# Sources of Irreversible Consumer Demand in U.S. Dairy Products

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**Abstract**
Irreversible demand is relevant to pricing strategy and demand modeling with weekly data. Competing explanations include loss aversion and stockpiling. Irreversible models for U.S. cheese and table spreads suggest that stockpiling dominates loss aversion. Price smoothing may be an inappropriate strategy in this case. Reversible demand models applied to weekly data may overestimate own-price elasticities.

**Keywords**: irreversible demand, dairy products, scanner data

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### Introduction

Food retailers often expect consumers to resent price increases more than they rejoice over price declines (Kahn and McAlister). This phenomenon, termed loss aversion, causes an irreversible demand curve that is more elastic given price increases, thereby justifying a retail price-smoothing strategy during periods of wholesale price volatility. The loss aversion hypothesis extends to the policy arena, as well, where price support programs are occasionally justified by their ability to stabilize retail prices (e.g., Barker). As we saw during the collapse of the hog market in late 1998, however, producers bitterly oppose the failure of retail prices to reflect upstream market conditions. Incomplete price transmission slows the liquidation of excess supplies, and dilutes expansion signals during periods of excess demand.

Loss aversion requires that consumers compare observed prices with reference prices that represent expectations and standards of fairness. The reference price literature posits the existence of psychological gains and losses from the act of purchasing goods, quite apart from the value of consumption (Thaler). Consumers thus seek to avoid paying prices they consider unfair, and sometimes purchase goods partly to get a good deal.

This paper presents intertemporal substitution as an alternative explanation for irreversible demand. Consumers may react to temporary price reductions by stockpiling goods for later consumption. Under the intertemporal substitution hypothesis, demand would still be irreversible, but demand would be more elastic given price *decreases*. If intertemporal substitution has more influence than loss aversion, the retailer would profit from a more responsive pricing strategy. The outcome in this case would coincide with, rather than conflict with, producers' preference for rapid price transmission across market levels.

One might not be able to discern loss aversion or stockpiling behavior from monthly, quarterly, or annual data. The accessibility of weekly scanner data, however, allows the researcher to test for irreversibility and its sources. Moreover, if loss aversion and stockpiling behavior are significant components of the demand response to a price change, a conventional reversible demand analysis would over-estimate own-price elasticities (in absolute value). Loss aversion and stockpiling behavior may help explain why demand elasticities estimated from weekly scanner data are often substantially more elastic than those derived from monthly commercial disappearance data (Bailey and Gamboa, Maynard and Liu).

The objectives of this study are to: (1) present a conceptual foundation for intertemporal substitution as a competing explanation for irreversible demand, (2) estimate demand models that allow short-run irreversibility to determine if consumers react more strongly to price increases than to price decreases, and (3) determine the extent to which loss aversion and stockpiling explain the difference between own-price elasticities estimated from scanner data and those estimated in previous studies using monthly, quarterly, or annual data.

Cheese and table spreads were selected for empirical study because they are storable yet purchased often enough for consumers to be aware of price changes. Reference price studies appear mainly in the business management literature; this study strengthens the economics discipline's contribution to an issue that food marketers consider important. The analysis differs from previous studies of irreversible demand by using a recently-developed empirical model that allows both short-run irreversibility and long-run reversibility (Vande Kamp and Kaiser). In addition, this study extends the implications of intertemporal substitution to a timely debate about the credibility of demand elasticity estimates obtained from data of varying periodicity.

**Loss Aversion as a Cause of Irreversible Demand**

Ferris (p. 10) notes that few treatments of irreversible demand exist in the economics literature, particularly on a theoretical level. The classic models of duopoly predict that firms may face kinked demand curves (Kreps, Friedman), but in this study evidence of irreversibility exists in aggregate data. The alternative to emphasizing firm strategic behavior is to focus on consumer behavior. Putler provides a conceptual foundation for irreversible demand rooted in utility maximization.

Putler assumed that consumers compare observed prices with reference prices, perceiving a gain if the observed price is lower than the reference price, and perceiving a loss if the observed price exceeds the reference price. The assumption allows a consumer's utility to depend not only on consumption of goods, but also on the circumstances under which they were purchased. The importance of reference prices to consumers is an example of a framing effect whereby one's evaluation of a stimulus is context-specific (Kahneman et al.). A risk-averse consumer derives greater disutility from a reference price loss than the utility derived from an equivalent reference price gain; this phenomenon is termed loss aversion.

Putler derived a generalized Slutsky equation that decomposes the effect of an own-price change into substitution, income, and reference price gain/loss effects:

$$\frac{\partial x_i}{\partial p_i} = \frac{\partial h_i^*}{\partial p_i} - x_i \frac{\partial x_i}{\partial m} + \left[ (1 - I_i) \frac{\partial m}{\partial g_i} - I_i \frac{\partial m}{\partial l_i} \right] \frac{\partial x_i}{\partial m} ,$$

where $x$ denotes Marshallian demand, $h$ denotes Hicksian demand, $m$ denotes income, $I$ equals one if the observed price exceeds the reference price and zero otherwise, and $g$ and $l$ refer to reference price gains and losses, respectively. The first term on the right-hand side of the Slutsky equation reflects both the traditional substitution effect and reference price effects:

$$\frac{\partial h_i^*}{\partial p_i} = \frac{\partial h_i}{\partial p_i} + I_i \frac{\partial h_i}{\partial l_i} + (1 - I_i) \frac{\partial h_i}{\partial g_i}.$$

