Some Evidence on the Importance of Sticky Prices

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We examine the frequency of price changes for 350 categories of goods and services covering about 70 percent of consumer spending, on the basis of unpublished data from the Bureau of Labor Statistics for 1995–97. In comparison with previous studies, we find much more frequent price changes, with half of prices lasting less than 4.3 months. Even excluding temporary price cuts (sales), we find that half of prices last 5.5 months or less. We also find that the frequency of price changes differs dramatically across goods. Compared to the predictions of popular sticky-price models, actual inflation rates are far more volatile and transient for sticky-price goods.

I. Introduction

The importance of price stickiness remains a central question in economics. Much recent work modeling business cycle fluctuations or analyzing monetary policy assumes that firms adjust prices only infre-

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quently.[1] Although empirical work measuring price stickiness is less extensive, a number of papers have shown that certain wholesale and retail prices often go unchanged for many months.[2]

We employ unpublished data from the U.S. Bureau of Labor Statistics (BLS) to obtain much broader evidence on the extent of retail price rigidities than examined in past studies. In Section II, we present data for 1995–97 on the monthly frequency of price changes for 350 categories of consumer goods and services constituting around 70 percent of consumer expenditures. We find much more frequent price changes than reported in most previous studies, with half of goods displaying prices that last 4.3 months or less. These results do not merely reflect frequent temporary sales. If we net out the impact of price changes reflecting temporary sales, on the basis of results from Klenow and Kryvtsov (2004), the median duration rises to only 5.5 months.

We also document dramatic differences in the frequency of price changes across goods. Prices seldom change for some goods; for example, prices of newspapers, men's haircuts, and taxi fares change less than 5 percent of months. But some prices change very frequently, with prices of gasoline, tomatoes, and airfares changing more than 70 percent of months. Not surprisingly, goods with little value added in final production, that is, energy-related goods and fresh foods, display much more frequent price changes. But excluding these goods, we still find much more frequent price changes than reported in prior work. Notably, durable goods actually show more frequent price changes than the overall consumer bundle. We also find that goods sold in more competitive markets, as measured by concentration ratios or wholesale markups, display more frequent price changes. But this result disappears if we control for a good being energy related or being a fresh food.

We began by noting that many recent papers incorporate sticky prices. Further, much of this work employs time-dependent pricing models. Prices are maintained for a set number of periods (as in Taylor [1999]), or each period a fixed fraction of firms have an opportunity to adjust prices to new information (as in Calvo [1983]). In both the Taylor and Calvo models, price changes are not synchronized across firms. In these settings, monetary policy can influence economic activity for some period of time if price changes are not too frequent. Our findings based on the BLS data suggest more frequent price adjustment than usually assumed in calibrated macro models. Chari et al. (2000), for instance,

[1] Goodfriend and King (1997), Rotemberg and Woodford (1997), Clarida, Gali, and Gertler (1999), Chari, Kehoe, and McGrattan (2000), Erceg, Henderson, and Levin (2000), and Dotsey and King (2001) represent only a few examples.

[2] Important references include Carlton (1986), Cecchetti (1986), Kashyap (1995), Levy et al. (1997), Blinder et al. (1998), MacDonald and Aaronson (2001), and Kackmeister (2002).

consider a benchmark case in which prices are set for one year. One possible conclusion from our Section II evidence might be that time-dependent models should be fit to more frequent price changes. We argue that this is very much the wrong message.

In Section III, we examine time-series data across 123 categories of goods to test whether goods' inflation rates behave as suggested by time-dependent pricing models. We require frequencies of price changes across the 123 goods to be consistent with observed frequencies in the micro BLS data for 1995–97. In the workhorse Calvo and Taylor models, price stickiness dampens the initial response of a good's inflation rate to a shock, stretching the inflation impact out over time as successive cohorts of firms adjust their prices. Price stickiness thereby reduces the magnitude of innovations to a good's inflation rate while at the same time raising the persistence of its inflation. We do not see this in the data. For nearly all 123 categories, inflation movements are far more volatile and transient than implied by the Calvo and Taylor models given the frequency of individual price changes in the BLS data. This discrepancy cannot be resolved by adding plausible measurement error or a plausible role for temporary sales. Across the 123 goods, volatility and persistence of a good's inflation rate are much less related to the good's frequency of price changes than predicted by these time-dependent pricing models. In other words, the popular sticky-price models fail most dramatically to predict inflation's behavior for goods with the least frequent price changes.

In Section IV, we summarize our findings and discuss how they can help in choosing between competing models of price stickiness.

II. BLS Data on the Frequency of Price Changes

For calculating the consumer price index (CPI), the BLS collects prices on 70,000–80,000 nonhousing goods and services per month.[3] The BLS collects prices from around 22,000 outlets across 88 geographic areas. The BLS chooses outlets probabilistically on the basis of household point-of-purchase surveys and chooses items within outlets on the basis of estimates of their relative sales. The BLS divides consumption into 388 categories called entry-level items (ELIs).

The BLS Commodities and Services Substitution Rate Table gives, for each ELI, the percentage of quotes with price changes. For example, the 1997 table indicates that 6,493 price quotes were collected on bananas in 1997 and that 37.8 percent of these quotes differed from the quote on the same type of bananas at the same outlet in the preceding

[3] The sources used for this section, unless otherwise noted, were U.S. Congress (1996) and U.S. Department of Labor (1997, chap. 17).

month. (The table does not contain information on the magnitude of price changes, just what share of price quotes involved some change in price.)[4] The field agents collecting prices use a detailed checklist of item attributes to try to make sure they are pricing the same item in consecutive months. When the item they wish to price has been discontinued, they begin pricing a closely related item at the outlet. These "item substitutions" are the focus of the BLS table. Item substitutions happen to be rare for bananas (only one in 1997) compared to other categories (3.1 percent of nonhousing price quotes in 1997).

The BLS has provided us with the unpublished Commodities and Services Substitution Rate Table for the years 1995–2001. The BLS revised the ELI structure in 1998, so frequencies cannot be readily compared before and after 1998. For the 168 ELI definitions that remained unchanged, however, the frequencies are quite stable over the seven years. The correlation for any pair of years lies between 0.96 and 0.98. In order to maximize the number of ELIs for which there is a price index covering more than a few years, we use the 1995–97 BLS data and its ELI structure. These data cover 350 ELIs.

In the Appendix (table A1), we list the 1995–97 average monthly frequency of price changes for each of the 350 ELIs. For food and energy ELIs, in which items are priced monthly, this is the simple average of the frequencies in the 1995, 1996, and 1997 BLS tables. For the other ELIs, the frequencies in the BLS tables are a mixture of one-month and two-month price change frequencies. In the five largest areas—New York City and suburbs, Chicago, Los Angeles and suburbs, San Francisco/Oakland/San Jose, and Philadelphia—the BLS collected quotes monthly for all goods and services. For the other geographic areas, the BLS collected quotes monthly only for food and energy and bimonthly for all other goods and services. For each of 1995, 1996, and 1997, we obtained from the BLS the fraction of price quotes that were monthly versus bimonthly.

If the monthly probability of a price change is the same across areas and from month to month for a given ELI in a given year, then we can identify the monthly frequency of price changes from the mixed frequency the BLS reports and the fraction of quotes that are monthly versus bimonthly. Let y be the mixture of monthly and bimonthly frequencies (data from the BLS tables), λ the constant monthly frequency of price changes (not directly observed), and z the fraction of quotes that are monthly (data we obtained from the BLS for each ELI for each

[4] The BLS attempts to collect prices net of sales and other promotions. For example, prices are collected net of rebates, store discounts, or coupons available with the item for sale. (No adjustments are made for coupons distributed outside the outlet.) So a temporary sale, including temporary rebates, will result in a price change. The role of temporary sales is discussed in greater detail below.

year). Then $y = z \cdot \lambda + (1 - z) \cdot [\lambda + (1 - \lambda) \cdot \lambda]$. Since $z \in (0, 1)$ and $\lambda \in [0, 1]$, the solution for λ is the negative root of this quadratic in λ.

In making this calculation, we assume that the probability that a price changes from p_a to p_b one month and then changes *back* to p_a the next month is zero. On the basis of scanner data for select seasonal goods at certain Chicago area supermarkets, Chevalier, Kashyap, and Rossi (2003) find that such temporary sales are actually quite common. To the extent that they occur, our estimated monthly frequencies understate the true monthly frequencies. Since Chevalier et al. find that temporary sales typically last less than one month, even monthly price quotes (as for the top five areas and for food and energy) understate the true frequency of price changes.

We do allow for the possibility that a price might change twice or more between BLS monthly (or bimonthly) data collection. This is presumably common for goods, such as gasoline, that display high rates of price change. If one assumes that prices can change at any moment, not just at monthly intervals, then the instantaneous probability of a price change is $-\ln(1 - \lambda)$. This implies a mean time between price changes of $-1/\ln(1 - \lambda)$ months. We use this formula to present the data on frequencies of price changes in terms of monthly durations that prices remain unchanged.

The Appendix reports λ, the monthly frequency of price changes, for each of the 350 ELIs. These frequencies are based on averages of the monthly frequencies we estimate for 1995, 1996, and 1997. They range from 1.2 percent for coin-operated apparel laundry and dry cleaning to 79 percent for regular unleaded gasoline. Figure 1 gives the histogram of frequencies for the 350 ELIs. Not all ELIs are equally important, however, since their weights in the 1995 Consumer Expenditure Survey (CEX) range from 0.001 percent (tools and equipment for painting) to 2.88 percent (electricity). The Appendix also provides the weight of each ELI and the resulting percentile of the ELI in the cumulative distribution of frequencies. When the ELIs are weighted, the monthly frequency of price changes averages 26.1 percent. The weighted median is 20.9 percent. For the median category the time between price changes averages 4.3 months. Thus, for items constituting one-half of nonhousing consumption, prices change less frequently than every 4.3 months.

Baharad and Eden (2003) argue for judging a distribution of price change frequencies by the mean duration of prices. (This mean duration is seven months for our sample.) In the NBER working paper version of this paper (Bils and Klenow 2002), we examine responses to nominal and real shocks in a multisector model with time-dependent price setting, where each sector has a distinct frequency with which prices change. We simulated versions with as many as 30 sectors, setting the

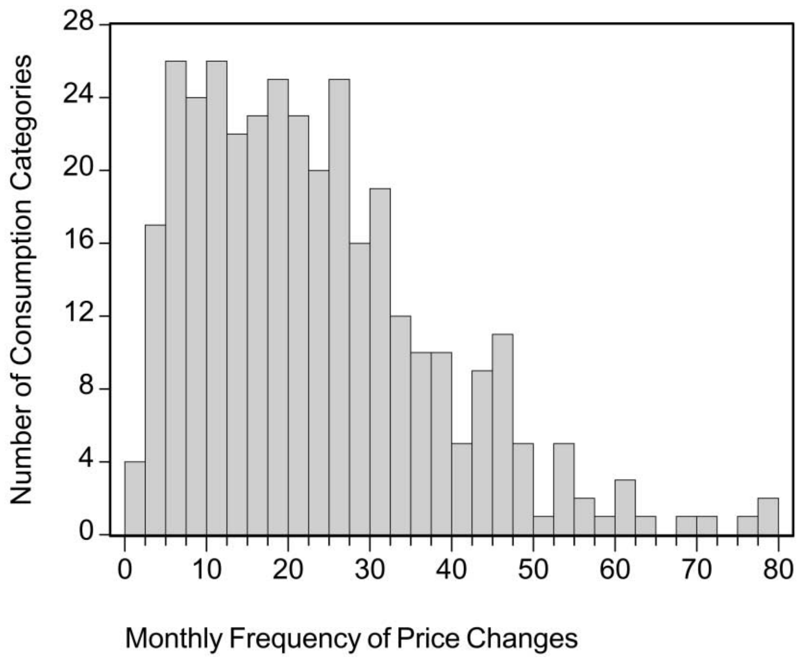

Fig. 1

stickiness and weight of sectors to approximate the empirical distribution displayed in the Appendix. We compare the aggregate response to shocks to those in a one-sector model in which all prices are fixed for the same duration. We find that a single-sector model with prices fixed for four months, roughly the median duration in the empirical distribution, most closely matches the aggregate response in the multisector models. One-sector models with durations near the reciprocal of the mean frequency (three months) or with the mean duration (seven months) do not mimic the multisector model nearly as well, on the basis of squared deviations over 20 months of impulse responses. For this reason we emphasize the median duration when summarizing the empirical distribution of price change frequencies.[5]

The 350 ELIs in the Appendix cover 68.9 percent of spending according to the 1995 CEX. The categories not covered are owner's equivalent rent and household insurance (20.0 percent weight), residential

[5] Klenow and Kryvtsov (2004) estimate a median price duration of 4.3 months in the BLS micro data from 1988 through 2003. They obtain 4.1 months when they apply our methodology of inverting the median ELI frequency. In contrast to our use of medians, using the inverse mean frequency could seriously understate the mean duration by Jensen's inequality, as stressed by Baharad and Eden (2003).

