenous markups implied by pricing in the face of deep habits is the key. While distortionary income taxes can also be an effective tool in offsetting habits externalities. The endogenous mark-ups also imply that government spending shocks can crowd in private consumption, in line with the empirical evidence, but differently from other models of habits. However, despite this fundamental change in the fiscal policy transmission mechanism, it is still the case that government spending gaps remain small in the face of technology and mark-up shocks, even as consumption and output gaps remain pronounced.

4. Optimal simple rules

In this section, we consider the ability of simple monetary and fiscal rules to achieve the welfare outcomes commensurate with the fully optimal Ramsey policy.[18] The monetary policy rule we consider captures the response of the nominal interest rate to inflation and allows for interest rate inertia

$$\widehat{R}_t = \phi_R \widehat{R}_{t-1} + \phi_\pi \widehat{\pi}_t^C \tag{13}$$

while the fiscal policy rules capture the adjustment of fiscal instruments (the tax rate and government spending) in response to debt dynamics:

$$\widehat{\tau}_t = \gamma \widehat{b}_{t-1}$$
$$\widehat{G}_t = \kappa \widehat{b}_{t-1}$$

These specifications are similar to those considered in Schmitt-Grohe and Uribe (2007), Linnemann (2006), and Leith and von Thadden (2008) for the tax rule, and Leith and Wren-Lewis (2000) for the government spending rule. We do not allow for output terms in the rules as these are typically found to be unimportant in the design of optimal simple rules – see Schmitt-Grohe and Uribe (2007) – indeed we find that certain permutations of these rules can achieve the welfare levels observed under the Ramsey policy.

We search across the rule parameter space using the Simplex method employed by the Fminsearch algorithm in Matlab (see, Lagarias et al., 1998) in order to minimize the second order approximation to the conditional welfare losses associated with the rule. We consider various permutations of rules and contrast their optimal parameterization with and without habits effects. This reveals striking differences in the characterization of optimal rules, which mirrors the differences in Ramsey policy with and without habits. The optimal parameterization of the tax and monetary policy rules under our benchmark calibration is given by

$$\widehat{R}_t = 1.0273 \widehat{R}_{t-1} + 0.1163 \widehat{\pi}_t^C$$
$$\widehat{\tau}_t = 1.2771 \widehat{b}_{t-1}$$

while the same rules in the absence of habits are optimally given by

$$\widehat{R}_t = 1.0046 \widehat{R}_{t-1} + 4.8139 \pi_t^C$$
$$\widehat{\tau}_t = 0.08211 \widehat{b}_{t-1}$$

In both cases, this combination of rules achieves welfare levels which are indistinguishable from those attained by the Ramsey optimal policy, however the optimal rule coefficients are radically different across the habits and non-habits

[18] We consider the determinacy properties of the rules in the appendix, which shows that the usual characterisation of active/passive monetary and fiscal policies can be affected by the extent of deep habits, in a manner which extends the effects of deep habits reported in Leith et al. (2012) and Zubairy (2010a). Nevertheless the optimized rules reported below are all determinate.

