Price Setting and Price Stickiness:  
A Behavioral Foundation of Inaction Bands  

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Abstract  

This paper puts forward a model of price setting based on three elements of Prospect Theory introduced by Kahneman and Tversky (1979) and refined by subsequent work: i) people evaluate different aspects of their choices separately (narrow bracketing); ii) people evaluate prospective outcomes relative to a reference point (reference dependence); iii) prospective losses loom larger than prospective gains (loss aversion). The model predicts a pricing rule that involves an inaction region. Firms underreact compared to the canonical neoclassical model when updating their prices upwards or downwards. The model replicates two empirical patterns of the microdata that standard menu cost models have difficulty accounting for: i) The distribution of price changes has both small and large price changes, and ii) the hazard function of price changes is downward sloping initially, that is, firms that have just recently changed their price have a higher probability of changing it again, while this probability becomes constant thereafter.

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1 Introduction

Price “stickiness” is crucially important to the field of monetary economics. In the absence of some sort of friction, monetary policy is neutral, i.e. it has no allocative role. While several theories have been proposed suggesting, for example, the presence of adjustment costs (menu cost models) or an exogenous arrival process for price setting (Calvo model) as sources of price rigidities, no consensus has been reached on the underpinnings of these assumptions, leaving our understanding of the sources of price frictions incomplete.

In addition, the empirical literature has identified two salient facts of pricing microdata that traditional models have difficulty accounting for. First, the distribution of price changes is dispersed, having both small and large price changes (Midrigan, 2011). Second, the hazard function of price changes is downward sloping for the first few periods, that is, firms that have just recently changed their price have a higher probability of changing it again, while this probability becomes constant after a few periods (Nakamura and Steinsson, 2008).

This paper argues we can improve our understanding of price rigidities by refining the way we model firm decision making. It suggests a new source of price friction by applying narrow bracketing (Thaler 1980, 1985; Tversky and Kahneman, 1981; Read et al., 1999) and prospect theory (Kahneman and Tversky, 1979) to model how firms set their prices. The model relies on three basic assumptions, all of which are supported by experimental evidence as discussed in the next section, and investigates how their incorporation sheds light on our understanding of documented facts in pricing microdata.

The first assumption builds on a classic experimental result due to Tversky and Kahneman (1981), where the vast majority of subjects made a choice clearly dominated by another option in their choice set, thus violating standard notions of rationality. Kahneman and Tversky suggested that the observed behavior was consistent with people evaluating different aspects of their choices separately. Such type of separation has been termed narrow
**bracketing.** This frame of evaluation is to be contrasted with one of broad bracketing, where, as in the rational benchmark, people are assumed to evaluate their options taking all aspects of the problem into consideration.

Even though narrow bracketing was artificially induced to the subjects in the experimental setting, it can emerge naturally in real-world settings. The current paper proposes the application that a firm manager evaluates revenues and costs separately.

The second assumption, a key tenet of prospect theory, is that in evaluating outcomes, the decisionmaker takes into account a *reference point*, typically identified with the “status quo.” That means that outcomes are perceived as gains or losses depending whether they are above or below a reference outcome that is judged neutral. In the context of a firm, a natural application of this idea is that the reference point for any prospective level of the firm’s revenues and costs is the revenues and costs of inaction, that is the revenues and costs if the manager leaves the price unchanged from its previous period value.

Finally, the paper assumes that in evaluating gains and losses (i.e. revenues and costs relative to reference points) the firm is *loss averse* – another fundamental assumption in all the literature that has applied and refined prospect theory. In the context of firm price setting, loss aversion captures that any prospective negative outcome – either in the form of increased cost or decreased revenue, is weighted more than a prospective gain – either in the form of increased revenues, or in the form of cost saving.

The main result of the paper is that these three assumptions, when applied in a context of a monopolist setting prices optimally, give rise to an inaction band. The decision maker chooses not to change the price if the previous period price is inside a well defined interval, otherwise they update the price to whichever bound of the interval is closer. Compared to the neoclassical benchmark, the model also predicts rigid reactions: when firms do update their price upwards or downwards, they underreact compared to how they would react in absence of the behavioral assumptions. The model replicates both facts of pricing microdata previously referred to that traditional models have a difficulty accounting for (Nakamura and Steinsson, 2008; Midrigan, 2011).
The key to understanding why prices may remain unchanged is that when considering whether to change its price, the firm overweights the negative aspects of such a choice because of loss aversion, compared to the benchmark case of no loss aversion. Consider a firm that wants to decrease its price relative to its past value due to a change in its marginal cost. This choice comes with the prospect of more units sold, thus higher total costs, but at the same time, assuming sufficiently more people will buy the product at the lower price, with the prospect of higher revenues. Higher prospective revenues are a positive outcome, while higher prospective costs a negative one. Assume that under no loss aversion the net outcome of the two is positive, thus the firm would indeed want to decrease its price. However, under sufficiently large loss aversion, the overweighting of the negative outcome (higher costs) will eliminate the prospective gain (higher revenues), making the net outcome of the choice a negative one, thus the firm will choose not to update its price. The same intuition can be applied when contemplating a price increase in response to a higher marginal cost. As we will see, this intuition captures the mechanism that creates inaction bands that become larger, as the degree of loss aversion becomes larger.

The most commonly used model of price rigidity, proposed by Calvo (1983), assumes that firms face a constant probability at each point in time of “being able” to adjust their price to their desired level. This reduced-form assumption, which forms the key building block of the New Keynesian workhorse model, has been proven extremely useful to allow us to study the real effects of monetary policy. It makes, however, no pretense of microfoundation, and there is no consensus as to what may give rise to the firm’s inability/unwillingness to change their price.

Originally proposed by Barro (1972), the family of models that has often been proposed as a more realistic modeling device than the Calvo model for the lack of price adjustment is “menu cost” models. Menu costs are assumed to correspond to either physical (printing of new catalogs) or metaphorical (time, effort etc.) price adjustment costs. Even though a number of influential papers (e.g. Golosov and Lucas, 2007; Nakamura and Steinsson, 2010) have studied the effects of monetary policy on aggregate production through such a lens, the empirical studies of Nakamura and Steinsson (2008) and Midrigan (2011) have highlighted
two facts of pricing microdata with which the standard menu cost model is not consistent. Midrigan (2011) proposed a “second generation” menu cost model refining the menu cost assumption. In that model, firms are assumed to face economies of scope in their adjustment costs. With this refinement and an assumed process of TFP shocks that features fat tails, the menu cost model is made consistent with the observed distribution of price changes but does not account for the downward sloping hazard function. Nakamura and Steinsson (2008) suggest that a refinement of the benchmark menu cost model with heteroskedastic shocks to input costs can account for the shape of the hazard function.

However, there is still no consensus in the literature on the exact interpretation of “menu costs,” making these models lose some of their appeal as a microfoundation, and making the credible measurement of such costs difficult. Contrary to the direction of “next generation” menu cost models, this paper takes the stand that the menu cost assumption doesn’t need to be refined, but instead replaced by behavioral assumptions that have been shown to be empirically relevant in experimental settings. As we will see this will allow us to capture some of the empirical patterns that existing models have struggled with.

Finally, a recent literature (e.g. Sibly, 2002; Rotemberg, 2005, 2010, 2011; Heidhues and Kőszegi, 2014; Eyster et al., 2019) explores how consumer behavioral biases affect rational firm pricing. In a sense that literature is the polar extreme of the current paper: both explore the implications of biases on pricing, but apply them to different sides of the customer-firm interaction. In that literature any bias on the firm side is shut down, allowing only for departures from the rational benchmark on the consumer side. In the present paper any bias on the consumer side is shut down, exploring the implications of biases on the firm side, bridging the literature on price rigidities with the biased managers perspective of behavioral corporate finance (Malmendier, 2018) and the related work on biased professionals (e.g. Camerer et al., 1997; Pope and Schweitzer, 2011).

The rest of the paper is structured as follows. Section 2 introduces notation and illustrates the application of prospect theory and narrow bracketing to firm price setting. In section 3, I derive analytically the existence of an inaction band and compare the model to its frictionless
counterpart. Section 4 discusses the generalizability and robustness of our assumptions. Section 5 is the main quantitative section of the paper: I solve a dynamic extension of the firm’s problem in a monopolistically competitive environment and present the empirically relevant results of the model. Section 6 concludes by providing a discussion of the findings and directions for future research.

2 Applying prospect theory and narrow bracketing to firm pricing decisions: An overview

This section goes over the notions of narrow bracketing, reference dependence, and loss aversion and shows how they can be applied in the context of firm price setting. The basic notation is introduced. Some of the key evidence in support of these assumptions and related studies that have used them are presented.

**Narrow bracketing:** Tversky and Kahneman (1981) presented subjects with the following hypothetical situation:

*Imagine that you face the following pair of concurrent decisions. First examine both decisions, then indicate the options you prefer.*

**Decision (i).** Choose between

- A. a sure gain of $240
- B. 25% chance to gain $1000, and 75% chance to gain nothing

**Decision (ii).** Choose between

- C. a sure loss of $750
- D. 75% chance to lose $1000, and 25% chance to lose nothing

Since the subjects have to make a decision both in (i) and (ii), it is apparent that they face four options to choose from: \{AC, BC, BD, AD\}. Among the subjects 73% chose the option AD, which combines a sure gain of $240 with a 75% chance to lose $1000, while only 3% chose the option BC, which combines a 25% chance to gain $1000 with a sure loss of $750. However, a simple computation yields that AD is dominated by BC. Indeed when Tversky and Kahneman presented subjects with the options explicitly combined, no subject chose AD:
Choose between
AD. a 25% chance to win $240, and 75% chance to lose $760 [0% of subjects]
BC. a 25% chance to win $250, and 75% chance to lose $750 [100% of subjects]

The authors suggested that the seemingly paradoxical behavior can be explained by how the problem was framed, artificially inducing the subjects to compare $A$ to $B$, and $C$ to $D$ in isolation using the prospect theoretic value function (Kahneman and Tversky, 1979) in each case:

![Figure 1: Narrow bracketing: subject evaluates outcomes by applying prospect theoretic value function in each bucket.](image)

\[(A > B) \& (D > C) \rightarrow AD > BC\]

The separation in the two “buckets” was artificially induced to the subjects in the experiment, but it can arise naturally in real-world contexts. The present paper suggests that a natural application in the context of firm pricing decisions is one where the “gains-inflows” bucket corresponds to “revenues,” and the “losses-outflows” bucket to “costs.”