TABLE 1
Monthly Frequency of Price Changes by Year, 1995–2002

Year	Median Frequency (%)	Median Duration (Months)
1995	21.3	4.2
1996	20.8	4.3
1997	19.9	4.5
1998	21.2	4.2
1999	21.4	4.1
2000	21.7	4.1
2001–2	22.0	4.0

Source.—U.S. Department of Labor, Commodities and Services Substitution Rate Table, various years.

Note.—2001–2 refers to the 15-month period from January 2001 through March 2002.

rent (6.6 percent), used cars (1.8 percent), and various unpriced items (collectively 2.7 percent). One question that arises is whether scanner data, which are becoming increasingly available to economists (e.g., Chevalier et al. 2003), might dominate the BLS average frequency data. Scanner data afford weekly prices and quantities for thousands of consumer items. At present, however, scanner data cannot match the category coverage of the BLS data. Hawkes and Piotrowski (2003) estimate that only 10 percent of consumer expenditures are scanned through A. C. Nielsen data for supermarkets, drugstores, and mass merchandisers. Categories not scanned include rent, utilities, restaurant meals (about 40 percent of spending on food), medical care, transportation, insurance, banking, and education. As noted, the 350 categories in the BLS table cover 68.9 percent of consumer expenditures.

Table 1 reports the median frequency and duration for years 1995–2002. We focus on the period 1995–97 to maximize compatibility with other data. Price changes are actually somewhat more frequent over 1998–2001 than over the 1995–97 period.

Comparison to Other Empirical Studies of Price Stickiness

The BLS data suggest much more frequent price adjustment than has been found in other studies. Blinder et al. (1998) surveyed 200 firms on their price setting. The median firm reported adjusting prices about once a year. Hall, Walsh, and Yates (2000) surveyed 654 British companies and obtained similar results: 58 percent changing prices once a year or more. In contrast, the median consumer item in the 1995–97 BLS tables changes prices every 4.3 months. For 87 percent of consumption, prices change more frequently than once a year. A possible contributor to the difference in findings is that firms in the Blinder et al. survey sell mostly intermediate goods and services (79 percent of their sales) rather than consumer items.

Even compared to other studies of consumer prices, the BLS data imply considerably more frequent price changes. Cecchetti (1986) studied newsstand prices of 38 American magazines over 1953–79. The number of years since the last price change ranged from 1.8 to 14 years. In our Appendix, magazines (including subscription as well as newsstand prices) exhibit price changes 8.6 percent of months, implying adjustment every 11 months on average. More important, magazines are at the sticky end of the spectrum; prices change more frequently than for magazines for 86 percent of nonhousing consumption.

Kashyap (1995) studied the monthly prices of 12 mail-order catalog goods for periods as long as 1953–87. Across goods and time, he found an average of 14.7 months between price changes. This contrasts with the 4.3-month median in the BLS data. On the basis of our Appendix, prices change more frequently than every 14.7 months for 90 percent of nonhousing consumption. The 12 Kashyap goods consist mostly of apparel. In the BLS data, prices actually change more frequently for clothing: the monthly hazard is 29 percent for apparel items versus 26 percent for all items. So prices for the goods in Kashyap's sample are far stickier than for the typical BLS item, apparel or other. Mail-order prices may tend to be stickier than prices in retail outlets. Another factor could be that Kashyap selected "well-established, popular selling items that have undergone minimal quality changes" (1995, p. 248). As we discuss below, changing product features appear to play an important role in price changes.

MacDonald and Aaronson (2001) examine restaurant pricing (more exactly, pricing for food consumed on premises) for the years 1995–97 using BLS data. They find that restaurant prices do not change very frequently, with prices displaying a median duration of about 10 months. These results are close to the durations we report for breakfast (11.4 months), lunch (10.7), and dinner (10.6) prices in the Appendix. This consistency is not surprising given that we are using the same underlying data source. Note, however, that prices change less frequently at restaurants than for the typical good in the CPI bundle. Prices change more frequently than for restaurant foods for about 80 percent of nonhousing consumption.

Kackmeister (2002) analyzes data on the price levels of up to 49 consumer products (depending on the period) in Los Angeles, Chicago, New York, and Newark, New Jersey, in 1889–91, 1911–13, and 1997–99. The goods are at the ELI level or are slightly more aggregated, and they include 27 food items, 14 home furnishing items, and eight clothing items. He finds that the frequency, size, and variability of price changes are higher in the last period than in the first period. For 1997–99, he finds that 31 percent of his goods change price each month. This is higher than the mean frequency of 26 percent in our data; we conjecture that the difference owes mostly to the composition of goods rather than the sample period or cities. With data on price levels, Kackmeister is able to investigate how often a price is temporarily marked down from a "regular" price that is itself much stickier. He finds that 22 percent of prices change each month, excluding price reductions that reverse themselves one month later. But, according to the BLS, temporary sales are much more common for food and clothing, the bulk of Kackmeister's sample.

Directly to this point, Klenow and Kryvtsov (2004) examine monthly rates of price changes over 1988–2003 in the top three urban areas (New York, Los Angeles, and Chicago). They show that, when goods are weighted by expenditure shares, temporary sales constitute 20 percent of monthly price changes for the broad set of goods we are studying. If the same share (20 percent) of price changes arose from temporary sales in our data, covering more cities but fewer years, then our median frequency net of temporary sales would be 16.7 percent (vs. 20.9 percent including temporary sales). The median time between changes in regular prices would be 5.5 months (vs. 4.3 months with temporary sales). Five and a half months is less than half of the 12 months or more found by previous studies. Moreover, one could argue that temporary sales represent a true form of price flexibility that should not be filtered out, say because the magnitude and duration of temporary sales respond to shocks.

Differences in Price Stickiness across Broad Consumption Categories

Column 1 of table 2 provides price change frequencies for selected broad categories of consumption. The first row shows that the (weighted) mean frequency is 26 percent for all items. The next three rows provide (weighted) mean frequencies for durable goods, nondurable goods, and services, respectively, based on U.S. National Income and Product Account (NIPA) classifications. Price changes are more frequent for goods (about 30 percent for both durables and nondurables) than for services (21 percent). The lower frequency of price changes for services could reflect the lower volatility of consumer demand for them.

The next seven rows in table 2 provide frequencies for each of the seven CPI major groups defined by the BLS. At the flexible end are transportation prices (e.g., new cars and airfares), almost 40 percent of which change monthly. At the sticky extreme are medical care prices (drugs and physicians' services) and prices of entertainment (admission

TABLE 2
Monthly Frequency of Price Changes for Selected Categories

	Price Quotes with Price Changes (%) (1)	Price Quotes with Price Changes, Excluding Observations with Item Substitutions (%) (2)
All goods and services	26.1 (1.0)	23.6 (1.0)
Durable goods	29.8 (2.5)	23.6 (2.5)
Nondurable goods	29.9 (1.5)	27.5 (1.5)
Services	20.7 (1.5)	19.3 (1.6)
Food	25.3 (1.8)	24.1 (1.9)
Home furnishings	26.4 (1.8)	24.2 (1.8)
Apparel	29.2 (3.0)	22.7 (3.1)
Transportation	39.4 (1.8)	35.8 (1.9)
Medical care	9.4 (3.2)	8.3 (3.3)
Entertainment	11.3 (3.5)	8.5 (3.6)
Other	11.0 (3.3)	10.0 (3.3)
Raw goods	54.3 (1.9)	53.7 (1.7)
Processed goods	20.5 (.8)	17.6 (.7)

Source.—U.S. Department of Labor (1997).
Note.—Frequencies are weighted means of category components. Standard errors are in parentheses. Durables, nondurables, and services coincide with U.S. NIPA classifications. Housing (reduced to home furnishings in our data), apparel, transportation, medical care, entertainment, and other are BLS major groups for the CPI.

prices, newspapers, magazines, and books), with about 10 percent changing monthly.

In the final two rows of table 2 we draw a distinction between "raw" and "processed" goods. By raw goods we mean those with relatively little value added beyond a primary input, for instance, gasoline or fresh fruits and vegetables. Because their inputs are not well diversified, these goods may be subject to more volatile costs. Raw goods are a subset of the food and energy items excluded by the BLS in its core rate of CPI inflation.[6] As expected, raw products display more frequent price changes (their prices change 54 percent of months) than processed products and services (whose average is 21 percent). Even for processed items, the frequency of price changes remains considerably higher than values typically cited in the literature based on narrower sets of goods.

As mentioned above, when field agents learn that an item has been discontinued at an outlet, they substitute the price of a closely related item, often a newer version of the item. These item substitutions occurred at a monthly frequency of 3.4 percent for our sample of prices. Substitutions are typically associated with a change in price. Column 2 of table 2 presents results excluding item substitutions. More exactly,

[6] The set of raw goods consists of gasoline, motor oil and coolants, fuel oil and other fuels, natural gas, electricity, meats, fish, eggs, fresh fruits, fresh vegetables, and fresh milk and cream. Unlike the BLS food and energy categories, it does not include meals purchased in restaurants or foods the BLS classifies as processed.

the number of price changes not involving item substitutions is compared to the total number of price quotes not involving item substitutions. Across all goods, the frequency of price change is reduced modestly from 26.1 percent to 23.6 percent. The impact is most striking for apparel, where item substitutions are most frequent. Overall, our results are little affected by item substitutions. Furthermore, we would argue that the price changes associated with the replacement of products in outlets do convey price flexibility, even if they do not reflect that outlets literally change the price on a given version of a product.

Market Structure and Price Flexibility

Models of price adjustment (e.g., Barro 1972) predict greater frequency of price changes in markets with more competition because firms therein face more elastic demand. The four-firm concentration ratio is often used as an inverse measure of market competition, with a higher value expected to correlate with less elastic demand. Several papers have found an inverse relation between the concentration ratio and the frequency of price changes or price volatility in producer prices (e.g., Carlton 1986; Caucutt, Ghosh, and Kelton 1999). We examine the relationship between the share of the largest four firms in manufacturing shipments and the frequency of price change for our goods. The concentration ratio is taken from the 1997 Census of Manufactures. To exploit this measure, we match the 350 consumer goods categories to manufacturing industries as classified by the North American Industrial Classification System (NAICS). This matching can be done for 231 of the goods. The categories we were unable to match are largely services.

We consider two other variables related to market competitiveness. One is the wholesale markup, defined as (wholesale sales minus cost of goods sold)/(wholesale sales). The data for wholesale markups are taken from the 1997 Census of Wholesale Trade. We can match 250 of the 350 consumer goods to a corresponding wholesale industry in the NAICS. Another factor potentially related to market competition is the rate at which substitute products are introduced.[7] We expect markets with greater product turnover, as measured by the rate of noncomparable substitutions, to price more flexibly. Changes in the product space may induce changes in the prices of incumbent products. Pashigian's (1988) markdown pricing model for fashion goods has this feature, as do many models in which quality improvements are introduced over

[7] A BLS commodity specialist compares the attributes of each substitute item with those of the discontinued item and classifies each substitute as either comparable or noncomparable to the discontinued item. Item substitutions occur for 3.4 percent of monthly price quotes in our sample. The BLS deemed 46 percent of all substitutions noncomparable over 1995–97.

