Do Higher Prices for New Goods Reflect Quality Growth or Inflation?

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Abstract

Much of CPI inflation for consumer durables reflects shifts to newer product models that display higher prices, not price increases for a given set of goods. I examine how these higher prices for new models should be divided between quality growth and price inflation based on: (a) whether consumer purchases shift toward or away from the new models, and (b) whether new-model price increases generate higher relative prices that persist through the model cycle. I conclude that two-thirds of the price increases with new models should be treated as quality growth. This implies that CPI inflation for durables has been overstated by almost 2 percentage points per year, with quality growth understated by the same magnitude.

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Much of economic growth occurs through growth in quality as new models of consumer goods replace older, sometimes inferior, models. Moulton and Moses (1997) estimate that Bureau of Labor Statistics (BLS) methods allowed for perhaps as much as 1 percent average quality growth in goods in 1995. It is often argued, however, that the Bureau of Labor Statistics (BLS) methods miss much of the growth in goods' quality.[1] I employ the *CPI Commodities and Services Survey*, the micro data underlying the CPI, to show that introduction of new models of durable goods generates large increases in unit prices. How these price increases are attributed to quality growth versus CPI inflation dramatically affects measured price inflation for durables. I present evidence that these price increases should largely be treated as quality growth. I conclude that price inflation for durables has been overstated by nearly 2 percentage points per year. Because most consumption deflators for the National Income and Product Accounts are based on BLS's measures of CPI inflation, any measurement error in CPI inflation will lead to an opposite error in rates of real growth in consumption and productivity. Thus my findings imply that measured consumption and productivity growth for consumer durables has been understated by almost 2 percentage points per year.[2]

In the next section I show that from January 1988 to December 2006 unit prices for consumer durables, excluding computers, increased at an annual rate of 2.5 percent. For the most part, the prices collected by the BLS can be compared to the price of the same item priced in a previous month at the same outlet. But for durables these matched items display a very different rate of price change than the overall rate of 2.5 percent, averaging deflation of 3.7 percent per year. The difference of over 6 percent between unit price inflation of 2.5 percent and this matched-rate of -3.7 percent reflects changes in the models being priced. At scheduled rotations the BLS draws a new sample of goods (and outlets) to better reflect current spending. In addition, an outlet may stop selling the priced item, forcing the BLS agent to substitute another model. Both the scheduled rotations and forced substitutions create shifts to models that are typically newer to the market and higher priced. For durables I find that scheduled rotations generate increases of a little over 2 percent annually in unit prices, while forced substitutions, occurring

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[1] Hausman, 2003, and Pakes, 2003, are two prominent examples. Shapiro and Wilcox, 1996, review much of the previous evidence. The Boskin Commission Report (1996) suggests that the BLS overstates inflation by perhaps one percent per year. Unmeasured growth in quality of goods is put forth as the most important component contributing an overstatement of inflation of 0.6 percent per year, including 1.0 percent for durables. But these estimates are based on examining a fairly limited set of goods and allowing no for bias for a number of goods.

[2] For example, multifactor productivity growth for motor vehicles and other transportation equipment (SIC 37) is estimated by the BLS to be only about one-half percent per year for my sample period. My estimates below suggest that productivity growth for vehicles has been understated by many times this.

much more frequently, generate increases of nearly 4 percent annually. The most important contributor to price increases with forced substitutions for durables, weighting by goods' expenditure shares, is the model year turnover for vehicles. These shifts in price quotes from last-year's models to newer models generate price increases averaging more than 5 percent per year.

How to allocate the price increases that accompany model changes between quality growth and inflation is an open question. In any month a large majority of collected quotes do follow prices of the same model. Because quality is fixed for these matched items, their rate of price increase provides one natural quality-adjusted measure of price inflation. From just above, this rate has averaged -3.7 percent since 1988. So adopting this as a measure of price inflation implies that durables, even excluding computers, have exhibit a dramatic rate of quality growth of just over 6 percent per year (equal to the excess of unit price inflation over this -3.7 percent rate for price inflation). Pakes (2003) suggests that even this is likely to understate quality growth because goods that exit the market are obsolete and, absent the substitution, were likely to experience a relative fall in price. By contrast, Triplett (1997), among others has argued that sellers use periods of model turnovers to increase price more than justified by quality improvements. In principle, hedonic pricing equations as developed by Adelman and Griliches (1961) and Griliches (1961) might be used to split goods' rates of unit-price inflation between quality growth and true declines in purchasing power. But in practice the exacting detail on product characteristics this requires is typically not collected.[3]

The BLS treats price increases at forced substitutions very differently than those at scheduled rotations, even though they reflect the same economic phenomenon--newer versions of goods sell at higher prices. The higher prices across scheduled rotations are not incorporated in measured inflation; so the price increases are implicitly treated as quality growth. By contrast, price increases accompanying forced substitutions, which are nearly twice as important, are largely attributed to CPI inflation, not quality growth. I calculate that BLS methods attributed less than one-fifth of the price increases from forced substitutions, only 0.7 percentage points per year, to quality growth, with 3.1 percentage points

[3]Hausman (2003) discusses practical limitations of hedonics given that the analyst typically possesses a quite small number of relevant characteristics. He notes that the shadow prices of characteristics are notoriously unstable and sometimes even appear perverse in sign. For instance, hedonic equations for automobiles can exhibit a negative coefficient for fuel efficiency, presumably reflected a negative correlation between fuel efficiency and unmeasured quality. The use of hedonic price equations by the BLS in constructing the CPI has been fairly limited. Computer equipment is one good where data on several relevant characteristics is collected (e.g., RAM, processor speed) and hedonic prices play an important role. But even here, hedonics are only employed at substitutions if it is possible to match brand and all but a small number of characteristics to the base-period product.

attributed to inflation. So if, supposing counterfactually, the BLS had measured inflation based only on price changes for models available in consecutive periods, this would have reduced CPI inflation for these goods by 3.1 percentage points per year, yielding higher measured quality growth of the same 3.1 percentage points.

This BLS treatment of price changes at forced substitutions implies that goods with model changes increase prices dramatically, net of quality growth, relative to those not changing models. If consumer's demands across competing goods do not shift systematically toward those exhibiting model changes, then these price increases, net of quality change, should cause the goods with model changes to lose market share. I test this prediction in Section 3. Using *Ward's Automotive* data for vehicles and scanner data for consumer electronics, I examine growth in market shares for goods with versus without model substitutions. These goods generate more 80 percent of the price increases from model substitutions for durables excluding computers. For all goods I find that market share increases with model turnover. The finding that goods with new models increase market share suggests that on average the price increases with model changes, and possibly more, should be attributed to increased quality, corresponding to quality growth for durables of 6 percent per year, 3 percentage points greater than measured by BLS methods.

Interpreting increased market share for new goods as a relative price decline assumes that relative demands are stable across model substitutions. If the demand for the new cars or other durables reflects a fashion-like component, with the good valued for its time on the market separate from other qualities, then a new model could exhibit increases in both relative price and market share even if not improved. Similarly, intertemporal price discrimination across buyers could generate price declines over a durable's model cycle that are reversed with the next model cycle. I test for the importance of these model-cycle demands in Section 4 by observing whether the size of price increases for new models persists across the model cycle. I find that, for the most part, price changes at model substitutions do persist in explaining the value of the good throughout its model cycle. There is some important regression back, however, especially for price increases that the BLS labels price inflation, not quality change. Allowing for these factors, I calculate that about a third of the price changes with model substitutions might reflect transitory demand increases with the model cycle, with two-thirds persistently valued as quality. Nevertheless, this leads to the conclusion that average quality growth for durables has been understated by nearly two percentage points per year.

2. *New-Model Price Changes*

To calculate the CPI the BLS tracks the prices of about 90,000 non-housing goods and services each month.[4] These prices are contained in the CPI Commodities and Services Survey, which is the primary data employed in the empirical work to follow. The goods followed change for two principal reasons. At scheduled rotations, roughly every four years, the BLS draws a new sample of stores and products within a geographic area to better reflect current spending.[5] In addition, a store may stop selling the particular product being priced. The BLS agent then substitutes another model of that brand or a similar product. These (forced) substitutions occur about every three to four years for all non-housing CPI items. They occur much more frequently, nearly once per year, for consumer durables. I first show that the price changes associated with new models, both those from scheduled rotations and forced substitutions, contribute greatly to goods' rates of increase in unit prices. For this reason, how these unit-price changes are divided between quality growth and price inflation has a dramatic impact on overall measured growth. The balance of the section discusses how BLS methods have divided these price changes between quality change and price inflation. I compare this division to the alternative of measuring price inflation based purely on price changes for goods that experience no model change.

Unit-price inflation can be broken into contributions from price changes at scheduled rotations plus that from following a particular price quote within a rotation. In turn, the latter component reflects the rate of inflation for continuously-followed (matched) models plus the systematically higher unit-price increases at forced substitutions because of model changes.

