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Deep Habits, Price Rigidities and the Consumption Response to Government Spending

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Deep Habits, Price Rigidities and the Consumption Response to Government Spending

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Abstract

This paper presents the novel implications of introducing price rigidities into a model of good-specific habit formation, for the response of private consumption following a positive government spending shock. With 'deep' habits in demand, the price elasticity of demand rises after the fiscal expansion and it is optimal for the firm to lower the mark-up while increasing production. This in turn raises the demand for labor and the real wage rises. Consequently, agents raise consumption at the expense of leisure and overcome the negative wealth effect of the fiscal shock. We show that increasing price stickiness in a model with deep habits hinders the crowding-in of consumption. If the degree of price stickiness is high enough, consumption is crowded out by government spending. These dynamics are in stark contrast to those in traditional models where price rigidities are known to weaken the crowding-out of consumption.

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1 Introduction

The impact of cyclical fluctuations in government purchases on private consumption has received considerable attention in the structural vector autoregression (SVAR) literature. A large number of SVAR studies report a rise in private consumption following a positive government spending shock.[1] The neoclassical model of macroeconomic fluctuations that is based on inter-temporally optimizing agents and unproductive government spending struggles to generate the positive response. A rise in government spending generates, *ceteris paribus*, a concurrent increase in the present value of lumpsum taxes. This negative wealth effect induced by the fiscal expansion results in the lowering of private consumption, a phenomenon known in the literature as 'crowding-out'. The New Keynesian (NK) model that incorporates nominal rigidities into the neoclassical framework exhibits the same wealth effect that crowds out consumption after an expansionary fiscal shock. However, replicating the empirically relevant 'crowding-in' comovement within the traditional paradigm has become less challenging in recent theoretical models.

A government spending shock financed by lumpsum taxes raises the agent's incentive to work and save more. The surge in the supply of labor causes the real wage to fall. If one can induce the real wage to rise or at least not fall strongly, the intra-temporal substitution of consumption for leisure may be strong enough to compensate for the unfavorable wealth effect. Not surprisingly, real wage dynamics and the ensuing substitution of consumption for leisure play pivotal roles in theoretical environments formulated to generate the rise in consumption following the fiscal expansion.

Galí *et al.* (2007) and Furlanetto (2011) use credit-constrained consumers who do not smooth consumption and simply consume their after-tax wage income. A rise in the real wage raises the consumption of the credit-constrained agent and if the share of these agents is high enough and the *ex ante* real interest rate does not rise strongly, the positive response of aggregate consumption can be replicated. In Monacelli and Perotti (2008) and Bilbiie (2011), consumption is positively stimulated due to the interaction between real wage dynamics and a utility function which is non-separable in consumption and leisure. Lopez-Salido and Rabanal (2006) generate the crowding-in of consumption in estimated

[1] An inexhaustive list includes Lewis and Winkler (2013), Ravn *et al.* (2012), Monacelli and Perotti (2008), Galí *et al.* (2007) and Blanchard and Perotti (2002). An exception is Peersman and Straub (2006) who find that consumption is mildly crowded out in the US and does not respond significantly in the Euro-Area.

models with credit-constrained consumers as well as non-separable preferences. On the other hand, Davig and Leeper (2011) demonstrate how the stance of monetary and fiscal policy alter the dynamics of the real interest rate and the real wage and generate the positive comovement. A vital element that contributes to the rise in the real wage in all these environments is price rigidity in the goods market. When there are barriers to raising the price, the profit-maximizing firm responds to the demand shock by hiring more labor to expand production. This in turn raises the real marginal cost or equivalently lowers the mark-up of the price over the nominal marginal cost. If the expansion in labor demand exceeds the increase in labor supply which accompanies the fiscal shock, hours worked will rise in equilibrium, raising the real wage.

In contrast, Ravn *et al.* (2012, 2006) propose an alternative mechanism to generate the positive response of private consumption, even while adhering to an environment with flexible prices.[2] They construct an economy where the government and private agents form habits over individual goods that are produced by monopolistically competitive firms. The presence of 'deep' habits - as opposed to the conventional 'superficial' habit formation at the level of the final good - implies that the demand function facing the firm has a component that depends on lagged demand. This novel component gives rise to a time-varying price elasticity of demand. The government spending shock triggers a strong procyclical movement in the price elasticity and hence a countercyclical movement in the mark-up. Since the mark-up and the demand for labor are negative correlated, the latter increases positively stimulating the real wage. Finally, the lower demand for leisure that follows the rise in the real wage generates a rise in consumption.

This paper shows that price stickiness hinders the rise in consumption after the government spending shock in an economy with deep habits. Starting from a deep habits model with flexible prices, we sequentially add higher degrees of price rigidity. Impulse response analysis of the sticky price deep habits model suggests that as prices become less flexible, the mark-up and the real wage cease to move substantially in response to the fiscal shock and the crowding-in of consumption is weakened. When the degree of stickiness is high enough, consumption is crowded out as in traditional forward-looking models. It is intriguing that the mark-up becomes less countercyclical with increasing price stickiness and worsens the crowding-in of consumption by government spending in the deep habits model. Other theoretical mechanisms briefly reviewed earlier, have relied on price

[2] Another mechanism that uses flexible prices is that of Devereux *et al.* (1996) where free firm entry yields mark-up and real wage dynamics that stimulate consumption.

rigidities as the source of mark-up countercyclicality to augment the positive response of consumption. Why do two frictions - sticky prices and deep habits - that support the crowding-in of consumption by government spending when used independently in general equilibrium models, weaken the fiscal stimulus when used in conjunction?

We illustrate that the composition of the Phillips curve lies at the heart of the counterintuitive consumption dynamics observed in deep habits economies as prices get more sticky. Just as in the flexible price scenarios examined by Ravn *et al.* (2012, 2006), a positive stimulus to government spending increases the price elasticity and gives the monopolist an incentive to lower the price and hence the mark-up to maximize profits when she raises production. The mark-up continues to be negatively correlated to the time-varying price elasticity even in the environment considered here. However, since prices are sticky, the expected path of infation exerts a positive influence on the mark-up. These two opposing effects are encapsulated in the deep habits Phillips curve.

Since the price level falls after the fiscal shock, inflation is expected to rise to restore the long-run equilibrium. Increasing price stickiness in the deep habits model, makes it more difficult to lower the price and the mark-up to react to the rise in price elasticity and consequently, the positive effect of expected inflation becomes more dominant. For this reason, the price and mark-up react *less* countercyclically to government spending under increasing price stickiness. Consequently, the real wage is less procyclical and fails to deliver a substitution effect on consumption that is strong enough to overcome the negative wealth effect of the fiscal expansion.

In contrast, in a model with no deep habit or only superficial habits, the price elasticity of demand is constant. In this case, the government spending shock acts more as a conventional demand shock by raising prices. As mentioned earlier, the fall in the mark-up is a consequence of price stickiness in this setting. As we increase price stickiness in the environment without deep habits, the stronger countercylicality of the mark-up - and the enhanced procyclicality of the real wage - weakens the crowding out of consumption by the fiscal shock.

This paper is not the first to introduce price stickiness in deep habits models and is related to an expanding literature that employs deep habits in the context of the transmission of monetary and fiscal policy. Ravn *et al.* (2010) study the response of price inflation to a monetary shock in a model with deep habits in private consumption. Leith *et al.* (2012) analyze optimal monetary policy in NK models of deep and superficial habits.

Zubairy (2011) studies the determinacy properties of NK models with deep habits. However, unlike this paper, they abstract from government spending. On the other hand, Zubairy (2013) uses deep habits in government and consumption spending to generate very small but positive consumption short-run multipliers in a medium-scale estimated NK DSGE model. Cantore *et al.* (2013) analyze the effects of fiscal policy in a theoretical sticky price economy with deep habits and unemployment. Cantore *et al.* (2012a) focusses on optimal monetary policy and the crowding-in of consumption by fiscal expansions in a theoretical sticky price deep habits model. Cantore *et al.* (2012b) compare fiscal stimuli in estimated sticky price models of superficial and deep habits. Given their complex modelling strategies and varied objectives, the aforementioned papers do not document the decrease in mark-up countercyclicality in deep habits models when price rigidities are incorporated and its role in determining the consumption response.[3] Our simplified analytical framework brings forth the mechanism behind this counterintuitive interaction which remains latent in their model environments.

The plan of the paper is as follows. In Section 2, we introduce sticky prices into a stylized baseline economy with deep habits and also discuss the restrictions that reduce the deep habits model to a simple sticky price model with no habit persistence. Section 3 examines the dynamics of the deep habits economy and shows how increasing price stickiness worsens the crowding-in of consumption by government spending. As a familiar benchmark, we will contrast the dynamics with those in the traditional sticky price model without deep habits in which price rigidities alleviate the crowding-out of consumption. We establish that the different dynamics of consumption can be traced to the composition of the Phillips curves in the two environments. In Section 4, we compare consumption responses under superficial and deep habits. We will also highlight the crucial role of habits in the public sector in generating crowding-in as well as the secondary role that private consumption habits play in the dynamics. We subsequently present the impact consumption responses when key parameters are allowed to vary along with price stickiness. Finally we verify that our baseline results are preserved in the more complex environment of Ravn *et al.* (2006). Section 5 draws the main conclusion. A technical appendix documents the derivation of the key equations.

[3] Subsequent to the findings of the working paper version of this paper, Cantore *et al.* (2013) also report the crowding-out of consumption in the deep habits model when prices get stickier. They relate the crowding-out of consumption, in part to a strong response of monetary policy to output. Here we find that consumption can be crowded out even when monetary policy avoids output stabilization. As in Cantore *et al.* (2013), a more aggressive monetary policy worsens crowding-out.

2 The Baseline Model of Deep Habits and Sticky Prices

Our objective is to demonstrate how the presence of price stickiness has different, and somewhat counterintuitive implications for the comovement of public and private consumption in economies with and without deep habits. To this end, we formulate a stylized deep habits model as the baseline case, which we subsequently reduce to a simple NK model with no habit formation. Later, we will conduct numerical experiments in both environments to examine the sequence of events that bridges a rise in government spending to an expansion or contraction of private consumption. The simplicity of the set-up considered helps us to distill the intuition behind the mechanisms that generate the dynamics observed here. In Section 4, we will demonstrate that our results are relevant in more complex settings.

We consider a closed-economy model with good-specific habit formation in consumption and government spending along the lines of Ravn *et al.* (2006), but with some simplifications.[4] Unlike them, we abstract from capital accumulation. Further, current expenditures on individual goods depend only on expenditures in the previous period and not on the entire history of expenditures as represented by a habit-stock. We then introduce sticky prices and a monetary policy rule into the deep habits environment. Finally, we impose restrictions on the deep habits model to reduce it to a simple sticky price model with no habit persistence.