Let us map the experimental setup to a firm price-setting context. A firm manager contemplates what price to set. They consider four options that correspond to four prospective
outcomes \{AC, BC, BD, AD\}. Revenue outcomes can take two values, denote \(r = \{A, B\}\), and cost outcomes can also take two values, denote \(c = \{C, D\}\). To simplify the exposition let us limit ourselves to the two options of direct interest, and assume the manager wants to decide between the two prices \(\{p_{BC}, p_{AD}\}\) that correspond respectively to the outcomes \(\{BC, AD\}\). The firm will then be seen to charge \(p_{AD}\), because it gives both better revenue and cost prospects compared to \(p_{BC}\) as shown by using the prospect theoretic value function to evaluate the outcomes in each bucket. In the figure we show how the prospect theoretic value function is used to compare the outcomes within each “bucket.”

More generally, denote by \(r, c\) revenues and costs respectively that depend on the choice of a price, and denote by \(v(\cdot)\) the prospect theoretic value function. The decision maker will be assumed to choose the price that maximizes

\[
v(r; \tilde{r}) + v(-c; -\tilde{c})
\]

where \(\tilde{r}, \tilde{c}\) are parameters - the reference points, which will be discussed momentarily. For now, as is the case in the above experiment, we can assume that \(\tilde{r} = \tilde{c} = 0\).

Narrow bracketing, most often combined with prospect theory as above, has found application in various contexts to explain choice both under risk and in the absence of it. In the above experiment, subjects choose between risky gambles. Barberis and Huang (2001) use narrow bracketing (combined with prospect theory) to explain stylized facts of stock prices: each “bucket” is a stock in the investor’s portfolio, and the choice is how much to invest in that stock. In a riskless context, Bordalo et al. (2019) use narrow bracketing to explain consumption choices, where the two “buckets” are the product’s quality and price. Prelec and Lowenstein (1998), also in a riskless context, combine narrow bracketing with prospect theory to propose a framework of consumer behavior where the “buckets” are time-stamped instances of consumption utility and payment.

**Reference dependence:** The prospect theoretic value function is defined on deviations from a reference point, to reflect that “[...] our perceptual apparatus is attuned to the
evaluation of changes or differences rather than to the evaluation of absolute magnitudes.” (Kahneman and Tversky, 1979)

As with narrow bracketing, a reference point can be artificially induced to subjects in experimental settings, but in the real world it depends on the particular context. Indeed, a number of theories have been proposed formalizing types of reference points that seem applicable in different contexts.\footnote{Prelec and Lowenstein (1998) suggest that within each “bucket” mentioned above, a reference point is present that captures the intuitively appealing example that at the time you “consume” vacation, you compare your utility with a sense of how much you have paid for it, and at the time you pay for a vacation package, part of the cost is buffered by the anticipation of its consumption. K˝oszegi and Rabin (2006) formalize the idea that in some contexts reference points are likely to correspond to ex-ante expected outcomes. For example, if you expect to dine at a restaurant but find it closed, you perceive it as a loss, however if you already knew there was good chance it would be closed, you don’t. Bordalo et al. (2019) propose a model of reference dependence reflecting that what is perceived as the “normal” or “representative” outcome varies by circumstance. For example, you expect to pay more for a bottle of water in an airport than in a grocery store. Galor and Savitsky (2018), in a context of long-run growth choose the level of subsistence consumption as the natural point of reference.}

A common choice for the reference outcome is the “status quo,” which corresponds to the decision maker’s “current position.” (Kahneman and Tversky, 1979, 1991) For example, the reference point in the above Tversky and Kahneman (1981) experiment is assumed to be 0, and it is an instance of the status quo alternative, corresponding to the outcome of not participating in the experiment. Samuelson and Zeckhauser (1988) present further experimental evidence consistent with people evaluating alternative decisions against a (preselected) status quo option.

The status quo is of relevance as a reference point because, as Samuelson and Zeckhauser (1988) put it, “[...] doing nothing or maintaining one’s current or previous decision is almost always a possibility,” and this option carries a very “influential label.” In other words it is natural to compare all alternative outcomes to the status quo, because it is the feasible outcome that stands out; it is the obvious alternative. Barberis et al. (2001) and Barberis and Huang (2001) propose the risk-free rate to be the reference point against which investors
evaluate stock returns. It is a modeling choice with a strong status quo flavor, as the risk-free asset can be thought as the default or “obvious” alternative option, instead of investing in any particular asset.

Considering the above, I choose the reference outcome in this model to be the revenues and costs the firm will get if it leaves its price unchanged, i.e. the status quo revenues and costs. This reference point yields the natural interpretation that the manager assesses each prospective outcome of setting a new price by comparing it to the default choice of doing nothing.

Revenues are a function of price $p$ and a demand shifter $\Gamma$.

$$r \equiv r(p; \Gamma)$$

Costs are a function of unit cost of production $w$, a productivity shifter $A$, and, through demand, price $p$ and the demand shifter $\Gamma$.

$$c \equiv c(p; w, A, \Gamma)$$

Now, $\tilde{r}, \tilde{c}$ are the reference points with respect to which the firm is loss averse. They are defined as follows:

$$\tilde{r} \equiv r(\tilde{p}; \Gamma)$$

$$\tilde{c} \equiv c(\tilde{p}; w, A, \Gamma)$$

The firm chooses $p$ while everything else is taken as given. $\tilde{p}$ corresponds to previous period price. Notice that in the reference points, $\tilde{p}$ is previous period price, while productivity, wages and the demand shifter are at current period levels. Thus the reference points capture the revenues and costs of inaction, i.e. the status quo. In other words, the price setter chooses their optimal response to the new reality, conditional on their cognitive-psychological biases.

**Loss aversion:** Loss aversion captures the empirically documented fact that “[t]he aggravation that one experiences in losing a sum of money appears to be greater than the pleasure associated with gaining the same amount.” (Kahneman and Tversky, 1979). Its impact on how outcomes are perceived is illustrated by an example noted by Thaler (1980). Shortly
before the writing of Thaler’s paper, it became apparent that firms would be allowed by law to pass on the cost of processing credit card payments to consumers, something that credit card companies had not been allowing them to do. Credit card companies then, presumably understanding that customers are loss averse and would thus be less willing to accept a loss than to forgo a gain, lobbied so that the difference in price be presented as a cash discount rather than a credit card surcharge. That way credit card companies tried to minimize the perceived cost by customers of paying by credit card.\footnote{Another experimental illustration of loss aversion is given by Problems 1 & 2 presented in Tversky and Kahneman (1981).}

Loss aversion is a key feature of prospect theory embedded in its proposed value function, which is steeper for losses (negative outcomes) than gains (positive outcomes).

For $x = \{r, -c\}$, the specification of the prospect theoretic value function used in our model is a piece-wise linear function, which is the specification most commonly used in the literature following the original Kahneman and Tversky (1979) paper (e.g. Kőszegi and Rabin (2006), Barberis et al. (2001))\footnote{One can think of this simplification as a local approximation of the value function around the reference point. The S-shape value function plotted in the figure in the beginning of the section features diminishing sensitivity in gains and losses.}

\[
v(x; \tilde{x}) = \begin{cases} 
  x - \tilde{x} & \text{if } x \geq \tilde{x} \\
  \lambda (x - \tilde{x}) & \text{if } x < \tilde{x}
\end{cases}
\]

Naturally a prospective increase in revenues is evaluated as a gain, as is a prospective decrease in costs. $\lambda > 1$ captures loss aversion reflecting that any gain, either in the form of increased revenues, or in the form of cost saving, is weighted less than a loss, either in the form of increased cost or decreased revenue.

### 3. An illustrative example

Let us start with the simplest possible case where future expectations play no role in today’s decision: a static setup. I show analytically that based on our assumptions, the firms’
pricing rule involves an inaction band, implying that firms exhibit price stickiness at times. In addition, the pricing rule is such that, even when firms do change their price, they exhibit some “rigidity” compared to the rational benchmark. I generalize the setup in section 4 for forward-looking agents and show numerically that the same pricing rule carries through.

As introduced in the previous section, the firm is assumed to maximize:

\[ U(r, c; \tilde{r}, \tilde{c}) = v(r; \tilde{r}) + v(-c; -\tilde{c}) \]

where \( r, c \) correspond to revenues and costs, respectively, and depend on the firm’s choice of price today, and \( \tilde{r}, \tilde{c} \) are the reference points corresponding to the status quo.

Let us assume a linear production function, with labor being the only factor of production. As introduced in the previous section, \( w \) denotes the unit cost of production and \( A \) denotes an idiosyncratic productivity shock. The firm is assumed to face an isoelastic demand curve, \( D(p; \Gamma) = \Gamma p^{-\epsilon} \), where \( \epsilon > 1 \) is the price elasticity of demand, assumed to be constant, and \( \Gamma > 0 \) is a demand shifter. \( p \) denotes this period’s price, chosen by the firm, and \( \tilde{p} \) denotes previous period price, i.e. the status quo price. We thus have:

\[
\begin{align*}
    r &\equiv r(p; \Gamma) = \Gamma p^{1-\epsilon} \\
    \tilde{r} &\equiv r(\tilde{p}; \Gamma) = \Gamma \tilde{p}^{1-\epsilon} \\
    c &\equiv c(p; w, A, \Gamma) = \frac{w}{A} \Gamma p^{-\epsilon} \\
    \tilde{c} &\equiv c(\tilde{p}; w, A, \Gamma) = \frac{w}{A} \Gamma \tilde{p}^{-\epsilon}
\end{align*}
\]

Thus both \( r(\cdot; \Gamma) \), and \( c(\cdot; w, A, \Gamma) \) are decreasing in their first argument. This monotonicity of revenues and costs allows us to express the objective as a function of \( p \), for given \( \tilde{p}, w, A, \Gamma \), in a straightforward way:

\[
U(p; \tilde{p}, w, A, \Gamma) = \begin{cases} 
    r - \tilde{r} - \lambda (c - \tilde{c}) & \text{if } p \leq \tilde{p} \\
    \lambda (r - \tilde{r}) - (c - \tilde{c}) & \text{if } p > \tilde{p}
\end{cases}
\]

where I have suppressed the arguments of \( r, c, \tilde{r}, \tilde{c} \) for expository convenience. The price \( p \) is the choice variable, while \( (\tilde{p}, w, A, \Gamma) \) is the state.

