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

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This draft: July 21, 2011. First draft: April 2009.

Abstract

This paper inspects the 'deep' habits mechanism originally used by Ravn, Schmitt-Grohé and Uribe (2006) to generate the positive comovement of public and private consumption observed in many VAR studies. In their set-up, the price-elasticity of demand is pro-cyclical and it is optimal for the firm to lower the mark-up while expanding production after the fiscal shock, raising the demand for labor and the real wage. Consequently, agents substitute consumption for leisure and overcome the negative wealth effect of the fiscal expansion. Here, we show that increasing price stickiness reduces the impact of the fiscal shock on the real wage and hinders the rise of consumption. If the degree of price stickiness is high enough, consumption is crowded-out. This is in contrast to the role of price rigidities in the standard New Keynesian model where they weaken the crowding-out of consumption.

JEL classification: E21, E31, E62.

Keywords: Deep Habits, Sticky Prices, Government Spending, Crowding-out.

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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, 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, López-Salido and Vallés (2007) 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, the positive response of aggregate consumption can be replicated. In Monacelli and Perotti (2011) and Bilbiie (forthcoming), consumption is positively stimulated due to the interaction between real wage dynamics and a utility function which is non-separable in consumption and leisure. On the other hand, Davig and Leeper (2011) demonstrate how the stance of monetary and fiscal policy alter the dynamics of the real

[1] An inexhaustive list includes Blanchard and Perotti (2002), Galí, López-Salido and Vallés (2007), Ravn, Schmitt-Grohé and Uribe (2011) and Monacelli and Perotti (2011). 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.

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, Schmitt-Grohé and Uribe (henceforth RSU) (2006, 2011) 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 additional component gives rise to a time-varying price-elasticity of demand. The government spending shock triggers a strong pro-cyclical movement in the price-elasticity and hence a counter-cyclical 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 demonstrates how price rigidities *hinder* 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. Simulations of the sticky-price model suggest 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 counter-cyclical 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 rigidities and consequent mark-up

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

counter-cyclicality to *augment* the positive response of consumption.

Here we illustrate that the reasons behind the crowding-out of consumption by government spending in deep habits economies with sticky prices can be traced to the constitution of the Phillips curve. Just as in the flexible price scenarios examined by RSU (2006, 2011), 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 because the positive effect of expected inflation becomes more dominant. For this reason, the price and mark-up react *less* counter-cyclically to government spending under increasing price stickiness. Consequently, the real wage is less pro-cyclical 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 the NK set-up, 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. When we increase price stickiness in the NK environment, the stronger counter-cylicality of the mark-up - and the enhanced pro-cyclicality of the real wage - weakens the crowding-out of consumption by the fiscal shock.

The plan of the paper is as follows. In Section 2, we introduce sticky prices into an economy with deep habits and also discuss the restrictions that reduce the deep habits model to an NK set-up with superficial habit. Section 3 calibrates the deep habits economy and shows how increasing price stickiness worsens the crowding-in of consumption by government spending in the deep habits economy. As a familiar benchmark, we will also illustrate the NK case in which price stickiness alleviates the crowding-out of consumption. We then establish that the contrasting dynamics of consumption can be attributed to the composition of the Phillips curves in the two environments. Finally, it also evaluates the thresholds of price stickiness at which consumption is crowded-out under alternative

parametric configurations in the deep habits model. Section 4 draws the main conclusion. A technical appendix documents the derivation of the key equations.

2 Deep Habits and Sticky Prices

Our objective is to demonstrate how the presence of price stickiness has different, and somewhat counter-intuitive implications for the comovement of public and private consumption in economies with and without deep habits. To this end, we formulate a simple deep habits model which we subsequently reduce to the standard NK case with superficial habit-formation in consumption. 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.

We first consider a model with good-specific habit-formation in consumption and government spending along the lines of RSU (2006, 2011) but with some simplifications. Unlike RSU (2006), we abstract from capital-accumulation.[3] 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 as in RSU (2006, 2011).[4] We then introduce sticky prices and a monetary policy rule into the deep habits environment. Finally, we impose restrictions on the sticky-price deep habits model to reduce it to the NK case.

Except in cases that are non-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 standard set-up (*e.g.* Smets and Wouters 2007) is that the public and

[3] Like in our case, RSU (2011) abstract from physical capital. However, unlike the model presented here, their economy is open to international trade.

[4] The qualitative implications of increasing price stickiness in the deep habits model are preserved even in a richer setting with capital-accumulation or habit-stocks. These additional results are available on request.

private sectors form habits over the consumption of *individual* goods. In standard models, government spending does not exhibit habit-formation and the private sector typically forms habits over the final consumption good. 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. In fact, as we shall later see in the dynamics in Section 3, 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.

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 are indexed by $i \in [0,\ 1]$. In every period t, the consumer allocates spending on an aggregate that is defined as $X_t^{C\ j} = \left[\int_0^1 \left(C_{it}^j - h_C C_{it-1}\right)^{\frac{\eta_P - 1}{\eta_P}} di\right]^{\frac{\eta_P}{\eta_P - 1}}$ such that $h_C \in [0, 1)$ and $\eta_{_P} > 1$. $C_i = \int_0^1 C_i^j dj$ denotes the average level of consumption of good i in the economy while h_C indicates the degree of external habit-formation. For a given level of $X_t^{C\ j}$, optimal consumption demand for good i is obtained by minimizing total expenditure $\int_0^1 P_{it} C_{it}^j di$ 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. The optimal demands from private consumption (aggregated across agents) and government spending for good i are given as $Z_{it} = \left(\frac{p_{it}}{P_t}\right)^{-\eta_P} X_t^Z + h_Z Z_{it-1}$ where $h_Z \in [0, 1)\ \forall Z \in \{C,\ G\}$. $P_t \equiv \left(\int_0^1 p_{it}^{1-\eta_P} di\right)^{\frac{1}{1-\eta_P}}$ is the aggregate nominal price index for habit-adjusted demand. The presence of deep habits splits demand for the good i into two components. The first component covaries negatively with the relative price $\frac{p_i}{P}$ and positively with aggregate habit-adjusted demand X^Z. However, the second component $h_Z Z_{it-1}$ is purely predetermined by habit-formation and is invariant to changes in the relative price.[5] The presence of this price-inelastic habit-component causes the price-elasticity of demand to be time-