Except in cases that are not standard in the literature, we proceed to the log-linearized versions of the equilibrium conditions without describing the non-linear equations. Steady-state variables are denoted by an upper bar and variables that are presented as logarithmic deviations from the steady-state are denoted by '$\widehat{\ }$'.

Good-specific Habit Formation The characteristic that sharply distinguishes this economy from the traditional framework is that the public and private sectors form habits over the consumption of individual goods. Traditionally (see for *e.g.* Smets and Wouters 2007), habit persistence is modelled in the private sector which forms habits over the final consumption good. In addition, government spending does not exhibit habit formation.

We will henceforth indicate the demands from the private sector and the government by c and g respectively. Agents in the economy are indexed by $j \in [0,\ 1]$ while goods varieties

[4] Ravn *et al.* (2012) analyze an open-economy model with deep habits.

are indexed by $\iota \in [0,\ 1]$. In every period t, the consumer derives utility from an aggregate that is defined as $x_t^{c\ j} = \left[\int\limits_0^1 \left(c_{\iota t}^j - h_c c_{\iota t-1} \right)^{\frac{\eta_p - 1}{\eta_p}} d\iota \right]^{\frac{\eta_p}{\eta_p - 1}}$ such that $h_c \in [0,1)$ and $\eta_p > 1$. $c_{\iota t-1} = \int\limits_0^1 c_{\iota t-1}^j dj$ denotes the average level of consumption of good ι and h_c indicates the degree of external habit formation in the economy. For a given level of $x_t^{c\ j}$, optimal consumption demand for good ι is obtained by minimizing total expenditure $\int\limits_0^1 p_{\iota t} c_{\iota t}^j d\iota$ subject to the aggregation constraint. Analogous to the private sector, the government forms external habits over the individual goods it purchases and faces a similar cost-minimization program for allocating its expenditures. Ravn *et al.* (2012) motivate external good-specific habit formation in public spending by appealing to situations in which the provision of public services in one community creates the desire in other communities to have access to the same services. Alternatively, they also suggest that procurement relationships create a tendency for the government to favour transactions with sellers that supplied public goods in the past. Habit formation in government spending is equivalent to a set-up where private agents value government spending in a way that is separable from private consumption and leisure and form good-by-good habits over public goods provided by the government (see also Zubairy 2013). As we shall later see in Section 4, as far as the rise of consumption after the fiscal expansion is concerned, habit persistence in the public sector - and not private consumption habit - is the crucial ingredient.

The optimal demands from private consumption (aggregated across agents) and government spending for good ι are given as $z_{\iota t} = \left(\frac{p_{\iota t}}{P_t} \right)^{-\eta_p} x_t^z + h_z z_{\iota t-1}$ where $h_z \in [0,1)\ \forall z \in \{c,\ g\}$. $P_t \equiv \left(\int\limits_0^1 p_{\iota t}^{1-\eta_p} d\iota \right)^{\frac{1}{1-\eta_p}}$ is the aggregate nominal price index for habit-adjusted demand. The presence of deep habits splits demand for the good ι into two components. The first component covaries negatively with the relative price $\frac{p_\iota}{P}$ and positively with aggregate habit-adjusted demand x^z. However, the second component $h_z z_{\iota t-1}$ is purely predetermined by habit formation and is invariant to changes in the relative price. The presence of this price-inelastic habit component causes the price elasticity of demand $\varepsilon_{\iota t}^z = -\frac{\partial z_{\iota t}}{\partial p_{\iota t}} \frac{p_{\iota t}}{z_{\iota t}}$ to be time-dependent. In particular, in a symmetric equilibrium, $\varepsilon_t^z = \eta_p \left(1 - h_z \frac{z_{t-1}}{z_t} \right)$. This is in contrast to models where the demand function has no habit component, *i.e.*

$h_z = 0$, so that the price elasticity is constant at η_p. We now express the price elasticity in log-linearized terms.

$$\hat{\varepsilon}_t^z = \frac{h_z}{1-h_z}\left(\hat{z}_t - \hat{z}_{t-1}\right) \; \forall z \in \{c,\ g\} \tag{1}$$

As we shall see later in this section, the time-varying nature of the price elasticity has important implications for pricing behavior. Note also that the price elasticities for sales to the private and public sectors can differ from each other due to varying degrees of habit persistence as well as relative inter-temporal changes in demand. By log-linearizing the dynamic demand functions, we can link habit-adjusted aggregate demand to the price elasticity as follows.

$$\hat{x}_t^z = \hat{\varepsilon}_t^z + \hat{z}_t \; \forall z \in \{c,\ g\} \tag{2}$$

Utility Maximization Consumers derive utility from habit-adjusted consumption $x^{c\,j}$ and disutility from supplying labor n^j. They provide labor services in a perfectly competitive labor market at a real wage w. Agents have access to a portfolio of state-contingent nominal assets d^j to smooth consumption over time. The consumer is entitled to dividends $d\iota v^j$ from the firm and also pays lumpsum taxes τ^j to finance public expenditure. The optimization program that faces the generic consumer is given as

$$\max_{c_t^j,\ n_t^j,\ d_{t+1}^j} \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\left(x_t^{c\,j}\right)^{1-\sigma_c}}{1-\sigma_c} - \frac{n_t^{j\ 1+\sigma_n}}{1+\sigma_n} \right],\ \sigma_c,\ \sigma_n \geqslant 0,\ \beta \in (0,1)$$

subject to the consumption aggregation constraint and the budget constraint which is given by

$$\frac{\int_0^1 p_{\iota t} c_{\iota t}^j d\iota}{P_t} + \frac{\mathbf{E}_t\left(\Lambda_{t,t+1} d_{t+1}^j\right)}{P_t} + \tau_t^j = w_t n_t^j + \frac{d_t^j}{P_t} + d\iota v_t^j$$

where $\mathbf{E}_0$ indicates the expectational operator conditional on the information set available when the decision is made and $\Lambda_{t,t+1}$ is the nominal stochastic discount factor.

We focus on first order conditions describing aggregate behavior in a symmetric equilibrium. The inter-temporal flow of aggregate habit-adjusted consumption is decided by the Euler equation.

$$\hat{c}_t = \frac{1}{1+h_c}\mathbf{E}_t\hat{c}_{t+1} + \frac{h_c}{1+h_c}\hat{c}_{t-1} - \frac{1-h_c}{1+h_c}\frac{1}{\sigma_c}\left(\hat{r}_t - \mathbf{E}_t\hat{\pi}_{t+1}\right) \tag{3}$$

π is the inflation rate in the aggregate price level and r is the gross nominal interest rate.[5] The labor supply schedule is determined by the equality between the marginal rate of substitution between leisure and consumption and the real wage.

$$\hat{w}_t = \sigma_n\hat{n}_t + \frac{\sigma_c}{1-h_c}\hat{c}_t - \frac{\sigma_c h_c}{1-h_c}\hat{c}_{t-1} \tag{4}$$

Production and Price-Setting The monopolistic firm uses labor n in a linear production function to produce quantity y of its differentiated good. A fixed cost $fc > 0$ is used in the technology in order to assure that profits are zero in steady-state. In log-linearized terms, $\hat{y}_t = \left(1 + \frac{fc}{\bar{y}}\right)\hat{n}_t$.

The crux of the deep habits mechanism lies in the price-setting behavior of the monopolist. We depart from Ravn *et al.* (2012, 2006) by introducing pricing frictions and embed adjustment costs *à la* Rotemberg (1982) in the firm's dynamic optimization problem. The firm maximizes the expected value of profits by choosing the labor input, price and quantities given the price adjustment cost as well as demand and resource constraints.[6]

$$\max_{n_{\iota t},\, p_{\iota t},\, g_{\iota t},\, c_{\iota t}} \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t u_{ct} \left(\begin{array}{l} \frac{p_{\iota t}}{P_t}\left(g_{\iota t} + c_{\iota t}\right) - w_t n_{\iota t} + \frac{\Phi_p}{2}\left(\frac{p_{\iota t}}{\bar{\pi} p_{\iota t-1}} - 1\right)^2 y_t \\ +\nu^g_{\iota t}\left[\left(\frac{p_{\iota t}}{P_t}\right)^{-\eta_p} x^g_t + h_g g_{\iota t-1} - g_{\iota t}\right] \\ +\nu^c_{\iota t}\left[\left(\frac{p_{\iota t}}{P_t}\right)^{-\eta_p} x^c_t + h_c c_{\iota t-1} - c_{\iota t}\right] \\ +\frac{1}{\mu_{\iota t}}\left(n_{\iota t} - fc - g_{\iota t} - c_{\iota t}\right) \end{array} \right)$$

The degree of price stickiness is increasing in $\Phi_p > 0$ and aggregate output y. u_c is the marginal utility of consumption and $\nu^{(\,)}$ are the Lagrange multipliers on the demand functions. The real marginal cost serves as the Lagrange multiplier on the resource constraint. Much of the discussion that follows centres on the reciprocal of the real marginal cost, *i.e.* the gross mark-up of the price over the nominal marginal cost represented by μ. It is hence convenient to express the real marginal cost in terms of the mark-up at the outset.

[5] In equilibrium, $1/r_t = \mathbf{E}_t\Lambda_{t,t+1}$

[6] Observe that the presence of the habit component in demand makes the firm's problem forward-looking even in the absence of sticky prices.

The log-linearized first order condition with respect to the labor input imposes a negative relationship between the real wage and the mark-up: $-\hat{\mu}_t = \hat{w}_t$.[7] In a symmetric equilibrium, the first order condition for satisfying demand from public and private consumption is

$$\nu_t^z = \frac{\mu_t - 1}{\mu_t} + \mathbf{E}_t \beta \frac{u_{ct+1}}{u_{ct}} h_z \nu_{t+1}^z \ \forall z \in \{c,\ g\} \tag{5}$$

ν^z measures the incremental addition of a unit of demand to the profit of the firm, *i.e.* the real marginal profit, and plays a crucial role in the deep habits environment. At the optimum, this equals the sum of profit from current sales given by $\frac{\mu-1}{\mu}$ and the discounted value of the profit generated from an additional h_z unit of demand obtained in the period $t+1$ due to the habit component. Log-linearizing Equation 5 and rearranging, we arrive at

$$\hat{\mu}_t = \frac{\bar{\mu}_{dh} - 1}{1 - \beta h_z} \left(\hat{\nu}_t^z - \beta h_z \mathbf{E}_t \left[\hat{\nu}_{t+1}^z + \hat{u}_{ct+1} - \hat{u}_{ct} \right] \right) \ \forall z \in \{c,\ g\} \tag{6}$$

where $\bar{\mu}_{dh}$ is the steady-state mark-up under deep habits. Equation 6 determines the inter-temporal effect of deep habits on the mark-up. If the present discounted value of future marginal profits is high due to a rise in demand, the firm has an incentive to lower the mark-up. Equivalently, lowering the mark-up in the present period ensures additional profits in the next period.