The following figure plots the objective function for a given state \( (\tilde{p}, w, A, \Gamma) \). The blue line corresponds to the top branch of equation (1), while the red line corresponds to the bottom
branch. For reference purposes, the black dotted line shows the objective function for the case when $\lambda = 1$.

![Diagram of objective function](image)

**Figure 2:** Objective function $U(p)$ at a given state $(\tilde{p}, w, A, \Gamma)$.

The blue line corresponds to the top branch of equation (1), while the red line corresponds to the bottom branch. The objective function is given by the two solid lines: for prices below $\tilde{p}$, $U(\cdot)$ is indicated by the blue line, while for prices above $\tilde{p}$ it is indicated by the red line. $p_*$ depicts the maximizer of the bottom branch, and $p^*$ the maximizer of the top branch of $U(\cdot)$. The dotted black line corresponds to the objective function for $\lambda = 1$.

For prices below $\tilde{p}$ we are on the top branch of equation (1), represented by the blue line in the figure. If we were to continue on the top branch for prices above $\tilde{p}$, we would stay on the blue line. However, for prices above $\tilde{p}$, we switch to the bottom branch of the objective function, thus to the red line, which is why the top branch of the objective function (blue line) is shown as dotted for prices above $\tilde{p}$. For the same reason the bottom branch of the objective function (red line) is shown as dotted for prices below $\tilde{p}$.

The top branch of the objective function (blue line) overweights the change in costs, while
the bottom branch overweights the change in revenues. Changes in revenues and costs are
evaluated relative to the reference point corresponding to the status quo. At the status quo
price, \( \tilde{p} \), the changes in revenues and costs are zero, hence the two branches intersect at 0.

Below \( \tilde{p} \) both revenues and costs are above their reference points. The change in revenues is
evaluated as a gain (positive outcome), while the change in costs as a loss (negative outcome).
The top branch of equation (1) overweights the negative outcome, while the bottom branch
overweights the positive outcome. This is why, for prices below \( \tilde{p} \), the red line is above the
no loss aversion line, and the blue line below it. The situation is flipped for prices above
\( \tilde{p} \), where the blue line overweights the positive outcome (drop in costs), while the red line
overweights the negative outcome (drop in revenues).

Other than \( \tilde{p} \), the figure depicts the two prices \( p^* \) and \( p_* \), which are the maximizers of the
top and bottom branches respectively. These two prices can be shown to have a simple
analytical expression:

\[
p^* = \lambda \frac{\epsilon}{\epsilon - 1} A^{-1} w \\
p_* = \lambda^{-1} \frac{\epsilon}{\epsilon - 1} A^{-1} w
\]

Notice that \( p^*, p_* \) are independent from \( \tilde{p} \), and that for \( \lambda \geq 1 \), their relative position is
known, in particular, \( p_* \leq p^* \).

**Proposition 1 (Optimal pricing).** The choice of optimal price depends on how previous
period price, \( \tilde{p} \), positions relative to the two critical prices \( p_*, p^* \). In particular there are
three cases:

1. If \( p_* < p^* < \tilde{p} \), then the optimal price is \( p^* \).
2. If \( \tilde{p} < p_* < p^* \), then the optimal price is \( p_* \).
3. If \( p_* \leq \tilde{p} \leq p^* \), then the optimal price is \( \tilde{p} \).

\( ^5 \)A lower price means more units sold, thus higher costs. For a price elasticity of demand greater than 1,
as assumed to be the case here, the net effect of more units sold at a lower price is higher revenues as well.

\( ^6 \)See proof of proposition 1.
Proof. See Appendix A.1.

The proof is a simple study of the monotonicity of the objective function. Since we know that \( p_* \leq p^* \), there are only three possible cases for the relative positions of \( p_*, p^*, \tilde{p} \). Figure 3 shows graphically these three cases, capturing the intuition of the proof of proposition 1.

Take case 1 for example. Below \( \tilde{p} \), the objective function is represented by the solid blue line thus the objective function is increasing below \( p^* \) and decreasing thereon. At \( \tilde{p} \) the objective function switches to the red line. However, since the maximizer of the red line, \( p_* \) is to the left of \( \tilde{p} \), the red line is on its decreasing part to the right of \( \tilde{p} \), and thus the objective function is decreasing after \( \tilde{p} \). Thus, the objective function is increasing until \( p^* \) and decreasing thereon, hence, \( p^* \) is the maximizer of the utility function in this case. The maximizer is found similarly in the other two cases.
Proposition 1 is the main prediction of the model. Before moving forward, it is useful to provide some discussion of it.

**Price stickiness and price rigidity, some intuition:** The interval \([p_*, p^*]\) is critical for determining stickiness or not, and its boundaries specify the new prices when these are updated. To build some intuition for the price stickiness result, let us zoom in case 3 of figure 3:

![Figure 4: Price stickiness, intuition](image)

In addition to the top and bottom branches comprising the objective function represented by the blue and red lines respectively, the figure also shows the objective function under no loss aversion (\(\lambda = 1\)) and its optimum, denoted by \(p^{noLA}\). Let us observe three things. First, for \(\lambda = 1\) the optimal price is the one charged under flexible pricing, i.e. \(p^{noLA} = \frac{\xi}{\epsilon - 1} A^{-1} w\).

Second, \(p^{noLA}\) is inside the critical interval, it is in fact the geometric mean of \(p_*\) and \(p^*\) for any degree of loss aversion \(\lambda > 1\). Third, at \(\tilde{p}\) the objective function is 0, for any level of
loss aversion, including the case of $\lambda = 1$.

Now, around its optimum, the no loss aversion objective function is “somewhat” flat. It is precisely this flatness that gives rise to the inaction band: whenever $\tilde{p}$ is sufficiently close to $p^{\text{noLA}}$, the flatness of the no loss aversion curve means that the margin of improvement from changing the price is small, thus in the presence of loss aversion, the gain from changing the price is eliminated from the over-weighted loss of doing so, pushing the objective function in negative territory.

More concretely, assume the firm’s previous price was $\tilde{p}$ as in the figure. Under no loss aversion, by moving towards $p^{\text{noLA}}$, it would be gaining in the revenues dimension and losing in the cost dimension. The trade-off between the two would be positive as seen by the fact that the objective function is positive left of $\tilde{p}$. However, the margin of this improvement is so small, that by overweighting the loss aspect of such a prospective choice, the balance of the trade-off becomes negative, which is why the blue line is negative to the left of $\tilde{p}$.

In light of this discussion, the economic interpretation of the critical interval $[p_*, p^*]$ is that it reflects, for the given degree of loss aversion, how far from $p^{\text{noLA}}$ one has to move for the gain of changing the price to be large enough to compensate for the corresponding (overweighted) loss. In other words, it represents the interval where the no loss aversion curve is “too flat” as represented in figure 4.

In addition to the stickiness result, proposition 1 indicates that there is rigidity in the way firms adjust their price, compared to the no loss aversion case. When firms adjust their prices downward (case 1 of proposition 1), they stop short in their adjustment: they set $p^*$, which is above what they would be charging under no loss aversion. Similarly, when they adjust their prices upwards (case 2), they set $p_*$, which is below what they would be charging under no loss aversion.

The intuition for the rigidity is similar to the one given for stickiness: when updating its price the firm is gaining in one dimension (say, revenues in case 1) but loses in the other dimension (costs in case 1). Because of the over-weighting of losses, the marginal gain is equated to the marginal loss sooner than in the no loss aversion case.
The comparison to the no loss aversion case is summarized in the following figure:

Figure 5: Downward rigidity (left), upward rigidity (right), stickiness (middle)

**Firm pricing behavior, further discussion:** In the absence of loss aversion, the critical interval collapses to a point, and the firm’s problem reduces to the benchmark case of flexible price-setting. Thus, in the absence of loss aversion neither narrow bracketing nor reference dependence have any bite. This relies on the linear specification of the value function and would not be true in the case of decreasing sensitivity in gains and losses.

Secondly, the pricing rule predicted by the model has a flavor very close to that of the benchmark model of no loss aversion, a property not very surprising, since our model features the benchmark case as the special case when $\lambda = 1$. In particular, whenever the firm adjusts its price, the chosen price is proportional to the “standard” term $\frac{\epsilon}{\epsilon-1}MC$, where $MC$ stands for marginal cost, but it also depends on the parameter of loss aversion.

Furthermore, according to our model, stickiness persists for any level of competition in the market, as that is measured by the size of the elasticity of substitution. In particular, even in the case of perfect competition ($\epsilon \to \infty$), in the presence of loss aversion it holds that $p_* < p^*$, and thus there is a region of inaction for the firm. The size of the inaction region $p^* - p_*$ however, is decreasing in $\epsilon$ and thus reaches its minimum value for $\epsilon \to \infty$.

The derivation of the inaction band in this model offers a novel interpretation to price stickiness as a case of *status quo bias* (Samuelson and Zekhauser, 1988) following from the decision maker’s (price setter’s) behavioral-cognitive biases.
In what follows, changes in $A$ are the shocks assumed to be hitting the firm between periods. The following simple lemma complements our understanding of the firm’s pricing behavior:

**Lemma** (Direction of change). *If a firm reacts to a shock by adjusting its price, it will do so in the same direction as it would in the frictionless (flexible pricing) case.*

*Proof.* See Appendix A.1

## 4 Generalizations & robustness

I have shown Proposition 1 for the specific case of a constant elasticity demand function and a linear production function, a special case routinely assumed in macroeconomic contexts. Let us now explore what are the key driving assumptions of the result and show its robustness to alternative functional forms.