The generalized Slutsky equation illustrates that an own-price demand elasticity may depend on both observed prices and reference prices. Furthermore, Putler's maintained hypothesis of loss aversion implies that demand is more elastic in response to price increases relative to price decreases. Putler rejected the hypothesis of symmetric gain and loss terms in a translog model of egg demand, but was unable to reject the hypothesis using an alternative demand specification. Estimated own-price demand elasticities (presumably from the translog model) of -0.78 given price increases versus -0.33 given price decreases supported the argument that loss aversion influences consumer choice.

Mayhew and Winer developed a multinomial logit model to isolate and measure the influence of internal reference prices, which the consumer bases on past experience, and external reference prices, which the marketer supplies in the purchasing environment (e.g., point of purchase displays). The results supported the hypothesis that internal reference price losses loomed larger in consumers' minds than internal reference price gains. The study also concluded, however, that external reference price effects were more pronounced than the impact of internal reference prices.

**Temporal Substitution as a Cause of Irreversible Demand**

Consumer use of reference prices in combination with risk aversion is not the only potential source of asymmetric demand responses. Unless otherwise specified, theoretical demand models reflect a temporal separability assumption. Under this assumption, consumers maximize utility subject only to a current-period income constraint. Previous behavior or expected future behavior do not appear as determinants of current demand. If a food demand analysis relies on monthly, quarterly, or annual data, the temporal separability assumption is probably innocuous. With the current accessibility of weekly scanner data, however, the assumption may not be warranted for storable products.

If one expects higher prices in the future, one can stockpile a storable food product for later consumption and avoid paying the higher price. If the consumer expects lower prices in the future, however, one must still pay the high current price if any consumption is to occur in the current period. A two-period model formalizes the intuitive notion that intertemporal substitution can elicit irreversible demand responses that are more elastic when prices decrease (note that the opposite occurs if loss aversion is the dominant influence).

Suppose a consumer receives a paycheck every two weeks, and shops for groceries each week. Substitution across goods does not affect the central result concerning temporal substitution, so consider only one good for the sake of clarity. Similarly, ignore factors such as discounting from one week to the next, and aversion to the risk of food spoilage. The good may be purchased in the first week and consumed in the second week. Assume the consumer spends her entire paycheck within each two-week period (i.e., only relax the temporal separability assumption within the two-week period under consideration). The consumer's problem is to choose in week one the quantity to be purchased in each week [*q1*, *E(q2)*], and the quantity stored between weeks one and two (*s*) so as to maximize the sum of utility (*u*) from weekly consumption given a bi-weekly budget constraint (*m*) and prices in each week [*p1*, *E(p2)*], where E(.) denotes the expectation operator:

$$\textbf{max}\ \{u(q1 - s) + u(E(q2) + s)\}$$

$$\text{s.t.} \quad p1*q1 + E(p2)*E(q2) \leq m$$

$$-s, -q1, -E(q2) \leq 0 .$$

Assigning multipliers of $\lambda_1$, $\lambda_2$, $\lambda_3$, and $\lambda_4$ to the budget constraint and to the non-negativity constraints on *s*, *q1*, and *E(q2)*, respectively, the first-order conditions are:

$u'(q1 - s) - \lambda_1*p1 + \lambda_3 = 0$;

$u'[E(q2) + s] - \lambda_1*E(p2) + \lambda_4 = 0$;

$-u'(q1 - s) + u'(E(q2) + s) + \lambda_2 = 0$;

$\lambda_1[m - p1*q1 - E(p2)*E(q2)] = 0$;

$\lambda_2*s = \lambda_3*q1 = \lambda_4*E(q2) = 0$;

$\lambda_1, \lambda_2, \lambda_3, \lambda_4 \geq 0$,

where $u'(\cdot)$ denotes the first derivative of the utility function with respect to consumption.

We will consider only solutions where the budget constraint binds (i.e., $\lambda_1>0$), and solutions where positive purchases occur in the first week (i.e., $\lambda_3=0$). Similarly, solutions in which E(q2) = s = 0 (i.e., both $\lambda_4>0$ and $\lambda_2>0$) are trivial. Rearrangement of the first-order conditions implies:

$$\frac{u'(q2+s)+\lambda_2}{u'(q2+s)+\lambda_4} = \frac{p1}{E(p2)} .$$

If the consumer stockpiles the good for later consumption (*s*>0), then $\lambda_2$ must equal 0. This solution can only occur when $p1 \leq E(p2)$. If the consumer makes any purchases in the second period [$E(q2)>0$], then $\lambda_4$ must equal 0. This solution can only occur when $p1 \geq E(p2)$. The model does not specify how the consumer would choose a unique combination of *E(q2)* and *s* when $p1 = E(p2)$. One could incorporate a reasonable decision rule into the model by recognizing discounting, storage constraints, risk of spoilage, etc., but for the purposes of exploring irreversible demand we are only concerned here with response to price movements.

