Deep Habits*

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Abstract

This paper generalizes the standard habit formation model to an environment in which agents form habits over individual varieties of goods as opposed to over a composite consumption good. We refer to this preference specification as 'deep habit formation.' Under deep habits, the demand function faced by individual producers depends on past sales. This feature is typically assumed ad-hoc in customer market and brand switching cost models. A central result of the paper is that deep habits give rise to countercyclical markups, which is in line with the empirical evidence. This result is important because ad-hoc formulations of customer-market and switching-cost models have been criticized for implying procyclical and hence counterfactual markup movements. Under deep habits, consumption and wages respond procyclically to government spending shocks. The paper provides econometric estimates of the parameters pertaining to the deep habit model. *JEL Classification:* D10, D12, D42, E30.

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1 Introduction

The standard habit-persistence model, be it of the internal or external type, assumes that households form habits from consumption of a single aggregate good. An important consequence of this assumption is that the introduction of habit formation alters the propagation of macroeconomic shocks only insofar as it modifies the way in which aggregate demand and possibly the supply of labor respond to such shocks.

In this paper, we generalize the concept of habit formation by considering the possibility that private agents do not simply form habits from their overall consumption levels, but rather from the consumption of individual goods. We have in mind an environment in which consumers can form habits separately over narrowly defined categories of goods, such as clothing, vacation destinations, music, cars, etc., not just over consumption defined broadly. We believe that this description of preferences, to which we refer as 'deep habits,' is more compelling than its standard, or, in our terminology, 'superficial,' counterpart. For example, the deep-habit formulation is embedded in Houthakker and Taylor's (1970) classic work on consumption demand. Moreover, the empirical literature on consumer behavior often finds that consumers' choices over different brands of goods are affected by past brand choices (see Chintagunta et al. 2001, for a recent example).

The assumption that agents can form habits on a good-by-good basis has two important implications for aggregate dynamics. First, the demand side of the macroeconomy—in particular the consumption Euler equation—is indistinguishable from that pertaining to an environment in which agents have superficial habits. Second, and more significantly, the assumption of deep habit formation alters the supply side of the economy in fundamental ways. Specifically, when habits are formed at the level of individual goods, firms take into account that the demand they will face in the future depends on their current sales. This is because higher consumption of a particular good in the current period makes consumers, all other things equal, more willing to buy that good in the future through the force of habit. Thus, when habits are deeply rooted, the optimal pricing problem of the firm becomes dynamic.

We embed the deep habit formation assumption into an economy with imperfectly competitive product markets. This combination results in a model of endogenous, time-varying markups of prices over marginal cost. A central result of this paper is that in the deep habit model markups behave countercyclically in equilibrium. In particular, we show that expansions in output driven by preference shocks, government spending shocks, or productivity shocks are accompanied by declines in markups. This implication of the deep habit model is in line with the empirical literature extant, which finds markups to be countercyclical (Rotemberg and Woodford, 1999).

The intuition for why the deep habit model induces countercyclical movements in markups is relatively straightforward. In a simple version of the deep habit model, the demand faced by an individual firm, say firm i, in period t is of the form $q_{it} = p_{it}^{-\eta}(q_t - \theta q_{t-1}) + \theta q_{it-1}$, where q_{it} denotes the demand for good i, p_{it} denotes the relative price of good i, and q_t denotes the level of aggregate demand. Firm i takes the evolution of q_t as given. The parameter $\theta \in [0, 1)$ measures the strength of external habit for good i. This demand function is composed of two terms. One term is $p_{it}^{-\eta}(q_t - \theta q_{t-1})$, displaying a price elasticity of η. The second term is θq_{it-1}, which originates exclusively from habitual consumption of good i. Therefore, the second term is perfectly price inelastic. The price elasticity of the demand for good i is a weighted average of the elasticities of the two terms just described, namely η and 0. The weight on η is given by the share of the price-elastic term in total demand. When aggregate demand, q_t, rises, the weight of the price-elastic term in total demand increases and as a result the price elasticity increases. We refer to this effect as the *price-elasticity effect* of deep habits. Because the markup is inversely related to the price elasticity of demand, it follows that under deep habits an expansion in aggregate demand induces a decline in markups. Under either superficial habits or no habits, the demand function faced by firm i collapses to $q_{it} = p_{it}^{-\eta} q_t$. In this case, the price elasticity of demand for good i is independent of the level of aggregate demand. In fact, it is constant and equal to η, implying a time-invariant markup.

In addition to the price-elasticity effect, deep habits influence the equilibrium dynamics of markups through an *intertemporal effect*. This effect arises because firms take into account that current price decisions affect future demand conditions via the formation of habits. According to the intertemporal effect, when the present value of future per-unit profits are expected to be high, firms have an incentive to invest in customer base today. They do so by building up the current stock of habit. In turn, this increase in habits is brought about by inducing higher current sales via a decline in current markups. The dynamic pricing problem at the level of the individual firm that is induced by the introduction of deep external habits is akin to that studied in partial equilibrium models of customer-market pricing (Phelps and Winter, 1970) or brand-switching costs (Klemperer, 1995). An important difference between the deep habit and the switching-cost/customer-market formulations is that in the deep habit model there is gradual substitution between differentiated goods rather than discrete switches among suppliers. One advantage of this implication of the deep-habit model, from the point of view of analytical tractability, is that under the deep habit formulation one does not face an aggregation problem. In equilibrium buyers can distribute their purchases identically and still suppliers face a gradual loss of customers if they raise their relative prices. The deep-habit-formation model can therefore be viewed as a natural vehicle for incorporating switching-cost/customer-market models into a dynamic general equilibrium framework.

Because not all components of aggregate demand may be subject to deep habit formation, it follows that changes in the composition of aggregate demand will in general affect the strength of the aforementioned price-elasticity and intertemporal effects of deep habits on markups. For instance, if investment spending is not subject to habit-forming behavior, a shock that increases the share of investment in aggregate spending, such as an aggregate productivity shock, would reduce the overall importance of habits and as a result alter the pricing behavior of firms.

The countercyclicality of markups is a particularly interesting implication of the deep habit model. For existing general equilibrium versions of customer-market and switching-cost models have been criticized on the grounds that they predict procyclical markups (Rotemberg and Woodford, 1991, 1995). This criticism, however, is based upon customer-market models in which the demand function faced by individual firms is specified ad-hoc and not derived from the optimizing behavior of households. Our results show that once the demand for individual goods is derived from first principles, a customer-market model is indeed capable of predicting an empirically relevant cyclical behavior of markups.

A further contribution of this paper is to estimate the structural parameters of the deep external habit model. Existing econometric estimates of the degree of habit formation identify the parameters defining habits from the consumer's Euler equation. This restriction continues to be present in our deep habit model. Therefore, available estimates of the degree of external habit formation can as well be interpreted as estimates of the degree of deep external habit formation. However, the deep habit model contains additional equilibrium conditions that can be used to identify the habit parameters, namely, supply-side restrictions stemming from the optimal pricing decision of firms. In our econometric work, we exploit these additional identifying restrictions to obtain more efficient estimates of the habit parameter. Our results are consistent with previous studies, which rely solely on Euler equation estimations, in that they suggest a relatively high degree of habit persistence and an inertial evolution of the stock of habit over time.

The remainder of the paper is organized in four sections. Section 2 develops the deep habit model in the context of a simple production economy without capital. Section 3 studies the equilibrium dynamics of the deep habit model within a fully-fledged real-business-cycle environment with endogenous labor supply, capital accumulation, and a government sector. That section investigates the response of aggregate activity, factor prices, and markups to a variety of shocks. It also reports econometric estimates of the parameters of the deep habit model. Much of the paper focuses on the case in which deep habits are external and additive.

Section 4 considers three important variations of this baseline specification. One variation is a model with good-specific subsistence points. In this model the price-elasticity effect mentioned above stands in isolation, and the intertemporal effect is absent. The second variation studies an environment with relative deep habits. In this economy, the price-elasticity effect is eliminated, whereas the intertemporal effect remains active. The third variation studies the case of internal deep habits. It shows that when households internalize their propensity to develop addiction to individual goods, the monopolist's pricing problem ceases to be time consistent. Section 5 concludes.

2 A Simple Economy with Deep Habits

Consider an economy populated by a continuum of identical households of measure one indexed by $j \in [0, 1]$. Each household j has preferences defined over consumption of a continuum of differentiated goods, c^j_{it}. Good varieties are indexed by $i \in [0, 1]$. Households also value leisure and thus derive disutility from labor effort, h^j_t. Following Abel (1990), preferences feature 'external habit formation,' or 'catching up with the Joneses.' The central difference between Abel's specification and ours is that we assume that consumption externalities operate at the level of each individual good rather than at the level of the composite final good. We refer to this variant as 'catching up with the Joneses good by good' or 'deep habits.' Specifically, we assume that household j derives utility from an object x^j_t defined by

$$x^j_t = \left[\int_0^1 \left(c^j_{it} - \theta c_{it-1} \right)^{1-1/\eta} di \right]^{1/(1-1/\eta)}, \tag{1}$$

where $c_{it-1} \equiv \int_0^1 c^j_{it-1} dj$ denotes the cross-sectional average level of consumption of variety i in period $t-1$, which the household takes as exogenously given. The parameter θ measures the degree of external habit formation in consumption of each variety. When $\theta = 0$, we have the benchmark case of preferences displaying no consumption externalities. The parameter $\eta > 0$ denotes the intratemporal elasticity of substitution of habit-adjusted consumption across different varieties.