**Proposition 2** (Generalization). *Let $D(\cdot)$ denote a demand function, $\epsilon(p) = -\frac{d\log D(p)}{d\log p}$ be the price elasticity of demand, and $g(\cdot)$ denote a production function. Assume $D(\cdot)$ is differentiable and decreasing in price; $\epsilon(\cdot)$ is (weakly) increasing in price; $g(\cdot)$ is differentiable, increasing and (weakly) concave. Then for a status quo price of $\tilde{p}$, a manager who maximizes $v(r; \tilde{r}) + v(-c; -\tilde{c})$, faces two pricing regimes:

(a) if $\epsilon(\tilde{p}) > 1$, the optimal pricing rule features an inaction band, exactly as described in proposition 1

(b) if $\epsilon(\tilde{p}) \leq 1$, the manager always increases the price.

*Proof.* See appendix A.2.

In other words, our result is robust within a fairly common family of production functions. The assumed demand function, however, with a constant elasticity of $\epsilon > 1$, does simplify our results in guaranteeing the manager only faces regime (a).
Proposition 3 (Irrelevance result). Let \( \pi(\cdot) \) denote profits. A price setter who maximizes \( v(\pi(p); \pi(\tilde{p})) \), sets prices exactly like a price setter who simply maximizes \( \pi(p) \).

Proof. See appendix A.3.

In other words, the narrow bracketing assumption is required for our results; a price setter integrating revenues and costs is indistinguishable in equilibrium from a profit maximizer.

I have maintained throughout the assumption of a constant unit cost of production. I have only considered a monopolistic market structure, and I have only considered the status quo as the reference point. Further generalizations remain to be explored in future work.

4.1 Prelude to the dynamic model

In conformity with prospect theory, in all previous discussion the objective function was defined only in terms of changes from the reference point, thus the objective function reflected the perceived prospective change in outcomes. To prepare the dynamic model, however, we change the specification minimally so that the objective function has an interpretation of perceived prospective outcome, in our case perceived prospective profits. Let us define the objective function:

\[
\tilde{U}(p; \tilde{p}, w, A, \Gamma) = \tilde{r} - \tilde{c} + U(p; \tilde{p}, w, A, \Gamma)
\]

\[
= \tilde{r} - \tilde{c} + \begin{cases} 
  r - \tilde{r} - \lambda (c - \tilde{c}) & \text{if } p \leq \tilde{p} \\
  \lambda (r - \tilde{r}) - (c - \tilde{c}) & \text{if } p > \tilde{p}
\end{cases}
\]

This specification does not alter the decision maker’s choice: \( \tilde{r} - \tilde{c} \) is a constant, hence it drops out when taking the FOC with respect to price. However, this specification allows for a different interpretation. \( \tilde{r}, \tilde{c} \) not only serve as reference points but also as starting points, and thus the objective function admits an interpretation as perceived profits: start from \( \tilde{r} \) and adjust it (up or down) by the perceived change in revenues, as this is captured by the prospect theoretic function applied to revenues; do the same for costs; take their difference to arrive at perceived profits.
An alternative specification could be one where, closer to the specification of Kőszegi and Rabin (2006), the objective function is defined as:

\[ \tilde{U}(p, \tilde{p}, w, A, \Gamma) = r - c + U(p; \tilde{p}, w, A, \Gamma) \]

\[ = r - c + \begin{cases} 
    r - \tilde{r} - \lambda(c - \tilde{c}) & \text{if } p \leq \tilde{p} \\
    \lambda(r - \tilde{r}) - (c - \tilde{c}) & \text{if } p > \tilde{p} 
\end{cases} \]

Such a specification would not alter the predictions of our model. However, it has the interpretation of the decision maker having, as in Kőszegi and Rabin (2006), a multi-attribute objective, caring for profits as well as gains-losses in revenues and costs. Even though such an objective does sound natural in, for example, a consumption context, it seems less tenable in a firm decision-making context. In contrast to the multi-attribute interpretation, the interpretation of our specification is that the decision maker cares only about profits. However, in evaluating these profits, decision makers’ cognitive-psychological biases get in the way, and they thus arrive at a distorted perceived measure compared to the rational benchmark.

\footnote{The two critical prices can be shown to be \( \lambda \frac{\epsilon}{c-1} w A^{-1} \) and \( \lambda^{-1} \frac{\epsilon}{c-1} w A^{-1} \), where \( \lambda \equiv \frac{1+\lambda}{2} \).}
5 A dynamic model of inaction bands

Let us now embed our model in a setup of monopolistic competition with forward-looking decision makers. All the intuition built in the simpler static case studied above carries through in the dynamic setup.

5.1 Problem formulation

For comparability purposes, our setup here follows Nakamura and Steinsson (2008) in all dimensions but the menu-cost assumption. A sector of the economy is assumed to be populated by a continuum of firms indexed by \( i \), which compete monopolistically. Thus demand for a firm’s good is:

\[
  y_t(i) = Y_t \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon}
\]

where \( P_t \) is an economy-wide price index and \( Y_t \) is an index of the aggregate (real) demand in the economy. The firm produces using a linear production function and is subject to idiosyncratic productivity shocks i.e.:

\[
  y_t(i) = A_t(i) L_t(i)
\]

The logarithm of the firm’s idiosyncratic shocks is assumed to follow an AR(1) process:

\[
  \log A_t(i) = \rho \log A_{t-1}(i) + \nu_t(i), \quad \text{where } \nu_t(i) \sim N(0, \sigma^2_\nu)
\]

I do partial equilibrium analysis, assuming the effect of the sector’s prices on the aggregate price level is negligible.\(^8\) The logarithm of the price level is assumed to fluctuate around a trend, following a random walk:

\[
  \log P_t = \mu + \log P_{t-1} + \eta_t, \quad \text{where } \eta_t \sim N(0, \sigma^2_\eta)
\]

\(^8\)To avoid confusion with costs, denoted by \( c_t \), let us incorporate here the market-clearing condition and denote demand by \( y_t \).

\(^9\)This assumption makes the firm’s problem independent from the distribution of prices of the other firms.
Each firm is assumed to solve

\[
V = \max_{\{p_t(i)\}_{t=0}^\infty} \mathbb{E}_0 \sum_{t=0}^\infty \beta^t \hat{U} \left( \frac{p_t(i)}{P_t}, \frac{p_{t-1}(i)}{P_t}, \frac{W_t}{P_t}, A_t(i), Y_t \right)
\]

taking the aggregate variables \(P_t, Y_t, W_t\), and the idiosyncratic shock \(A_t(i)\) as given.

The objective function \(\hat{U}()\) is a slight modification of the objective function of the static problem. As explained in the previous section, this modification assures that the per period objective function has a physical interpretation as perceived real profits, thus ensuring that the present discounted value of the objective function is interpretable. In particular I define:

\[
\hat{U}(\cdot) \equiv \underbrace{\frac{p_{t-1}(i)Y_t(p_{t-1}(i)/P_t)^{-\epsilon}}{P_t}}_{\text{real revenues starting point}} - \underbrace{\frac{W_t(1/A_t(i))Y_t(p_{t-1}(i)/P_t)^{-\epsilon}}{P_t}}_{\text{real costs starting point}} + \underbrace{\frac{\lambda[p_t(i)Y_t(p_t(i)/P_t)^{-\epsilon} - p_{t-1}(i)Y_t(p_{t-1}(i)/P_t)^{-\epsilon}]}{P_t}, \text{if } p_t(i) \leq p_{t-1}(i)}}_{\text{real revenues perceived change}} \]

\[
- \underbrace{\frac{\lambda[W_t(1/A_t(i))Y_t(p_{t-1}(i)/P_t)^{-\epsilon} - W_t(1/A_t(i))Y_t(p_{t-1}(i)/P_t)^{-\epsilon}]}{P_t}, \text{if } p_t(i) > p_{t-1}(i)}}_{\text{real costs perceived change}}
\]

Thus the only modification compared to the static case is that the status quo revenues and costs not only serve as reference points, but also as starting points, which the decision maker adjusts upwards or downwards according to the perceived prospective change in revenues and costs to arrive at an estimate of the level of perceived revenues and costs. The objective function is the difference of perceived revenues and costs, and thus reflects perceived profits.

Let us also notice that with the given specification, for \(\lambda = 1\), i.e. in the absence of loss aversion, the problem collapses to the benchmark case of maximizing the present discounted value of real profits.

To close the model in the simplest way in partial equilibrium, let us make two assumptions.
Assume aggregate real demand \( Y_t \), and the real wage \( \frac{W_t}{P_t} \) are constant over time.\(^{10}\) Denote:

\[
Y_t = \bar{Y}, \quad \frac{W_t}{P_t} = \bar{w}
\] (7)

The equilibrium consists of a sequence of state-contingent prices \( \{p_t(i)\}_{t=0}^{\infty} \) that solve (6) subject to the laws of motions (4), (5), and (7), and an initial condition \( p_{-1}(i) \); (2) and (3) have been substituted in (6).

The import of assumption (7) is that it greatly reduces the computational burden of the problem. It can be shown (see appendix C) that neither the level of \( \bar{w} \), nor the level of \( \bar{Y} \) matter for the price decisions, in the sense that the firm can be seen as solving the equivalent normalized sequence problem (SP):

\[
\max_{\{p_t(i)\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u_N \left( \frac{p_t(i)}{W_t}, \frac{p_{t-1}(i)}{W_t}, A_t(i) \right)
\]

s.t.

\[
\log W_t = \mu + \log W_{t-1} + \eta_t, \quad \text{where } \eta_t \sim N(0, \sigma^2) \quad (SP)
\]

\[
\log A_t(i) = \rho \log A_{t-1}(i) + \nu_t(i), \quad \text{where } \nu_t(i) \sim N(0, \sigma^2)
\]

where \( u_N \left( \frac{p_t(i)}{W_t}, \frac{p_{t-1}(i)}{W_t}, A_t(i) \right) \equiv \tilde{U} \left( \frac{p_t(i)}{W_t}, \frac{p_{t-1}(i)}{W_t}, 1, A_t(i), 1 \right) \)

The above problem can be written in recursive form as a functional equation problem (FE) where I have dropped the time index; tilde variables correspond to the previous period.

