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Incomplete cost pass-through under deep habits ☆

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ABSTRACT

A number of empirical studies document that marginal cost shocks are not fully passed through to prices at the firm level and that prices are substantially less volatile than costs. We show that in the relative-deep-habits model of Ravn, Schmitt-Grohé, and Uribe [Ravn, M., Schmitt-Grohé, S., Uribe, M., 2006. Deep habits. Review of Economic Studies 73, 195–218], firm-specific marginal cost shocks are not fully passed through to product prices. That is, in response to a firm-specific increase in marginal costs, prices rise, but by less than marginal costs leading to a decline in the firm-specific markup of prices over marginal costs. Pass-through is predicted to be even lower when shocks to marginal costs are anticipated by firms. In our model unanticipated firm-specific cost shocks lead to incomplete pass-through (or a decline in markups) of about 20 percent and anticipated cost shocks are associated with incomplete pass-through of about 50 percent. The model predicts that cost pass-through is increasing in the persistence of marginal cost shocks and U-shaped in the strength of habits. The relative-deep-habits model implies that conditional on marginal cost disturbances, prices are less volatile than marginal costs.

1. Introduction

A number of empirical studies document that marginal cost shocks are not fully passed through to prices at the firm level. The observed sluggish response of prices to cost disturbances is also reflected in prices being substantially less volatile than costs. See, for instance, Goldberg (1995) for the automobile industry, Kadiyali (1997) for the photographic film industry, Hellerstein (2004) for the beer industry, and Nakamura (2006) for the coffee industry.

This paper develops a theoretical explanation for the observed incomplete pass-through of marginal cost disturbances to prices. The central element of our proposed theory is habit formation at the level of individual goods. In particular, we adopt the model of external relative deep habits due to Ravn et al. (2006). When habits are formed on a good-by-good basis, the demand function for an individual good depends not only upon its relative price but also on past consumption of that good. This is because demand depends positively on the stock of habit, and the stock of habit, in turn, is an increasing function of past consumptions.

There is vast empirical support for working with preferences that give rise to a link between current and past demand. Houthakker and Taylor (1970) study goods level demand functions and identify past sales as a central determinant of current consumption of goods at the disaggregated level. In a seminal study of scanner data, Guadagni and Little (1983) document

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a large predictive power of past brand choices on current brand choices (commonly referred to as state dependence) in an application to ground coffee purchases. While econometric methods have developed over time, these findings have been reproduced by many researchers (Chintagunta et al., 2001, discuss some of the econometric issues related to the estimation of such state dependence).[1] Browning and Collado (2007) instead study goods levels consumption demand functions controlling both for unobserved consumer heterogeneity and for goods-level habits. They find that there is a substantial number of goods for which there are habits at the goods-level. Our contribution is to analyze how such features affect firms' incentives to pass on marginal cost shocks into prices.

A consequence of allowing for good-specific habit formation is that the profit maximization problem of the firm becomes dynamic. For higher current sales generate revenue not only in the current period but also in future periods by raising future habitual demand. Firms take this intertemporal connection of revenues into account in their price setting decision. In Ravn et al. (2006) we explore the consequences of preference specifications featuring deep habits for the transmission of aggregate shocks in general equilibrium. The aim of the current paper is instead to examine how idiosyncratic marginal cost shocks affect the pricing policy of individual firms producing differentiated goods, thus linking up more closely with the empirical literature on cost pass-through. This emphasis makes the current paper relevant for interpreting microeconometric studies of the effects of cost changes on markups. The main theoretical gap in the existing empirical literature is the pervasive use of static demand systems (or sometimes non-micro-founded, dynamic systems based on the ad-hoc addition of lags). Our study sheds light on these issues by placing at center stage intertemporal tradeoffs in determining the degree of pass through of shocks affecting the firm's cost structure. We show that neglecting these intertemporal channels might introduce significant biases in the estimated size of pass through. We therefore see the contribution of the current paper as a potential guide for empirical work on pass through.

We demonstrate that in the relative deep-habit model cost pass-through is incomplete. In particular, we show that a temporary increase in marginal costs induces firms to increase prices less than proportionally resulting in lowered markups. Firms find it optimal to narrow profit margins in the current period to limit the decline in future habitual demand triggered by the price increase. It follows that firms pass on only a fraction of the increase in marginal costs they experience. Our emphasis on desired markup adjustments in explaining incomplete cost pass-through is in line with the available empirical evidence. Hellerstein (2004), for instance, finds that 68 percent of incomplete cost pass-through in the beer industry is explained by desired markup adjustments. Nakamura (2006) attributes a smaller but still sizable role to desired markup adjustments in explaining the response of prices to marginal cost shocks in the coffee industry.

Our relative deep-habit model predicts that pass-through increases with the persistence of marginal cost shocks. The reason is that when the cost increase is more persistent, it is less valuable for the firm to maintain the size of its customer base, as production conditions are expected to be unfavorable for a number of periods. A consequence of the positive relationship between pass-through and the persistence of cost shocks is that the ratio of price volatility to marginal-cost volatility also increases with the persistence of cost shocks.

The deep-habit model further predicts that anticipation of marginal cost disturbances exacerbates incomplete pass-through. The reason is that when firms learn about a future cost increase they find it optimal to gradually adjust prices upward as a way to disinvest in customer base. Consequently, the required increase in prices at the time the shock is actually realized is smaller than it would have been had the shock been unanticipated. This finding suggests that structural econometric estimations of incomplete cost pass-through should attempt to distinguish between the pass through of anticipated and unanticipated cost shocks. For failing to do so may result in an overestimation of the incompleteness of pass through.

The deep habits mechanism that we study is related to a number of existing studies that share as the central transmission mechanism a demand function that depends proportionally on a measure of past sales. Phelps and Winter (1970) develop a model of customer markets, by assuming that current demand is proportional to the firm's market share in the previous period. Klemperer (1987, 1995), Froot and Klemperer (1989), and Kleshchelski and Vincent (2007) assume that customers face a fixed cost of switching suppliers. Thus, the current propensity to consume a particular good depends in part on past consumption of that good. Of these papers, the one most closely related to our study is Kleshchelski and Vincent (2007), as it focuses on the effects of firm-specific marginal cost shocks. An important difference between switching cost models and our deep-habit formulation is that in the deep habit model there is gradual substitution between differentiated goods, rather than discrete switches among suppliers. One advantage of this, from the point of view of analytical tractability, is that under the deep-habit formulation one does not face an aggregation problem. Buyers can distribute their purchases identically and still suppliers face a gradual loss of customers if they raise their relative prices.

In their seminal contribution, Froot and Klemperer (1989) conjecture that quite generally any model in which lagged sales increase current demand will imply incomplete pass through of marginal cost shocks. We establish in this paper that in order for this conjecture to hold, it is critical that past sales (or a function thereof) enter the demand function in a multiplicative fashion. In fact, we show that if past sales enter the demand function in an additive rather than multiplicative fashion, the model no longer predicts incomplete pass-through.

[1] A partial list of recent papers that have documented a link between current and past brand choices includes: Roy et al. (1996) for catsup brand choices; Keane (1997) for ketchup brand choices; Goldfarb (2006) for consumer purchases at an Internet portal; Zhang and Krishna (2007) for an on-line retailer; Bell et al. (1999) and Seetharaman et al. (1999) for a wide selection of goods.

Our paper and those discussed in the previous two paragraphs belong to a literature in which incomplete pass through is due to desired movements in markups. Many papers in the international economics literature have opted instead to explain incomplete pass through in the context of models featuring undesired movements in markups due to nominal price rigidities. We therefore examine how the consequences for pass-through of the deep habits mechanism differ from those arising from a sticky price model. We introduce nominal rigidities as in Rotemberg (1982) by assuming that firms face quadratic adjustment costs of changing nominal prices. Costs of changing prices can give rise to low pass-through on impact, but in general induce quite temporary movements in markups. By contrast, the deep habits mechanism gives rise to persistent markup dynamics. We show that the combination of these two features can generate both volatile and persistent markup adjustments even when marginal cost changes are quite persistent.