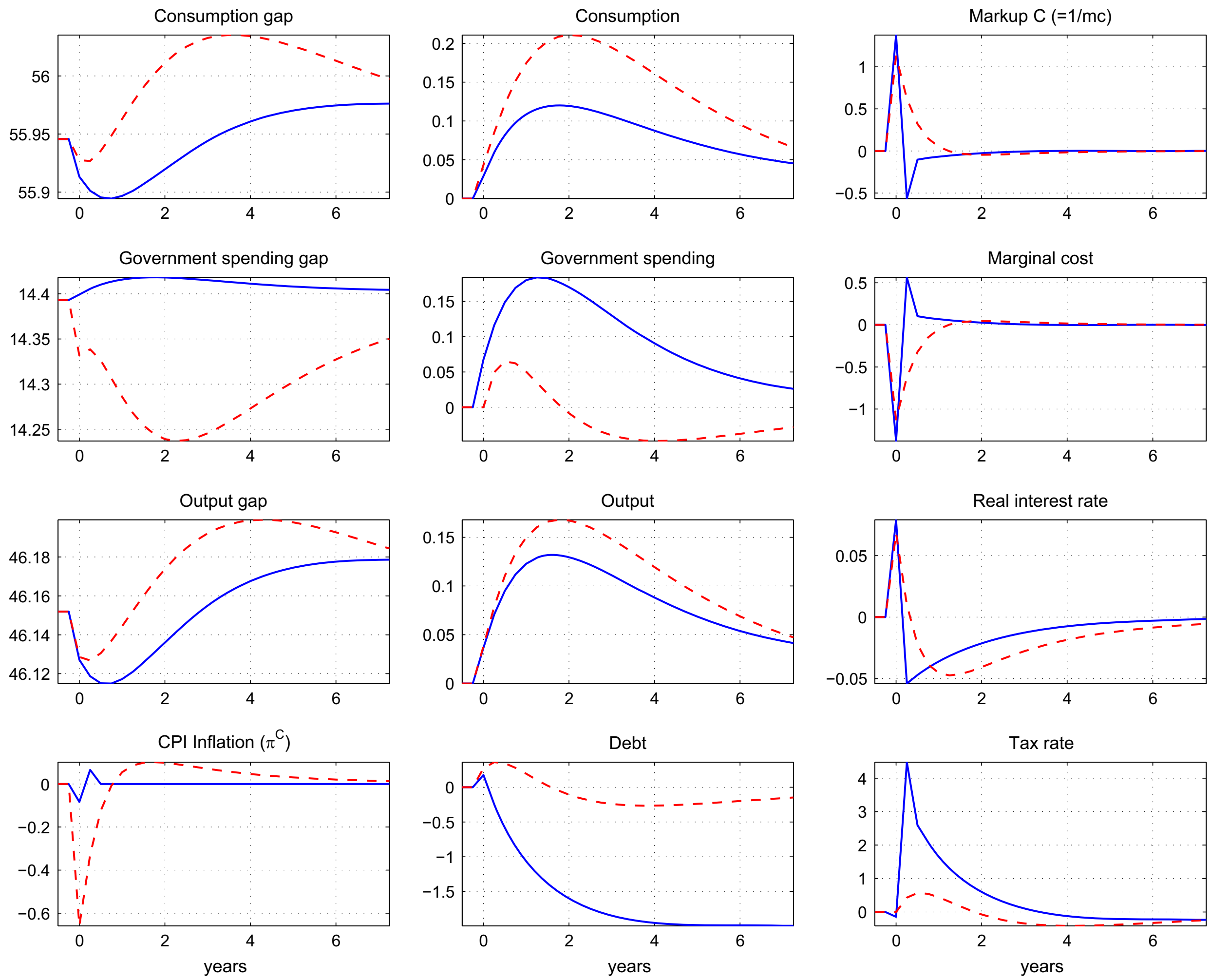

Fig. 7. Impulse responses to a +1% technology shock under the Ramsey optimal policy (solid lines) and the optimal simple rules (dash lines), under the benchmark calibration for deep habits with common pricing. The inflation and interest rate variables are expressed in annualized terms.

versions of the model. Without habits, we obtain the usual result that the interest rate rule should be inertial (in fact super-inertial in this case) and featuring a strong response to inflation, to mimic some of the commitment benefits of price level control, while in line with the random walk in debt found under the Ramsey policy, the tax response to movements in government debt should be sufficient to stabilise debt, but extremely slowly. In contrast, in the model with deep habits the optimized rule coefficients imply a much stronger fiscal adjustment through the tax rate, which moves more than one-for-one with the level of debt, not to stabilize debt rapidly per se, but to allow the tax rate to mimic the Ramsey response to the consumption externality. Moreover, while the interest rate rule retains its superinertial response to the lagged interest rate when we introduce habits, the weight attached to inflation in the rule is greatly reduced, as the policy maker faces a significant trade-off in stabilising inflation and the consumption externality, but can also rely on the inflationary effects of tax rates acting in a stabilizing manner. Effectively, the monetary and tax rule combine to manage the consumption externality without generating excessive inflation.[19]

When, instead, the fiscal policy rule is described in terms of changes in government spending, the optimal parameterization in the presence of habits is

$$\widehat{R}_t = 1.0558\widehat{R}_{t-1} + 0.1297\widehat{\pi}_t^C$$
$$\widehat{G}_t = -0.1337\widehat{b}_{t-1}$$

[19] Impulse response functions for these rules are available upon request. However, they are similar to the best performing rules presented below.

and in the absence of habits

$$\widehat{R}_t = 1.0031\widehat{R}_{t-1} + 0.4688\widehat{\pi}_t^C$$
$$\widehat{G}_t = -0.1208\widehat{b}_{t-1}$$

In this case, government spending does not play a particularly significant role in stabilizing the economy, other than doing the minimum necessary to ensure stability of the stock of government debt, regardless of the presence or absence of habits effects. Since the government spending rule does not contribute much to macroeconomic stabilization, welfare is significantly lower under this combination of rules, with the welfare costs of shocks under the rules being equivalent to 0.056% of consumption in the presence of habits under the Ramsey policy.