(1) $$\pi_{unit-price} = \pi_{rotations} + \pi_{within-rotations} = \pi_{rotations} + \pi_{matched} + s(\pi_{changes} - \pi_{matched}) .$$

[4] Prices are collected from about 22,000 outlets in 87 Primary Sampling Units across 45 geographic areas. About half of goods are priced monthly, with the others priced bimonthly. The BLS chooses outlets probabilistically based on household point-of-purchase surveys, and choose items within outlets based on estimates of their relative sales. The BLS sampling methods are described in detail in Armknecht, et al. (1997) and the BLS Handbook of Methods (1997).

[5] These rotations occurred every 5 years historically, including much of my sample period. The BLS has moved to even more frequent sample rotations for consumer electronics.

$\pi_{rotations}$ reflects both the share of quotes experiencing rotations as well as the percentage increase in price between the old and new quotes. I express the extra unit-price inflation associated with forced model changes as the share of quotes with forced model substitutions (*s*) multiplied by the excess inflation rate at these substitutions ($\pi_{changes} - \pi_{matched}$). Implicit are subscripts denoting a particular category of good and time period.

I examine the importance of each of these components for 50 separate categories of consumer durables using information from the *CPI Commodities and Services Survey* for January 1988 through December 2006. The 50 categories of consumer durables are listed in Table 1. I focus on durables because forced substitutions are much higher for durables and because I am able to examine data on quantities for vehicles and a number of other durables. Goods with a strong seasonal fashion cycle exhibit large price reductions as the seasons change. I exclude apparel and other goods with important seasonal or fashion cycles, such as motor boats or entertainment CD's, to limit the importance of these fashion changes. I also exclude used vehicles.[6] I observe a total of 987,086 price changes within sample rotations for the 50 durables. 95 percent reflect changes over one or two months--the average duration is 1.7 months. 90.7 percent of price quotes follow the same model version, whereas 9.3 percent are forced substitutions. For the remainder of the paper I present weighted statistics. In each year a category is weighted by its expenditure share as measured from the Consumer Expenditure Surveys.[7] The second

[6] The BLS does not collect price information on used vehicles. Price information in the CPI for used cars and trucks comes from the N.A.D.A. Official Used Car Guide. These prices are adjusted for estimated depreciation. As prices are not collected at outlets, there are no forced substitutions. The sample is updated by one model year each fall to maintain the same ages of vehicles over time. These updates create increases in unit prices. The quality adjustments made for used vehicles reflect the same rates of quality adjustments that were made for those vehicles by the BLS when the vehicles were priced as new models. So to the extent this paper concludes that the BLS understates quality growth for new vehicles, that result can be translated precisely one-to-one to used car prices. The expenditure share for used vehicles is about thirty percent that of new vehicles. The results combining all durables would suggest modestly more growth if this additional weight is given to vehicles. In particular, the conclusion in Section 4 that quality has increased by 2.5 percent year would increase to 2.7 percent.

[7] Expenditure shares by category were obtained from the BLS for each year for 1988 to 1995 and for 1999 to 2004. The CPI reflects weights that are only periodically updated. For instance, in 2002 the CPI weights began reflecting expenditures by category from the 1999-2000 period, replacing weights that reflected expenditures during 1993-95. (Since 2002 the BLS has updated more frequently.) Related to this, and to a revision in expenditure categories that occurred between 1997 and 1998, it was not possible to obtain disaggregate expenditure shares for 1996 to 1998 or after 2004. I employ the 1995 relative shares for 1996 and 1997, 1999 shares for 1998, and 2004 shares for 2005 and 2006. I also examined results employing fixed weights by category, based on 1995 expenditure shares. For the most part, results are very similar to those reported here. With fixed weights scheduled rotations are associated with less unit-price inflation for electronics and computers.

In constructing mean inflation rates at the category and year level, I weight the price quote's inflation rate by the duration it covers (usually one or two months). I exclude price changes that are measured, due say to repeated stock outs, over a period of more than 6 months. The BLS selects outlets proportionally to their importance column of Table 1 provides the average annual spending share for each category for 1988 to 2006. The combined share for the 50 goods is 10.3 percent of the CPI, with vehicles making up about half of this. Weighting increases the share of forced substitutions to 12.5 percent.

The top panel of Table 2 breaks down unit-price changes according to equation (1). I calculate the overall rate of increase in unit prices as follows. I first construct the average price (in logs) for each year for each category of good, then calculate its annual rate of growth. For each year, I then construct an average growth rate by weighting each category's rate by its expenditure share for that year. The overall average is then given by averaging these annual averages over the 19 years of data. Looking at Column A, unit prices for durables (excluding computers) increased at a rate of 2.5 percent per year for January 1988 to December 2006. BLS treatment of price changes associated with model changes for computers markedly differs from other durables. The statistics to follow are for the 49 durables excluding computer equipment, with results for computers presented separately.

This 2.5 percent unit-price inflation can be broken into contributions from price changes across scheduled rotations and the rate of growth in unit prices within a rotation sample (Table 2, rows 2 and 3). The rate of price increases within sample rotations is first calculated separately by category and year then aggregated based on expenditures shares. The average annual rate of price increase within rotations equals 0.2 percent. This implies that almost all of the average growth rate in unit prices for the 49 durables, 2.3 percentage points per year, reflected price increases across sample rotations. But the small average rate of price inflation of 0.2 percent within rotations hides big differences across price quotes without and with forced substitutions (rows 4 and 5). Absent model substitutions, the average price change was quite negative, translating into an inflation rate averaging -3.7 percent per year. By contrast, across forced substitutions unit prices increase on average by 4.2 percent. Although these forced substitutions constituted only 12 percent of the price quotes, their price increases relative to inflation for matched models added 3.8 percent annually to inflation in unit-prices.

The price increases with new models contribute price increases of 6.1 percent per year, 2.3 percent from sample rotations and 3.8 percent from forced substitutions. How these price increases are divided between price inflation and quality change dramatically affects measured growth for durables.

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in a somewhat wider product category than an ELI, for instance, based on men's clothing, not the specific ELI men's shirts. In constructing ELI-level statistics I weight by the percentage of sales within the broader category at the outlet corresponding to that ELI. The BLS refers to this as the percent of pops category.

How do BLS methods treat the components of price changes? Price inflation for the goods without model changes, -3.7 percent, is obviously treated as part of CPI inflation. The price increases associated with sample rotations, 2.3 percent per year, are implicitly treated as quality growth. For time *t* prices are collected for both the outgoing and incoming samples. The rate of inflation for *t-1* to *t* is based on price changes for the outgoing sample; the rate for *t* to *t+1* is based on price changes for the incoming sample. As there is no direct comparison of prices across the two samples, price increases from sample rotations have no impact on measured inflation. By contrast, for many forced substitutions the BLS does compare prices across the old and new versions.

The BLS treats forced substitution by several methods. These are described in detail by Armknecht and Weyback (1989). Appendix Table A1 shows the prevalence of each procedure and associated price increases. For more than a third of substitutions the new models were judged strictly comparable to the former ones, with quality growth set to zero. These substitutions had new-model prices that were 2.7 percent higher on average, with this entirely allocated to CPI inflation. The other common method for durables, also employed in over a third of substitutions, is to make a quality adjustment based on certain characteristics of the old and new models. New models averaged 4.5 percent higher prices for these substitutions. Despite the quality adjustments, by my calculations only one ninth of this 4.5 percent was attributed to quality growth, with most attributed to inflation. One sixth were treated with less direct quality adjustments; these exhibited 7.4 percent higher prices after substitution, with only one third of this allocated to quality growth. Finally, for 10 percent of forced substitutions the BLS omitted the price change in calculating CPI inflation. This parallels the treatment of prices changes with sample rotations, with these quotes implicitly assigned the CPI inflation for other quotes in that category. These averaged price increases of 2.3 percent, with all of this attributed to quality growth.

Putting these together I calculate that, of the price increases of 3.8 percent per year from forced substitutions, BLS methods attributed only 0.7 percentage points, to quality growth, with the balance attributed to CPI inflation. Measured quality growth depends critically on this treatment as illustrated in the second panel of Table 2. BLS methods result in measured quality growth of 2.9 percent per year. But much of this reflects the price increases of 2.3 percent per year from sample rotations. The quality growth attributed by the BLS to the newer goods introduced with forced substitutions contributes less than one-fourth of the 2.9 percent. By contrast, suppose price inflation was based solely on the rate of price changes for goods without model changes. This treatment has intuitive appeal. When products are replaced, it treats the increased price for the newer model, relative to increases for matched models, as a measure of quality change. With this measure of inflation, quality growth would have averaged 3.2 percentage points higher, at 6.1 percent per year. Growth at 2.9 percent per year implies quality of durables increased by a factor of 70 percent over the 19 year period, January 1988 to December 2006. But, if growth was at 6.1 percent per year, the growth factor over the 19 years exceeds 200 percent.