The optimal price-setting plan is given by

$$\Phi_p \frac{\pi_t}{\bar{\pi}} \left(\frac{\pi_t}{\bar{\pi}} - 1 \right) = \beta \Phi_p \mathbf{E}_t \frac{u_{ct+1} y_{t+1}}{u_{ct} y_t} \frac{\pi_{t+1}}{\bar{\pi}} \left(\frac{\pi_{t+1}}{\bar{\pi}} - 1 \right) - \eta_p \left[\frac{\nu_t^c x_t^c}{y_t} + \frac{\nu_t^g x_t^g}{y_t} \right] + 1 \tag{7}$$

The crucial distinction from the conventional price-setting equation lies in the presence of the marginal profits $\nu^{()}$ and habit-adjusted demands $x^{()}$. As noted earlier, the marginal profits covary positively with the mark-up and future profits while habit-adjusted demand exerts a positive influence on the price elasticity of demand. Log-linearizing Equation 7, we arrive at the Phillips curve which links price inflation to the mark-up (via Equation 6) and the price elasticities (via Equation 2). For the analysis of the dynamics that follows in Section 3, it is convenient to rearrange terms to express the Phillips curve in terms of

[7] In the non-linear model, the marginal product of labor is a mark-up over the real wage. Since production is linear in labor, the marginal product is constant at unity. Hence, the marginal product does not appear in the log-linear model, the real wage is simply the mirror-image of the mark-up.

the mark-up instead of inflation as in the standard case.

$$\begin{aligned}\hat{\mu}_t &= \frac{m_0\Phi_p}{\left(\eta_p m_0 - 1\right) m_1}\left(\beta\mathbf{E}_t\hat{\pi}_{t+1} - \hat{\pi}_t\right) - m_g\left(\hat{\varepsilon}^g_t + \beta h_g \mathbf{E}_t\left[\hat{\nu}^g_{t+1} + \hat{u}_{ct+1} - \hat{u}_{ct}\right] + \left[\hat{g}_t - \hat{y}_t\right]\right) \\ &\quad - m_c\left(\hat{\varepsilon}^c_t + \beta h_c \mathbf{E}_t\left[\hat{\nu}^c_{t+1} + \hat{u}_{ct+1} - \hat{u}_{ct}\right] + \left[\hat{c}_t - \hat{y}_t\right]\right) \qquad (8)\end{aligned}$$

where m_0, m_1, m_g and m_c are positive constants that are functions of the deep habit parameters.[8] A positive stimulus to aggregate demand, such as an increase in government spending, raises the price elasticity and also generates additional profits in the future. Both factors contribute in lowering the current mark-up. However, in contrast to the flexible price environments considered by Ravn *et al.* (2012, 2006) since prices are sticky, expected changes in inflation play a role in guiding the mark-up. In particular, when there is a rise in aggregate demand, the positive influence of expected inflation on the mark-up opposes the negative impact of the price elasticity and future profits. This additional effect will later prove crucial to understanding the effects of price stickiness on the crowding-in of consumption. By setting $\Phi_p = 0$, we obtain the flexible price scenario.

Monetary Policy The presence of price rigidities paves the way for monetary policy to stimulate real economic activity. The *ex ante* real interest rate affects inter-temporal substitution in two distinct ways in the deep habits environment. The first is the conventional channel via the consumption Euler (Equation 3) so that a rise in the real interest rate dampens demand. The second impetus is channelled through the present value of expected future marginal profits to the current mark-up. In particular, when we substitute the real interest rate for the growth in marginal utility in Equation 6, we get

$$\hat{\mu}_t = \frac{\bar{\mu}_{dh} - 1}{1 - \beta h_z}\left(\hat{\nu}^z_t - \beta h_z\left[\mathbf{E}_t\hat{\nu}^z_{t+1} - \left(\hat{r}_t - \mathbf{E}_t\hat{\pi}_{t+1}\right)\right]\right) \ \forall z \in \{c,\ g\} \qquad (9)$$

A rise in the interest rate decreases the present value of expected profits so the firms increase current mark-ups, lowering wages and hence weakening consumption demand. This additional effect is absent in an economy with only superficial habit or no habit formation at all. We draw the monetary policy rule from the estimated deep habits model of Ravn *et al.* (2010) allowing the monetary authority to set the policy rate in response to inflation and output. $r_r \in [0, 1)$ governs the degree of inertia in the monetary policy

[8] See appendix for definitions of these constants.

response.

$$\hat{r}_t = r_r \hat{r}_{t-1} + (1 - r_r)(r_\pi \hat{\pi}_t + r_y \hat{y}_t), \; r_\pi > 1, \; r_y \geq 0 \tag{10}$$

Market Clearing and Fiscal Policy The market for labor clears when the demand for labor equals the supply of labor from the household. Since all agents are identical and financial markets are complete, the state-contingent assets are in zero net-supply. The goods market clears when output produced by the firms is absorbed by the private and public sectors: $\hat{y}_t = (1 - \bar{g}_y)\hat{c}_t + \bar{g}_y \hat{g}_t$ where $\bar{g}_y$ is the steady-state ratio of government spending in output. The government operates under a simple fiscal rule with its expenditure fully financed by lumpsum taxes: $\hat{g}_t = \hat{\tau}_t$. Government spending is the only source of uncertainty in the economy and follows an AR(1) process given by $\hat{g}_t = \rho_g \hat{g}_{t-1} + \epsilon_t$ such that $\epsilon_t \sim N(0, \sigma_g)$ and $\rho_g \in [0, 1)$.

2.1 The Nested New Keynesian Model

The sticky price deep habits model can be reduced to a simple NK model with no habit formation by setting $h_c = h_g = 0$. Unlike in the deep habits model, the demand function facing the monopolist is now static and the price elasticity of demand is constant at η_p. Thus time-varying price elasticities play no role in determining the mark-up. Also, the monopolist has no incentive to lower the price and the mark-up to generate additional future profits after a fiscal expansion. Movements in the mark-up are now strictly tied down to expected changes in inflation in the New Keynesian Phillips curve (NKPC).

$$\hat{\mu}_t = \frac{\Phi_p}{\eta_p - 1}(\beta \mathbf{E}_t \hat{\pi}_{t+1} - \hat{\pi}_t) \tag{11}$$

This simple model along with an monetary policy authority which reacts only to inflation $(r_y = 0)$, will serve as a familiar benchmark in the dynamics that will be presented in Section 3. The additional restriction of a purely inflation-targetting regime facilitates comparison with other models of consumption crowding-in as that of credit-constrained households in Gali *et al.* (2007) and non-separable utility as in Monacelli and Perotti (2008) and Bilbiie (2011). The importance of a less aggressive monetary policy stance for the strengthening of a fiscal stimulus has been noted by Linnemann and Schabert (2003). We will refer to this set-up as the nested NK model.

2.2 The Mark-Up and Intra-temporal Substitution

The labor demand condition imposes an inverse one-to-one relationship between the mark-up and the real wage in our environment. Remember also that the real wage stimulates consumption via the substitution between consumption and leisure in the labor supply condition given in Equation 4. Combining these insights, we establish a direct link between the dynamics of the mark-up and consumption.

$$-\hat{\mu}_t = \sigma_n \hat{n}_t + \frac{\sigma_c}{1-h_c}\hat{c}_t - \frac{\sigma_c h_c}{1-h_c}\hat{c}_{t-1} \tag{12}$$

To understand the effect of the fiscal shock on consumption, what is important is the response of the mark-up. As can be observed in Equation 12, a downward movement in the mark-up may positively stimulate consumption. If this stimulus dominates the downward pressure on consumption exerted by the wealth effect of the fiscal shock, consumption will rise in equilibrium. The two set-ups described above employ different means to achieve this common end: while the deep habits model relies on the rise in the price elasticity and expected future profits, the nested NK case instead depends on price stickiness to deliver the fall in the mark-up. However, little is known about the effects of price stickiness on the behavior of the mark-up when habit formation is good-specific. In the following section, we will perform numerical experiments to understand the effects of price stickiness on the link between government spending, the mark-up and consumption in the deep habits economy. As a benchmark, we begin by analyzing the analogous dynamics observed in the nested NK model with no habits.

3 Dynamics of the Baseline Model

3.1 Parameter Values

Table 1 displays the parameter values that are used in the impulse response analysis of the baseline deep habits model and its nested simplification as well other variants that we will consider. Later in Section 4, we will evaluate the changes in model dynamics when the baseline parameter values are varied over wide ranges. The monetary policy rule, exhibits a high degree of interest rate smoothing with r_r calibrated at 0.80 while the coefficients on inflation (r_π) and output (r_y) are set at 1.5 and 0.1 respectively. These values are within the ballpark of the estimates in empirical deep habits models (*e.g.* Zubairy 2013, Cantore *et al.* 2012b and Ravn *et al.* 2010) or other NK DSGE models (*e.g.* Jacob and Peersman 2013, Smets and Wouters 2007). We take most other parameter values from Ravn *et al.* (2006). The autoregressive parameter of the government spending shock (ρ_g) is set at 0.90. The Frisch elasticity $(1/\sigma_n)$ is given a relatively high value of 1.3. The utility curvature (σ_c) is fixed at 2 and the price elasticity of habit-adjusted demand (η_p) is given a value of 5.3. The long-run share of government spending in output $(\bar{g}_y)$ is set at 0.12. We use a lower degree of habit formation in consumption than in government spending with h_c set at 0.5, rather than imposing $h_c = h_g = 0.86$ as in Ravn *et al.* (2006).[9]

Keeping all other parameters constant, we now increase the degree of price stickiness (Φ_p) in both environments.

3.2 Mark-Up and Consumption Dynamics

We examine the dynamics induced by a temporary and unanticipated increase in government purchases in the two economies, focussing mainly on the responses by the mark-up and consumption. The spending stimulus is generated by an exogenous innovation of one percent to the shock process. The dynamic responses in the nested NK model are presented in Figure 1 and those for the deep habits model are exhibited in Figure 2.