The deep-habits model coupled with nominal rigidities gives rise to both desired and undesired movements in the markup. Bergin and Feenstra (2001) study an alternative model featuring desired and undesired markup variations. The source of undesired markup movements that they consider is, as in the present study, the presence of sluggish price adjustment. However, the source of desired markup movements that they consider is based on the assumption of a translog demand structure that gives rise to a price elasticity of demand that varies with the level of expenditure. An important difference between the deep-habits and the translog-preference model is that in the latter, desired time variations in markups are static in nature, depending only on the level of current demand, whereas in the former such variations in markups are inherently dynamic, depending on past, current, and expected future levels of demand. Our focus on good-specific habit formation is motivated by the extensive empirical evidence that finds that past levels of demand are important determinants of the current level of demand.

The remainder of the paper is organized in six sections. Section 2 presents a preference specification in which habits are good-specific, external to the household, and relative. It also derives the demand functions for individual goods. Section 3 characterizes the dynamic pricing problem of the firm. Section 4 presents the key predictions of the relative deep-habits model regarding pass through, namely, the incomplete pass-through of marginal cost shocks, the excess volatility of marginal costs relative to prices, the incompleteness of pass through due to anticipation, and the effect of persistence of cost shocks on pass through. Section 5 establishes that when habits enter additively in the demand for individual goods, incomplete pass-through fails to obtain. Section 6 compares the predictions of the deep habits model with those of a sticky price model. Section 7 concludes.

2. Demand with good-specific 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 consumption goods, c_{it}^j indexed by $i \in [0,1]$. Following Ravn et al. (2006), preferences feature habit formation at the level of individual goods, or deep habits. We assume that habits are of the relative external type. That is, for each good variety i, households derive utility from a quasi-ratio of current consumption to a measure of lagged aggregate consumption. Specifically, household j derives utility from an object x_t^j defined by

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

where s_{it-1} denotes the stock of external habit in good i in period $t-1$, which the household takes as exogenously given. The parameter $\eta > 1$ denotes the intratemporal elasticity of substitution of habit-adjusted consumption of different varieties. The parameter θ measures the degree of time nonseparability in consumption of each variety. When $\theta = 0$, we have the benchmark case of time separable preferences.

The stock of habit is assumed to evolve according to the following law of motion

$$s_{it} = \rho s_{it-1} + (1-\rho) c_{it}, \tag{2}$$

where

$$c_{it} \equiv \int_0^1 c_{it}^j \, dj$$

denotes the aggregate per capita level of consumption of variety i, which the household takes as exogenously given. 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, the stock of habit is simply given by past consumption of good i.

For any given level of x_t^j, purchases of each variety $i \in [0,1]$ in period t must solve the problem of minimizing total expenditure,

$$\int_0^1 P_{it} c_{it}^j \, di,$$

subject to the aggregation constraint (1), where P_{it} denotes the price of good i. The optimal level of c_{it}^j for $i \in [0,1]$ is then given by

$$c_{it}^j = \left(\frac{P_{it}}{P_t}\right)^{-\eta} s_{it-1}^{\theta(1-\eta)} x_t^j, \tag{3}$$

where

$$P_t \equiv \left[\int_0^1 \left(P_{it} s_{it-1}^{\theta}\right)^{1-\eta} di\right]^{\frac{1}{1-\eta}}$$

is a price index such that at the cost-minimizing consumption allocation

$$P_t x_t^j = \int_0^1 P_{it} c_{it}^j \, di.$$

The case of habit formation emerges when, ceteris paribus, the demand for a particular variety is increasing in the stock of habit associated with that variety. That is, when $\theta(1-\eta) > 0$. In the absence of deep habits, η 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 our model with and without deep habits. It follows that habit formation obtains only if θ is negative.

An alternative way to visualize that habit formation requires $\theta(1-\eta) > 0$ is to examine the household's optimality condition according to which the marginal rate of substitution of good i for good k is equated to their relative price. For the preferences given in Eq. (1) this optimality condition takes the form

$$\left(\frac{c_{it}^j}{c_{kt}^j}\right)^{-\frac{1}{\eta}} \left(\frac{s_{it-1}}{s_{kt-1}}\right)^{\frac{\theta(1-\eta)}{\eta}} = \frac{P_{it}}{P_{kt}}.$$

Clearly, for the marginal rate of substitution of good i for good k to be increasing in the stock of habit of good i, it is necessary that $\theta(1-\eta)$ be positive. Accordingly, for the remainder of this paper we will assume that $\theta \leqslant 0$.

Integrating the individual demand functions for good i over all households, one obtains the following aggregate demand function for good i:

$$c_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} s_{it-1}^{\theta(1-\eta)} x_t, \tag{4}$$

where $x_t \equiv \int_0^1 x_t^j \, dj$ is a measure of aggregate demand.

3. Pricing to habits

We assume that each variety of goods is produced by a monopolistically competitive firm. The producer of good i faces the demand function given in Eq. (4). Firms take the aggregate price index P_t and the measure of aggregate demand x_t as exogenously given. At the same time, firms internalize the fact that current sales affect the strength of future demand through the habit stock s_{it}.

Because we are interested only in firm dynamics taking as given the aggregate state of the economy, given by P_t and x_t, we simplify the demand function to:

$$c_{it} = A P_{it}^{-\eta} s_{it-1}^{\theta(1-\eta)}, \tag{5}$$

where A is a positive constant.

The marginal cost of producing good i, denoted by MC_{it}, is assumed to be exogenous and independent of scale. Then period profits of firm i can be written as:

$$(P_{it} - MC_{it}) c_{it}.$$

An important implication of the presence of deep habits is that the pricing problem at the firm level becomes dynamic. Firms are assumed to discount future profits at the constant rate $\beta \in (0, 1)$.[2] The firm's problem consists in choosing processes for prices P_{it} and quantities c_{it} to maximize the present discounted value of profits, given by

$$\sum_{t=0}^{\infty} \beta^t E_0 (P_{it} - MC_{it}) c_{it},$$

subject to the law of motion for the stock of habit and the demand function for good i, given in Eqs. (2) and (5), respectively, and taking as given the exogenous process for MC_{it} and the initial stock of habit $s_{i_{-1}}$.

To gain insight into the nature of the firm's incentives, we now concentrate on the simple case that the stock of habits fully depreciates after one period. That is, we focus on the case $\rho = 0$ in Eq. (2), which implies that $s_{it-1} = c_{it-1}$. The first-order conditions associated with the firm's problem then are the demand function

$$c_{it} = A P_{it}^{-\eta} c_{it-1}^{\theta(1-\eta)} \tag{6}$$

and

$$P_{it}\left(1 - \frac{1}{\eta}\right) + \beta\theta \frac{1-\eta}{\eta} E_t P_{it+1} \frac{c_{it+1}}{c_{it}} = MC_{it}. \tag{7}$$

Optimality condition (7) can be interpreted as follows. The first term on the left side, $P_{it}(1 - 1/\eta)$, is the classical expression for marginal revenue in the static monopoly problem. In the absence of deep habits (i.e., when $\theta = 0$), this standard measure of marginal revenue is equated to the marginal cost, MC_{it}, appearing on the right side. The second term on the left side, $\beta\theta \frac{1-\eta}{\eta} E_t P_{it+1} \frac{c_{it+1}}{c_{it}}$, can be interpreted as the future marginal revenue stemming from a sale today. This extra marginal revenue is habitual in nature. It emerges because higher current sales increase the stock of habits with which consumers enter the market in the next period, thereby raising future demand. Specifically, the second term on the left side represents the present value of profits in period $t + 1$ generated by a unit increase in c_{it} holding constant c_{it+j} for all $j \geqslant 1$, and P_{it+j} for all $j \geqslant 2$, and increasing P_{it+1} so as to keep c_{it+1} invariant. Because under this calculus of variation argument future expected sales are held constant, future marginal costs do not enter in the optimality condition.