Based on the analysis of market shares to follow, I separate out two sets of durables: (i) vehicles, and (ii) consumer electronics (video, audio, and telephone equipment). This is done in Columns B and C of Table 2. Both vehicles and consumer electronics display frequent forced substitutions, each with rates of 15 percent compared to 7 percent for the balance of the 49 durables. Forced substitutions generated unit-price increases of 5.2 percent per year for vehicles; BLS methods attributed only a small part, 0.7 percentage points per year, to quality growth.[8] Forced substitutions generated 6.0 percent annual increases in unit-prices for consumer electronics; I calculate that BLS methods attributed just over half of this, 3.2 percentage points, to quality growth. If we consider measuring price inflation based on the inflation rate for goods without model changes, the implied rates of quality growth would be higher by 4.5 percentage points per year for vehicles and by 2.8 percentage points for electronics.

These calculations omit computer equipment. The last column of Table 2 presents results for computers. The substitution rate for computing equipment is 31 percent. The matched-model rate of inflation is very negative, -20 percent per year. But prices jump up greatly with substitutions, adding nearly 17 percent to annual growth in unit prices, so that unit prices decline within rotations by only 3 percent per year. Unlike other durables, price increases with substitutions do not translate into CPI inflation. For computers the BLS often uses hedonic adjustments or omits price changes across model changes. My calculations show that BLS methods imputed about 18 percent annual quality growth from substitutions for computing equipment, slightly more than the associated price increases of 17 percent. So the measured rate of quality growth would actually have been lower by 1 percent if the BLS had based CPI inflation just on matched-model price changes. Although computing equipment is a small share of

[8] Table 2 reports a matched rate of inflation of -3.8 percent per year for vehicles. Based on data from J.D. Power and Associates for model years 1999 to 2003, Corrado, Dunn, and Otoo (2006) report a rate of price change for vehicles within the model year of about -6 percent. Most of this difference reflects sample period--for years 1999 to 2003 I find a matched-model rate of -5.6 percent. The small remaining difference may largely reflect that the J.D. Power data, unlike the CPI data, do not control for changes in how the vehicle is equipped with options.

the CPI for these durables, their inclusion more than doubles quality growth from forced substitutions using BLS methods, from 0.7 to about 1.5 percent per year.

3. *Growth in Market Share with New Goods*

The price increases with new models caused unit prices for durables to increase by 6 percent per year relative to the rate of price change for matched models, that is, those without model changes. So if we measure price inflation simply by the rate of price increase for the matched models, we would infer that quality growth averaged 6 percent. As just discussed, BLS methods do not take this approach, instead attributing much of the price increases with forced substitutions to price inflation. As a result measured inflation is higher by 3 percentage points per year, with quality growth reduced by the same amount. Note that BLS methods imply that goods experiencing forced substitutions exhibit large price increases relative to the matched models. If we assume that goods' demands are decreasing in relative price, and relatively stable across substitutions, then this predicts that consumers will substitute away from goods with model changes. In this section I test this prediction for vehicles and consumer electronics. I find that consumer purchases move toward the models experiencing model changes, suggesting that the rate of price inflation for matched models does not understate inflation.

The goal is to measure inflation allowing for possible quality changes. Let ϵ be the rate of price inflation for a particular category of goods. (Indices for the goods category and time period are implicit.) ϵ is a weighted average of inflation rates for distinct product models within the category, $\epsilon = \sum_{i=1}^{N} s^i \epsilon^i$, where n indexes models, each weighted by s_n to reflect its expenditure share. Number the models so that the first M correspond to matched models, those without model substitutions; M+1 to N are those with substitutions. Let $\epsilon_{matched}$ equal the average inflation rate for matched models. Inflation can be expressed in terms of this inflation rate for matched models plus any differential inflation for models with substitutions.

(2) $$\epsilon = \epsilon_{matched} + \sum_{i=M+1}^{N} s^i (\epsilon^i - \epsilon_{matched}) \ .$$

Consider measuring inflation purely by matched models' price changes--would this understate inflation and overstate quality growth? The answer is no unless models with substitutions systematically display higher inflation.

To test for that scenario, I examine what happens to the market share, in physical units, for models with versus without model substitutions. The intuition is straightforward. If the inflation rate for goods with substitutions exceeds that for matched products, then we expect their market share to fall as some consumers will be driven toward the goods without model changes. Hausman (2003) argues that constructing a price index requires data on quantities, so that price changes accompanying quality changes can be based on a good's change in quantity demanded divided by its price elasticity of demand. The approach here is directly related, but more conservative in that it provides a bound, rather than an estimate, of quality growth.[9] But it has an important practical advantage in not requiring knowledge of goods' demand elasticities. Furthermore, despite only providing a bound, it suggests annual growth that is dramatically higher, by more than 3 percent per year, than based on BLS methods.

The key identifying assumption is that relative shifts in demands across competing models are orthogonal to the timing of model substitutions. Introducing a new model of a good presumably takes time to implement. This suggests that model substitutions are plausibly predetermined with respect to innovations to relative product demands for that month. Of greater concern is that demands shift systematically in response to the product cycle. The discussion here assumes that a good is valued based on its characteristics, separately from how long the product has existed on the market. If consumers place a value on consuming a new-to-the-market product, everything else equal, then this can violate the assumption that shifts in model demands be orthogonal to timing of product substitutions. As an example, consider novels. Persons may prefer to consume a novel shortly after its arrival on the market, perhaps because they wish to discuss the book with others currently reading it (or avoid hearing it discussed

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[9] In Bils (2004), I consider a discrete-choice model for purchasing a durable. There I explicitly tie an estimate of price inflation for goods with quality changes to the inflation rate for matched models and the change in market share for the goods with versus without substitutions. But, as in Hausman (2003), this hinges on knowing elasticities of substitution across durable models that are not readily estimated. There I follow the literature on discrete choice across differentiated models (e.g., Anderson, et al., 1992) in assuming that consumer demands are defined symmetrically over the competing models. In discrete choice models all competing models are gross substitutes. So, if we see consumers moving toward the models that change, then this implies that their relative price has decreased. Without symmetry across models, there is a caveat. Suppose there are three competing brand models--A, B, and C; but A competes only with B for consumers, and B only with C . Suppose C experiences a substitution. Then it would be possible to construct a scenario where market share rises for C, because its price fall relative to B; but its price does not fall relative to a weighted average of A and B. Given the findings to follow that, averaging over many products and over many months, goods with model substitution increase market share, this caveat should not seriously qualify the conclusions.

before they read it). New releases might sell more copies even if their prices are higher; but we would not want to infer from this that novels are getting better and better. I allow for this in two ways in the empirical work. First, I exclude goods, including all apparel, that is likely to have an important seasonal or fashion cycle. Secondly, I test for this fashion component by observing whether larger price increases with substitutions fail to persist across the product cycle. Such a saw tooth pattern in prices is predicted by the fashion story. These tests are described more fully in Section 4.

I first examine for automobiles, vans, pickup trucks, and SUV's how growth in market share responds to a spike in forced substitutions for that vehicle model. Secondly, I present market-share results based on sales scanner data for televisions, audio goods, and other consumer electronics. Together the vehicles and consumer electronic goods make up more than 50 percent of consumer spending on all the durables detailed in Table 1. Because substitution rates are skewed toward these goods, they constitute over 80 percent of extra price increases accompanying forced substitutions for durables, excluding computers, weighting by spending share.

Model substitutions and changes in market shares for automobiles and other vehicles

Data on monthly unit sales by car, van, and pickup model are compiled by Ward's Automotive for their *Automotive Yearbook*--I obtained this data for January 1988 to January 2005. Secondly, I construct a data table of substitution rates by vehicle model from the CPI data covering the same period.[10] Combining this table with the Ward's data provides a panel data set with 29,680 observations on forced substitution rates, price increases, and sales growth by vehicle model.[11]

[10] The BLS field agent records some descriptive information for an item when it is selected for pricing. I am able to identify the vehicle model for 98 percent of price quotes for automobiles and 96 percent of other vehicles. 89 percent of substitutions for cars, and 87 percent for other vehicles, are accompanied by a model-year change. Less than 1 percent of quotes result in a change in the vehicle model being priced. These are not reflected in the substitution rates in the regressions below. Only quotes in the CPI data covering one or two months are included. For quotes of two-month duration, I allocate inflation equally between the months. For two-month quotes with substitutions I allocate slightly over one half substitution to each month. The amount over one-half reflects the small probability of exhibiting substitutions in consecutive months, with this probability estimated from quotes that are monthly in duration.

[11] The Ward's data combines leased vehicles with regular sales. Leased vehicles are not incorporated into the *CPI Commodities and Services Survey* until 1998, and then only gradually. Also lease quotes are not readily separated between cars and other vehicles. Therefore, my analysis of substitution rates, here and in Section 2 is based on purchased vehicles. But model turnover dates for a specific model should be similar for vehicles leased versus purchased. Furthermore, estimates are very similar for the first and second halves of the sample strongly suggesting that vehicle leasing, which is much less important in the first half of the sample, is not driving the results.

