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A Theory of Price Adjustment under Loss Aversion

Steffen Ahrens*, Inske Pirschel† and Dennis J. Snower‡

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Abstract

We present a new theory of price adjustment, based on consumer loss aversion in the price dimension. In line with prospect theory, the consumers' perceived utility losses from price increases are weighted more heavily than the perceived utility gains from price decreases of equal magnitude. Price changes are evaluated relative to an endogenous reference price, which depends on past realized prices.

By implication, demand responses are more elastic for price increases than for price decreases and thus firms face a downward-sloping demand curve that is kinked at the consumers' reference price. Firms adjust their prices flexibly in response to variations in this demand curve, in the context of an otherwise standard dynamic neoclassical model of monopolistic competition. The resulting theory of price adjustment is starkly at variance with past theories. The size of the price adjustment is shown to depend on both the size and sign of the underlying demand shocks. Whereas prices are rigid in the presence of some shocks, they respond sluggishly to others. This pricing is state-dependent and asymmetric with respect to shocks.

JEL classification: D03, D21, E31, E50.

Keywords: price sluggishness, loss aversion, state-dependent pricing

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1 Introduction

The standard neoclassical model of instantaneous price adjustments to clear markets is challenged by a large body of empirical research suggesting that prices evolve sluggishly (e.g. Bils and Klenow 2004, Klenow and Kryvtsov 2004, 2008). In response, economists have developed models of sluggish price adjustment that are time- and state-dependent.¹ However neither the time-dependent nor the first-generation state-dependent pricing models have been successful in accounting for the empirical facts on firms' price setting behavior (Klenow and Kryvtsov 2008, Nakamura and Steinsson 2008a, Klenow and Malin 2010).² Second-generation state-dependent models, which additionally to fixed price adjustment costs include idiosyncratic shocks (Golosov and Lucas 2007, Gertler and Leahy 2008, Costain and Narkov 2011a, 2011b, Dotsey et al. 2008, Midrigan 2011), perform better empirically but at the cost of much greater complexity.

This paper presents a new theory of firms' price adjustment in response to consumer loss aversion, as specified in prospect theory (Kahnemann and Tversky 1979). Our model captures many of the observed empirical regularities described in the literature above. As for our two main results, it provides a microfounded account of (i) price sluggishness and (ii) asymmetric responses to positive and negative demand shocks.

The basic idea underlying our theory is simple. Price increases are associated with utility losses for consumers, whereas price decreases are associated with utility gains. In the spirit of prospect theory, losses are weighted more heavily than gains of equal magnitude. Consequently demand responses are more elastic to price increases than to price decreases. The result is a kinked demand curve, for which the kink depends on the consumers' reference price. In the spirit of Kőszegi and Rabin (2006), we assume that the reference price is the agents' rational price expectations from the recent past.

Now suppose that there is an exogenous shift of the demand curve. Since this demand curve is assumed to be kinked, sufficiently small shifts will evoke no change in the firm's price. This is the case of price rigidity. For larger shifts, the firm's price will respond, but the size of the response will be different for positive and negative shifts of equal magnitude. (After all, consumers respond more readily to price increases than to price decreases.) This means that prices are state-dependent and respond asymmetrically to positive and negative shocks.

When prices increase in response to a positive demand shock, the firm can foresee not only the fall of the quantity demanded, but also the resulting change in the consumers' reference price. Whether or not there is a change in the

¹The time-dependent models are based primarily on the staggered contracts model of Taylor (1979) and the random duration model of Calvo (1983). The state-dependent models include e.g. the quadratic adjustment cost model of Rotemberg (1982) and the menu cost model of Caplin and Spulber (1987).

²Especially the time-dependent specifications have been harshly criticized for being a too restrictive description of the price setting process (Caplin and Leahy 1991, Wolman 1999). But despite its empirical weakness and its lack of micro-foundations, the Calvo (1983) model has been the most widely adopted price updating scheme in the literature on monetary policy, simply due to its mathematical tractability.

reference price depends on whether the demand shock is temporary or long-lasting.³ (Long-lasting shocks induce a change in the reference price, whereas temporary shocks do not.)

Our model could easily be extended to a multi-product, heterogeneous-firm model, which could thereby explain non-synchronized price changes, the occurrence of small and large price changes at the same time, and the heterogeneity of the frequency of price changes across products and firms.

The paper is structured as follows. Section 2 reviews the relevant literature. Section 3 presents our general model setup and in Section 4 we analytically and numerically analyze the effect of various demand shocks on prices and quantities while differentiating between myopic and forward-looking firms. In Section 5 empirical evidence in support of our results is presented. Section 5 concludes.