It follows from Eq. (7) that the markup of prices over marginal cost, which we denote by

$$\mu_{it} \equiv \frac{P_{it}}{MC_{it}},$$

is time varying. That is, the presence of relative deep habits gives rise to a theory of endogenous markup determination at the firm level. Rearranging optimality condition (7), yields the following expression for the markup:

$$\mu_{it} = \frac{\eta}{\eta - 1} \frac{1}{1 - \beta\theta E_t \frac{P_{it+1} c_{it+1}}{P_{it} c_{it}}}.$$

According to this expression, firms set markups below average whenever sales revenues are expected to grow. The sensitivity of the markup to expected future revenue growth is higher the higher the degree of habit formation—i.e., the larger is θ in absolute value—and the more patient firms are—i.e., the larger is the discount factor β. It is worth noting that in this model the markup is time varying in spite of the fact that the short-run price elasticity of demand is constant over time and equal to η. This feature of the model represents a key difference with models of time varying markups due to a translog preference specification.

3.1. Steady-state markup

Under deep habits the steady-state markup is no longer governed by a single parameter, namely the price elasticity of demand η, but depends on the degree of habit formation θ as well as on the discount factor β. Specifically, the steady-state markup is given by

$$\mu = \frac{1}{1 - \beta\theta} \frac{\eta}{\eta - 1} < \frac{\eta}{\eta - 1}. \tag{8}$$

The inequality highlights the fact that under deep habits the steady-state markup is smaller than in the standard static monopolistic case, in which the markup equals $\eta/(\eta - 1)$. The reason the markup is lower is that under deep habits the long-run price elasticity of demand, given by $\frac{\eta}{1-\theta(1-\eta)}$, is larger than the short-run, or static, price elasticity η.[3] This is

[2] In Ravn et al. (2006), which undertakes a general equilibrium approach, the discount factor of the firm is an endogenous variable given by the representative household's intertemporal marginal rate of substitution.

[3] The parameter restrictions imposed thus far do not rule out the possibility that $\frac{\eta}{1-\theta(1-\eta)} < 0$, that is, the possibility that demand is increasing in the price in the long run. As it will become clear shortly, however, this possibility is ruled out by the requirements of nonnegativity of the steady-state markup and of uniqueness of firm's dynamics.

because under deep habits a price increase leads to demand losses not only in the current period but also in the future, as the weakening in habitual demand entails a loss in customer base. For sufficiently large absolute values of θ, the steady-state markup becomes less than unity, implying long-run pricing below marginal cost. We rule out this possibility and require that μ be larger than one. This restriction imposes the following constraint on the habit elasticity of demand, $\theta(1-\eta)$:

$$\theta(1-\eta) < \frac{1}{\beta}, \tag{9}$$

which we maintain throughout our analysis.

3.2. Stability of firm dynamics

In this section we derive the set of values of the parameter θ, measuring the strength of good-specific habits, for which pricing dynamics are locally unique. Combining optimality conditions (6) and (7) one obtains a second-order stochastic difference equation in c_{it} driven by the exogenous forcing process MC_{it}. The variable c_{it-1} is a predetermined state in period t.

We limit the characterization of price and sales dynamics to stationary stochastic fluctuations that are expected to remain forever in a vicinity of and converge to the deterministic steady state. Letting $\hat{x}_t \equiv \ln(x_t/x)$ denote the log deviation of the variable x_t from its deterministic steady-state value x, the evolution of the quantity sold can be written up to a first-order approximation as:

$$\begin{bmatrix} E_t\hat{c}_{it+1} \\ \hat{c}_{it} \end{bmatrix} = A \begin{bmatrix} \hat{c}_{it} \\ \hat{c}_{it-1} \end{bmatrix} + B\widehat{MC}_{it}.$$

Local uniqueness of the firm's pricing dynamics requires that the matrix A have one root inside the unit circle and one root outside the unit circle. One can show that if the steady-state markup is greater than one (i.e., if restriction (9) holds), then local uniqueness of firm dynamics obtains if and only if

$$\theta(1-\eta) < 1. \tag{10}$$

The left side of this condition represents the elasticity of current demand with respect to the stock of habit (see Eq. (4)). Thus, the restriction says that an increase in current demand must raise future demand less than proportionally, holding future prices constant. The stability condition (10) further implies that the long-run demand function is decreasing in the good's own price.

4. Incomplete pass-through

Pass-through of marginal cost shocks is said to be incomplete if a one-percent increase in marginal cost leads to a less-than-one-percent increase in prices. Equivalently, pass-through is incomplete when markups decline in response to an increase in marginal costs. To ascertain whether in our pricing-to-habit model pass-through is incomplete, we characterize the impulse response of prices and markups to innovations in marginal costs.

We assume that the logarithm of marginal costs follows a univariate autoregressive process of order one. Formally,

$$\widehat{MC}_{it} = \lambda\widehat{MC}_{it-1} + \epsilon_{it}, \tag{11}$$

where $\lambda \in [0,1)$ denotes the serial correlation of marginal costs and ϵ_{it} is an i.i.d. shock with mean zero and standard deviation σ_ϵ.

Given this autoregressive specification of the marginal costs process, the equilibrium dynamics of consumption and prices that follow from a first-order approximation can be shown to be given as:

$$\widehat{c}_{it} = a_1\widehat{c}_{it-1} + \frac{1-\beta\theta}{\theta}\frac{\eta}{\eta-1}\frac{a_1}{1-\lambda\beta a_1}\widehat{MC}_{it}, \tag{12}$$

$$\widehat{p}_{it} = \left(\frac{\theta(1-\eta)-a_1}{\eta}\right)\widehat{c}_{it-1} - \frac{1-\beta\theta}{\theta}\frac{1}{\eta-1}\frac{a_1}{1-\lambda\beta a_1}\widehat{MC}_{it}, \tag{13}$$

where

$$a_1 \equiv \frac{1}{2}\left[\theta + \frac{\eta}{\eta-1}\frac{\beta\theta-1/\eta}{\beta\theta} - \sqrt{\left(\theta + \frac{\eta}{\eta-1}\frac{\beta\theta-1/\eta}{\beta\theta}\right)^2 - \frac{4}{\beta}}\,\right] \in [0;1). \tag{14}$$

Noting that $\lim_{\theta\to 0} a_1 = 0$ and that $\lim_{\theta\to 0}(a_1/\theta) = 1-\eta$, it follows that in the absence of goods-level habits (i.e., as $\theta \to 0$), the elasticity of prices to marginal costs equals unity ($\lim_{\theta\to 0}\hat{p}_{it} = \widehat{MC}_{it}$). Thus, in the absence of good-specific habits there is complete pass-through of marginal costs into prices. Moreover, in the environment without deep habits, the model becomes static, as the elasticities of both prices and sales with respect to past sales vanish.

Table 1
Response to a temporary increase in marginal cost.

Period	Marginal cost	Pricing to habits ($\theta = -0.1$)		No habits ($\theta = 0$)	
		Price	Markup	Price	Markup
0	1	0.81	−0.19	1	0
1	0	−0.11	−0.11	0	0
2	0	−0.04	−0.04	0	0
3	0	−0.01	−0.01	0	0

Note: Marginal costs, prices, and markups are measured in percent deviations from their respective steady-state values.

In the presence of goods-level habits, $\theta < 0$, we have that $a_1 > 0$, and therefore current sales become an increasing function of past sales. More importantly, the elasticity of prices to marginal cost shocks ceases to be unity. That is, the model implies endogenous markup movements in response to marginal cost shocks. Specifically, the response of the markup, $\hat{p}_{it} - \widehat{MC}_{it}$, to a marginal cost shock is given by $-\frac{1-\beta\theta}{\theta}\frac{1}{\eta-1}\frac{a_1}{1-\lambda\beta a_1} - 1$. One can think of this response being affected by the persistence of consumption, given by the parameter a_1, and the firm's incentive to vary markups in the face of such persistent movements in its demand. Incomplete marginal costs pass-through occurs when $-\frac{1-\beta\theta}{\theta}\frac{1}{\eta-1}\frac{a_1}{1-\lambda\beta a_1} < 1$. It follows immediately that the pass-through elasticity is increasing in the persistence of the shocks to marginal costs. Thus, the less persistent are the marginal costs shocks, the more likely it is that firms will not pass costs fully into prices. This effect is not induced through the persistence of consumption but through producers' incentive to vary markups in response to marginal cost shocks. As we will explain below, when marginal costs are very persistent, producers have little reason to lower the current markup in order to retain market share.