[5] In RSU (2006, 2011), current demand depends on lagged habit-stocks that follow $S_{it}^Z = \omega^Z S_{it-1}^Z + \left(1 - \omega^Z\right) Z_{it}$, $\omega^Z \in [0, 1)$ and $Z \in \{C,\ G\}$. We simplify matters by setting $\omega^C = \omega^G = 0$.

dependent. In particular, $\varepsilon^Z_{Pt} = \frac{\partial Z_{it}}{Z_{it}} \frac{p_{it}}{\partial p_{it}} = -\eta_{_P} \left(1 - h_Z \frac{Z_{it-1}}{Z_{it}}\right)$. This is in contrast to models where the firm's demand function has no habit-component, *i.e.* $h_Z = 0$, so that the price-elasticity is constant at $-\eta_{_P}$. After imposing a symmetric equilibrium, we now express the price-elasticity in log-linearized terms.

$$\hat{\varepsilon}^Z_{Pt} = \frac{h_Z}{1 - h_Z} \left(\hat{Z}_t - \hat{Z}_{t-1}\right) \ \forall Z \in \{C,\ G\} \tag{1}$$

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 possibly 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

$$X^Z_t = \hat{\varepsilon}^Z_{Pt} + \hat{Z}_t \ \forall Z \in \{C,\ G\} \tag{2}$$

Utility Maximization Agents derive utility from habit-adjusted consumption $X^{C\ j}$ and disutility from labor N^j. They provide labor services in a perfectly competitive labor market at a real wage w. They have access to a portfolio of state-contingent nominal assets D^j to smooth consumption over time. Agents are entitled to dividends Div^j from the firm and also pay lumpsum taxes T^j to finance public expenditure. The representative agent faces the following optimization program:

$$\max_{\substack{C^j_t,\, N^j_t,\\ D^j_{t+1}}} \ \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\left(X^{C\ j}_t\right)^{1-\sigma_C}}{1 - \sigma_C} - \frac{N^{j\ 1+\sigma_N}_t}{1 + \sigma_N} \right],\ \sigma_C, \sigma_N \geqslant 0,\ \beta \in (0,1)$$

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

$$\frac{\int_0^1 p_{it} C^j_{it} di}{P_t} + \frac{\mathbf{E}_t \left(\Lambda_{t,t+1} D^j_{t+1}\right)}{P_t} + T^j_t = w_t N^j_t + \frac{D^j_t}{P_t} + Div^j_t$$

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.[6] 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 in a linear production function to produce its differentiated good. In log-linearized terms, $\hat{Y}_t = \left(1 + \frac{fc}{\bar{Y}}\right)\hat{N}_t$. fc is a fixed cost used in the technology in order to assure that profits are zero in steady-state.

The crux of the deep habits mechanism lies in the price-setting behavior of the monopolist. We depart from RSU (2006, 2011) by introducing pricing frictions and embed adjustment costs *à la* Rotemberg (1982) in the firm's 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.[7]

$$\max_{\substack{N_{it},\, p_{it} \\ G_{it},\, C_{it}}} \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t U_{Ct} \left(\begin{array}{l} \frac{p_{it}}{P_t}\left(G_{it}+C_{it}\right) - w_t N_{it} + \frac{\Phi_P}{2}\left(\frac{p_{it}}{\bar{\pi}p_{it-1}} - 1\right)^2 Y_t \\ +\nu_t^G\left[\left(\frac{p_{it}}{P_t}\right)^{-\eta_P} X_t^G + h_G G_{it-1} - G_{it}\right] \\ +\nu_t^C\left[\left(\frac{p_{it}}{P_t}\right)^{-\eta_P} X_t^C + h_C C_{it-1} - C_{it}\right] \\ +\frac{1}{\mu_t}\left(N_{it} - fc - G_{it} - C_{it}\right) \end{array} \right)$$

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.

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

[7] 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: $-\hat{\mu}_t = \hat{w}_t$.[8] 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 (*i.e.* in the absence of deep habits) lies in the dependence of price-inflation on the marginal profits $\nu^{()}$ and habit-adjusted demands $X^{()}$.[9] 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. These implicit relations are exploited to log-linearize and simplify Equation 7, to obtain the Phillips curve which links inflation to the mark-up, the price-elasticities and expected future profits. For the analysis of the dynamics that follows

[8] 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.

[9] In a world without deep habits, the marginal profit is given by $\nu_t^Z = \frac{\mu_t - 1}{\mu_t}$. Thus in conventional price-setting equations, the price-inflation is related to the mark-up or the real marginal cost instead of the marginal profit.

in Section 3, it is convenient to rearrange terms to express the Phillips curve in terms of the mark-up instead of inflation as in the standard case.

$$\begin{aligned}\hat{\mu}_t &= \frac{m_0\Phi_P}{(\eta_P m_0 - 1)\, m}\left(\beta \mathbf{E_t}\hat{\pi}_{t+1} - \hat{\pi}_t\right) \\ &\quad -m_{G1}\left(\hat{\varepsilon}^G_{Pt} + \beta h_G \mathbf{E}_t\left[\hat{\nu}^G_{t+1} + \hat{U}_{Ct+1} - \hat{U}_{Ct}\right]\right) - m_{C1}\left(\hat{\varepsilon}^C_{Pt} + \beta h_C \mathbf{E}_t\left[\hat{\nu}^C_{t+1} + \hat{U}_{Ct+1} - \hat{U}_{Ct}\right]\right) \\ &\quad +m_{G2}\hat{G}_t + m_{C2}\hat{C}_t\end{aligned} \tag{8}$$

where m, m_0, m_{G1}, m_{C1}, m_{G2} and m_{C2} are positive constants that are functions of the deep habit parameters.[10] 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 mark-up. However, in contrast to the flexible price environments considered by RSU (2006, 2011), 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.

