

Relative Thinking and Markups*

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First Version: September 2011

Current Version: November 2013

Abstract

In experiments subjects regularly trade off time and money at inconsistent rates, apparently becoming less sensitive to money when considering the purchase of a more-expensive item. In this paper I introduce a demand function that matches this behaviour, and derive the predictions for equilibrium market structure, and discuss market evidence. The demand function is derived from a utility function which has context-dependent sensitivity to different goods (e.g., time, money). In market equilibrium with unit total demand the model predicts three phenomena: higher cost goods tend to have higher markups; higher cost goods tend to have greater price dispersion; and higher cost goods will have a larger number of sellers. The first two facts are commonly observed in the empirical IO literature. Finally I introduce a novel dataset of 3,500 costs and prices from a branch of a chain drugstore, with cross-section evidence in support of the theory.

1 Introduction

In the study of industrial organisation, assumptions about utility can put important restrictions on demand functions. Assuming a utility function means

*I am especially grateful to Francesco Caselli, Erik Eyster, David Laibson and Andrei Shleifer for their support and advice. I have also benefited greatly from comments by Mark Armstrong, Ruchir Agarwal, Ariel Pakes, Matthew Rabin, Rani Spiegler, Tomasz Strzalecki, Glen Weyl and seminar participants at Harvard, LSE, and the IIES for extremely helpful comments.

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assuming that consumers trade off different goods at consistent rates.

However a famous laboratory experiment seems to show that rates of trade-off between time and money can vary drastically between situations. Tversky and Kahneman (1981) found that most of their experimental subjects stated they were willing to drive 20 minutes to save \$5 from a \$15 item, but not to drive 20 minutes to save \$5 from a \$125 item. If the subjects had utility linear in money, then their willingness to drive should be the same in both situations. If instead they had concave utility of money, the reversal in preferences should go in the opposite direction.

If people are subject to this bias in the real world, i.e. valuing money less when considering larger values, this will have important effects on demand functions, and therefore important effects on the equilibrium distribution of prices and quantities. In this paper I show how this relative thinking will affect demand under fairly general assumptions, deriving three predictions about equilibrium. First, margins will be increasing in cost (equivalently, pass-through will be greater than 1, or demand will be cost-amplifying¹). Second, price dispersion will be increasing in cost. This holds whether dispersion is measured as the range or standard deviation of prices. Third, entry will be increasing in cost. Each follows simply because higher costs, insofar as they lead to higher prices, lower customers' sensitivity to marginal units of money, having an effect on prices equivalent to an increase in transport costs (more generally, an increase in any costs of substitution between goods).

Much empirical literature supports these predictions. For the markup predictions, most time series studies find pass-through rates greater than 1. For the dispersion predictions we only have cross section studies, though again these strongly support the predictions. I discuss in detail other explanations for these patterns.

In this paper I also introduce a novel dataset of 3,500 costs and prices from a branch of a chain drugstore. The dataset is unusual in having both cost and price, and therefore markups. The dataset shows an extremely close relationship between cost and markup (here defined as price minus cost). One striking feature is how few outliers there are. For example, there are around 400 products with

¹Weyl and Fabinger (2009)

a cost (to the retailer) of more than ten dollars, and around 400 with a cost of less than one dollar. Seventy percent of the former have a markup of more than \$5. Yet, of the latter, not a single product has a markup of more than \$5. Aside from relative thinking, differences in markups can be caused by many factors: elasticity of demand, customer demographics, frequency of purchase. But it is remarkable that there should not be a single \$1 item with the right mix of elasticity, demographics, and purchase frequency to justify a \$5 markup.

2 Relative Thinking

Tversky and Kahneman (1981) introduced relative thinking into the literature on biases in economic decision-making with this pair of questions, given to two different groups of subjects:

(A) Imagine that you are about to purchase a jacket for \$125, and a calculator for \$15. The calculator salesman informs you that the calculator you wish to buy is on sale for \$10 at the other branch of the store, located 20 minutes drive away. Would you make the trip to the other store?

(B) Imagine that you are about to purchase a jacket for \$15, and a calculator for \$125. The calculator salesman informs you that the calculator you wish to buy is on sale for \$120 at the other branch of the store, located 20 minutes drive away. Would you make the trip to the other store?

Someone who makes consistent trade-offs between time and money should give the same answer to both questions. However Tversky and Kahnemann found that in case A, when the \$5 discount is off a \$15 total, then 68% of subjects said they would make the trip to the other store. In case B, when the \$5 discount is off a \$125 total, only 29% of subjects said they would make the trip.

The effect has been replicated in many variations, though mostly in hypothetical experiments. As an illustration of the magnitude of these hypothetical responses, subjects in Azar (2011) were asked how large a saving would justify a 20 minute trip to another store. When contemplating buying a \$10 pen, the

median response was a \$4 saving. When contemplating a \$1000 computer, the median response was a \$50 saving. When contemplating a \$10,000 car, the median response was a \$300 saving.²

There is not an agreement in the literature on how to describe the source of this inconsistency. Tversky and Kahneman (1981) say it comes from diminishing sensitivity and narrow bracketing. Azar (2008) says that higher prices tend to lower psychic transport costs. Cunningham (2013) gives an alternative explanation: tradeoff decisions are influenced by the choice set, such that observing higher magnitudes along any dimension will tend to lower sensitivity to that dimension. Thus higher prices cause lower sensitivity to money, leading to demand which is less sensitive for high prices than for low prices.

3 Modeling Relative Thinking

I here introduce a model of decision-making where the utility function depends on the choice set in a particular way. The model is discussed in greater detail in Cunningham (2013).