In general, the degree of marginal-cost pass-through into prices depends on parameter values. For this reason, we proceed to calibrate the model. We use a quarter as the time unit. To highlight the role of pricing to habits in propagating the effect of marginal cost disturbances, we initially restrict attention to a purely temporary increase in MC_{it} by setting the parameter λ equal to zero. We set the firm's discount factor β equal to 0.99, so that the rate at which profits are discounted is 4 percent per year. This is a standard value in business-cycle studies. We set the short-run price elasticity of demand, η, equal to 6, which is a value well within the range found in models with varieties à la Dixit Stiglitz. This value is conservative, i.e., it does not imply too much market power. For instance, Nakamura (2006) reports a median price elasticity of 3.46 for the coffee industry. Nevo (2001) finds a median price elasticity of 2.9 for breakfast cereals, and Villas-Boas (2007) finds price elasticities between 3 and 4 for yogurt. We set the deep-habit parameter θ to -0.1. This value together with the one assigned to η implies that the elasticity of demand with respect to the stock of habit is 1/2 and that the steady-state markup is 9 percent. This markup value is in line with available empirical estimates of value-added markups (see, for instance, Basu and Fernald, 1997). In reality, the short run price elasticity and the habit parameter are likely to differ across goods. Certain types of non-branded goods may not be associated with very strong goods specific habits while very branded goods are better modeled by large values of θ. For that reason, we explore the impact of θ and η on the results in Section 4.4 below.

Table 1 displays the response of prices and marginal costs to a purely temporary one-percent increase in marginal costs. In the period of impact, the firm increases prices but proportionally less than the increase in the marginal cost. Only 81 percent of the increase in marginal costs are passed through to product prices. As a result, the markup of prices over marginal costs declines by 19 percent. The resulting incomplete pass-through is the consequence of an intertemporal tradeoff: Increasing current prices prevents the erosion of current profit margins. At the same time, it leads to a decline in current sales and hence a corresponding reduction in the stock of habits, which weakens the strength of future demand. One period after the shock, marginal costs are back to their steady-state value. However, markups are not. Firms need to rebuild their customers' stock of habit, which had declined after the initial price hike. To this end, firms keep markups below average along the entire transition. This transition can be interpreted as a pure investment in customer base. The cost of this investment is a sequence of below-average per unit profits.

The firm's dynamics in the absence of habits is quite different. As shown in the last two columns of Table 1, prices move one for one with marginal costs and markups are unaffected by the cost disturbance. Without a habit stock to maintain, the firm faces no intertemporal tradeoff, but simply a static, isoelastic demand function. Thus, in the absence of habits markups are constant at all times and dictated by the price elasticity of demand η.

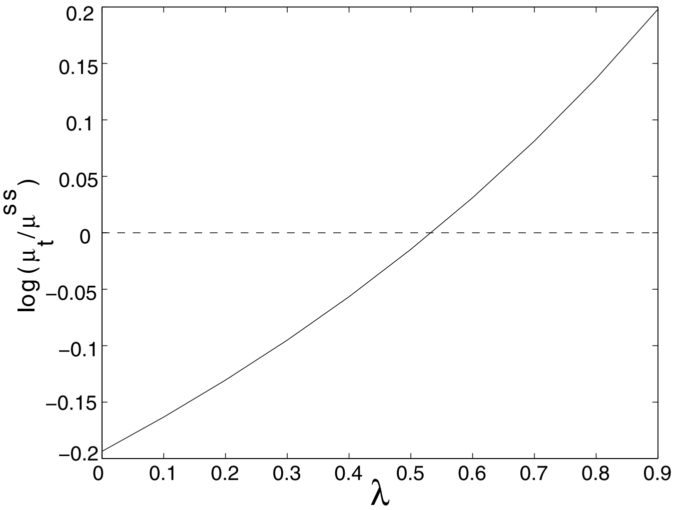
4.1. Anticipated cost shocks

Pass-through can appear to be even more incomplete when marginal cost disturbances are anticipated. This is because firms find it optimal to increase prices already at the time they learn about the arrival of a future cost shock. By the time the shock is actually realized, demand is already weakened by a smaller habit stock, mitigating the incentive to contain sales further via higher prices. Table 2 displays the response of prices and markups to an anticipated temporary one-percent increase in marginal costs. In the case of the anticipated cost increase, agents learn in period −1 that in period 0 marginal cost will be 1 percent above average. The table also reproduces from Table 1 the responses of prices and marginal costs when the cost shock is unanticipated. In this case, agents are surprised in period 0 with a 1 percent increase in marginal

Table 2
Response to an anticipated temporary increase in marginal cost.

Period	Marginal cost	Anticipated		Unanticipated	
		Price	Markup	Price	Markup
−1	0	0.29	0.29	0	0
0	1	0.77	−0.23	0.81	−0.19
1	0	−0.12	−0.12	−0.11	−0.11
2	0	−0.05	−0.05	−0.04	−0.04
3	0	−0.02	−0.02	−0.01	−0.01

Note: Marginal costs, prices, and markups are measured in percent deviations from their respective steady-state values.



Note: The vertical axis measures the percent deviation of the markup from steady state in the period of impact of a one-percent increase in marginal cost. The horizontal axis measures the degree of persistence of marginal costs.

Fig. 1. Pass-through and persistence of cost shocks.

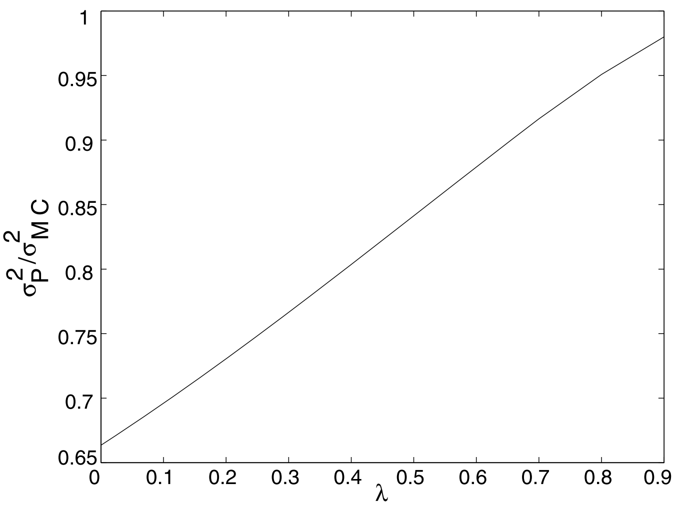
cost. In period 0, prices increase by 0.48 percent in the case in which the shock is anticipated. By contrast, when the shock is unanticipated, the increase in prices in period 0 is 0.81 percent. It follows that in this example when the cost increase is anticipated pass-through falls significantly. We note that in the absence of good-specific habit formation, pass-through is perfect, regardless of whether the cost shock is anticipated or unanticipated.

This finding has potentially significant implications for measuring pass through. In effect, existing econometric studies of incomplete pass-through do not distinguish between anticipated and surprise innovations in marginal costs. The finding of this section suggests that anticipated cost shocks when wrongly identified as surprise cost shocks, lead to overestimating the degree of incompleteness of pass-through. To the extent that a significant fraction of actual cost shocks are indeed anticipated, our finding suggests that actual measures of incomplete cost pass-through may indeed be upwardly biased.