This simple model predicts that data of short periodicity (e.g., weekly) may reflect intertemporal substitution in the form of more elastic responses to temporary downward price movements relative to temporary price increases. Downward price movements may induce the consumer to stock up for the future, but price increases will not induce a corresponding "stocking down" effect. More formally, a downward price movement that causes *p1* to be less than *E(p2)* will elicit a demand response equal to the positive income effect plus the quantity stored for later use. An upward price movement that causes *p1* to exceed *E(p2)* will elicit a demand response consisting only of the negative income effect.

Empirical tests can suggest which of the alternative explanations of irreversible demand, loss aversion or intertemporal substitution, are dominant for a particular food product or category. If loss aversion is the dominant influence, a stable, everyday-low-price (EDLP) strategy is appropriate, particularly if the response to price increases is elastic and the response to price decreases is inelastic. If intertemporal substitution is the dominant influence, a high-low pricing strategy featuring occasional deep discounts is more likely to be appropriate.

**Empirical Models of Irreversible Demand**

Wolffram proposed a method for segmenting an independent variable into increasing and decreasing phases to test the hypothesis of reversibility. Houck suggested an equivalent but more convenient approach that, along with Wolffram's method, has since been used to study supply relationships and asymmetric price transmission across market levels (e.g., Heien, Ward, Kinnucan and Forker, Lass et al.). Given a dependent variable *y* and an independent variable *x*, Wolffram suggested the following segmentation:

$$y_t = \alpha_0 + \alpha_1 x'_t + \alpha_2 x''_t \text{ , where}$$

$$x'_t = x_0 + \sum_{i=0}^{t-1} \max(\Delta x_{t-i}, 0) \text{ , and}$$

$$x''_t = x_0 + \sum_{i=0}^{t-1} \min(\Delta x_{t-i}, 0) \text{ , where } t = 0,\ldots,T \text{ and } \Delta x_j = x_j - x_{j-1}.$$

The function is irreversible if one can reject the null hypothesis that $\alpha_1 = \alpha_2$.

Unbeknownst to Wolffram and Houck, Farrell proposed an equivalent approach years earlier. Farrell specified the following model:

$$\frac{y_t}{y_{t-1}} = e^{\alpha_0} \left[ \max\left( \frac{x_t}{x_{t-1}}, 1 \right) \right]^{\alpha_1} \left[ \min\left( \frac{x_t}{x_{t-1}}, 1 \right) \right]^{\alpha_2} .$$

Logging both sides and letting $Y_t = \ln(y_t)$ and $X_t = \ln(x_t)$ yields:

$$Y_t - Y_{t-1} = \alpha_0 + \alpha_1 \max(\Delta X_t, 0) + \alpha_2 \min(\Delta X_t, 0) .$$

Substituting recursively for $Y_{t-1}$ and all subsequent lags of Y produces:

$$Y_t - Y_0 = \alpha_0 t + \alpha_1 \sum_{i=0}^{t-1} \max(\Delta X_{t-i}, 0) + \alpha_2 \sum_{i=0}^{t-1} \min(\Delta X_{t-i}, 0) \ ,$$

which is identical to Houck's equation (4).

Farrell acknowledged weaknesses in the model. Constant parameters impose permanent irreversibility, implying that if a good's price rose and then returned to its previous level, the quantity demanded would differ from its original level in perpetuity. Farrell speculated about demand functions that are reversible in the long-run and irreversible in the short-run. Vande Kamp and Kaiser recently addressed this problem, adapting Wolffram's model by parameterizing each of the lagged terms that comprise the segmented variable:

$$y_t = \alpha_0 + (\alpha_{1,T} + \alpha_{2,T}) x_0 + \sum_{i=0}^{t-1} \alpha_{1,i} \max(\Delta x_{t-i}, 0) + \sum_{i=0}^{t-1} \alpha_{2,i} \min(\Delta x_{t-i}, 0) \quad ,$$

where $t = 0,\ldots,T$. One imposes long-run reversibility by setting $\alpha_{1,i} = \alpha_{2,i} = 0$ for all $i > n$. After algebraic manipulation, the model reduces to a convenient form for estimation:

$$y_t = \beta_0 + \beta_1 x_t + \sum_{i=0}^{n} \alpha_i^{I} \max(\Delta x_{t-i}, 0) + \sum_{i=0}^{n} \alpha_i^{D} \min(\Delta x_{t-i}, 0) \quad .$$

The immediate marginal impact on *y* of an increase in *x* equals $\beta_1 + \alpha_0^I$, while the immediate marginal impact of a decrease in *x* equals $\beta_1 + \alpha_0^D$. Shocks in *x* only affect *y* for *n* periods following the shock, thereby allowing long-run reversibility. One tests for short-run irreversibility by evaluating the null hypotheses $\alpha_i^I = \alpha_i^D$ for $i = 0,\ldots,n$. One might also test the joint hypothesis $\Sigma\alpha_i^I = \Sigma\alpha_i^D$, where summation is from $i = 0,...,n$. In addition to greater realism, the Vande Kamp and Kaiser model lacks the inherently nonstationary variables formed by segmentation in the Wolffram and Houck models (Farrell used a differential model that probably mitigated nonstationarity).