For any given level of x^j_t, purchases of each variety $i \in [0, 1]$ in period t must solve the dual problem of minimizing total expenditure, $\int_0^1 P_{it} c^j_{it} di$, subject to the aggregation constraint (1), where P_{it} denotes the nominal price of a good of variety i at time t. The optimal level of c^j_{it} for $i \in [0, 1]$ is then given by

$$c^j_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\eta} x^j_t + \theta c_{it-1}, \tag{2}$$

where $P_t \equiv \left[\int_0^1 P_{it}^{1-\eta} di\right]^{\frac{1}{1-\eta}}$, is a nominal price index. Note that consumption of each variety is decreasing in its relative price, P_{it}/P_t, increasing in the level of habit-adjusted consumption, x_t^j, and, for $\theta > 0$, increasing in past aggregate consumption of the variety in question. At the optimum, we have that $P_t x_t^j = \int_0^1 P_{it}(c_{it}^j - \theta c_{it-1})di$.

The utility function of the household is assumed to be of the form

$$E_0 \sum_{t=0}^{\infty} \beta^t U(x_t^j, h_t^j), \tag{3}$$

where E_t denotes the mathematical expectations operator conditional on information available at time t, $\beta \in (0, 1)$ represents a subjective discount factor, and U is a period utility index assumed to be strictly increasing in its first argument, strictly decreasing in its second argument, twice continuously differentiable, and strictly concave.

In each period $t \geq 0$, households are assumed to have access to complete contingent claims markets. Let $r_{t,t+j}$ denote the stochastic discount factor such that $E_t r_{t,t+j} z_{t+j}$ is the period-t price of a random payment z_{t+j} in period $t+j$. In addition, households are assumed to be entitled to the receipt of pure profits from the ownership of firms, Φ_t^j. Then, the representative household's period-by-period budget constraint can be written as

$$x_t^j + \omega_t + E_t r_{t,t+1} d_{t+1}^j = d_t^j + w_t h_t^j + \Phi_t^j, \tag{4}$$

where $\omega_t \equiv \theta \int_0^1 (P_{it}/P_t) c_{it-1} di$. The variable w_t denotes the real wage rate. In addition, households are assumed to be subject to a borrowing constraint that prevents them from engaging in Ponzi games. The representative household's optimization problem consists in choosing processes x_t^j, h_t^j, and d_{t+1}^j so as to maximize the lifetime utility function (3) subject to (4) and a no-Ponzi-game constraint, taking as given the processes for w_t, ω_t, and Φ_t^j and initial asset holdings d_0^j.

The first-order conditions associated with the household's problem are (4),

$$-\frac{U_h(x_t^j, h_t^j)}{U_x(x_t^j, h_t^j)} = w_t, \tag{5}$$

and

$$U_x(x_t^j, h_t^j) r_{t,t+1} = \beta U_x(x_{t+1}^j, h_{t+1}^j). \tag{6}$$

2.1 Firms

Each variety of goods is assumed to be produced by a monopolistically competitive firm.

Equation (2) implies that aggregate demand for good i, $c_{it} \equiv \int_0^1 c_{it}^j dj$, is given by

$$c_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} x_t + \theta c_{it-1}, \tag{7}$$

where $x_t \equiv \int_0^1 x_t^j dj$ is a measure of aggregate demand. The key implication of this demand function is that its price elasticity is procyclical. In effect, an increase in the level of aggregate demand, x_t, raises the relative importance of the price elastic term $(P_{it}/P_t)^{-\eta} x_t$, and reduces the relative importance of the price-inelastic, or purely habitual, demand component, θc_{it-1}. As a result, the price elasticity of demand for good i faced by the monopolist increases with aggregate demand. We refer to this effect as the *price-elasticity effect* of deep habits. To the extent that markups of prices over marginal costs are inversely related to the price elasticity of demand, the deep habit model predicts that markups move countercyclically.

Each good $i \in [0, 1]$ is manufactured using labor as an input via the linear production technology $y_{it} = A_t h_{it}$, where y_{it} denotes output of good i, h_{it} denotes labor input, and A_t denotes an aggregate technology shock. Firms are assumed to be price setters, to take the actions of all other firms as given, and to stand ready to satisfy demand at the announced prices. Formally, firm i must satisfy $y_{it} \geq c_{it}$. Firm i's profits in period t are given by $\Phi_{it} \equiv (P_{it}/P_t)c_{it} - w_t h_{it}$. Note that real marginal costs are equal to w_t/A_t and are independent of scale and common across firms. Nominal marginal costs are thus given by $MC_t = (P_t w_t/A_t)$. Let μ_{it} denote the markup of prices over marginal costs charged by firm i, and μ_t the average markup charged in the economy, that is, $\mu_{it} = P_{it}/MC_t$ and $\mu_t = P_t/MC_t$. We can then express profits of firm i in period t as

$$\Phi_{it} = \frac{\mu_{it} - 1}{\mu_t} c_{it} \tag{8}$$

and the aggregate demand faced by firm i as

$$c_{it} = \left(\frac{\mu_{it}}{\mu_t}\right)^{-\eta} x_t + \theta c_{it-1}. \tag{9}$$

The firm's problem consists in choosing processes μ_{it} and c_{it} so as to maximize the present discounted value of profits,

$$E_t \sum_{j=0}^{\infty} r_{t,t+j} \Phi_{it+j}, \tag{10}$$

subject to (8) and (9), given processes $r_{t,t+j}$, μ_t, and x_t.

The Lagrangian of firm i's problem can be written as

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} r_{0,t} \left\{ \frac{\mu_{it}-1}{\mu_t} c_{it} + \nu_{it} \left[\left(\frac{\mu_{it}}{\mu_t} \right)^{-\eta} x_t + \theta c_{it-1} - c_{it} \right] \right\},$$

where ν_{it} is a Lagrange multiplier associated with equation (9). The first-order conditions corresponding to this optimization problem are (9) and

$$\nu_{it} = \frac{\mu_{it}-1}{\mu_t} + \theta E_t r_{t,t+1} \nu_{it+1}$$

$$c_{it} = \eta \nu_{it} \left(\frac{\mu_{it}}{\mu_t} \right)^{-\eta-1} x_t.$$

The multiplier ν_{it} represents the shadow value of selling an extra unit of good i in period t. The first of the above optimality conditions states that the value of selling an extra unit of good i in period t, ν_{it}, has two components. One is the short-run profit of a sale, given by $(\mu_{it}-1)/\mu_t$. The second component reflects future expected profits associated with selling an extra unit of good i in the current period. In effect, a unit increase in sales in the current period induces, via habit formation, additional sales in the amount of θ units in the next period. The present discounted value of these θ additional units of sales is $\theta E_t r_{t,t+1} \nu_{it+1}$, which is precisely the second term on the right-hand side of the first optimality condition shown above. The second optimality condition equates the costs and benefits of a unit increase in the relative price. The benefit is given by an increase in revenue in the amount of c_{it} stemming from selling all intramarginal units at a higher price. The cost is the decline in demand that the price increase induces, and is given by $\eta \left(\frac{\mu_{it}}{\mu_t} \right)^{-\eta-1} x_t$, evaluated at the shadow value of sales, ν_{it}. It is straightforward to see from the above two optimality conditions that in the absence of habit formation ($\theta = 0$), the markup is constant and equal to $\eta/(\eta-1)$.

We note that the pricing decisions of the monopolist are time consistent. This is because the current demand is independent of future expected values of P_{it}/P_t. This independence of current demand from future expected relative prices is a consequence of our maintained assumption that deep habits are external. Under the alternative hypothesis that habit formation is internal, the demand for good i in period t will depend not just on the price of good i in period t but also on future expected prices. This feature of demand in the internal deep habit model in conjunction with the fact that past sales affect the monopolist's current price setting behavior may give rise to time inconsistency problems. We discuss the case of deep internal habits further in section 4.3.

2.2 Equilibrium

Because all households are identical, consumption and labor supplies are invariant across individuals. It follows that we can drop the superscript j from all variables. We assume that the initial conditions c_{it}, $t = -1$, are the same for all goods $i \in [0, 1]$. Further, we restrict attention to symmetric equilibria in which all firms charge the same price. Therefore, we can also drop the subscript i from all variables. A stationary competitive equilibrium can then be defined as a set of stationary processes $\{x_t, c_t, h_t, r_{t,t+1}, w_t, \nu_t, \mu_t\}$ satisfying

$$x_t = c_t - \theta c_{t-1}, \tag{11}$$

$$U_x(x_t, h_t) r_{t,t+1} = \beta U_x(x_{t+1}, h_{t+1}), \tag{12}$$

$$w_t = -\frac{U_h(x_t, h_t)}{U_x(x_t, h_t)}, \tag{13}$$

$$\mu_t = \frac{A_t}{w_t}, \tag{14}$$

$$c_t = A_t h_t, \tag{15}$$

$$\nu_t = \theta E_t r_{t,t+1} \nu_{t+1} + 1 - \frac{1}{\mu_t}, \tag{16}$$

$$c_t = \eta(c_t - \theta c_{t-1})\nu_t. \tag{17}$$

It is of interest to compare these equilibrium conditions to those arising from the standard habit formation model. That is, from a model where the single-period utility function depends on the quasi difference between current and past consumption of the composite good as opposed to the quasi difference between current and past consumption of each particular variety. It is straightforward to show that the superficial habit model shares with our deep habit model equilibrium conditions (11)-(15). Of particular interest is the fact that because the consumption Euler equation (12) is common to the deep habit model as well as to the standard superficial habit formation models, existing Euler-equation-based empirical estimates of the degree of habit formation can be interpreted as uncovering the degree of deep habit persistence. Because in our model the parameter θ that measures the strength of deep habits appears in equations other than the consumption Euler equation (12), our model provides additional identification restrictions. In section 3.4, we exploit these additional restrictions in conjunction with the Euler equation to obtain a more efficient estimate of θ.

