Price Setting in Forward-Looking Customer Markets[☆]

Emi Nakamura[a], Jón Steinsson[a,]

[a]*Columbia University, NBER, CEPR*

Abstract

If consumers form habits in individual goods, firms face a time-inconsistency problem. Low prices in the future help attract customers in the present. Firms therefore have an incentive to promise low prices in the future, but price gouge when the future arrives. We show that in this setting, firms benefit from "committing to a sticky price." If consumers have incomplete information about costs and demand, the firm-preferred equilibrium has the firm price at or below a "price cap". Our model therefore provides an explanation for the simultaneous existence of a rigid regular price and frequent sales.

Keywords: Time-inconsistency, Price Rigidity, Habit Formation, Asymmetric Information

JEL Classification: E30

1. Introduction

A consumer's past purchases of a particular product often exert a strong positive influence on his current demand for this product. Such time non-separability of preferences arises for many different reasons. Some goods are addictive while consumers develop a sense of "brand-loyalty" to others. Consumers favor some products that they have used in the past because of compatibility with other equipment while they favor other products because the quality of competing products is unknown to them. And consumers continue using some products simply because of the large transaction costs associated with switching to a competitor (e.g., another bank or another internet service provider). For all these reasons,

it is common for consumers to be partially locked into purchasing a particular product once they have begun purchasing it. Similar lock-in effects are common when firms purchase from suppliers (Shapiro and Varian, 1999).

In this paper, we study the implications that such lock-in effects have for firm price setting. It is well known that consumer lock-in implies that firms face a time-inconsistency problem. This was first shown in models with consumer switching costs (Klemperer, 1995).[1] More recently, Ravn et al. (2006) have shown that the same is true when consumers form good-specific habits. The fact that consumers are partially locked-in—by switching costs and habits—implies that consumer demand is forward-looking; consumer demand depends negatively not only on the current price of the product but also on the consumer's expectations about the good's future prices. This implies that firms would like to promise that they will keep their prices low in the future. However, when the future arrives, the firms have an incentive to renege on their earlier promises and price gouge locked-in consumers. The consumers understand these incentives and don't take the firms' promises at face value unless the firms are able to make credible commitments.

We adopt the good-specific habit model of Ravn et al. (2006) and use it to explore how the firm's time-inconsistency problem gives rise to various forms of price rigidity.[2] If firms are not able to make credible commitments, the time-inconsistency problem leads them to set prices that are sub-optimally high both from a profit perspective and from the perspective of overall welfare. When firms and consumers interact repeatedly, they can improve on this discretionary outcome by entering into "implicit contracts". To formalize this idea, we study sustainable plans of the infinitely repeated game played by a firm and its consumers (Chari and Kehoe, 1990). We show that implicit contracts involving price rigidity can be sustained as equilibria in the good-specific habit model.

In standard models without consumer lock-in, price rigidity is simply a constraint on

---

[1]In an important early contribution, Diamond (1971) provides a particularly dramatic example where even an infinitesimally small switching cost yields monopoly pricing unless firms are able to make credible commitments about future prices.

[2]The primary focus of Ravn et al. (2006) is on a model with good-specific external habits—'keeping up the Jonses' at the good level—in which no time-inconsistency problem arises. However, in section 4.3 of their paper, they discuss a model with good-specific internal habits in which the time-inconsistency problem discussed above arises. We adopt this good-specific internal habit model.

firms' ability to set the price they would like to set. In these models, implicit contracts involving price rigidity yield lower profits than the discretionary outcome and thus cannot be sustained as equilibria. However, in models with consumer lock-in, implicit contracts involving price rigidity serve as a partial commitment device and therefore helps firms overcome their time-inconsistency problem. To see this, consider an implicit contract in which firms promise to change their price only every other period. Such a contract leads firms to set a lower price and earn higher profits than in the discretionary equilibrium since their incentive to price gouge already locked-in consumers is tempered by a desire not to negatively affect next period's demand. Firms are induced not to deviate from the terms of such implicit contracts by the threat that a deviation would trigger an adverse shift in customer beliefs about future prices.

Many components of a typical firm's marginal costs and demand are either unobservable or very costly for a consumer to observe. In the standard no-habit model, this is irrelevant since consumer demand is determined solely by the firm's current price. However, in the habit model, asymmetric information limits the variables that it is possible, even in principle, for the firm and customers to make use of in implicit contracts. We use the results of Athey et al. (2004) to show that the most desirable sustainable price path from the firm's perspective under this kind of asymmetric information takes the form of an implicit contract that limits the firms discretion by setting a "price cap" above which the firm cannot set its price. Under this policy, the firm acts with discretion when its marginal costs and demand are relatively low; but sets its price equal to the price cap when marginal costs and demand are high. The price cap has the beneficial effect that it lowers the customers' expectations about future prices and thereby increases demand. Given plausible assumptions about the process followed by the firm's desired price and the extent of informational asymmetries, the firm's price will be "stuck" at the price cap a significant fraction of the time. It will, however, frequently drop below the price cap and exhibit much more flexibility when it is not at the price cap.

Our asymmetric information model implies that the price cap should be a function of observable variables. It should therefore trend upward with the aggregate price level, since the aggregate price level is observable. And even if observing the price level on a regular

3

basis is too costly to be worthwhile for consumers, the price cap should trend upward because of expected movements in the price level. Empirically, nominal price rigidity is pervasive (e.g., Nakamura and Steinsson, 2008). From the viewpoint of our model, this implies that the equilibrium in most markets is not the one that is strictly most preferred by firms.

One possible explanation for this is that firms may find it easier to convincingly communicate a fixed price cap rather than a trending price cap. In other words, fixed nominal prices may be a focal point in the efforts of firms and consumers to avoid the discretionary outcome. Hall (2005) has recently emphasized how a similar equilibrium selection issue is fundamental to labor market models with wage bargaining.[3] This issue of equilibrium selection—coordination of firms and consumers on an equilibrium that is superior to a discretionary outcome—does not arise at all in price setting models without consumer lock-in. In price setting models without consumer lock-in, there is a unique equilibrium and nominal rigidities only arise as a consequence of real frictions such as menu costs.[4]

The asymmetric information version of our model implies that: 1) Goods prices should spend a significant portion of their time at a rigid upper bound; 2) Below this upper bound, they should be much more flexible. The model therefore endogenously generates both rigid "regular" prices and frequent "sales". The salience of rigid regular prices and frequent sales is well documented (Hosken and Reiffen, 2004; Pesendorfer, 2002). We add to this evidence by showing that sales prices are about 8 times more flexible than regular prices. There are numerous models of sales in the industrial organization literature. However, these models do not in general provide an explanation for the simultaneous existence of a rigid regular price and frequent sales.

---

[3]Hall's results follow from the fact that once workers and firms have been matched (which is costly) they face a bilateral bargaining problem regarding the wage with a wide set of candidate wage outcomes that are acceptable to both parties in that they improve on their outside options. For this reason, the wage is indeterminate in such a model. Hall (2005) argues that social norms cause fixed wages to be a focal point within the bargaining set. An important difference between our setting and Hall's is that wage rigidities do not lead to allocative inefficiencies in Hall's setting because wages do not affect labor supply conditional on a match. See also MacLeod and Malcomson (1993).

[4]In the context of explicit contracts, costs of writing complicated contracts are often cited as a reason why observed contracts are extremely incomplete. Perhaps it is similarly "more costly" to coordinate on and enforce a complicated state-contingent implicit contract than simple fixed price rules. More generally, explaining why observed contracts are incomplete is an important topic in contract theory (see, e.g., Hart and Moore; 1999).

In our model, the consumers' habit implies that they are partially locked into purchasing certain goods. Kleshchelski and Vincent (2009) consider a model of customer lock-in in which consumers must incur costs to switch sellers/brands. They focus on the Markov perfect equilibrium of the model and show that firms adjust prices less than one-for-one in percentage terms to a given change in prices.[5] Motivated by costs of attention, Soderberg (2010) captures consumer lock-in by assuming that consumers can only adjust their relative demand for a fraction of the products they purchase. This yields a similar consumer demand specification as our model. Soderberg focuses on the commitment equilibrium and assumes nominal rigidity. He shows that consumer lock-in affects the aggregate dynamics of the economy and the welfare effects of monetary policy.[6]

A number of other recent papers also study adverse reactions by consumers as a source of price rigidity. L'Huillier (2010) studies a setting in which firms avoid price increases to avoid incurring negative reactions from uninformed consumers, who do not realize that the aggregate price level has risen. Rotemberg (2008) presents a model in which consumers become angry if they perceive firm pricing to be unfair. Heidhues and Koszegi (2010) study a model in which loss aversion of consumers generates a motive for sticky regular prices and sales.