Market Clearing, Fiscal and Monetary 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 firm is absorbed by the private and public sectors: $\hat{Y}_t = (1 - s_G)\,\hat{C}_t + s_G\hat{G}_t$ where s_G 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. Government spending is the only source of uncertainty in the economy and follows an AR(1) process given by $\hat{G}_t = \rho\hat{G}_{t-1} + \epsilon_t$ such that $\epsilon_t \sim N(0, \sigma^G)$ and $\rho \in [0, 1)$.

The model is closed with the monetary authority following a rule to set the nominal interest rate in response to both inflation and the output-gap, *i.e.* the difference between output under sticky prices and that produced when prices are perfectly flexible. $\rho_M \in [0, 1)$

[10] See appendix for definitions of these constants.

governs the degree of inertia in the interest rate response.

$$\hat{R}_t = \rho_M \hat{R}_{t-1} + (1-\rho_M)\left(\phi_\pi \hat{\pi}_t + \phi_y \left[\hat{Y}_t - \hat{Y}_t^F\right]\right) \tag{9}$$

2.1 The New Keynesian Case

The sticky-price deep habits model can be reduced to the traditional NK set-up with superficial habit by using a few restrictions. Firstly, the demand for intermediate goods exhibits no habit-formation so that the demand function facing the monopolist is static and the price-elasticity of demand is constant at $-\eta_P$. Secondly, consumers form habits over the final good while government spending displays no habit-formation. Hence, habit-persistence in the consumption Euler (Equation 3) is retained in the NK case. The most crucial implication of these restrictions is that the habit coefficients are eliminated from the price-setting Equation 8. Movements in the mark-up are now strictly tied down to expected changes in inflation in the New Keynesian Phillips curve (NKPC).[11]

$$\hat{\mu}_t = \frac{\Phi_P}{\eta_P - 1}\left(\beta \mathbf{E_t} \hat{\pi}_{t+1} - \hat{\pi}_t\right) \tag{10}$$

2.2 The Mark-Up and Intra-temporal Substitution

Irrespective of whether habit-formation is good-specific or superficial, 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.

$$-\hat{\mu}_t = \sigma_N \hat{N}_t + \frac{\sigma_C}{1-h_C}\hat{C}_t - \frac{\sigma_C h_C}{1-h_C}\hat{C}_{t-1} \tag{11}$$

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 11, 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

[11] In the appendix, we list the mathematical conditions that are substituted into Equation 8 to obtain the NKPC.

this common end: while the deep habits model relies on the rise in the price-elasticity and expected future profits, the 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 familiar NK environment.

3 Simulation

3.1 Calibration

Table 1 displays the parameter values that are used in the simulation of the deep habits model and the traditional NK model with superficial habit in consumption. The monetary policy rule exhibits a high degree of interest rate smoothing with ρ_M calibrated at 0.80 while the coefficients on inflation (ϕ_π) and the output-gap $\left(\phi_y\right)$ are set at 1.5 and 0.1 respectively. These values are within the ballpark of the estimates in the empirical literature (*e.g.* Smets and Wouters 2007). We draw most other parameter values from RSU (2006). The autoregressive parameter of the government spending shock (ρ) 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 (s_G) is set at 0.12. We use a different 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 RSU (2006).[12] Keeping all other parameters constant, we now increase the degree of price stickiness (Φ_P) in both set-ups.

3.2 Mark-Up and Consumption Dynamics

We examine the dynamics induced by a temporary increase in government purchases in the two economies, focussing mainly on the responses by the mark-up and consumption.

[12] In both flexible and sticky price versions of the the deep habits model, we do not find a determinate solution path for values of h_C exceeding 0.58, when other parameters are calibrated as in RSU (2006).

The spending stimulus is generated by an exogenous innovation of one percent to the shock process. The dynamic responses for the NK case are presented in Figure 1 and those for the deep habits model are exhibited in Figure 2.

The New Keynesian Case We begin with analyzing the dynamics in a real business cycle model with monopolistic competition (depicted in Figure 1 using thick black lines). The mark-up (and the real wage) is now constant and its log-linearized version that is depicted here is stationary at zero. The intra-temporal substitution effect does not overcome the negative wealth effect of the fiscal shock and consumption is crowded-out. What happens when we introduce sticky prices? As a first step, we keep the adjustment cost parameter Φ_P very low at about 4.3 that corresponds to a price-duration of about one and a half quarters.[13] The inflexibility in price adjustment induces a downward movement in the mark-up and strengthens the substitution of consumption for leisure. Consequently, consumption appears to be 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. In the absence of additional model 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 Case Consider first the dynamics under flexible prices (depicted in Figure 2 using thick black lines). Unlike the NK 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.[14] However, as we increase the price adjustment cost, the response of the mark-up becomes progressively dampened. At Φ_P =26, *i.e.* a price-duration of roughly three quarters (depicted by a solid line with circular markers), the downward movement in the mark-up - or equivalently the rise in the real wage - is too mild to prevent consumption from being crowded-out.[15]

Why does higher price stickiness induce stronger movements in the mark-up in the NK case while it appears to dampen its cyclicality in the deep habits model? Understanding

[13] At Φ_P= 4.3, the slope of the NKPC is unity, given the baseline calibration.

[14] Observe that the fall in the mark-up is steep to below 0.6 per cent but short-lived. The absence of inertia is because we have not modelled the habit-stock that RSU (2006, 2011) employ (see Footnote 5).

[15] The precise threshold of price stickiness at which consumption is crowded out is given by $\Phi_P = 13.40$ (see Subsection 3.4).

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 variables in the two Phillips curves, we will now superscript the variables in the deep habits and the NK cases by 'DH' and 'NK' respectively. In Figure 3, we present impulse response functions of the constituents of the Phillips curves in the deep habits and NK cases. In our discussion, we will also refer to the price and inflation 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.

$$\underbrace{\hat{\mu}_t^{DH}}_{\hat{P}_t^{DH}-\widehat{NMC}_t^{DH}} = \underbrace{\frac{m_0\Phi_P}{(\eta_P m_0-1)\,m}\left(\beta\mathbf{E_t}\hat{\pi}_{t+1}^{DH}-\hat{\pi}_t^{DH}\right)}_{\text{Expected Inflation Change}} - \underbrace{m_{G1}\hat{\varepsilon}_{Pt}^{G,DH}}_{\text{Price Elasticity (G)}} + \underbrace{\widehat{OE}_t^{DH}}_{\text{Other Effects}} \qquad (12)$$

where the term $\widehat{OE}_t^{DH}$ ('other effects') captures the cumulated effects of the price-elasticity of consumption demand and all other elements in Equation 8.