TABLE 3
Predicting Price Changes across Goods
Dependent Variable: Frequency of Price Changes across ELIs

Regressors	(1)		(2)	
Four-firm concentration ratio	−.30	(.04)	−.002	(.04)
Wholesale markup	−1.20	(.12)	−.10	(.13)
Noncomparable substitution rate	1.25	(.33)	2.17	(.26)
Raw good	…		34.1	(2.7)
Adjusted R^2	.36		.63	

Note.—The number of observations, goods, equals 221. Each good is weighted by its importance in the 1995 consumer expenditures. Standard errors are in parentheses.

time. Frequent introduction of new products may also proxy for ease of market entry more generally.

Column 1 of table 3 provides regression results relating the frequency of price changes to the three measures of market structure: concentration ratio, wholesale markup, and rate of noncomparable substitutions. (This is a weighted least squares regression with weights given by the goods' importance in 1995 consumer expenditures.) Each coefficient has the anticipated sign and is economically and statistically significant. The coefficient on the concentration ratio, −0.30, implies that raising the concentration ratio from 23 percent (the value for pet food) to 99 percent (the value for cigarettes) tends to decrease the monthly frequency of price changes by more than 20 percentage points.[8] The coefficient of −1.20 on the wholesale margin implies that increasing the margin from 12 percent (the value for meat products) to 35 percent (the value for toys and games) tends to decrease the monthly frequency of price changes by more than 25 percentage points. A 1 percent higher noncomparable substitution rate, meanwhile, goes along with a 1.25 percent higher frequency of price changes (standard error 0.3 percent).

As presented in table 2, products closely linked with primary inputs (raw products) display more frequent price changes. The regression in column 2 of table 3 examines how the frequency of price changes covaries with the three measures of market power, but now controlling for whether a good is a raw product. The coefficient implies that price changes are 34 percent more common for raw products (standard error 2.7 percent). The four-firm concentration ratio and wholesale markup, both of which appear very important in the column 1 regression, become quite unimportant when we control for whether a good is raw or processed. The rate of product turnover does continue to predict more frequent price changes. Its coefficient actually increases in column 2,

[8] The weighted correlation between four-firm concentration ratio and frequency of price change, calculated for all 231 goods with data on concentration ratio, is a very statistically significant −0.39.

with 1 percent more monthly substitutions associated with 2.2 percent more price changes (standard error 0.3 percent).

We conclude that market power, at least as measured by concentration ratio or wholesale markup, is not a robust predictor of the frequency of price changes. The frequency of price changes is more clearly related to the importance of product turnover and the importance of raw materials. These variables are perhaps more readily related to volatility of shocks to supply of and demand for a good rather than market competitiveness.

We also considered whether a good's frequency of price change is related to the absolute size of the good's price. For goods with very low unit prices, small desired price changes might be technically difficult or economically inefficient. For example, changing the price on an $800 refrigerator by 1 percent might be more practical than changing the price on a 50 cent pack of chewing gum by the same 1 percent. We employed the micro CPI data contained in the BLS Commodities and Services Data for 1995–97 (see Klenow and Kryvtsov [2004] for more detail) to construct a series of dummy variables for whether the average price for the good was less than $2, between $2 and $10, between $10 and $100, or greater than $100. To our surprise, we found that goods with an average price below $2 show the most frequent price changes, changing price with a monthly frequency 27 percent greater than goods with an average price between $2 and $100. (Goods with prices between $2 and $10 and goods with prices between $10 and $100 show a comparable frequency of price change.) This effect is statistically very significant, with a *p*-value less than .0001. Controlling for whether goods are processed or raw cuts the estimated magnitude in half, but it remains statistically very significant. High-priced goods, with an average price above $100, also change prices more frequently than goods with an average price between $2 and $100, but by only about 7 percent. Including these dummies for average price had little impact on the coefficient estimates reported in table 3. The biggest impact was on the coefficient for being a raw good, which was reduced from 34 percent to 29 percent.

III. Actual Inflation Compared to Inflation in the Calvo and Taylor Models

Many recent papers incorporate Calvo (1983) or Taylor (1999) sticky-price models, in which price setting is time-dependent and not synchronized across firms. Much of this work focuses on whether such models can generate persistent and important responses of output to purely monetary shocks.[9] We focus, however, on the pricing equation central to the Taylor and Calvo models of price stickiness. We see this as a more direct test of these workhorse models of price stickiness. We show that the models imply much more persistent and much less volatile inflation than we observe in the data for reasonable depictions of time series for the marginal costs of producing. We find that it is even more difficult for the models to explain the cross-good patterns we observe for persistence and variability of inflation. In sum, we do not see support for popular time-dependent models of price stickiness.[10]

Inflation in the Calvo Model

Popular time-dependent models of infrequent price changes contain a strong force ratcheting up inflation persistence and holding down inflation volatility, relative to the underlying marginal cost of producing. Consider the Calvo (1983) model, as outlined in Rotemberg (1987), Roberts (1995), and many recent papers on price stickiness.[11] In each period, firms in consumption category i change their price with probability λ_i. This probability is fixed and therefore independent of how many periods have elapsed since a firm's last price change. Conditional on changing price in period t, firms set price as a markup over the average (discounted) marginal cost the firm expects to face over the

[9] Chari et al. (2000) and Dotsey and King (2001) provide discussions of this issue. Because our findings point to more frequent price changes than typically assumed in calibrated models, they suggest greater difficulty for these models in generating persistent output responses to nominal shocks.

[10] These facts might be easier to reconcile with state-dependent models of price stickiness in which the frequency of price changes is endogenously greater in the presence of more volatile shocks. In these models, such as Caplin and Spulber (1987), Dotsey, King, and Wolman (1999), and Willis (2000), firm price adjustments can be more synchronized in response to sectoral shocks, producing much larger inflation innovations and much less inflation persistence.

[11] Although we focus on the Calvo formulation here, the discussion applies as well to the Taylor model. The Taylor model shares critical features of the Calvo model: in any period, many sellers do not adjust their prices, and those who do set their prices to reflect the expected discounted value of marginal cost viewed over a considerable time horizon. In the figures to follow we report on the ability of the Calvo model to fit the persistence and volatility of goods' inflation rates. We obtained very similar results when we conducted the same exercises with the Taylor model. In this paper's NBER working paper version (Bils and Klenow 2002), we take a model with Taylor-style staggered price setting and ask how goods' inflation rates respond to realistic monetary and technology shocks. We allow for two consumer goods. For one good, prices are quite flexible, whereas for the other, prices are quite sticky. For plausible shocks, we find that both the flexible and sticky-price goods exhibit much greater inflation persistence than is observed in the data. The mismatch with the data is particularly striking for the sticky-price good. We explore whether hitting the sticky-price sector with additional transitory shocks can help fit the data. Because the sticky-price model predicts little response of price to a transitory shock, we find that transitory shocks must be implausibly large to help match the data.

duration of time the price remains in effect. The natural log of this price (minus the constant desired markup) is

$$x_{it} = [1 - (1 - \lambda_i)\beta] \sum_{\tau=0}^{\infty} (1 - \lambda_i)^\tau \beta^\tau E_t(z_{it+\tau}),$$

where z_{it} is nominal marginal cost and β is the discount factor. If shocks are not too large, the average price in category i at time t is approximately

$$p_{it} = (1 - \lambda_i)p_{it-1} + \lambda_i x_{it},$$

as each period $1 - \lambda_i$ of the firms carry prices forward, with λ_i setting their price at x_{it}.

To illustrate, suppose that the log of nominal marginal cost follows a random walk, an assumption that, as we discuss below, is roughly consistent with the evidence. In this case the model implies a process for inflation for good i of

$$\pi_{it} = (1 - \lambda_i)\pi_{it-1} + \lambda_i \epsilon_{it}, \tag{1}$$

where ϵ_{it} is the independently and identically distributed (i.i.d.) growth rate of good i's marginal cost. If price changes are infrequent (i.e., λ_i is well below one), the sticky-price model exerts a powerful force for creating persistence in inflation and sharply dampening its volatility. For the consumer goods examined in Section II, the median monthly probability of price change is roughly 0.2. If, as an example, we reduce λ_i from one (perfect price flexibility) to 0.2, the serial correlation in inflation implied by the model goes from zero to 0.8. At the same time, the standard deviation of innovations to the inflation process is reduced by 80 percent and the unconditional standard deviation of the inflation rate is reduced by two-thirds.

Inflation Behavior across Consumer Goods

Do we observe persistence and volatility of inflation across goods that are consistent with the Calvo and Taylor models, given the frequency of price changes reported in Section II? To answer this, we match our 350 categories of consumer goods to available NIPA time series on prices from the Bureau of Economic Analysis.[12] The data run from January 1959 to June 2000. Although we can match most of our 350 ELI cate-

[12] For the vast majority of categories, the personal consumption expenditure deflators are CPIs. For the following categories in our sample the Bureau of Economic Analysis puts weight on input prices as well as the CPI: (in order of their weight) hospital services, college tuition, airline fares, high school and elementary school tuition, technical and business school tuition, and nursing homes. These categories add up to 5.7 percent of consumption and 8.5 percent of our sample.

TABLE 4
Aggregate and Sectoral Monthly Inflation Rates

Variable	Short Sample (January 1995 to June 2000) (1)	Long Sample (January 1959 to June 2000) (2)
	A. Aggregate of 123 Sectors	
ρ	.20 (.13)	.63 (.03)
σ_ϵ	.22	.22
	B. Across $i = 1, \ldots, 123$ Sectors	
Mean ρ_i	−.05 (.02)	.26 (.02)
Mean $\sigma_{\epsilon,i}$	.83 (.08)	.91 (.07)
Correlation between ρ_i and λ_i	.26 (.09)	−.06 (.09)
Correlation between $\sigma_{\epsilon,i}$ and λ_i	.68 (.07)	.52 (.08)

Note.—dp_t is the first difference of p_t, where p_t is the log of the price deflator. $dp_t = \rho dp_{t-1} + \epsilon_t$, where ϵ_t is i.i.d. with standard deviation σ_ϵ; so the standard deviation of dp_t is $[\sigma_\epsilon^2/(1-\rho^2)]^{1/2}$, which equals 0.19 for the short sample and inflation and 0.27 for the long sample. $dp_{i,t} = \rho_i dp_{i,t-1} + \epsilon_{i,t}$, where $\epsilon_{i,t}$ is i.i.d. with standard deviation $\sigma_{\epsilon,i}$; so the standard deviation of $dx_{i,t}$ is $[\sigma_{\epsilon,i}^2/(1-\rho_i^2)]^{1/2}$. The 123 sectors represent 63.3 percent of the 1995 consumer expenditures, and each sector is weighted by its expenditure share. Standard errors are in parentheses.

gories to NIPA time series, in many cases the NIPA categories are broader. The matching results in 123 categories covering 63.3 percent of 1995 consumer spending and most of our 350 ELIs (which made up 68.9 percent of spending).

In table 4 we examine the persistence and volatility of inflation for the 123 goods. We place particular emphasis on how inflation rates differ in persistence and volatility across goods in conjunction with underlying frequencies of price change as measured from the BLS panel. Column 1 of table 4 restricts attention to inflation from January 1995 to June 2000. Column 2 repeats all statistics for the considerably longer period of January 1959 to June 2000. Implicit in examining this longer period is an assumption that the relative frequencies of price changes across goods after 1995 represent reasonably well the relative frequencies for the earlier sample period.

We first examine persistence and volatility of aggregate inflation, where the aggregation is over our 123 consumer goods. We fit this aggregate monthly inflation rate to an AR(1) process. Column 1 of panel A in table 4 shows that the aggregate inflation rate is not very persistent over 1995–2000. Its serial correlation is 0.20 (standard error 0.13).