The paper proceeds as follows: In section 2, we discuss evidence supporting the customer market view of price rigidity developed in this paper. In section 3, we analyze the basic time-inconsistency problem that arises in the good specific habit model and present results about the sustainability of implicit contracts that entail nominal rigidity. In section 4, we consider the case in which firms have private information about their marginal costs and demand and show the optimality of a price cap rule in this setting. In section 5, we present empirical evidence on the flexibility of prices during sales. Section 6 concludes. Proofs are available in an on-line appendix on the authors' and the journal's websites.

---

[5]In our model, prices adjust proportionately to costs in the Markov perfect equilibrium, making the time inconsistency problem the sole source of price rigidity.

[6]This contrasts with our focus on the time-inconsistency problem and its implications micro-pricing behavior in the absence of explicit costs of price adjustment

2. Evidence for the Customer Markets View of Price Rigidity

The model we analyze is a model of "customer markets". The seminal paper on customer markets is Phelps and Winter (1970).[7] Explaining price rigidity was a major motivation for the original development of customer markets models. According to Okun's (1981) "invisible handshake" version of the customer markets idea, firms have implicit agreements with their customers not to take advantage of tight market conditions by raising their price in exchange for stable prices in weak markets. This view of price rigidity finds strong support in the views of firm managers. In Blinder et al. (1998), 64.5% of firms report that they have implicit contracts with their consumers and an overwhelming majority of these firms (79%) indicate that these implicit contracts are an important source of price rigidity. When asked why they didn't change their prices more often, by far the most frequent answer given by firm managers was that they feared that this would "antagonize" their customers. Similar surveys in a host of other countries have since confirmed that the most important reason cited by firm managers for price rigidity is that they are loathe to "damage customer relations" by changing their prices.[8]

The customer markets view of price rigidity suggests that prices should be more rigid in markets in which customers and firms interact repeatedly. There is direct experimental evidence to this effect. In an experiment on price-setting in a market with search costs, Cason and Friedman (2002) show that higher search costs lead customers to remain with sellers for longer periods. Sellers respond to this increase in loyalty with significantly more rigid prices. Renner and Tyran (2004) study a setting in which buyers are uncertain about the quality of competing products. They show that the price rigidity is more pronounced in a customer market than a market without repeat customers following an increase in costs, and that price rigidity is more pronounced if the increase in costs is unobservable than if it

---

[7]Other contributions include Okun (1981), Bils (1989), Rotemberg and Woodford (1991, 1995), Bagwell (2004) as well as Ravn et al. (2006).

[8]See Apel et al. (2004) for a survey of Swedish firms; Hall et al. (1997) for U.K. firms; Amirault et al. (2004) for Canadian firms; and Fabiani et al. (2004) for a meta-study of surveys of firms in Belgium, Germany, Spain, France, Italy, Luxembourg, the Netherlands, Austria and Portugal. A consistent finding across these surveys is that firms rate implicit and explicit contracts as the most important (or, in a few cases, among the most important) sources of price rigidity. In contrast, menu-costs and information costs typically rank rather low among the reasons for price rigidity. Fabiani et al. (2004) is particularly noteworthy due to its size (over 10,000 respondents) and scope (nine countries and many different sectors).

is public information. The latter finding lines up well with the implications of our model, as we discuss in section 4.

Survey evidence also suggests that the link between customer markets and price rigidity may be important. In a survey of British firms, Hall et al. (1997) find that companies with over 75% of their customer relationships lasting for longer than five years rated fixed-price contracts as more important than firms with a smaller fraction of long-term customers. Small and Yates (1999) find that customer turnover seems to have a significant effect on the responsiveness of prices to changes in cost, but not to changes in demand. Carlton (1986) finds no evidence for a relationship between price rigidity and the importance of long-term contracts in a cross-industry study of the Stigler-Kindahl data set. However, the number of observations in Carlton's study is small and the result may be confounded by other differences across industries.

One problem with the invisible handshake story of Okun (1981) has been that in the context of the standard model without customer lock-in, it is difficult to rationalize why firms would enter into implicit contracts that impose restrictions on their future prices. In the context of the habit model we present, firms make such commitment as part of their efforts to manage the expectations of their customers about their future prices. The firms' price commitments are part of their efforts to convince their customers that they will not take advantage of them in future periods. We argue that models with customer lock-in therefore provide one way of explaining why firms enter into implicit contracts regarding their prices.[9]

A brief survey of the media yields numerous examples of firms' efforts to convince customers that they do not plan on raising their prices. For example, On May 23 2002, Marvel CEO Bill Jemas began a pricing conference with the statement: "Read my lips, we will not raise prices." On Oct 9 2000, Revlon Inc. announced as part of its new terms of trade a "commitment not to raise prices for its retail partners in 2001". On Dec 1 2004, Apple Computer "flatly denied a report that...[it] was planning to raise prices for songs bought on

---

[9]Zbaracki et al. (2004) document large costs associated with convincing customers of the logic of a price change to prevent price changes from antagonizing customers.

the popular iTunes online music store...'These rumors aren't true,' said Apple spokeswoman Natalie Sequerira. 'We have multiyear agreements with the labels and our prices remain 99c a track.'" The web-hosting company Tech Trade Internet Services states on its website "Price Freeze Guarantee. Same Price. Forever."[10]

In some cases, an explanation is provided. The large fence manufacturer Sarel states:

> Sarel ... has had no price increases for more than five years and no price changes are expected in the foreseeable future. ... When [customers have] made their choice, the exceptional stability of our prices means that they know not only that they're getting superb value for their money today, but also that they will continue to do so in the future.

A small photofinishing company "Color Express" states:

> Once we publish our price list, our track record proves that we commit to those prices: it's not uncommon to maintain prices for one or two years barring significant increases in the paper industry. Take a look at other published prices, and you will find revisions sometimes as frequently as every 3-6 months. Even if the competitions prices are "slashed", doesn't it make you wonder?

Though far from conclusive, these anecdotes provide concrete examples of firms seeking to "commit to a sticky price", sometimes for the stated purpose of affecting consumers' future price expectations.[11] A notable feature of these price commitments is that they are often asymmetric. The firms announce that they will not *raise* their prices rather than committing that they will not *change* their prices. We return to this point in section 4.

3. The Model with Complete Information

This section considers the interactions of a monopolistic firm and a continuum of consumers that form habits in particular goods in a setting of complete information. We

---

[10]These examples were collected from news articles and company webpages on the internet. A number of similar examples for various industrial and consumer goods industries are presented in an online appendix to this paper. It is important to note that in many of these examples, the firms' consumers are other firms rather than households. As discussed in Shapiro and Varian (1999), lock-in effects are prevalent in many ongoing firm-to-firm purchasing relationships.

[11]Another potential explanation for firms pre-announcing their prices is collusion.

consider both a case in which the firm can make credible commitments about future prices and also explore two types of equilibria when firms cannot make such commitments. In all three cases, consumer choice must satisfy the same demand function. We therefore begin the section by deriving consumer demand.

3.1. Consumer Demand

Consider a continuum of consumers who purchase a continuum of differentiated products.[12] Consumers' preferences over the consumption of these products are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t), \tag{1}$$

where

$$C_t = \left[\int_0^1 \left(c_t(z) - \gamma c_{t-1}(z) \right)^{\frac{\theta_t - 1}{\theta_t}} dz \right]^{\frac{\theta_t}{\theta_t - 1}}, \tag{2}$$

$c_j(z)$ denotes the consumption of good z at time j, θ_t determines the elasticity of substitution between goods, β is the consumer's subjective discount factor and E_0 denotes an expectations operator conditional on information at time t. This utility function implies that consumers' utility from the consumption of a particular good is not time separable. Rather, the utility a consumer derives from good z in a particular period depends not only on his level of consumption in that period but also on how much he consumed of this good in the previous period. In other words, the consumer has a habit in each of the differentiated goods. The parameter γ is a measure of the degree of this good-specific habit. We assume that $0 \leq \gamma \leq 1$. The time variation in θ_t should be viewed as a stand-in for all time varying features of demand that affect the firm's optimal price and that are not explicitly modeled. To ensure that the model has an equilibrium, we follow Schmitt-Grohe and Uribe (2007) in assuming that consumers will drop a firm's product from their consumption bundle unless they archive a given level of utility from that product. Without this assumption, firms have an incentive to raise their prices to infinity in the discretionary equilibrium since consumer demand has an inelastic term (see equation (4) below).[13]

---

[12]The analysis in this section follows that in section 4.3 of Ravn et al. (2006).