Finally, we consider the case where we combine a monetary policy rule with fiscal rules for both taxes and government spending with habits

$$\widehat{R}_t = 1.019\widehat{R}_{t-1} + 0.0842\widehat{\pi}_t^C$$
$$\widehat{\tau}_t = 1.5659\widehat{b}_{t-1}$$
$$\widehat{G}_t = 0.1799\widehat{b}_{t-1}$$

and without

$$\widehat{R}_t = 0.9918\widehat{R}_{t-1} + 4.1916\widehat{\pi}_t^C$$
$$\widehat{\tau}_t = 0.0672\widehat{b}_{t-1}$$

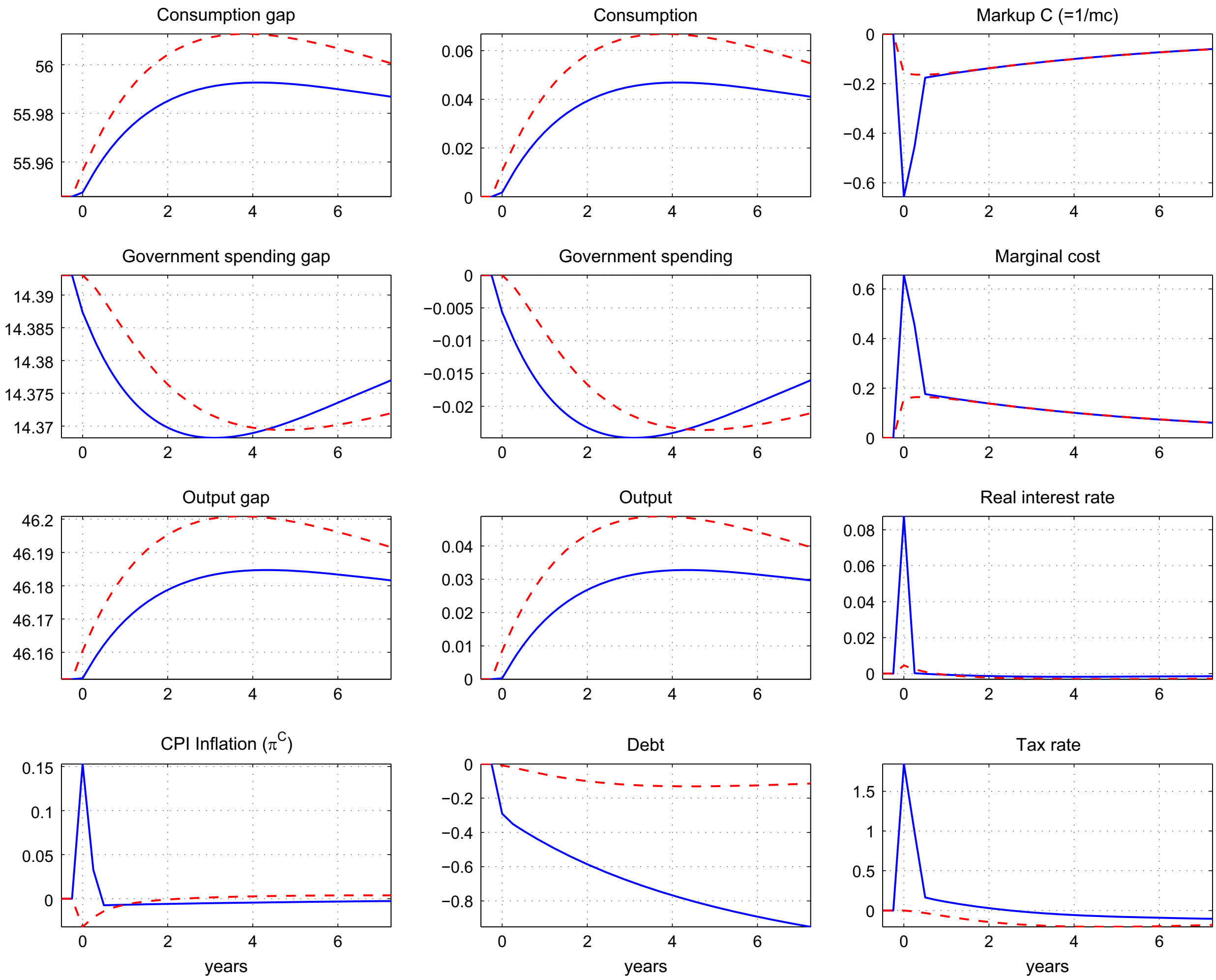

Fig. 8. Impulse responses to negative markup shock (+1% change in η_t) under the Ramsey optimal policy (solid lines) and the optimal simple rules (dash lines), under the benchmark calibration for deep habits with common pricing. The inflation and interest rate variables are expressed in annualized terms.