2 Relation to the Literature

The degree of price flexibility or sluggishness has been investigated in numerous empirical studies from several different angles. For example, Mussa (1981), Cecchetti (1986), Weiss (1993), Kashyap (1995) and others analyze the time series properties of prices for single product categories such as newspapers, magazines or retail catalogues, while Bills and Klenow (2004), Klenow and Kryvtsov (2004, 2008) Nakamura and Steinsson (2008a, b) and others study the behavior of aggregate price indices such as the CPI or the PPI relying on US data of the BLS. Levy et al. (1997), Blinder et al. (1998), Dutta et al. (1999) and Eichenbaum et al. (2008) investigate the movement of prices on the individual firm level by means of firm survey or scanner data from supermarket chains. While the US are the focus of the majority of empirical studies on pricing, some focus on the Euro Area, such as Alvarez et al. (2006), Dyhne et al. (2006) and Vermeulen (2012). Comprehensive meta studies on price sluggishness include Taylor (1999), Wolman (2000) and Mackowiak and Smets (2008).

Despite their different methodologies, the studies above indicate that prices do not change flexibly. There is significant heterogeneity in the frequency, sign and size of price changes across goods and regions that a theoretical model of price sluggishness should account for.

The time-dependent staggered pricing models based on Taylor (1979) and Calvo (1983), in which a firm changes its price every n periods, where n can be a fixed or a random number, fail to account for the heterogeneity in the frequency of price changes across goods and the asymmetry of price changes with respect to size and sign. However due to their analytical tractability, these models are nevertheless prominent in the contemporary macroeconomic literature. State-dependent models such as those of Rotemberg (1982), Caplin and Spulber (1987), Caballero and Engel (1993, 2007) and Golosov and Lucas (2007) use the (S, s) rule to determine the timing and size of a price change (an

³The endogeneity of the reference price enables our model to replicate the well-known finding in the marketing literature (Thaler 1985, Putler 1992) that changes in the consumers' reference price exert significant influence on the quantity demanded.

approach that originated from Sheshinski and Weiss (1977)) and thereby the resulting pricing pattern mimics the empirically observed price sluggishness.

The implications of these models for the effectiveness of monetary policy are wide open because, as Caplin and Spulber (1987) have shown, individual price sluggishness may under certain circumstances be compatible with aggregate price flexibility, implying neutrality of monetary policy.

In this paper we explore how price sluggishness arises from consumer loss aversion in an otherwise standard model of monopolistic competition. The literature on the empirical relevance of consumer loss aversion is extensive: Kalwani et al. (1990), Mayhew and Winer (1992), Krishnamurthi et al. (1992), Putler (1992), Hardie et al. (1993), Kalyanaram and Little (1994), Raman and Bass (2002), Dossche et al. (2010) and many others find evidence for consumer loss aversion with respect to many different product categories available in supermarkets. Apart from supermarket products, loss aversion in prices is also well documented in diverse activities such as restaurant visits (Morgan 2008), vacation trips (Nicolau 2008), real estate trade (Genesove and Mayer 2001), phone calls (Bidwell et al. 1995), and energy use (Griffin and Schulman 2005, Adeyemi and Hunt 2006, Ryan and Plourde 2007).

In our model loss averse consumers evaluate prices relative to a certain reference price. Köszegi and Rabin (2006, 2007, 2009) and Heidus and Köszegi (2005, 2008, 2010) argue that reference points are determined by agents' rational expectations about outcomes from the recent past. There is much of the empirical evidence suggesting that reference points are determined by expectations, in concrete situations such as the US TV show "Deal or no Deal" (Post et al. 2008), in police performance after final offer arbitration (Mas 2006), in cab drivers' labor supply decisions (Crawford and Meng 2011), in the effort choices of professional golf players (Pope and Schweitzer 2011) or with respect to domestic violence (Card and Dahl 2011). In the context of laboratory experiments, Knetsch and Wong (2009) and Marzilli Ericson and Fuster (2011) find supporting evidence from exchange experiments and Abeler et al. (2011) do so through an effort provision experiment. In our model price changes influence the consumers' future reference price and through what we call the "reference-price updating effect" alter their demand functions. This effect is well known in the marketing literature where firms are even advised to increase the demand for their product by raising their consumers' reference price through, for example, setting a suggested retail price that is higher than the price actually charged (Thaler 1985, Putler 1992).⁴

Modeling price sluggishness by means of a kinked demand curve is of course a well-trodden path. Sweezy (1939) and Hall and Hitch (1939) modeled price rigidity in an oligopolistic framework along these lines. In these models, oligopolistic firms do not change their prices flexibly because of their expected asymmetric competitor's reactions to their pricing decisions. A game theoretic foundation of such model is presented by Maskin and Tirole (1988).

⁴This literature also suggests that consumers' reference prices may also be influenced by other product characteristics such as product quality, which goes beyond the scope of our model.

There are only a few other papers that study the implications of consumer loss aversion on firms' pricing decisions. In a static context, Sibly (2002, 2007) analyzes how the pricing decision of a monopolist is affected by loss averse consumers, but in his model the consumer's reference price is exogenously given, and he does not distinguish between the different kinds of shocks and does not formally derive his results. Heidhus and Köszegi (2008) and Spiegler (2012) analyze monopolistic pricing decisions under the assumption that the reference price is determined as a consumers' recent rational expectation personal equilibrium in the spirit of Köszegi and Rabin (2006). In line with Sibly (2002, 2007) they find price variation to be considerably reduced when consumers are loss averse. In contrast to the models described here, we consider a dynamic approach with endogenous reference price formation, where the results are entirely driven by the assumption of loss averse consumers. The study closest to ours is probably Popescu and Wu (2007), who also analyze optimal pricing strategies in repeated market interactions with loss averse consumers and endogenous reference prices. However, they do not analyze the model's reaction to demand shocks.