[13]See Schmitt-Grohe and Uribe (2007) for a detailed description of the assumptions needed to guarantee that an equilibrium exists in this model.

Consumers face two types of decisions about consumption. They must decide how much to spend on consumption at each point in time and how to allocate their spending at each point between the different goods. These two problems may be analyzed separately. We focus on the allocation of spending across goods at a particular point in time. Given a state contingent path for total consumption $\{C_{t+j}\}_{j=0}^{\infty}$, the consumers seek to minimize their expenditures. Formally, the consumers choose $c_t(z) > 0$ to minimize

$$E_t \sum_{j=0}^{\infty} M_{t,t+j} \int_0^1 p_{t+j}(z) c_{t+j}(z) dz \tag{3}$$

subject to $\{C_{t+j}\}_{j=0}^{\infty}$, where $M_{t,t+j}$ denotes the stochastic discount factor that the consumers use to value future cash flows.

The solution to this optimization problem implies that consumer demand for good z is

$$c_t(z) = \gamma c_{t-1}(z) + C_t \left(\frac{E_t \sum_{j=0}^{\infty} \gamma^j M_{t,t+j} p_{t+j}(z)}{P_t} \right)^{-\theta_t}. \tag{4}$$

where P_t denotes the price level in period t.[14] Notice that when $\gamma = 0$ this demand curve reduces to an iso-elastic Dixit-Stiglitz demand curve. When $\gamma \neq 0$, consumer demand differs from this simple benchmark in two ways. First, current demand depends on consumption in the previous period. Second, demand in period t is negatively influenced not only by $p_t(z)$ but also by $E_t p_{t+j}(z)$. The intuition for these two effects is straight-forward. When the consumers have a habit, their flow utility at a given point in time depends directly on their consumption in the previous period. Their demand today therefore depends on their consumption in the previous period. However, the consumers also understand that by consuming a particular good today, they are increasing their habit in this good, thereby increasing their future demand for it. As a consequence, the consumers' demand today is affected by how costly it will be to feed their habit in the future, i.e., their demand today depends negatively on the future price of the good.

---

[14]P_t is the Lagrange multiplier in the consumer's constrained expenditure minimization problem. It therefore measures the shadow cost of attaining an extra unit of C_t.

3.2. The Firm's Problem

Our primary interest is in the pricing decision of a monopolist producer of product z. Firm z chooses the price of its product $p_t(z) > 0$ to maximize its value

$$E_0 \sum_{t=0}^{\infty} M_{0,t}[p_t(z)c_t(z) - S_t c_t(z)], \tag{5}$$

subject to the demand for its product, given by equation (4) taking aggregate demand C_t, the aggregate price level P_t and its marginal cost S_t as given.

We are interested in comparing equilibria under commitment with equilibria under discretion. Solving analytically for equilibria when firms optimize under discretion is intractable in general. We must thus adopt a numerical method or an approximation method for solving the model. We choose to adopt an approximation method of the sort that is widely used in monetary economics (see, e.g., Woodford, 2003; and Benigno and Woodford, 2004). We approximate the firm's problem around its steady state solution with commitment and assume that exogenous shocks and the habit coefficient, γ, are small.[15] In addition, we assume that the exogenous shocks S_t and θ_t are i.i.d.. Allowing for persistent shocks would, of course, be highly desirable for macroeconomic applications, but renders the model intractable in the asymmetric information case, as we discuss in section 4.

Given these assumptions, we show in the on-line appendix that a second order approximation of the firm's value is

$$E_0 \sum_{t=0}^{\infty} p(z)c(z)\beta^t \left[\left(\hat{p}_t(z) + \frac{1}{2}\hat{p}_t(z)^2 \right) + \frac{1}{\theta} \left(\hat{c}_t(z) + \frac{1}{2}\hat{c}_t(z)^2 \right) + \hat{p}_t(z)\hat{c}_t(z) \right.$$
$$\left. - \frac{\theta - 1}{\theta}\hat{S}_t\hat{c}_t(z) + \hat{p}_t(z)\hat{M}_{0,t} + \frac{1}{\theta}\hat{c}_t(z)\hat{M}_{0,t} \right], \tag{6}$$

where $\hat{c}(z) = \log(c_t(z)/c(z))$, hatted versions of other variables are defined analogously. A second order approximation of the consumer demand curve is

$$\left(\hat{c}_t(z) + \frac{1}{2}\hat{c}_t(z)^2 \right) - \gamma\hat{c}_{t-1}(z) - \frac{1+\theta}{2\theta(1-\gamma)}\hat{c}_t(z)^2 - \theta\hat{P}_t - \hat{C}_t + \hat{P}_t\hat{c}_t(z)$$
$$+ \frac{1}{\theta}\hat{C}_t\hat{c}_t(z) + (\theta - 1)\hat{c}_t(z)\hat{\Upsilon}_t = -\theta(1 - \gamma - \gamma\beta)\hat{p}_t(z) - \frac{\theta}{2}\hat{p}_t(z)^2 - \theta\gamma\beta\hat{p}_{t+1}^e(z) \tag{7}$$

---

[15]More precisely, we characterize the equilibrium of the original non-linear model up to a residual of order $\mathcal{O}(||\xi, \gamma||^2)$, where ξ denotes a vector of the exogenous shocks and $||\xi, \gamma||$ denotes the standard Euclidian distance norm in (ξ, γ) space. See Woodford (2003, pp. 383-392 and 630-635) for a detailed discussion of the validity of this approximation method.

where $\hat{\Upsilon}_t = -\hat{\theta}_t/(\theta - 1)$, we have dropped exogenous second order terms, since they do not affect the analysis below and $\hat{p}_{t+1}^e(z)$ denotes consumers' expectations at time t of the price firm z will charge at time $t + 1$. We write the last term in the demand function as $\hat{p}_{t+1}^e(z)$ to emphasize that this is a choice variable of the households in each period. It will be a condition of equilibrium that $\hat{p}_{t+1}^e(z) = E_t \hat{p}_{t+1}(z)$. As noted above, we seek to characterize a first order approximation of the solution of the model. Since, up to a first order, the model has no endogenous state variables and the exogenous shocks are assumed to be i.i.d., $\hat{p}_{t+1}^e(z)$ is a constant in equilibrium.

3.3. Commitment

We begin by analyzing a situation in which the firm is able to make commitments about future prices. More precisely, we assume that at the beginning of period 0 the firm chooses a state-contingent path for its price for all future periods. After the firm announces this state-contingent path for prices, consumers choose how much to demand in each state of the world. We assume that the firm has access to a commitment device that prevents it from reneging on these choices in future periods. We limit attention to symmetric equilibria in which all firms set the same price and all consumers demand the same quantity.

An equilibrium given these assumptions is a state-contingent path for prices and demand that satisfies two conditions: 1) For any path for $p_t(z)$, the path for consumer demand $c_t(z)$ satisfies equation (4), 2) The path for firm z's price $p_t(z)$ maximizes expression (5) subject to equation (4). We refer to this as the commitment equilibrium.

If we use the demand curve—equation (7)—to eliminate $\hat{c}_t(z)$ from the firm's objective function—equation (6)—we get that the value of the firm is

$$E_0 \sum_{t=0}^{\infty} p(z)c(z)\beta^t \left[\frac{1-\theta}{2}\hat{p}_t(z)^2 + (\theta - 1)\hat{\Upsilon}_t \hat{p}_t(z) + (\theta - 1)\hat{S}_t \hat{p}_t(z) \right] + p(z)c(z)\gamma \hat{p}_0(z), \quad (8)$$

ignoring irrelevant terms and terms of 3rd and higher order (see on-line appendix for details). We then have the following result about the firm's optimal pricing policy in a commitment equilibrium.

Proposition 1. *In a commitment equilibrium, the price set by firm z in period $t \geq 1$ is*

$$\hat{p}_t^c(z) = \frac{1}{12}\hat{S}_t + \hat{\Upsilon}_t, \quad (9)$$

up to an error of order $\mathcal{O}(||\xi,\gamma||^2)$.

Proof: See on-line appendix ∎

As we noted above, $\hat{\Upsilon}_t$ is meant to be a stand-in for demand-side features that affect the firm's optimal price but are not modeled explicitly. It is possible to show that this proposition holds exactly—i.e., without approximation—in the case of no markup shocks (constant θ_t).[16]

This result contrasts the results of earlier customer market models based on ad hoc demand specifications such as those in Phelps and Winter (1970) and Rotemberg and Woodford (1991, 1995). In Phelps and Winter (1970) firms optimally vary their price less than one for one with marginal costs. Thus, markups vary countercyclically. In Rotemberg and Woodford (1991, 1995) the cyclicality of markups is in general ambiguous but they vary procyclically in the case the authors focus on. The idea that motivates the demand specifications assumed in these papers is that consumers respond sluggishly to changes in prices—due to switching costs and habits. Firms can invest in their "customer base" by lowering their current price. Likewise, by raising their price, firms not only lower current demand but also erode their customer base thereby negatively affecting future demand.