Intuitively, the model states that subjects become less sensitive to a marginal difference when they are confronted with larger magnitudes of that attribute. Thus when they are considering large amounts of money, a small difference comes to seem less important. So for more expensive goods, consumers are less likely to take a trip to save some money.³

Let subjects choose from a choice set A containing m alternatives denoted $\{x^1, \dots, x^m\} = A$, where each alternative is a vector of n attributes $x^i = \{x_1^i, \dots, x_n^i\} \in \mathbb{R}^n$. An ordinary utility function is just a function of the attributes of each alternative $U(x_1, \dots, x_n)$, whereas we here instead consider a choice-set dependent

²The effect is so strong, it seems to sometimes affect economists writing on markups. For example Lach (2002) explains some data as consistent with rationality because “search costs are low relative to the high price of the good and, as a consequence, more searching for the lowest price is undertaken.”

³Incidentally this also predicts an effect of price on add-on purchases, as Savage (1954) puts it: “a man buying a car for \$2,134.56 is tempted to order it with a radio installed, which will bring the total price to \$2,228.41, feeling that the difference is trifling. But, when he reflects that, if he already had the car, he certainly would not spend \$93.85 for a radio for it, he realizes that he made an error.”

utility function $U(x_1, \dots, x_n|A)$.

Definition 1. A choice-set dependent utility function $U(x|A)$ exhibits *relative thinking* if, for every $1 \leq i, j \leq n$ and alternative $0 \leq k \leq |A|$,

$$\frac{\partial}{\partial x_i^k} MRS_{i,j} \equiv \frac{\partial}{\partial x_i^k} \frac{\partial U / \partial x_i}{\partial U / \partial x_j} \leq 0$$

The formula expresses that an increase in the magnitude of any of the alternatives' attributes along dimension i will cause the relative sensitivity to everywhere decrease, i.e. the marginal rate of substitution will get smaller. Figure 1 shows that, when B shifts out along the horizontal dimension, this causes marginal utility with respect to that dimension to decrease, and therefore causes the MRS to fall, i.e. the indifference curves to flatten (in each case, we plot only the indifference curve which passes through alternative A).

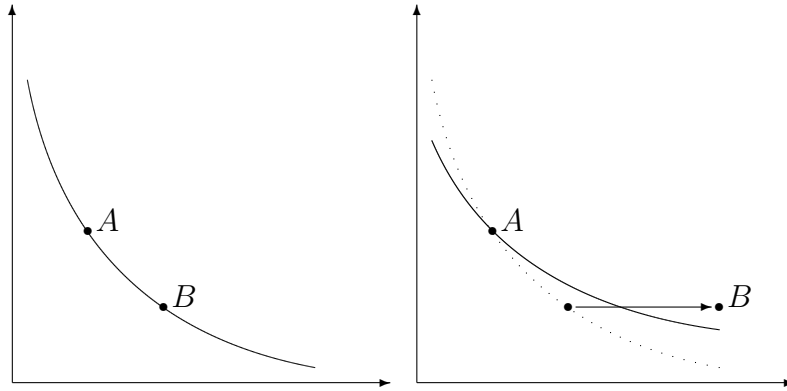


Figure 1: The Effect of Changes in the Choice Set on Indifference Curves

4 Relative Thinking in Market Equilibrium

I begin with a baseline model to show how there will be perfect pass-through of costs in a model of differentiation under two conditions used in the standard Hotelling model: (i) unit demand (meaning that every consumer buys exactly one product, i.e. total demand is inelastic); and (ii) money is linearly separable in the utility function, i.e. there are no income effects. All proofs are in an Appendix.

Suppose there are N firms, and a unit mass of consumers, indexed with j . Each consumer chooses to purchase one firm's product, from the vector of prices $p = (p_1, \dots, p_N) \in \mathbb{R}^N$, and each consumer has a vector of idiosyncratic valuations for each of the N products, $v_j = (v_{j,1}, \dots, v_{j,N}) \in \mathbb{R}^N$. The valuations are drawn from the continuously differentiable joint distribution F .

I assume quasilinear utility, i.e. the utility that consumer j receives from purchasing product i is assumed to be:⁴

$$U_{j,i} = v_{j,i} + \beta(m_j - p_i)$$

where m_j is the consumer's wealth, and $v_{j,i}$ is consumer j 's idiosyncratic value for good i . For now I consider β to be a constant; in the next section I will allow β to depend on the prices observed.⁵

Each consumer will choose the good i which maximises the term $v_{j,i} - \beta p_i$. I assume that in equilibrium the maximum value of $v_{j,i} - \beta p_i$ is always greater than an outside option $\underline{u} = 0$; this assumption makes total demand inelastic - i.e., every customer buys exactly one good.

Demand can be written as an integral over the density of preferences:

$$D^i(p) = \int_{\beta p_i}^{\infty} \int_{\prod_{j \neq i} S_{j,i}} f(v) dv_{-i} dv_i$$

Where $S_{j,i} = (-\infty, \beta p_j + v_i - \beta p_i)$, which represents the set of valuations of good j such that, at given prices, good i will be preferred to good j . By our assumption of unit demand, $v_{j,i} > \beta p_i$, so we can simplify this to

$$D^i(p) = \int_{-\infty}^{\infty} \int_{\prod_{j \neq i} S_{j,i}} f(v) dv_{-i} dv_i$$

This says that the total density inside the intersection of $S_{j,i}$ for all $j \neq i$ is equal to the demand for good i . Note that this demand function is invariant to

⁴Technically this is an indirect utility function, equivalent to a utility function which is linear in consumption of the outside good.