Table 3 presents results on how a vehicle model's monthly rates of growth in prices and unit sales respond to its rate of forced substitutions. Results are presented separately for automobiles and other light vehicles. (Each observation is weighted by the number of BLS price quotes underlying that month's substitution rate for the vehicle model.) The regressions include time-period dummies; so the coefficients should be interpreted as the growth rate in the dependent variable for models that experienced a 100 percent rate of forced substitutions for that month relative to the growth rate for models experiencing no substitutions. (Aggregate variations in sales of cars or in sales of other vehicles are not a factor.) The first two rows show the impact of substitutions on unit-price inflation and unit-price inflation net of the BLS adjustment for quality growth. The findings are consistent with the results reported in Section 2. For cars substitutions are associated with 5.1 percent greater price increases with only about one-seventh of this captured as an increase in quality. For vans, pickups, and SUV's substitutions are associated with 4.5 percent greater price increases with only about one-tenth captured as increased quality.

The third row shows the impact on market share. For automobiles forced substitutions are associated with a considerable increase in market share of units sold of 14.2 percent (with standard error of 2.0 percent). I also examined results separately by five classes of vehicle, ranging from subcompact to luxury; the positive impact of substitutions on market share is quite consistent across classes. For vehicles other than cars the estimated impact of substitutions on the rate of growth in market share is positive, but very small and insignificant, equaling 1.2 percent (with standard error of 2.3 percent). I also estimated the impact of substitutions on growth in market share separately for vans, pickups, and SUV's, but results look similar across these categories.[12]

There is also no evidence that model changes that generate larger price increases lose market share. I estimated further specifications that interact the monthly relative price change for a vehicle model with its substitution rate for that month. For both automobiles and other vehicles a price increase, absent

[12] Nearly half of forced substitutions for vehicles occur in the two fall months of October and November. (Model changes have been less skewed to the autumn during the last twenty years than historically.) The timing of these forced substitutions might be viewed as more exogenous. If I allow a differential impact for these two months, the impact on market share of a substitution is more positive for October and November. For cars a fall substitution increases market share by 17.6 percent (standard error 3.1 percent); but substitutions in other months still have a large and statistically significant impact on market share of 11.9 percent (standard error 2.6 percent). For other vehicles the effect of a substitutions is statistically insignificant both for fall substitutions and for those outside of October and November. I also used this seasonality in substitutions to estimate by instrumental variables. I instrument for a model's rate of forced substitutions by its rate 11, 12, and 13 months prior. This actually yields a more positive impact of substitutions on market share; but standard errors for the estimates are much larger.

model change, predicts a significant decline in market share--a one percent relative price increase predicts a decline in share of 2.5 percent for automobiles and by 1.5 percent for other vehicles (both estimates with standard errors of 0.2 percent). By contrast, a greater price increase associated with model substitutions predicts increased market share, with this impact statistically significant for automobiles. For automobiles a one percent higher price increase at model change predicts greater growth in market share by 1.8 percent (standard error 0.5 percent), for other vehicles by 0.7 percent (standard error 0.6 percent).

Table 4 presents results for a more general specification that allows growth in a vehicle's market share to also depend on its recent market-share growth and substitution rates, captured by lagged values for the previous 4 months. The first column gives results for automobiles. The substitution rates as a group are statistically very significant, though the contemporaneous rate is easily the most important. The estimates imply a dynamic response to a substitution of an initial increase in market share by 14.2 percent, growing to 17.2 percent by the third month, and 20.3 percent in the sixth. The faster growth in market share accompanying a model substitution is not offset in the subsequent few months, as might be expected, say, if it reflected an advertising burst at the time of substitution. The second column gives results for vans, pickups, and SUV's. Here the results suggest perhaps a small increase in market share from substitutions, though much less in magnitude than for cars, with the biggest increase in the month after a substitution. The estimated response to a substitution is a very small decrease in market share in the first month, but an increase of 6.7 percent as of the third month, and 5.5 percent in the sixth. The substitution rates, as a group, have a p-value of .02.

These results suggest that price increases accompanying model substitutions should be treated as quality improvements as substitutions do not reduce market share. In fact, for cars they suggest that quality growth may more than rationalize the 5 percent impact on price at forced substitutions. One might argue that part of households' willingness to pay more for the next-year model reflects, akin to a fashion statement, a desire for the most-recent version on the market independent of vehicle features and quality. Several points suggest this is not the primary factor in the spending shift toward new models. The impact on market share is very consistent across class of cars--as strong for economy cars as for upscale ones, where fashion would presumably matter more. Secondly, market share continues growing, though slowly, for several months after a substitution. If the increase in market share reflects desire for the most-recent available car model, separate from quality, the impact on sales should be more concentrated at introduction. Finally, cars are a very durable good. So the benefit of having the most-recent model year is limited to a quite short period of the asset's life.[13] A related concern might be that the demand for a vehicle is depressed prior to a model change because dealers provide poorer selections. But growth in model sales is about the same as usual the month prior to substitutions. Related to this, estimating the regressions in Table 3 over a two-month window, rather than one, yields very similar results. In further response to these concerns, I examine in Section 4 whether the size of price change at model turnover persists over the entire model cycle. Relative price shifts that transcend the model cycle clearly do not just reflect timing within the model cycle.

Model changes and expenditures for video, audio, and telecommunications products

I examine monthly scanner data on prices and expenditures for video, audio, and other consumer electronics by product model for the two years March 2000 to February 2002. The data are collected by the company NPDTechworld.[14] I present results for 18 categories of goods. These categories are listed in Table 5, together with the number of observations and expenditure shares. Color televisions is the most important category, making up 39 percent of spending on these goods. The table also presents monthly entry and exit rates by good, i.e., what fraction of products appears for the first time and what fraction appears for the last time. These rates are quite high--the median is 4 percent. By comparison, the CPI data show forced substitutions, translated to a monthly rate, of almost 9 percent. It is not surprising that forced substitutions occur more frequently--a forced substitution is generated by a product no longer being carried at an outlet, whereas the exit rate for the scanner data is generated by the product dropping out of all outlets. The last column of Table 5 presents the average rate of inflation for each of the 18 categories based just on product models that can be matched across months (matched-model inflation). It shows quite rapid deflation; the median rate is close to that for televisions of -1.1 percent monthly. This is quite consistent, however, with the rate from the *CPI Commodities and Services* data of -11 percent per year, especially considering that inflation rates for years 2000 and 2001 were relatively low.

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[13] Similar to the effect of a fashion demand, a possible advantage separate from quality to the newer model year is that, if later sold used, it may be viewed as a slightly newer vehicle, assuming the used buyer does not know the car's exact age. But allowing for time-discounting and discounting for the price of used to new cars, I calculate that this can rationalize only a small part of the jump up in price with model changes.

[14] I was kindly provided access to this data as a visitor of the BLS under an IPA (Intergovernmental Personnel Act) agreement. The data are compiled at a variety of types of retailing outlets. For the most part national coverage rates are reasonably high. For instance, coverage is about 95 percent for electronic appliance stores, though only about 60 percent at more general mass merchandisers.

Columns one and two of Table 6 present the average price and units sold for products entering the scanner data relative to those exiting. For each good category, price is significantly higher for entering goods, for instance, 62 percent higher for color televisions. At the same time the entering models exhibit considerably higher sales than exiting models (though smaller than typical for continuing models). Unit sales per period could be understated for the last, or first, month on the market, as the product may have been available for less than the entire month. The third column of Table 6 recalculates the relative unit sales for entering and exiting models broadening the window to reflect the next-to-last month of sales for those exiting and second month of sales for those entering. The results remain qualitatively very similar. Because entering products have higher prices and more unit sales than those exiting, the market share of the matched goods declines for each of the 18 goods categories. Results by category are given in the last column of Table 6; the decline in share for matched goods is typically about 2 percent per month. This decline does not just reflect an expanding number of models. I also examined what happened to average size, in terms of sales, of the matched goods relative to all models. With the exception of two goods with very rapid entry rates, DVD players and telephone headsets, this relative size always declines, typically by 1.5 to 2 percent per month.

In Bils (2004), I examine how price increases of matched models react to months that exhibit unusually large numbers of product substitutions. If product substitutions are associated with price increases greater than justified by quality, then we might expect the matched products to face less competition, justifying an increase in their prices. But for consumer electronics the opposite occurs. Periods with high rates of product substitutions are clearly associated with bigger price declines for matched models. For each additional percentage of forced substitutions, the matched-model inflation rate is reduced by 2.7 percentage points. (Price increases for matched models for other durables show no clear response to high rates of forced substitutions.) This reinforces the picture from scanner sales data that product substitutions for consumer electronics exhibit quality improvements perceived as sufficient to justify the price increases.

Table 2 showed that forced substitutions for consumer electronics increased unit prices annually by 6 percent. The results here suggest that these price increases are justified by quality, implying quality growth of at least 6 percent per year for forced substitutions, almost double the rate based on past BLS adjustments.

4. ***Allowing for a Fashion Cycle***

The previous section showed that vehicles and consumer electronics gain market share at model changes. This is consistent with quality growth that justifies the larger price increases at model changes. But it also consistent with a taste for the newest-styled model, independent of the quality of its features. Relative inflation and market share could then both increase across model changes absent trend quality growth. In this section I examine how the price increase at model change affects the price of the new model versus that of old, but with the price of the old also evaluated at the beginning of its model cycle. I show that comparison speaks to the importance of quality growth at model substitutions. The key assumption is that fashion's impact on price is more transitory than that of quality growth because the ability to charge more for a car, for example, at the beginning of its model year, separate from quality, is predictably reversed over the year. By contrast, if larger price increases at model changes reflect greater quality growth, then we should expect much of the price change at model change to persist into year-over-year price changes.