Column 1 of panel B in table 4 depicts how persistence and volatility of inflation vary across goods. For each of the 123 categories, we fit the good's monthly inflation rate to an AR(1) process. This allows us to examine how inflation persistence and volatility differ across goods in relation to each good's underlying frequency of price changes over 1995–97. We use the AR(1) coefficient to measure persistence. We focus on the standard deviation of innovations to a good's AR(1) process for inflation as a measure of volatility. We do so because, as discussed above, it is straightforward to depict how price stickiness dampens the volatility of innovations to inflation with Calvo and Taylor pricing.

The average serial correlation across the 123 sectors is close to zero at −0.05 (standard error 0.02). Across the 123 categories, the correlation between the frequency of price changes and the degree of serial correlation is 0.26 (standard error 0.09). Thus, contrary to the predictions of the Calvo and Taylor models of price stickiness, goods with more frequent price changes exhibit inflation rates with more serial correlation. Consistent with the sticky-price models, however, goods with more frequent price changes display more volatile innovations to inflation. (The correlation between the frequency of price changes and the standard deviation of inflation innovations is 0.68 [standard error 0.07].)

Column 2 of the table examines the patterns of persistence and volatility for the broader 1959–2000 period. Across the 123 goods, inflation does show positive serial correlation over the longer period. But the magnitude of this persistence, averaging 0.26 (standard error 0.02) across goods, is fairly modest. There is a negative correlation between a good's frequency of price changes for 1995–97 and its inflation persistence over 1959–2000, as anticipated by the sticky-price model. But it is small in magnitude and not statistically significant (−0.06, standard error 0.08). The correlation between the frequency of price changes and the volatility of innovations to inflation is 0.52 (standard error 0.08). This positive correlation is predicted by the Calvo and Taylor sticky-price models, since less frequent price changes should mute the volatility of inflation innovations. Alternatively, one could infer that sectors facing larger shocks choose to change prices more frequently.

These results are based on data that are seasonally adjusted. Importantly, this implies that regular seasonal cycles in pricing, for example, synchronized seasonal sales, do not generate the transience and volatility we see in goods' inflation rates.

Calvo Model versus Actual Inflation Rates for Realistic Marginal Cost

If nominal marginal cost is highly persistent in levels, then equation (1) suggests that price inflation should be highly persistent for goods with infrequent price changes. But table 4 shows that inflation rates have not been very persistent, even for those goods with a low frequency of price changes.

Figure 2 makes this point more fully. Across the 123 categories of consumer goods for which we have monthly time series for inflation, the frequency of price changes (based on the BLS panel) varies from less than 0.05 to more than 0.70. The solid line graphs the serial cor-

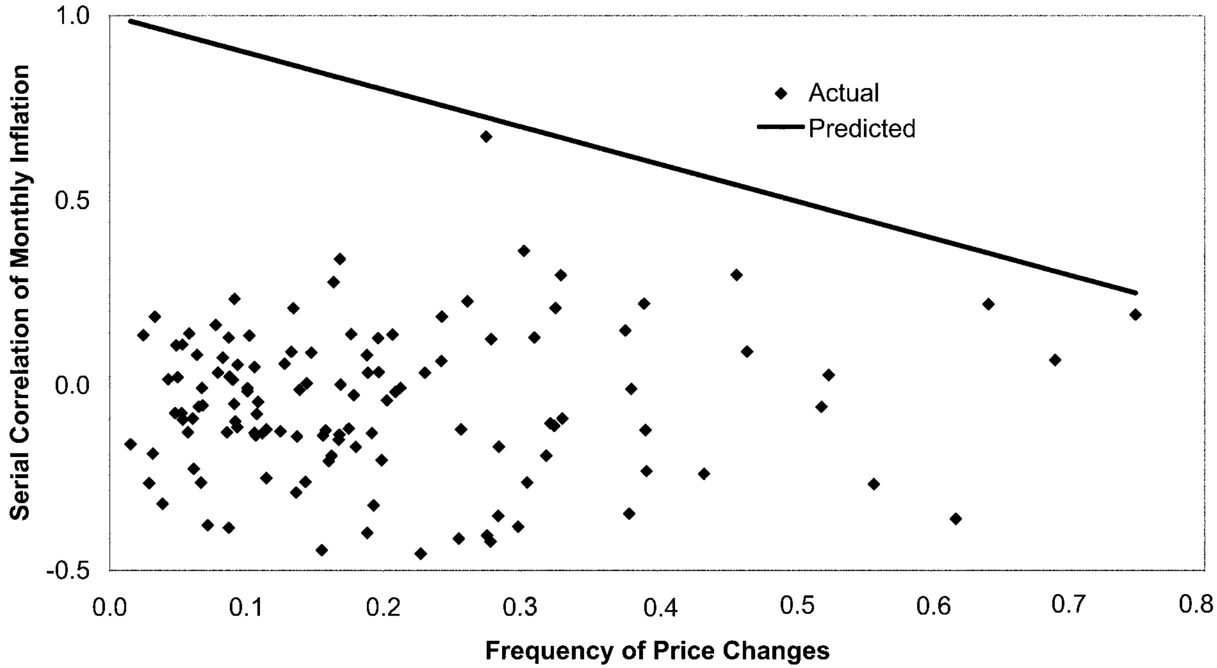

FIG. 2.—Predicted vs. actual inflation persistence (Calvo model, 1995–2000, 123 consumption categories)

relation of monthly inflation predicted by the Calvo model as a function of this frequency of price change. Under the assumption that the growth rate of marginal cost is serially uncorrelated, this predicted serial correlation is simply one minus the frequency of price change. The figure also graphs the observed serial correlation for each of the 123 consumer goods for the shorter sample period January 1995 to June 2000. With only a few exceptions, the observed serial correlation falls far below the model's prediction. The average observed serial correlation is close to zero, whereas the average predicted value is around 0.8. For goods with frequencies of price change below the median value of 21 percent, no good exhibits a serial correlation in the data that is within 0.4 of the model's prediction.

Figure 3 repeats the exercise in figure 2, except that it presents inflation's observed serial correlation over the entire 1959–2000 period. The goods' inflation rates are more often positively serially correlated for the longer sample period, as reported in table 4. But, for all but a handful of goods, the observed persistence is well below that anticipated by the Calvo model. In fact, the observed persistence is typically closer to zero than to the model's prediction, especially for goods with less frequent price changes.

Figures 2 and 3 presume a growth rate for marginal cost that is serially uncorrelated. Perhaps the failure of the Calvo model in these figures is an artifact of our assuming too much persistence in innovations to marginal cost. Addressing this question requires a measure of marginal cost, or at least its persistence. Bils (1987) creates a measure of movements of marginal cost under the assumption that output, Y_{it}, can be linked by a power function to at least one of its inputs, call it N_{it}:

$$Y_{it} = N_{it}^{\alpha} f_{it}(\text{all other inputs}).$$

The Cobb-Douglas form is a special case for which any input can take the role of input N. Bils focuses on the case in which N is production labor. Marginal cost can be expressed as the price of N, call it W, relative to N's marginal product. For the production function above, the natural log of marginal cost is simply

$$z_{it} = \ln(\alpha) + w_{it} + n_{it} - y_{it}, \tag{2}$$

where w, n, and y refer to the natural logs of their uppercase counterparts. Gali and Gertler (1999) and Sbordone (2002) also use this approach to construct a measure of marginal cost in order to judge the impact of price stickiness.

Suppose that we treat labor as the relevant input, n, and measure WN

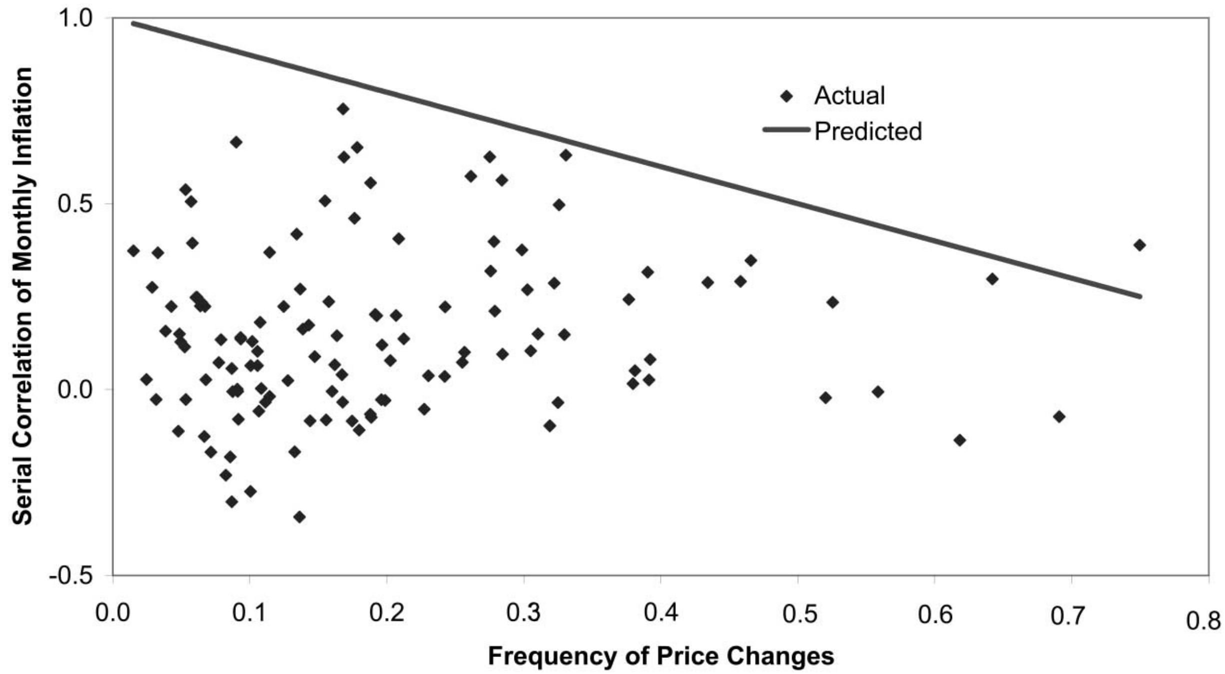

FIG. 3.—Predicted vs. actual inflation persistence (Calvo model, 1959–2000, 123 consumption categories)

simply as payments to labor.[13] In this case, z_{it} is, up to a constant term, simply the natural log of the ratio of the wage bill to real output. The BLS publishes a quarterly time series on this ratio, labeled unit labor costs, for the aggregate business sector. We examined the persistence in the growth rate of this quarterly series. For our shorter sample period, 1995–2000, the growth rate of unit labor cost is actually positively serially correlated, but not significantly so. The AR(1) parameter is 0.12, with standard error 0.25. For the broader 1959–2000 sample, the growth rate of unit labor cost is more serially correlated. The AR(1) parameter equals 0.41, with standard error 0.07. This is consistent with the observation from table 4 of greater serial correlation in inflation over the longer period. We obtained results with the BLS series on unit labor costs for the nonfarm business sector very similar to those for the aggregate business sector. None of these estimates suggest less persistence in marginal cost than presumed by our assumption of a random walk for marginal cost. In fact, the persistence in the growth rate for this measure of marginal cost suggests that the lack of persistence in inflation rates is even more problematic for the Calvo and Taylor models.

We also examined the persistence and volatility of unit labor cost as measured for 459 manufacturing industries in the NBER Productivity Database. The advantage of this source is that the data are much more disaggregate than the BLS measure of unit labor cost. The drawbacks are that they are available only annually and only for manufacturing. Manufacturing output is considerably more volatile than consumption. Also, average sales across the 459 manufacturing industries are an order of magnitude smaller than average consumption across the 123 categories. So there is reason to think that, if anything, marginal cost is more volatile for these manufacturing industries than for the consumption sectors.