What sets the deep and superficial habit models apart is the fact that under superficial habits equilibrium conditions (16) and (17) are replaced by the requirement that the markup, μ_t, be constant and equal to $\eta/(\eta - 1)$. This is a significant difference. The deep habit formation model introduces a dynamic wedge between factor prices and their associated marginal products. That is, the deep habit model gives rise to time varying markups.

2.3 The Price-Elasticity and Intertemporal Effects of Deep Habits

It is convenient to express the markup as a function of the short-run price elasticity of demand and the present value of expected per-unit future profits. The reason is that these two variables capture the main channels through which deep habits affect markup dynamics. Iterating equation (16) forward and assuming that $\lim_{j\to\infty}\theta^j E_t r_{t,t+j}\nu_{t+j}=0$, one can express ν_t as the present discounted value of expected future per unit profits induced by a unit increase in current sales, that is, $\nu_t = E_t\sum_{j=0}^{\infty}\theta^j r_{t,t+j}\left(\frac{\mu_{t+j}-1}{\mu_{t+j}}\right)$. In turn, equation (17) implies that

$$\nu_t = \frac{1}{\eta(1-\theta c_{t-1}/c_t)}. \qquad (18)$$

It follows from equation (7) that the denominator on the right-hand side of this expression is the short-run price elasticity of demand for each particular variety of goods in equilibrium. Note that the short-run price elasticity of demand under deep habits, $\eta(1-\theta c_{t-1}/c_t)$, is smaller than the price elasticity of demand in the absence of deep habits, which is given by η. Furthermore, an increase in current aggregate demand, c_t, relative to habitual demand, θc_{t-1}, increases the short-run price elasticity of demand.

Using equation (18) to eliminate ν_t from (16) and rearranging terms yields

$$\mu_t = \left[1-\frac{1}{\eta(1-\theta c_{t-1}/c_t)}+\theta E_t r_{t,t+1}\nu_{t+1}\right]^{-1}. \qquad (19)$$

This expression defines the equilibrium markup as a function of the short-term price elasticity of demand, $\eta(1-\theta c_{t-1}/c_t)$, and the present value of future per-unit profits induced by a unit increase in current sales, $\theta E_t r_{t,t+1}\nu_{t+1}$. Clearly, all other things constant, an increase in current aggregate demand rises the short-term price elasticity of demand inducing a decline in equilibrium markups. This is the price-elasticity effect of deep habits on markups.

At the same time, an increase in the present value of future per-unit profits causes a decline in markups. This is the intertemporal effect of deep habits on markups. The size of the intertemporal effect of deep habits is determined by two components, the discount factor $r_{t,t+1}$ and the present value of future per unit profits, ν_{t+1}. The equilibrium markup is decreasing in the discount factor, which implies that, all else constant, a rise in the real interest rate should be associated with an increase in the current markup. This is because if the real interest rate is higher, then the firm discounts future profits more and thus has less incentives to invest in market share today. Also, the markup is decreasing in ν_{t+1}, the value of future per unit profits discounted to period $t+1$. The intuition for why the current markup is decreasing in ν_{t+1} is that if future per-unit profits are expected to be high, then the value of having market share in the future is also high, and thus there is an incentive to increase the future customer base. A higher customer base in the future can be achieved by charging lower markups today.

The implied negative relation between markups and expected future profits and between markups and the discount factor distinguishes the markup dynamics in the deep-habit model from those implied by the implicit-collusion model of Rotemberg and Saloner (1986) and Rotemberg and Woodford (1992). In that model collusion among firms is sustained by the credible threat of reverting to a perfect competition, marginal-cost-pricing regime in the event that any firm fails to abide to the terms of the implicit agreement. Thus, the maximum sustainable markup in the collusive equilibrium is decreasing in the short-run benefit from deviating from the implicit collusion and increasing in the long-run benefit of staying in the collusive relationship. The benefit of cheating is an increasing function of current output, while the benefit of sticking to the implicit pricing arrangement is an increasing function of the present discounted value of future expected profits.

If $\theta = 0$, that is, in the absence of deep habits, then both the price-elasticity and intertemporal effects vanish rendering the markup time invariant and equal to $(\eta/(\eta - 1)$. A natural next step is to explore how the price-elasticity and intertemporal effects of deep habits affect quantitatively the dynamics of output and markups within the context of a more realistic model of the macroeconomy.

3 A Fully-Fledged Model With Deep Habits

In this section, we embed deep habits into a fully-fledged dynamic general equilibrium model of the business cycle. The goal is to quantitatively characterize the equilibrium behavior of markups in response to a variety of aggregate demand and supply shocks. We contrast the response of markups in the model with deep habits to that arising either in models featuring no habit formation or in standard habit formation models incorporating dynamic complementarities at the level of aggregate consumption (i.e., superficial habits).

The theoretical framework considered here is richer than the one studied in section 2 in that it features capital accumulation, a more general formulation of deep habits, and three sources of aggregate fluctuations: government purchases, preference, and productivity shocks. In what follows we sketch the structure of the model, leaving a more detailed derivation to a separate appendix (Ravn, Schmitt-Grohé, and Uribe, 2004a).

3.1 Households

Household $j \in [0,1]$ is assumed to have preferences that can be described by the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t U(x_t^j - v_t, h_t^j),$$

where v_t is an exogenous and stochastic preference shock that follows a univariate autoregressive process of the form $v_t = \rho_v v_{t-1} + \epsilon_t^v$, with $\rho_v \in [0,1)$ and ϵ_t^v distributed i.i.d. with mean zero and standard deviation σ_v. This shock is meant to capture innovations to the level of private non-business absorption.

Unlike in the simple model of section 2, we now consider a preference specification in which the stock of external habit depends not only upon consumption in the previous period but also on consumption in all past periods. Formally, the level of habit-adjusted consumption, x_t^j, is now given by

$$x_t^j = \left[\int_0^1 \left(c_{it}^j - \theta s_{it-1}\right)^{1-1/\eta} di\right]^{1/(1-1/\eta)},$$

where s_{it-1} denotes the stock of external habit in consuming good i in period $t-1$, which is assumed to evolve over time according to the following law of motion

$$s_{it} = \rho s_{it-1} + (1-\rho) c_{it}.$$

The parameter $\rho \in [0,1)$ measures the speed of adjustment of the stock of external habit to variations in the cross-sectional average level of consumption of variety i. When ρ takes the value zero, preferences reduce to the simple case studied in section 2.

Households are assumed to own and invest in physical capital. At the beginning of a given period t, household j owns capital in the amount of k_t^j that it can rent out at the rate u_t in period t. The capital stock is assumed to evolve over time according to the following law of motion

$$k_{t+1}^j = (1-\delta) k_t^j + i_t^j,$$

where i_t^j denotes investment by household j in period t. Investment is assumed to be a composite good produced using intermediate goods via the technology

$$i_t^j = \left[\int_0^1 \left(i_{it}^j\right)^{1-1/\eta} di\right]^{1/(1-1/\eta)}.$$

Note that we do not assume any habit in the production of investment goods. However, if we were to reinterpret our deep-habit model as a switching costs model, then one may plausibly argue that in fact, the aggregate investment good should depend not only on the current level of purchases of intermediate investment goods but also on their respective past levels.

3.2 The Government

Each period $t \geq 0$, nominal government spending is given by $P_t g_t$. We assume that real government expenditures, denoted by g_t, are exogenous, stochastic, and follow a univariate first-order autoregressive process of the form $\ln(g_t/\bar{g}) = \rho_g \ln(g_{t-1}/\bar{g}) + \epsilon_t^g$, where the innovation ϵ_t^g distributes i.i.d. with mean zero and standard deviation σ_g. The government allocates spending over intermediate goods g_{it} so as to maximize the quantity of a composite good produced with intermediate goods according to the relationship

$$x_t^g = \left[\int_0^1 (g_{it} - \theta s_{it-1}^g)^{1-1/\eta} di\right]^{1/(1-1/\eta)}.$$

The variable s_{it}^g denotes the stock of habit in good i, and is assumed to evolve over time as

$$s_{it}^g = \rho s_{it-1}^g + (1-\rho) g_{it}.$$

We justify our specification of the aggregator function for government consumption by assuming that private households value government spending in goods in a way that is separable from private consumption and leisure and that households derive habits on consumption of government provided goods. The government's problem consists in choosing g_{it}, $i \in [0,1]$, so as to maximize x_t^g subject to the budget constraint $\int_0^1 P_{it} g_{it} \leq P_t g_t$ and taking as given the initial condition $g_{it} = g_t$ for $t = -1$ and all i. In solving this maximization problem, the government takes as given the effect of current public consumption on the level of next period's composite good—i.e., habits in government consumption are external. Conceivably, government habits could be treated as internal to the government even if they are external to their beneficiaries, namely, households. This alternative, however, is analytically less tractable.

Public spending is assumed to be fully financed by lump-sum taxation.

3.3 Firms

Each good $i \in [0,1]$ is manufactured using labor and capital as inputs via the following production technology:

$$y_{it} = A_t F(k_{it}, h_{it}) - \phi,$$

where y_{it} denotes output of good i, k_{it} and h_{it} denote services of capital and labor, and ϕ denotes fixed costs of production.[1] The variable A_t denotes an aggregate technology shock. We assume that the logarithm of A_t follows a first-order autoregressive process $\ln A_t = \rho_a \ln A_{t-1} + \epsilon_t^a$, where ϵ_t^a is a white noise disturbance with standard deviation σ_a.