3 Model

We incorporate reference-dependent preferences and loss aversion into an otherwise standard model of monopolistic competition. Consumers are perfect competitors (price takers). They are loss averse with respect to prices. Prices are evaluated relative to the consumers' reference prices which depend on their rational price expectations. Prices higher than the reference price are associated with utility losses, while prices lower than the reference price are associated with utility gains. Losses are weighted more heavily than gains of equal magnitude. Firms are monopolistic competitors, supplying non-durable differentiated goods. Firms can change their prices freely in every period, in accordance with profit maximization.

3.1 Consumers

The consumer's period-utility U_t depends positively on the consumption of i imperfectly substitutable nondurable goods $q_{i,t}$ and negatively on the ratio of the price $p_{i,t}$ of good i to the consumer's respective reference price $r_{i,t}$ of the good. The consumer's preferences in period t are represented by the following utility function:

$$U_t(q_{1,t}, \dots, q_{n,t}) = \left[\sum_{i=1}^n \left(\left(\frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} q_{i,t} \right)^\rho \right]^{\frac{1}{\rho}}, \quad (1)$$

where $0 < \rho < 1$ denotes the substitutability between the different goods. The parameter μ is a constant, described below. The consumer's reference price $r_{i,t}$ is formed at the beginning of each period. In the spirit of Köszegi and Rabin (2006), we assume that the consumer's reference price depends on her rational

price expectations. Shocks materialize unexpectedly in the course of the period and therefore do not enter the information set available to the consumer at the beginning of the period. We assume that consumers know, with a one-period lag, whether a shock is temporary or permanent. While temporary shocks do not provoke a change in the consumers' reference point, the reference price changes in the period after the occurrence of a permanent shock. Consequently, the consumer's reference price is given by $r_{i,t} = E_{t-1}[p_{i,t}]$. The parameter μ in the consumer's utility function (1) is an indicator function of the form

$$\mu = \begin{cases} \Gamma & \text{for } p_{i,t} < r_{i,t}, \text{ i.e. gain domain} \\ \Delta & \text{for } p_{i,t} > r_{i,t}, \text{ i.e. loss domain} \end{cases}, \quad (2)$$

which describes the degree of the consumer's loss aversion. For loss averse consumers, $\Delta > \Gamma$, i.e. the utility losses from price increases are larger than the utility gains from price decreases of equal magnitude. The consumer's budget constraint is given by

$$\sum_{i=1}^n p_{i,t} q_{i,t} = I_t, \quad (3)$$

where I_t denotes the consumer's income in period t which is assumed to be constant. For simplicity, we abstract from saving. This implies that consumers are completely myopic⁵. In each period the consumer maximizes her period-utility function (1) with respect to the budget constraint (3). The result is the consumer's period t demand for the differentiated good i which is given by

$$q_{i,t}(p_{i,t}, r_{i,t}, \mu) = \tilde{p}_t^{\eta-1} \left(\frac{p_{i,t}}{r_{i,t}} \right)^{-\mu(\eta-1)} \frac{I_t}{\tilde{p}_{i,t}^\eta}, \quad (4)$$

where $\eta = \frac{1}{1-\rho}$ denotes the elasticity of substitution between the different product varieties. The aggregate price index \tilde{p}_t is given by

$$\tilde{p}_t = \left[\sum_{i=1}^n \left(p_{i,t} / \left(\frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} \right)^{1-\eta} \right]^{\frac{1}{1-\eta}}. \quad (5)$$

A large number of firms n is assumed, so that the pricing decision of a single firm does not affect the aggregate price index \tilde{p}_t . Defining $\lambda = \eta(1 + \mu) - \mu$, we can simplify equation (4) to

$$q_{i,t}(p_{i,t}, r_{i,t}, \lambda) = r_{i,t}^{(\lambda-\eta)} p_{i,t}^{-\lambda} \tilde{p}_t^{\eta-1} I_t, \quad (6)$$

where the parameter λ denotes the price elasticity of demand, which depends on μ and therefore takes different values for losses and gains. To simplify notation, we define

$$\lambda = \begin{cases} \gamma & \text{for } p_{i,t} < r_{i,t} \\ \delta & \text{for } p_{i,t} > r_{i,t} \end{cases}, \quad (7)$$

⁵Evidence to support this assumption is provided by Elmaghraby and Keskinocak (2003) who show that many purchase decisions take place in economic environments which are characterized by myopic consumers.