⁵The assumption that consumers share a common β is without loss of generality, because of the lack of restriction on the distribution of v .

a constant addition to all prices, i.e. it is preserved when prices are transformed $p_i = p_i + \tau$. In words, consumers' decisions are determined only by the differences between prices.

Turn now to the producers. Each producer faces the same marginal cost, c , and all choose their price simultaneously, prior to consumers' demand decisions. They thus have a profit function

$$\pi_i = (p_i - c)D^i(p)$$

With first-order condition,

$$(p_i - c)D^{ii}(p) + D^i(p) = 0$$

where $D^{ii} = \frac{\partial}{\partial p_i} D^i(p)$.

The model so far allows great flexibility in the demand system, and does not guarantee either existence or uniqueness of an equilibrium set of prices. For simplicity I therefore assume that demand is twice differentiable, and the Jacobian of the demand system is negative definite, which guarantees existence and uniqueness (Vives (2001), p145).⁶ The model thus encompasses both horizontal and vertical differentiation.⁷

This allows our first comparative static,

Proposition 1. *Without the comparison effect $\frac{dp_i}{dc} = 1$ for all i .*

This simply states that, because demand depends only on *differences* between prices, the equilibrium in relative prices will be independent of the level of cost, in other words aggregate pass-through will be exactly 1. It is easy to see that price dispersion will be unaffected by cost, as will entry (margins stay the same, therefore profits stay the same, so the incentives for entry are unaffected).

⁶I will assume this holds both for the ordinary demand function and the demand function incorporating a comparison effect. Caplin and Nalebuff (1991) have an extended discussion of conditions on utility functions which will underlie a demand system with an equilibrium.

⁷Typically in vertical differentiation models consumers have the same preferred ranking among alternatives; in horizontal differentiation, they have different rankings. Because I put so few constraints on F , either can occur in this model. In a two-firm Hotelling model with uniform customers and quadratic transport costs (Tirole (1994) p281), the difference in utilities $u_{j,1} - u_{j,2}$ would be distributed uniformly.

4.1 Demand with a Comparison Effect

I now introduce a utility function with menu dependence. In particular, I assume that demand is quasilinear in money for a *given* choice set, but sensitivity to money decreases with the magnitude of prices in the current choice set, i.e.:

$$U_{j,i} = v_{j,i} + \beta(p_1, \dots, p_N) [m_j - p_i]$$

with

$$\beta > 0, \frac{\partial \beta(p_1, \dots, p_N)}{\partial p_k} < 0, \forall k$$

The marginal rate of substitution between money and quality is now:

$$MRS_{p,v} = \frac{\partial U / \partial p}{\partial U / \partial v} = -\beta(p_1, \dots, p_N)$$

Thus, because β is decreasing in every price, the utility function exhibits the comparison effect.

For now I will assume that firms do not internalise their own effect on β ; relaxing this assumption is discussed later. Though β may vary between customers, our results here do depend on $\frac{\partial \beta}{\partial p_i}$ being the same for all customers. Similar results could be derived if I allowed $\frac{\partial \beta}{\partial p_i}$ to vary between customers, but we would require restrictions on the distribution of v and its covariance with $\frac{\partial \beta}{\partial p_i}$.

Using this representation, pass-through will be greater than one, i.e., higher cost goods will have higher markups:

Proposition 2. *With relative thinking then $\frac{dp_i}{dc} \geq 1$, for all i , i.e. aggregate pass-through is greater than one.*

This holds simply because when prices are higher, customers become less sensitive to price differences (in the Hotelling model, it is equivalent to an increase in transport costs). For every firm, the sensitivity of demand to price becomes less, so they will raise their price.

Proposition 3. *With relative thinking then for any i and j , $\frac{|dp_i - dp_j|}{dc} \geq 0$, i.e. dispersion is increasing in cost.*

The result may be thought to be surprisingly unambiguous, given the lack of assumptions on demand. Mathematically it holds because the demand function depends only on weighted price differences $\beta(p_j - p_i)$. Thus, if all prices increase by the same fixed amount, the first-order conditions will still hold. Likewise if β increases by some fixed factor, and all price differences decrease by the same factor (equivalently, if all margins decrease by this factor) then the terms $\beta(p_j - p_i)$ will remain unchanged, and the first-order conditions will hold.

Intuitively, when consumers become 10% less sensitive to prices (β falls by 10%), then having all firms increase their margins by 10% will return demand and marginal demand to exactly the same position as before, restoring equilibrium.

4.2 Endogenous Entry

So far I have assumed a fixed number of firms, implying that the profit earned will vary with cost (because cost increases markups, without affecting quantity sold). Free entry will naturally eliminate the effect of cost on profits. Nevertheless, as I will show, the effect on markups remains, at least in the simplified case of symmetric competition on a circle, i.e. in a Salop model.

For simplicity I assume a large market and thus treat the number of firms n as a continuous variable.

Proposition 4. *When customers are distributed uniformly on a circle, with quadratic transport costs, and the number of firms n is determined by a fixed cost C and a zero profit condition, then*

$$\begin{aligned}\frac{dn}{dc} &> 0 \\ \frac{dp}{dc} &> 1\end{aligned}$$

The lower sensitivity to price is now taken up in two ways: firms charge higher markups, and more firms enter.

Thus for high-priced goods which are sold at multiple outlets, we should see many retailers, each selling relatively few goods. This may be true in some markets, e.g. jewellers, car dealers, estate agents, optometrists, where it could be thought that there are many low-volume, high-margin outlets. As with most

cross-industry predictions, this is extremely difficult to test, because many other characteristics important for industry structure are likely to covary with the cost of the good being sold (Sutton (1992)).