The Nested NK Model We begin with analyzing the dynamics in a real business cycle model with monopolistic competition (depicted in Figure 1 using thick black lines) which is simply the flexible price version of the nested NK model. The mark-up (and the real wage) is now constant and its log-linearized version that is depicted here is static at zero. The intra-temporal substitution effect does not overcome the negative wealth effect of the fiscal shock and consumption is crowded out. We now return to the nested NK model, reintroducing sticky prices and monetary policy into the RBC model and switching off the monetary policy response to output $(r_y = 0)$. As a first step, we keep the adjustment cost

[9] Once we set a high value for government spending habit as $h_g = 0.86$, we do not find a determinate solution path for $h_c > 0.58$ in both flexible and sticky price versions of the baseline model. In the presence of deep habits, an expected rise in demand will lower mark-ups, increase wages and hence raise current demand which will again raise expectations of future demand. When overall habit formation in aggregate demand is very high, these mutually reinforcing elements lead to self-fulfilling equilibria. Ravn *et al.* (2004) find indeterminacy in a flexible price model with only consumption when $h_c > 0.43$. Leith *et al.* (2012) and Zubairy (2011) report the insufficiency of the Taylor principle to guarantee determinacy in an NK model when deep habits are very strong. In subsection 4.3, when we introduce capital accumulation (without investment habits) as in Ravn *et al.* (2006), we find a unique equilibrium for the original configuration of $h_c = h_g = 0.86$. See also footnote 16.

parameter Φ_p low at about 8.5 that corresponds to a price duration of about two quarters. The inflexibility in price adjustment induces a downward movement in the mark-up and strengthens the substitution of consumption for leisure. Consequently, consumption is less crowded out by the government spending shock than in the flexible case. As we slowly increase the price adjustment cost, the crowding-out of consumption is weakened.[10] Note that the mark-up and consumption movements that price stickiness induces are extremely small in quantitative terms. In the absence of other features such as credit-constrained agents or non-separable utility previously used in the literature, price stickiness by itself is unable to generate the crowding-in of consumption.

The Deep Habits Model Consider first the dynamics under flexible prices (depicted in Figure 2 using thick black lines). Unlike the previous case, the mark-up falls sharply even in the absence of sticky prices, allowing the positive intra-temporal substitution effect to overcome the negative wealth effect, stimulating consumption. However, when we introduce price stickiness, the response of the mark-up is dampened and for a price duration of roughly two quarters (depicted by a dashed red line), the downward movement in the mark-up - or equivalently the rise in the real wage - is already too mild to prevent consumption from being crowded out.

Why does higher price stickiness induce stronger movements in the mark-up in the nested NK model while it appears to dampen its cyclicality in the deep habits economy? Understanding these interactions is critical to contrast the consumption responses to the government spending shock in the two environments. In the following subsection, we delve deeper into this issue.

3.3 Crowding-In and the Composition of the Phillips Curve

Here we demonstrate that at the heart of the distinct consumption dynamics delivered by the two models in the face of price rigidities, lies the constitution of the Phillips curves. Intimately related to the nature of the Phillips curves, is the fact that a rise in government spending generates *opposite* responses from the price level in the two set-ups. To differentiate the common variables in the two Phillips curves, we will now superscript

[10] In the baseline calibration of the deep habits model, note that the central bank reacts mildly positively to output movements. This policy rule worsens crowding-out if used in the simple no-habits NK model because the real interest rate rises. In subsection 4.2, we briefly discuss the consumption response in the deep habits model when the monetary authority avoids output-stabilization as in the nested NK model.

the variables in the deep habits model by '*dh*'. In Figure 3, we present impulse response functions of the constituents of the Phillips curves in the deep habits and the nested NK economies. In our discussion, we will also refer to the price, inflation and *ex ante* real interest rate dynamics exhibited in Figures 1 and 2.

We rewrite the deep habits Phillips curve in Equation 8 by expressing the mark-up as the difference between the price and the nominal marginal cost and grouping terms.

$$\underbrace{\hat{\mu}_t^{(dh)}}_{\hat{p}_t^{(dh)} - \widehat{nmc}_t^{(dh)}} = \underbrace{\frac{m_0 \Phi_p}{\left(\eta_p m_0 - 1\right) m_1} \left(\beta \mathbf{E}_t \hat{\pi}_{t+1}^{(dh)} - \hat{\pi}_t^{(dh)}\right)}_{\text{Expected Inflation Change}} - \underbrace{m_g \hat{\varepsilon}_t^g}_{\text{Price Elasticity (g)}} + \underbrace{\widehat{OE}_t}_{\text{Other Effects}} \tag{13}$$

where the term $\widehat{OE}$ ('other effects') captures the cumulated effects of all other elements in Equation 8.

Consider first the dynamics when $\Phi_p = 8.5$ (indicated by dashed red lines), a price duration of two quarters. The fiscal expansion leads to a sharp rise in the price elasticity of public sector demand (Panel 2) defined as $\hat{\varepsilon}_t^g = \frac{h_g}{1-h_g}\left(\hat{g}_t - \hat{g}_{t-1}\right)$. The monopolist maximizes profit by *lowering* the price (Panel 3 of Figure 2) and inflation is hence expected to rise to restore the long-run equilibrium (Panel 7 in Figure 2) and exerts a strong positive effect on the mark-up. The magnitudes of the impacts of the price elasticity of consumption sales and other elements, encapsulated in the component labelled 'other effects', are imperceptibly mild and are not exhibited in Figure 3. The aggregate impact on the mark-up is mainly determined by the negative effect of the price elasticity of public sector demand which dominates the positive influence of rising expected inflation (Panel 3). At this juncture, the substitution of consumption for leisure is already too weak to overcome the wealth effect of the fiscal shock and consumption is crowded-out.

Increasing Φ_p to 26 (indicated by solid magenta lines) has little influence on movements in the price elasticity of public sector demand. However, now it is more costly for the monopolist to lower the price in response to the rise in price elasticity and cannot set the price as low as before (Panel 3 of Figure 2). Inflation is again expected to rise (Panel 7 of Figure 2), but not as much as in the previous case. However, note from Table 1 that at $\Phi_p = 26$, the elasticity of the mark-up to expected changes in inflation is three times than that observed in the first case, amplifying the positive effect of expected inflation (Panel 3) on the mark-up. This positive influence of expected inflation strongly dominates the downward pressure from the price elasticity. For this reason, the mark-up is less countercyclical, enfeebling the substitution of consumption for leisure even further.

It is important to note that the presence of pricing frictions also allows monetary policy to play an influential role in guiding consumption dynamics via the *ex ante* real interest rate, exhibited in Panel 8 of Figure 2. As we increase price rigidities, the dampened decreases in inflation imply that the real interest rate falls progressively less. The higher real interest rate erodes the present value of future profits, giving the firm the incentive to push up current profits and the mark-up. This in turn weakens labor demand and leads to a lower wage which exerts a downward pressure on consumption.

Observe that in the baseline framework, the price elasticity effect is only short-lived and reverses sign after a quarter. Recall that the price elasticity of public sector demand is given as $\hat{\varepsilon}_t^g = \frac{h_g}{1-h_g}(\hat{g}_t - \hat{g}_{t-1})$. On impact, a positive shock to government spending raises current demand with respect to lagged demand and hence increases the price elasticity. However, in the ensuing period, government spending is less than its value on impact and the price elasticity falls thereby reversing mark-up cyclicality. Thus the intra-temporal substitition effect on consumption reinforces the negative wealth-effect in the periods after impact.

The dynamics of the price elasticity are absent in the nested NK economy where the mark-up is explained purely by the expected path of inflation.

$$\underbrace{\hat{\mu}_t}_{\hat{p}_t - \widehat{nmc}_t} = \underbrace{\frac{\Phi_p}{\eta_p - 1}(\beta \mathbf{E}_t \hat{\pi}_{t+1} - \hat{\pi}_t)}_{\text{Expected Inflation Change}} \tag{14}$$

In the absence of a rising price elasticity, the monopolist has no incentive to lower the price level. Instead, she is better off *raising* the price while expanding production to meet the additional demand from the public sector. Note that a rise in the price level and inflation from steady-state (Panels 3 and 5 in Figure 1) implies that future inflation is now expected to be lower than current inflation to restore the long-run equilibrium (Panel 7 in Figure 1). When prices get stickier, the monopolist is unable to raise the price to the extent possible under more flexible prices. Therefore, it raises labor demand and hence the nominal marginal cost, to produce more output. Since the rise in the nominal marginal cost exceeds the rise in price, the mark-up falls. Thus in this scenario, the sluggish adjustment of the price level to the demand shock is the *source* of countercyclicality in the mark-up.[11] The now familiar substitution of consumption for leisure ensures that consumption does not contract as much as in a real business cycle model. When prices gets stickier, the (negative) gap between future inflation and current inflation is expected to be smaller in absolute value. Consequently, the elasticity of the mark-up to the expected change in inflation is increasing in the adjustment cost parameter (see Table 1).[12] For this reason, the fall in the mark-up is more pronounced, *i.e.* it becomes more countercyclical. Concurrently, the real wage becomes more procyclical and consumption is progressively less crowded out (Panel 8).

In a nutshell, a key point of distinction between the dynamics of the two set-ups is that the government spending shock *lowers* the price level on impact in the deep habits model while in the nested NK model, it acts as a conventional demand shock by *raising* prices. As price stickiness increases, the deep habits mark-up is guided by the positive influence of the expected path of inflation and the downward pressure emanating from the price elasticity is less effective. The dampened countercyclicality of the mark-up implies that the real wage is less procyclical and agents do not substitute consumption for leisure as much. If price stickiness is high enough, the negative wealth effect of the fiscal shock prevails and consumption is crowded out in the deep habits model.

4 Variants of the Baseline Model and Calibration

Naturally, the conditional cyclicality of consumption is also contingent on the nature of other frictions in the evironment, besides price rigidities. Furthermore, it will depend on the choice of parameter values. In this section, we first contrast the consumption response under deep habits to that observed in the more commonly used superficial habit set-up. We also illustrate the pivotal role of deep habits in government spending as compared to private consumption habit in generating the rise in consumption in flexible as well as sticky price models. Subsequently, we examine the influence of sticky prices on the consumption response when key parameters are allowed to vary (one at a time). Finally, we introduce persistent habit-stocks and capital accumulation as in Ravn *et al.* (2006) and verify that our results are preserved in their framework.

[11] Observe also that the movement in the mark-up is very gentle in the absence of a time-varying price elasticity.

[12] Equivalently, if the NKPC is written in terms of inflation rather than the mark-up, the pass-through of mark-up changes into *current* inflation is decreasing in the cost parameter.