Framework for separating quality from fashion pricing

Consider prices collected monthly on new automobiles, with model-year cycle 12 months. (The discussion is focused on automobiles to be concrete, but with results presented for other durables as well.) I introduce the age of a vehicle model on the market as a factor in price, with a model of monthly age a_v^i discounted by $-\delta_v^i a_v^i$ relative to a model, everything else equal, that is new to the market. Here i denotes vehicle model; v, short for $v(t)$, denotes the model version (model year) that is priced at t. For example, for a 2009 Honda Accord LX i equals Honda Accord LX and v equals 2009. δ_v^i denotes the monthly impact of the model's age on price. This impact can differ by vehicle model and model year, but is assumed constant within the model year.

For vehicles that exhibit no model change at month t, model age increases by one from $t-1$ to t. So price change is given by

$$ln\left(\frac{p_{v,t}^i}{p_{v-1,t-1}^i}\right) = -\delta_v^i + \epsilon_t^i \,, \tag{3}$$

where ϵ_t^i captures idiosyncratic price inflation--that is, inflation not related to model age. This rate is specific to the vehicle model, i. By contrast, vehicles that exhibit a model change at t will see a drop in age on the market from 11 to 0 months. For these, price change is given by

(4) $$ln(\frac{p_{v,t}^i}{p_{v-1,t-1}^i}) = q_v^i + 11\delta_{v-1}^i + \epsilon_t^i\ .$$

q_v^i reflects the rate of price increase justified by the change in quality going from the old model version, $v-1$, to the new, v.

Section 2 showed model changes are associated with a markedly higher rate of unit-price increase than typical for matched models. Using (3) and (4), the difference between the average unit-price increase for model changes and for match models, averaging across models and time periods, is

(5) $$\pi_{changes} - \pi_{matched} = q + 12\delta + (\epsilon_{changes} - \epsilon_{matched}) = q + 12\delta.$$

q denotes the average quality change accompanying model changes. δ denotes the average discount from a vehicle model aging by a month. $(\epsilon_{changes} - \epsilon_{matched})$ reflects any differential between the average rates of idiosyncratic inflation, that is inflation not driven by the model cycle, for changing versus matched models. The second equality in (5) reflects an assumption that the *average* rate of idiosyncratic inflation at model changes does not differ from its average for matched models. If sellers time model changes to coincide with those times they anticipate, even absent the model change, a relative price increase, then this could cause $\epsilon_{changes}$ to exceed $\epsilon_{matched}$. But, from Section 3, goods gain market share at model changes, implying that the higher price increases at model changes are not driven by a higher average ϵ_t^i at model changes. To further test for higher idiosyncratic inflation at model changes, I ask whether model changes that cannot be predicted 12 months in advance display greater price changes. More exactly, I regress the increase in the price quote for a vehicle on whether a model change occurs both by OLS and instrumenting with the occurrence of a model change 12 months prior. I find that predicted and unpredicted model changes have a very similar impact on unit-price increases. This evidence is not consistent with model changes responding to an expectedly high rate of idiosyncratic inflation ϵ_t^i.[15]

For 1988 to 2007 the average rate of price increase was 3.8 percentage points higher at model changes for durables (5.2 percent for vehicles). From (5), average quality growth, q, is related to this differential by $q = \frac{q}{(q+12\delta)}(\pi_{changes} - \pi_{matched})$. That is, measuring quality growth requires multiplying that differential of 3.8 percentage points by the ratio $\frac{q}{(q+12\delta)}$.

I assume that, after conditioning on a set of variables $\boldsymbol{x}_v^i$ associated with a model change, including size of price increase, the two random variables q_v^i and δ_{v-1}^i are distributed jointly normal. Expected quality growth then projects on $(q_v^i + 11\delta_{v-1}^i)$ as

(6) $$E\Big(q_v^i \,|\, q_v^i + 11\delta_{v-1}^i, \boldsymbol{x}_v^i\Big) = \mu(\boldsymbol{x}_v^i) + \beta(\boldsymbol{x}_v^i)(q_v^i + 11\delta_{v-1}^i)\,,$$

and expected quality growth, conditional on the observed $\boldsymbol{x}_v^i$ is

(7) $$E\Big(q_v^i \,|\, \boldsymbol{x}_v^i\Big) = \mu(\boldsymbol{x}_v^i) + \beta(\boldsymbol{x}_v^i)E\Big(q_v^i + 11\delta_{v-1}^i | \, \boldsymbol{x}_v^i\Big)\,,$$

For the observed variables $\boldsymbol{x}_v^i$ at model change, I focus on both the size of the price increase and how BLS methods suggest dividing that increase between quality growth versus a fashion price component. Let s_v^i denote BLS-inferred quality growth divided by $E(q_v^i + 11\delta_{v-1}^i | \, \boldsymbol{x}_v^i)$.[16] I treat the case of $\mu(\boldsymbol{x}_v^i)$ equal to zero and $\beta(\boldsymbol{x}_v^i)$ approximated by a linear function of s_v^i

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[15] The OLS-estimated impact is 5.06 percent, with standard error of 0.04 percent. The IV-estimated impact is actually slightly higher at 5.25 percent, with standard error of 0.25 percent. (All regressions include a full set of time period dummies; so purely seasonal effects on price are eliminated.).

A separate argument why prices at model changes could reflect higher values, on average, for ϵ_t might be based on price stickiness, with sellers delaying price changes prior to model changes, foreseeing that prices will be changing shortly with the model change. But there are two problems with this argument. Price changes are very frequent for durables. 40 percent of the price quotes for durables show a price change even absent a model change. Secondly, among these price changes, decreases are fifty percent more common than increases. So, to the extent price changes at model changes reflect diverted idiosyncratic inflation from adjacent months, this should decrease, rather than increase $\epsilon_{changes}$ relative to $\epsilon_{matched}$.

[16] The empirical counterpart of s_v^i depends on how expected idiosyncratic inflation is assumed to depend on $\boldsymbol{x}_v^i$. For the benchmark empirical case, reflecting equation (12), s_v^i simply equals BLS-measured quality growth relative to the net price increase at the model change. Where net means after subtracting the matched-model inflation rate for that period.

(8) $$E\left(q_v^i \,|\, \boldsymbol{x}_v^i\right) = \left(\alpha s_v^i + \rho(1 - s_v^i)\right) E\left(q_v^i + 11\delta_{v-1}^i | \, \boldsymbol{x}_v^i\right),$$

This specification, together with the assumptions outlined below, is sufficiently strong to identify the role of fashion. At the same time it is flexible enough to nest the starkly different treatments of quality growth implied by (a) BLS methods for quality adjustment, and (b) measuring price inflation based solely on price increases for matched-models. The dramatic difference in results from these approaches was outlined in Table 2. BLS methods imply that $\alpha = 1,\ \rho = 0$, as well as requiring that $\mu(\boldsymbol{x}_v^i) = 0$. The matched-model approach, which treats the higher price increases at model changes as the measure of quality growth, is captured by the parameter combination $\alpha = \rho = 1$, while also requiring that $\mu(\boldsymbol{x}_v^i) = 0$. I base estimates for α and ρ, as discussed just below, on whether differences in the size of price increases at model change persist over the model cycle and how this persistence depends on the BLS division of the price increase between quality growth and CPI inflation. To test the flexibility of (8), below I contrast empirical results for two goods, computers and apparel, that exhibit particularly large price increases at substitutions. The results attribute these price increases nearly entirely to quality for computers, while attributing them mostly to fashion for apparel.

Manipulating equations (5) and (8) yields the average rate of quality change

(9) $$q = \frac{q}{q+12\delta}\left(\pi_{changes} - \pi_{matched}\right) = \frac{(12\alpha-\rho)s + 11\rho(1-s)}{12-\rho}\left(\pi_{changes} - \pi_{matched}\right).$$

s equals the ratio of BLS-estimated average quality growth to $(\pi_{changes} - \pi_{matched})$. (It weights each s_v^i at model change by its size of price increase, net of the corresponding matched-model rate of price increase.) From Table 2, s is about 0.2 for durables, and even lower for vehicles. Given data on $\pi_{changes} - \pi_{matched}$ and s, the problem of estimating q reduces to finding values for parameters α and ρ.

To find values for α and ρ, I compare the price at model change, not to the price at $t - 1$, but instead to the price at the beginning of the old model's cycle at date $t - 12$.

(10) $$ln\left(\frac{p_{v,t}^i}{p_{v-1,t-12}^i}\right) = q_v^i + \sum_{\tau=0}^{11} \epsilon_{t-\tau}^i \ .$$

This comparison draws prices on both old and new model at the beginning stage of the model cycle, purging time-on-market effects.