4.3 Endogenising β

The model presented does not allow firms to take into account the effect of their own price on price-sensitivity, β . I will discuss briefly the consequences of this in a 2-firm model.

Call the two firms H and L , with names assigned such that $p_H \geq p_L$. Let the proportion of customers who buy good L be given by $F(\beta(p_H - p_L))$. The two profit functions and first-order conditions will be

$$\begin{aligned}\pi_L &= (p_L - c)F(\beta(p_H - p_L)) \\ \pi_H &= (p_H - c)[1 - F(\beta(p_H - p_L))] \\ \pi'_L &= F - (p_L - c)\beta F' + \frac{\partial \beta}{\partial p_L}(p_H - p_L)(p_L - c)F \\ \pi'_H &= 1 - F - (p_H - c)\beta F' - \frac{\partial \beta}{\partial p_H}(p_H - p_L)(p_H - c)F'\end{aligned}$$

Only the final term in each first-order condition is new. Because $\frac{\partial \beta}{\partial p_L}$ and $\frac{\partial \beta}{\partial p_H}$ are both negative, the new term will be negative for firm L and positive for firm H . Firm L has an additional incentive to lower their price because a lower price makes each consumer more sensitive to a given difference in prices, and the marginal consumer therefore switches to the low-price firm. The corresponding term is positive for firm H because they are better off when the marginal consumer becomes *less* sensitive to a given difference in prices. In a symmetric equilibrium where $p_H = p_L$ the term disappears because neither firm cares about their influence on β ; a change in β will not affect the choice of any customer.

In this case endogenising β gives an extra incentive towards price dispersion. This is of relevance to the principal predictions if $\beta(\bar{p})$ is decreasing and convex, because as c rises, and prices rise, then β' will become smaller, lowering the incentives for dispersion. The net effect may then go in the opposite direction from Proposition 3. It remains to be shown under what conditions the direct

effect dominates this indirect effect, though when there are many firms this effect (of endogenising β) will be small.

4.4 Income Effects

I have assumed that the underlying utility function is linearly separable in money for a given β , i.e. the consumer is risk neutral. Introducing concave utility for money is not trivial, but it is likely to reinforce the results. As prices increase, terminal wealth decreases, so the marginal utility of money increases. The effect thus is similar to an increase in β , raising the sensitivity to differences in price, and thus lowering equilibrium markups and equilibrium dispersion - i.e. the effect is in the opposite direction from that predicted by relative thinking. Put another way, risk aversion does not seem to help explain the observed positive relationship between price and markup, if anything it would seem to predict the opposite.

5 Evidence

Here I survey the evidence for the first two predictions: that markup is increasing in cost, and that dispersion is increasing in cost.

To summarise, there is strong evidence for both effects in the cross-section of products. However in cross-section studies identification is not strong, I discuss a variety of possible confounding factors. In time series studies identification is much stronger, and published studies largely supports the model's predictions for markup. Unfortunately I am not aware of any time-series studies which look at price dispersion.

The paper's predictions for prices are driven through relative thinking's distortions of the demand function. We are thus indirectly looking for features of demand by observing costs and prices. There are then two factors we should consider in interpreting the evidence: first, whether the inferred shape of demand could occur without relative thinking. Second, whether observed prices may not reveal demand, due to other confounding factors.

Tackling the first problem, the prediction can be stated as pass-through rates being greater than one ($\frac{dp}{dc} > 1$). Pass-through rates depend on the industry

structure. If the industry is perfectly competitive then the rate of pass through must be less than or equal to 1 (as long as demand slopes down and supply slopes up). At the other extreme, for a monopolist, their pass-through rate depends on the curvature of the demand curve they face: it will be greater than 1 if and only if the demand curve is log convex.⁸ Of interest here is the oligopoly case, because all the studies I cite consider homogenous goods sold at different outlets. As I have shown in the previous sections, with unit demand and quasilinear preferences, pass-through will always be equal to 1. Any deviation must therefore be due to a violation of unit demand, i.e. total demand varying with cost.⁹ In a symmetric model this must mean that as prices rise all firms face a decreased ratio of marginal consumers to inframarginal, i.e. demand has a decreasing hazard rate (a.k.a. a heavy-tailed distribution). I cannot rule this out as an alternative explanation of the results.

Turning to price dispersion, most models predict that dispersion is independent of cost, because most assume unit demand and quasilinear preferences: i.e., they set up the problem as choosing which store to buy an item from, ignoring the question of how many items to buy. The problem is thus entirely independent of cost (maintaining quasilinearity), and this holds for dispersion driven by differentiation (as in this paper), or dispersion driven by imperfect information (see Baye et al. (2006) for a survey). It is not clear what can be said about cost and dispersion when the assumption of unit demand is relaxed.

5.1 Evidence on Markups

Because cost data is difficult to obtain (and because of endogeneity problems) estimates of pass-through have often been based on tax changes, which largely find pass-through rates greater than one. For cigarette taxes Barzel (1976) found pass-through slightly greater than one. For alcohol taxes Kenkel (2005) and Young and Bielinska-Kwapisz (2002) both find pass-through greater than one. Estimating pass-through using changes in broad-based sales taxes, Poterba (1996) finds pass-

⁸The monopolist's first order condition is $(p - c) = -Q(p)/Q'(p)$, so $\frac{dp}{dc} = \frac{1}{1 + \frac{\partial}{\partial p} \frac{Q(p)}{Q'(p)}}$, and $\frac{\partial^2}{\partial^2 p} \log(Q(p)) = \frac{\partial}{\partial p} \frac{Q'(p)}{Q(p)}$, thus log convexity or concavity determines the pass-through rate.