with $\delta = \eta(1 + \Delta) - \Delta > \gamma = \eta(1 + \Gamma) - \Gamma$. Equation (6) indicates that the consumer's demand for good i is kinked at the reference price $r_{i,t}$. The kink, lying at the intersection of the two demand curves $q_{i,t}(p_{i,t}, r_{i,t}, \gamma)$ and $q_{i,t}(p_{i,t}, r_{i,t}, \delta)$, is given by the price-quantity combination

$$(\widehat{p}_{i,t}, \widehat{q}_{i,t}) = \left(r_{i,t}, r_{i,t}^{-\eta} \widetilde{p}_t^{\eta-1} I_t \right), \quad (8)$$

where " $\widehat{}$ " denotes the value of a variable at the kink. Changes in the reference price $r_{i,t}$ give rise to a change of the position of the kink and also shift the demand curve as a whole. However, the sign of the first order derivative of $q_{i,t}$ with respect to $r_{i,t}$ obviously depends on the sign of the difference $\lambda - \eta$. We restrict our analysis to $\lambda \geq \eta$, since that is the only case that is empirically relevant (see Thaler 1985 and Putler 1992).

Needless to say, abstracting from reference-dependence and loss aversion in the consumer's preferences represented by utility function (1), restores the standard textbook consumer's demand function for a differentiated good i , given by

$$q_{i,t}(p_{i,t}) = p_{i,t}^{-\eta} \widetilde{p}_t^{\eta-1} I_t. \quad (9)$$

We use the standard model as benchmark case, against which we compare the pricing decisions of a monopolistic competitive firm facing loss averse consumers.

3.2 Monopolistic Firms

All firms are identical, enabling us to drop the subscript i . In what follows we assume that the firm's total costs are given by $C_t(q_t) = \frac{\varepsilon}{2} q_t^2$, implying that marginal costs are linear in output: $MC_t = cq_t$. In the presence of loss aversion ($\delta > \gamma$), the downward-sloping demand curve has a concave kink at the current reference price: $\widehat{p}_t = r_t$. Thus the firm's marginal revenue curve is discontinuous at the kink:

$$MR_t(\lambda, r_t, q_t) = \left(1 - \frac{1}{\lambda} \right) \left(\frac{q_t}{r_t^{(\lambda-\eta)} \widetilde{p}_t^{\eta-1} I_t} \right)^{-\frac{1}{\lambda}}, \quad (10)$$

with $\lambda = \gamma$ for gain domain and $\lambda = \delta$ for the loss domain, respectively. The interval $[MR(\widehat{q}_t, \gamma), MR(\widehat{q}_t, \delta)]$, where $MR(\widehat{q}_t, \gamma) < MR(\widehat{q}_t, \delta)$, we call "marginal revenue gap" $MRG(\widehat{q}_t)$. We assume that in the initial steady state, the exogenously given reference price is r_{ss} . Furthermore, in the steady state the firm's marginal cost curve intersects in the marginal revenue gap, as depicted in Figure 1.

This implies that the firm's optimal price in the initial steady state p_{ss}^* is equal to r_{ss} . The proof is straightforward: Let ε be arbitrarily small. Then for prices equal to $r_{ss} + \varepsilon$ the firm faces a situation in which marginal revenue is higher than marginal costs and decreasing the price would raise the firm's profit, while for prices equal to $r_{ss} - \varepsilon$ the firm faces a situation in which marginal revenue is lower than marginal costs and increasing the price would

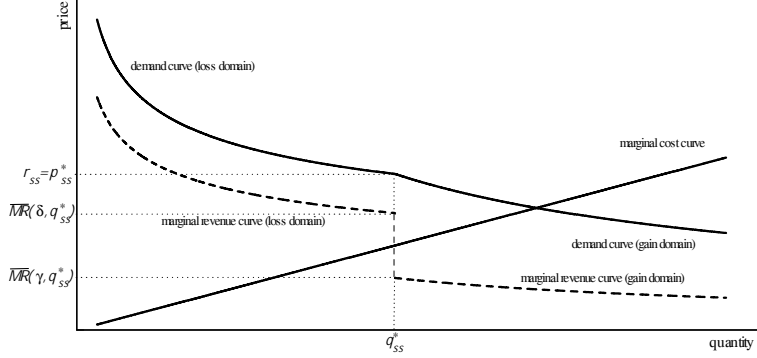


Figure 1: Initial Problem of the Monopolistic Competitor

raise the firm's profit. Thus $p_{ss}^* = r_{ss}$ has to be the profit maximizing price in the initial steady state. In the following analysis we distinguish between two types of firms facing loss averse consumers: the myopic firm and the strategic firm. While the former simply seeks to maximize its current period profit, the latter optimizes intertemporally. We compare the pricing behavior of these two firms to our benchmark case which we will refer to as the standard firm.