For each of the 459 industries, we estimated a separate AR(1) model for the log level of production workers' unit labor cost. On the basis of annual data for 1959–96, the average AR(1) parameter is 0.98 (standard deviation 0.05 across industries) and the average standard error of innovations to marginal cost is 6.9 percent (standard deviation 3.1 percent across industries). This is not statistically different from a random walk.[14]

[13] Bils (1987) argues against this assumption. If labor is quasi-fixed, he shows that the marginal price of labor may be much more procyclical than the average wage rate paid to labor. We pursued the correction suggested there for calculating a marginal wage rate that reflects the marginal propensity to pay overtime premia. Incorporating this adjustment alters little the results we depict below in figs. 4 and 5.

[14] The implied monthly AR(1) process consistent with this annual evidence has a serial correlation of 0.997 and an innovation standard error of 2.5 percent. (Note that annual data compare averages for each year, not simply two months that are 12 months apart.) Estimates based on labor costs for all workers, not just production workers, yield almost the same results. Estimates based on unit materials cost also produce very similar results, with an average AR(1) parameter in annual data of 0.99 rather than 0.98.

If we take only the most recent third of the NBER data, years 1984–96, the data show less persistence and less volatility in unit labor cost. The average AR(1) parameter falls to 0.75 (standard deviation 0.27) and the average innovation standard error to 4.9 percent (standard deviation 2.6 percent across industries).[15]

Finally, we compare these estimates to the behavior of marginal cost needed to explain the behavior of actual inflation rates for the 123 consumer goods. Figures 4 and 5 plot, with a point for each good, what persistence and volatility of marginal cost reconcile the Calvo model with the observed persistence and volatility of that good's inflation rate. Figure 4 is based on inflation rates for 1995–2000 and figure 5 on those for 1959–2000. The figures make clear that the popular time-dependent sticky-price models predict not only far too much persistence, but also far too little volatility.

Figure 4 shows that, to be consistent with observed inflation, many of the goods require little or no persistence in marginal cost in conjunction with tremendous volatility of innovations. In most cases, marginal cost innovations need to exhibit a standard deviation well above 10 percent monthly. The figure employs three separate symbols for goods that rank among the stickiest third, middle third, and most flexible third according to their frequency of price changes in the BLS panel. The volatility required of marginal cost is enormous for goods with infrequent price changes. The figure also plots, for reference, the average persistence and volatility of marginal cost estimated for 1984–96 of the NBER Productivity Database. Even if we move two standard deviations below the mean persistence and two standard deviations above the mean volatility, these values are far removed from what is needed for the Calvo model to fit the behavior of most goods' inflation rates.

Figure 5 shows the required marginal cost processes given goods' inflation rates over 1959–2000 (rather than 1995–2000). The figure also presents mean behavior of marginal cost based on the years 1959–96 of the NBER Productivity Database. Here a handful of goods do exhibit inflation rates that are consistent with the average estimated process for marginal costs. But, for the vast majority of goods, inflation is far too transient and its innovations far too volatile to be consistent with the Calvo model under plausible behavior for marginal cost.

The Role of Measurement Error and Temporary Sales

The figures display a very sharp contradiction between the predictions of the Calvo model and observed rates of inflation. Measurement error

[15] The implied monthly AR(1) process has serial correlation 0.96 and innovation standard error 2.1 percent.

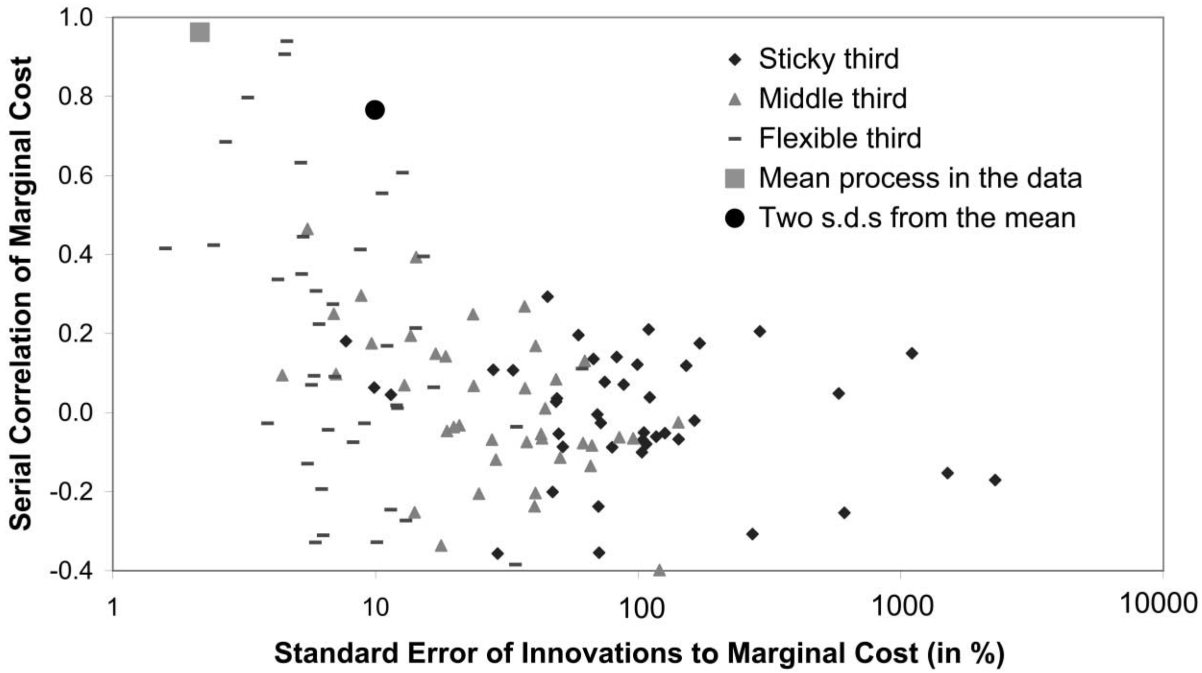

Fig. 4.—Marginal cost needed to generate sectoral inflation (Calvo model, 1995–2000, data for 123 categories)

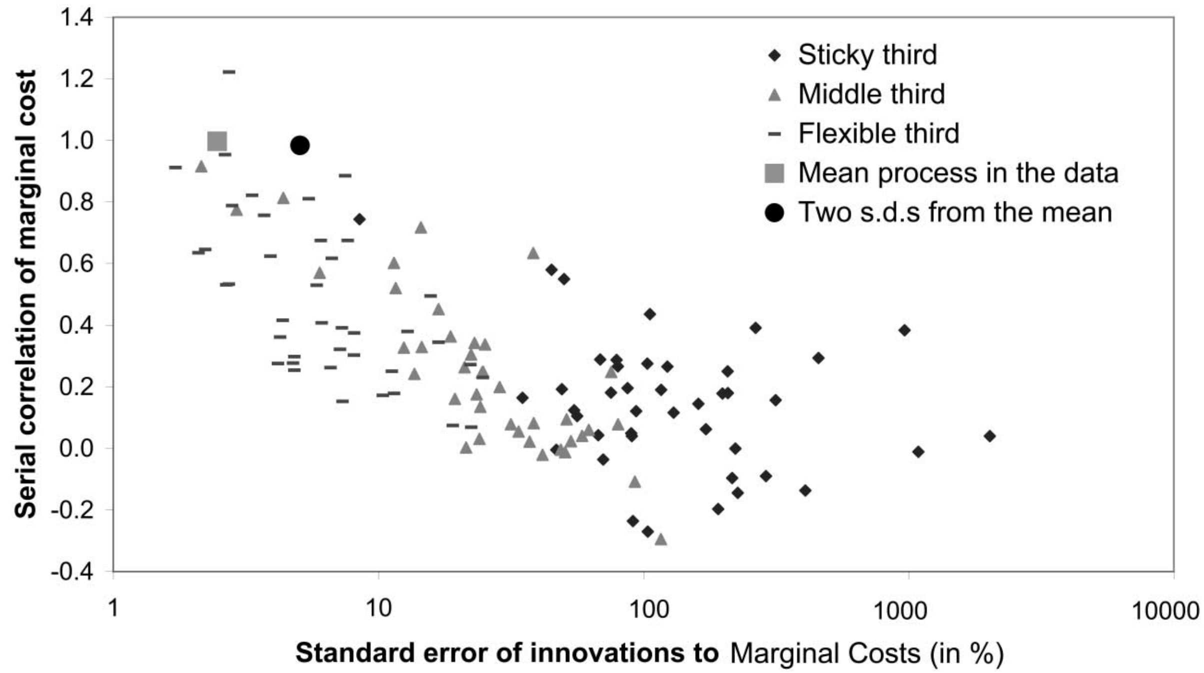

FIG. 5.—Marginal cost needed to generate sectoral inflation (Calvo model, 1959–2000, data for 123 categories)

in the underlying BLS price quotes could conceivably explain the divergence between theory and evidence. Serially uncorrelated errors in price levels would contribute negative serial correlation to inflation, making inflation appear too transient. They would also, of course, add noise and make measured inflation more volatile. To fully reconcile the theory and evidence, however, such measurement error would have to be implausibly large. Prices are collected by different field agents at 22,000 outlets across 88 geographic areas, so measurement error is unlikely to be correlated across quotes. And given that the median number of quotes in a sector is 700 per month, uncorrelated errors should largely average out in the aggregation up to the sectoral level. To explain the low serial correlation of sectoral inflation rates (-0.05 in the data vs. 0.79 in theory), the standard deviation of measurement error at the quote level would have to be around 27 percent conditional on a given price change.[16] This is much larger than the 13 percent average absolute size of price changes in Klenow and Kryvtsov's (2004) micro data. It also exceeds the "tolerances" in the BLS Data Collection Manual: field representatives must verify and explain changes in prices exceeding 20 percent for food items and 10 percent for other items.

In the preceding calculation, we assume measurement error only when the BLS field representative records a change from the previous price. Field agents of the BLS must circle the previous price (shown on their collection sheets) if it is the same as the current price, presumably limiting the number of spurious price changes. When a field agent records no change in price when one has in fact occurred, however, this should contribute nonclassical measurement error and mimic the predictions of the Calvo model. That is, such measurement error should affect the frequency of price changes and the sectoral inflation rates just as true price stickiness does in the Calvo model.

As discussed in Section II, Klenow and Kryvtsov (2004) find that temporary price discounts constituted 20 percent of price changes for our set of goods, on the basis of the three largest cities (each sale accounting for two price changes). Their results also imply that the average temporary price discount could be no larger than about 32 percent. Temporary sales clearly work to reduce the persistence of price changes. Unless they are synchronized across sellers, however, they face the same

[16] The observed serial correlation should be a weighted average of 0.79 and -0.50, with the weights equal to the fraction of inflation variance coming from the signal and the noise, respectively. Noise would need to contribute 65.1 percent of the variance to drive inflation's serial correlation down from 0.79 to -0.05. In table 4 the mean variance of inflation is 0.691 percent, so the standard deviation of measurement error in inflation would have to be 0.671 percent. Measurement error in the level of sectoral prices would need a standard deviation of 0.474 percent ($=\sqrt{0.5} \times 0.671$), and in the levels of individual prices it would need to be 12.5 percent ($= \sqrt{700} \times 0.474$). Finally, conditional on a price change, the standard deviation would have to be 27.4 percent ($=$ 12.5 percent$/\sqrt{0.21}$).

difficulty as measurement errors in explaining the low persistence of inflation rates. We calculated the impact of temporary sales on the volatility and persistence of inflation rates on the basis of Klenow and Kryvtsov's figures. Temporary sales of that magnitude would reduce the serial correlation for the median good from a model value of 0.79 to only 0.67. This remains well above the average value in the data of −0.05. These temporary sales help even less in addressing the volatility puzzle. Eliminating the impact of these sales would cut the standard deviation of the inflation rate by only 6 percent for a good with the mean variability of inflation.