⁹I discussed earlier why violations of quasi-linearity are likely to push in the other direction.

through close to 1, but Besley and Rosen (1999) find a higher pass-through.

5.2 Evidence from a Drugstore

I have collected a new dataset, which documents the cross-section relationship of cost and markup. The data are 3,500 observations of cost and price from a Cambridge, Massachusetts branch of a national drugstore chain. It is unusual to observe cost for a retailer: a comparable dataset is used in Eichenbaum et al. (2011), who say “we’re really, I think, one of the first people to ever get data on marginal costs and you see fascinating patterns” (Eichenbaum and Vaitilingam (2009)). However Eichenbaum et al. are not able to publish data on markups, as I am, because they say “[o]ur agreement with the retailer does not permit us to report information about the level of the markup for any one item or group of items.”

The dataset is documented further in an appendix. Figure 2 plots item cost against item markup, and shows the very strong relationship between the two variables. On average a \$1.00 increase in cost is associated with an increase in absolute markup of \$0.73, thus proportional markup is decreasing in cost, although slowly.

One feature in particular is notable: the absence of outliers, i.e. goods with either low-cost and high-markup, or high-cost and low-markup. If the cost-markup relationship was driven by a correlation between cost and demographics, the correlation must be extremely strong. Put another way, the graph would imply that there are almost no low-cost goods with high-demographic customers, or high-cost goods with low-demographic customers. As examples, various types of branded lip balm, coffee filters, and scented candles (plausibly high-demographic goods) all have cost below \$1 and markup below \$1. Whereas only two products out of 400 with cost above \$10 have a markup below \$1.¹⁰

Because this is cross-section evidence, the cost-markup relationship does not directly identify the shape of the demand functions: it could be driven by confounding factors. Three factors are worth discussing: the demographics of the customers, the substitutability with other goods sold by the firm, and the fre-

¹⁰Huggies nappies and Pampers nappies.

quency of purchase. All three factors are reasons why demand might be less sensitive for high cost items, so they could predict both the markup and dispersion relationships.

First, if high-cost goods were bought by customers with less sensitive demand (lower hazard rates), this would cause them to be associated with higher markups. An important determinant of demand sensitivity should be income, determining the opportunity cost of your time, thus if high-cost items are bought by high-income customers, this would predict a positive relationship between cost and markup.

Second, if firms sell multiple products then the optimal markup depends on interactions: if low-cost goods tend to be more complementary with other goods than are high-cost goods, this would again predict the observed relationship. A strong source of complementarity would come from any fixed cost of a visit to a store because, in effect, if a good is often purchased in a basket with other goods, the total markup can be spread out over the total basket. Thus if low-cost goods are more often bought in a basket with other goods, this will also generate a positive cost-markup relationship in the cross-section.

Third, if a good is more frequently purchased, there is a stronger incentive to collect price information, potentially leading to a higher price sensitivity (Sorensen (2000)). If high-cost goods tend to be purchased less frequently, high cost goods should thus have higher markups, and higher price dispersion.

Finally, there are some biases which may affect estimation. First, the observed marginal cost of goods does not account for other variable costs, such as handling. If high cost goods tend to have higher handling costs, this would also account for higher *measured* margins, even when the true margins are the same. (One handling cost certainly higher for high-cost goods is the cost of capital). Second, there may be some censoring due to turnover. If a good is sold infrequently, the opportunity cost of allocating shelf-space to this good may be too high. Thus if there is a negative correlation between cost and turnover, we should expect to observe positive correlation between cost and markup in products observed due to censoring. Third, firms may simply use a rule of thumb in pricing, marking up by a constant fraction, even when it departs from the profit maximising price. Looking again at Figure 2, if firms used a rule of thumb we would expect observations to be

lined up along upward sloping lines. Instead we see much variation for products with the same cost, indicating that the firm conditions on information other than cost when setting price (i.e., they do not use a simple rule of thumb).

5.3 Evidence on Dispersion

There are a number of empirical papers which document the correlates of price dispersion. Most papers do not have access to cost data, but they do report the relationship between price and dispersion. Unfortunately I do not know of any papers about dispersion which use a strongly exogenous source of cost variation, as in the literature above which measures the effect of tax changes on markups. Instead all the papers I describe here are in the cross section, and so are subject to the caveats that I have already mentioned.

In short, every study I know of has found a very strong positive relationship between price and price dispersion. The effect is so strong that a number of papers use as their basic measure of dispersion the *proportional* dispersion of prices, i.e. using $\frac{p_1 - p_2}{\frac{1}{2}(p_1 + p_2)}$ instead of $(p_1 - p_2)$. If proportional price dispersion is constant in cost, then absolute dispersion is increasing in cost. However to be consistent with the models they cite, these papers should be measuring absolute price dispersion (see, for example, Baye et al. (2004), Clay et al. (2002), Jaeger and Storchmann (2011), Lach (2002)).¹¹

An early paper on price dispersion was Pratt et al. (1979), using a variety of different goods, and they find a strong positive relationship between price and dispersion. So do Aalto-Setälä (2003) for groceries, Baye et al. (2004) and Pan et al. (2001) for goods sold online, Clay et al. (2002) for books sold online, Hoomissen (1988) and Lach (2002) for consumer goods, Jaeger and Storchmann (2011) for wine, and Sørensen (2000) for prescription drugs. The empirical literature is surveyed in Ratchford (2009).