Distinguishing between anticipated and unanticipated cost shocks in econometric studies is important for discriminating between static and dynamic models of pass through. In a static setting anticipation has no effect on the strength of pass through. It follows that if observed pass through of anticipated shocks turns out to be different from observed pass through of surprise shocks, then one would conclude that a dynamic model of pricing is empirically more compelling.

4.2. Persistent cost shocks

Thus far, we have limited attention to the case of purely temporary cost shocks. We now explore the relationship between pass-through and the degree of persistence in the marginal cost process. In the AR(1) specification given in Eq. (11), persistence is governed by the parameter λ. Fig. 1 displays the impact effect of a one-percent increase in marginal costs on the markup as a function of λ. As we pointed out above, pass-through is increasing in the persistence of the shock: the more persistent the shock is, the larger is the initial price increase in response to a one-percent increase in marginal costs. Intuitively, if marginal cost shocks are temporary, firms are reluctant to pass the cost increase on to prices to avoid erosion of their customer base, as they expect costs to go back down quickly to their normal level. On the other hand, if the cost shock is persistent, firms do not mind losing customers because cost conditions are expected not to be favorable for many periods. For this reason, firms choose to pass on a larger fraction of the marginal cost increase to prices. If the cost shock is sufficiently persistent (in our example when λ is greater than 0.5), then firms find it optimal to pass through to prices more than the entire increase in marginal costs, resulting in an increase in markups.



Note: σ_p^2 and σ_{mc}^2 denote, respectively, the variances of prices and marginal costs. The parameter λ measures the persistence of the marginal-cost shock.

Fig. 2. The price–cost volatility ratio.

4.3. The price–cost volatility ratio

Empirical studies have documented that marginal costs tend to be more volatile than product prices. Nakamura (2006), for instance, studies pass through of changes in coffee commodity costs to coffee retail and wholesale prices. She finds that over the past decade commodity coffee prices have exhibited much higher volatility than retail and wholesale coffee prices.

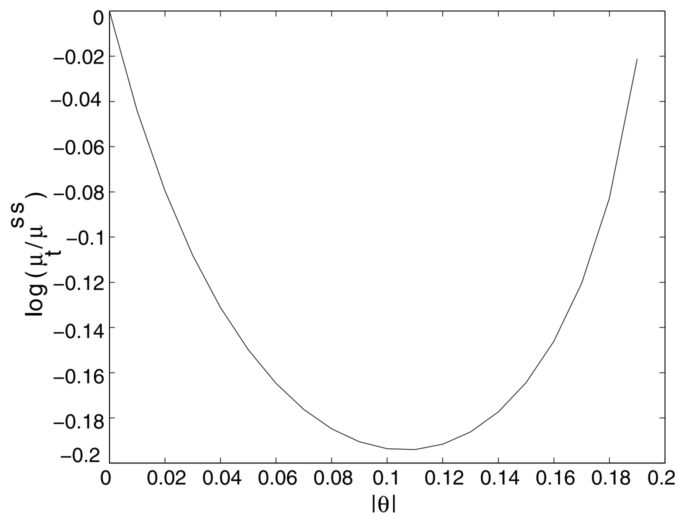
The fact that under good-specific habit formation pass-through of marginal costs to prices is incomplete, suggests that prices might be less volatile than marginal costs at the firm level. This is indeed the case. Fig. 2 displays the ratio of the variance of prices, denoted σ_p^2, to the variance of marginal costs, denoted σ_{mc}^2, as a function of the serial correlation of marginal costs, λ. When the cost shock is purely temporary, the price–cost volatility ratio is 0.66, implying that prices are about 30 percent less volatile than marginal cost. The price–cost volatility ratio increases with the persistence of the shock, but remains below unity for all values of λ in $[0, 1)$. It is remarkable that prices are less volatile than marginal costs for values of λ above 0.5, because for this range of values firms pass-through more than one hundred percent of marginal cost innovations on impact (see Fig. 1). The reason why prices continue to be less volatile than marginal costs when marginal costs are highly persistent is that although markups increase on impact when the firm is hit with an unexpected increase in marginal cost, prices converge to their long-run value faster than marginal costs resulting in the latter being above the former along most of the transition. The reason for the faster convergence of prices is the firm's desire to rebuild the stock of habits by charging below-average markups shortly after a shock realization.

4.4. Pass-through, the strength of habits and markups

The results so far have focused on the parameter configuration $\theta = -0.1$ and $\eta = 6$. These parameter values imply that the habit elasticity of demand (the exponent of s_{it-1} in the demand function (6)) is 0.5, that the short-run price elasticity (the exponent of P_{it} in the demand function (6)) is 6, that the long-run price elasticity (given by $\eta/(1 - \theta(1 - \eta))$) is 12, and the steady-state markup is 9 percent. These parameters are likely to be good specific. Existing econometric studies of good-specific demand functions suggest that there is a range of relevant values for the short-run price elasticity (η) and for the effect of past purchases on current demand ($\theta(1 - \eta)$). Therefore, we now examine the sensitivity of predicted pass through to variations in these parameters.

We look at the following three experiments. In the first experiment we examine the impact of the strength of habits, θ, holding constant the short-run price elasticity, η. The second experiment varies instead the short-run price elasticity, η, holding constant the habit parameter θ. Both of these experiments give rise to changes in the implied value of the steady-state markup. Therefore, we also look at a third experiment in which, as we vary η, we appropriately adjust θ to keep the implied steady-state markup constant.

In order to understand the results of this sensitivity analysis, it is useful first to inspect the mechanism through which changes in parameters affect the incentives of firms to vary markups in response to changes in marginal costs. There are two basic reasons why firms do not keep the markup constant. First, demand is dynamic and firms may wish to invest in future demand for their good by charging a low markup. When marginal cost shocks are not persistent, this effect is determined by the habit elasticity $\theta(1 - \eta)$ which captures the extent to which current sales is reflected in future demand. When this elasticity equals zero (which occurs either when $\theta = 0$ or when $\eta \to 1$ and θ is held fixed), firms have no reason not to pass cost changes directly on to consumers and there is complete pass-through. Increases in the habit elasticity give firms a greater incentive to invest in future demand and they become less reluctant to lower the markup when marginal



Note: The vertical axis measures the percent deviation of the markup from steady state in the period of impact of a one-percent temporary increase in marginal cost. The horizontal axis measures the degree of habit persistence.

Fig. 3. Pass-through and the strength of habits.

costs rise. For that reason, the larger is the habit elasticity, the more likely it is that pass-through will be incomplete. We refer to this transmission channel as the habit-elasticity effect.

Secondly, in the steady-state equilibrium, the long-run price elasticity (given by $\eta/(1-\theta(1-\eta))$) exceeds the short-run price elasticity η. This gives rise to a subtle price-elasticity effect due to the induced incentive on the part of the firm to increase prices when marginal costs rise in order to exploit the (relatively) low short-run price elasticity. Higher values of $|\theta|$ and η make the demand function relatively more elastic in the long run than in the short run and therefore produce incentives to charge larger markups in the short-run when marginal costs increase. Together these two opposing effects imply that the impact on pass-through of changes in θ and η will be non-monotonic depending on the relative strengths of the habit- and the price-elasticity effects.

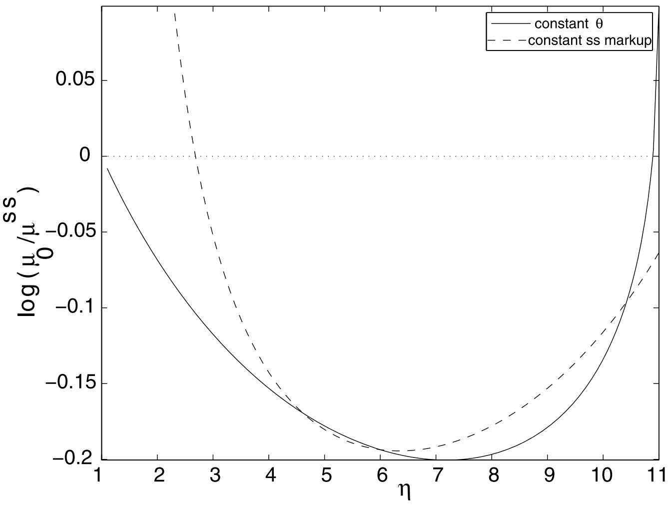
Fig. 3 displays the impact effect on the markup of a purely temporary increase in marginal cost as a function of the parameter governing the strength of habits, $|\theta|$. In this experiment we hold η constant and equal to the benchmark value of 6. Habits are stronger the larger is θ in absolute value. The largest possible value of $|\theta|$ for which the firm's dynamics are locally unique and the long-run markup is positive is $1/(\eta-1)$, which under our benchmark calibration imposes an upper bound of 0.2 on $|\theta|$. The range $[0, 0.2)$ of feasible values of $|\theta|$ may seem narrow but implies that the habit elasticity of demand ranges from 0 to 1.