$$\widehat{G}_t = -0.0179\widehat{b}_{t-1}$$

Again different parameterizations reflect the changing nature of the policy problem in the presence of deep habits. Without habits, we obtain a very strong anti-inflationary monetary policy rule which attempts to mimic Ramsey policy through adding history dependence in the form of interest rate inertia. While fiscal policy in the form of both tax and spending rules very gradually responds to movements in government debt – merely doing what is necessary to achieve fiscal solvency and playing little role in macroeconomic stabilization. When we introduce habits effects, the monetary policy response to inflation is massively reduced, the tax response to government debt hugely increased and government spending actually rises rather than falls in the presence of an increase in government debt. As Figs. 7 and 8 show, these optimized rules largely succeed in replicating the Ramsey policy's responses to both technology and markup shocks, other than in the initial period of the shock. This implies that they are indistinguishable from Ramsey in welfare terms.

5. Sensitivity analysis

In this section and the associated online appendix, we evaluate the sensitivity of our results with respect to alternative specifications regarding the labor supply elasticity and the degree of nominal inertia. We vary these parameters within plausible empirical ranges, as indentified in the literature, and consider the economy's response to the exogenous government spending shock (under optimal monetary policy), as well as the responses to technology and markup shocks under the full commitment policy in the model variant with debt and distortionary taxes.

We observe slight changes in policy setting and the economy's response to shocks, but these are primarily quantitative in nature, such that the main conclusions of the model generally hold.

Considering the *Frisch labor supply elasticity*, the general pattern of responses to shocks is similar to the benchmark case, but where a more elastic labor supply typically implies larger changes in equilibrium labor, output and consumption. This means that, when faced with an exogenous increase in government expenditures, the crowding-in effect is larger when labor supply is more elastic, but the effect would be reduced and can possibly be even reversed for a sufficiently low labor supply elasticity. In the case of technology shocks, we note a subtle shift in the monetary policy setting, which does not relax policy as much in response to an increase in TFP, thus limiting the consumption response. This is essentially aiming to replicate the effects observed in the social planner's allocation – where consumption and output rise by less with a more elastic labor supply in response to a positive technology shock.[20]

Varying the *degree of nominal inertia* affects the relative balance between real and nominal adjustment as one would expect, but does not affect the qualitative responses to government spending shocks – the crowding in of private sector consumption remains – or markup and technology shocks. There is only a slight change in the initial tax policy in the face of a technology shock, which essentially seeks to enhance the effects of the initial change in inflation on the eventual steady-state stock of debt.

6. Conclusion

In this paper, we explored optimal monetary and fiscal policy in a New Keynesian economy subject to deep habits in consumption, where the habits externality exists at the level of individual goods. Employing second-order approximation methods, we consider various forms of optimal policy of increasing richness in the context of a significantly distorted economy. We begin by considering the consumption response to government spending shocks, when monetary policy is optimal. We find that deep habits can indeed result in increases in public consumption significantly crowding in private consumption, implying that this modelling device increases government spending multipliers from significantly below one, to above one. However, despite the efficacy of this fiscal policy instrument being improved in this sense, it remains the case that government spending gaps (the difference between actual government spending and that which would be chosen by a benevolent social planner) under optimal policy are both small and relatively stable in the face of technology and mark-up shocks. This is in contrast to private consumption and output gaps which are both large in steady state and vary significantly in the face of shocks. In other words, while the introduction of deep habits has significant implications for the conduct of monetary and tax policy, government spending remains relatively impotent despite the fundamental change in its transmission mechanism.

When we consider the trade-offs between business cycle stabilization and fiscal solvency, we find that it remains optimal to allow steady-state debt to follow a random walk following shocks, although the transition to that steady-state is more gradual than that observed in simpler models, due to the additional consumption externality faced by the policy maker when consumers possess deep habits. In terms of the operation of individual instruments, monetary policy largely ensures that the consumption gap is stabilized in the face of technology shocks, while the income tax instrument serves to offset the consumption externality associated with habits and any shocks to the imperfectly competitive firms' desired markups.

Finally, we assessed the ability of simple linear monetary and fiscal policy rules to achieve the levels of welfare associated with the Ramsey policy. Relatively simple interest rate and tax rate rules perform well and are able to successfully mimic the Ramsey policy. However, in doing so their optimized coefficients are radically different from those obtained under similar

[20] This result is due to the fact that an increase in TFP allows for an increase in output, while labor input falls.

rules in a model without habits. These differences reflect the different nature of the policy problem under deep habits where the very strong response of interest rates to inflation and of tax rates to government debt (along with the apparently perverse rule which raises government spending as debt rises) enable debt to be stabilized gradually, while the combined interest rate and tax policy successfully manage the evolution of habits-adjusted consumption without generating high rates of inflation.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jedc.2014.11.005.

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