What about temporary sales that are synchronized across items within a sector? Can they address both the transience and volatility puzzles? As we noted earlier, the data on sectoral inflation rates are seasonally adjusted; so synchronized sales that reflect seasonal pricing do not appear to explain these puzzles. More promising, we believe, are random sales that cover a large fraction of a sector. Note, however, that such sales imply that sellers are conditioning on each other's pricing decisions; we view this as support for state-dependent pricing behavior. Importantly, even synchronized sales cannot explain why the staggered-pricing model falls so far short in explaining the transience and volatility for goods that display infrequent price changes. The importance of temporary sales is limited for these goods, since otherwise they could not display such low frequency of price changes.

Comparison with Selected Previous Studies

We find that inflation rates show much greater volatility and much less persistence, conditional on the behavior of nominal marginal cost, than predicted by Calvo-type pricing equations. Fuhrer and Moore (1995) consider a model with Taylor (1999) staggered wage contracts and contend that the aggregate inflation rate is too persistent relative to model predictions. Note, however, that their work does not contradict our conclusions. Fuhrer and Moore assume perfect price flexibility and constant price markups in output markets. This implies that inflation rates show the same persistence, and volatility, as nominal marginal cost. If we assumed that all goods have perfectly flexible prices ($\lambda = 1$), we would also conclude that inflation rates are too persistent given pricing equation (1). But, given the evidence in Section II, the case of perfect price flexibility is clearly not an empirically interesting one.

Gali and Gertler (1999) use the Calvo pricing equation to relate aggregate inflation to a measure of real marginal cost, as well as inflation's past and future expected values. They measure marginal cost in accordance with equation (2). Their preferred estimate implies an average price duration of five quarters. This would appear to conflict with our conclusion that the behavior of inflation is not consistent with infrequent price changes. There are several important differences with the analysis here.[17] In particular, they estimate the frequency of price changes on the basis of covarying inflation with estimated changes in the measure of real marginal cost. As they discuss, their estimate of the frequency of price changes is likely to be biased downward, with price duration biased upward, given that they have only a proxy for marginal cost. Gali and Gertler (p. 218, fig. 2) display the time-series behavior of the actual inflation rate versus the rate predicted by their estimated model. Consistent with what we conclude, this comparison appears to show that actual inflation is considerably less persistent than implied by the estimated model with average price duration of five quarters.

IV. Conclusions

We have exploited unpublished data from the BLS for 1995–97 on the monthly frequency of price changes for 350 categories of consumer goods and services. We found considerably more frequent price changes than previous studies of producer prices or consumer prices based on narrower sets of goods. The time between price changes was 4.3 months or shorter for half of consumption. Our finding of more frequent price changes does not merely reflect frequent temporary sales. If we net out the impact of price changes reflecting temporary sales, the time between price changes remains under 5.5 months for half of consumption. Taylor (1999, p. 1020) summarized the prior literature as finding that prices typically change about once a year.

We examined whether time series for inflation are consistent with the workhorse Calvo and Taylor sticky-price models, given the frequency of price changes we observe. We found that, for nearly all consumer goods, these models predict inflation rates that are much more persistent and much less volatile than we observe. The models particularly overpredict persistence and underpredict volatility for goods with less frequent price changes.

A model with synchronized price changes within sectors might explain the volatility and transience of observed inflation rates. Synchronization might arise because of large sector-specific shocks under state-dependent pricing. Allowing for synchronized sales in models with state-dependent pricing appears more promising, as does variation in desired price markups more generally. Purely seasonal sales would not do the

[17] Gali and Gertler employ aggregate deflator data, whereas we are employing consumption deflators disaggregated across more than 100 categories. As shown in table 4, persistence of inflation is somewhat greater for our data aggregated.

trick, however, as it is in seasonally adjusted inflation rates that we find low persistence and high volatility.

We have focused on implications of the popular Calvo and Taylor versions of sticky-price models. More elaborate sticky-price models may preserve the predictions of these models while better explaining the observed behavior of prices at the aggregate and good levels. Sims (2003), for instance, models firms as actively responding to market-level information, yet choosing to largely ignore monetary policy variables. We believe that the behavior of prices we observe, particularly the volatility and transience of inflation rates for goods with infrequent price changes, should provide a useful testing ground for such models.

Appendix

TABLE A1
Frequency of Price Changes by Category

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Weighted statistics:							
Median		20.9	4.3	1.7	.8		
Mean		26.1	3.3	3.4	1.6		
Coin-operated apparel laundry and dry cleaning	44012	1.2	79.9	.53	.17	.148	.21
Vehicle inspection	52014	1.4	69.9	.00	.00	.033	.26
Driver's license	52013	1.8	56.3	1.04	.39	.023	.30
Coin-operated household laundry and dry cleaning	34045	2.1	46.4	.00	.00	.014	.32
Intracity mass transit	53031	2.5	40.2	.66	.14	.223	.64
Local automobile registration	52012	2.8	34.8	3.26	.66	.019	.67
Legal fees	68011	2.9	34.3	.48	.37	.289	1.09
Vehicle tolls	52054	3.2	31.2	.70	.00	.059	1.17
Safe deposit box rental	68021	3.3	30.2	.70	.70	.019	1.20
Newspapers	59011	3.3	29.9	.56	.31	.245	1.56
Alterations and repairs	44013	3.3	29.4	.36	.25	.022	1.59
Automobile towing charges	52055	3.4	28.7	.56	.00	.017	1.61
Parking fees	52053	3.7	26.8	.38	.10	.096	1.75
Haircuts and other barbershop services for males	65021	3.9	25.5	.19	.11	.162	1.99
Beauty parlor services for females	65011	4.3	22.9	.42	.23	.338	2.48
State automobile registration	52011	4.3	22.7	1.00	.22	.278	2.88
Services by other medical professionals	56041	4.5	22.0	.83	.62	.217	3.19
Hearing aids	55034	4.7	20.8	1.19	.93	.024	3.23
Shoe repair and other shoe services	44011	4.8	20.4	.63	.57	.009	3.24
Garbage and trash collection	27041	4.9	20.0	.89	.44	.249	3.60
Pet services	62053	4.9	19.7	.13	.07	.064	3.70
Taxi fares	53032	5.0	19.7	.33	.04	.045	3.76
Care of invalids, elderly, and convalescents in the home	34071	5.1	19.1	1.53	.75	.125	3.94

TABLE A1
(*Continued*)

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Household laundry and dry cleaning, excluding coin-operated	34044	5.1	19.0	.61	.54	.039	4.00
Watch and jewelry repair	44015	5.2	18.5	.27	.13	.018	4.02
Photographic and darkroom supplies	61022	5.3	18.4	2.41	1.71	.005	4.03
Physicians' services	56011	5.3	18.3	.71	.54	1.366	6.01
Film processing	62052	5.3	18.2	1.17	.87	.101	6.16
Wine away from home	20052	5.5	17.6	2.63	1.26	.078	6.27
Postage	34011	5.6	17.5	.00	.00	.214	6.58
Water softening service	34042	5.7	17.2	.91	.91	.009	6.60
Apparel laundry and dry cleaning, excluding coin-operated	44021	5.7	17.0	.21	.17	.269	6.99
Plumbing supplies and equipment	24015	6.0	16.2	1.51	.51	.003	6.99
Repair of television, radio, and sound equipment	34061	6.1	16.0	.39	.16	.026	7.03
Dental services	56021	6.1	15.8	.28	.17	.750	8.12
Other entertainment services	62055	6.2	15.7	.90	.53	.260	8.49
Beer, ale, other alcoholic malt beverages away from home	20051	6.4	15.2	1.69	.98	.125	8.68
Checking accounts and special check services	68022	6.4	15.2	1.27	.56	.088	8.80
Intrastate telephone services	27061	6.4	15.2	.16	.04	.460	9.47
Veterinarian services	62054	6.5	14.9	.66	.59	.182	9.74
Domestic services	34031	6.5	14.9	.82	.60	.310	10.19
Club membership dues and fees	62011	6.7	14.5	1.23	.85	.340	10.68
Elementary and high school books and supplies	66021	6.8	14.2	1.63	.95	.031	10.72
Fees for lessons or instructions	62041	6.9	14.0	2.53	2.19	.211	11.03
Miscellaneous supplies and equipment	24041	7.1	13.7	2.26	.93	.044	11.09
Cemetery lots and crypts	68032	7.2	13.5	.78	.53	.044	11.16
Day care and nursery school	67031	7.2	13.5	.90	.50	.539	11.94
Encyclopedias and other sets of reference books	66022	7.5	12.9	3.70	.09	.005	11.95
Technical and business school tuition and fixed fees	67041	7.7	12.4	1.37	.77	.050	12.02
Residential water and sewer service	27021	7.9	12.1	.86	.41	.663	12.98
Distilled spirits away from home	20053	7.9	12.1	1.10	.58	.114	13.15
Tax return preparation and other accounting fees	68023	8.3	11.6	.76	.61	.147	13.36
Breakfast or brunch	19032	8.4	11.4	1.01	.59	.378	13.91
Magazines	59021	8.6	11.2	1.27	.74	.122	14.09
Housing at school, excluding board	21031	8.7	11.0	.83	.45	.197	14.37
Admission to movies, theaters, and concerts	62031	8.8	10.9	1.79	.56	.416	14.98
Eyeglasses and eyecare	56031	8.9	10.8	2.05	.97	.333	15.46
Lunch	19011	9.0	10.7	1.48	.87	1.762	18.02
Dinner	19021	9.0	10.6	1.74	1.05	2.515	21.67

TABLE A1
(*Continued*)

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Nonelectric articles for the hair	64012	9.1	10.5	4.42	3.03	.016	21.69
Other information-processing equipment	69015	9.1	10.5	4.17	.00	.015	21.71
Photographer fees	62051	9.1	10.5	2.68	1.86	.067	21.81
Nursing and convalescent home care	57022	9.2	10.4	1.12	.72	.024	21.85
Elementary and high school tuition and fixed fees	67021	9.3	10.2	.50	.17	.312	22.30
Moving, storage, freight expense	34043	9.4	10.2	.74	.29	.106	22.45
Tenants' insurance	35011	9.5	10.1	1.19	.11	.026	22.49
Snacks and nonalcoholic beverages	19031	9.5	10.0	1.87	1.25	.414	23.09
Tools and equipment for painting	24012	9.7	9.8	4.55	1.81	.001	23.09
Inside home maintenance and repair services	23011	9.8	9.7	.96	.60	.085	23.21
Supportive and convalescent medical equipment	55033	9.8	9.7	3.14	1.58	.013	23.23
Medical equipment for general use	55032	9.8	9.7	3.01	2.77	.009	23.25
Clothing rental	44014	10.0	9.5	1.67	1.38	.011	23.26
College tuition and fixed fees	67011	10.1	9.4	.82	.18	.951	24.64
Intercity train fare	53022	10.2	9.3	.07	.05	.068	24.74
Plastic dinnerware	32031	10.2	9.3	4.17	1.76	.005	24.75
College textbooks	66011	10.2	9.3	2.68	1.55	.128	24.93
Electrical supplies, heating and cooling equipment	24016	10.5	9.0	3.20	.81	.002	24.93
Fees for participant sports	62021	10.6	9.0	1.00	.44	.339	25.43
Reupholstery of furniture	34063	10.7	8.9	1.30	.66	.040	25.49
Interstate telephone services	27051	10.8	8.8	.11	.10	.768	26.60
Power tools	32042	10.8	8.8	2.16	.68	.051	26.67
Other hardware	32043	10.8	8.7	2.81	1.30	.052	26.75
Nonpowered hand tools	32044	10.9	8.6	2.84	1.70	.030	26.79
Cosmetics, bath/nail/makeup preparations, and implements	64031	11.1	8.5	2.65	1.47	.362	27.32
Kitchen and dining room linens	28013	11.2	8.4	4.56	2.17	.035	27.37
Blacktop and masonry materials	24014	11.2	8.4	1.36	.00	.001	27.37
Stationery, stationery supplies, giftwrap	33032	11.4	8.2	6.30	2.54	.219	27.69
Records and tapes, prerecorded and blank	31033	11.4	8.2	4.95	1.03	.179	27.95
Hospital services	57041	11.4	8.2	1.63	1.25	1.426	30.01
Gardening and lawn care services	34041	11.5	8.2	1.84	1.15	.241	30.36
Automotive maintenance and servicing	49031	11.6	8.1	9.36	.46	.550	31.16
Film	61021	11.8	8.0	2.33	.63	.041	31.22
Purchase of pets, pet supplies, and accessories	61032	11.8	8.0	3.49	1.49	.188	31.50
Sewing notions and patterns	42012	12.0	7.8	2.71	.51	.007	31.51