The same caveats apply from last section, regarding correlates of cost. However the two studies which control for purchase frequency find that it makes very little

¹¹Confusion on this point leads to some errors in interpretation. For example, Clay et al. (2002) say “The increase in standard deviation with price is ... somewhat surprising ... given that search models predict that customers will engage in more search for higher priced items and so price dispersion will be lower.” Lach (2002) says “search costs are low relative to the high price of the good and, as a consequence, more searching for the lowest price is undertaken.”

change to the estimated relationship between dispersion and price. In Pratt et al. (1979), the estimated coefficient of $\ln(\text{price})$ on $s.d.(\text{price})$ shrank from 0.892 to 0.836, when a proxy for purchase frequency was introduced. Sorensen (2000) reports results using both cost and purchase frequency as explanatory variables, and finds that a \$1 higher cost is associated with a 20 cent increase in the range of prices.

5.4 Related Literature

This IO application of the comparative thinking model paper broadly belongs to a family of recent literature examining the effects of non-standard decision making in different market equilibrium settings, surveyed in Ellison (2006) and Spiegler (2011).

The idea that proportional thinking may help explain patterns in price dispersion has been brought up a number of times, first by Tversky and Kahneman (1981), in the course of introducing the jacket/calculator example, who mention that it may explain the relationship between price and price dispersion found in Pratt et al. (1979). Grewal and Marmorstein (1994) make the same claim, and report that willingness to search seems related to the base price of a good, and that dispersion seems to be increasing the price of goods.

Most closely related to this paper is Azar (2008), which constructs a 2-firm model with horizontal differentiation. Azar shows that in that model dispersion is increasing in transport costs, and proposes that relative thinking can be modeled as transport costs increasing in price.¹² The model presented here extends Azar's work in a number of ways: in deriving the behavioural results from a general model of relative thinking, in deriving the results from a more general model, in deriving predictions for both the level and dispersion of prices, as well as firm entry, and finally in introducing new data on the level of markups.

¹²Using this interpretation, Azar (2008) says that higher prices can have negative welfare effects through raising the unpleasantness of travel. It seems more natural to assume, as in this paper, that relative thinking works through higher prices lowering the subjective value of *money*, rather than raising the subjective value of transport. The distinction is useful for welfare analysis, but also if we are to predict how tradeoffs are made against other goods apart from time or money.

6 Conclusion

This paper has shown how relative thinking will change a system of demand functions, which would ordinarily imply constant markups, such that in equilibrium higher cost will be associated with higher markups, higher dispersion, and more entry. We have shown that data supports the predictions, both in time series and in cross-section, though other explanations are also consistent with the data. Finally we introduced a large dataset of costs and prices from a drugstore, which shows a very tight relationship between cost and price.

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Appendix 1: Description of Drugstore Data

The data is from a Cambridge, Massachusetts branch of a large national chain of drugstores. The store has floorspace of approximately 500 square meters (5400 square feet). Another drugstore of a similar size, belonging to a competing chain, is located directly across the road.

The store sells a variety of products, principally snacks, groceries, beauty products, stationary, and drugs (both over-the-counter and prescription drugs, however I was not able to observe the labels for the latter). The data was collected by individually photographing price labels for 3,582 different products over a period of 5 days (28 March - 3 April, 2011), from an estimated 6,000 products in the entire store. From each photo I transcribed the product's ID number, cost code, and price. The ID numbers were matched against a list of ID numbers downloaded from the chain's website on April 4th 2011, which contained much comprehensive information about each product. However 25% of the products photographed were not listed on the website.

The cost (i.e., cost to the retailer) was inferred from the cost code, a sequence of letters on the label. Originally I found the cipher used to decode it posted in an online forum. Subsequently I have talked to staff at the store, one of whom confirmed that the code represents cost. The patterns of cost are consistent with plausible changes in product composition. For example, all half-gallons of milk sell for the same price, \$2.29, however the cost varies depending on fat content, the costs for 0%, 1%, 2%, and full fat milk are \$1.66, \$1.72, \$1.76 and \$1.78 respectively.

Some products were marked both with a regular price and a temporary sale price. For these I recorded only the regular price. If a promotion was subsidised by the manufacturer without updating the cost (in my observation, cost codes were not updated when switching to and from a promotion), then this would lead to incorrect measurement of margins. Note that in the US the FTC regulates former price comparisons, requiring that the former price be one at which "the article was offered to the public on a regular basis for a reasonably substantial period of time."¹³

¹³See <http://www.ftc.gov/bcp/guides/decptprc.htm>

I have asked two employees about the cost code. One was not aware of the code, the other confirmed that it represented cost. She said that they use it for making decisions about items to promote, especially when they have leftover stock. She also said that it was not used often, because most pricing decisions are made at the firm's headquarters.