The crucial difference between our model and earlier customer markets models is that in our model consumers realize that their demand in future periods depends on their actions in the current period. Consumers therefore decide to become customers of a particular firm not only based on the current price of the firm's product but also based on their expectations about its future prices. In contrast, the earlier customer market literature assumes that changes in a firm's market share are a function only of the firm's current price. This assumption is not consistent with the interpretation that consumer's sluggish responses are due to switching costs. Surely consumers realize that if they become customers of a particular firm they will become partially locked into that relationship in the future.

Equation (9) shows that, given the functional form assumptions embedded in consump-

---

[16]Proposition 1 describes the pricing policy of the firm in the period after the commitment is made and in subsequent periods. This is analogous to the common approach in monetary economics of analyzing the commitment case from the "timeless perspective" (Woodford, 2003). If consumers start off with a habit in the period in which the commitment is made, the firm has an incentive to price gouge in this initial period and promise never to do so again.

tion aggregator (2), it is optimal for a firm facing forward looking consumers to let its price vary one-for-one in percentage terms with marginal costs. Furthermore, in this case, the price set by the firm under commitment is independent of the degree of habit γ. These results simplify our analysis and help focus attention on the sources of price rigidity that arise because of the firm's inability to make commitments.

3.4. Discretion

Now consider the case in which the firm can not commit to future actions. At the beginning of period t, the exogenous shocks θ_t and S_t are realized. Then the firm sets a price for period t. Finally, consumers update their expectations about future prices and choose how much to purchase of each good. Since firms are not able to commit to a future price policy, consumer expectations reflect the incentives firms will have in the future when they set future prices. We refer to the behavior of the firm in this case as optimization under discretion.

In general, consumers and the firm can vary their decisions depending on the history of exogenous variables, the history of the distribution of prices set by firms in earlier periods and the history of the distribution of consumption choices made by consumers. We again limit attention to symmetric equilibria in which all firms set the same price and all consumers demand the same quantity. In this section, we, furthermore, restrict attention to equilibria in which firm z's price in period t is a function only of the current exogenous shocks. We refer to these equilibria as Markov perfect equilibria (Maskin and Tirole, 2001).[17] In section 3.5, we consider the more general case in which firm z's pricing decision may vary with the history of its own price.

Formally, a Markov perfect equilibrium is a path for $p_t(z)$, $c_t(z)$ and $p^e_{t+1}(z)$, where these three variables are functions only of pay-off relevant variables in each period and they satisfy the following three conditions in each period t: 1) Consumers' expectations are formed such that $\hat{p}^e_{t+1}(z) = E_t \hat{p}_{t+1}(z)$, 2) given $p_t(z)$ and $\hat{p}^e_{t+1}(z)$, consumers choose $c_t(z)$ to satisfy their demand curve—equation (7), 3) Firms maximize their value—equation (6)—subject

---

[17]The model we are analyzing has no lagged endogenous variables as state variables given our approximation. The only pay-off relevant state variables of the model are thus the current exogenous shocks.

to consumer demand—equation (7)—taking $\hat{p}_{t+1}^e(z)$ as given. We have the following result about the firm's optimal pricing policy under discretion:

Proposition 2. *In the Markov perfect equilibrium of our model, firm z sets its price equal to*

$$\hat{p}_t^m(z) = \frac{\gamma}{\theta - 1} + \hat{S}_t + \hat{\Upsilon}_t, \tag{10}$$

Proof: See on-line appendix. ∎

The positive constant term in equation (10) implies that in the discretionary equilibrium the firm sets a higher price than it does when it can make commitments.[18] The higher price implies a lower demand and lower profits for the firm. The higher price, of course, also hurts consumers. Social welfare is therefore lower in the discretionary equilibrium than when the firm can make state-contingent commitments. Proposition 2 shows that when consumers form habits the firm faces a time-inconsistency problem which leads it to set a price that is "too high". Each period, the firm takes advantage of its customers' habits and "price gouges". It knows that customer's expectations about future price gouging negatively affects its profits. But its inability to honor commitments prevents it from setting lower prices and experiencing higher profits.

In our model, all consumers are infinitely lived. Our model therefore abstracts from customer turnover. If firms can price discriminate between different cohorts of consumers, the model with customer turnover is a straightforward extension of our model. In the absence of commitment, firms offer an "introductory low price" to new consumers but set suboptimally high prices for existing consumers. The pricing policy for existing consumers is, therefore, similar to the overall pricing policy in a model without customer turnover.[19]

---

[18]Equation (10) is calculated using an approximation around the steady state under commitment rather than the steady state under discretion. For this to yield a solution that is accurate up to a residual of order $\mathcal{O}(||\xi,\gamma||^2)$, it is important that we assume that γ is small (formally that $\gamma = \mathcal{O}(||\xi,\gamma||)$). The steady states under commitment and discretion differ merely by $\gamma/(\theta-1)$. The fact that $\gamma = \mathcal{O}(||\xi,\gamma||)$ implies that the approximation error that occurs due to the difference in the steady state that we linearize around and the steady state under discretion is of order $\mathcal{O}(||\xi,\gamma||^2)$. This guarantees the desired accuracy for the overall approximation. See Woodford (2003, pp. 385) for a detailed discussion of this approach.

[19]As in the model without price discrimination, the efficient outcome cannot be attained in the absence of commitment. Farrell and Shapiro (1989) show that an efficient outcome can be obtained in the case of

Introducing customer turnover is more difficult if firms cannot price discriminate between new and old consumers. In this case, the fact that new consumers are not born with habit decreases the incentive of firms to price gouge. However, an offsetting effect applies to consumers nearing the end of their lives as customers. Firms have a greater incentive to price gouge these customers since they have a habit but do not care as much about the future as younger customers. Analyzing the model with customer turnover in the absence of price discrimination is beyond the scope of the present paper.

In equation (4), we assume that consumers form habits in individual goods. For some products, it may be more realistic to assume that consumers form habits in product varieties. For example, consumers may form a habit in coffee rather than Folgers coffee. In this case, while the formal structure of our model would not apply, the intuition for the "commitment problem" would go through as long as an increase in a given firm's price leads to an increase in the price index of the product category: that is, a rise in the price of Folgers coffee leads to a rise in the price of the consumer's "coffee habit". In this case, Folgers would face a time inconsistency problem. Raising the price of its coffee would lead to a short-term increase in profits due to locked-in coffee consumers, but a long-run decrease in demand for coffee.

3.5. Implicit Contracts as a Substitute for Commitment

When consumers and firms interact repeatedly, the firm may be able to overcome its time-inconsistency problem even if it is unable to make commitments by what is often referred to as reputation formation but in this context might be called an implicit contract with its consumers (Okun, 1981). These implicit contracts sustain equilibria in which the firm is induced not to take advantage of its customers' habits by the threat that doing so would trigger an adverse shift in customer beliefs about its future behavior.

As in section 3.4, we assume that the firm and consumers act sequentially and we don't endow the firm with any ability to make commitments. Also, we again limit attention to symmetric equilibria in which all firms set the same price and all consumers demand the same quantity. However, in this section, we consider equilibria in which the firm's price may

---

inelastic demand and non-linear pricing. MacLeod and Malcomson (1993) show that in the case of inelastic demand, price rigidity can be efficient.

be contingent on its own past actions as well as current and past exogenous shocks. We refer to such equilibria as sustainable equilibria (Chari and Kehoe, 1990) and the path for prices in such an equilibrium as a sustainable price plan.

Formally, a sustainable equilibrium is a path for $p_t(z)$, $c_t(z)$ and $p_{t+1}^e(z)$, where these three variables may be functions of current and past exogenous shocks as well as the history of past prices and they satisfy the following three conditions in each period t: 1) Consumers' expectations are formed such that $\hat{p}_{t+1}^e(z) = E_t\hat{p}_{t+1}(z)$, 2) given $p_t(z)$ and $\hat{p}_{t+1}^e(z)$, consumers choose $c_t(z)$ to satisfy their demand curve—equation (7), 3) Firms maximize their value—equation (6)—subject to consumer demand—equation (7)—taking $\hat{p}_{t+1}^e(z)$ as given.