4.1 Crowding-in and the Nature of Habit Formation

Habits are typically assumed to be formed at the 'superficial' level of the final good and modelled only in private consumption expenditure (see for *e.g.* Smets and Wouters 2007 among many others). Public sector consumption is reduced to being a purely unproductive, stochastic shock that enters the aggregate resource constraint of the economy. Thus by incorporating good-specific habit formation in government spending in addition to consumption, the deep habits economy departs significantly from the traditional set-up.

In each panel of Figure 4, we exhibit the impact responses of consumption (top) and mark-up (bottom) to the government spending shock in various economies featuring habit persistence. The first economy, analyzed in Panel (1), is a real business cycle model with superficial habit persistence in consumption. This model is obtained by imposing the restrictions ($h_c = h,\ h_g = 0$) while also removing the habit components in the demand functions that the monopolist faces in the flexible price deep habits model earlier examined in Figure 2. Keeping all other parameters at the baseline values (see Column 3 in Table 1), we increase habit persistence in consumption. Observe that it limits the degree of crowding-out but never induces a positive response of consumption to the fiscal shock.[13] On the other hand, since habit is now assumed to be at the final good level and the monopolistic firm that produces the intermediate variety no longer faces a dynamic demand function, the mark-up is always constant. In Panel 2, we consider the deep habits economy when prices are flexible, *i.e.* the real model we earlier examined in Figure 2. The consumption impulse response surface generated by different combinations of the consumption and government spending habit parameters shows that the crowding-in is far more sensitive to changes in the government spending habit than to the private consumption analog. In fact, even when the private consumption habit channel is switched off ($h_c = 0$), higher degrees of government spending habit alone can deliver crowding-in, given the baseline configuration for the other parameters. Adding higher degrees of consumption habit reinforces the positive response of consumption by steepening the reactions of the mark-up and the real wage. Alternatively, when public sector habit formation is turned off, the consumption response is very mild when we increase consumption habit. Thus, fiscal transmission in deep habits models is contingent not merely on the good-specificity

[13] Since we observe indeterminacy at higher degrees of consumption habit in the deep habits model, we only exhibit the case of $h = h_c \in [0, 0.50]$ to facilitate comparison. Note that even for $h > 0.90$ in the superficial habits case, consumption is never crowded in by government spending. This is the case both in flexible as well as sticky price models. Results are available on request.

of habit formation but also quite critically on the strength of government spending habits.

In Panel 3, we deactivate consumption habit and focus on the effect of sticky prices in an economy with deep habits in only government spending. Notice how the introduction of price stickiness dampens the consumption response. While in the previous case, increasing government habit in the absence of consumption habit could deliver maximum consumption responses of about 0.05 percent, the maximum impact is less than halved at below 0.02 percent even when prices are relatively flexible. In the following subsection, we will analyze the implications of increasing price stickiness for the consumption response when specific parameters in the baseline model are allowed to vary one at a time.

4.2 Changing Baseline Parameter Values

In Figure 5, we present a sensitivity analysis of the impact consumption response under sticky prices when selected model parameters are perturbed from the baseline values. In Panels (1) and (2) we begin with the familiar habit parameters in government spending and consumption.[14] In the baseline case of $h_g = 0.86$ and $h_c = 0.50$, consumption is crowded out at $\Phi_p = 6.50$ which implies a price duration of about one and a half quarters. As one would expect from the earlier discussion of Figure 4, the degrees of habit persistence required to crowd in consumption increase when price rigidities get stronger. In Panel (3), we see that a higher Frisch elasticity $(1/\sigma_n)$ of labor supply makes consumption respond more positively to the rise in the real wage or equivalently a fall in the mark-up (see Equation 12) and consequently a higher degree of price stickiness is required to crowd out consumption under these conditions. A higher persistence coefficient (ρ_g) on the government spending shock process strengthens the negative wealth effect on consumption. Thus, observe in Panel (4) that a lower price adjustment cost is required to crowd out consumption when the shock is very persistent.

Finally, we arrive at the monetary policy parameters which are naturally influential in sticky price economies. Note in Panels (5) and (6), despite the fact that we consider a wide range of possible values for the interest rate smoothing coefficient (r_r) and the interest rate elasticity to inflation (r_π), consumption responses to the fiscal expansion become negative at thresholds of price stickiness which are comparable to the baseline case. The output coefficient (r_y) is relatively more influential in quantitative terms. In Panel (7)

[14] Note that, unlike in Panel 3 in Figure 4, we do not deactivate consumption habit here and set $h_c = 0.50$ as in the baseline model, when we increase the h_g parameter.

the impulse response surface slants downwards steeply and becomes more negative as the monetary authority reacts strongly to output movements. Observe that consumption is crowded out for low degrees of price stickiness in the deep habits model when we consider a policy regime that avoids output-stabilization ($r_y = 0$), the case we examined earlier in the nested NK model without deep habits. The crowding-out of consumption worsens as price stickiness increases in the empirically appealing scenario in which the interest rate response to output is mild. Remember that in deep habits models, a rise in the real interest rate decreases consumption not merely through the standard consumption Euler channel but also via the supply-side by lowering the present value of future profits. The latter effect raises the current mark-up which weakens intra-temporal substitution. For this reason, a less aggressive monetary policy is even more important in strengthening the fiscal stimulus in this environment.

4.3 Habit-Stocks and Capital Accumulation

We now embed price rigidities in the more elaborate model of Ravn *et al.* (2006) and examine the consequences for the crowding-in of consumption.[15] Unlike our baseline model, Ravn *et al.* (2006) model habit persistence using habit-stocks so that current demand depends on the entire history of expenditures. The aggregation of the intermediate varieties is given as $x_t^z = \left[\int_0^1 \left(z_{\iota t} - h_z s_{\iota t-1}^z\right)^{\frac{\eta_p - 1}{\eta_p}} d\iota\right]^{\frac{\eta_p}{\eta_p - 1}}$ where $s_t^z = \omega_z s_{t-1}^z + (1 - \omega_z) z_t$, $\omega_z \in [0, 1)$ $\forall\ z \in \{c,\ g\}$. In addition, Ravn *et al.* (2006) incorporate investment (i) in physical capital (k) by the household according to the law of motion $i_t = k_{t+1} - (1 - \delta) k_t$ where $\delta \in [0, 1]$ denotes the depreciation rate. Importantly investment, unlike consumption and government demand, does not feature habit formation and is defined by the aggregator $i_t = \left(\int_0^1 i_{\iota t}^{\frac{\eta_p - 1}{\eta_p}} d\iota\right)^{\frac{\eta_p}{\eta_p - 1}}$. The predetermined capital stock is combined with labor in the production function of the firm: $y_t = k_t^{\alpha} n_t^{1-\alpha} - fc$, $\alpha \in [0, 1]$. In Column 4 of Table 1, we report the parameter values we use to calibrate this final specification.[16]

[15] In Jacob (2013), we derive the firm's optimality conditions, including the deep habits Phillips curve, in the sticky price version of the Ravn *et al.* (2006) model.

[16] With the introduction of investment, we do not find indeterminacy and hence can revert to the habit configuration of Ravn *et al.* (2006): $h_c = h_g = 0.86$. The lack of habit formation in investment implies that the overall degree of habit in aggregate demand may not be high enough to induce self-fulfilling equilibria. In an experiment introducing investment habit into the Ravn *et al.* (2006) flexible price parametrization,

In Figure 6, we present the consequences of increasing price rigidities in this more sophisticated environment. The dynamics of the flexible price model of Ravn *et al.* (2006) are indicated by the thick black lines. An important implication of the incorporation of habit-stocks is that the log-linearized price elasticity is now given as $\hat{\varepsilon}_t^z = \frac{h_z}{1-h_z}\left(\hat{g}_t - \hat{s}_{t-1}^z\right)$ such that $\hat{s}_t^z = \omega_z \hat{s}_{t-1}^z + (1-\omega_z)\,\hat{z}_t \;\forall\; z \in \{c,\ g\}$. Notice that in the baseline model, we simplified matters considerably by imposing $\omega_z = 0$. Recall from subsection 3.3 that the procylicality of the price elasticity and the fall in the mark-up was noticed merely on the impact of the fiscal shock. As seen in Panel (1), this is no longer the case as the rise of the price elasticity of public sector demand is sustained over longer periods. Consequently, the fall in the mark-up and the rise in consumption are persistent, exactly as in Ravn *et al.* (2006).

Increasing price stickiness has little impact on the price elasticity as in our baseline model (in Figure 3). This is not the case with inflation and the mark-up in Panels (2) and (3) which fall progressively less with more price stickiness. As detailed in subsection 3.3, the reduced mark-up countercyclicality is explained by the deflationary effect of the fiscal expansion exerted through the structure of the deep habits Phillips curve. As a consequence, wages rise less (not exhibited) and the consumption response is negative at all horizons at a price duration of a year. As far as the impact response is concerned, the crowding-out of consumption is observed at the threshold of $\Phi_p = 9.88$ as opposed to $\Phi_p = 6.50$ in the baseline case. Thus while the qualitative predictions of the baseline model are preserved, the threshold of price stickiness that induces the crowding-out of consumption is slightly delayed in the Ravn *et al.* (2006) framework.

5 Conclusion

This paper documents the interaction of price rigidities in economic environments with good-specific formation and its implications for the response of private consumption to a government spending expansion. We find that while the two frictions, sticky prices and deep habits, induce a weakening of consumption crowding-out when used independently in general equilibrium models, they worsen crowding-out when used in conjunction. We demonstrate that if price stickiness is high enough in the deep habits model, the fiscal stimulus may not have a positive impact on consumption.

we find indeterminacy in the model beyond the investment habit threshold of 0.20.

The presence of deep habits gives rise to a strongly procyclical price elasticity of demand. A rise in government spending increases the price elasticity and gives the monopolist an incentive to lower the price and the mark-up to maximize profits when she raises production. Thus the rise in government spending expansion is deflationary in the presence of deep habits. This is strikingly different from standard sticky price models where the price elasticity is invariant to economic activity and government spending expansions are typically inflationary.

The deep habits Phillips curve encapsulates two opposing effects on mark-up dynamics. The first is the negative influence of the price elasticity of demand. The second is the conventional channel originating from the expected path of inflation. Inflation is expected to rise after a fall in the price level. Under increasing price stickiness, the positive influence of the expected rise in inflation is strengthened and dampens the countercyclicality of the mark-up in the deep habits model. This reflects in a weaker rise in the real wage and reduces the agent's incentive to substitute consumption for leisure. If the substitution effect is not strong enough to overcome the negative wealth effect of the fiscal expansion, consumption is crowded out by government spending.