Appendix 2: Proofs

Proof of Proposition 1. Corresponding to each first-order condition, there is a total derivative (suppressing the arguments to D):

$$\begin{aligned} (dp_i - dc)\beta[D_{ii}] + \beta^2(p_i - c) \sum_{j=1}^m dp_j D_{ij} - dp_1 \beta^2(p_i - c) \sum_{j=1}^m D_{ii1} \\ + \beta \sum_{j=1}^m dp_j D_{ij} - dp_1 \beta \sum_{j=1}^m D_{ij} = 0 \end{aligned}$$

Where we define $D_{ij} = \frac{\partial}{\partial x_j} D_{ii}$. Dividing by dc and rearranging:

$$\left(\frac{dp_i}{dc} - 1\right)\beta[D_{ii}] + \beta^2(p_i - c) \sum_{j=1}^m \left[\frac{dp_j}{dc} - \frac{dp_1}{dc}\right] D_{ij} + \beta \sum_{j=1}^m [dp_j - dp_1] D_{ij} = 0$$

It can be seen that this equation is solved exactly when $\frac{dp_1}{dc} = \frac{dp_2}{dc} = \dots = \frac{dp_m}{dc} = 1$. Because we are assuming a unique solution to the first-order conditions, this must be the only solution to the set of total-derivative equations. $\square$

Proof of Proposition 2. The first order condition remains

$$\beta(p_i - c)D_{ii}(p) + D_i(p) = 0$$

where demand is

$$\begin{aligned} D^i(p) &= \int_{-\infty}^{\infty} \int_{\prod_{j \neq i} S_{j,i}} f(v) dv_{-i} dv_i \\ S_{j,i} &= (-\infty, \beta p_j + v_i - \beta p_i) \end{aligned}$$

This can be written in terms of β times the margin of each firm, $\beta(p_i - c)$:

$$S_{j,i} = (-\infty, v_i + \beta(p_j - c) - \beta(p_i - c))$$

Thus the first-order conditions will all be satisfied if $d[\beta(p_i - c)] = 0$, for all i .

Thus, letting $\beta = \beta(p_1, \dots, p_n)$, and $\beta_j = \frac{\partial \beta(p_1, \dots, p_n)}{\partial p_j}$,

$$\begin{aligned} d[\beta(p_1, \dots, p_n)(p_i - c)] &= (p_i - c) \sum_{j=1}^m dp_j \beta_j + \beta(dp_i - dc) = 0 \\ \frac{dp_i - dc}{p_i - c} &= -\frac{1}{\beta} \sum_{j=1}^m \beta_j dp_j \end{aligned}$$

This quantity cannot be negative.¹⁴ This shows that the proportional change in margins is equal for every firm. This also can be written as:

$$\frac{dp_i}{dc} = 1 - \frac{(p_i - c)}{\beta(\bar{p})} \sum_{j=1}^m \beta_j(\bar{p}) dp_j$$

Because $\beta_j < 0$ for all j , and markups are always non-negative, this proves the proposition. $\square$

Proof of Proposition 3. If $p_i > p_j$, then

$$\frac{|dp_i - dp_j|}{dc} = \frac{dp_i}{dc} - \frac{dp_j}{dc} = -\frac{(p_i - p_j)}{\beta} \sum_{k=1}^m \beta_k dp_k$$

which is greater than zero, because $\beta' < 0$. The argument is analogous for $p_j > p_i$. $\square$

Proof of Proposition 4. We assume a continuum of firms, so that we can stipulate a zero profit condition which holds with equality: profits must equal the fixed cost C . In a symmetric equilibrium the two conditions will be:

$$\begin{aligned} (p - c)F &= C \\ (p - c)\beta f &= F \end{aligned}$$

When F is uniform, then the conditions become

$$(p - c)\frac{1}{n} = C$$

¹⁴Suppose $dp_i/dc < 0$, then $\frac{dp_i/dc - 1}{p - c} < \frac{dp_i/dc}{p} < 0$, so the effect on β is larger than the effect on p , which we ruled out.

$$(p - c)\beta = \frac{1}{n}$$

Solving these two conditions we get

$$\begin{aligned} n &= (\beta C)^{-1/2} \\ p - c &= C^{1/2} \beta^{-1/2} \end{aligned}$$

Then we get:

$$\begin{aligned} dp - dc &= -dp \left[\frac{1}{2} \frac{\partial \beta}{\partial p} C^{\frac{1}{2}} \beta^{-\frac{3}{2}} \right] \\ \frac{dp}{dc} - 1 &= -\frac{dp}{dc} \frac{\beta' C^{1/2} \beta^{-3/2}}{2} \\ \frac{dp}{dc} &= \frac{1}{1 + \frac{\beta' C^{1/2} \beta^{-3/2}}{2}} > 1 \end{aligned}$$

and

$$\frac{dn}{dc} = -\frac{1}{2} \left(\frac{C}{\beta} \right)^{-1/2} \frac{d\beta}{dc} > 0$$

Because $\frac{d\beta}{dc} = \frac{\partial \beta}{\partial p} \frac{dp}{dc} < 0$.