Many sustainable price plans exist. In particular, if the firm is sufficiently patient the pricing policy chosen by the firm under commitment can be sustained by an implicit contract. Proposition 3 formalizes this idea.

Proposition 3. *If $\beta > \underline{\beta}$, the following price path is a sustainable price plan: At time 1, $\hat{p}_1(z) = \hat{p}_1^c(z)$, where $\hat{p}_1^c(z)$ is the commitment price of proposition 1. At time $t > 1$, $\hat{p}_t(z) = \hat{p}_t^c(z)$ if $\hat{p}_\tau(z) = \hat{p}_\tau^c(z)$ for all $0 < \tau < t$. Otherwise $\hat{p}_t(z) = \hat{p}_t^m(z)$, where $\hat{p}_t^m(z)$ is the price set in the Markov perfect equilibrium of proposition 2.*

Proof: See on-line appendix. ■

This implicit contract involves a trigger strategy. If the firm deviates from $p_t^c(z)$, consumers believe that the firm will set its price as in the discretionary equilibrium from then on. This adverse shift in consumer beliefs induces the firm not to deviate from $p_t^c(z)$.

A prominent stylized fact about most goods prices is that they exhibit nominal rigidity. In the standard no-habit model, nominal rigidity does not arise as an equilibrium outcome. In contrast, when consumers form habits in specific goods, nominal rigidity can arise as an equilibrium outcome. Proposition 4 characterizes a simple sustainable price plan with two period nominal rigidity.

Proposition 4. *Assume that $\beta > \underline{\beta}$ and*

$$\gamma^2 > (\theta - 1)^2 \frac{1 + \beta - \beta^2}{2\beta + \beta^2} var(\hat{S}_t + \hat{\Upsilon}_t). \tag{11}$$

The following price path is a sustainable price plan: Set

$$\hat{p}_t(z) = \frac{\gamma}{(\theta - 1)(1 + \beta)} + \frac{1}{1 + \beta}(\hat{S}_t + \hat{\Upsilon}_t). \tag{12}$$

in periods $t \in \{1, 3, 5, ...\}$ and do not change the price in the even numbered periods as long as all past prices have been set in this way. Otherwise, set $\hat{p}_t(z) = \hat{p}_t^m(z)$.

Proof: See on-line appendix. ∎

This price path may be viewed as an implicit contract between the firm and its consumers which stipulates: 1) The firm's prices should remain fixed for 2 periods at a time; and 2) If the firm ever deviates from this, consumers expect the firm to set its price as in the discretionary equilibrium from then on. Given this type of trigger strategy by the consumers, equation (12) is the firm-preferred price path.[20] Proposition 4 can easily be extended to the case of n-period price rigidity.

The firm can be induced not to deviate from this implicit contract because the price rigidity it entails helps the firm partially overcome its incentive to price gouge. Notice that the constant term in equation (12) is smaller than the constant term in equation (10). The firm sets a lower average price in this case because a high price in period t raises consumer's expectations about the firm's price in period $t + 1$ and therefore raises the consumer's cost of forming a habit in the good. Against this benefit, the firm must weigh the cost of price inflexibility. Since the firm can only change its price every other period, it is not able to respond optimally to fluctuations in marginal costs and demand. Instead of responding one-for-one in percentage terms to variations in marginal costs and demand as in equation (10), the firm only changes its price by $1/(1+\beta)$ percent for each percentage point deviation in marginal costs or demand. Condition (11) determines how strong the consumers' habit must be for the commitment benefit to outweigh the costs of inflexibility.

Our model suggests that price rigidity may be due to implicit contracts between firms and consumers. The punishment phase of such implicit contracts provides an interpretation for consumers' adverse reactions to price increases that are not justified by observable increases in costs. Consumers often perceive such price increases as "unfair" (see, e.g., Kah-

---

[20]This is shown in the proof to proposition 4.

neman et al., 1986; and Rotemberg, 2002 and 2004). If firms and consumers enter into implicit contracts, it is exactly these types of price increases that lead to adverse reactions by customers.

Many other implicit contracts yield sustainable price paths in our model. Some entail price rigidities and others don't. Whether equilibria with price rigidity occur is therefore a matter of equilibrium selection. In a market with a large number of atomistic buyers, a firm with market power may disproportionately be able to influence equilibrium selection. All else equal, the firm would prefer the equilibrium described in Proposition 3, which does not involve price rigidity. One motivation for the asymmetric information model presented in section 4 is that, in that setting, firms respond incompletely to some shocks, even in the firm-preferred equilibrium.

In the complete information case, the firm could potentially prefer an equilibrium with price rigidity because it is easier to coordinate on. It may be easier for the firm to communicate a policy in which prices remain unchanged for several periods than a more complicated state-dependent pricing rule (though we are not aware of direct evidence on this point). It is important to note, however, that firms and consumers must also coordinate on off-equilibrium play to sustain the trigger strategy equilibria considered in Propositions 3 and 4. The multiplicity of equilibria embedded in our model may help explain some of the huge sectoral variation in the frequency of price change documented in the recent literature (see, e.g., Bils and Klenow, 2004)—perhaps equilibria with nominal rigidity become norms in some industries but not others.

The mechanism for price rigidity described in this section is fundamentally different from other models in the literature. The idea that firms face menu costs and other barriers to price changes is arguably the most important idea used by macroeconomists to explain price rigidity. The standard view in the literature is that the existence of menu costs hurt firms. Firms therefore have an incentive to adopt technologies that eliminate menu costs. The existence of a time-inconsistency problem in the habit model discussed above suggests a dramatically different view of menu costs. In the habit model, menu costs can be beneficial to a firm since they can help the firm overcome its incentive to price gouge.

19

4. Asymmetric Information

Many components of a typical firm's marginal costs and demand are either unobservable or very costly for a consumer to observe. In section 3, we showed that in a complete-information setting the most favorable sustainable price path from the firm's perspective is one in which the price is a function of the firm's marginal costs and its demand. If marginal costs and demand are unobservable to the consumers, such price paths are unsustainable since there is no way for consumers to verify whether the firm deviates from them or not. This observation raises the question: What is most favorable sustainable price path from the firm's perspective when it has private information about its marginal costs and demand?

It turns out that this question is formally related to the problem studied by Athey et al. (2004). They study the time-inconsistency problem of a central bank that has private information about the state of the economy. Using methods developed by Abreu et al. (1990), they are able to show that under relatively mild restrictions this type of problem has a surprisingly simple solution. Proposition 5 states a similarly simple result about the most favorable sustainable price path from the firms perspective when marginal costs and demand are unobservable.[21]

Proposition 5. *Assume that $\hat{S}_t$ and $\hat{\Upsilon}_t$ are unobservable to the consumers but that their probability distributions are known and the probability distribution of $\hat{\Phi}_t = \hat{S}_t + \hat{\Upsilon}_t$ is bounded on the interval $[\underline{\hat{\Phi}}, \overline{\hat{\Phi}}]$ and satisfies a monotone hazard condition. Assume also that $\beta > \underline{\beta}$. The sustainable price plan that maximizes the value of the firm at time 0 in this case has the firm do one of two things from $t = 1$ on:*

I. If $\gamma > -\underline{\hat{\Phi}}$, the firm sets a constant price $\hat{p}_t(z) = E\hat{p}^c(\hat{\Phi}_t, z) = 0$.

II. If $\gamma < -\underline{\hat{\Phi}}$, the firm sets

$$
\hat{p}_t(z) = \begin{cases} \hat{p}^m(\hat{\Phi}_t; z) & \text{if } \hat{\Phi}_t \in [\underline{\hat{\Phi}}, \hat{\Phi}^*] \\ \hat{p}^m(\hat{\Phi}^*; z) & \text{if } \hat{\Phi}_t \in [\hat{\Phi}^*, \overline{\hat{\Phi}}]. \end{cases}
\tag{13}
$$

---

[21]For simplicity, we model the unobservability of demand by assuming that $\hat{\Upsilon}_t$ is unobservable to the consumers. One way to motivate the unobservability of $\hat{\Upsilon}_t$ is to suppose that the population is made up of two groups: Group 1 has no habit and a low $\hat{\Upsilon}$. Group 2 has habits and a higher $\hat{\Upsilon}$. Unobservable variation in the relative size of these two groups then causes unobservable variation in the market $\hat{\Upsilon}_t$.

If the firm deviates from this, it sets $p_t(z) = p_t^m(z)$ forever after.