---

\(^{10}\) The constant real wage assumption can be thought as following from the constant \( Y_t \) assumption in general equilibrium, where a representative household has a linear disutility of labor (an assumption maintained by Golosov and Lucas (2007), Nakamura and Steinsson (2010), and Midrigan (2011)). E.g. assume an instantaneous household utility of \( U(Y_t, L_t) = \frac{1}{1-\gamma} Y_t^{1-\gamma} - \omega L_t \). In that case the household’s labor supply equation amounts to \( \frac{W_t}{P_t} = \omega U_y(Y_t) \), and thus assuming \( Y_t \) is constant, \( \frac{W_t}{P_t} \) is constant.
primed variables to the next period\textsuperscript{11}

\[
V (\tilde{p}_R(i), A(i)) = \max_{p_R(i)} \left\{ u_N (p_R(i); \tilde{p}_R(i), A(i)) + \beta \mathbb{E} \left[ V \left( p'_R(i), A' \right) \middle| p_R(i), A(i) \right] \right\}
\]

s.t.

\[
\begin{align*}
\log p'_R(i) &= -\mu + \log p_R(i) + \eta, \quad \text{where } \eta \sim N(0, \sigma^2_\eta) \quad \text{(FE)} \\
\log A'(i) &= \rho \log A(i) + \nu(i), \quad \text{where } \nu(i) \sim N(0, \sigma^2_\nu)
\end{align*}
\]

I solve the recursive problem numerically by value function iteration. I specify a grid for \(p_t/W_t\) and \(A_t\). For the transition probabilities required to compute the expectation I discretize the probability distribution following Tauchen (1986)\textsuperscript{12}

\subsection*{5.2 Model solution}

The policy function, call it \(g(\cdot)\), is a function of \(p_{t-1}(i)/W_t\) and \(A_t(i)\). Having solved the dynamic program, that is having computed \(g(\cdot)\), the firm’s decision is straightforward: choose a nominal price \(p^*_t(i)\), such that

\[
\frac{p^*_t(i)}{W_t} = g(p_{t-1}(i)/W_t, A_t(i))
\]

where \(p_{t-1}, W_t, A_t(i)\) are all taken as given.

The pricing rule (policy function) can be seen to possess the same qualitative properties as established in proposition 1. In the following figure we plot a slice of the policy function \(g(\cdot)\) for a fixed \(A_t(i)\):

\textsuperscript{11}Explicitly, the notation used is: \(\tilde{p}_R(i) \equiv \frac{p_{t-1}(i)}{W_t}\), \(p_R(i) \equiv \frac{p_t(i)}{W_t}\), \(p'_R(i) \equiv \frac{p_{t+1}(i)}{W_{t+1}}\), \(A(i) = A_t(i), A'(i) = A_{t+1}(i)\).

\textsuperscript{12}The robustness of the solution has been checked by increasing the range and fineness of the grids.
Figure 6: Pricing rule (policy function) conditional on realization of $A$

For previous period prices below some cutoff, we see that optimal behavior calls for updating to a low price (low boundary of inaction band); this is the left flat part of the policy function. For previous period prices above some cutoff, optimal behavior calls for updating to a high price (upper boundary of inaction band); this is the right flat part of the policy function. For all previous period prices in between the firm leaves its price the same; the policy rule for that range of states is the 45° line.

The following figure complements our understanding of the solution:
Figure 7: Pricing rule (policy function) for the grid space of $A_{it} \times \frac{p_{t-1}^{(i)}}{W_t}$.

The blue lines in the figure show the boundaries of the inaction band for our standard calibration explained in the following section ($\lambda = 7$). The red lines show the boundaries of the inaction band for a lower $\lambda$ ($\lambda = 3$). The dotted line plots the optimal price in the absence of any bias, i.e. in the case of flexible pricing ($\lambda = 1$).[13]

[13] The figure points to an interesting feature: as the state variable $A$ increases, the lower boundary of the inaction band converges to the optimal flexible price. Thus for high enough $A$, the firm behaves as if there was no bias, conditional on increasing their price; however, still inaction exists in both directions, and under-reaction persists when updating the price downwards. I have not explored this asymmetry further, which is not present in the myopic model.
5.2.1 Calibration

Nakamura and Steinsson (2008) calibrate the two parameters of the idiosyncratic shock process ($\sigma^\nu, \rho$) and the menu cost by targeting three moments in the data: the monthly frequency of price changes, the fraction of price changes that are increases, and the average size (in absolute value) of price changes. To make a fair assessment of the performance of this model compared to the benchmark menu cost model, let us conduct the analogous exercise of calibrating $\sigma^\nu, \rho,$ and the loss aversion parameter $\lambda$ targeting the same three quantities, while keeping $\beta, \epsilon, \mu, \sigma^\eta$ at their Nakamura and Steinsson (2008) values. The calibration yields $\sigma^\nu = 0.395, \rho = 0.81,$ and $\lambda = 7.$

Table 1: Moments in data and models

<table>
<thead>
<tr>
<th></th>
<th>This model</th>
<th>CPI data</th>
<th>Benchmark model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly Freq. of $\Delta p$</td>
<td>8.75%</td>
<td>8.7%</td>
<td>13.9%</td>
</tr>
<tr>
<td>Fraction Up</td>
<td>58.09%</td>
<td>64.8%</td>
<td>64.5%$^d$</td>
</tr>
<tr>
<td>Mean $</td>
<td>\Delta p</td>
<td>$</td>
<td>8.46%</td>
</tr>
<tr>
<td>$</td>
<td>\Delta p</td>
<td>&lt; 1%$</td>
<td>6.82%</td>
</tr>
<tr>
<td>$</td>
<td>\Delta p</td>
<td>&lt; 2.5%$</td>
<td>22.34%</td>
</tr>
<tr>
<td>$</td>
<td>\Delta p</td>
<td>&lt; 5%$</td>
<td>40.84%</td>
</tr>
<tr>
<td>$</td>
<td>\Delta p</td>
<td>&lt; 10%$</td>
<td>67.34%</td>
</tr>
<tr>
<td>$</td>
<td>\Delta p</td>
<td>&lt; 20%$</td>
<td>91.69%</td>
</tr>
</tbody>
</table>


14If we had a model of more degrees of freedom, a better fit of the data wouldn’t come as a surprise.

15$\beta = 0.96^{1/12}, \epsilon = 4, \sigma^\eta = 0.0032, \mu = 0.002$
We notice that this model presents a significant improvement compared to the benchmark menu cost model in matching the whole distribution of price changes, as seen by comparing lines 4-8 in the table. The degree of the calibration’s undershooting of the fraction of price increases (58% vs 65%) is considered of minor quantitative importance, especially when balanced with the significant improvement in matching untargeted moments of the data (see lines 4-8 in table and next section).

One point worth commenting on is the value of $\lambda$ required by the calibration to fit the data. A value of 7 is somewhat higher than conventional experimental estimates of loss aversion, which are between 1.5 and 2.5 (Kahneman, 2011). As is typical in macro calibrations, the time discount factor was set to match a steady state level annual interest rate of 4%. Robustness checks of the calibration have shown that the required value of $\lambda$ is much smaller for a lower time discounting factor. In light of this, this model suggests that decision makers in firms may be discounting the future much more than we typically assume them to do.

It is also worth exploring further how the calibration is affected by making further refinements to the model, such as adding decreasing sensitivity to the value function as in the originally proposed specification by Kahneman and Tversky (1979), or adding non-constant weights to prospective revenue and cost changes as suggested by some recent work (e.g. Bordalo et al. 2019).

5.3 Results

Our model makes two key predictions of direct empirical relevance: (a) large price changes coexist with small ones for a given product, and (b) the shape of the hazard function is downward sloping at first, that is, firms that have just recently changed their price have a higher probability of changing it again, while this probability asymptotes to a constant soon after. Both can be thought as “overidentification” restrictions since they were not targeted

\[ \beta = 0, \text{ the required } \lambda \text{ is about 1.7.} \]
in any way.

5.3.1 Coexistence of small and large price changes

The literature has documented robust empirical evidence of the distribution of (non-zero) price changes that are at odds with the predictions of standard menu cost models such as those in Nakamura and Steinsson (2008) and Golosov and Lucas (2007). The distribution of price changes features a large proportion of small price changes in addition to large ones. This salient fact of the data was first stressed by Midrigan (2011), who analyzes data from a large retailer, and who also proposed a “second generation” menu cost model with economies of scope to account for it. Our model proposes an alternative explanation of this stylized fact, completely outside the paradigm of menu cost. Early evidence of the coexistence of small and large price changes was provided by Kashyap (1995) who analyzed prices of retailers selling through mail catalogs. Further evidence is provided by Klenow and Kryvtsov (2008), which I take as my main evidence of reference since it is from the same dataset as the one used by Nakamura and Steinsson (2008) and thus closely related to what the calibrated model should be able to explain.

The following figures are largely the visual analogs of untargeted moments of the price change distribution matched by our model reported in Table I.
Figure 8: Non-zero price change distributions; empirical (left), simulated benchmark menu cost model (right).

Notes: Empirical distribution reproduced from Klenow and Kryvtsov (2008). The figure represents the distribution of (log) price changes of the median/representative good and was constructed as follows: each good-month observation is given an appropriately defined weight; the height of each bin corresponds to the fraction of the total weight over the whole period (Jan. 1988- Jan. 2005) represented by the price changes in that bin; the sample is restricted to the three largest metropolitan areas (New York, Los Angeles, Chicago). The simulation is from a calibrated version of the menu cost model of Nakamura and Steinsson (2008).

In contrast to the standard menu cost model, which predicts a distinctively bimodal distribution of price changes, our model has a superior qualitative fit of the data, filling the “missing middle” of small price changes.