Alone (10) is not helpful in establishing the importance of quality, as the impact of quality growth on price is confounded with the average rate of inflation inherent in $\sum_{\tau=0}^{11} \epsilon_{t-\tau}^{i}$. But parameters α and ρ can be estimated by relating the size of the 12-month price change for a vehicle in (10) to its corresponding monthly change in price at model change. Looking *across model changes*, the 12-month price change projects on the information on price change at model turnover and its BLS treatment according to

$$(11) \qquad E\Big(\Delta ln(\frac{p_{v,t}^{i}}{p_{v-1,t-12}^{i}}) \,|\, \boldsymbol{x}_v^i\Big) \;=\; E\Big(\Delta q_v^i \,|\, \boldsymbol{x}_v^i\Big) + E\Big(\sum_{\tau=0}^{11} \Delta\epsilon_{t-\tau}^{i} \,|\, \boldsymbol{x}_v^i\Big)$$

$$=\; \big(\alpha s_v^i(\Delta) + \rho(1 - s_v^i(\Delta))\big) E\Big(\Delta(q_v^i + 11\delta_{v-1}^i) \,|\, \boldsymbol{x}_v^i\Big) + \phi_\epsilon E\Big(\Delta\epsilon_t^i \,|\; \boldsymbol{x}_v^i\Big)\;,$$

$$\text{where, } \phi_\epsilon \;=\; E\Big(\sum_{\tau=0}^{11} \Delta\epsilon_{t-\tau}^{i} \,|\, \Delta\epsilon_t^i\Big) \;=\; \frac{E\Big((\Delta\epsilon_t^i)' \sum_{\tau=0}^{11} \Delta\epsilon_{t-\tau}^{i}\Big)}{\sigma_{\Delta\epsilon}^2}\;.$$

The Δ symbol denotes the demeaned value for that variable, with the mean calculated across all model changes at t. $s_v^i(\Delta)$ denotes the share of the expected value of $\Delta(q_v^i + 11\delta_{v-1}^i)$ that BLS methods attribute to relative quality growth. For instance, if a vehicle displayed a one percentage point higher price change than the average for changers and BLS methods attribute one percentage point higher quality growth to that vehicle than the average at t, then $s_v^i(\Delta) = 1$. $\boldsymbol{x}_v^i$ will reflect both the relative size of price increase at model change, $\Delta ln\big(\frac{p_{v,t}^{i}}{p_{v-1,t-1}^{i}}\big)$, and its BLS treatment, $s_v^i(\Delta)$.

The first equality in (11) reflects that a time-on-market component in price does not influence the vehicle' price at t relative to 12 months prior. So any projection of the 12-month price change on the price increase at date t model change should reflect either quality growth at t or a persistent (12 month) impact of idiosyncratic inflation at t. With no dispersion in idiosyncratic inflation at model changes, then regressing $\Delta ln\big(\frac{p_{v,t}^{i}}{p_{v-1,t-12}^{i}}\big)$ on the price change at model change, $\Delta ln\big(\frac{p_{v,t}^{i}}{p_{v-1,t-1}^{i}}\big)$, broken by shares BLS attributes to quality growth versus price inflation, yields estimates of the parameters of interest α and ρ. The approach here exploits this comparison, but does allow for dispersion in idiosyncratic inflation.

The second equality in (11) reflects the assumptions that the idiosyncratic component of year-over-year inflation, $\sum_{\tau=0}^{11}\epsilon_{t-\tau}$, is not correlated with the quality growth or the size of the fashion component at model change. We might expect narrow categories of goods with faster quality growth to be associated with faster obsolescence and thereby lower inflation $\sum_{\tau=0}^{11}\epsilon_{t-\tau}$, throughout the model cycle. If so, the approach here will understate the persistence in the component $\Delta(q_v^i + 11\delta_{v-1}^i)$, exaggerating the role of fashion and understating the importance of quality growth. As an example, high-definition televisions may have displayed not only larger quality increases, but also faster obsolescence than conventional televisions. For vehicles we might expect relatively similar rates of advance across vehicle classes, making this less of an issue.

Equation (11) divides the price increase at model change into a component of expected idiosyncratic inflation, $\Delta\epsilon_t^i$, and a component that is the sum of expected quality growth plus fashion, $\Delta(q_v^i + 11\delta_{v-1}^i)$. For the benchmark results I assume that the expectation of $\Delta\epsilon_t^i$ is a linear projection on the size of price change at model substitution $\Delta ln\big(\frac{p_{v,t}^i}{p_{v-1,t-1}^i}\big)$, so that

(12) $$E\big(\Delta\epsilon_t^i\,|\,\boldsymbol{x}_v^i\big) \;=\; \lambda_\epsilon\Big(\Delta ln\big(\frac{p_{v,t}^i}{p_{v-1,t-1}^i}\big)\Big)\,,$$

$$E\big(\Delta(q_v^i + 11\delta_{v-1}^i)\,|\,\boldsymbol{x}_v^i\big) \;=\; (1-\lambda_\epsilon)\Big(\Delta ln\big(\frac{p_{v,t}^i}{p_{v-1,t-1}^i}\big)\Big)\,,$$

$$\text{where,}\;\; \lambda_\epsilon \;=\; \frac{\sigma_{\Delta\epsilon}^2}{\sigma_{\Delta(q+11\delta)}^2+\sigma_{\Delta\epsilon}^2}\,.$$

This assumes that the ratio of variance components, $\sigma_{\Delta\epsilon}^2/\sigma_{\Delta(q+11\delta)}^2$, reflected by λ_ϵ is independent of the size of price increase and independent of how that price increase is treated by the BLS. I also generalize (12) to allow λ_ϵ to depend on the BLS treatment of the price change, with λ_ϵ larger for price increases that the BLS treat as price inflation. But the results are not sensitive to plausible alternatives. (These are discussed in footnotes in the results section.) The treatment in (12) also implies that the share of expected $\Delta(q_v^i + 11\delta_{v-1}^i)$ that BLS methods would attribute to quality is simply $s_v^i(\Delta) = \Delta\widehat{q}_v^i/\Delta ln\big(\frac{p_{v,t}^i}{p_{v-1,t-1}^i}\big)$, where $\varDelta\widehat{q}_v^i$ denotes the BLS defined quality growth at model change relative to its mean for all model changes at time t.

Combining (11) and (12), then substituting for $s_v^i(\varDelta)$ yields

$$(13)\quad E\Big(\varDelta ln\big(\frac{p_{v,t}^i}{p_{v-1,t-12}^i}\big)\,|\,\boldsymbol{x}_v^i\Big) = \Big((1-\lambda_\epsilon)\big(\alpha s_v^i(\varDelta) + \rho(1 - s_v^i(\varDelta))\big) + \lambda_\epsilon\phi_\epsilon\Big)\varDelta ln\big(\frac{p_{v,t}^i}{p_{v-1,t-1}^i}\big)$$

$$= (1-\lambda_\epsilon)\Big(\alpha\varDelta\widehat{q}_v^i + \rho\Big(\varDelta ln\big(\frac{p_{v,t}^i}{p_{v-1,t-1}^i}\big) - \varDelta\widehat{q}_v^i\Big)\Big) + \lambda_\epsilon\phi_\epsilon\varDelta ln\big(\frac{p_{v,t}^i}{p_{v-1,t-1}^i}\big)\,.$$

If idiosyncratic inflation plays no role in price changes at substitutions, then the parameters α and ρ can be estimated by regressing the twelve-month price change on the increase in price at model change, with that change broken between what the BLS does and does not label as quality growth. More generally, that regression's coefficients will be biased away from these parameters, with this bias reflecting the size of λ_ϵ and the extent that idiosyncratic inflation differs in its persistent effect on year-over-year price changes from the size of α and ρ. I allow for these effects in the calculations below by calibrating the size of λ_ϵ and the persistence ϕ_ϵ based on the size and persistence of relative rates of inflation away from model changes. But this has little impact. For instance, for vehicles the variance of price changes at model changes is 9 times that in months without new models, implying a small value for λ_ϵ. Furthermore, I show below that price changes that accompany model changes display more persistence on year-over-year inflation than do price changes without model changes, implying that the regression coefficients are not importantly biased due to the impact of idiosyncratic inflation at model changes. The calibration of λ_ϵ and ϕ_ϵ to months without model changes is imperfect. From (3), price changes for matched models reflect the combined terms ($-\varDelta\delta_v^i + \varDelta\epsilon_t^i$), rather than just idiosyncratic inflation $\varDelta\epsilon_t^i$. If dispersion in the fashion component $\varDelta\delta_v^i$ is nontrivial, even for months without model changes, then the calibration will overstate the volatility and overstate the persistence of the idiosyncratic component $\varDelta\epsilon_t^i$. Because my allowance for the impact of idiosyncratic inflation reduces (slightly) estimated growth, overstating volatility and persistence of $\varDelta\epsilon_t^i$ acts to understate the importance of quality growth.