4 Demand Shocks

We assume that the government can affect the demand for each product i , either temporarily or permanently. These demand shocks, represented by ε_t , are unexpected and enter the demand function multiplicatively:

$$q_t(p_t, r_t, \lambda, \varepsilon_t) = r_t^{(\lambda-\eta)} p_t^{-\lambda} \tilde{p}_t^{\eta-1} I_t \varepsilon_t, \quad (11)$$

The corresponding marginal revenue functions of the firm are

$$MR_t(\lambda, r_t, q_t, \varepsilon_t) = \left(1 - \frac{1}{\lambda}\right) \left(\frac{q_t}{r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t \varepsilon_t}\right)^{-\frac{1}{\lambda}}. \quad (12)$$

We consider the effects of a demand shock that hits the economy in period $t = 0$. To fix ideas, we will assume that initially the marginal cost curve crosses the midpoint of the discontinuity in the marginal revenue curve.⁶ This assumption permits us to derive the symmetry characteristics of responses to positive and negative demand shocks. The demand shock shifts the marginal revenue curve, along with the marginal revenue gap $MRG(\hat{q}_t)$. Naturally, for a sufficiently

⁶To satisfy this condition, the slope parameter c of the marginal cost curve has to take the value $c = \frac{1}{2q_{ss}} [MR(\delta, r_{ss}, q_{ss}) + MR(\gamma, r_{ss}, q_{ss})]$

small shock, the marginal cost curve still intersects the marginal revenue curve at the discontinuity in the latter, but for a sufficiently large shock, this is not the case. The maximum size of a small shock for the demand function (11) is

$$\bar{\varepsilon}(\lambda) = \left(1 - \frac{1}{\lambda}\right) \frac{r_{SS}^{1+\eta}}{c \tilde{p}_{SS}^{\eta-1} I_{SS}}, \quad (13)$$

i.e. $\bar{\varepsilon}(\lambda)$ is the shock size for which the marginal cost curve lies exactly on the boundaries of the shifted marginal revenue gap $MRG(\hat{q}_0, \bar{\varepsilon}(\lambda))$.⁷ We consider small and large demand shocks separately and distinguish between temporary and permanent demand shocks.

4.1 Myopic Firms

The myopic firm simply cares about maximizing its current period profit. The model therefore collapses to a one-period model and we do not need to distinguish between temporary and permanent shocks for the analysis of the myopic firm's behavior.⁸ As noted, for a small demand shock $\varepsilon_t^s \leq \bar{\varepsilon}(\lambda)$ the marginal cost curve still intersects the marginal revenue gap, i.e. $MC(\hat{q}_0) \in MRG(\hat{q}_0)$. Therefore, the prevailing steady state price remains the myopic firm's profit maximizing price,⁹ i.e. $p_0^* = p_{SS}^*$, and we have complete price rigidity. Consequently, the shock elasticity of price for small demand shocks η_{p,ε^s} is zero. By contrast, the profit-maximizing quantity changes in response to a small demand shock. The new profit-maximizing quantity is $q_0^* = r_{SS}^{-\eta} \tilde{p}_0^{\eta-1} I_{SS} \varepsilon_0^s$ while the change of quantity is given by

$$\Delta q^* = \frac{q_0^*}{q_{SS}^*} = \frac{\varepsilon_0^s}{\varepsilon_{SS}} = \varepsilon_0^s \neq 1. \quad (14)$$

The shock elasticity of demand for small shocks η_{q,ε^s} is unity. Both holds true irrespective of the sign of the small demand shock.

The result of full price rigidity for small demand shocks is in clear contrast to the behavior of the standard firm since demand shocks always induce quantity and price adjustment in that case.¹⁰

For large shock, i.e. $\varepsilon_t^l > \bar{\varepsilon}(\lambda)$, the marginal cost curve intersects the marginal revenue curve outside the discontinuity of the latter. Consequently both, a price and a quantity reaction are induced. The new profit maximizing quantity of the myopic firm is

$$q_0^* = \left(\frac{1}{c} \left(1 - \frac{1}{\lambda}\right)\right)^{\frac{\lambda}{\lambda+1}} \left(r_{SS}^{(\lambda-\eta)} \tilde{p}_0^{\eta-1} I_{SS} (1 + \varepsilon_0^l)\right)^{\frac{1}{\lambda+1}}, \quad (15)$$

⁷For $\bar{\varepsilon}(\delta)$, the marginal cost curve intersects the marginal revenue gap on the upper bound, whereas for $\bar{\varepsilon}(\gamma)$ it intersects it on the lower bound.

⁸Obviously this distinction can be omitted for the standard firm in the one-period model as well.

⁹Compare the proof from Section 3.2.