Figure 9: Simulated distribution of price changes of our calibrated model
Given the shape of the policy function, we can explain that result heuristically: in our model, when the firm is hit by an idiosyncratic or inflationary shock that brings it just outside the inaction region, it updates its price to the closest boundary, thus making a small change in the price. In a similar situation, under a menu cost model, the firm would update its price to the interior of the inaction band, thus making a larger price change. A virtually identical figure to that of Klenow and Kryvtsov (2008), which I reproduced here, is provided by Midrigan (2011) [figure 2, p. 1146]. Another feature of the price change distribution he stresses is that it is leptokurtic. The distribution of price changes in our calibration has a kurtosis just above 4, and is thus leptokurtic.

5.3.2 The hazard function

The hazard function is defined as \( h(t) = Pr(T = t|T \geq t), \forall t \geq 1 \), where \( T \) is a random variable denoting the length of a price spell; time is assumed to be discrete. \( h(t) \) corresponds to the probability that the price changes today, given that it hasn’t changed up to today, i.e. the previous \( t - 1 \) periods. An upward sloping hazard function corresponds to situations where prices become more probable to change the longer they have remained unchanged; a downward sloping hazard function corresponds to situations where prices changed recently are more likely to change again.

Nakamura and Steinsson (2008) estimate hazard functions for various product categories and find that they all share the same qualitative properties: they are (somewhat) decreasing for the first few months and then stay largely constant thereon. They also show that the hazard function in their calibrated standard menu cost model has a distinctively upward sloping part. Both figures are reproduced below:

\[ ^{17} \text{See appendix B for a direct comparison of the policy function of the menu cost model to that of our behavioral model.} \]

\[ ^{18} \text{The distribution of price changes has been leptokurtic in all simulations of the model I have run, for different parameterizations. A distribution is called leptokurtic when it has a kurtosis above 3, the kurtosis of the normal distributions family; qualitatively leptokurtosis means the distribution has “fatter tails” than the normal distribution, i.e. more mass in the extremes.} \]
Figure 10: Hazard function; empirical (left), simulated benchmark menu cost model (right).
Notes: Figures reproduced from Nakamura and Steinsson (2008). Empirical hazard function is for processed food category; hazard functions of other categories (except services) are reported to possess identical qualitative properties.

In contrast to the standard menu cost model, our behavioral model gives rise to a hazard function, which is decreasing at first and becomes flat afterwards:

Figure 11: Simulated hazard function of our calibrated model

Our model matches the shape of the empirical hazard function quite closely, even if quantitatively it has a steeper downward sloping part than its empirical counterpart. The predicted
shape of the hazard function stems from the firm’s pricing rule. In our model as soon as there is a price change there is a non-negligible chance that it will be followed by another price change. This is the case when the firm is hit by a second shock in the same direction: since after the price change the reference price is at one boundary of the inaction band, the shock in the same direction pushes with certainty the reference price outside the band, yielding a second price change.

In contrast, for a spell to have survived a second period it means the firm has been hit by a shock in the opposite direction from the initial that made it change its price. Thus the reference price is in the interior of the inaction band and now there is a “buffer” so that the firm can be hit by shocks in both directions and still remain in the interior of the band. Thus the probability that we see a 2-period spell ending, i.e. \( h(2) \), is less than the probability that we see a one period spell ending, i.e. \( h(1) \).

The argument extends to the next periods: let us assume without loss of generality that after surviving the 1st period, the state variable of the previous period price is closer to the lower boundary of the inaction band. Conditional on surviving the 2nd period, the firm is more likely to have been hit by a shock that brought it closer to the midpoint of the inaction band than one that brought it even closer to the lower boundary since some of the shocks pushing it towards the lower boundary would have resulted in the ending of the spell in two periods. In other words, conditional on having survived the two periods, the firm is likely to have moved closer to the midpoint of the inaction band, and have “enough buffer” to absorb shocks in both directions.

After the first few periods, the hazard function becomes virtually flat: conditional on having survived, the initial condition, which brings the firm on the boundary of its inaction region, has become irrelevant as the firm has moved to the midpoint of the inaction band.\(^{19}\)

\(^{19}\)Let us note that the empirical evidence on the shape of the hazard function is not clear-cut. It depends on the treatment of heterogeneity across firms and sectors, and on the construction of regular prices from posted prices. In fact, Klenow and Kryvtsov (2008), without looking at different product categories and following a different empirical approach from Nakamura and Steinsson (2008), report virtually flat hazard functions everywhere. In any case, our model makes a clear-cut prediction that remains to be tested by further empirical work.
6 Discussion

This paper puts forward a theory of price setting and shows how price stickiness can be derived within the paradigm of behavioral decision making. It is the first paper applying portable features which have already found application in consumption theory, labor supply, and finance, to firm decision making, thus extending the contexts where we can test the behavioral paradigm’s predictions.

A conceptual distinction made by Kahneman and Tversky (1984) is of particular relevance for this paper. They write:

The concepts of utility and value are commonly used in two distinct senses: (a) *experience value*, the degree of pleasure or pain, satisfaction or anguish in the actual experience of an outcome; and (b) *decision value*, the contribution of an anticipated outcome to the overall attractiveness or aversiveness of an option in a choice. The distinction is rarely explicit in decision theory because it is tacitly assumed that decision values and experience values coincide.

Indeed the objective function which is being maximized in the current paper is to be given a *decision value* interpretation, not an experience value one. This paper does not make any claim that the price setter of the firm has *preferences* for changes in revenues and costs per se. The intended interpretation is one of a *computational process* to evaluate outcomes.

Even with this clarification, the incorporation of behavioral biases in a model of price setting may be viewed with skepticism by some readers, as it implies that a manager is “leaving money on the table” compared to the rational benchmark. This paper does not take a stand on the sources of the cognitive-psychological biases incorporated in the model. It rather follows prospect theory in taking these assumptions as given to propose a *descriptive* model of price setting. A recent and very much active research agenda has taken up the task of going deeper to identify the possible sources of such biases.

Loss aversion and reference dependence have been argued to have an intricate relationship with our human nature. Galor and Savitskiy (2018) have argued that loss aversion is the
outcome of the evolutionary process of our species. Researchers have also argued that reference dependence, among other features of prospect theory, reflect an efficient use of resources in the presence of natural limitations to our cognitive capacity (see e.g. Glimcher, 2011, p. 274; Woodford, 2019).

As for narrow bracketing its sources have not been conclusively identified by the literature. There are however two points worth making for the context we are considering.

Firstly, revenues and costs are different quantities - one is associated with a plus sign, the other with a minus. They involve different parties - revenues involve customers while costs involve suppliers; and they arrive at different times. Based on theories of categorization of cognitive psychology (e.g. Rosch and Lloyd, 1978; Henderson and Peterson, 1992) people are likely to mentally organize the two in different categories, thus storing, recalling, and evaluating them separately.

Secondly, I wish to argue that our context hints that, as suggested for other biases (Woodford, 2019), narrow bracketing may also be the outcome of an efficient response to natural limitations. Take a manager of a small firm who brackets revenues and costs separately. As the scale of operations increases and ultimately outgrows the manager’s mental abilities, we see two separate departments emerging in the firm to deal with the two tasks: a revenues/sales department and a costs/supply department. This separation in departments can be thought as revealing to us the separation in the manager’s head, which we of course cannot observe directly.

Now the separation in the two departments is a phenomenon that we believe we understand well. It is the firm’s way to take advantage of the benefits of specialization and counteract decreasing returns to scale. It is thus plausible that mental separation is also performed for similar reasons. After all we do know that our brain is compartmentalized and different parts are “responsible” for different tasks.

**Directions of future research:** A natural follow-up to the present paper is to embed

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20Recent papers have started exploring particular situations in which narrow bracketing arises as the optimal frame of evaluation (e.g. Koch and Nafziger, 2016).
the model in a general equilibrium framework and evaluate the impact of monetary policy. What are the aggregate dynamics of real output in response to a monetary shock and how does the aggregate Phillips curve look like?

Another path that seems worth pursuing is to extend the analysis to within period behavior. The present model proposes how a firm sets its price for a given period, say a month. The revenues and costs corresponding to the chosen price can be said to be the target revenues and costs for the period. Now, within the period, say every week, the firm can do temporary adjustments, e.g. sales, to its price depending on how it is doing compared to the target. Such type of fine-tuning seems consistent with the documented pricing patterns: authors\textsuperscript{21} have distinguished between “regular” prices, which prevail over periods of time, and temporary departures from the regular price (typically a sale), which are applied for a brief period of time, before the firm reverts to the regular price. Behavioral models with strong such flavor have typically been used to analyze within day labor supply decisions (chosen hours), assuming a given income target for the day; Thakral and Tô (forthcoming) is a recent example.

The experimental setup of Tversky and Kahneman (1981) we discussed in section 2 induces the separation of inflows and outflows to subjects. However, in that setup, all possible combinations of inflows and outflows are possible, in other words inflow and outflow outcomes are uncorrelated. In a pricing setup though, revenue and cost outcomes are correlated: to each price corresponds a fixed revenue and cost pair, thus only a subset of possible combinations is possible. I propose a variation of the experiment where outcomes are correlated using the idea of \textit{duplex gambles} (e.g. Payne and Braunstein, 1971). For example, I hypothesize that among subjects asked to choose between the two options in appendix figure D.1 (treatment), a significant fraction would choose the top option, while, as in Tversky and Kahneman (1981), almost nobody would choose \textit{AD} if offered the options in figure D.2 (control). Variants of the experiment where the computations are harder to perform and where subjects are asked to choose among more than 2 options would be of interest to explore the variation in the size of violations of first-order stochastic dominance.

\textsuperscript{21}Golosov and Lucas, 2007; Nakamura and Steinsson, 2008; Klenow and Ktyvtsov, 2008; Midrigan, 2011
**Conclusion:** This paper proposed a model of price setting grounded in the experimental findings of how people make decisions. We showed that the model’s predictions match some key facts of the pricing microdata and got a new, uniquely interpretable, source of price stickiness. A number of issues remain to be explored by future research, some of which we touched upon in this concluding section. As the literature reaches consensus as to the sources of the cognitive-psychological assumptions incorporated in the model, it may be useful to work out a version of the model where the assumptions emerge from optimizing foundations that reflect efficient choice in the presence of physical limitations.
Bibliography


Appendices

A Proofs of section 2

A.1 Proof of Proposition 1 & Lemma

Proposition (Optimal pricing). The choice of optimal price depends on how previous period price, \( \bar{p} \), positions relative to the two critical prices \( p_* , p^* \), where \( p_* \equiv \lambda^{-1} \frac{\epsilon}{\epsilon - 1} A^{-1} w \), \( p^* \equiv \lambda \frac{\epsilon}{\epsilon - 1} A^{-1} w \). In particular there are three cases:

1. If \( p_* < p^* < \bar{p} \), then the optimal price is \( p^* \).
2. If \( \bar{p} < p_* < p^* \), then the optimal price is \( p^* \).
3. If \( p_* \leq \bar{p} \leq p^* \), then the optimal price is \( \bar{p} \).