TABLE A1
(*Continued*)

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Tableware and nonelectric kitchenware	32038	12.0	7.8	5.82	3.02	.064	31.60
Laundry and cleaning equipment	32014	12.3	7.6	5.55	2.44	.042	31.66
Books not purchased through book clubs	59023	12.4	7.5	8.20	2.07	.167	31.90
Electric personal care appliances	64017	12.6	7.4	6.26	3.39	.014	31.92
Calculators, adding machines, and typewriters	69014	12.8	7.3	7.78	6.20	.018	31.95
Women's hosiery	38043	12.9	7.2	2.78	.77	.082	32.07
Clocks	32021	13.0	7.2	5.92	2.74	.012	32.08
Videocassettes and discs, blank and prerecorded	31022	13.0	7.2	6.66	1.68	.084	32.21
Deodorant/suntan preparations, sanitary/foot care products	64016	13.2	7.1	2.39	1.04	.090	32.34
Coolant, brake fluid, transmission fluid, and additives	47022	13.3	7.0	2.01	.51	.015	32.36
Paint, wallpaper, and supplies	24011	13.3	7.0	1.81	.61	.011	32.37
Hard surface floor covering	24042	13.5	6.9	1.62	1.00	.015	32.39
Unpowered boats and trailers	60012	13.5	6.9	4.70	.44	.055	32.47
Telephone services, local charges	27011	13.6	6.8	.72	.23	1.221	34.25
Internal and respiratory over-the-counter drugs	55021	13.7	6.8	1.82	1.35	.257	34.62
Dental products, nonelectric dental articles	64014	13.8	6.7	2.30	1.24	.078	34.73
Toys, games, and hobbies	61011	13.9	6.7	6.58	2.67	.403	35.32
Infants' and toddlers' underwear	41013	14.0	6.6	4.00	1.57	.158	35.55
Topicals and dressings	55031	14.2	6.6	2.40	1.65	.071	35.65
Slipcovers and decorative pillows	28015	14.2	6.5	7.69	2.28	.015	35.67
Distilled spirits at home (excluding whiskey)	20022	14.2	6.5	.61	.27	.056	35.75
Replacement of installed wall-to-wall carpet	23013	14.3	6.5	5.61	4.48	.024	35.79
Floor coverings	32011	14.4	6.4	4.19	2.17	.057	35.87
Funeral expenses	68031	14.5	6.4	2.56	1.47	.261	36.25
Landscaping items	24043	14.9	6.2	2.47	1.53	.005	36.26
Shaving products, nonelectric shaving articles	64015	15.0	6.1	2.76	1.52	.041	36.32
Products for the hair	64011	15.0	6.1	1.94	1.13	.131	36.51
Whiskey at home	20021	15.3	6.0	.54	.25	.050	36.58
Automobile insurance	50011	15.5	5.9	1.51	.12	2.460	40.15
Lawn and garden supplies	33052	15.5	5.9	3.54	1.68	.200	40.44
Vehicle parts and equipment other than tires	48021	15.8	5.8	3.84	1.02	.260	40.82
Other laundry and cleaning products	33012	15.9	5.8	1.81	.99	.145	41.03
Infants' equipment	32013	15.9	5.8	5.32	2.48	.013	41.04
Nonelectric cooking ware	32037	16.1	5.7	5.28	2.30	.034	41.09

TABLE A1
(*Continued*)

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Music instruments and accessories	61013	16.2	5.7	3.06	1.12	.064	41.19
Photographic equipment	61023	16.4	5.6	4.47	1.58	.042	41.25
Candy and chewing gum	15011	16.4	5.6	2.10	1.03	.237	41.59
Computer software and accessories	69012	16.5	5.5	5.53	2.57	.067	41.69
Household decorative items	32023	16.6	5.5	8.12	4.24	.213	42.00
Indoor, warm weather, and winter sports equipment	60021	16.6	5.5	5.01	2.12	.255	42.37
Tobacco products other than cigarettes	63012	16.7	5.5	.96	.75	.063	42.46
Prescription drugs and medical supplies	54011	16.8	5.4	1.22	.62	.648	43.40
Miscellaneous household products	33051	16.8	5.4	2.21	1.01	.272	43.80
Repair of household appliances	34062	16.9	5.4	.60	.29	.014	43.82
Fabric for making clothes	42011	17.0	5.4	3.96	.86	.018	43.84
Boys' underwear, night wear, and hosiery	37014	17.1	5.3	3.20	.42	.034	43.89
Hunting, fishing, and camping equipment	60022	17.1	5.3	4.27	1.66	.064	43.98
Boys' accessories	37015	17.2	5.3	5.33	1.54	.020	44.01
Infants' furniture	29042	17.5	5.2	4.76	1.60	.025	44.05
Pet food	61031	17.5	5.2	2.13	.80	.251	44.41
Men's underwear and hosiery	36031	17.6	5.2	2.31	.40	.114	44.58
Salt and other seasonings and spices	18041	17.6	5.2	1.41	.64	.070	44.68
Sewing materials for household items	28016	17.7	5.1	2.45	.71	.036	44.73
Men's night wear	36032	17.8	5.1	5.37	.70	.013	44.75
Telephone, peripheral equipment, and accessories	69013	17.8	5.1	4.79	3.24	.065	44.84
Books purchased through book clubs	59022	17.9	5.1	7.56	3.12	.031	44.89
Indoor plants and fresh-cut flowers	32061	18.0	5.0	4.88	3.07	.164	45.13
Flatware	32033	18.3	4.9	3.91	1.93	.014	45.15
Glassware	32034	18.4	4.9	5.12	2.44	.014	45.17
Automotive brake work	49022	18.5	4.9	9.94	1.25	.141	45.37
Automotive drivetrain repair	49021	18.5	4.9	9.65	1.13	.178	45.63
Men's accessories	36033	18.7	4.8	4.62	.78	.130	45.82
Watches	43011	18.8	4.8	5.08	1.32	.069	45.92
Living room tables	29032	18.8	4.8	4.13	2.55	.063	46.01
Portable cool/heat equipment, small electric kitchen appliances	32052	19.0	4.8	5.15	2.02	.078	46.13
Soaps and detergents	33011	19.2	4.7	3.16	2.05	.214	46.44
Wine at home	20031	19.3	4.7	3.24	.84	.187	46.71
Lamps and lighting fixtures	32022	19.4	4.6	6.26	2.61	.035	46.76
Repair to steering, front end, cooling systems, and air conditioners	49023	19.5	4.6	10.18	1.26	.154	46.98

TABLE A1
(*Continued*)

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Community antenna or cable television	27031	19.6	4.6	1.91	.20	.784	48.12
Bicycles	60013	19.6	4.6	6.94	1.10	.047	48.19
Automotive body work	49011	19.7	4.6	10.11	1.45	.098	48.33
Window coverings	32012	19.9	4.5	2.13	.71	.038	48.39
Other condiments (excluding olives, pickles, relishes)	18044	20.1	4.5	.95	.51	.054	48.46
Rolls, biscuits, muffins (excluding frozen)	2022	20.1	4.5	2.48	1.35	.135	48.66
Intercity bus fare	53021	20.3	4.4	1.31	.09	.051	48.73
China and other dinnerware	32032	20.4	4.4	5.19	2.34	.042	48.79
Outboard motors and powered sports vehicles	60011	20.5	4.3	6.98	.96	.176	49.05
Sweet rolls, coffee cake, and doughnuts (excluding frozen)	2063	20.6	4.3	4.06	2.68	.073	49.16
Canned ham	4032	20.7	4.3	3.45	2.06	.007	49.17
Bedroom furniture other than mattress and springs	29012	20.8	4.3	4.35	2.30	.193	49.45
Occasional furniture	29044	20.9	4.3	4.92	3.25	.125	49.63
Beer, ale, and other alcoholic malt	20011	20.9	4.3	1.03	.36	.308	50.07
Baby food	18062	20.9	4.3	1.03	.33	.088	50.20
Cakes and cupcakes (excluding frozen)	2041	21.0	4.3	3.49	2.12	.119	50.37
Nondairy cream substitutes	16013	21.0	4.2	1.11	.57	.024	50.41
Tea	17052	21.0	4.2	1.09	.53	.057	50.49
Automotive power plant repair	49041	21.1	4.2	10.09	1.75	.404	51.08
Other noncarbonated drinks	17053	21.1	4.2	2.21	.88	.069	51.18
Lumber, paneling, wall and ceiling tile, awnings, glass	24013	21.6	4.1	1.68	.67	.006	51.19
Nuts	18032	21.6	4.1	2.28	1.23	.062	51.28
Cigarettes	63011	21.6	4.1	.35	.22	.801	52.44
Mattress and springs	29011	21.9	4.1	5.44	2.36	.146	52.65
Smoking accessories	63013	21.9	4.0	3.83	.00	.004	52.66
Women's underwear	38042	22.1	4.0	3.28	.77	.108	52.81
Men's footwear	40011	22.2	4.0	4.84	.79	.348	53.32
Other sweets (excluding candy and gum)	15012	22.5	3.9	1.95	1.16	.075	53.43
Admission to sporting events	62032	22.6	3.9	4.80	3.64	.155	53.65
Bathroom linens	28011	22.6	3.9	3.40	1.10	.055	53.73
Serving pieces other than silver or glass	32036	22.9	3.9	5.30	3.98	.005	53.74
Sugar and artificial sweeteners	15021	22.9	3.8	1.30	.70	.073	53.84
Girls' hosiery and accessories	39017	23.0	3.8	7.01	2.17	.030	53.89
Lawn and garden equipment	32041	23.1	3.8	5.92	1.02	.131	54.08
Video game hardware, software, and accessories	31023	23.4	3.8	10.15	5.65	.051	54.15
Jewelry	43021	23.4	3.7	4.86	1.76	.401	54.73
Curtains and drapes	28014	24.0	3.6	3.25	1.08	.057	54.81
Kitchen and dining room furniture	29041	24.1	3.6	5.47	3.40	.163	55.05

TABLE A1
(*Continued*)