The monopolist producing good i faces the following demand function:

$$c_{it} + i_{it} + g_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} (x_t + i_t + x_t^g) + \theta(s_{it-1} + s_{it-1}^g).$$

3.4 Estimation and Calibration

We compute a log-linear approximation to the policy functions in the neighborhood of the non-stochastic steady state of the economy. We calibrate the model to the U.S. economy. The time unit is meant to be one quarter. We estimate the preference parameters defining deep habits using a nonlinear GMM estimator. The approach that we take is to exploit the fact that the deep habit parameters enter both the intertemporal consumption Euler equation—as in superficial habit formation models—and the equilibrium conditions determining the dynamics of the markup, which originate on the supply-side of the economy. This characteristic of the deep habit model is particularly useful because it allows for a more efficient estimation of the habit parameters than standard estimates of habit parameters that are derived solely from the consumption Euler equation.

To facilitate estimation, we assume that utility is separable in consumption and leisure. Specifically, we assume that $U(x,h) = \frac{x^{1-\sigma}-1}{1-\sigma} + \gamma \frac{(1-h)^{1-\chi}-1}{1-\chi}$, where $0 < \sigma \neq 1$, $0 < \chi \neq 1$, and $\gamma > 0$. We use U.S. quarterly data spanning the period 1967:Q1 to 2003:Q1. For a detailed presentation of the econometric estimation see Ravn, Schmitt-Grohé, and Uribe (2004d). Based on our estimation we set $\theta = 0.86$, $\rho = 0.85$, $\eta = 5.3$, and $\sigma = 2$.

Following Prescott (1986), we set the preference parameter γ to ensure that in the deterministic steady state households devote 20 percent of their time to market activities. The calibration restrictions that identify the remaining structural parameters of the model are taken from Rotemberg and Woodford (1992). We follow their calibration strategy to facil-

[1] The presence of fixed costs introduce increasing returns to scale in the production technology. We model fixed costs to ensure that profits are relatively small on average as is the case for the U.S. economy in spite of equilibrium markups of prices over marginal cost significantly above zero.

itate comparison of our model of endogenous markups due to deep habits to their ad-hoc version of the customer-market model. We assume that the production function is of the Cobb-Douglas type, $F(k,h) = k^{\alpha}h^{1-\alpha}; \quad \alpha \in (0,1)$. We set the labor share in GDP to 75 percent, the consumption share to 70 percent, the government consumption share to 12 percent, the annual real interest rate to 4 percent, and the Frisch labor supply elasticity equal to 1.3. These restrictions imply that the capital elasticity of output in production, α, is 0.25, the depreciation rate, δ, is 0.025 per quarter, the subjective discount factor, β, is 0.99, and the preference parameter χ is 3.08.

We show in Ravn, Schmitt-Grohé, and Uribe (2004a) that the steady-state markup of price over marginal cost, μ, is given by

$$\mu = \frac{\eta m}{\eta m - 1},$$

where

$$m \equiv (s_c + s_g)\left[\frac{(1-\beta\rho)(1-\theta)}{\beta\theta(\rho-1)+1-\beta\rho}\right] + s_i \leq 1,$$

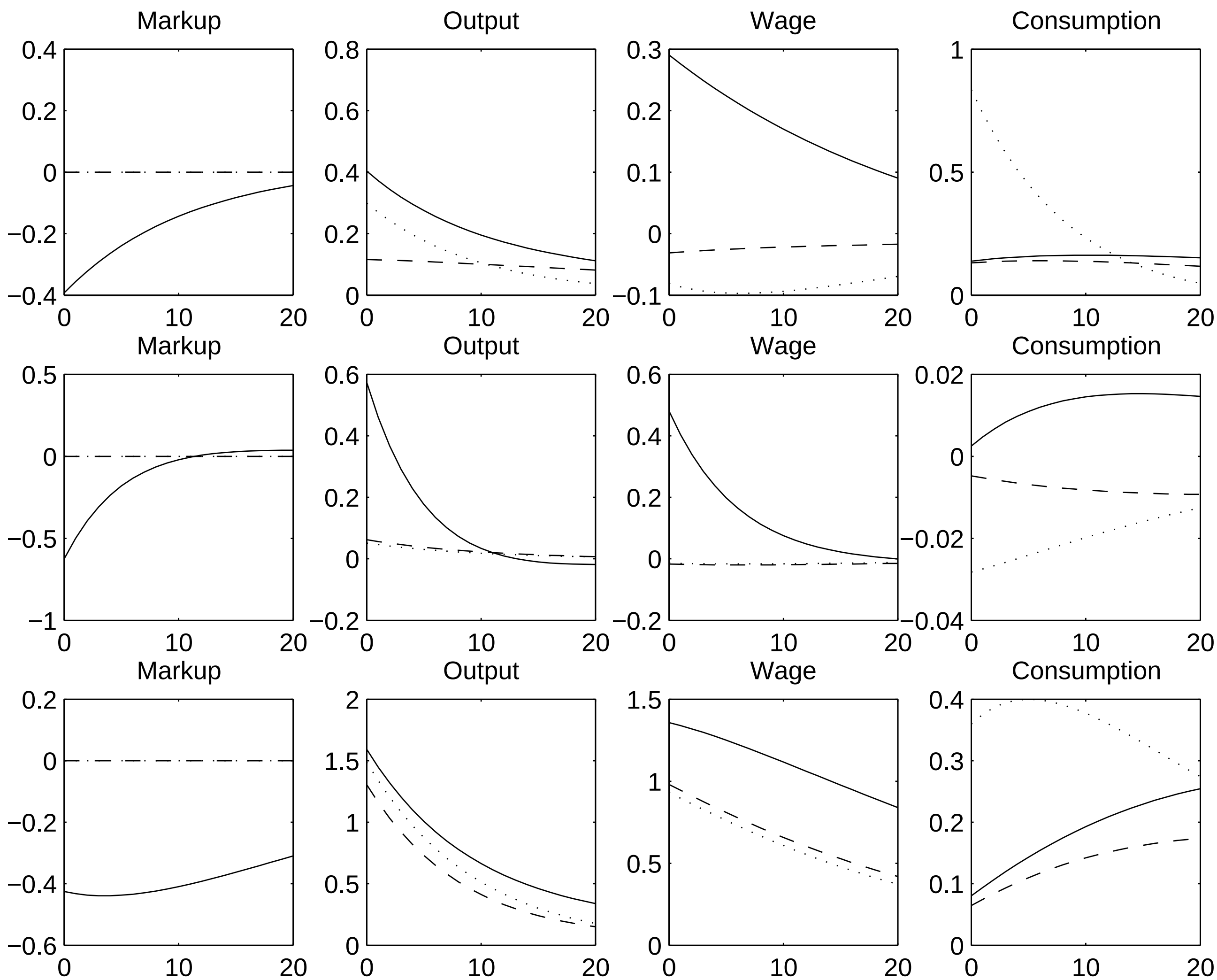
where s_c, s_g, and s_i denote the steady-state shares of consumption, government purchases, and investment in output, respectively. Our calibration implies a somewhat high average markup of 1.32. Note that in the case of perfect competition, that is, when $\eta \to \infty$, the markup converges to unity. In the case of no deep habit, i.e., when $\theta = 0$, we have that m equals one, and the markup equals $\eta/(\eta-1) = 1.23$, which relates the markup to the intratemporal elasticity of substitution across varieties in the usual way. Because under deep habits, the parameter m is less than unity, firms have more market power under deep habits than under superficial habits. This is because in the former formulation firms take advantage of the fact that when agents form habits on a variety-by-variety basis, the short-run price elasticity of demand for each variety is less than η.

We set the serial correlation of all three shocks to 0.9 (i.e., $\rho_v = \rho_g = \rho_a = 0.9$.). Table 1 summarizes the calibration.

3.5 Aggregate Dynamics

We now characterize quantitatively the response of the deep habit model to a variety of exogenous shocks. We consider three sources of aggregate fluctuations: preference shocks, v_t, government spending shocks, g_t, and productivity shocks, A_t. The first row of figure 1 displays impulse responses of the markup, output, wages, and consumption to an increase in the preference shock v_t in the amount of 1 percent of steady-state habit-adjusted consumption. The response of the deep habit model is shown with a solid line. For comparison, the

Figure 1: Impulse Responses Under Deep Habits



——— Deep Habit   _ _ _ Superficial Habit   ..... No habit

Row 1: Preference Shock. Row 2: Government Spending Shock. Row 3: Technology shock. Impulse responses are measured in percent deviations from steady state. Horizontal axes display the number of quarters after the shock.

Table 1: Calibration

Symbol	Value	Description
β	0.9902	Subjective discount factor
σ	2	Inverse of intertemporal elasticity of substitution
θ	0.86	Degree of habit formation
ρ	0.85	Persistence of habit stock
α	0.25	Capital elasticity of output
δ	0.0253	Quarterly depreciation rate
η	5.3	Elasticity of substitution across varieties
ϵ_{hw}	1.3	Frisch elasticity of labor supply
h	0.2	Steady-state fraction of time devoted to work
$\bar{g}$	0.0318	Steady-state level of government purchases
ϕ	0.0853	Fixed cost
ρ_v, ρ_g, ρ_a	0.9	Persistence of exogenous shocks

figure also depicts the response of economies with superficial habit, shown with a dashed line, and no habit, shown with a dotted line.

Under all three model specifications, consumption and output increase as a result of the preference shock. Consumption increases because the shock raises the marginal utility of consumption. At the same time, the shock induces an expansion in labor supply because it reduces the value of leisure in terms of consumption. This explains why output increases in all three cases. The expansion in the supply of labor puts downward pressure on wages. In the economies with superficial habit or no habit, the labor demand schedule is unaffected by the preference shock on impact. In these two economies, the combination of an unchanged labor demand schedule and an increase in the labor supply, causes the equilibrium wage to fall.