The dampening of the crowding-in of consumption when sticky prices are introduced into the deep habits model suggests that it may be necessary to augment the model environment with other features in order to be able to replicate the empirical evidence. Cantore *et al.* (2012a) analyze fiscal transmission under deep habits through the lens of the design of monetary policy and show that the consumption response can be improved if the monetary policy response is welfare-optimal. A second strategy would be to employ deep habits in conjunction with a utility function featuring complementarity between consumption and hours worked as in Bilbiie (2011) and Monacelli and Perotti (2008). Zubairy (2013) and Cantore *et al.* (2013, 2012a, 2012b) incorporate these preferences into their sticky price deep habits models. Another alternative modelling device that will strengthen the fiscal transmission would be to allow for complementarity between public and private consumption as in Pappa (2009). Cantore *et al.* (2012b) use this additional non-separability in the utility function in their sticky price deep habits economy. These augmentations are likely to make the fiscal stimulus under deep habits more robust to the exposure to price rigidities.

A Appendix

Steady-State Mark-Up: In steady-state, the first order condition for the firm's choice of quantities, *i.e.* Equation 5 is given by $\bar{\nu}^z = \frac{\bar{\mu}_{dh}-1}{(1-\beta h_z)\bar{\mu}_{dh}}\ \forall z \in \{c,\ g\}$. Note that (i) there are no price adjustment costs in steady-state: $\Phi_p = 0$ (ii) habit-adjusted aggregate demands are given by $\bar{x}^z = \bar{z}\,(1-h_z)\ \forall z \in \{c,\ g\}$ and (iii) the great ratios are related as $\bar{c}_y = \frac{\bar{c}}{\bar{y}} = 1 - \frac{\bar{g}}{\bar{y}} = 1 - \bar{g}_y$. Impose these conditions on the price-setting condition Equation 7 in steady-state to get $\eta_p^{-1} = \bar{c}_y\,(1-h_c)\,\bar{\nu}^c + \bar{g}_y\,(1-h_g)\,\bar{\nu}^g$. Now substitute in $\bar{\nu}^z = \frac{\bar{\mu}_{dh}-1}{(1-\beta h_z)\bar{\mu}_{dh}}\forall z \in \{c,\ g\}$ to obtain $\eta_p^{-1} = \frac{\bar{\mu}_{dh}-1}{\bar{\mu}_{dh}}\left(\bar{c}_y\frac{1-h_c}{1-\beta h_c} + \bar{g}_y\frac{1-h_g}{1-\beta h_g}\right)$. This expression yields the gross steady-state mark-up $\bar{\mu}_{dh} = \frac{\eta_p m_0}{\eta_p m_0 - 1}$ such that $m_0 = \bar{c}_y\frac{1-h_c}{1-\beta h_c} + \bar{g}_y\frac{1-h_g}{1-\beta h_g} < 1$.

Deep Habits Phillips Curve: The primitive form of the log-linearized version of the price-setting Equation 7 is given by

$$\hat{\pi}_t = \beta \mathbf{E}_t \hat{\pi}_{t+1} - \frac{\eta_p}{\Phi_p}\left(\bar{\nu}^c\bar{c}_y\,(1-h_c)\,[\hat{\nu}_t^c + \hat{x}_t^c - \hat{y}_t] + \bar{\nu}^g\bar{g}_y\,(1-h_g)\,[\hat{\nu}_t^g + \hat{x}_t^g - \hat{y}_t]\right)$$

We substitute in Equations 2 and 6 and the expressions for the steady-state deep habits mark-up and real marginal profits, to obtain the Phillips curve in Equation 8. Finally, we express the Phillips curve in terms of the mark-up. We define $m_1 = \bar{g}_y\,(1-h_g) + \bar{c}_y\,(1-h_c)$ and $m_z = \frac{1-h_z}{1-\beta h_z}\frac{\bar{z}_y}{(\eta_p m_0 - 1)m_1}\ \forall\ z \in \{c,\ g\}$. When we set $h_z = 0\ \forall\ z \in \{c,\ g\}$, it follows that $m_0 = m_1 = 1$, $m_z = \frac{\bar{z}_y}{\eta_p - 1}$ and $\hat{\varepsilon}_t^z = 0$. Finally after imposing the goods market-clearing condition, we recover the NKPC exhibited in Equation 11. Jacob (2013) provides more details.

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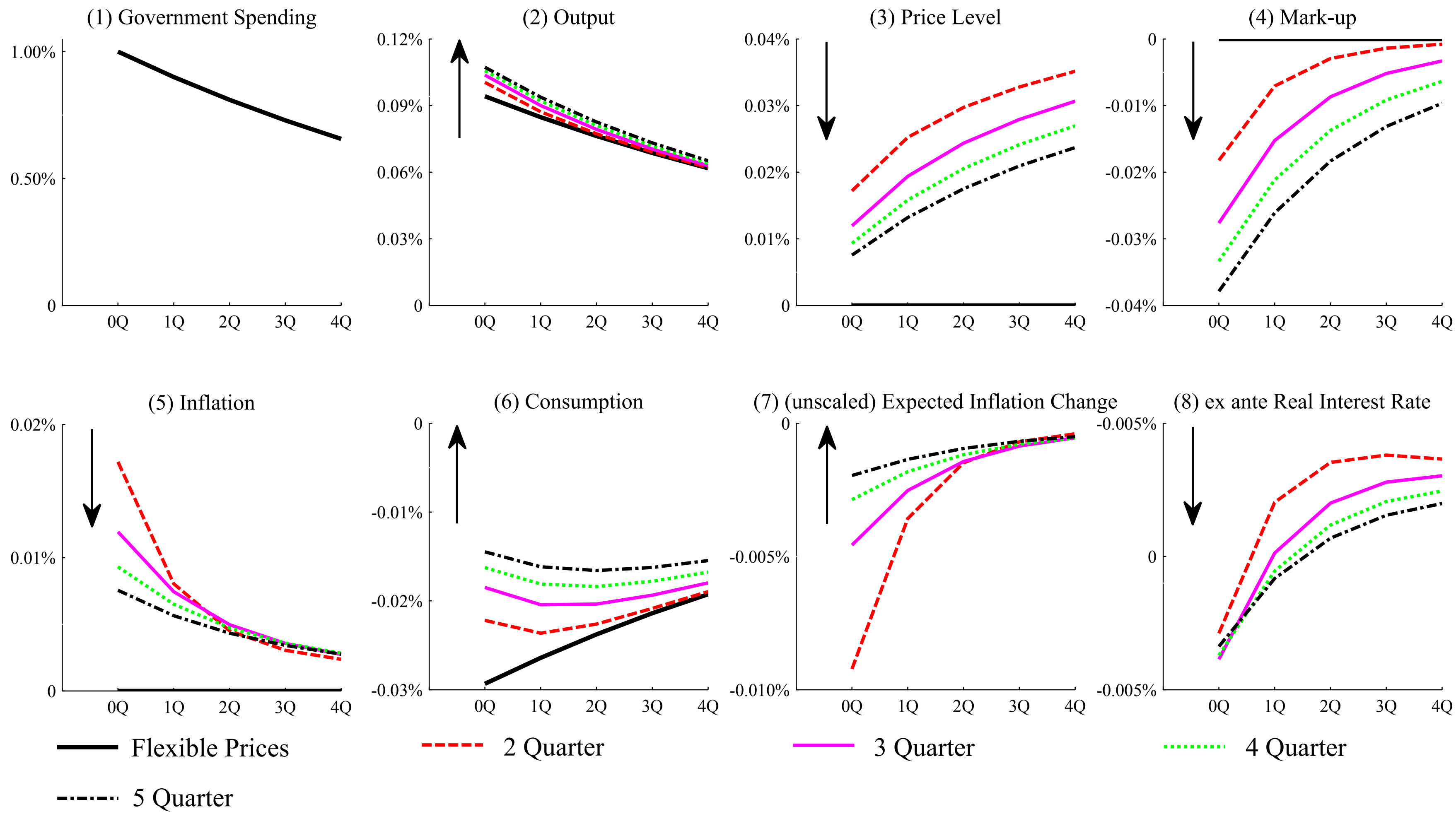
Table 1: Calibration

PARAMETER	DESCRIPTION	SPECIFICATIONS (1) Baseline DH	(2) Nested NK	(3) SH	(4) RSU
σ_c	Utility curvature	2	2	2	2
β	Subjective discount factor	0.9902	0.9902	0.9902	0.9902
$1/\sigma_n$	Frisch elasticity	1.3	1.3	1.3	1.3
η_p	Elasticity of substitution between goods varieties (habit-adjusted demand with deep habits)	5.3	5.3	5.3	5.3
h_c	External habit in consumption	0.50	0	0.50	0.86
h_g	External habit in government spending	0.86	0	0	0.86
ω	Persistence in habit-stock	-	-	-	0.85
α	Share of physical capital in production	-	-	-	1/4
δ	Depreciation	-	-	-	0.025
$\bar{g}_y$	Steady-state share of government in output	0.12	0.12	0.12	0.12
$\bar{c}_y$	Steady-state share of consumption in output	0.88	0.88	0.88	0.70
ρ_g	Persistence of government spending shock	0.90	0.90	0.90	0.90
σ_g	Standard deviation of shock	1%	1%	1%	1%
r_r	Interest rate smoothing	0.80	0.80	0.80	0.80
r_π	Interest rate response to inflation	1.50	1.50	1.50	1.50
r_y	Interest rate response to output	0.1	0	0.1	0.1
$\bar{\mu}_{dh}, \bar{\mu}$	Implied steady-state mark-ups $(1 + fc/\bar{y})$	1.2370	1.2326	1.2326	1.3219
Φ_p	Rotemberg price adjustment cost				

Value (~ Price Duration)	Coefficient on $\boldsymbol{E}_t\beta\hat{\pi}_{t+1} - \hat{\pi}_t$ in the Phillips Curve: Baseline DH $\frac{m_0\Phi_p}{\left(\eta_p m_0 - 1\right)m_1}$	Nested NK $\frac{\Phi_p}{\eta_p - 1}$
8.5 (~ 2 Quarter)	4.34	1.98
26 (~ 3 Quarter)	13.28	6.05
50 (~ 4 Quarter)	25.55	11.63
83 (~ 5 Quarter)	42.41	19.30