Consider first the dynamics when $\Phi_P = 4.3$ (indicated by dashed lines), a price-duration of one quarter and a half. The fiscal expansion leads to a sharp rise in the price-elasticity of public-sector demand (Panel ii) and hence, it is profitable for the monopolist to lower the price (Panel vi) when she expands production. Inflation is expected to rise to restore the long-run equilibrium (Panel vii 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 negligible in comparison (Panel iv). 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 iii). At this juncture, the substitution of consumption for leisure is strong enough to overcome the negative wealth effect of the fiscal shock and consumption expands.

Note however that the price-elasticity effect is short-lived and reverses sign after a quarter. Recall that the price-elasticity of public sector demand is defined as $\hat{\varepsilon}^G_{Pt} = \frac{h_G}{1-h_G}\left(\hat{G}_t - \hat{G}_{t-1}\right)$. 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.[16] The intra-temporal substitution mechanism is reversed and consequently, consumption declines below trend after about two quarters.

Increasing Φ_P to 8.5, a price-duration of about two quarters, 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 vi). Inflation is again expected to rise (Panel vii of Figure 2), but not as much as in the previous case. Observe that the elasticity of the mark-up to *expected changes* in inflation is increasing in the degree of price rigidities (equivalently, the pass-through of fluctuations in the mark-up into current inflation is decreasing in the cost parameter). In particular, note from Table 1 that at $\Phi_P = 8.5$, the elasticity almost doubles that observed in the first case and strengthens the positive effect of expected inflation (Panel iii) on the mark-up. When we increase the cost parameter more, the positive influence of the expected rise in inflation progressively dominates the downward pressure from the price-elasticity on the mark-up. For this reason, the mark-up is less counter-cyclical, enfeebling the substitution of consumption for leisure. At a price-duration of about three quarters, the counter-cyclicality of the mark-up is too weak to overcome the negative wealth effect of the fiscal expansion is not overcome. Consequently, consumption is crowded-out as in conventional forward-looking models.

In stark contrast, the price-elasticity is invariant to economic activity in the NK case. In this set-up, the mark-up is solely determined by the expected path of inflation.

$$\underbrace{\hat{\mu}^{NK}_t}_{\hat{P}^{NK}_t - \widehat{NMC}^{NK}_t} = \underbrace{\frac{\Phi_P}{\eta_P - 1}\left(\beta \mathbf{E_t}\hat{\pi}^{NK}_{t+1} - \hat{\pi}^{NK}_t\right)}_{\text{NK Expected Inflation Change}} \tag{13}$$

In the absence of a rising price-elasticity, the monopolist has no incentive to lower the

[16] The reversal of sign will be delayed when the habit-stock is allowed to be extremely persistent as in RSU (2006, 2011). In that case, the price-elasticity is given as $\hat{\varepsilon}^G_{Pt} = \frac{h_G}{1-h_G}\left(\hat{G}_t - \hat{S}^G_{t-1}\right)$ such that $\hat{S}^G_t = \omega^G \hat{S}^G_{t-1} + \left(1-\omega^G\right)\hat{G}_t,\ \omega^G \in [0,1)$. A related finding is that while increasing price stickiness worsens the rise in consumption even in the presence of inertial habit-stocks, the threshold of the price adjustment cost required to crowd-out consumption is increasing in the persistence of the habit-stocks.

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 iii and v in Figure 1) implies that future inflation is now expected to be lower than current inflation to restore the long-run equilibrium (Panel vii 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 counter-cyclicality in the mark-up. The now familiar substitution of consumption for leisure ensures that consumption does not contract as much as in a real business cycle model. As we increase the price adjustment cost, the gap between future inflation and current inflation is expected to be smaller in absolute value (Panel vii in Figure 1). However, just as in the deep habits model, the elasticity of the mark-up to the expected change in inflation is increasing in the adjustment cost in the NK case (see Table 1). For this reason, the fall in the mark-up is more pronounced, *i.e.* it becomes more counter-cyclical. Concurrently, the real wage becomes more pro-cyclical and consumption is progressively less crowded-out (Panel x).

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 NK case, 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 effect is less effective. The dampened counter-cyclicality of the deep habits mark-up implies that the real wage is less pro-cyclical 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.

3.4 Sensitivity to Other Parameters

Naturally, the response of consumption is also contingent on values assigned to other parameters. In Figure 4, we plot the threshold of price adjustment cost at which consumption is crowded-out on impact of the fiscal shock, when selected parameters are perturbed (one at a time) from their baseline calibration. In the baseline case (not exhibited), consumption is crowded-out at $\Phi_P = 13.40$ which implies a price duration of roughly two quarters.

A higher persistence coefficient on the government spending shock process strengthens the negative wealth effect on consumption. Consequently, a lower adjustment cost is required to crowd-out consumption when the shock is very persistent (Panel i). Not surprisingly, the consumption response is increasing in the degree of habit-formation in government due to the strong negative effect of the rising price-elasticity of public sector demand on the mark-up. Hence, consumption responds negatively only at higher values of the cost parameter (Panel ii). Similarly, a higher degree of habit-persistence in consumption augments the positive consumption response.[17] Increasing the consumption habit raises the consumption price-elasticity which in turn lowers the mark-up and raises the real wage through second-round effects and hence the threshold cost parameter is increasing in the degree of consumption habit (Panel iii). A higher Frisch elasticity of labor-supply makes consumption respond more positively to the rise in the real wage and a higher degree of price stickiness is required to crowd-out consumption under these conditions (Panel iv). Consumption responses to the fiscal shock are imperceptibly mild when the three monetary policy rule parameters are perturbed (not exhibited) and the thresholds do not vary drastically over ranges which are empirically relevant (Panels v through vii).