By contrast, in the deep habit model the markup falls significantly on impact by about 0.4 percent. This decline in the markup leads to an increase in the demand for labor at any given wage rate. This expansion in labor demand more than compensates the increase in labor supply, resulting in an equilibrium increase in wages of about 0.3 percent. The reason why markups fall in the deep habit model is that in response to the increase in the demand for goods, the habitual, price-inelastic component of demand becomes relatively less important, making demand for each individual variety of goods more price elastic. In turn, the increase in price elasticity leads firms to cut markups. This pricing strategy induces agents to form habits which firms can later on exploit by charging higher markups. Summarizing, the difference between the deep habit model and the models with either superficial or no habit is that under deep habits the markup behaves countercyclically and real wages are procyclical in response to an expansionary preference shock.

Row two of figure 1 shows the response of the three economies under analysis to a 1 percent increase in government consumption. Government spending shocks are similar to preference shocks of the type described above in that they increase aggregate absorption and labor supply. In the case of government spending shocks, the labor supply increases because the expansion in unproductive public spending leaves households poorer. The increase in labor supply introduces downward pressure on wages. In the economies with superficial habits or no habits, the real wage indeed falls in equilibrium. In the economy with deep habits firms reduce markups by about half a percent. The resulting expansion in labor demand is strong enough to offset the income effect on labor supply. As a result, in equilibrium real wages rise. Thus, as in the case of innovations in private spending, government purchases shocks trigger countercyclical markup movements and procyclical wage movements. This finding hinges on our maintained assumption that government consumption is subject to good-specific habit formation.

Of particular interest is the fact that the deep habit model predicts that private consumption rises in response to an increase in government spending. In the model without deep habit formation (with or without superficial habit formation) private consumption spending declines as government spending rises. This decline in consumption is driven by the negative income effect introduced by higher unproductive public spending. Under deep habits, the negative income effect is offset by a strong substitution effect away from leisure and into consumption induced by the increase in wages associated with the fall in markups. The positive response of private consumption to government spending shocks predicted by the deep habit model is in line with the data. For recently, a number of authors have found that autonomous increases in government spending lead to higher private sector consumption, see, for example, Blanchard and Perotti (2002), Fatás and Mihov (2001), and Galí et al. (2003). In particular, Galí et al. (2003) document that for the U.S. economy a 1 percent increase in government spending is followed by a persistent and significant increase in private consumption that peaks at over 0.25 percent after 10 quarters. Although the deep-habit model underpredicts the magnitude of the consumption increase, it is remarkable that it can overturn the prediction of standard neoclassical models of a negative relationship between public and private consumption.

The third row of figure 1 displays the consequences of a 1 percent increase in total factor productivity. Here under deep habits firms also choose to cut markups to gain customer base. As a result, the wage rate increases by more under deep habits than under either superficial habits or no habits.

In the past decade a growing literature has argued that productivity shocks play only a limited role as a source of business-cycle fluctuations. For example, in a recent survey of this literature, Galí and Rabanal (2004) estimate that technology is responsible for about 15 percent of the variations in output and hours at business-cycle frequency. Moreover, these authors conclude that the empirical evidence points to demand factors as the main force behind the positive comovement between output and labor input measures. It follows from the Galí and Rabanal conclusion that a measure of the ability of any model to fit the data is its predictions regarding the comovement between labor and output conditional on demand shocks being the main source of fluctuations. Cooley and Prescott (1995) report a correlation between labor productivity and output of 0.34. Our deep-habit formation model predicts a correlation of 0.33 conditional on government purchases shocks being the sole source of uncertainty and of 0.72 when only preference shocks are present. By contrast the respective predicted correlations under the superficial-habit model are -0.1 and -0.85. This finding suggests that the deep habit model has the potential to offer a better explanation of salient business-cycle regularities than the standard neoclassical framework, with or without superficial habits.

The predicted countercyclical behavior of markups in the deep-habit model stands in stark contrast to ad-hoc versions of switching cost or customer market models such as the one developed in Rotemberg and Woodford (1991, 1995). For a formal quantitative comparison of the deep habit model and the Rotemberg-Woodford (1991, 1995) version of the customer market model, see Ravn, Schmitt-Grohé, and Uribe (2004d). There, we show that under all three shocks considered above, the Rotemberg and Woodford customer-market model predicts that the markup moves in the same direction as output. Also, in response to demand shocks, whether private or public, wages move countercyclically.

To understand why the Rotemberg and Woodford version of the customer-market model produces so different markup behavior than the customer-market model based on deep habit formation, it is important to note that in the deep habit model the demand faced by an individual firm features a positive, price-insensitive term, $\theta(s_{it-1} + s^g_{it-1})$, that depends only on past sales. Due to this term, the price elasticity of demand for an individual variety increases with current aggregate demand, providing an incentive for firms to lower markups. In the Rotemberg-Woodford customer-market model there is no such price-insensitive term. As a result, the elasticity of demand for an individual variety is independent of current aggregate demand conditions. As we discuss later in section 4.2, a version of our deep-habit model in which the single-period utility function depends not on the quasi-difference between current and past consumption of each variety but rather on the quasi-ratio of these two variables, delivers a specification for the demand function faced by an individual firm that is closer to the one adopted ad-hoc by Rotemberg and Woodford.

4 Extensions

Thus far, we have focused on an additive specification of deep habits. We identified two channels through which the presence of deep habits affects markups, factor prices, and aggregate activity: A static price-elasticity effect and an intertemporal effect. In the fully-fledged deep habit model of section 3, the price-elasticity effect of deep habits dominates the equilibrium dynamics of markups in the sense that increases in aggregate demand, regardless of their origin, cause an increase in the price-elasticity of the demand for each variety of goods, thereby inducing a decline in markups. Here, we study two extensions of the deep-habit model that allow us to analyze the price-elasticity and intertemporal effects in isolation. First, we shut down the intertemporal effect by considering a model with good-specific subsistence points. Second, we eliminate the price-elasticity effect while maintaining the intertemporal effect by considering an environment with relative deep habit formation.

An assumption maintained up to this point is that deep habits are external to the individual consumer. The main rational for adopting this modeling strategy is analytical convenience. A natural extension is to consider the case in which households internalize their addictive propensity. We take on this task at the end of this section.

4.1 Good-Specific Subsistence Points

In this extension, we consider a variant of the fully-fledged model of section 3 in which the intertemporal effect of deep habits vanishes whereas the price-elasticity effect remains active. Specifically, we assume here that agents derive utility from the quasi difference between consumption of individual varieties and a good-specific subsistence point. Formally, we replace the aggregator function (1) with

$$x_t^j = \left[\int_0^1 \left(c_{it}^j - c_i^* \right)^{1-1/\eta} di \right]^{1/(1-1/\eta)},$$

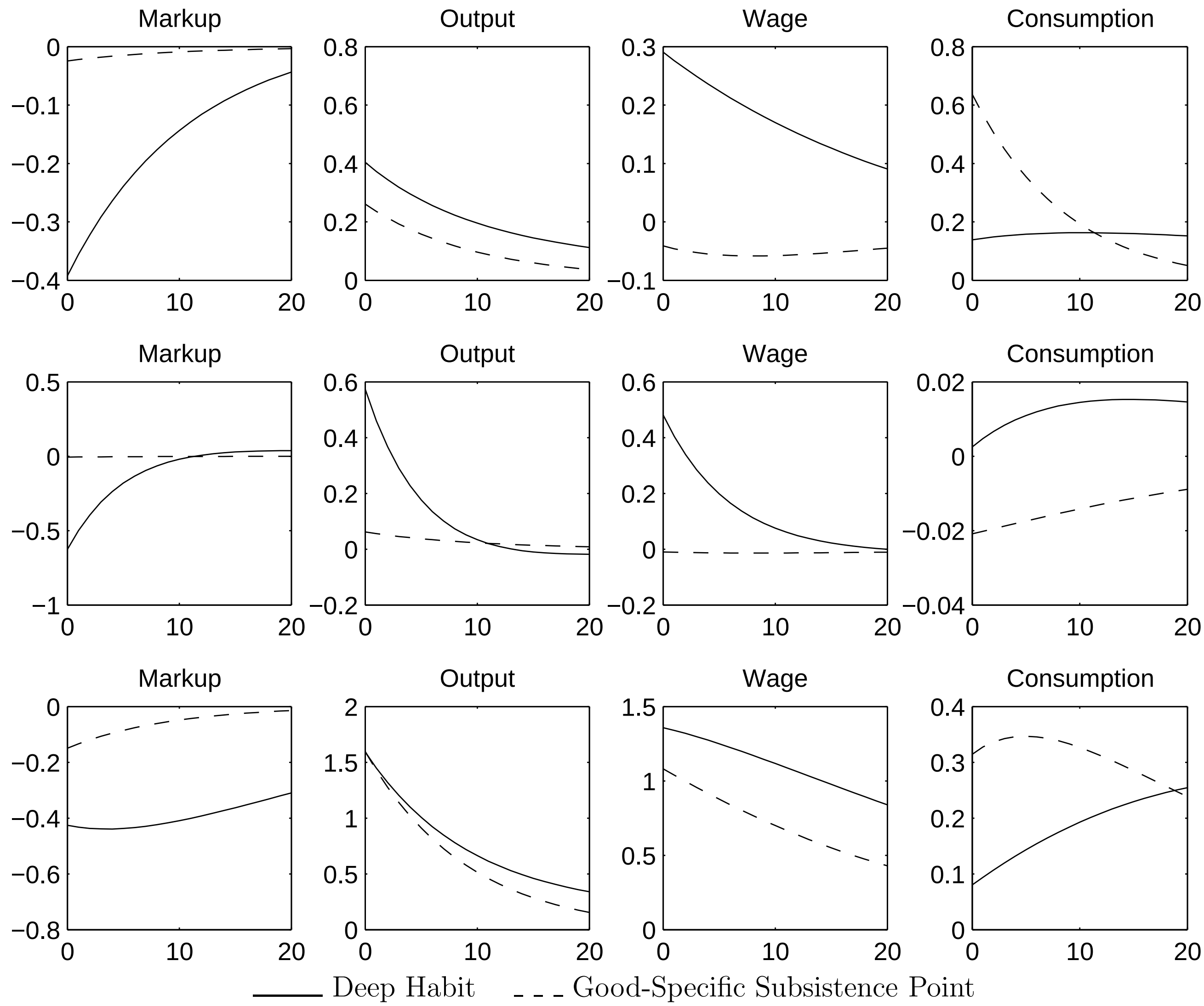
where c_i^* is a constant subsistence level of consumption of variety i. We incorporate good-specific subsistence points for the consumption of public goods as well. This preference specification gives rise to an aggregate demand schedule for each individual variety of the form

$$c_{it} + g_{it} + i_{it} = p_{it}^{-\eta}(x_t + x_t^g + i_t) + c_i^* + g_i^*.$$