□

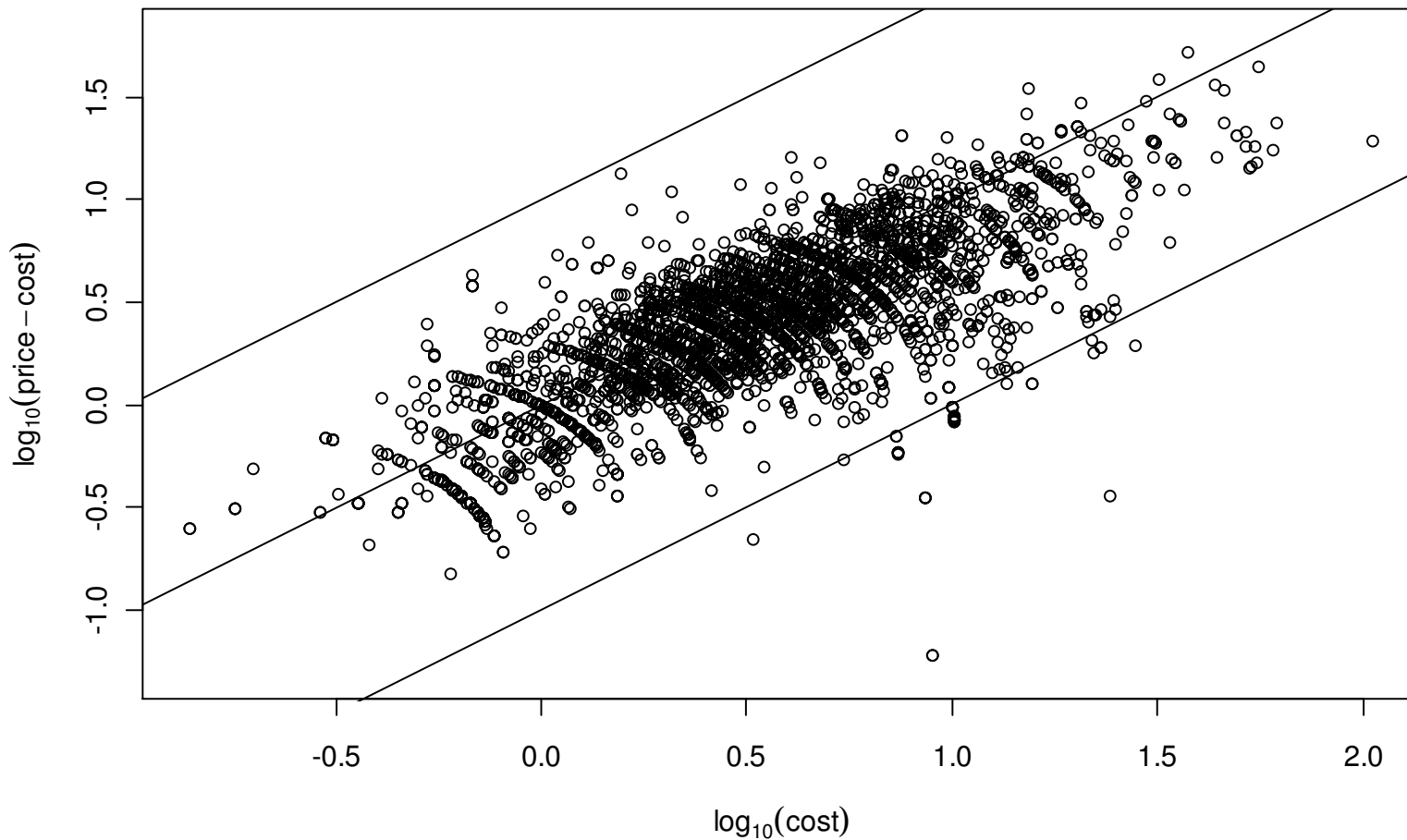


Figure 2: Cost and Markup in 3,500 Items from a Drugstore.

Both axes are plotted on a base-10 log scale; the three upward-sloping lines thus represent constant proportional markup rates of 10%, 100%, and 1000%. The curved downward-sloping lines formed by the data points are caused by clustering of prices at common price-points, e.g. 49 cents, 99 cents, etc.

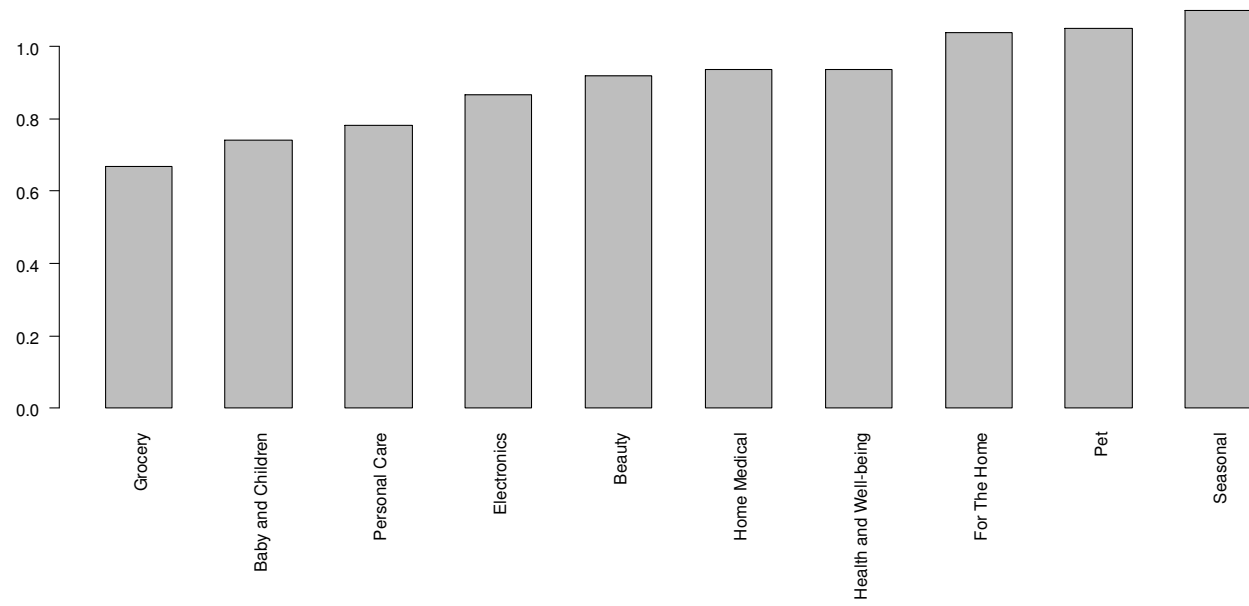


Figure 3: Average Proportional Markup ($\frac{p-c}{p}$) by Product Category