4 Conclusion

This paper provides a closer examination of the nexus between deep habits, countercyclical mark-ups and the crowding-in of private consumption as a result of increases in purchases by the public sector as documented by Ravn, Schmitt-Grohé and Uribe (2006, 2011). We demonstrate that introducing price rigidities into the deep habits economy weakens the positive response of consumption to government spending and if stickiness is high enough, consumption is crowded-out. The crowding-out of consumption in the sticky-price deep habits model is due to the composition of the Phillips curve, which encapsulates two opposing effects on mark-up dynamics. The presence of deep habits gives rise to a strongly pro-cyclical 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. However with increasing price stickiness, a second - and more conventional - channel emanates from the expected

[17] However, the consumption response is positive even when the consumption habit coefficient is set to zero (not exhibited) implying that it is the degree of habit-persistence in the public sector that is the vital ingredient to obtain crowding-in.

path of inflation. The Phillips curve stipulates that inflation is expected to rise after a fall in the price-level. For this reason, the positive influence of the expected rise in inflation dampens the downward pressure on the mark-up generated by the rising price-elasticity. Consequently, the counter-cyclicality of the mark-up is weaker and this reflects in a milder rise in the real wage which in turn 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 as in standard forward-looking business cycle models.

A Appendix

Steady-State Marginal Profit: In steady-state, the first order condition for the firm's choice of quantities, *i.e.* Equation 5 is given by

$$\frac{\bar{\mu}_{DH}-1}{\bar{\mu}_{DH}}\left[\frac{1}{1-\beta h_Z}\right]=\bar{\nu}^Z\ \forall Z\in\{C,\ G\} \tag{A1}$$

This condition is useful in deriving Equation 6 in the main text.

Steady-State Mark-Up: Note that (i) there are no price adjustment costs in steady-state: $\Phi_P=0$ (ii) Habit-adjusted aggregate demands are given by $\bar{X}^Z=\bar{Z}\left(1-h_Z\right)\forall Z\in\{C,\ G\}$ and the great ratios are related as $\frac{\bar{C}}{\bar{Y}}=1-\frac{\bar{G}}{\bar{Y}}=1-s_G$. Impose these conditions on the price-setting condition Equation 7 in steady-state to get $\eta_P=\frac{1}{(1-s_G)(1-h_C)\bar{\nu}^C+s_G(1-h_G)\bar{\nu}^G}$. Use this expression to substitute out the Lagrange multipliers $\bar{\nu}^Z$ in Condition A1 to obtain $\eta_P=\frac{1}{\frac{\bar{\mu}_{DH}-1}{\bar{\mu}_{DH}}\left[(1-s_G)\frac{1-h_C}{1-\beta h_C}+s_G\frac{1-h_G}{1-\beta h_G}\right]}$. This expression yields the gross steady-state mark-up $\bar{\mu}_{DH}=\frac{\eta_P m_0}{\eta_P m_0-1}$ such that $m_0=(1-s_G)\frac{1-h_C}{1-\beta h_C}+s_G\frac{1-h_G}{1-\beta h_G}<1$.

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

$$\hat{\pi}_t=\beta\mathbf{E}_t\hat{\pi}_{t+1}-\frac{\eta_P}{\Phi_P}\left[\bar{\nu}^C\left(1-s_G\right)\left(1-h_C\right)\left(\hat{\nu}_t^C+\hat{X}_t^C-\hat{Y}_t\right)+\bar{\nu}^G s_G\left(1-h_G\right)\left(\hat{\nu}_t^G+\hat{X}_t^G-\hat{Y}_t\right)\right]$$

We substitute the following conditions in the above equation to obtain the Phillips curve in Equation 8: (i) Equations 2 and 6 together with the goods market clearing condition (ii) Condition A1 and the expression for the steady-state deep habits mark-up. Finally, we manipulate to express in terms of the mark-up. We define $m_{C1}=\frac{(1-s_G)\frac{1-h_C}{1-\beta h_C}}{\left(\eta_P m_0-1\right)m}$, $m_{G1}=$

$\frac{s_G \frac{1-h_G}{1-\beta h_G}}{\left(\eta_P m_0 - 1\right) m}$, $m_{C2} = \frac{(1-s_G)\left(m_0 - \frac{1-h_C}{1-\beta h_C}\right)}{\left(\eta_P m_0 - 1\right) m}$ and $m_{G2} = \frac{s_G\left(m_0 - \frac{1-h_G}{1-\beta h_G}\right)}{\left(\eta_P m_0 - 1\right) m}$ such that $m = s_G\left(1 - h_G\right) + \left(1 - s_G\right)\left(1 - h_C\right)$.

New Keynesian Phillips Curve: We set the habit coefficients to zero in the deep habits Phillips curve: $h_Z = 0 \; \forall \; Z \in \{C, \, G\}$. It follows that the log-linearized price-elasticities are zero and $m_0 = m_{CG} = 1$ and $m_{G2} = m_{C2} = 0$. Using these expressions in Equation 8, we recover the NKPC exhibited in Equation 10. However, note that habit-persistence is retained in the consumption Euler in the NK model.