For a detailed analysis of this model see Ravn, Schmitt-Grohé, and Uribe (2004c). This demand function shares with the one corresponding to the deep-habit model the presence of a purely price inelastic term, here given by $c_i^* + g_i^*$. As a result, the price elasticity of demand, like in the deep-habit model, is smaller than η and procyclical. This means that the presence of good-specific subsistence points induce a price-elasticity effect that renders the markup countercyclical. A significant difference between the good-specific-subsistence-point and the deep-habit models is that in the former the price-inelastic term of the demand function is exogenous to the firm. Consequently, the pricing problem of the firm is static and the intertemporal effect present in the deep-habit model ceases to exist. The good-specific-subsistence-point model is therefore an ideal environment to study the price elasticity effect in isolation.

Figure 2 displays with broken lines the dynamics of markups, wages, output, and consumption in response to positive preference, government-spending, and productivity shocks in the good-specific-subsistence-point model. For comparison, the figure also reproduces with solid lines the corresponding dynamics of the fully-fledged deep habits model. The calibration of the subsistence-point model mimics that of the fully-fledged additive deep-habit model presented in section 3. We set the subsistence level of aggregate absorption $c^* + g^*$ so that the steady-state markup is 32 percent as in the deep-habit model. The figure shows that, as expected, for all three shocks considered, the markup behaves countercyclically in the good-specific-subsistence-point model. However, in comparison to the deep-habit model, the markup movements are small. Indeed, the decline in markups is insufficient to induce procyclical wage movements in response to demand shocks, a feature of the data that has been used to judge the empirical performance the standard real business cycle model as well as alternative theories of endogenous markups (Rotemberg and Woodford, 1992). Similarly, the good-specific-subsistence-point model fails to deliver a procyclical consumption response following an increase in government spending, an empirical regularity stressed in Galí et al. (2003). One reason why the deep-habit and the subsistence-point models imply quantitatively so different dynamics is the fact that for given values of the steady-state markup and the parameter η, the deep-habit model features a much larger price-inelastic component of demand. As a consequence, the price elasticity effect is stronger in the deep-habit model than in the good-specific-subsistence-point model. The reason why the price inelastic component of demand is small in the good-specific-subsistence-point model is the absence of the intertemporal effect present in the deep-habit model. The deep-habit model has the ability to be consistent both with a relatively large price-inelastic component of demand and a realistic average markup because the intertemporal effect pushes the long-run markup down. In turn, the reason why the intertemporal effect lowers long-run markups is that the marginal revenue schedule that is relevant to the firm includes, in addition to the traditional static marginal revenue schedule, a positive component originating in the fact that an additional sale in the present increases sales in the future by expanding customer base through habits.

Figure 2: Impulse Responses Under Good-Specific-Subsistence-Points



Row 1: Preference Shock. Row 2: Government Spending Shock. Row 3: Technology shock. Impulse responses are measured in percent deviations from steady state. Horizontal axes display the number of quarters after the shock.

4.2 Relative Deep Habits

A key ingredient in generating the price-elasticity effect of deep habits in the fully-fledged model of section 3 is a price inelastic term in the demand for individual varieties. We now wish to shut down the price-elasticity effect in order to shed more light on the intertemporal effect of deep habits. We do so by turning attention to a relative formulation of deep habits. In contrast to additive habits, relative habits give rise to demand functions for individual varieties of goods that do not feature a price inelastic term. As a result, under relative habits the price elasticity of demand is constant. In this case equilibrium movements in markups are driven exclusively by intertemporal effects.

A single feature distinguishes the relative deep habit model from its additive counterpart. Namely, the fact that under relative deep habits the aggregator function depends on the quasi ratio of consumption of each variety to past (or habitual) consumption of that variety, as opposed to depending on the quasi difference between these two variables, as is the case under additive deep habits. Formally, under relative deep habits, each household $j \in [0,1]$, derives utility from an object x_t^j, given by

$$x_t^j = \left[\int_0^1 \left(\frac{c_{it}^j}{c_{it-1}^{\theta}} \right)^{1-1/\eta} di \right]^{1/(1-1/\eta)} .$$

This aggregator function gives rise to an aggregate demand for each variety of goods $i \in [0,1]$ of the form

$$c_{it} = \left(\frac{P_{it}}{\tilde{P}_t} \right)^{-\eta} c_{it-1}^{\theta(1-\eta)} x_t, \tag{20}$$

where $\tilde{P}_t$ is a price index that firms take as exogenously given. We note that in the standard model without deep habits, the parameter η, denoting the intratemporal elasticity of substitution across varieties, must be greater than one in order for the monopolist problem to be well defined. We maintain this assumption here in order to be able to compare the dynamic implications of models with and without deep habits. It follows that if the demand for each particular variety is to be increasing in the stock of habit (c_{it-1} in the simple formulation analyzed here), then the parameter θ must be negative. In the numerical analysis that follows we set θ at -0.1.[2] We show elsewhere (Ravn, Schmitt-Grohé, and Uribe; 2004b) that in the context of the simple economy without capital of section 2, the above demand function

[2] The possibility that positive values of θ give rise to counterintuitive implications for the relation between the stock of habit and the demand for goods also arises in the superficial formulation of relative habits. In effect, in this case, the marginal utility of consumption is decreasing in the stock of habit when θ is positive and the curvature of the period utility function is less pronounced than under logarithmic preferences.

gives rise in equilibrium to a markup of the form

$$\mu_t = \left[1 - \frac{1}{\eta} + \theta E_t r_{t,t+1} \nu_{t+1} (1-\eta) \frac{c_{t+1}}{c_t}\right]^{-1}. \tag{21}$$

This expression is directly comparable with its counterpart in the additive deep habit model, given by equation (19). Under relative deep habits, the price-elasticity effect of deep habits on markups vanishes. This can be seen from the fact that the second term in the bracketed expression, denoting the short-run price elasticity of demand, is constant and equal to $1/\eta$. By contrast, under additive deep habits, the short-run price elasticity is procyclical, which contributes to the countercyclicality of markups. It follows that under deep relative habits the only channel through which deep habits affect markups is the intertemporal effect, embodied in the third term of the bracketed expression. As in the case of additive deep habits, this term represents the discounted value of future demand induced by an additional sale in the current period. This term is different from its additive-habits counterpart in two respects. First, under additive habits, a unit increase in current sales raises next period's sales by θ. Under relative habits, a unit increase in current sales raises next period's sales by $\theta(1-\eta)c_{t+1}/c_t$. As a result, under relative deep habits, an expected increase in the growth rate of aggregate demand induces firms to lower current markups so as to broaden their customer base. The second difference is that under relative deep habits the shadow value of a unit sale in period t, ν_t, is constant and equal to $1/\eta$ (see Ravn, Schmitt-Grohé, and Uribe, 2004b), whereas under additive deep habits it is time varying and countercyclical. A feature common to both the relative- and the additive-habit models is the prediction that equilibrium markups increase with interest rates (i.e., μ_t increases when $r_{t,t+1}$ falls).

In the simple version of the relative deep habit model analyzed here, markups move countercyclically in response to productivity shocks (A_t), but procyclically in response to shocks to private aggregate demand (v_t). (See figure 1 in Ravn, Schmitt-Grohé, and Uribe; 2004b.) The difference in the cyclical behavior of markups under supply and demand shocks is entirely driven by the dynamics of the interest rate. Under both types of shock, aggregate demand increases on impact and then converges monotonically to its steady-state position. This means that c_{t+1}/c_t is below its steady-state level along the entire transition. According to equation (21), this pattern of consumption growth should contribute to elevated markup levels under both types of shock. However, under demand shocks the interest rate increases, reinforcing the rise in markups, whereas under the supply shock the real interest rate falls, offsetting the effect of consumption growth. The reason why the real interest rate rises in response to a positive preference shock is that preference-shock-adjusted consumption, $x_t - v_t$, falls on impact and converges monotonically to its long-run position. In turn, the reason why the real interest rate falls in response to a positive technology shock is that, in the absence of any investment opportunities, agents must be given disincentives to save (or incentives to consume) the initial increase in output. This disincentive takes the form of low real interest rates.