¹⁰It can be easily shown that the shock elasticities of price and demand for the standard firm are $\tilde{\eta}_{\varepsilon,p}, \tilde{\eta}_{\varepsilon,q} \in (0, 1)$.

and its corresponding profit-maximizing price is

$$p_0^* = \left(\frac{r_{SS}^{(\lambda-\eta)} \tilde{p}_0^{\eta-1} I_{ss} (1 + \varepsilon_0^l)}{q_0^*} \right)^{\frac{1}{\lambda}}. \quad (16)$$

In comparison to the standard firm the price reaction of the myopic firm to a large demand shock is smaller whereas the quantity reaction is larger. For large demand shocks we therefore find that loss aversion induces price sluggishness for the myopic firm. The intuition is obvious once we decompose the demand shock into the maximum small shock and the remainder:

$$\varepsilon_0^{large} = \bar{\varepsilon}(\lambda) + \varepsilon_0^{rem}. \quad (17)$$

From our theoretical analysis above we know that the maximum small shock $\bar{\varepsilon}(\lambda)$ has no price effects, but feeds one-to-one into demand for the myopic firm but not for the standard firm. By contrast, the remaining shock ε_0^{rem} induces a price and quantity reaction for both. Yet, the price reaction of the myopic firm induced by ε_0^{rem} is smaller. The reason is that the degree, to which the adjustment takes place, depends negatively on the price elasticity of demand in the respective firm's demand function. According to equations (6) and (9), the price elasticities of demand are λ for the myopic firm and η for the standard firm. Since by definition $\lambda > \eta$, the price reaction of the myopic firm must be smaller than that of the standard firm. Hence, for the myopic firm the overall effect is clearly less pronounced for prices, which implies a larger output reaction.

Next, it is easy to show that the price-quantity responses of the myopic firm to large positive and large negative demand shocks of the same size are asymmetric. To see this, the decomposition (17) again proves useful. As we have seen, the maximum small shock $\bar{\varepsilon}(\lambda)$ has symmetric effects for the myopic firm: no price effect and symmetric quantity effects. This holds true irrespective of the sign of the shock. However, the remainder ε_0^{rem} has asymmetric effects, for the simple reason that large positive demand shocks move the myopic firm along the relatively flat portion of the demand curve, whereas large negative demand shocks move it along the relatively steep portion of the demand curve. The reaction of the optimal price and quantity of the myopic firm in response to a large positive shock is therefore smaller than the reaction to a large negative shock. This asymmetry in the reaction to positive and negative large demand shocks is a distinct feature of consumer loss aversion and stands clearly in contrast to the case of the standard monopolist where no such asymmetry is found.

4.2 Strategic Firms

The strategic firm seeks to maximize the discounted stream of current and future profits. The one-period-lagged updating of the consumers' reference price induced by permanent demand shocks therefore influences the strategic firm's immediate pricing decision in the shock period. In order to capture this we

extend the model of the previous section to two periods.¹¹ Since there is no updating of the consumers' reference price in the case of temporary demand shocks, the behavior of the strategic firm in the shock period is identical to that of the myopic firm and needs not to be repeated.

Instead we focus on permanent demand shocks. If the strategic firm changes its price in the shock period $t = 0$ in response to a permanent demand shock to p_0^* , consumer's update their reference point in the following period $t = 1$, i.e. $r_1 = E_0[p_1] = p_0^*$. Therefore, price increases in response to permanent positive demand shocks lead to increases in the consumer's reference price. Consequently, the demand curves shift and the kink rises to

$$(\hat{p}_1, \hat{q}_1) = \left(r_1, r_1^{-\eta} \tilde{p}_1^{\eta-1} I_0 \varepsilon_1 \right). \quad (18)$$

Analogously, for price decreases in response to permanent negative demand shocks the reference price falls and the kink drops. The strategic firm can anticipate this. Thus it may have an incentive to set its price above the optimal myopic price ($p'_0 > p_0^*$) in order to drive up the consumers reference price and thereby increase the demand for its product in the following period. We term this phenomenon the "reference-price-updating effect."¹²

Whether or not the strategic firm exploits the reference-price-updating effect depends on the outcome of the following tradeoff. Increasing the price above the current period profit maximizing price¹³ will lower the firm's current period profit suboptimally. However, the rightward shift of the kinked demand curve resulting from updating the consumers' reference price in the next period increases demand in that period and hence profits. To analyze which effect dominates, we calibrate the model and solve it numerically.

4.3 Calibration

We calibrate the model for a quarterly frequency in accordance with standard values in the literature. We assume an annual interest rate of 4%, which yields a discount factor $\beta = 0.99$. We follow Schmitt-Grohé and Uribe (2007) and set the monopolistic markup to 25%, i.e. $\eta = 5$, which is also close to the value supported by Erceg et al. (2000) and which implies that goods are only little substitutable, i.e. $\rho = 0.8$. Since we impose $\lambda \geq \eta$, we set $\gamma = 6$ in our base calibration. Loss aversion is measured by the relative slopes of the demand curves in the gain and loss domain, i.e. $\kappa = \frac{\delta}{\gamma}$. The empirical literature on loss aversion in prices finds that losses induce demand reactions approximately twice as large as gains (Tversky and Kahnemann 1991, Putler 1992, Hardie et al 1993, Griffin and Schulman 2005, Adeyemi and Hunt 2007). Therefore, we

¹¹The two-period problem approximates the case in which the firm is non-myopic, but a hyperbolic discounter.

¹²Needless to say, lowering the price with the aim to decrease the reference point permanently is not a preferable option for the strategic firm. The resulting drop of the reference price crowds out future demand and therewith profits.