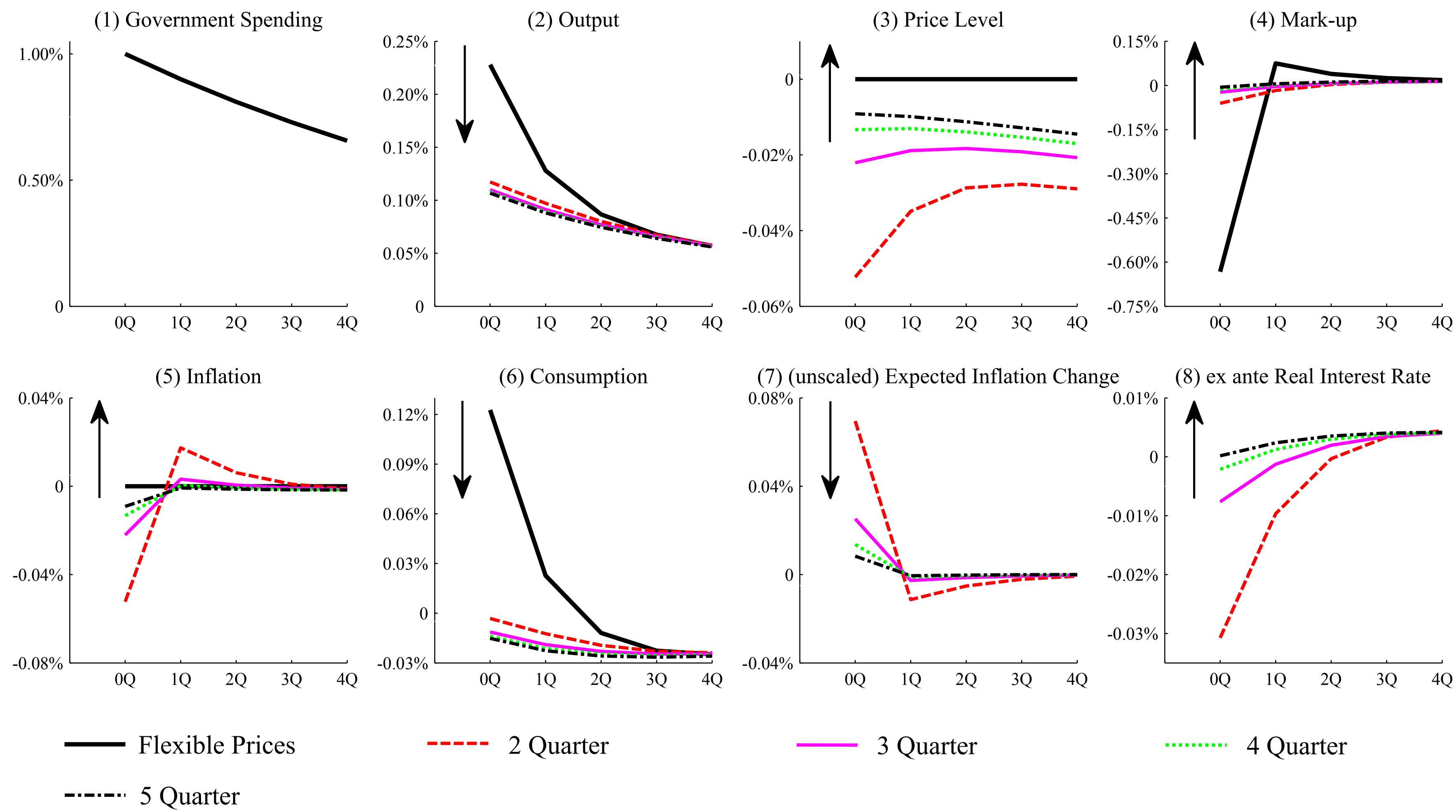
Note: Other parameters required in the log-linearized models are obtained from the respective steady-state restrictions. The quarterly price-duration interpretation of the Rotemberg adjustment cost parameter is based on a comparison of the slopes of the NK Phillips curves under Rotemberg and Calvo price-setting. 'Baseline DH' indicates the baseline deep habits model without investment, 'Nested NK' indicates the simple New Keynesian model nested in the baseline model, 'SH' indicates the variant of the baseline model with superficial habit in subsection 4.1 and 'RSU' incorporates sticky prices into the Ravn *et al.* (2006) framework with habit-stocks and investment as in subsection 4.3. Note that unlike in the Baseline DH specification which does not have investment, we do not face indeterminacy in the RSU specification which uses investment (without investment habit). Hence, the parameter values except those for price stickiness and the monetary policy rule are identical to those in Ravn *et al.* (2006).

Figure 1: Impulse Responses to a Government Spending Shock in the Nested NK Model under Increasing Price Stickiness



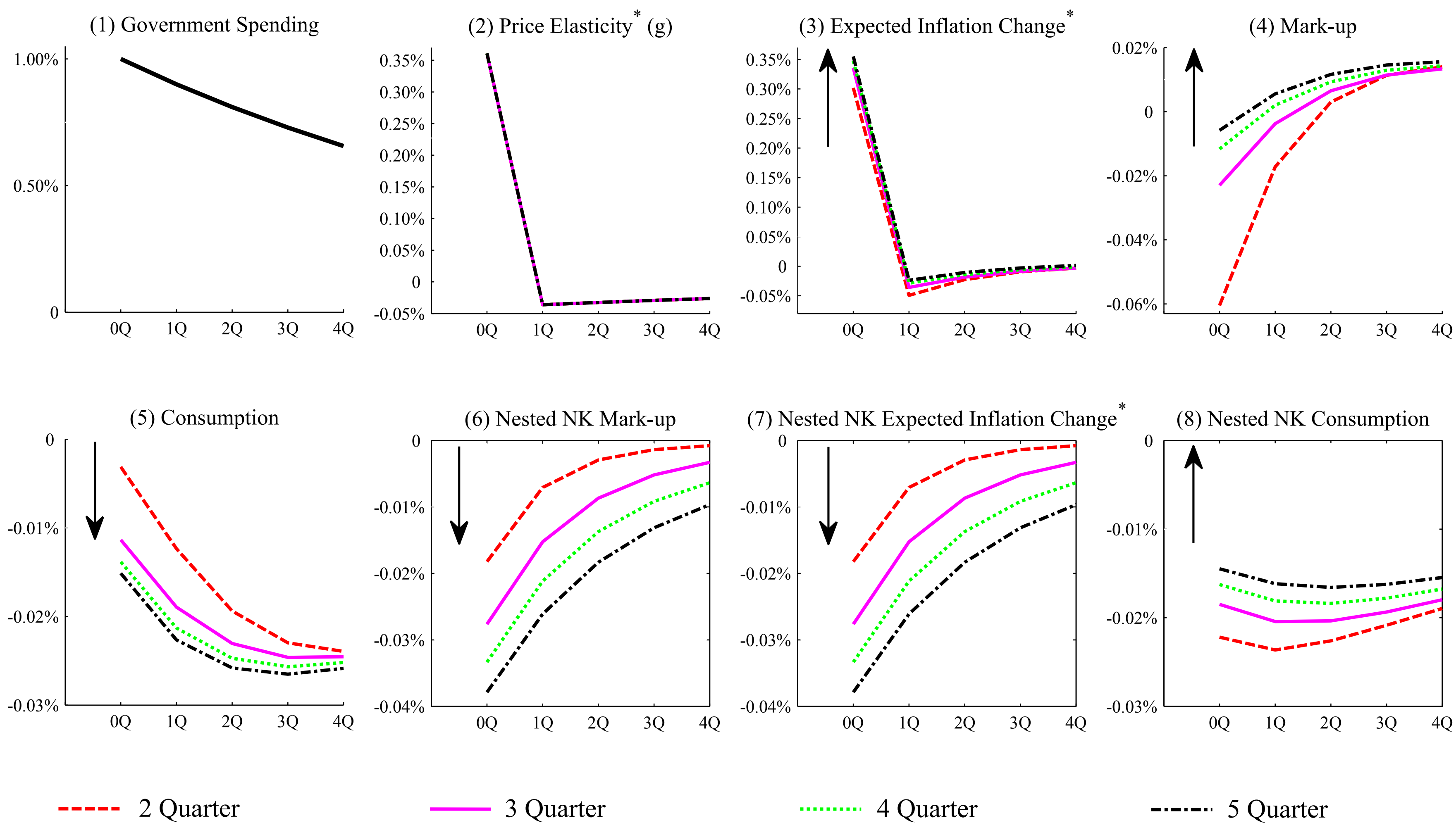
Note: The IRFs are measured in percentage deviations from steady-state. The mark-up is the negative of the real wage and the real marginal cost. The IRF of hours worked is identical to that of output except that it is slightly less volatile because hours worked are obtained by scaling output by the steady-state gross fixed cost to output ratio (>1) in the log-linearized production function. The prefix (unscaled) used for the expected inflation change indicates that the variable has not been multiplied by the relevant slope parameter.

Figure 2: Impulse Responses to a Government Spending Shock in the Baseline Deep Habits Model under Increasing Price Stickiness