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Table 1: Calibration

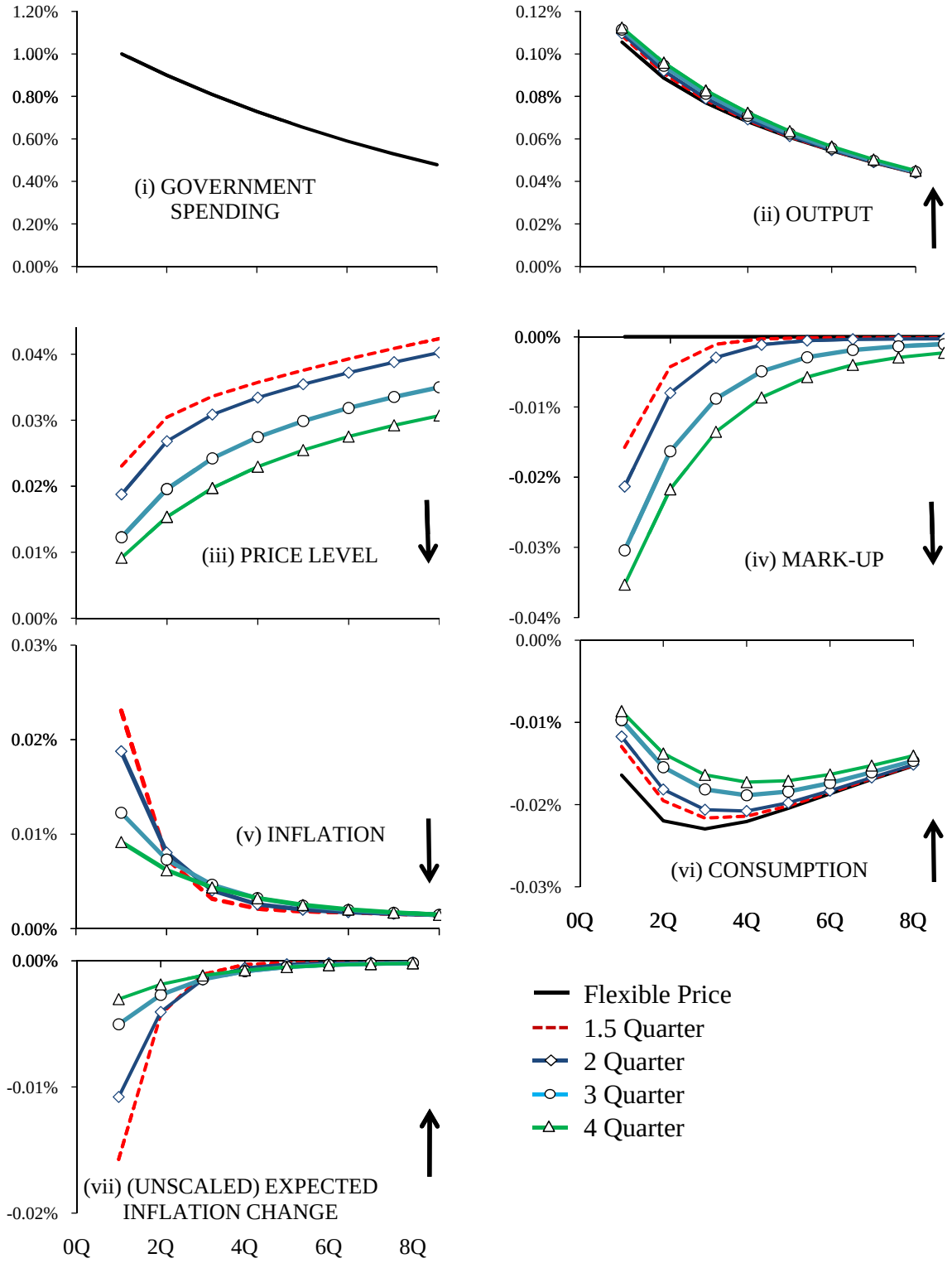
SYMBOL	DESCRIPTION	**Deep Habit (Flex. Price)**	**Deep Habit (Sticky Price)**	**NK (Superficial Habit)**
σ_C	Utility Curvature	2	2	2
β	Subjective Discount Factor	0.9902	0.9902	0.9902
$1/\sigma_N$	Frisch Elasticity	1.3	1.3	1.3
η_P	Elasticity of Substitution between Goods Varieties (habit-adjusted demand)	5.3	5.3	5.3
h_C	External Habit in Consumption	0.50	0.50	0.50
h_G	External Habit in Govt. Spending	0.86	0.86	0
s_G	Steady-state Share of Govt in output	0.12	0.12	0.12
ρ	Persistence of Govt. Spending Shock	0.90	0.90	0.90
σ^G	Standard Deviation of Shock	1%	1%	1%
ρ_M	Interest Rate Smoothing	-	0.80	0.80
ϕ_π	Interest Rate Response to Inflation	-	1.50	1.50
ϕ_y	Interest Rate Response to Output	-	0.10	0.10
$\bar{\mu}_{DH}, \bar{\mu}_{NK}$	Implied Steady-State Mark-Ups $\left(= 1 + \frac{fc}{\bar{Y}}\right)$	1.2370	1.2370	1.2326

Φ_P Rotemberg Price Adjustment Cost

Value (~ Price Duration)		Coefficient on $E_t\beta\hat{\pi}_{t+1} - \hat{\pi}_t$ in the Phillips Curve	
		$\frac{m_0\Phi_P}{(\eta_P m_0 - 1)m}$	$\frac{\Phi_P}{\eta_P - 1}$
4.3 (~ 1.50 Q)	-	2.19	1
8.5 (~ 2.00 Q)	-	4.34	1.98
26 (~ 3.00 Q)	-	13.28	6.05
50 (~ 4.00 Q)	-	25.55	11.63