The twelve-month price change in (13) compares prices of the new and old models for both at the beginning of their pricing cycles. Alternatively, one could draw comparisons at dates further into the model year which, since done for both the new and old model, also control for time on market. I report additional results based on the models in their last months, or averaged over the entire model cycle for both new and old model. But I find that a large price change at model substitution predicts greater reductions in prices prior, rather than after, the model change. As a result, the price comparison I stress, taken at the beginning of model cycles, yields more conservative estimates of quality growth than comparisons based later in the model cycles. One interpretation for this pattern is that quality growth at model changes more than justifies the price increases. The anticipation of the newer model, with its combination of price and quality, then lowers the prices of closer substitutes, including the old version of the same vehicle. In this scenario inflation prior to larger quality increases is predictably lower. This violates the assumption that quality growth is uncorrelated with the twelve months of inflation ending with the substitution, causing the estimate based on (13) to understate the importance of quality growth. But an alternative interpretation as in Lazear (1986) is that, as sellers learn the popularity of their models over the model year, they cut prices more sharply for those that are less popular than expected. These models will then predictably increase in price more sharply with the changeover to a new model. In this scenario comparing prices of the new and old models each at the end of their model years would not completely control for the fashion cycle, as larger price changes at substitution may follow bigger fashion failures. Comparing prices of the new and old model when both are new-to-market eliminates this impact of fashion failures. For this reason, I choose the more conservative estimates of quality based on price comparisons at the beginning of the model cycle.

Results

I turn first to results for vehicles. Because results vary little across vehicle types, I combine cars with other vehicles. Any regression combining categories includes separate intercepts by good category. The sample period is January 1988 through January 2005. I include zero-one dummy variables to capture the month of the current and previous model change; so aggregate variations in vehicle prices are not a factor. Unlike my example above, the span between substitutions often is not exactly 12 months. I restrict the sample to observations for which that span is between 4 and 20 months.[17]

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[17] The framework above assumes that the beginning of BLS pricing of the model coincides with its arrival on the market. This assumption does not conform precisely with the CPI data, though it should be a reasonable approximation for the durables studied here. Vehicles make up 54 percent of the expenditure share on the 49 durables. They make up an even greater share, 74 percent, of the extra increases in prices that occur at forced

The first column of Table 7 presents estimates from regressing the twelve-month price change for the new versus old model, both based on their first month in the CPI, on the size of the one-month price change at model substitution. A one-percent larger price increase at substitution predicts a larger price increase from the first month of the old model to the first month of the new of 0.79 percentage points (with standard error of 0.005). While nearly 80 percent of relative price changes at substitutions survives the model cycle, this could just reflect the persistent impact of inflation unrelated to the model cycle. But this is not the case. For one, the variance of price changes at model changes is 9 times that for months without substitutions. So, even if price changes unrelated to model cycle are very persistent, this would create only a small upward bias to the persistence estimate of 0.79. In terms of equation (12), λ_ϵ is small at 0.11. Secondly, price changes at substitutions exhibit a slightly more persistent impact on price than inflation in other months. For months without model changes, I calculate the impact of that month's inflation on the rate of price change relative to ten months before.[18] A one percent larger price change in a month with no substitution results in a 0.76 percent higher price compared to 10 months prior; so the presence of this component at substitutions acts to slightly reduce the persistence estimate down to the reported 0.79 in Table 7.

Column 2 repeats the regression, but separates the price change at substitution into changes attributed to quality change versus CPI inflation by the BLS. The impact on the full-model-cycle price change depends on the BLS treatment. A one percent increase in BLS quality growth predicts a 0.88 percentage point higher price for the new model relative to the old's beginning price; but if this increase at substitution is treated as CPI inflation the response is 0.64 percentage points. These coefficients can be employed using equation (13) to obtain parameters α and ρ in order to calculate the average rate of quality growth from model changes. The bottom panel of Table 7 reports the results for α and ρ and for the estimated share of quality growth in the larger average price increase at model changes. Idiosyncratic inflation biases the regression coefficients from α and ρ based on its importance, λ_ϵ, and its persistent

substitutions. The BLS begins pricing a new model-year vehiclel when its unit sales at the dealer first exceed those for the outgoing model-year. So any interval between arrival at the dealer and entry into the CPI data should be relatively short. For other categories the BLS begins pricing the new model when the outlet discontinues that model's predecessor. So, if the outlet keeps both items in stock for some period, there could be a greater descrepancy between arrival on the market and beginning of pricing. But given the high rate of obsolescence for many of these categories (e.g., electronics, home appliances), that period of overlap should presumably also be relatively short.

[18] I pick ten months because this is the even number closest to the average duration of 10.7 months for model-cycle changes underlying the regression for vehicles in Table 7. Differencing by an odd-number months would exclude quotes sampled bimonthly.

impact on year-over-year price, ϕ_ϵ. As discussed just above, I calibrate values for λ_ϵ and ϕ_ϵ of 0.11 and 0.76 for vehicles based on months without model changes. This yields values for parameters α and ρ equal to 0.89 and 0.62. These remain close to respectively the regression coefficients of 0.88 and 0.64. Putting these parameters, with a value for s of 0.14, into equation (9) yields that growth explains nearly two thirds, 0.64, of the higher average price increase at model changes for vehicles.[19]

What does this imply for average quality growth for vehicles? From Table 2, price increases at substitutions add 5.2 percentage points to the annual inflation in unit prices, but BLS methods attributed only a small fraction, 0.7 percentage points, to quality growth. By contrast, if inflation had been measured solely by price inflation for matched models, all the extra growth in prices at substitutions of 5.2 percent per year would be attributed to quality growth. These points are repeated in the first column of Table 8. The results in Table 7 suggest attributing just over a third of the higher price increases at model changes for vehicles to a fashion cycle. The last row of Table 8 reports that, after accounting for this fashion component, the resulting rate of quality growth at forced substitutions for vehicles is 3.3 percent per year. This is 1.9 percentage points lower than if all the extra price increases at substitutions are attributed to quality, but still much higher, by 2.6 percentage points, than captured by BLS methods.

The regressions in Table 7 compare prices of the new and old models when both are at the beginning of their pricing cycle. I estimated the same regression, but with the price comparison based on both models in their final month. The size of price change at substitutions has a more persistent impact on relative prices when prices are judged at end of model cycles--the persistence reported in Column 1 of 0.79 increases to 0.87. The weighted average of the estimates of α and ρ, weighting by the fractions of price changes allocated by the BLS to quality change and CPI inflation, increases as well. The implied

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[19] The value for ϕ_ϵ of 0.76 is less than the regression coefficient of 0.87 on relative price increases BLS-attributed to quality; so correcting for the impact of idiosyncratic inflation yields a value for α, 0.89, slightly above that regression coefficient. For price increases BLS-attributed to price inflation, the correction lowers the value of ρ from the regression coefficient of 0.63 to 0.62. These combined adjustments to α and ρ slightly reduce the calculated importance of quality, $q/(\pi_{changes} - \pi_{matched})$, from 0.65 to 0.64. The impact on ρ dominates because the BLS attributes most of the higher average price increase at model changes to price inflation, rather than to quality growth.

The results in Table 7 follow the assumption from equation (11) that idiosyncratic inflation projects to the same degree λ_ϵ on relative price increases at model change that the BLS labels quality growth or price inflation. As an alternative I allow that idiosyncratic inflation projects considerably more on price changes that the BLS attributes to inflation rather than to quality. For this alternative I impose that the relative importance of idiosyncratic versus fashion price inflation at model change be unrelated to how the BLS attributes the price increase. This reduces the values for α and ρ very slightly, with the calculated share of quality growth in price changes at model turnover reduced by only about 0.01. The impact for the durables other than vehicles is even smaller.

quality growth for vehicles with these estimates would be about 4 percent per year. Estimates for durables other than vehicles are discussed shortly. Across all categories there is a larger impact on relative prices at the end of model cycles than on those reported based on the front of cycles. I also examined price comparisons averaging over the entire model cycle for both new and old models. This produces estimates both for persistence and for quality growth that are slightly larger than those reported in Tables 7 and 8.[20]

For vehicles the approach here attributes about one-third of the price increase at substitutions to a pure time-on-the-market, or fashion, effect. Before considering results for the remaining durables, I first compare these results for vehicles to what the same exercise produces for two goods that exhibit much larger price increases at substitutions, computers and apparel. As shown in Table 2, forced substitutions have increased unit prices by 17 percent per year for computing equipment, with the BLS attributing quality growth of a little more than this amount, 18 percent per year, to these substitutions. For apparel I calculate that substitutions increase unit prices by about 18 percent per year.[21] By sharp contrast to computers, BLS methods give only a small fraction of these price increases, about a percentage point per year by my calculations, to quality increases. Of course BLS methods will not perfectly capture quality change for either computers or apparel--the Boskin Report's calculations assume quality growth for apparel was understated by the CPI by 1.0 percent annually for 1985-1996. But one expects the quality constant, time-on-market impact to be more important for pricing of apparel than computers.

For computers I find that price increases at model substitutions are highly persistent over the model cycle with 90 percent of the price increase surviving across the model cycle. Conducting the same exercise for estimating quality growth, that reported in the bottom panel of Table 7, attributes less than a tenth of the average computer model-change price increase to time-on-market, compared to one-third for vehicles, with over nine tenths attributed to quality growth. Though it attributes most of the typical price increase for model change to quality growth, it falls a little short of that allocation by BLS methods, which slightly exceeds 100 percent.