As explained above, for $|\theta| = 0$, pass-through is complete. In this case, the markup of prices over marginal cost is unchanged by the innovation in marginal cost, implying that prices increase proportionally with marginal costs. The figure also shows that for all positive admissible values of $|\theta|$, the markup falls in response to an increase in marginal costs. That is, under deep habits cost pass-through is incomplete for the entire admissible range of $|\theta|$.

Notably, there is a non-monotonic relationship between the extent of incomplete pass-through and the degree of habit formation. When habit formation is weak (i.e., at low absolute values of θ) pass-though becomes more incomplete as $|\theta|$ increases. The reason is that, for this range of values of θ, the habit-elasticity effect dominates. At a value of $|\theta|$ of about 0.1 incomplete pass-through reaches a maximum. When habits are strong (i.e., for values of $|\theta| > 0.1$) pass-through becomes less incomplete as $|\theta|$ increases because the price-elasticity effect becomes relatively more important.

Fig. 4 reports with a solid line the impact effect on the markup of a temporary one-percent increase in marginal cost as a function of the short-run price elasticity η, holding constant all other structural parameters (in particular, θ is fixed at -0.1). The parameter η takes values in the range $(1, 11)$ to be consistent with local uniqueness of price dynamics and a positive steady-state markup. This range of values for η and the assumed fixed value of θ imply that the habit elasticity of demand takes on values between 0 and 1. The results of this exercise are analogous to those that we derived for the experiment involving variations in $|\theta|$. When $\eta \to 1$, the habit elasticity goes to zero and this implies a constant markup and complete cost pass-through. For moderate values of the short-run price elasticity, the habit elasticity effect dominates and therefore pass-through is more incomplete the higher is η. Incomplete pass-through reaches its maximum for η close to 7. When η rises beyond this value, pass-through rises quite sharply and there is complete pass-through when η is arbitrarily close to its upper limit. This result arises again because of the induced price elasticity effect that gives firms an incentive to exploit the relatively low short-run price elasticity.

Both of the sensitivity experiments discussed thus far in this subsection involve changes in the markup as we adjust θ or η. In the latter of these experiments, the steady-state markup varies from about 900 percent to close to 0 percent as η increases from 1 to 11. For this reason, in Fig. 4 we present with a broken line the case in which as η varies the



Note: The vertical axis measures the percent deviation of the markup from steady state in the period of impact of a one-percent temporary increase in marginal cost. The horizontal axis measures the short-run price elasticity of demand.

Fig. 4. Pass-through and the short-run price elasticity.

parameter θ is appropriately adjusted to keep the steady-state markup constant at its baseline value of 9 percent.[4] The pattern that emerges is similar regardless of whether the steady-state markup or θ are held constant as η varies. The most notable difference is that at small values of the short-run price elasticity there is more than complete pass through when the steady-state markup is held constant. We attribute this result to the price elasticity effect: When the markup is held constant, the long-run price elasticity is virtually insensitive to η, whereas the short-run elasticity moves one for one with this parameter. Hence, at low values of η, the short-run price elasticity is low relative to the long-run elasticity providing an incentive for firms to temporarily increase markups in response to temporary positive cost innovations. Note that incomplete pass through obtains for values of the short-run price elasticity η larger than 2.6. In light of the fact that in most econometric estimates of demand functions for differentiated goods the short-run price elasticity is found to be above this threshold, we conclude that incomplete pass through is a robust prediction of the deep-habit model.

4.5. Perverse pass-through

Froot and Klemperer (1989) use the term ‘perverse pass-through’ to refer to a situation in which the firm cuts prices in response to an increase in marginal costs. In the context of our model, perverse pass-through is a pathological case in the sense that it occurs only under parameterizations for which the steady-state markup is negative. Formally, one can establish the following result: If $\eta > 1/\beta$ and $\mu > 1$, then perverse pass-through cannot be supported as a stationary solution to the firm's profit maximization problem.[5] The condition $\eta > 1/\beta$ is quite weak. For example, in the calibration exercise of this section, it is satisfied whenever the markup is below nine thousand percent, an astronomically large number. It follows from this result that firms will always increase prices in response to an upward innovation in marginal costs.

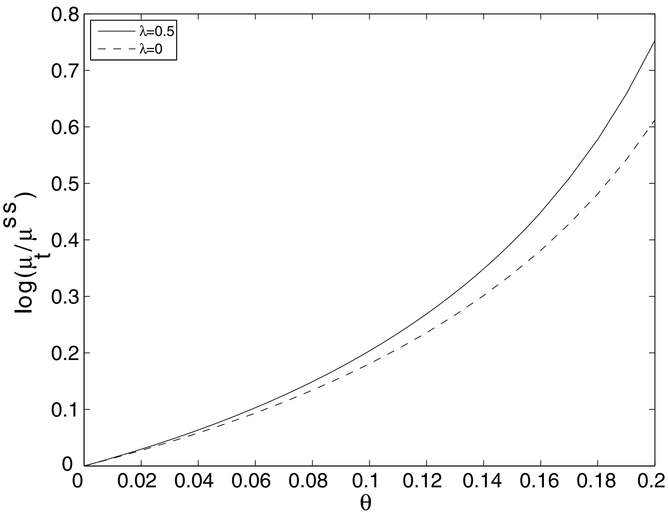
5. Additive habits

It is of interest to ascertain whether the incomplete pass-through prediction of the model analyzed thus far depends on the particular way in which past sales affect current demand conditions. Froot and Klemperer (1989), for instance, state that quite generally any model in which past sales increase current demand will generate the prediction of incomplete pass through. In their words, “we need not impose a specific demand function or reason why market share matters. The effects that we isolate in this way are therefore very general and transcend the particularities of simple models that can be solved explicitly” (p. 640).

We examine the sensitivity of our incomplete pass-through result to an alternative specification of the demand function. This alternative specification originates in a different assumption about the way habits affect period utility than the one maintained in Section 2. Specifically, following Ravn et al. (2006), we assume that habits are of the additive external type.

4 Specifically, the restriction imposed on θ is $\theta = \beta^{-1} - \frac{\eta}{(\eta-1)\mu\beta}$.

5 The proof of this claim is available from the authors on request.



Note: The vertical axis measures the percent deviation of the markup from steady state in the period of impact of a one-percent increase in marginal cost. The horizontal axis measures the degree of habit persistence.

Fig. 5. Lack of incomplete pass-through under additive habits.

That is, for each good variety i, households derive utility from a quasi-difference of current consumption to a measure of lagged aggregate consumption. Household j derives utility from an object x_t^j defined by

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

where $\theta \in [0, 1)$ defines the degree of habit persistence. The optimal level of c_{it}^j for $i \in [0, 1]$ is then given by

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

where $P_t \equiv [\int_0^1 (P_{it})^{1-\eta} di]^{\frac{1}{1-\eta}}$ is a price index. This individual demand function for good i gives rise to the following aggregate demand for good i:

$$c_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} x_t + \theta s_{it-1}. \tag{15}$$

The firm's optimization problem is identical to the one studied in Section 3. Fig. 5 displays with a solid line the impact effect on the markup of a one-percent increase in the marginal cost. The broken line displays the case of a persistent marginal-cost shock ($\lambda = 0.5$). The firm's dynamics are stable for values of θ between 0 and 0.25. Contrary to what happens under relative habits, under additive habits, regardless of whether the shock is persistent or transitory, firms pass through on to prices more than the full increase in marginal cost. As a result, the markup increases in response to the innovation in marginal cost.