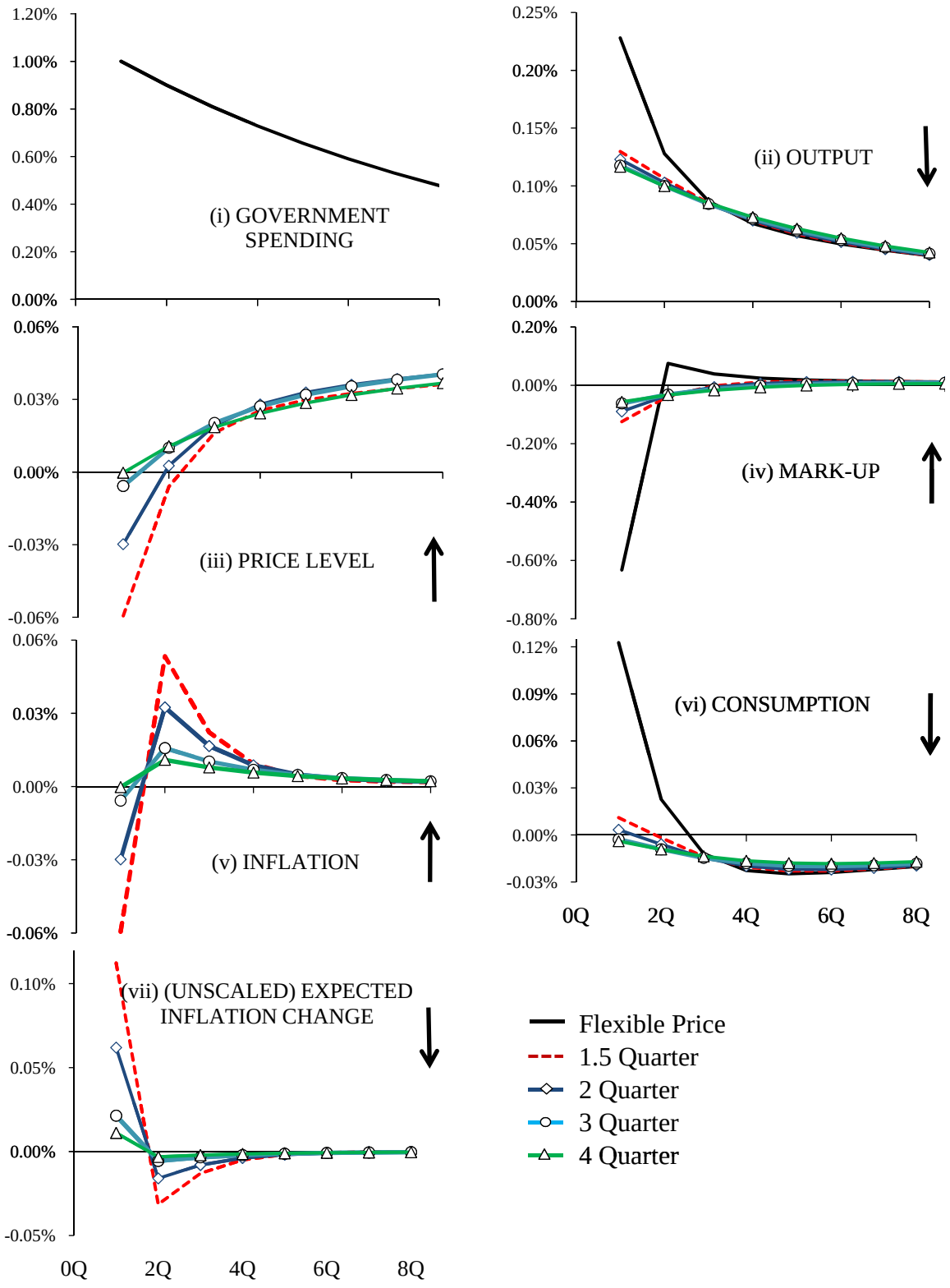
Note: 'NK' is the abbreviation for the New Keynesian model. The quarterly price-duration interpretation of the Rotemberg adjustment cost parameter is based on a comparison of the slopes of the NK Phillips curves under Rotemberg and Calvo price-setting.

Figure 1: Impulse Responses to a Government Spending Shock in the New Keynesian Model with Superficial Habit under Increasing Price Stickiness



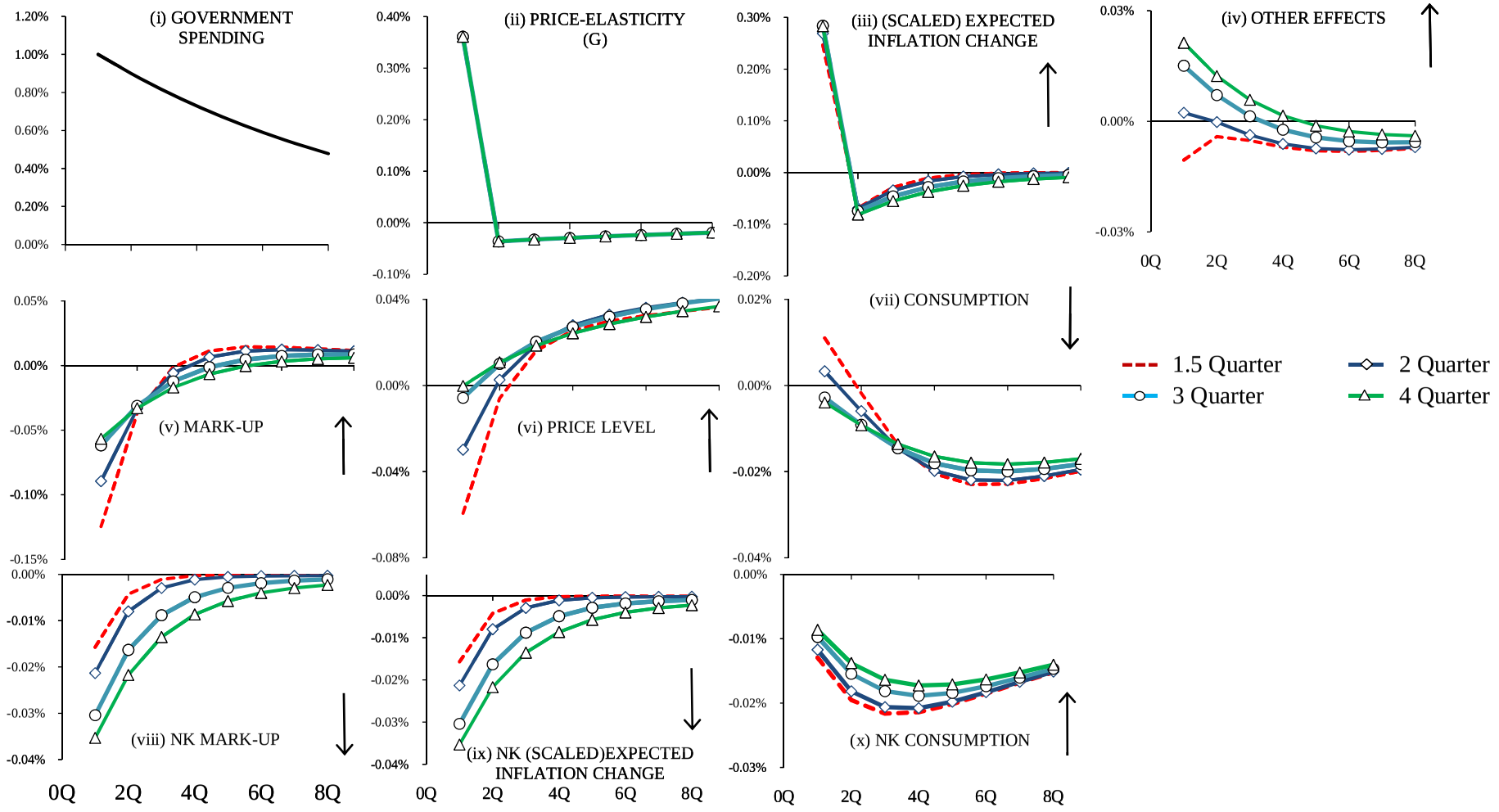
Note: The IRFs are measured in percentage deviations from steady-state. The mark-up is the negative of the real wage and the real marginal cost. The IRF of hours worked is identical to that of output except that it is slightly less volatile because hours worked are obtained by scaling output by the steady-state 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 Deep Habits Model under Increasing Price Stickiness