Vande Kamp and Kaiser found evidence of asymmetric advertising influences on fluid milk demand. In this study, a similar empirical model provides insight into the dominance of loss aversion versus temporal substitution in U.S. consumer demand for cheese and table spreads. Cheese and table spreads were selected for the empirical analysis as representative products with short-run storability and moderate price volatility.

In the absence of other information that might influence consumers' expectations, such as advertising and promotional activities, Putler assumed that consumers form reference prices [denoted $E(p_t)$] from past prices. Under this assumption, a price decrease following a period of price stability would imply that $p_t < E(p_t)$, and the opposite would apply to price increases. Similarly, if expectations of future prices [denoted $E(p_{t+1})$] were assumed to be a weighted average of current and past prices, a price decrease would imply that $p_t < E(p_{t+1})$. Thus, if a model of irreversible demand suggests that the quantity demanded is more responsive to current and past price *increases*, the hypothesis of loss aversion would appear more credible. If the quantity demanded appears more responsive to current and past price *decreases*, temporal substitution would appear dominant.

## Data and Estimation

The price and quantity data used in this study are weekly scanner data collected by A.C.

Nielsen and purchased by the International Dairy Foods Association. The data set covers the period from the week ending July 20, 1996 to the week ending October 31, 1998. Weekly quantity data exist for seven categories of cheese (excluding cream cheese) and two categories of table spreads sold in U.S. grocery stores with over $2 million in annual sales. The cheese categories are chunk/loaf, sliced, grated, shredded/crumble, spread/snack, cubed, and all other forms. The table spread categories are butter and all other spreads (the vast majority of which is margarine in stick or tub packaging). National average weekly prices in dollars per pound accompany the quantity data. Monthly U.S. personal consumption expenditures were obtained from Bureau of Economic Analysis news releases (U.S. Dept. of Commerce), interpolated to reflect weekly values, and treated as a proxy for income. Prices and expenditures were deflated by the Consumer Price Index (Bureau of Labor Statistics), which was also interpolated to reflect weekly values.

Table 1 provides descriptive statistics of the quantity, price, and expenditure data (nominal prices and expenditures are shown in Table 1 for ease of comprehension, although real values were used in the analysis). Chunk cheese and sliced cheese are the dominant varieties in terms of sales volume, while cubed cheese is the lowest-volume product form. Price volatility is modest in most cases, with cubed cheese exhibiting the most volatile cheese price and by far the most volatile quantity. Butter and margarine quantities tended to be more volatile than cheese quantities, and butter prices were the most volatile of the products considered.

Double-log ordinary demand models were estimated for each of the seven categories of cheese, using the seemingly unrelated regressions estimator to exploit contemporaneous correlation. Regressors included own price, substitute prices, total expenditures, a cosine seasonality variable that equals one in summer and negative one in winter, a dummy variable representing the seven major holidays, and a time trend. Each model originally included six short-run irreversibility terms in the form of segmented own-price upswing and downswing variables extending three weeks into the past. The choice of lag length was based on statistical significance of the segmented variables in initial estimation, and on the need for parsimonious models to mitigate multicollinearity (a common problem in irreversible demand analysis). Regarding specification testing, the joint conditional mean and variance tests suggested by McGuirk, Driscoll, and Alwang were performed and corrective action was taken when necessary.

One would expect to find the strongest evidence of irreversibility in products that meet four criteria. First, consumer awareness of prices encourages reference price formation that motivates loss aversion and stockpiling incentives. Consumers are most likely to be familiar with prices of products that are frequently purchased and packaged in consistent sizes. Chunk cheese, sliced cheese, and table spreads appear most likely to fit this criterion. Second, storability affects stockpiling incentives. None of the products considered here require substantial storage space. The table spreads, sliced cheese, and grated cheese are the least perishable of the products considered in this study, while shredded cheese, snack/spread cheese, and cubed cheese are the most perishable. Third, importance of the product in consumers' daily diets positively affects stockpiling incentives and constrains loss aversion. Margarine and possibly sliced cheese fit the third criterion. Snack/spread cheese, cubed cheese, and grated cheese are the least likely to be frequently purchased. Fourth, products that are more heavily merchandised are more likely to exhibit irreversible demand due to stockpiling incentives. Table spreads, snack/spread cheese, sliced cheese, shredded cheese, and grated cheese are often branded products that are expected to be more heavily promoted than products such as chunk cheese and cubed cheese.

**Results**

Initial estimates suffered from autocorrelation and heteroskedasticity (the sliced cheese and grated cheese models were homoskedastic). The Cochrane-Orcutt procedure was used to correct for autocorrelation, and all results that follow are weighted least squares estimates that mitigate heteroskedasticity. Following these data transformations, joint conditional mean and variance tests suggested that the models were adequately specified at a 0.05 significance level.

For comparison purposes, Table 2 shows estimation results for cheese before including the irreversibility terms. $R^2$ values ranged from 0.53 (grated cheese) to 0.87 (all other forms). In all cases except shredded cheese, demand is own-price elastic, and in most cases it is highly elastic. Own-price demand elasticities for the best selling product forms, chunk cheese and sliced cheese, are -2.2 and -2.0, respectively. Own-price elasticity estimates for cheese are typically inelastic (e.g., Haidacher, Blaylock, and Myers; Heien and Wessells; Huang). Weekly data often appear to produce more elastic estimates (Bailey and Gamboa), perhaps due to temporal disaggregation. Other reasons to expect more elastic estimates in this analysis include disaggregation across product forms and exclusive emphasis on supermarket sales, unlike commercial disappearance data that include purchases through the hotel, restaurant, and institutional sector.