Proof: See on-line appendix. ∎

The firm-preferred price path takes the form of an implicit contract that limits the firms discretion by setting a "price cap" above which the firm can not set its price. When $\hat{\Phi}_t$ is relatively low, the firm acts with discretion—i.e. sets $\hat{p}_t(z) = \hat{p}_t^m(z)$. However, when $\hat{\Phi}_t > \hat{\Phi}^*$, the firm sets its price equal to the price cap (which is equal to the discretionary price for $\hat{\Phi}_t = \hat{\Phi}^*$). Athey et al. (2004) refer to this as bounded discretion. The level of the price cap depends on the severity of the time-inconsistency problem, which in turn depends on the strength of the habit that consumers develop in the firm's good. In other words, the cutoff $\hat{\Phi}^*$ is decreasing in γ. Thus, the firm's desire to limit its discretion increases with the severity of the time-inconsistency problem. For $\gamma > 0$, $\hat{\Phi}^* < \bar{\hat{\Phi}}$. Thus, the price distribution over time for the firm will have a mass-point at its upper bound so long as consumers have a habit.

Conditional on the firm choosing a static pricing policy, the intuition for the price cap result is fairly straightforward. The time inconsistency problem leads to sub-optimal profits because consumers anticipate that firms will price gouge in the future, leading them to demand less of the habit-forming good today. To improve on the Markov perfect equilibrium, a pricing policy must lower consumers' expectations of future prices, implying that the pricing policy should constrain prices from above rather than below. Given that the pricing policy cannot be contingent on any relevant variable (which are assumed to be private information) a price cap policy is the best the firm can do. Unfortunately, the intuition for why the pricing policy must be static is much more complex. We are not aware of a simple intuition for this result.

We have derived results for the simple case in which the consumer cannot observe any of the variables that the firm would like to make its price depend on. Our results can, however, be extended to a setting in which the consumer observes some such variables but not others. In this case, the variables that the consumer observes are state variables and the price cap would be a function of these variables. Since the aggregate price level is trending upward, firms' price caps should trend upward. The fact that the regular price of most goods in the U.S. economy are fixed in nominal terms for considerable periods is thus a deviation from

the equilibrium that is strictly most preferred by firms in our model. Another limitation of our result in this section is that it holds only for i.i.d. shocks. It is notoriously difficult to characterize dynamic incentive problems with private information and persistent shocks.[22]

5. Dynamic Pricing Implications

Proposition 5 shows that in our model the firm's optimal pricing policy when it has private information about its desired price is one in which its price is upward-rigid at a price cap. Below this cap the firm's price is flexible. A substantial amount of empirical evidence supports the view that many products have a rigid regular price and that temporary sales are common. Hosken and Reiffen (2004) and Nakamura and Steinsson (2008) provide extensive evidence for the presence of this type of pricing behavior using data on a wide variety of consumer goods from the U.S. Bureau of Labor Statistics.[23] Hosken and Reiffen (2004) document a clear asymmetry between price increases and decreases. "Reverse sales"—i.e., brief periods during which the price of a good rises above its regular price and then returns back to the regular price—are extremely uncommon. This is one empirical implication of our dynamic pricing model.

Another implication of our model is that prices should be substantially more flexible *during* sales than during other periods. By definition, price changes occur at the beginning and end of a sale. But multi-week sales account for somewhat less than half of all sales in many grocery products categories. Our model suggests that prices should be more flexible over the course of these multi-week sales. In addition, our model implies that there is likely to be a great deal of price flexibility across different sale spells. In other words, the sale prices that arises in one sale spell are likely to differ from the sale prices that arise in the subsequent sale spells. This feature of the data has not been previously studied in the empirical literature on pricing to our knowledge.

To investigate these predictions of the model, we use weekly price data from the Dominick's Finer Foods (DFF) data set mentioned above.[24] We identify sale periods using

---

[22]See Fernandes and Phelan (2000) and Athey and Bagwell (2008).

[23]Pesendorfer (2002) and Kehoe and Midrigan (2010) present similar evidence for scanner data.

[24]DFF is the second-largest supermarket chain in the Chicago metropolitan area with ap-

the filter described in Nakamura and Steinsson (2008) with the parameters J=8, K=3 and L=3.[25] To give the reader a feel for the data and the procedure used to identify sales, Figure 1 shows the original and "regular price" series for a popular item, Nabisco Premium Saltines 16oz. The figure shows that the regular price series generated by this procedure corresponds well with our intuition about how to define a sale. The price series has infrequent adjustments in regular prices and frequent sales. When no recurring regular price can be identified from the data, the sales filter simply sets the regular price equal to the observed price.

According to this sales filter, sales occur about 13% of the time in the Dominick's data set. The regular price often remains fixed for significant periods of time—the frequency of price adjustment of regular prices is 6.1% or less in more than half of the categories included in the Dominick's data. It is important to note that the answers to the questions we investigate regarding the flexibility of prices during sales are not guaranteed by the definition of sales. One might think of prices as oscillating between two distinct values: a regular price and a sale price, each of which exhibits substantial price rigidity. In this case, one would not expect to see a substantial difference in the flexibility of sale prices as compared to regular prices.

Columns 1 and 2 of Table 1 compare the frequency of price adjustment for regular prices versus sale prices during multi-week sales, not including the price changes at the start and end of the sale. The frequency of price adjustment during sales is about 8 times as high as the frequency of adjustment of the regular price.[26] Existing menu cost models of price rigidity do not provide any reason why the price of a good should be more flexible when it

---

proximately 100 stores and a 25% market share. DFF provided the University of Chicago Graduate School of Business (GSB) with weekly store-level scanner data, available at http://gsbwww.uchicago.edu/kilts/research/db/dominicks/. See Chevalier et al. (2003) for a more detailed description of this data set. We use data from store number 126 since the data from this store has the least missing data points.

[25]Our qualitative findings are not sensitive to the exact parameters used in the sales filter. Related approaches to identifying sales based on the time series behavior of prices have been suggested by Kehoe and Midrigan (2010) and Hosken and Reiffen (2004). An alternative approach would be to use data on the timing of promotions. The labeling of promotions in the Dominick's data set is, however, undependable. According the University of Chicago GSB website describing the data, "if the variable is set it indicates a promotion, if it is not set, there might still be a promotion that week".

[26]Levy et al. (2005) find an even greater difference in the flexibility of regular prices and sales prices in the DFF data set. Using a different algorithm to identify sales they estimate that sales prices are 64 times more likely to change than regular prices.

is on sale. This pricing pattern is however a natural implication of our model.[27] From the perspective of the customer markets model presented in this paper, this pattern of pricing reflects the fact that the firm optimally chooses to commit to a sticky price cap.

Column 4 of Table 1 reports our measure of the flexibility of prices during sales. The table reports the number of unique sale values as a fraction of the total number of weeks spent on sale. This statistic would equal one if there were a unique sale price in every sale period and would approach zero if only one sale price was ever visited. Column 3 of the table reports an analogous statistic for regular prices. Sale prices are considerably more variable than regular prices. The median value of this fraction across categories for sale prices is 43%. In contrast, the same statistic for regular prices is 4.5%, about 10 time smaller.[28] The data are not, therefore, consistent with the idea that the price always returns to a particular sale price when the product goes on sale.

In conjunction with the earlier evidence discussed above, Table 1 shows that the data support the presence of a rigid upper bound in prices with much more price flexibility below the upper bound. These features of the data are consistent with our model of the regular price as a commitment mechanism. These features of the data do not, however, arise naturally in standard models of price adjustment. Menu costs and other barriers to price changes are the dominant paradigm for explaining price rigidity in macroeconomics. Yet, it is difficult to reconcile menu cost models with the large amount of price flexibility that arises during temporary sales. Kehoe and Midrigan (2010) consider a model in which a different menu cost applies to sale price changes than to other types of price adjustments. A complete model of pricing behavior must, however, explain why the barriers to price adjustment are greater for some types of price adjustments than others.

In the industrial organization literature, there are several important models of temporary sales in retail stores. Varian (1980) considers a model in which the presence of uninformed consumers supports a mixed strategy equilibrium in prices. The price variation

---

[27]Again, these empirical facts do not arise from the particular approach used to identify sales, since our algorithm does not in any way affect the dynamics of prices during a sale.

[28]An even higher fraction of sale prices are unique if the prices are defined in terms of percent off the regular price, or an absolute amount off the regular price.

associated with this mixed strategy equilibrium may be interpreted as representing temporary sales. Sobel (1984) presents an alternative model in which temporary sales arise when low-valuation, low discount-factor consumers build up in the market. As the stock of potential consumers varies over time, the firm has an incentive to vary its prices. These cyclical variations in prices may be interpreted as temporary sales. Aguirregabiria (1999) presents a motive for temporary sales based on store inventories. In this model, temporary sales arise when firms wish to rid themselves of excess inventories. This model generates cyclical movements in prices due to movements in the shadow value of inventory that can be interpreted as temporary sales.