Consider now the effects of relative deep habits in the fully-fledged model with capital accumulation and government purchases presented in section 3. In this model, the aggregate demand for each variety of goods $i \in [0, 1]$ faced by a monopolist is given by:

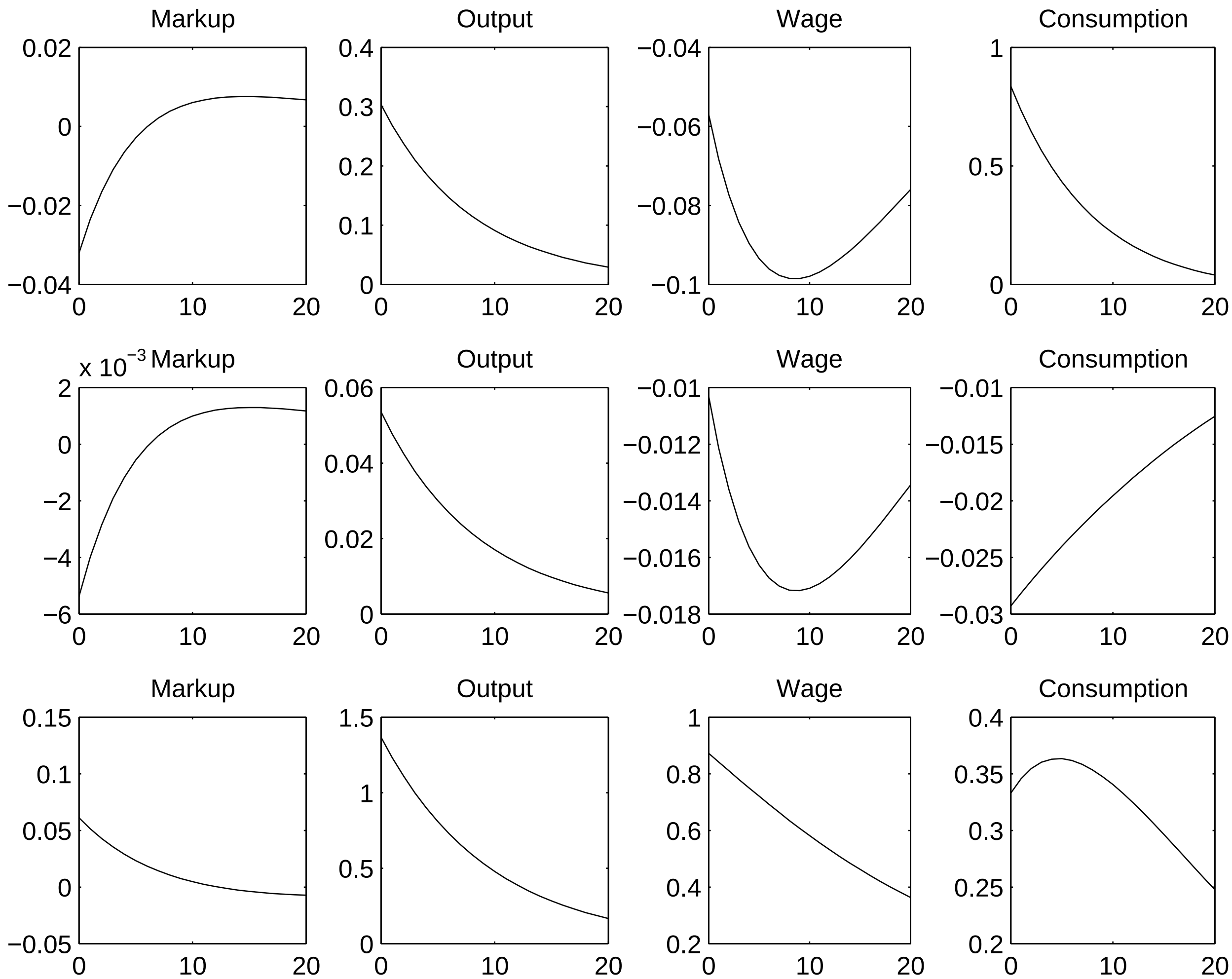
$$c_{it} + g_{it} + i_{it} = \left(\frac{P_{it}}{\tilde{P}_t}\right)^{-\eta} x_t s_{it-1}^{\theta(1-\eta)} + \left(\frac{P_{it}}{\tilde{P}_t^g}\right)^{-\eta} x_t^g [s_{it-1}^g]^{\theta(1-\eta)} + \frac{P_{it}}{P_t}^{-\eta} i_t,$$

where $\tilde{P}_t$, $\tilde{P}_t^g$, and P_t denote price indices of habit-adjusted private consumption, habit-adjusted public consumption, and private investment, respectively, which the firm takes as exogenously given. (For a detailed derivation of the above demand schedule, see Ravn, Schmitt-Grohé, and Uribe, 2004b.) As in the case of the simple model without capital accumulation or government spending analyzed earlier in this section, all terms on the right-hand side of the above demand function are price elastic, with an elasticity equal to η. As a result, the price-elasticity effect of deep habits, stemming from the presence of purely inelastic terms, is also absent in the fully-fledged variant of the relative habit model analyzed here. As a result, the intertemporal effect of deep habits determines the behavior of markups.

There is, however, a key difference between the above demand function and the one belonging to the simpler formulation where the only component of aggregate demand is private consumption, given by equation (20). Namely, in the above demand function not all terms include the stock of habit as a factor. Specifically, the third term does not feature a habitual factor, reflecting the assumption that the demand for individual varieties of goods for investment purposes are not subject to habit formation. This characteristic of the demand functions for individual varieties in the fully-fledged model is of fundamental importance in shaping the dynamic response of markups. Specifically, changes in the *composition of demand* will alter the strength of the intertemporal effect. For instance, a technology shock that affects mostly the demand for private investment, which is not subject to habit formation, will induce a pricing behavior closer to that pertaining to an economy without habit formation, than the pricing decision that are induced by either a preference shock or a government spending shock, which affect primarily the demand for habit-affected components of aggregate demand.

Figure 3 displays the dynamic response of the markup and other macroeconomic variables of interest to positive preference, government spending, and technology shocks. The behavior of markups shown in the figure are dominated by changes in the composition of

Figure 3: Impulse Responses Under Relative Deep Habits



Row 1: Preference Shock. Row 2: Government Spending Shock. Row 3: Technology Shock. Impulse responses are measured in percent deviations from steady state. Horizontal axes display the number of quarters after the shock.

aggregate demand. To understand the effects of changes in the composition of demand on the equilibrium markup, it is of use to determine the steady-state value of the markup in the fully-fledged relative habit model, denoted μ, and in two variants thereof. Namely, the steady-state markup in the absence of deep habits ($\theta = \theta^g = 0$), denoted μ^{NOH}; and the steady-state markup in a model where investment spending is subject to habit formation, that is the steady-state markup in an economy where all components of aggregate demand are subject to habit formation, denoted μ^{ALLH}. It can be shown that $\mu^{ALLH} < \mu < \mu^{NOH}$ (see Ravn, Schmitt-Grohé, and Uribe, 2004b). Now, because both the preference shock and the government spending shock amplify the importance of the habitual demand for goods, firms have an incentive to lower the markup from its steady-state value μ toward μ^{ALLH}, the steady-state markup belonging to an economy where all components of aggregate demand are subject to habit formation. Similarly, in response to a positive productivity shock that enlarges the component of aggregate demand not subject to habit formation, firms will have a tendency to raise the markup from its steady-state value to some level closer to μ^{NOH}, the steady-state markup pertaining to an economy without habits.

4.3 Internal Deep Habits

Thus far, we have restricted attention to the case in which habits for each individual variety are external. This case can be interpreted in two ways. One is that households are catching up with their neighbors on a good by good basis. For instance, if the Joneses buy an expresso machine, their neighbors feel the urge to purchase one as well. Alternatively, external habits can be interpreted as arising from addicted individuals that fail to internalize their dependence. We adopt the external form of habit formation, as opposed to the internal one, for purely analytical reasons. Namely, the assumption of external habit formation on a good by good basis preserves the separation of the problem of choosing total consumption expenditures over time, from that of choosing expenditures on individual varieties of goods at a given point in time. Under deep internal habits, such separation is broken, and the consumer problem becomes more complex. Here, we explicitly consider the case of internal deep habits. In the appendix, we show that under internal deep habits the aggregate demand for good i in the simple production economy without capital of section 2 takes the form

$$c_{it} = \left[\sum_{k=0}^{\infty} \theta^k E_t r_{t,t+k} p_{it+k}\right]^{-\eta} X_t + \theta c_{it-1},$$

where X_t is a measure of aggregate demand.

This demand function shares key characteristics with that arising in the case of external deep habits (equation (7)). Namely, the demand for each good variety is composed of two terms. A habitual term, θc_{it-1}, that is completely price inelastic; and a price elastic term, $\left[\sum_{k=0}^{\infty} \theta^k E_t r_{t,t+k} p_{it+k}\right]^{-\eta} X_t$ that is increasing in some measure of aggregate activity, X_t. All other things equal, if aggregate demand increases (X_t goes up), the relative importance of the price elastic term rises and the elasticity of demand increases. This suggests a procyclical price elasticity as in the case of external deep habits.

However, a fundamental difference between external and internal deep habits is that under internal deep habits current demand for a particular variety depends not only on its current relative price but also on all future expected relative prices. This difference dramatically changes the nature of the firm's problem. In particular, under internal deep habits the firm's problem is no longer time consistent, as in each period the monopolist has the incentive to renege from price promises made in the past that were optimal (profit maximizing) at the time they were made. A full analysis of the optimal pricing behavior under alternative economic environments (e.g., commitment or discretion in its many different forms such as Markov-perfect equilibria, or reputational equilibria) is beyond the scope of this paper and is left for future research.