All expenditures elasticity estimates are negative and statistically insignificant except in the sliced cheese model, perhaps reflecting relatively stable cheese demand in the midst of a booming economy,. The strongest substitution relationships are between grated and shredded cheese, as expected. Shredded cheese appears to be a substitute for sliced cheese, and grated cheese appears to substitute for several product forms (although it is not intuitively obvious how grated cheese would substitute for snack/spread cheese, for example). Seasonality is a significant demand shifter for most of the product forms. The results indicate greater demand for chunk, grated, and shredded cheese in the winter months, while demand for sliced cheese is greater in the summer months. Chunk cheese and snack/spread cheese are in greater demand during the holidays. Although U.S. cheese demand has been growing over the last 25 years, the trend was not statistically evident over the two-year study period.

Table 3 shows the estimation results after including the irreversibility terms. Accounting for potential loss aversion and intertemporal substitution produced short-run own-price elasticity estimates that often bordered those obtained from the reversible models. For example, the own-price elasticity of sliced cheese immediately following a price increase was -1.72 (i.e., -1.21 - 0.50), while the estimated elasticity immediately following a price decrease was -2.55 (i.e., -1.21 - 1.329), compared to the estimate of -2.05 from the reversible model. Own price was not significant at a .05 level in the grated and snack cheese models. The reversible and irreversibile models returned similar results in terms of expenditure, substitution, seasonality, holiday, and trend effects.

The irreversibility terms, however, offer new insights. Theory suggests that the parameter estimates will be negative, 35 of the 42 estimates are in fact negative, and all nine of the statistically significant estimates are negative. Seven of the nine significant estimates are associated with downward price movements. Irreversible responses in cheese demand appear to occur within two weeks of a price change, and might not be discernible from monthly data. Chunk cheese is the only product form to demonstrate significant irreversible responses to both upswings and downswings at a .05 level. Significant downward irreversibility occurs in sliced, grated, and shredded cheese demand. Demand for snack/spread cheese, cubed cheese, and all other forms appears to be reversible, perhaps because consumers buy these forms of cheese infrequently, are unlikely to form reference prices, and have little incentive to stockpile perishable specialty items.

Recall that risk averse consumers basing decisions on reference prices would react more strongly to price increases, while stockpiling behavior (intertemporal substitution) manifests itself through stronger responses to price decreases. The larger number of significant downward price response terms relative to upward price response terms implies that stockpiling incentives outweigh reference price effects in explaining U.S. sliced, grated, and shredded cheese demand. The hypothesis that the sum of responses to downward price movements equals zero is rejected in the chunk, sliced, and grated cheese models (with F-values of 10.58, 13.67, and 4.95, respectively). Conversely, the sum of responses to upward price movements is statistically different from zero in the chunk and grated cheese models (with F-values of 11.29 and 4.29, respectively). Only in the sliced cheese model is the sum of downward price responses statistically greater than the sum of upward price responses (F = 4.70). As sliced cheese is the highest-volume product form, as well as the least perishable, it appears reasonable that sliced cheese demand shows stronger signs of irreversibility than the other product forms.

The results from the table spread demand models offer stronger evidence of irreversibility, as shown in Table 4. Based on the joint conditional mean and variance tests, the table spread models appeared to be better specified when the time trends and the most distant lags of the irreversibility terms were removed. $R^2$ values in the butter and margarine models were 0.90 and

0.87, respectively. As expected, table spread demand is highest in the colder months, and demand is high during the holidays. The butter model returned an unexpected sign on the cross-price term, and the margarine model contained an unexpected sign on the expenditure term. Own-price and expenditures were not significant in the butter model. As with all of the estimates obtained from this scanner data set, own-price elasticities tend to be considerably higher than those obtained from monthly, quarterly, or annual disappearance data.

The statistically significant irreversibility terms were all of the expected sign in the butter and margarine models. The short-run own-price elasticity for butter immediately following a price increase was -1.94, compared to the estimated elasticity of -1.11 immediately following a price decrease. One week following a price decrease, the elasticity estimate is -1.30, whereas butter demand one week after a price increase is -0.27. The margarine model differs in that demand is not immediately irreversible, but *lagged* responses are significantly stronger following a price decrease relative to a price increase.

In both the butter and margarine models, the results suggest that stockpiling incentives outweigh loss aversion. Downward irreversibility terms are statistically significant at both one and two lags, while upward irreversibility is significant only at the first lag. In both models, the sum of downward price responses is statistically greater than the sum of upward price responses (F = 7.06 for butter; F = 4.87 for margarine). In both models, the joint hypothesis of equality between upswing and downswing terms at one lag and at two lags is rejected at a .05 level (F = 3.64 for butter; F = 4.68 for margarine). Table spreads are less perishable than most cheeses, and table spread prices (especially butter prices) are more volatile than those of most cheeses. The stronger evidence of stockpiling incentives in the table spread models is thus consistent with expectations.