The intuition for why pass-through is predicted to be more than complete under additive habits can be developed by inspecting the demand function given in Eq. (15). The aggregate demand for good i is the sum of a price elastic term, $(\frac{P_{it}}{P_t})^{-\eta} x_t$, with elasticity η, and a price inelastic term, θs_{it-1}. The price inelastic term stems from the additive structure of habit formation. The price elasticity of demand is a weighted average of η and 0, with the weight on η determined by the share of the price-elastic component of demand. Naturally, in response to the increase in marginal cost, the firm increases the price. To understand whether the price increase should be proportionally larger or smaller than the cost increase, notice that any increase in price reduces the relative size of the price elastic term in total demand. As a consequence, the price elasticity falls. Because the markup is inversely related to the price elasticity, the increase in marginal cost is associated with an increase in the desired markup.

The intertemporal effect of deep habits stressed in the relative-habit formulation of Section 4 is still present in the additive-habit model. That is, firms have an incentive not to pass the full increase in costs on to price, to avoid losing customer base in the future, due to the erosion in habits. This intertemporal effect is reflected in the fact in Fig. 5 the broken line, associated with a temporary marginal cost shock, lies below the solid line, associated with a persistent marginal cost shock. However, this intertemporal effect is dominated by the price-elasticity effect described in the previous paragraph, causing prices to rise by more than marginal costs.

These results beg one to ask which of the two habit formulations that might be more appropriate? One crucial difference between the two habit formulations is that the additive habit specification implies a demand function that has a price inelastic term while this is not the case for the relative habit formulation. The presence of this inelastic term under the additive habit formulation gives producers an incentive to set very high prices unless households can simply drop this good from their basket due to the existence of close substitutes. On the other hand, the additive habit formulation captures the effect that the short run elasticity of demand may depend on shocks to aggregate demand, an effect that is stressed by e.g. Bergin and Feenstra (2001). For that reason, the relative habit formulation may be more relevant in environments with relative few producers while the additive habit formulation may better capture the impact of habits in aggregate models that typically rely on modeling the market as consisting of many producers.

6. A comparison with sticky prices

A standard interpretation of imperfect cost pass-through is that nominal rigidities prevent firms from optimally adjusting their prices in response to changes in the costs of production. Our analysis has shown that a flexible price model with deep habits can generate imperfect cost pass-through. We now examine how these two models differ in their predictions for pass-through of cost shocks. Moreover, we will also ask whether these two mechanisms of generating movements in markups have interesting implications when combined in a single model.

We introduce nominal rigidities by assuming that firms are subject to quadratic costs of changing prices as in Rotemberg (1982). In that environment, nominal rigidities are justified on the basis of reputational effects, which are central to Rotemberg's assumption of convex price adjustment costs: “The reputation of firms is presumably more affected by large price changes, which are very noticeable, than by small price changes. Therefore, the costs of price adjustments are assumed to be quadratic in the percentage change of prices” (Rotemberg, 1982, p. 1190).

One significant difference between the sticky-price and the deep-habit formulations is that in the former all markup variations are undesired, whereas in the latter all markup variations are desired, or optimal. Secondly, in the deep habits model, the incentive to suppress price changes stems not only from the fact that price changes lead to changes in current demand but also from the fact that price changes affect future demand. Thus, dynamics are essential to our theory. The reputational effects referred to by Rotemberg (1982) are instead static in nature in the sense that they rely upon disproportionally larger effects on current demand from large price changes. Thus, we believe that the mechanisms that lead to markup dynamics in these two models differ and are complementary rather than competing.

When there are quadratic costs of changing prices, the firm's objective function is given by

$$\sum_{t=0}^{\infty} \beta^t E_0 (P_{it} - MC_{it}) c_{it} - \frac{\xi}{2} (P_{it} - P_{it-1})^2,$$

where $\xi \geqslant 0$ parameterizes the extent of nominal rigidities. When $\xi = 0$, prices are fully flexible, while $\xi \to \infty$ leads to constant prices. The firm chooses processes for P_{it} and c_{it} to maximize the expected present discounted value of profits subject to the demand equation (6), which we reproduce here for convenience:

$$c_{it} = A P_{it}^{-\eta} c_{it-1}^{\theta(1-\eta)}.$$

The first-order conditions for the firm's problem are this demand function and the following two equations:

$$(P_{it} - MC_{it}) = \lambda_{it} - \beta\theta(1-\eta) E_t \frac{c_{it+1}}{c_{it}} \lambda_{it+1}, \tag{16}$$

$$\eta \lambda_{it} \frac{c_{it}}{P_{it}} = c_{it} - \xi (P_{it} - P_{it-1}) + \xi \beta E_t (P_{it+1} - P_{it}), \tag{17}$$

where λ_{it} is the multiplier on the demand function for the firm's product (Eq. (6)). These two conditions reduce to Eq. (7) when prices are flexible. When prices are sticky (i.e., when $\xi > 0$), firms smooth price changes over time in order to economize on adjustment costs.

We log-linearize Eqs. (6), (16), and (17) around the deterministic steady state and solve the resulting set of linear stochastic difference equations. It is instructive first to examine the case without deep habits ($\theta = 0$). In this case, assuming that marginal costs are given by the autoregressive specification in Eq. (11), the solutions for prices and consumption are given by

$$\widehat{c}_{it} = b_1 \widehat{c}_{it-1} - \eta \frac{\eta - 1}{\xi} \frac{b_1}{1 - \beta b_1 \lambda} \widehat{MC}_{it}, \tag{18}$$

$$\widehat{p}_{it} = b_1 \widehat{p}_{it-1} + \frac{\eta - 1}{\xi} \frac{b_1}{1 - \beta b_1 \lambda} \widehat{MC}_{it}, \tag{19}$$

$$b_1 = \frac{1}{2} \left(\frac{1}{\xi\beta} \big((1+\beta)\xi + \eta - 1 \big) - \sqrt{ \left(\frac{1}{\xi\beta} \big((1+\beta)\xi + \eta - 1 \big) \right)^2 - \frac{4}{\beta} } \right). \tag{20}$$

From Eq. (19), it is clear that the sticky price model gives rise to imperfect pass-through whenever prices are sticky (i.e., whenever $\xi > 0$). As in the deep habits model, the pass-through elasticity, $\frac{\eta-1}{\xi} \frac{b_1}{1-\beta b_1 \lambda}$, is increasing in the persistence

Table 3
Deep habits vs. sticky prices.

	No persistence ($\lambda = 0.0$)					Persistence ($\lambda = 0.5$)				
Period	Marginal costs	Deep habits		Sticky prices		Marginal costs	Deep habits		Sticky prices	
		Price	Markup	Price	Markup		Price	Markup	Price	Markup
0	1	0.81	−0.19	0.81	−0.19	1	0.99	−0.01	0.85	−0.15
1	0	−0.11	−0.11	0.08	0.08	0.5	0.36	−0.14	0.51	0.01
2	0	−0.04	−0.04	0.01	0.01	0.25	0.13	−0.12	0.26	0.01
3	0	−0.01	−0.01	0.00	0.00	0.125	0.05	−0.08	0.13	0.01

Table 4
Deep habits combined with sticky prices.