¹³This is just the optimal price chosen by the myopic firm.

	myopic firm		strategic firm		standard firm	
	$\tilde{\eta}_{\varepsilon,p}$	$\tilde{\eta}_{\varepsilon,q}$	$\tilde{\eta}_{\varepsilon,p}$	$\tilde{\eta}_{\varepsilon,q}$	$\tilde{\eta}_{\varepsilon,p}$	$\tilde{\eta}_{\varepsilon,q}$
$\varepsilon_0^s = 1.01$	0	1	0.0100	0.8789	0.1660	0.1660
$\varepsilon_0^s = 1.03$	0	1	0.0667	0.1866	0.1646	0.1646
$\varepsilon_0^l = 1.05$	0.0035	0.9560	0.0755	0.0717	0.1633	0.1633
$\varepsilon_0^l = 1.07$	0.0232	0.7046	0.0790	0.0216	0.1620	0.1620

Table 1: Shock elasticities of price and output in $t = 0$ to positive permanent demand shocks, $\bar{\varepsilon}(\gamma) = 1.0476$

	myopic firm		strategic firm		standard firm	
	$\tilde{\eta}_{\varepsilon,p}$	$\tilde{\eta}_{\varepsilon,q}$	$\tilde{\eta}_{\varepsilon,p}$	$\tilde{\eta}_{\varepsilon,q}$	$\tilde{\eta}_{\varepsilon,p}$	$\tilde{\eta}_{\varepsilon,q}$
$\varepsilon_0^s = 0.99$	0	1	0	1	0.1674	0.1674
$\varepsilon_0^s = 0.97$	0	1	0	1	0.1688	0.1688
$\varepsilon_0^l = 0.95$	0.0072	0.9592	0.0012	0.9934	0.1702	0.1702
$\varepsilon_0^l = 0.93$	0.0484	0.7264	0.0013	0.9927	0.1717	0.1717

Table 2: Shock elasticities of price and output in $t = 0$ to negative permanent demand shocks; $\bar{\varepsilon}(\delta) = 0.9524$

set $\kappa = 2$. The exogenous variables income I and price index \tilde{p}_t are normalized to unity.¹⁴

4.4 Numerical Simulation

Tables 1 and 2 present the numerical results of our base calibration for positive and negative demand shocks in the two-period model. In the tables we report the shock-arc-elasticities of price ($\tilde{\eta}_{\varepsilon,p} = \frac{\% \Delta p}{\% \Delta \varepsilon}$) and output ($\tilde{\eta}_{\varepsilon,q} = \frac{\% \Delta q}{\% \Delta \varepsilon}$) in the period of the shock $t = 0$ for the myopic firm, the strategic firm and the standard firm. We focus on permanent demand shocks since we are interested in the influence of the reference-price-updating-effect on the immediate price and output reaction of the strategic firm.¹⁵

The results in Table 1 and 2 confirm the theoretical analysis above for the myopic firm. For small demand shocks we find complete price rigidity. For large demand shocks the pricing reaction of the myopic firm is more sluggish compared to the standard firm while output adjusts to a larger degree. Finally when comparing the shock-arc-elasticities for large positive demand shocks in Table 1 to the shock-arc-elasticities for large negative demand shocks of the same size in Table 2, we find the asymmetry described in Section 4.1, i.e. the

¹⁴All results are completely robust to variations of these numerical values.

¹⁵Note that in the two-period model there is no difference in the immediate price and output reaction of the myopic firm and the standard firm with respect to temporary and permanent demand shocks. The reason is that the myopic firm simply ignores future periods for its current period decision while the problem of the intertemporally optimizing standard firm is completely time-separable.

price-quantity reaction of the myopic firm in response to large positive shocks is smaller than the reaction to a large negative shocks.

The numerical results in Tables 1 and 2 show that not all of these results carry over to the strategic firm. Due to the reference-price-updating effect the price adjustment of the strategic firm is generally more pronounced than that of the myopic firm for positive demand shocks, while it is muted for negative demand shocks. We find that in response to positive demand shocks the strategic firm increases its price irrespective of the size of the shock (see Table 1). The reference-price-updating-effect therefore invalidates the result of full price rigidity for small positive demand shocks found for the myopic firm. However, for small negative demand shocks Table 2 shows that prices of the strategic firm are fully rigid. For large negative demand shocks the strategic firm adjusts its price but to a considerably lower extent than for large positive shocks of equal size. The reference-price-updating effect therefore gives rise to a completely different asymmetry in the case of the strategic firm, namely that price rigidity is considerably more pronounced for negative than for positive demand shocks. This asymmetry can easily be explained intuitively. By keeping the price (almost) unaltered in response to negative demand shocks, the strategic firm seeks to stabilize the consumer's reference price. This in turn avoids the negative reference-price-updating effect, which otherwise would follow from the price decrease. This also has striking implications for the analysis of price setting strategies. Since the strategic firm avoids price reductions, which lead to downward-adjustments in the reference price, but conducts price reductions, which do not influence the reference price, loss aversion offers a simple rationale for the firm's practice of sales.