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Cleansing and toilet tissue, paper towels, napkins	33031	24.2	3.6	3.37	2.25	.208	55.35
Girls' footwear	40022	24.2	3.6	7.43	1.27	.119	55.52
Sofas	29021	24.2	3.6	6.73	3.50	.277	55.93
New motorcycles	45031	24.3	3.6	9.30	1.31	.082	56.04
Instant and freeze-dried coffee	17032	24.3	3.6	1.17	.67	.056	56.13
Girls' underwear and night wear	39016	24.4	3.6	6.80	1.77	.026	56.16
Other processed vegetables	14023	24.6	3.5	2.04	.40	.113	56.33
Other fuels	25023	24.8	3.5	.71	.29	.014	56.35
Canned and dried fruits	13031	24.9	3.5	2.10	.68	.068	56.45
Noncarbonated fruit-flavored drinks	17051	25.0	3.5	2.20	.92	.088	56.58
Other fats and oils	16012	25.3	3.4	1.16	.46	.172	56.83
Outdoor equipment	32015	25.3	3.4	8.33	6.19	.014	56.85
Macaroni and cornmeal	1032	25.5	3.4	1.22	.65	.094	56.98
Cereal	1021	25.5	3.4	1.69	.87	.333	57.47
Radio, phonographs, and tape recorders/players	31031	25.5	3.4	7.80	4.96	.030	57.51
Pies, tarts, turnovers (excluding frozen)	2065	25.6	3.4	5.47	2.05	.044	57.57
White bread	2011	25.7	3.4	1.48	.83	.124	57.75
Truck rental	52052	25.7	3.4	1.60	.25	.287	58.17
Canned beans other than lima beans	14021	25.8	3.3	1.79	.37	.037	58.22
Boys' suits, sport coats, and pants	37016	25.9	3.3	4.82	1.22	.119	58.40
Men's suits	36011	26.0	3.3	3.27	1.03	.126	58.58
Canned and packaged soup	18011	26.3	3.3	1.48	.69	.108	58.73
Lamb, organ meats, and game	5014	26.4	3.3	1.88	.82	.044	58.80
Men's pants and shorts	36051	26.4	3.3	3.39	.84	.242	59.15
Women's accessories	38044	26.4	3.3	11.10	2.02	.057	59.23
Rice	1031	26.5	3.2	1.10	.58	.073	59.34
Canned or packaged salads and desserts	18061	26.6	3.2	2.12	1.05	.079	59.45
Living room chairs	29031	26.7	3.2	7.05	3.17	.136	59.65
Infants' and toddlers' sleepwear	41014	26.9	3.2	7.37	1.42	.014	59.67
Other dairy products	10012	26.9	3.2	1.48	.58	.077	59.78
Bedroom linens	28012	27.0	3.2	5.02	1.60	.170	60.03
Prepared flour mixes	1012	27.1	3.2	2.14	.85	.043	60.09
Other frozen fruits and fruit juices	13012	27.1	3.2	1.28	.55	.025	60.13
Canned fish or seafood	7011	27.4	3.1	1.80	.75	.058	60.21
Sauces and gravies	18043	27.6	3.1	1.01	.55	.134	60.41
Margarine	16011	27.9	3.1	1.48	.39	.043	60.47
Bologna, liverwurst, salami	5012	28.0	3.0	2.02	1.22	.085	60.59
Ship fares	53023	28.0	3.0	4.78	1.10	.101	60.74
Women's footwear	40031	28.0	3.0	6.80	1.62	.424	61.35
Other canned or packaged foods	18063	28.1	3.0	1.80	.76	.223	61.68
Olives, pickles, relishes	18042	28.1	3.0	1.50	.71	.035	61.73
Dryers	30022	28.5	3.0	5.43	.21	.042	61.79
Automobile finance charges	51011	28.6	3.0	1.84	.04	.493	62.50

TABLE A1
(*Continued*)

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Lunch meats	5013	28.7	3.0	2.79	1.08	.150	62.72
Microwave ovens	30032	29.0	2.9	8.16	1.39	.030	62.77
Potato chips and other snacks	18031	29.1	2.9	2.62	1.57	.212	63.07
Boys' footwear	40021	29.7	2.8	9.51	1.26	.094	63.21
Bread other than white	2021	29.7	2.8	2.07	1.27	.137	63.41
Outdoor furniture	29043	29.8	2.8	9.88	4.63	.040	63.47
Window air conditioners	30034	29.9	2.8	7.22	2.00	.039	63.52
Men's sport coats and tailored jackets	36012	30.1	2.8	4.47	1.39	.030	63.57
Frozen bakery products	2064	30.3	2.8	2.68	1.22	.076	63.68
Tires	48011	30.5	2.7	2.72	.58	.290	64.10
Men's coats and jackets	36013	30.9	2.7	8.28	2.51	.116	64.27
Frozen vegetables	14011	31.0	2.7	1.95	.79	.099	64.41
Peanut butter	16014	31.0	2.7	1.10	.48	.040	64.47
Televisions	31011	31.0	2.7	9.03	3.61	.269	64.86
Floor covering equipment and sewing machines	32051	31.1	2.7	7.45	1.56	.060	64.94
Videocassette recorders, disc players, cameras	31021	31.2	2.7	10.70	4.09	.095	65.08
Portable dishwashers	30033	31.2	2.7	3.65	2.50	.002	65.08
Ice cream and related products	10041	31.4	2.7	1.96	.96	.178	65.34
Bread and cracker products	2062	31.5	2.6	1.99	1.99	.014	65.36
Women's pants and shorts	38033	31.5	2.6	7.71	2.44	.345	65.86
Other fresh milk and cream	9021	31.6	2.6	1.08	.22	.222	66.19
Flour	1011	31.7	2.6	.75	.38	.029	66.23
Bottled or tank gas	25021	31.7	2.6	.69	.38	.055	66.31
Canned cut corn	14022	31.9	2.6	.91	.29	.023	66.34
Luggage	42013	31.9	2.6	6.21	2.62	.034	66.39
Carbonated drinks other than cola	17012	32.4	2.6	1.99	.91	.146	66.60
Motor oil	47021	32.7	2.5	1.00	.33	.045	66.67
Men's shirts	36041	32.7	2.5	6.20	1.55	.270	67.06
Cheese	10021	32.9	2.5	1.82	.85	.307	67.50
Stoves and ovens excluding microwave ovens	30031	33.0	2.5	7.45	1.09	.037	67.56
Girls' skirts and pants	39014	33.2	2.5	10.10	3.28	.076	67.67
Refrigerators and home freezers	30011	33.5	2.5	7.14	.85	.106	67.82
Cookies	2042	33.7	2.4	2.27	1.51	.157	68.05
Fresh, canned, or bottled fruit juices	13013	33.7	2.4	2.28	1.03	.210	68.35
Playground equipment	61012	33.8	2.4	12.07	8.25	.007	68.36
Components and other sound equipment	31032	34.1	2.4	9.25	5.42	.132	68.56
Frozen orange juice	13011	34.4	2.4	.95	.43	.030	68.60
Fresh whole milk	9011	34.4	2.4	.79	.12	.201	68.89
Washers	30021	35.4	2.3	6.80	.65	.057	68.97
Other poultry	6031	36.0	2.2	5.38	.96	.129	69.16
Frankfurters	5011	36.1	2.2	2.22	.92	.077	69.27
Boys' shirts	37013	36.2	2.2	10.17	3.24	.063	69.36
Infants' and toddlers' play and dress wear	41012	36.3	2.2	14.68	4.60	.049	69.43
Other beef	3043	36.4	2.2	.94	.75	.053	69.51

TABLE A1
(*Continued*)

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Frozen prepared foods other than meals	18022	36.5	2.2	2.24	1.15	.158	69.74
Shellfish (excluding canned)	7021	37.0	2.2	2.39	1.22	.124	69.92
Roasted coffee	17031	37.1	2.2	1.36	.68	.103	70.07
Frozen prepared meals	18021	37.4	2.1	3.53	1.72	.072	70.17
New trucks	45021	37.7	2.1	10.80	9.04	1.953	73.01
Men's active sportswear	36035	37.8	2.1	10.80	2.14	.061	73.10
Pork sausage	4042	37.9	2.1	1.40	.63	.077	73.21
Lodging while out of town	21021	38.1	2.1	1.80	.52	1.571	75.49
Personal computers and peripheral equipment	69011	38.4	2.1	16.12	7.79	.488	76.19
Infants' and toddlers' outerwear	41011	38.6	2.1	19.32	7.70	.011	76.21
Cola drinks	17011	38.8	2.0	.91	.42	.306	76.66
New cars	45011	39.1	2.0	10.26	8.11	2.747	80.64
Women's coats and jackets	38011	39.2	2.0	14.86	6.93	.155	80.87
Fresh whole chicken	6011	39.4	2.0	2.12	.14	.088	80.99
Women's night wear	38041	40.6	1.9	15.50	3.04	.088	81.12
Fresh or frozen chicken parts	6021	40.7	1.9	1.39	.38	.273	81.52
Apples	11011	41.4	1.9	.18	.04	.102	81.67
Other roasts (excluding chuck and round)	3041	42.2	1.8	.93	.75	.050	81.74
Fish (excluding canned)	7022	42.4	1.8	2.55	1.42	.167	81.98
Crackers	2061	42.5	1.8	1.53	.91	.075	82.09
Girls' tops	39013	42.7	1.8	17.00	5.47	.070	82.19
Women's skirts	38032	42.9	1.8	16.69	7.81	.071	82.30
Bananas	11021	43.0	1.8	.07	.03	.106	82.45
Electricity	26011	43.4	1.8	.64	.08	2.884	86.63
Bacon	4011	43.5	1.7	1.51	.74	.071	86.74
Girls' active sportswear	39015	43.6	1.7	18.93	5.51	.033	86.78
Girls' coats and jackets	39011	43.8	1.7	19.43	6.02	.023	86.82
Women's active sportswear	38034	44.6	1.7	17.26	3.43	.092	86.95
Women's tops	38031	45.0	1.7	17.94	6.93	.471	87.63
Men's sweaters	36034	45.3	1.7	13.53	4.85	.046	87.70
Butter	10011	45.5	1.6	.90	.24	.042	87.76
Boys' coats and jackets	37011	45.7	1.6	15.27	5.81	.024	87.80
Ground beef	3011	46.1	1.6	.67	.32	.288	88.21
Boys' active sportswear	37017	46.6	1.6	19.12	3.96	.027	88.25
Pork roast, picnics, other pork	4041	46.8	1.6	1.44	.75	.131	88.44
Other steak (excluding round and sirloin)	3042	46.8	1.6	.72	.53	.156	88.67
Diesel	47017	47.2	1.6	.70	.03	.254	89.04
Potatoes	12011	47.3	1.6	.41	.13	.098	89.18
Women's suits	38051	47.3	1.6	19.45	8.45	.123	89.36
Pork chops	4021	47.9	1.5	.35	.19	.138	89.56
Round steak	3051	48.2	1.5	.62	.46	.060	89.65
Sirloin steak	3061	48.4	1.5	.65	.48	.084	89.77
Boys' sweaters	37012	48.4	1.5	17.18	5.47	.007	89.78
Women's dresses	38021	48.5	1.5	25.44	11.08	.296	90.21
Ham (excluding canned)	4031	50.4	1.4	4.00	2.03	.118	90.38
Fuel oil	25011	52.5	1.3	.40	.18	.169	90.63
Other fresh vegetables	12041	52.8	1.3	.17	.07	.250	90.99
Round roast	3031	53.1	1.3	.48	.40	.045	91.05

TABLE A1
(*Continued*)

Category Name	ELI	Freq	Months	Subs	NSub	Weight	CDF
Chuck roast	3021	54.3	1.3	.76	.65	.043	91.12
Oranges	11031	54.7	1.3	.45	.11	.057	91.20
Girls' dresses and suits	39012	55.1	1.2	28.49	12.80	.045	91.26
Automobile rental	52051	56.8	1.2	2.86	.40	.758	92.36
Other fresh fruits	11041	59.7	1.1	.24	.08	.247	92.72
Other motor fuel	47018	61.8	1.0	4.46	1.80	.032	92.77
Eggs	8011	61.8	1.0	.64	.26	.107	92.92
Lettuce	12021	62.4	1.0	.06	.05	.064	93.02
Utility natural gas service	26021	64.2	1.0	.34	.08	1.012	94.48
Airline fares	53011	69.1	.9	.45	.25	.829	95.69
Tomatoes	12031	71.0	.8	.22	.03	.078	95.80
Premium unleaded gasoline	47016	76.2	.7	2.81	.89	.998	97.25
Mid-grade unleaded gasoline	47015	77.5	.7	2.55	.82	.865	98.50
Regular unleaded gasoline	47014	78.9	.6	2.56	.83	1.031	100.00

SOURCE.—U.S. Department of Labor.

NOTE.—ELI is the entry-level item in the CPI (around four to five items priced each month in each geographic area). Freq is the estimated average monthly frequency of price changes over 1995–97 (λ in the text). Months is the mean duration between price changes implied by λ ($=-1/\ln[1-\lambda]$). Subs is the average item substitution rate in the ELI over 1995–97. NSub is the average noncomparable item substitution rate in the ELI over 1995–97. Weight is the share of the ELI in the 1995 CEX (these sum to 68.9). CDF is the cumulative distribution function of frequency within the share of CPI covered.

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