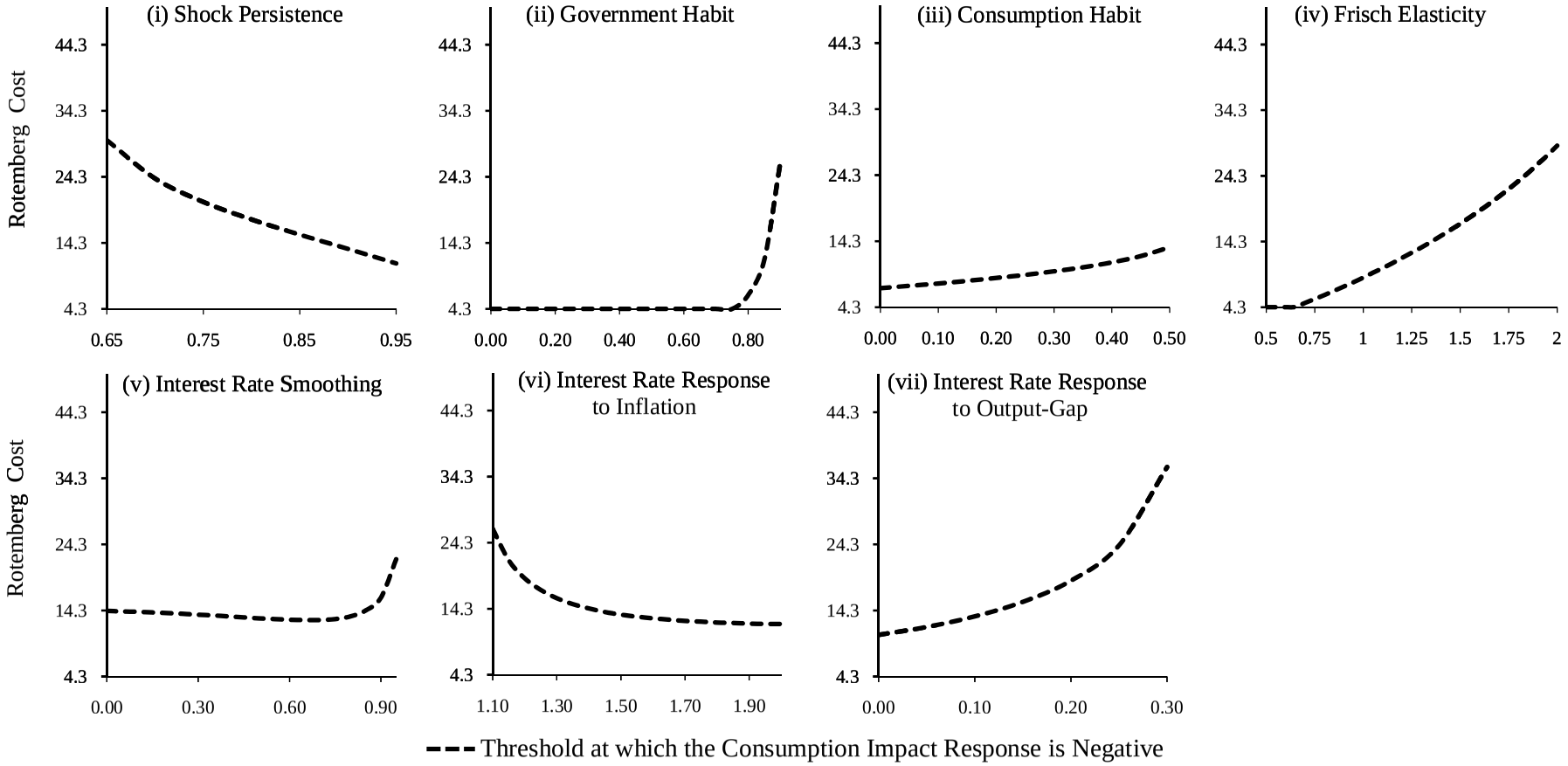
Note: The IRFs are measured in percentage deviations from steady-state. The mark-up is the negative of the real wage and the real marginal cost. The IRF of hours worked is identical to that of output except that it is slightly less volatile because hours worked are obtained by scaling output by the steady-state 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: Deep Habits vs New Keynesian Models



Note: IRFs are measured in percentage deviations from steady-state. In the deep habits model, the terms in the Phillips curve is decomposed as Mark-Up = Expected Inflation Change - Price Elasticity (G) + Other Effects . The components have been multiplied by positive constants (See main text). The prefix '(SCALED)' is used to distinguish the Expected Inflation Change in both models from those exhibited in Figures 1 and 2 where they have not been multiplied with the positive constants.

Figure 4: Values of Rotemberg Cost at which Consumption is Crowded Out by Government Spending when Parameter Values are Allowed to Vary in the Deep Habits Model



Rotemberg cost parameter interpreted in terms of a price-duration in months in the NKPC context

4.3 ~ 5 months 20 ~ 8 months 30 ~ 10 months 40 ~ 11 months 50 ~ 12 months

Note: Each parameter is allowed to vary with a step-size of 0.05 over a specified interval. 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.