## Implications

This analysis highlights issues of importance to demand modelers and to retail food marketers. Different forces can cause demand to be irreversible. Moreover, the direction of irreversibility depends on which force is stronger. In this study two potential causes were considered: loss aversion and stockpiling incentives. Loss aversion causes demand to be more elastic when price increases, but stockpiling causes demand to be more elastic when price decreases. In this study, stockpiling incentives appeared to exert a stronger influence on supermarket demand for sliced cheese and table spreads (weaker evidence supported this conclusion in the case of shredded and grated cheese).

The dominance of stockpiling behavior over loss aversion implies that retailers should not pursue a strategy of price smoothing in sliced cheese and table spreads, but rather they should pass along price fluctuations as they occur. Given the increasing price volatility in dairy products resulting from recent U.S. policy changes and increasingly global markets (Marchant and Neff), the opportunity cost of an inappropriate pricing strategy is greater now than in the past. Farther up the marketing stream, faster and more complete price transmission across market levels would clear markets faster and send more timely signals to producers, processors, and wholesalers.

Loss aversion and stockpiling behavior each require consumers to maintain reference prices. Mayhew and Winer refer to internal reference prices as those based on past experience and stored in the consumer’s memory, while external reference prices are supplied by the marketer in the purchase environment. The informational requirements of maintaining a schedule of internal reference prices for many products are formidable. Dickson and Sawyer asked 802 shoppers to name the price of items they had placed in their shopping carts 30 seconds earlier. Over 20 percent of the shoppers could not even hazard a guess, and only 56 percent of the shoppers' guesses were within five percent of the actual price. Perhaps it is unrealistic to expect consumers to maintain internal reference prices for any but the most frequently purchased items. Informational constraints may limit the influence of loss aversion, where the burden is entirely on the consumer to discern price increases.

In the case of stockpiling behavior, however, merchandizing may provide consumers with external reference prices where none existed before. Dickson and Sawyer found that 29 percent of shoppers chose items promoted at a special price, although their price estimates were no more accurate than the sample as a whole. Marketers willingly provide consumers with information about price decreases. Asymmetric information appears to be one reasonable explanation for the finding that stockpiling behavior dominates loss aversion. The results of this study are consistent with Mayhew and Winer's finding that external reference price effects (which are associated only with price decreases) dominate internal reference price effects (which are associated with both price increases and decreases).

Both causes of irreversibility may coexist in equal measure, so that demand does not appear to be irreversible. Chunk cheese demand exhibited this behavior. Individual irreversibility terms were statistically significant, but the upward influence was not statistically different from the downward influence. The reversible and irreversible demand models estimate almost identical short-run elasticity estimates immediately after a price change. The reversible model estimate is -2.23, the irreversible upswing elasticity is -2.20, and the irreversible downswing elasticity is -2.34.

The important difference between the models is that the irreversible model expresses the *persistent* influence of the price change as an own-price elasticity of only -1.69. In other words, if the price of chunk cheese rose by one percent and remained at that level, the irreversible model predicts that, three weeks later, quantity demanded would be 1.69 percent lower, while the reversible model predicts that quantity demanded would be 2.23 percent lower. One of the study's objectives was to identify explanations for the tendency of weekly scanner data to produce highly elastic demand estimates. While the elasticity estimates from this application remain relatively high even after isolating the influence of loss aversion and stockpiling, irreversibility appears to be one component of the difference between elasticities estimated from weekly scanner data versus monthly disappearance data.

Regarding directions for future research, the hypotheses tested in this analysis could be more reliably studied using household-level data that includes information about product merchandising. With such data, one could determine the extent to which consumers rely on advertising and promotion to form reference prices. Store-level scanner data would also be useful in assessing the impact of a store's pricing strategy on the nature of irreversible demand. Partch found greater price awareness among patrons of every-day low price (EDLP) supermarkets than among shoppers at stores using a high-low pricing strategy. One would expect loss aversion to be more prevalent in EDLP stores, where the informational requirements of maintaining reference prices are not as great. Extending the empirical model to a complete demand system framework would be helpful, especially for the analysis of product categories with larger expenditure shares (e.g., beef and chicken as opposed to butter and margarine). Finally, it would be useful to test if the results from this study hold true for other products, with an emphasis on frequency of purchase and storability as hypothesized determinants of the direction of irreversibility.

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**Table 1. Descriptive Statistics: U.S. Weekly Scanner Data, 7/20/96 - 10/31/98**