	No persistence ($\lambda = 0.0$)			Persistence ($\lambda = 0.5$)		
Period	Marginal costs	Price	Markup	Marginal costs	Price	Markup
0	1	0.67	−0.33	1	0.86	−0.14
1	0	−0.03	−0.03	0.5	0.40	−0.10
2	0	−0.04	−0.04	0.25	0.15	−0.10
3	0	−0.02	−0.02	0.125	0.05	−0.08

of the marginal cost shock. The intuition for this property, however, is quite different from the deep habits model. In the sticky price model, firms trade-off the adjustment costs that arise from changing prices with the foregone profits that derive from setting prices that differ from their optimal, flexible price, level. When marginal cost shocks have little persistence, the profit loss from keeping prices unchanged are purely transitory and firms therefore absorb marginal costs shocks through variations in markups. When marginal cost changes are very persistent, it is optimal for firms to adjust prices gradually to the new higher level of the cost of production. Thus, while a firm operating under deep habits is concerned about its customer stock, firms subject to costs of changing prices are concerned with minimizing the costs of changing prices relative to the profits foregone from setting prices that differ from their flexible price level.

A key difference between the deep habits model and the sticky price model is that in the latter, marginal cost pass-through can never be larger than one, $\frac{\eta-1}{\xi}\frac{b_1}{1-\beta b_1 \lambda} \in [0, 1]$ (as long as the steady-state markup is positive). The reason is that in the absence of deep habits, the incentive to change prices depend only on the path of current and future expected marginal costs, and there is no reason for firms to adjust prices more than the current change in marginal costs. Another important difference between the deep habits model and the sticky price model is that in the latter the consumption dynamics affects the price dynamics only when $\theta \neq 0$. For that reason it is difficult to directly compare the solutions for the two models in terms of their implications for price dynamics without looking at the quantitative implications. Table 3 reports the price and markup adjustments of the two models in response to unanticipated marginal costs shocks assuming that these are either purely temporary or have a persistence of 50 percent. We calibrate the sticky price model such that the pass-through elasticity in the period where the marginal cost shock occurs is exactly the same as in the deep habits model assuming that $\lambda = 0$. Using the calibration of η, and β from Section 4, this implies that $\xi = 0.6358$.

Our calibration strategy implies that the impact responses of prices to purely transitory changes in the marginal cost are identical in the two models. However, the transitional dynamics are quite different across models. In the sticky price model, the initial decline in the markup is purely transitory. In fact, after period 0, the markup is above its steady-state value along the entire transition. By contrast, in the deep-habit model the markup remains below its steady-state value throughout the adjustment process. When marginal costs display persistence, on impact there is less pass-through of marginal costs on prices in the sticky price model than in deep habits model. However, from period 1 onwards, the markup is approximately back at its steady state value in the sticky price model while the markup remains below its steady-state level along the transition in the deep habits model. Effectively, unless price adjustment costs are very high, the predictability of future marginal costs allows the firm to set a path of prices such that it can emulate the future marginal costs. In the deep habits model instead, the markup displays persistent deviations from its steady state level in response to changes in marginal costs even when these are persistent. Given the evidence on the persistence of incomplete cost pass-through, this may indicate that the deep habits model that we have proposed may provide a more promising route for explaining persistent variations in markups to changes in marginal costs than sticky price models.

A different question is whether the two mechanisms in combination have interesting implications. In order to examine this, Table 4 repeats the exercise of Table 3 when we allow for both sticky prices and for deep habits. We assume that $\theta = -0.1$ and that $\xi = 0.6358$. In this case, the model implies that not only is there is low pass-through upon impact, but the dynamics of the markup that follows a change in marginal costs are very persistent. In other words, the combination of these two mechanisms inherits the low impact pass-through from the nominal rigidity and the persistence of the incomplete pass through from deep habits. One interesting feature of this exercise is that the price–cost volatility ratio is much lower in this model than in the models that assume either nominal rigidities but no deep habits or deep habits but flexible prices. When $\lambda = 0$, the price–cost volatility ratio is around 0.66 in both the sticky price model and in the deep habits model but only 0.45 in the model that combines these two features; The corresponding numbers when $\lambda = 0.5$ are 0.84 for the deep habits model, 0.81 for the sticky price model, and 0.69 for the combined model.

Thus, we conclude that it might be interesting to introduce customer markets features, in the form of relative deep habits, into models with nominal rigidities, because this allows one to account for persistent imperfect pass-through and for the fact that prices are smoother than marginal costs.

7. Discussion and conclusion

In this paper, we present a model of cost pass-through at the firm level that can explain qualitatively the empirical regularity that firm-specific cost disturbances are passed on to prices incompletely. Our explanation is based on the assumption of external, relative, deep habits in consumption, an assumption that we believe has solid empirical support. When habits are deeply rooted, firms face demand functions that depend not only on the current price but also on the stock of habits, which in turn is a function of all past sales of the good the firm produces. The firm's pricing problem becomes dynamic, and it is no longer optimal to equate current marginal revenue to marginal cost. Instead, firms take into account the future marginal revenues generated by a current sale through its effect on habits.

We show that an unanticipated firm-specific cost shock leads to incomplete pass-through (or a decline in markup) of about 20 percent, and that an anticipated cost shock of equal size is associated with incomplete pass-through of about 50 percent. We also show that pass through increases with the persistence of cost shocks. These results are significant in light of the fact that, due to their ad-hoc nature, most existing empirical models of pass through are ill suited to disentangle the effects of anticipated versus unanticipated or temporary versus persistent firm-level cost shocks. Indeed, our results imply that failing to distinguish between these various types of shock may lead to significant biases in the size of the estimated pass through.

We compare the deep habits model with the predictions of a model in which firms face costs of changing prices. Both models can account for low pass-through on impact when marginal costs change but only the deep habits model is able to account for persistent declines in the markup in response to an increase in marginal costs. In a model that combines deep habits with nominal rigidities, we show that one can account simultaneously for low pass-through on impact, a persistent decline in the markup, and for low volatility of prices relative to marginal costs.

Our theoretical analysis is concerned with the pass-through of firm-specific marginal cost shocks. The predictions of our model could be applied to interpret the vast empirical evidence on incomplete pass-through of nominal exchange-rate changes. The reason why cost pass-through and exchange-rate pass-through may appear to be related can best be illustrated with an example. Consider a German exporter of cars to the United States. Assume that marginal cost of that exporter are in Euro and are unaffected by a change in the Euro–dollar exchange rate. Further assume that the exporter faces no local or distribution costs in the United States. Then one can express period profits of the German exporter in U.S. dollar terms as $(P_{it} - MC_{it}/S_t)q_{it}$, where P_{it} is the dollar price at which the German exporter offers the car for sale in the United States, MC_{it} is the marginal cost denominated in Euro, S_t is the Euro price of one dollar, and q_{it} is the demand for a particular type of German car in the United States. Suppose now that the U.S. dollar depreciates, that is, S_t decreases. Then one could interpret the U.S. dollar depreciation as an increase in marginal cost of the exporter of German cars, and one might consider using our deep habit model to study the effects of a dollar depreciation on the dollar price of the German car in the U.S. market.

In interpreting an exchange rate change as a firm-specific marginal cost shock, the following issues emerge. One of the assumptions we maintain throughout the paper is that all variables that are not firm-specific such as the aggregate price level and the level of aggregate demand are unaffected by the firm-specific marginal cost shock. This assumption may not be compelling if one were to identify a marginal cost shock with an exchange-rate change. For the exchange-rate change may have an effect on the aggregate price level and on aggregate demand, P_t and x_t, respectively, in terms of the notations of the demand function given in Eq. (4). Furthermore, we assume that the discount factor that firms apply to future profits, β, is unaffected by the firm-specific marginal cost change. If the source of the marginal cost change is an exchange-rate change, then this assumption might be incorrect. For example, Froot and Klemperer (1989) in their classic study on exchange rate pass-through attribute part of the observed incomplete exchange-rate pass-through to an interest rate effect, whereby a dollar depreciation leads to an increase in the discount factor, increasing the rate of return on investment in market share. When firms invest more in market share they let their profit margins dip. And lower profit margins are associated with lower markups or incomplete pass-through.

These caveats notwithstanding, it is our belief that, given the encouraging results on limited cost pass-through presented in this paper, it would be worthwhile to test the deep-habit hypothesis using firm-specific price and cost data.

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