Proof. The proof relies on studying the monotonicity of the objective function. We study each branch of the objective function separately:

For the top branch, i.e. \( p < \bar{p} \):

\[
U' \geq 0 \iff (1 - \epsilon)p^{-\epsilon} + \lambda w A^{-1} \epsilon p^{-\epsilon - 1} \geq 0 \iff \\
\lambda w A^{-1} \epsilon p^{-\epsilon - 1} \geq (\epsilon - 1)p^{-\epsilon} \iff \\
p \leq \lambda \frac{\epsilon}{\epsilon - 1} A^{-1} w
\]

That is, for \( p \leq \bar{p} \),

\[
U(\cdot) \text{ increasing iff } p \leq p^* , \quad p^* \equiv \lambda \frac{\epsilon}{\epsilon - 1} A^{-1} w
\]

Similarly, we derive that for \( p \geq \bar{p} \) (bottom branch),

\[
U(\cdot) \text{ increasing iff } p \leq p_* , \quad p_* \equiv \lambda^{-1} \frac{\epsilon}{\epsilon - 1} A^{-1} w
\]
It is trivially seen that for $\lambda \geq 1$, it follows that $p_* \leq p^*$, and the inequality is strict unless $\lambda = 1$ (no loss aversion).

The fact that $p_* < p^*$, allows for only three cases of relative positions of $p^*$, $p_*$, $\tilde{p}$. We study each case separately:

Assume $p_* < p^* < \tilde{p}$. Then from the monotonicity of the top branch, $U(\cdot)$ is increasing for all $p \in (-\infty, p^*)$, and decreasing for $p \in (p^*, \tilde{p})$. From the monotonicity of the bottom branch $U(\cdot)$ is decreasing for all $p \in (\tilde{p}, \infty)$, since it is decreasing for all $p \in (p_*, \infty)$, and $p_* < \tilde{p}$. It follows that $U(\cdot)$ is increasing for all $p \in (-\infty, p^*)$ and decreasing for all $p \in (p^*, \infty)$, thus $p^*$ is the unique maximum.

The other two cases are worked out analogously completing the proof of the theorem: if $\tilde{p} \leq p_* < p^*$, then $u(\cdot)$ is increasing for all $p \in (-\infty, p_*)$ and decreasing for all $p \in (p_*, \infty)$, thus $p_*$ is the unique maximum; if $p_* \leq \tilde{p} \leq p^*$, $U(\cdot)$ is increasing for all $p \in (-\infty, \tilde{p})$ and decreasing for all $p \in (\tilde{p}, \infty)$, thus $\tilde{p}$ is the unique maximum.

**Lemma** (Direction of change). If a firm reacts to a shock by adjusting its price, it will do so in the same direction as it would in the frictionless (flexible pricing) case.

**Proof.** Assume the firm faces currently a TFP of $A_L$ and its current price is $\tilde{p} \in [\lambda^{-1}A_L^{-1}, \lambda A_L^{-1}]$.

Now assume the firm is hit by a positive shock (increase in $A$) making the critical interval $[\lambda^{-1}A_H^{-1}, \lambda A_H^{-1}]$, where $A_L < A_H$.

$\tilde{p} \geq \lambda^{-1}A_L^{-1}$, and $A_H > A_L$ imply $\tilde{p} > \lambda^{-1}A_H^{-1}$. Thus the firm will either not react ($\tilde{p} \leq \lambda A_H^{-1}$ case) or it will decrease its price to $\lambda A_H^{-1}$ ($\lambda A_H^{-1} < \tilde{p}$ case).

Similarly for a negative shock. 

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22 For expository purposes I normalize $\epsilon^{\frac{\epsilon}{\epsilon-1}}w$ to 1.
A.2 Proof of Proposition 2

Assume function $D(\cdot)$ denotes demand and function $g(\cdot)$ denotes production, they are differentiable and satisfy the following:

\begin{align*}
D > 0, \quad D' < 0 \\
g \geq 0, \quad g' > 0, \quad g'' \leq 0
\end{align*}

(A1)

In addition we will assume that the price elasticity of demand $\epsilon(p) = -\frac{d\log D(p)}{d\log p}$ is weakly increasing in $p$. This assumption does not follow from the assumptions characterizing the demand function, however it holds for the common demand functions (e.g. constant demand elasticity, linear) and it is a minimal extra structure we need to solve the problem at sufficient generality.

$\epsilon(p)$ is (weakly) increasing in $p$  
(A2)

Revenues and costs are respectively

\begin{align*}
 r(p) &= pD(p) \\
c(p) &= wg^{-1}(D(p))
\end{align*}

We start by showing the following simple lemma:

Lemma. Revenues are decreasing in price iff $\epsilon(p) > 1$

\begin{align*}
(pD(p))' < 0 &\iff D(p) + pD'(p) < 0 &\iff 1 + p\frac{D'(p)}{D(p)} < 0 &\iff -p\frac{D'(p)}{D(p)} > 1 &\iff \epsilon(p) > 1 \quad \square
\end{align*}
Denote by $p^1$ the price for which $\epsilon(p^1) = 1$. From (A2) it follows that $\epsilon(p) > 1$ iff $p > p^1$.

**Case 1: $\epsilon(\tilde{p}) > 1$**

We first observe that the manager will never want to price below $p^1$, as $\forall p < p^1$ it holds $r(p) < r(p^1)$ and $c(p) > c(p^1)$. That is $p^1$ dominates any $p < p^1$. Then $\forall p \in [p^1, +\infty)$, we have

$$U = \begin{cases} [pD(p) - \tilde{p}D(\tilde{p})] - \lambda w [g^{-1}(D(p)) - g^{-1}(\tilde{D}(\tilde{p}))] & \text{if } p \leq \tilde{p} \\ \lambda [pD(p) - \tilde{p}D(\tilde{p})] - w [g^{-1}(D(p)) - g^{-1}(\tilde{D}(\tilde{p}))] & \text{if } p > \tilde{p} \end{cases}$$

Then

$$U' = \begin{cases} [D(p) + pD'(p)] - \lambda w [g'(g^{-1}(D(p)))^{-1} D'(p)] & \text{if } p < \tilde{p} \\ \lambda [D(p) + pD'(p)] - w [g'(g^{-1}(D(p)))^{-1} D'(p)] & \text{if } p > \tilde{p} \end{cases}$$

For $p < \tilde{p}$ we have:

$$U' \geq 0 \iff D(p) + pD'(p) - \lambda w [g'(g^{-1}(D(p)))^{-1} D'(p)] \geq 0 \iff \frac{D(p)}{D'(p)} + p - \lambda w [g'(g^{-1}(D(p)))^{-1} D'(p)] \leq 0 \iff \left(1 - \frac{1}{\epsilon(p)}\right) p - \lambda w [g'(g^{-1}(D(p)))^{-1} D'(p)] \leq 0$$

Similarly for $p > \tilde{p}$ we derive:

$$U' \geq 0 \iff \left(1 - \frac{1}{\epsilon(p)}\right) p - \lambda^{-1} w [g'(g^{-1}(D(p)))^{-1} D'(p)] \leq 0$$

We define the function

$$G(p; \gamma) = \left(1 - \frac{1}{\epsilon(p)}\right) p - \gamma w [g'(g^{-1}(D(p)))^{-1} D'(p)]$$

From (A1), (A2) it follows that $G(\cdot)$ is increasing in $p$. We also have that $G(p^1; \gamma) < 0$, and $\lim_{p \to \infty} G(p; \gamma) > 0$ thus $G(\cdot)$ has a unique solution in $[p^1, \infty)$ for a given $\gamma$. The following

\[\text{For } \epsilon(p) > 1 \text{ we have } \lim_{p \to \infty} (1 - 1/\epsilon(p))p = \infty \text{ and from (A1) we have } 0 \leq \lim_{p \to \infty} \gamma w [g'(g^{-1}(D(p)))^{-1} D'(p)] < \infty, \text{ thus } \lim_{p \to \infty} G(p; \gamma) = \infty\]
two conditions implicitly define the maximizers of $U$ for $p < \tilde{p}$, $p > \tilde{p}$, which to keep the connection to proposition 1 direct, we denote by $p^*, p_*$ respectively:

$$G(p^*; \lambda) = 0$$
$$G(p_*; \lambda^{-1}) = 0$$

Denote by $p$ any price satisfying $G(p; \gamma) = 0$. From the implicit function theorem we can get that $\partial p / \partial \gamma > 0$:

$$\frac{\partial p}{\partial \gamma} = -\frac{\frac{\partial G}{\partial \gamma}}{\frac{\partial G}{\partial p}} = \frac{w \left[ g' \left( g^{-1} \left( D(p) \right) \right) \right]^{-1} \left( 1 - \frac{1}{e(p)} \right) + \gamma w \left[ g' \left( g^{-1} \left( D(p) \right) \right) \right]^{-2} g'' \left( g^{-1} \left( D(p) \right) \right) \left[ g' \left( g^{-1} \left( D(p) \right) \right) \right]^{-1} D'(p)}{> 0}$$

Since for $\lambda > 1$, it holds that $\lambda > \lambda^{-1}$, we get that $p^* > p_*$.\footnote{The argument for the relative positions of $p^*, p_*$ can also be seen graphically: The characterization of $p^*, p_*$ comes from the two equations $\left( 1 - \frac{1}{e(p)} \right) p = \lambda w \left[ g' \left( g^{-1} \left( D(p) \right) \right) \right]^{-1}$, and $\left( 1 - \frac{1}{e(p)} \right) p = \lambda^{-1} w \left[ g' \left( g^{-1} \left( D(p) \right) \right) \right]^{-1}$ respectively. The LHS is the same, and an increasing function in $p$; the RHS is decreasing in $p$, and the RHS of the latter is a shift inwards of the RHS of the former.}

Thus, as in proposition 1, the monotonicity of $U(\cdot)$ depends on the relative positions of $\tilde{p}, p^*, p_*$, yielding the same three cases for the maximizing price:

1. $p_* < p^* < \tilde{p} \Rightarrow$ the optimal price is $p^*$.
2. $\tilde{p} < p_* < p^* \Rightarrow$ the optimal price is $p_*$.\footnote{The argument for the relative positions of $p^*, p_*$ can also be seen graphically: The characterization of $p^*, p_*$ comes from the two equations $\left( 1 - \frac{1}{e(p)} \right) p = \lambda w \left[ g' \left( g^{-1} \left( D(p) \right) \right) \right]^{-1}$, and $\left( 1 - \frac{1}{e(p)} \right) p = \lambda^{-1} w \left[ g' \left( g^{-1} \left( D(p) \right) \right) \right]^{-1}$ respectively. The LHS is the same, and an increasing function in $p$; the RHS is decreasing in $p$, and the RHS of the latter is a shift inwards of the RHS of the former.}
3. $p_* \leq \tilde{p} \leq p^* \Rightarrow$ the optimal price is $\tilde{p}$.