Finally, a result that directly carries over from the myopic to the strategic firm is that prices are generally more sluggish compared to the standard firm. Loss aversion therefore induces price sluggishness irrespective of the sign or the size of the demand shock, even in a non-static framework.

5 Empirical Evidence

The main results of our model can be summarized as follows: (i) consumer loss aversion with respect to prices generates price sluggishness (ii) price adjustment is asymmetric for positive and negative demand shocks of equal size and (iii) the firm's pricing decision is state-dependent. In this section we confront these theoretical results with the available microeconomic and macroeconomic evidence.

To our knowledge, there is no hard evidence for a direct link from consumer loss aversion to price sluggishness yet. However, there is ample evidence from survey data on firms' pricing behavior for the Euro Area, the United States and a number of single industrialized countries such as the UK or Canada stating that the most important driver of firms's reluctance to adjust prices flexibly is their disinclination to harm their relationships with their customers (see Blinder et al. 1998, Hall et al. 2000, Amirault et al. 2004, Zbaracki et al. 2004, Fabiani et

al. 2006, Kwapil et al. 2010, Martins 2010, Greenslade and Parker 2012). Since these customers are loss averse, which has been well documented in the literature (see Section 2), this evidence suggests that loss aversion could indeed lead to price sluggishness. For a firm trying to avoid antagonizing its customers through price increases, the more sensitive the customers are to price increases (i.e. the more loss averse they are), the more sluggish this firm’s pricing behavior will be. While our model accounts for the important role of customer relationships for the firm’s pricing decision neither time-dependent nor other state-dependent models of price sluggishness do.¹⁶ A cross-country experimental study by Rieger et al. (2011) indicates that people are more loss averse in the Euro area compared to residents of the United States. Along the lines of our model this implies that prices should be stickier in the Euro area compared to the United States which is indeed empirically confirmed by the literature (Alvarez et al. (2006), Dhyne et al. (2006), Nakamura and Steinsson 2008, Klenow and Malin 2010).

According to our model prices react asymmetrically for positive and negative demand shocks of equal size. This finding is empirically confirmed by a number of survey studies, e.g. Fabiani et al. (2006) for the Euro Area, Hall et al. (2000) for the UK, Martins (2010) for Portugal, and Kwapil et al. (2010) for Austria. Dhyne et al. (2009) who develop three indicators of price rigidity additionally provide econometric evidence for the asymmetric reaction of prices for the Euro Area.¹⁷

With respect to output our model predicts that permanent negative demand shocks induce larger output responses than analogous positive demand shocks. Evidence in support of this finding the context of monetary policy shocks is found, for instance by DeLong and Summers (1988), Cover (1992), Morgan(1993), Weise (1999), Kandil (2002), and Ravn and Sola (2004) for the United States, by Karras (1996) for a variety of European economies, Karras and Stokes (1999) for 12 different OECD countries, and Tan et al. (2010) and Mehrara and Karsalari (2011) for a variety of non-OECD countries. Kandil (1998, 1999) documents such asymmetry for a wide range of developing and developed countries in response to aggregate demand shocks. Finally, Kandil (2001, 2002) provides empirical evidence for the asymmetric output reaction to government spending shocks in the United States.

For the state-dependence of the firms’ pricing decision the survey data provides supportive evidence as well. Fabiani et al. (2006) find that in the Euro Area for more than 60 percent of the firms pricing is indeed driven by the current state of the environment. Blinder et al. (1998) confirm this result for the United States. In Sweden it is even 75 percent of the firms that have some form of state dependent pricing (Apel et al. 2005) while in the UK state-dependent pricing seems to be somewhat less important (Hall et al. 2000). In Portugal state-dependent pricing is dominant (Martins 2010). Menu costs, giving rise to

¹⁶One example here is Rotemberg (2005, 2010) who specifically accounts for “customer anger” and “customer regret” to model price sluggishness.

¹⁷Moreover, Kwapil et al. (2010) find that for small demand shocks most firms keep prices constant which is also in line with the predictions from our model.

one of the most prominent state-dependent pricing models, are clearly rejected as significant driver for deferred price adjustments (see e.g. Apel et al. 2005, Hall et al. 2000, Greenslade and Parker 2012, Amirault et al. 2004, Kwapil et al. 2010, Martins 2010).

6 Conclusion

In contrast to the standard time-dependent and state-dependent models of price sluggishness, our theory of price adjustment is able to account for different price and quantity adjustments to large and small shocks and asymmetric price and quantity responses to positive and negative shocks of equal magnitude. Again in contrast to the standards time-dependent and state dependent models, our explanation of price adjustments is derived entirely from microfoundations, without any recourse to ad hoc assumptions concerning the frequency of price change or physical costs of price adjustments.

Future research needs to extend our theory in various ways. Consideration of heterogeneous firms and multiproduct firms will enable this model to generate asynchronous price changes, as well as the simultaneous occurrence of large and small price changes and heterogeneous frequency of price changes across product. Extending the model to a stochastic environment will generate testable implications concerning the variability of individual prices.

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