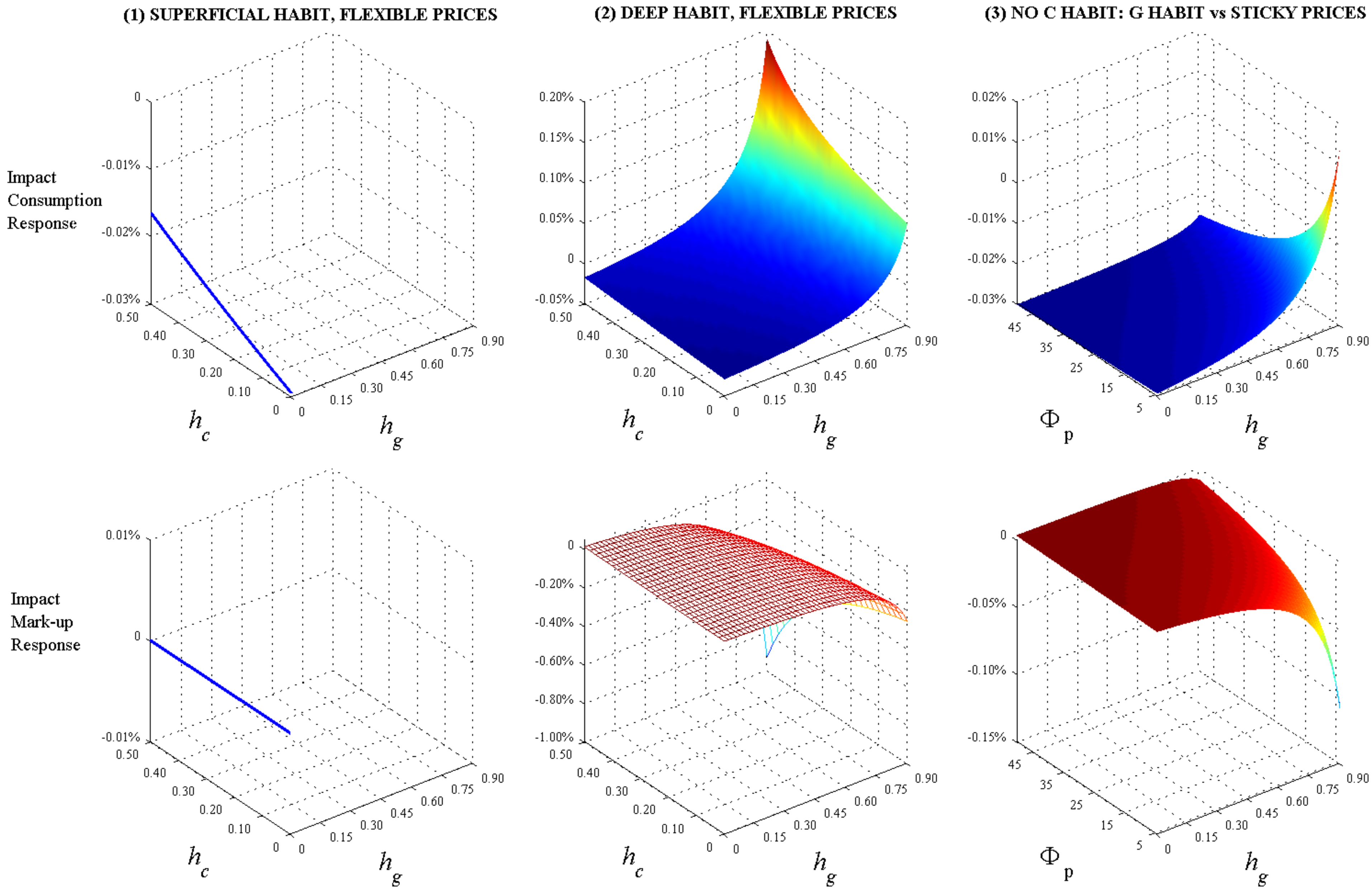
Note: The IRFs are measured in percentage deviations from steady-state. The mark-up is the negative of the real wage and the real marginal cost. The IRF of hours worked is identical to that of output except that it is slightly less volatile because hours worked are obtained by scaling output by the steady-state gross fixed cost to output ratio (>1) in the log-linearized production function. The prefix (unscaled) used for the expected inflation change indicates that the variable has not been multiplied by the relevant slope parameter.

Figure 3: Impulse Responses of the Components of the Phillips Curve to a Government Spending Shock under Increasing Price Stickiness
Baseline Deep Habits Model vs Nested NK Model



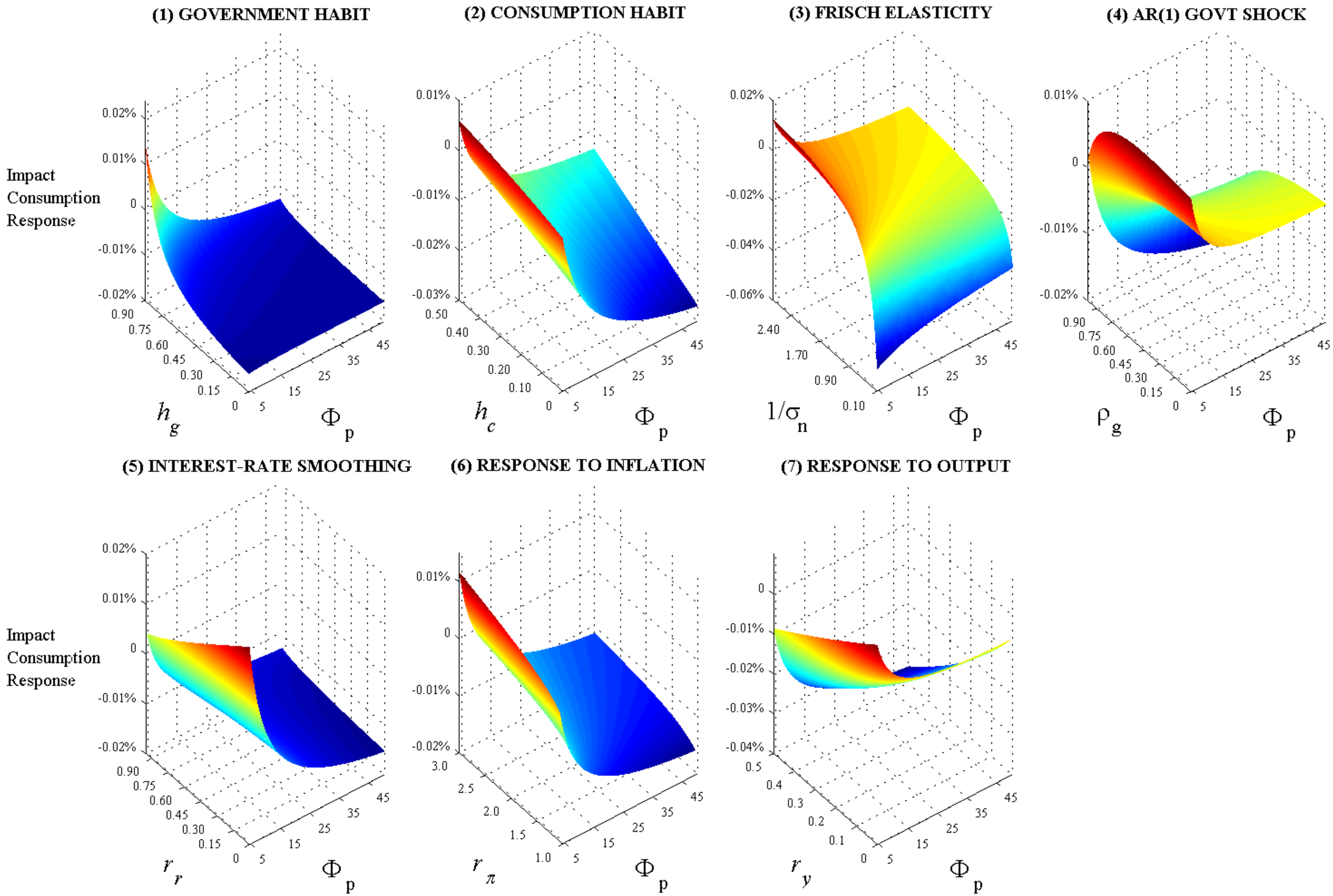
Note: IRFs are measured in percentage deviations from steady-state. In the deep habits model, the Phillips curve is decomposed as Mark-Up = Expected Inflation Change* - Price Elasticity* (g) + Other Effects. The superscript * is used to indicate that the variables have been multiplied by positive constants (see main text). In Figures 1 and 2, the variables have not been scaled by the positive constants.

Figure 4: Habit-Formation, Mark-up Cyclicality and the Crowding-out of Consumption



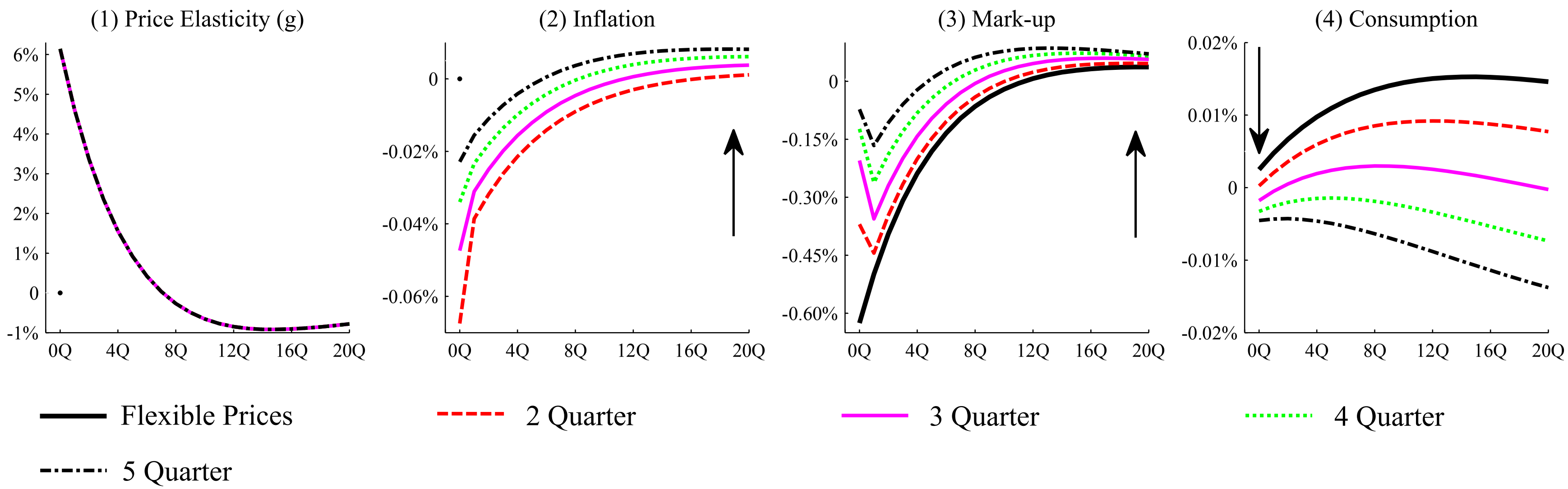
Note: The parameters are varied with a step-size of 0.02. The Rotemberg cost in Panel (3) is allowed to vary between 4.3 and 50. The lower bound of 4.3 is chosen so that the slope of the NKPC is unity, given the baseline calibration. The cost parameter can be interpreted in terms of a price-duration in months in the NKPC context. In particular, 4.3 ~ 5 months, 20 ~ 8 months, 30 ~ 10 months, 40 ~ 11 months, 50 ~ 12 months.

Figure 5: Sticky Prices and the Impact Consumption Response when Baseline Parameter Values Change



Note: The parameters are varied with a step-size of 0.02. The Rotemberg cost is allowed to vary between 4.3 and 50. The lower bound of 4.3 is chosen so that the slope of the NKPC is unity, given the baseline calibration. The cost parameter can be interpreted in terms of a price-duration in months in the NKPC context. In particular, 4.3 ~ 5 months, 20 ~ 8 months, 30 ~ 10 months, 40 ~ 11 months, 50 ~ 12 months.

Figure 6: Impulse Responses to a 1% Government Spending Shock in the Ravn et al. (2006) model under Increasing Price Stickiness



Note: The IRFs are measured in percentage deviations from steady-state. Unlike in the baseline deep habits model, we incorporate habit-stocks and physical capital accumulation as in Ravn et al. (2006).