| | | Mean | Std. Dev. | C.V. (%) | Min. | Max. |
|---|---|---|---|---|---|---|
| Cheese | Qchunk (lb) | 11016.94 | 1282.02 | 11.64 | 9345.61 | 17907.60 |
| | Qslice (lb) | 11579.02 | 719.45 | 6.21 | 9929.09 | 13794.80 |
| | Qgrated (lb) | 1058.39 | 76.35 | 7.21 | 882.19 | 1258.18 |
| | Qshred (lb) | 6770.07 | 551.48 | 8.15 | 5887.38 | 9530.11 |
| | Qsnack (lb) | 2259.65 | 332.52 | 14.72 | 1949.47 | 4169.00 |
| | Qcube (lb) | 42.07 | 38.78 | 92.17 | 12.57 | 154.25 |
| | Qother (lb) | 1604.18 | 491.71 | 30.65 | 1017.81 | 3731.94 |
| | Pchunk ($/lb) | 3.22 | 0.07 | 2.10 | 3.08 | 3.43 |
| | Pslice ($/lb) | 2.98 | 0.09 | 2.89 | 2.78 | 3.18 |
| | Pgrated ($/lb) | 6.49 | 0.09 | 1.42 | 6.25 | 6.73 |
| | Pshred ($/lb) | 3.91 | 0.08 | 2.03 | 3.75 | 4.13 |
| | Psnack ($/lb) | 4.41 | 0.09 | 1.93 | 4.22 | 4.67 |
| | Pcube ($/lb) | 5.44 | 0.66 | 12.15 | 4.41 | 6.49 |
| | Pother ($/lb) | 1.88 | 0.11 | 5.79 | 1.47 | 2.02 |
| Table Spreads | Qbutter (000 lb) | 7665.51 | 2392.70 | 31.21 | 5649.95 | 18370.68 |
| | Qmargarine (000 lb) | 27477.60 | 3364.60 | 12.24 | 22930.80 | 40956.00 |
| | Pbutter ($/lb) | 2.33 | 0.46 | 19.80 | 1.63 | 3.75 |
| | Pmargarine ($/lb) | 0.92 | 0.03 | 3.27 | 0.84 | 0.98 |
| Consumer Expenditures ($bn/yr) | | 5546.35 | 226.23 | 4.08 | 5161.36 | 5910.70 |

Q denotes quantity, P denotes price
Prices and expenditures are in nominal terms

**Table 2. Reversible Double-log Cheese Demand Models**

| | Dependent Variable | | | | | | |
|---|---|---|---|---|---|---|---|
| | Qchunk | Qsliced | Qgrated | Qshred | Qsnack | Qcube | Qother |
| Constant | 41.297 | 70.987* | 20.914 | 21.837 | 65.569 | 2.358 | 21.586 |
| | (30.880) | (30.071) | (31.795) | (27.868) | (41.731) | (38.193) | (26.515) |
| Pchunk | -2.231* | 0.126 | 0.031 | -0.348 | 0.120 | -0.323 | -0.678 |
| | (0.362) | (0.350) | (0.387) | (0.338) | (0.518) | (1.235) | (0.492) |
| Psliced | -0.154 | -2.046* | -1.272* | 0.013 | 0.127 | 0.258 | 0.672 |
| | (0.324) | (0.311) | (0.353) | (0.304) | (0.459) | (0.923) | (0.599) |
| Pgrated | 1.729* | 0.331 | -1.097* | 1.186* | 1.698* | 3.401 | 1.879* |
| | (0.446) | (0.422) | (0.480) | (0.427) | (0.678) | (1.854) | (0.782) |
| Pshred | 0.767 | 1.402* | 1.119* | -0.880* | 0.043 | 1.458 | -0.025 |
| | (0.393) | (0.381) | (0.435) | (0.376) | (0.593) | (1.531) | (0.707) |
| Psnack | -0.099 | -0.576 | -0.442 | -0.639 | -1.327* | -1.708 | -0.890 |
| | (0.418) | (0.390) | (0.447) | (0.399) | (0.615) | (1.493) | (0.761) |
| Pcube | -0.169* | -0.018 | 0.076 | -0.126* | -0.317* | -3.032* | -0.185 |
| | (0.061) | (0.602) | (0.070) | (0.059) | (0.096) | (0.269) | (0.095) |
| Pother | -0.405* | -0.068 | -0.458* | -0.234* | -0.550* | -0.915* | -2.914* |
| | (0.096) | (0.088) | (0.098) | (0.088) | (0.133) | (0.287) | (0.148) |
| Expend. | -1.912 | -3.537* | -0.832 | -0.859 | -5.208 | -0.578 | -5.157 |
| | (1.875) | (1.771) | (2.200) | (1.896) | (3.658) | (15.063) | (6.975) |
| Season | -0.052* | 0.047* | -0.061* | -0.066* | -0.022 | 0.001 | -0.088 |
| | (0.010) | (0.008) | (0.011) | (0.010) | (0.019) | (0.126) | (0.054) |
| Holiday | 0.049* | -0.009 | -0.014 | 0.006 | 0.074* | 0.052 | 0.011 |
| | (0.010) | (0.008) | (0.009) | (0.010) | (0.014) | (0.029) | (0.016) |
| Trend | 0.001 | 0.002 | 0.000 | 0.001 | 0.003 | 0.002 | 0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.002) | (0.001) |

standard errors in parentheses
* denotes statistical significance at the .05 level