It is not clear, however, that these models present a convincing explanation for the presence of a rigid upper bound in retail prices, a pattern we document above. In Sobel's (1984) model, a fixed "regular" price only arises if the discount factor of the low valuation consumers is exactly zero and the distribution of consumer valuations is bounded from above. Pesendorfer (2002) considers a model similar to Sobel's (1984) model in which the presence of consumers with high and low valuations leads prices to oscillate between two values. However, it is not clear that this motive for rigidity survives in a model with a continuous distribution of consumer types. The model also fails to generate an asymmetry in the flexibility of sale vs. regular prices. Finally, the fixed ordering costs considered in Aguirregabiria (1999) lead to continual cyclical movements in prices since the shadow cost of store inventories is continually adjusting. The sticky upper bound in retail prices is an important feature for models of temporary sales to explain, since one of the most salient features of temporary sales is the tendency of prices to return to the original price following the sale.

A fuller quantitative analysis of our model would evaluate its predictions for other features of the pricing distribution, such as the size of sale price changes and the fraction of time prices spend at the price cap. Rearranging equation (15) in the appendix yields a relationship between the habit parameter, the distribution of prices below the cap, the fraction of time spent at the price cap, and the price elasticity of demand that could be studied

empirically.[29] For example, a back-of-the-envelope calculation suggests that a high value of the habit parameter is be required to rationalize the observed price rigidity if the distribution of desired prices is uniform, whereas a smaller value is required if the distribution is bimodal. Recent work suggests that a bimodel of distribution of desired prices could arise from a structural model of price discrimination (Guimaraes and Sheedy, 2010). This type of quantitative analysis is, however, beyond the scope of the present paper.

6. Concluding Remarks

In an environment in which consumers are partially locked-in to purchasing particular goods, firms face a time-inconsistency problem when they set prices. They would like to promise low prices in the future. But when the future arrives they have an incentive to take advantage of the locked-in consumers and price gouge. We show how various forms of price rigidity arise as equilibrium outcomes in this environment. The reason equilibria involving price rigidity can be sustained is that price rigidity serves as a partial commitment device that helps firms overcome their desire to price gouge locked-in consumers.

If firms have private information about their desired prices, the firm-preferred equilibrium involves the firm committing to set its price equal to or below a price cap. Our model therefore implies that prices should spend a significant portion of their time at a rigid upper bound. Below this upper bound, prices should be much more flexible. As we show in section 5, the behavior of retail prices bears a striking resemblance to this price cap policy. In contrast, the combination of a rigid regular price and frequent sales is difficult to explain within standard models in which price rigidity arises from menu costs alone. Our model also helps explain why firms fear adverse reactions to price changes, why sales prices are more flexible than regular prices and why firms make explicit promises not to change prices.

We have derived results for the simple case in which the consumer cannot observe any of the variables that the firm would like to make its price depend on. If the consumer observes some such variables but not others, the variables that the consumer observes are state variables and the price cap would be a function of these variables. One extension of our

---

[29]We thank an anonymous referee for suggesting this line of argument.

model we find interesting is to consider a model incorporating small costs of coordinating on complex equilibria. Such a model might, in principle, yield simple pricing strategies (such as those with fixed prices) as equilibria even in the presence of common state variables.

References

Abreu, D., Pearce, D., Stacchetti, E., 1990. Toward a theory of discounted repeated games with imperfect monitoring. Econometrica 58 (5), 1041–1063.

Aguirregabiria, V., 1999. The dynamics of markups and inventories in retail firms. Review of Economic Studies 66, 275–308.

Amirault, D., Kwan, C., Wilkinson, G., 2004. A survey of the price-setting behavior of canadian companies. Bank of Canada Review winter 2004–2005, 29–40.

Apel, M., Friberg, R., Hallsten, K., 2005. Micro foundations of macroeconomic price adjustment: Survey evidence from swedish firms. Journal of Money, Credit and Banking 37 (2), 313–338.

Athey, S., Atkeson, A., Kehoe, P. J., 2005. The optimal degree of discretion in monetary policy. Econometrica 73 (5), 1431–1475.

Athey, S., Bagwell, K., 2008. Collusion with persistent cost shocks. Econometrica 76 (3), 493–540.

Bagwell, K., 2004. Countercyclical pricing in customer markets. Economica 71 (284), 519–542.

Benigno, P., Woodford, M., 2005. Inflation stabilization and welfare: The case of a distorted steady state. Journal of the European Economic Association 3, 1185–1236.

Bils, M., 1989. Pricing in a customer market. Quarterly Journal of Economics 104 (4), 699–718.

Blinder, A. S., Canetti, E. R. D., Lebow, D. E., Rudd, J. B., 1998. Asking About Prices. Russell Sage Foundation, New York, New York.

Carlton, D. W., 1986. The rigidity of prices. American Economic Review 76, 637–658.

Cason, T. N., Friedman, D., 2002. A laboratory study of customer markets. Advances in Economic Analysis and Policy 2 (1), Article 1.

Chari, V., Kehoe, P. J., 1990. Sustainable plans. Journal of Political Economy 98 (4), 783–802.

Chevalier, J. A., Kashyap, A. K., Rossi, P. E., 2003. Why don't prices rise during peak demand periods? evidence from scanner data. American Economic Review 93 (1), 15–37.

Diamond, P. A., 1971. A model of price adjustment. Journal of Economic Theory 3, 156–168.

Fabiani, S., Druant, M., Hernando, I., Kwapil, C., Landau, B., Loupias, C., Martins, F., Matha, T., Sabbatini, R., Stahl, H., Stokman, A., 2004. The pricing behavior of firms in the euro area: New survey evidence, paper Presented at Conference on "Inflation Persistence in the Euro Area" at the European Central Bank.

Farrell, J., Shapiro, C., 1989. Optimal contracts with lock-in. American Economic Review 79, 51–68.

Fernandes, A., Phelan, C., 2000. A recursive formulation for repeated agency with history dependence. Journal of Economic Theory 91, 223–247.

Guimaraes, B., Sheedy, K., 2010. Sales and monetary policy. American Economic Review-Forthcoming.

Hall, R. E., 2005. Employment fluctuations with equilibrium wage stickiness. American Economic Review 95 (1), 50–65.

Hall, S., Walsh, M., Yates, T., 1997. How do uk companies set prices? Bank of England Quarterly Bulletin, 180–192.

Hart, O., Moore, J., 1999. Foundations of incomplete contracts. Review of Economic Studies 66 (1), 115–138.

Heidhues, P., Koszegi, B., 2010. Regular prices and sales, working Paper, University of California at Berkeley.

Hosken, D., Reiffen, D., 2004. Patterns of retail price variation. Rand Journal of Economics 35 (1), 128–146.

Kahneman, D., Knetsch, J. L., Thaler, R., 1986. Fairness as a constraint on profit seeking: Entitlements in the market. American Economic Review 76 (4), 728–741.

Kehoe, P., Midrigan, V., 2010. Prices are sticky after all, working Paper, New York University.

Klemperer, P., 1995. Competition when consumers have switching costs: An overview with applications to industrial organization, macroeconomics, and international trade. Review of Economic Studies 62, 515–539.

Kleshchelski, I., Vincent, N., 2009. Market share and price rigidity. Journal of Monetary Economics 56, 344–352.

L'Huillier, J.-P., 2010. Consumer' imperfect information and nominal rigidities, working Paper, Einaudi Institute for Economics and Finance.

MacLeod, W. B., Malcomson, J. M., 1993. Investments, holdup, and the form of market contracts. American Economic Review 83 (4), 811–837.

Maskin, E., Tirole, J., 2001. Markov perfect equilibrium. Journal of Economic Theory 100, 191–219.

Nakamura, E., Steinsson, J., 2008. Five facts about prices: A reevaluation of menu cost models. Quarterly Journal of Economics 123 (4), 961–1013.

Okun, A. M., 1981. Prices and Quantities: A Macroeconomic Analysis. Brookings Institution, Washington, DC.

Pesendorfer, M., 2002. Retail sales: A study of pricing behavior in supermarkets. Journal of Business 75 (1), 33–66.

Phelps, E. S., Winter, S. G., 1970. Optimal price policy under atomistic competition. In: Phelps, E. S. (Ed.), Microeconomic Foundations of Employment and Inflation Theory. W.W. Norton, New York, New York.

Ravn, M., Schmitt-Grohé, S., Uribe, M., 2006. Deep habits. Review of Economic Studies 73 (1), 195–218.

Renner, E., Tyran, J.-R., 2004. Price rigidity in customer markets: An empirical study. Journal of Economic Behavior and Organization 55 (4), 575–593.