Case 2: $\epsilon(\tilde{p}) \leq 1$

In this case we know that the manager will not set a price below $\tilde{p}$, as this will yield both lower revenues and higher costs, i.e. $\tilde{p}$ dominates any $p < \tilde{p}$. Furthermore revenues will be increasing and costs decreasing in $p$ for any $p \in [\tilde{p}, p^1]$. Thus $p^1$ dominates any price $p < p^1$. Thus the maximum is achieved at a price $p^{**} \geq p^1 > \tilde{p}$.

To characterize $p^{**}$ we proceed as follows: $pD(p)$ is decreasing in $[p^1, \infty)$ and $p^1D(p^1) > \tilde{p}D(\tilde{p})$. Assuming sufficient boundary conditions hold (as is the case for constant demand elasticity, and linear demand functions) such that $\lim_{p \to \infty} pD(p) = 0$, it follows that there
exists a price $\bar{p} \in [p^1, \infty)$ s.t. $\bar{p}D(\bar{p}) = \bar{p}D(\bar{p})$. Then for any $p > p^1$ the objective function is

$$U = \begin{cases} [pD(p) - \bar{p}D(\bar{p})] - w [g^{-1}(D(p)) - g^{-1}(D(\bar{p}))] & \text{if } p < \bar{p} \\ \lambda [pD(p) - \bar{p}D(\bar{p})] - w [g^{-1}(D(p)) - g^{-1}(D(\bar{p}))] & \text{if } p > \bar{p} \end{cases}$$

and its derivative is

$$U' = \begin{cases} [D(p) + pD'(p)] - w [g'(g^{-1}(D(p)))^{-1} D'(p)] & \text{if } p < \bar{p} \\ \lambda [D(p) + pD'(p)] - w [g'(g^{-1}(D(p)))^{-1} D'(p)] & \text{if } p > \bar{p} \end{cases}$$

The maximizers of the top and bottom branches are given respectively by

$$G(\bar{p}^*; 1) = 0 \quad G(\bar{p}_*; \lambda^{-1}) = 0$$

where by the same argument as before, since $\lambda^{-1} < 1$ it follows that $\bar{p}_* < \bar{p}^*$. As in proposition 1, $p^{**}$ is one of $\bar{p}_*, \bar{p}^*, \bar{p}$, all of which are above $\bar{p}$. Depending on their relative positions:

1. $\bar{p}_* < \bar{p}^* < \bar{p} \Rightarrow p^{**} = \bar{p}^*$.
2. $\bar{p} < \bar{p}_* < \bar{p}^* \Rightarrow p^{**} = \bar{p}_*$.
3. $\bar{p}_* < \bar{p} < \bar{p}^* \Rightarrow p^{**} = \bar{p}$.

A corollary of proposition 2 is that a manager maximizing perceived profits according to the cognitive-behavioral biases of this paper, always sets a price on the elastic part of the demand curve ($\epsilon(p) > 1$), as is the case of the standard monopolist maximizing profits.

A.3 Proof of Proposition 3

**Proposition 4** (Irrelevance result). Let $\pi(\cdot)$ denote profits. A price setter who maximizes $v(\pi(p); \pi(\bar{p}))$, sets prices exactly like a price setter who simply maximizes $\pi(p)$.

**Proof.** The firm is assumed to solve:

$$\max_p v(\pi(p; w); \pi(\bar{p}; w))$$
where $w$ is a parameter (exogenous shock, e.g. wage). $v(\cdot)$ is an increasing transformation of $\pi$, which means $u(\cdot)$ is maximized at maximum $\pi$, thus at the same price the monopolist who is not loss averse maximizes profits.\textsuperscript{25}
B Behavioral model - Menu cost model comparison

Figure B.1: Policy functions conditional on realization of A
C Assumption (7): Reduction of state space

We have that the instantaneous objective function at time $t$ is

$$U_t = Y_t \left( \frac{p_{t-1}(i)}{P_t} \right)^{1-\epsilon} - \frac{W_t}{P_t} Y_t \left( \frac{p_{t-1}(i)}{P_t} \right)^{-\epsilon} +$$

$$+ \left\{ \begin{array}{ll}
Y_t \left( \frac{p_t(i)}{P_t} \right)^{1-\epsilon} - Y_t \left( \frac{p_{t-1}(i)}{P_t} \right)^{1-\epsilon}, & \text{if } \frac{p_t(i)}{P_t} \leq \frac{p_{t-1}(i)}{P_t} \\
\lambda Y_t \left( \frac{p_t(i)}{P_t} \right)^{1-\epsilon} - Y_t \left( \frac{p_{t-1}(i)}{P_t} \right)^{1-\epsilon}, & \text{if } \frac{p_t(i)}{P_t} > \frac{p_{t-1}(i)}{P_t}
\end{array} \right.$$

$$- \left\{ \begin{array}{ll}
\lambda \frac{W_t}{P_t} Y_t \left( \frac{p_t(i)}{P_t} \right)^{-\epsilon} - \frac{W_t}{P_t} A_t(i) Y_t \left( \frac{p_{t-1}(i)}{P_t} \right)^{-\epsilon}, & \text{if } \frac{p_t(i)}{P_t} \leq \frac{p_{t-1}(i)}{P_t} \\
\frac{1}{A_t(i)} \left( \frac{p_t(i)}{W_t} \right)^{-\epsilon} - \frac{1}{A_t(i)} \left( \frac{p_{t-1}(i)}{W_t} \right)^{-\epsilon}, & \text{if } \frac{p_t(i)}{W_t} > \frac{p_{t-1}(i)}{W_t}
\end{array} \right.$$

we multiply both sides by $\left( \frac{W_t}{P_t} \right)^{\epsilon-1}$ and divide by $Y_t$ to get

$$\frac{U_t}{Y_t} \left( \frac{W_t}{P_t} \right)^{\epsilon-1} = \left( \frac{p_{t-1}(i)}{W_t} \right)^{1-\epsilon} - \frac{1}{A_t(i)} \left( \frac{p_{t-1}(i)}{W_t} \right)^{-\epsilon} +$$

$$+ \left\{ \begin{array}{ll}
\left( \frac{p_t(i)}{W_t} \right)^{1-\epsilon} - \left( \frac{p_{t-1}(i)}{W_t} \right)^{1-\epsilon}, & \text{if } \frac{p_t(i)}{W_t} \leq \frac{p_{t-1}(i)}{W_t} \\
\lambda \left( \frac{p_t(i)}{W_t} \right)^{1-\epsilon} - \left( \frac{p_{t-1}(i)}{W_t} \right)^{1-\epsilon}, & \text{if } \frac{p_t(i)}{W_t} > \frac{p_{t-1}(i)}{W_t}
\end{array} \right.$$

$$- \left\{ \begin{array}{ll}
\lambda \frac{1}{A_t(i)} \left( \frac{p_t(i)}{W_t} \right)^{-\epsilon} - \frac{1}{A_t(i)} \left( \frac{p_{t-1}(i)}{W_t} \right)^{-\epsilon}, & \text{if } \frac{p_t(i)}{W_t} \leq \frac{p_{t-1}(i)}{W_t} \\
\frac{1}{A_t(i)} \left( \frac{p_t(i)}{W_t} \right)^{-\epsilon} - \frac{1}{A_t(i)} \left( \frac{p_{t-1}(i)}{W_t} \right)^{-\epsilon}, & \text{if } \frac{p_t(i)}{W_t} > \frac{p_{t-1}(i)}{W_t}
\end{array} \right.$$

Under the assumption that $\left( \frac{W_t}{P_t} \right)$, and $Y_t$ are constant $\forall t$, the maximization of the discounted sum of $U_t$ and $\frac{U_t}{Y_t} \left( \bar{w} \right)^{\epsilon-1}$, is achieved for the same prices, since $\left( \bar{w} \right)^{\epsilon-1}$ factors out from all terms. Thus the firm can be seen to maximize the normalized discounted sum of

$$u_N \left( \frac{p_t(i)}{W_t}, \frac{p_{t-1}(i)}{W_t}, A_t(i) \right) = \frac{U_t}{Y_t} \left( \bar{w} \right)^{\epsilon-1} = U \left( \frac{p_t(i)}{W_t}, \frac{p_{t-1}(i)}{W_t}, 1, A_t(i), 1 \right)$$

D Duplex gambles

Treatment: Imagine that you face the following two gambles (known as duplex gambles). Each gamble consists of two spinning wheels: the left spinning wheel controls what you earn, the right controls what you pay. Which one do you choose?
Control: Imagine that you face the following two gambles. Each gamble is depicted by a spinning wheel. Which one do you choose?

Figure D.1: Choice between two gambles (treatment)

Figure D.2: Choice between two gambles (control)