4.4 Deep Habits and Sticky Prices

Over the past decade focus in macroeconomic research has shifted from the real-business-cycle paradigm to models in which nominal frictions are at center stage, namely to the new Keynesian synthesis. The key elements of the new Keynesian model are sticky product prices and monopoly power at the level of intermediate-goods producing firms.

As in the deep-habit model, in the sticky-price model markups of prices over marginal costs are positive and time varying. However, the markup dynamics implied by these two formulations are quite different. Indeed, Schmitt-Grohé and Uribe (2004) study a calibrated model with sticky prices à la Calvo-Yun and superficial habits, among several other real and nominal rigidities. Figures 1 and 2 of that paper display the response of the economy to productivity and government spending shocks, respectively, under the assumption that monetary policy takes the form of a simple Taylor rule. A number of features of these impulse responses serve as a guide to empirically distinguish between a sticky-price model with superficial habits and a flexible-price model with deep habits. In response to a positive productivity shock the deep habit model predicts a decline in markups, whereas the sticky-price model predicts an increase in markups.[3] Further, in response to a positive government spending shock, consumption and real wages fall in the sticky-price model, whereas in the

[3] For the intuition behind this prediction of the sticky-price model see Schmitt-Grohé and Uribe (2004).

deep habit model both variables increase. Like the deep-habit model, the sticky-price model predicts a decline in markups in response to an increase in public spending. However, the movements in markups implied by the sticky-price model are quantitatively negligible (of the order of 0.01 percent in response to a 1 percent increase in public spending). Doing justice to a comparison of the predictions of the deep-habit and sticky-price models lies outside the scope of the present study.

A natural question that emerges from the above comparison is whether incorporating deep habits into the sticky-price model could improve the behavior of markups implied by this model. In Ravn, Schmitt-Grohé, and Uribe (2004e) we study the case of sticky prices and deep habits. When deep habits are combined with sticky prices, the linearized Phillips curve becomes

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa \hat{mc}_t + \theta \left[\frac{\kappa\beta}{1-\beta\theta} \hat{mc}_t - \kappa \frac{\mu-1}{\mu} \beta [E_t \hat{\nu}_{t+1} + E_t \hat{r}_{t,t+1}] - \kappa \frac{\mu-1}{\mu} \frac{1}{1-\theta} (\hat{y}_t - \hat{y}_{t-1}) \right],$$

where a hat over a variable denotes percent deviations from steady state, κ is a positive constant, and mc_t denotes marginal costs. Marginal costs are just the inverse of the markup, or $\mu_t = 1/mc_t$. All other variables and parameters are as defined earlier in the paper. First, note that in the absence of deep habits, that is, when $\theta = 0$, the Phillips curve is the same as in the standard neo-Keynesian model. We note that for a given inflation path, the markup in the sticky price model with deep habits differs from that in a sticky-price model without deep habit as follows: (1) All else constant, an increase in current output, $\hat{y}_t > 0$, reduces the markup. and (2) All else constant, an increase in the future value of sales, $\hat{\nu}_{t+1} > 0$, or a reduction in the discount rate, $\hat{r}_{t,t+1} > 0$ reduce the markup. When monetary policy takes the form of a simple Taylor rule, then inflation falls in the sticky price model without deep habits in response to a positive technology shock. The above equation shows that as long as the current decline in inflation is larger than the expected future inflation decline marginal costs must fall, which is, markups must rise. However, in the presence of deep habits, it is in principle possible that markups instead fall because output increases and the present value of future sales, $E_t r_{t,t+1} \nu_{t+1}$, may increase. So there is the possibility that adding deep habits to a sticky price model will result in the prediction that markups fall in response to a positive technology shock.

Another noteworthy feature of the Phillips curve in the sticky price model with deep habits is that it features lagged values of output. This is interesting because the inflation dynamics predicted by the model may display more inertia. Standard sticky-price models have been criticized heavily for their inability to predict the observed inertial behavior of inflation.

5 Conclusion

In modern macroeconomics, it is commonplace to assume that households have preferences over a large number of differentiated goods. This assumption is made, for instance, in models with imperfectly competitive product markets. At the same time, there appears to be some consensus that the assumption of habit formation is of great use in accounting for key business-cycle regularities, in particular, consumption and asset-price dynamics. An obvious question that emerges in modeling economies with habit formation and a large variety of goods available for consumption is at what level habits are formed. That is, are habits created at the level of each individual consumption good or at the level of a consumption aggregate. The existing literature has focused exclusively on the latter modeling strategy. This paper is motivated by our reading of the available empirical literature on consumption behavior suggesting that the former alternative is at least equally compelling.

A central finding of our investigation is that the level at which habit formation is assumed to occur is of great macroeconomic consequence. When habits are formed at the level of each individual variety of consumption goods, the demand function faced by a firm depends not only on the relative price of the good and aggregate income—as in the standard case—but also on past sales of the particular good in question. This characteristic of the demand function alters the optimal pricing behavior of the firm. For today's prices are set taking into account that they will affect not just today's sales but also future sales through their effect on future demand. In this way, the assumption of deep habits results in a theory of time-varying markups.

The deep habit model developed in this paper provides microfoundations for other models in which past sales affect current demand conditions at the level of each individual good, such as customer-market and switching-cost models. General equilibrium versions of these models have been criticized for having the counterfactual implication that markups are procyclical. To our knowledge, all existing general equilibrium treatments of customer-market/switching-cost models use ad-hoc specifications of the demand function faced by individual firms. In this paper, we show that once the demand faced by firms is derived from the behavior of optimizing households, the resulting equilibrium comovement between markups and aggregate activity can be in line with the empirical evidence.

Most existing theories of countercyclical markups face a tradeoff between the elasticity of the markup with respect to aggregate demand and the level of the markup. Typically, when the average markup is restricted to empirically realistic levels, available theories predict too low an elasticity of the markup to explain the cyclical behavior of wages and consumption in response to demand shocks. An attractive feature of the additive version of the deep-habit model developed in this paper is that it overcomes this tradeoff. That is, our theory can predict high markup elasticities without requiring empirically unrealistic levels of average markups. This property suggests that the additive specification of deep habits offers the most fertile ground for further investigation.

For analytical convenience, in most of our analysis habit formation is treated as external. In the existing related literature, however, the assumption of internal habit formation is prominent. Moreover, there is vast empirical support for the hypothesis of rational addictive behavior at the level of individual consumption goods. We study the case of internal habit formation in section 4.3. There, we show that the assumption of internal good-specific habit formation renders the pricing behavior of firms time inconsistent. However, because of the scope of this paper, our analysis falls short of fully characterizing equilibrium dynamics under internal deep habit formation. We believe that pursuing this avenue is perhaps the most relevant next step in this research program.

Appendix: Internal Deep Habits

When good-specific habits are assumed to be internal, household j's problem is to maximize the utility function (3) subject to the aggregation technology

$$x_t^j = \left[\int_0^1 \left(c_{it}^j - \theta c_{it-1}^j\right)^{1-1/\eta} di\right]^{1/(1-1/\eta)},$$

the budget constraint

$$\int_0^1 p_{it} c_{it}^j di + E_t r_{t,t+1} d_{t+1}^j = d_t^j + w_t h_t^j + \Phi_t^j,$$

and some borrowing limit to avoid Ponzi schemes. The first-order conditions associated with this problem are

$$U_x(x_t^j, h_t^j)\frac{\partial x_t^j}{\partial c_{it}^j} + \beta E_t U_x(x_{t+1}^j, h_{t+1}^j)\frac{\partial x_{t+1}^j}{\partial c_{it}^j} = \lambda_t^j p_{it},$$

$$-U_h(x_t^j, h_t^j) = \lambda_t^j w_t,$$

and

$$\lambda_t^j r_{t,t+1} = \beta \lambda_{t+1}^j.$$

Noting that $\partial x_{t+1}^j / \partial c_{it}^j = -\theta \partial x_{t+1}^j / \partial c_{it+1}^j$, we can write the first of the above optimality conditions as

$$z_{it}^j = \lambda_t^j p_{it} + \beta\theta E_t z_{it+1}^j,$$

where

$$z_{it}^j = U_x(x_t^j, h_t^j)[x_t^j]^{1/\eta}(c_{it}^j - \theta c_{it-1}^j)^{-1/\eta}.$$

Integrating the first of these expressions forward and under the assumption that z_{it}^j is stationary (which is be the case in the class of equilibria we restrict attention to in this paper), we have

$$z_{it}^j = \sum_{k=0}^{\infty} (\beta\theta)^k E_t \lambda_{t+k}^j p_{it+k}.$$

Combining the last two expressions we obtain

$$c_{it}^j = \left[\sum_{k=0}^{\infty} (\beta\theta)^k E_t \lambda_{t+k}^j p_{it+k}\right]^{-\eta} U_x(x_t^j, h_t^j)^\eta x_t^j + \theta c_{it-1}^j.$$

Recalling that $\lambda_t^j r_{t,t+1} = \beta\lambda_{t+1}^j$, we can write the above expression as

$$c_{it}^j = \left[\sum_{k=0}^{\infty} \theta^k E_t r_{t,t+k} p_{it+k}\right]^{-\eta} \left[\frac{U_x(x_t^j, h_t^j)}{\lambda_t^j}\right]^{\eta} x_t^j + \theta c_{it-1}^j.$$

Integrating across households we obtain the following aggregate demand function for good i in period t

$$c_{it} = \left[\sum_{k=0}^{\infty} \theta^k E_t r_{t,t+k} p_{it+k}\right]^{-\eta} X_t + \theta c_{it-1},$$

where $X_t \equiv \int_0^1 \left[\frac{U_x(x_t^j, h_t^j)}{\lambda_t^j}\right]^{\eta} x_t^j dj$ is a measure of aggregate demand.

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