Rotemberg, J. J., 2005. Customer anger at price increases, changes in the frequency of price changes and monetary policy. Journal of Monetary Economics 52 (4), 829–852.

Rotemberg, J. J., 2008. Fair pricing. Journal of the European Economic AssociationForthcoming.

Rotemberg, J. J., Woodford, M., 1991. Markups and the business cycle. In: Blanchard, O. J., Fischer, S. (Eds.), NBER Macroeconomics Annual. MIT Press, Cambridge, Mass.

Rotemberg, J. J., Woodford, M., 1995. Oligopolistic pricing and the effects of aggregate demand on economic activity. In: Cooley, T. F. (Ed.), Frontiers of Business Cycle Research. Princeton University Press, Princeton, New Jersey.

Schmitt-Grohe, S., Uribe, M., 2007. Why the monopolist does not deviate from the symmetric equilibrium in a model with good-specific subsistence points, working Paper.

Shapiro, C., Varian, H. R., 1999. Information Rules. Harvard Business School Press, Boston, MA.

Small, I., Yates, T., 1999. What makes prices sticky? some survey evidence for the united kingdom. Bank of England Quarterly Bulletin, 262–271.

Sobel, J., 1984. The timing of sales. Review of Economic Studies 51, 353–368.

Soderberg, J., 2010. Customer markets and the welfare effects of monetary policy. Journal of Monetary EconomicsForthcoming.

Varian, H. R., 1980. A model of sales. American Economic Review 70, 651–659.

Woodford, M., 2003. Interest and Prices. Princton University Press, Princeton, NJ.

Zbaracki, M. J., Ritson, M., Levy, D., Dutta, S., Bergin, M., 2004. Managerial and customer costs of price adjuestment: Direct evidence from industry markets. Review of Economics and Statistics 86 (2), 514–533.

Table 1: Adjustment of Regular versus Sale Prices

Product	Frequency of Price Change		Number of Unique Prices as a Fraction of Total Weeks	
	Regular Prices	Sale Prices	Regular Prices	Sales Prices
Analgesics	0.036 (0.001)	0.411 (0.013)	0.035 (0.001)	0.578 (0.019)
Bath Soap	0.026 (0.002)	0.354 (0.025)	0.031 (0.002)	0.531 (0.047)
Bathroom Tissues	0.110 (0.003)	0.491 (0.014)	0.064 (0.004)	0.359 (0.029)
Beer	0.063 (0.001)	0.200 (0.006)	0.040 (0.002)	0.195 (0.016)
Bottled Juices	0.084 (0.001)	0.454 (0.006)	0.053 (0.002)	0.404 (0.014)
Canned Soup	0.058 (0.001)	0.418 (0.007)	0.042 (0.001)	0.464 (0.016)
Canned Tuna	0.069 (0.002)	0.304 (0.008)	0.046 (0.003)	0.331 (0.013)
Cereals	0.069 (0.001)	0.528 (0.010)	0.061 (0.001)	0.668 (0.014)
Cheeses	0.111 (0.001)	0.530 (0.005)	0.080 (0.007)	0.395 (0.010)
Cigarettes	0.036 (0.001)	—	0.053 (0.001)	0.580 (0.037)
Cookies	0.046 (0.001)	0.500 (0.005)	0.034 (0.001)	0.426 (0.009)
Crackers	0.065 (0.001)	0.445 (0.008)	0.044 (0.002)	0.349 (0.013)
Dish Detergent	0.054 (0.001)	0.453 (0.011)	0.047 (0.002)	0.434 (0.018)
Fabric Softeners	0.057 (0.001)	0.404 (0.011)	0.045 (0.003)	0.495 (0.023)
Front-end-Candies	0.028 (0.001)	0.344 (0.008)	0.024 (0.001)	0.338 (0.016)
Frozen Dinners	0.066 (0.002)	0.551 (0.011)	0.040 (0.003)	0.432 (0.022)
Frozen Entrees	0.054 (0.001)	0.495 (0.006)	0.039 (0.001)	0.446 (0.007)

Continued on next page

Product	Frequency of Price Change		Number of Unique Prices as a Fraction of Total Weeks	
	Regular Prices	Sale Prices	Regular Prices	Sales Prices
Frozen Juices	0.081 (0.002)	0.522 (0.009)	0.051 (0.002)	0.344 (0.011)
Grooming Products	0.034 (0.001)	0.497 (0.007)	0.036 (0.001)	0.442 (0.011)
Laundry Detergents	0.061 (0.001)	0.425 (0.009)	0.049 (0.003)	0.538 (0.027)
Oatmeal	0.071 (0.002)	0.530 (0.019)	0.062 (0.004)	0.607 (0.029)
Paper Towels	0.086 (0.003)	0.482 (0.015)	0.045 (0.004)	0.301 (0.023)
Refrigerated Juices	0.133 (0.002)	0.635 (0.008)	0.089 (0.005)	0.447 (0.016)
Shampoos	0.043 (0.001)	0.443 (0.010)	0.038 (0.001)	0.443 (0.013)
Snack Crackers	0.073 (0.001)	0.529 (0.007)	0.051 (0.002)	0.428 (0.013)
Soaps	0.051 (0.002)	0.510 (0.011)	0.039 (0.003)	0.449 (0.026)
Soft Drinks	0.076 (0.001)	0.652 (0.004)	0.042 (0.001)	0.309 (0.006)
Toothbrushes	0.049 (0.001)	0.406 (0.011)	0.045 (0.002)	0.403 (0.016)
Toothpastes	0.056 (0.001)	0.492 (0.009)	0.048 (0.001)	0.443 (0.013)
Median	0.061	0.487	0.045	0.434

Note: Standard Errors are in parentheses. The total number of observations is 985,022. The regular price and sale prices of a good are identified using the sales filter that is described in appendix C. The frequency of price change is calculated by dividing the total number of price changes by the total number of weeks. The statistics in columns three and four are calculated by first dividing the number of unique regular or sale prices observed for a product by the total number of weeks at the regular price or on sale and then averaging within categories.
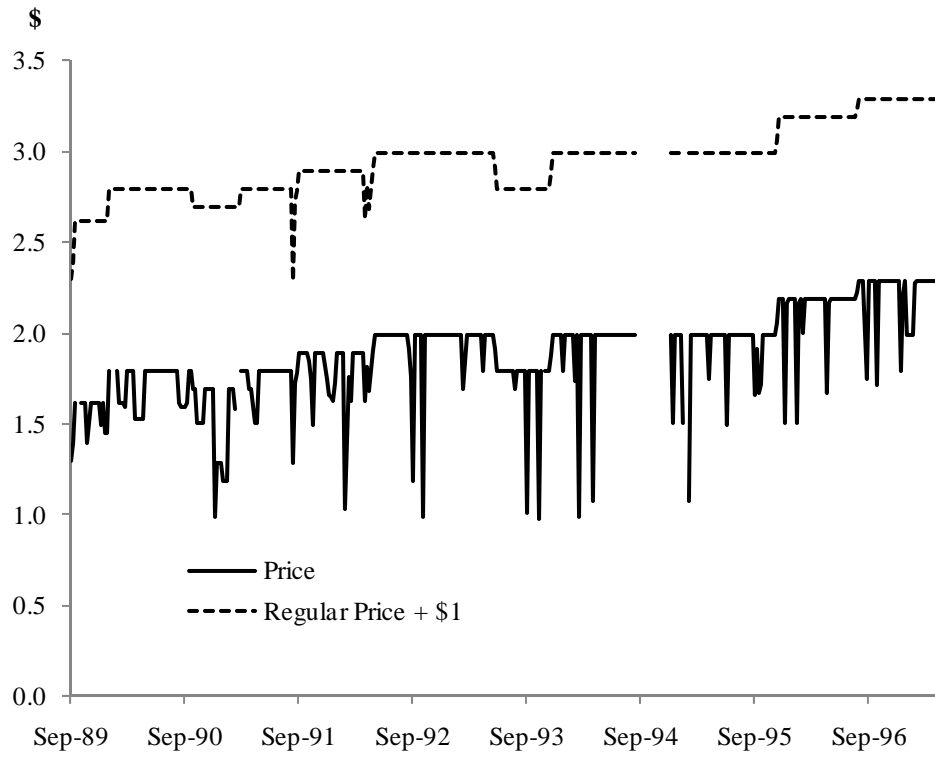
Figure 1
Nabisco Premium Saltines 16 oz.
The solid line is the price of Nabisco Premium Saltines. The dotted line is the regular price of Nabisco Premium Saltines shifted up by $1.