**Table 3. Irreversible Cheese Demand Models Suggest Stronger Response to Price Decreases**

| | Dependent Variable | | | | | | |
|---|---|---|---|---|---|---|---|
| | Qchunk | Qsliced | Qgrated | Qshred | Qsnack | Qcube | Qother |
| Constant | 41.297 | 59.569* | 19.439 | 20.048 | 73.677 | 13.372 | 14.405 |
| | (30.327) | (28.563) | (33.398) | (29.549) | (39.855) | (31.229) | (26.073) |
| Pchunk | -1.692* | 0.233 | 0.223 | -0.424 | -0.239 | -0.887 | -0.594 |
| | (0.400) | (0.338) | (0.417) | (0.388) | (0.607) | (1.237) | (0.603) |
| Psliced | -0.226 | -1.221* | -1.345* | -0.059 | -0.013 | -0.309 | 0.284 |
| | (0.324) | (0.355) | (0.369) | (0.321) | (0.478) | (0.926) | (0.593) |
| Pgrated | 2.002* | 0.398 | -0.154 | 1.413* | 2.262* | 3.832* | 1.684* |
| | (0.456) | (0.413) | (0.657) | (0.454) | (0.712) | (1.712) | (0.805) |
| Pshred | 0.087 | 0.808* | 1.139* | -0.976* | -0.886 | -1.219 | -0.881 |
| | (0.410) | (0.405) | (0.453) | (0.439) | (0.621) | (1.335) | (0.744) |
| Psnack | 0.076 | -0.544 | -0.498 | -0.520 | -0.455 | -0.623 | -0.310 |
| | (0.460) | (0.376) | (0.472) | (0.440) | (0.961) | (1.427) | (0.775) |
| Pcube | -0.180* | 0.030 | 0.061 | -0.123 | -0.328* | -3.965* | -0.095 |
| | (0.063) | (0.061) | (0.074) | (0.064) | (0.104) | (0.680) | (0.115) |
| Pother | -0.459* | -0.116 | -0.483* | -0.267* | -0.647* | -1.057* | -2.698* |
| | (0.098) | (0.085) | (0.102) | (0.095) | (0.142) | (0.274) | (0.464) |
| Expend. | -2.134 | -2.875 | -0.782 | -0.747 | -5.938 | -4.813 | -3.247 |
| | (1.841) | (1.682) | (2.313) | (2.010) | (3.493) | (12.319) | (6.858) |
| Season | -0.060* | 0.056* | -0.063* | -0.069* | -0.037* | 0.134 | -0.121* |
| | (0.009) | (0.008) | (0.011) | (0.010) | (0.018) | (0.114) | (0.052) |
| Holiday | 0.046* | -0.013 | -0.015 | 0.004 | 0.069* | 0.034 | 0.007 |
| | (0.010) | (0.008) | (0.010) | (0.009) | (0.015) | (0.031) | (0.017) |
| Trend | 0.001 | 0.002 | 0.000 | 0.001 | 0.003 | 0.002 | 0.000 |
| | (0.001) | (0.001) | (0.002) | (0.001) | (0.002) | (0.001) | (0.001) |
| Down3 | -0.165 | -0.590 | -0.600 | -0.049 | -0.179 | 0.423 | -0.109 |
| | (0.166) | (0.313) | (0.604) | (0.358) | (0.396) | (0.359) | (0.287) |
| Down2 | -0.715* | -1.172* | -1.336* | -0.377 | -0.347 | 0.839 | -0.454 |
| | (0.198) | (0.383) | (0.655) | (0.385) | (0.471) | (0.505) | (0.453) |
| Down1 | -0.649* | -1.329* | -1.301* | -0.818* | -0.312 | 1.196 | -0.117 |
| | (0.211) | (0.393) | (0.652) | (0.375) | (0.571) | (0.629) | (0.467) |
| Up1 | -0.503* | -0.500 | -0.654 | 0.302 | -0.577 | 0.829 | -0.369 |
| | (0.185) | (0.379) | (0.682) | (0.345) | (0.603) | (0.513) | (0.317) |
| Up2 | -0.370* | -0.392 | -1.329 | 0.051 | -0.096 | 0.330 | -0.147 |
| | (0.149) | (0.380) | (0.681) | (0.367) | (0.528) | (0.399) | (0.165) |
| Up3 | -0.235 | 0.252 | -1.089 | -0.495 | -0.292 | -0.458 | -0.066 |
| | (0.134) | (0.360) | (0.596) | (0.312) | (0.410) | (0.303) | (0.128) |

standard errors in parentheses

* denotes statistical significance at the .05 level

**Table 4. Stockpiling Incentives Outweigh Loss Aversion in Demand for Table Spreads**

| | Dependent Variable | |
|---|---|---|
| | Qbutter | Qmargarine |
| Constant | 2.674 | 36.365* |
| | (6.162) | (2.842) |
| Pbutter | -0.024 | 0.153* |
| | (0.097) | (0.030) |
| Pmargarine | -4.061* | -1.598* |
| | (0.385) | (0.184) |
| Expend. | 0.371 | -0.796* |
| | (0.375) | (0.113) |
| Season | -0.065* | -0.059* |
| | (0.016) | (0.006) |
| Holiday | 0.173* | 0.081* |
| | (0.026) | (0.013) |
| Down2 | -1.277* | -1.098* |
| | (0.280) | (0.294) |
| Down1 | -1.915* | -1.581* |
| | (0.281) | (0.315) |
| Up1 | -1.083* | -1.472* |
| | (0.270) | (0.198) |
| Up2 | -0.250 | 0.100 |
| | (0.261) | (0.186) |

standard errors in parentheses
* denotes statistical significance at the .05 level
real prices, quantities, and real expenditures are logged