[20] I also examined the longer term effect of the price changes at substitutions by observing whether goods within a category that on average exhibit larger price increases at substitutions display on average relative price increases over its entire sample period, typically four or five years. This again yields modestly higher estimates of quality growth than those reported in Table 8.
[21] For apparel I include all outer clothing items, including shoes and children's clothing, but exclude underclothing and nightwear. For computers I do not impose the restriction that the span between the beginning of the old and new models be at least 4 months, as this eliminates half the sample.

For apparel the regression exercise shows that price increases at forced substitutions are much less persistent over the product cycle. In particular, each percentage point increase treated by the BLS as CPI inflation persists by only one third over the product cycle. But even this figure is likely upward biased. Unlike durables, for apparel price changes in months without substitutions are much more persistent than price changes at substitutions. Also, compared to durables, price changes without substitutions are much more variable. Whereas for vehicles the variance of price changes is 9 times larger at substitutions, for apparel it is only 3.6 times at large. And if we consider only those months with non-zero price changes, to allow for some price rigidity, this ratio drops to 1.7. As a result, for apparel we can infer that much of the persistence of price changes at substitutions simply reflects persistence in the component of inflation unrelated to the model cycle. Basing λ_ϵ and ϕ_ϵ on the variance and persistence of inflation in months without substitutions, I can calculate respective shares of quality growth and fashion (time on the market) of about one-fourth and three-fourths in the higher price increases at forced substitutions for apparel. Recall that the same calculations for vehicles attributes almost two thirds to quality growth. If we instead calculate λ_ϵ based on months without substitutions and non-zero price changes, then the share attributed to quality growth actually drops just below zero. I conclude that the approach implies quality growth for apparel that is between zero and one-fourth of the price increases at substitutions, with the fashion component contributing three fourths to all. The quality growth attributed to forced substitutions by BLS methods is nearer the bottom of that range. But the middle of this range only requires that these methods understate quality growth by about 1 to 1.5 percentage points per year.

The remaining columns in Table 7 report results separately for consumer electronics, other than computers, and for the 43 remaining durables. Looking at Column 3 for consumer electronics, a one percentage point greater increase in price at substitution predicts an increase in price of 0.83 percentage points over the full model cycle. For price increases treated as quality growth by BLS methods the predicted response is considerably larger, at 0.89 percentage points, than if treated as CPI inflation, at 0.58 percentage points. The bottom panel of Table 7 shows that the implied parameters α and ρ at 0.91 and 0.57. These values attribute nearly three fourths of price increases at model changes, relative to the matched-model rate, to quality growth. Looking at the second column of Table 8, forced substitutions increased unit prices for consumer electronics by 6.0 percent per year. BLS methods attributed a little over half of this to quality growth; so, had inflation been measured solely by price inflation for matched models, annual quality growth would have been 2.8 percentage points higher. The last row reports quality growth allowing for a possible fashion cycle. If nearly three-fourths of higher price increases at substitutions reflect quality growth, this implies quality growth of 4.4 percent per year, 1.2 percentage points above the BLS rate. For the balance of durables the fraction of model-change price increase that persists across the cycle is 0.81, with this fraction considerably higher, 0.88, if the increase is treated as BLS quality growth than if treated as CPI inflation, 0.59. The implication is that just over 60 percent of the larger price increases at model changes for these goods reflect quality growth. Turning to Table 8, that implies quality growth of 1.0 percent per year for other durables, compared to only 0.2 percent with BLS methods.

The last column of Table 8 combines all 49 durables. Measuring inflation by matched-model price changes, rather than BLS methods, would raise quality growth at forced substitutions from 0.7 percent to 3.8 percent per year. Allowing for a pure time-on-market impact yields quality growth that averages 2.5 percent per year. This remains 1.8 percentage points higher than the rate calculated with BLS methods, so it continues to suggest that quality growth for durables has been substantially understated.

5. *Conclusions*

It is difficult to distinguish quality growth from true price increases for goods, such as consumer durables, that display frequent model changes. I show that one can arrive at vastly different measures of price inflation and real growth under arguably plausible competing assumptions. I try to make progress on this measurement by examining (a) whether consumer purchases shift toward or away from the new models, and (b) whether new-model price increases generate higher relative prices that persist throughout the model cycle.

I find the following. Based on vehicles and consumer electronics, goods with model changes gain market share. Furthermore, larger price increases at the model change do not lessen this gain. This suggests that quality growth justifies the large price increases for new models for durables. At the same time, I see that one-third of larger price increases at model changes is given back within the model cycle. There are two possible explanations for this finding. One is that durable models that exhibit faster quality improvement also obsolesce more rapidly, as they compete more directly with models that improve rapidly in quality. An alternative explanation is that part of the price increases for new models reflects valuation of fashion-type stylistic changes that depreciate over the model cycle. In order to provide a lower bound on quality growth, I stress the latter interpretation. Nevertheless, I can still conclude that two thirds of the price increases with model changes should be allocated to quality growth.

What do these results imply about rates of quality growth? My results suggest that quality growth for durables has been understated by almost 2 percent per year since 1988.[22] With this addition, quality for durables, even excluding computers, increased by 2.5 percent per year from model changes, with higher rates of 3.3 percent for vehicles and 4.4 percent for consumer electronics.[23] To judge overall quality growth for durables it is important to also include the impact of consumers moving to better products, e.g., from a midsize to luxury sedan or from conventional to plasma television. The analysis of price changes across BLS sample rotations suggests this contributes another 2.3 percent annually to quality. Added to the estimated 2.5 percent from model changes, this yields overall quality growth for durables, excluding computers, of nearly 5 percent per year.

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[22] My results suggest faster quality growth for durables than the Boskin Commission Report, which said BLS methods understated quality growth for durables by one percent, about half my estimate. This derives from two main differences. The Boskin Report assumed no quality bias for a number of durables and assumed no quality growth for vehicles except from greater durability.

[23] Increasing quality growth for durables by 2 percent per year, given their expenditure share of about 10 percent, would alone increase overall quality growth by 0.2 percent per year. Product substitutions are more important for consumer durables than for most consumer goods; so it would not be appropriate to project the magnitudes here to nondurables. We can see from the BLS *Commodities and Services Substitution Rate Tables* that rates of forced substitutions for all goods and services, excluding housing, average about 3 percent, or only one-fourth the rate for the durables analyzed here. We also know, from Moulton and Moses (1997), that price changes associated with forced substitutions are larger for durables than for other goods, especially if we exclude apparel based on its strong seasonal pricing. This implies that the analysis, if conducted across all goods, would yield a much lower rate of unmeasured quality growth from model changes than I estimate for durables. (This does not address, of course, the impact of new types of goods, such as in medical services.)

Table 1: Durable Goods Studied

Good	Spending Share
Watches	.069
Jewelry	.416
Personal computers & equipment	.370
Telephone & equipment	.080
Calculators, typewriters, etc.	.014
Electric personal care products	.021
Luggage	.027
Infant's equipment	.018
Curtains & Drapes	.064
Window coverings	.053
Mattresses & springs	.146
Bedroom furniture	.193
Sofa & slipcover	.276
Living room chairs	.122
Living room tables	.057
Kitchen & dinning room furniture	.162
Infant's furniture	.025
Occasional furniture	.148
Refrigerator & home freezer	.083
Washers & dryers	.103
Stoves	.030
Microwaves	.029
Vacuums	.064
Small kitchen appliances	.034
Other Electric appliances	.079
Lamps & lighting	.040
Clocks & decorative items	.325
Dishes	.083
Flatware	.014
Non-electric cookware	.039
Tableware & non-electric kitchenware	.057
Power tools	.058
Misc. hardware	.096
Non-powered hand tools	.026
Medical equipment for general use	.011
Supportive & convalescent equipment	.031
Televisions	.246
Other video equipment	.104
Audio equipment	.164
Bicycles	.044
General sports equipment	.229
Hunting, fishing & camping equipment	.086
Photography equipment	.057
Sewing machines	.044
Musical instruments & accessories	.069
New cars	3.265
Pickups & Vans	1.992
New motorcycles	.072
Tires	.270
Other vehicle equipment accessories	.212

Data: *CPI Commodities and Services Survey*.

Table 2: Annual Price Inflation and Quality Growth — January 1988 to December 2006

		(A) Durables Excluding Computers	(B) Cars, Vans, Trucks, SUV's	(C) Video, Audio, Telephones	(D) Computers and equipment
Panel A	$\pi_{unit-price}$	2.5%	3.6%	−0.6%	−0.1%
	$= \pi_{sample\ rotations}$	2.3	2.1	4.3	2.9
	$+ \pi_{within\ rotations}$	0.2	1.4	−4.9	−2.9
	$= \pi_{matched}$	−3.7	−3.8	−10.9	−19.6
	$+ s(\pi_{forced} - \pi_{matched})$	3.8	5.2	6.0	16.7
Panel B	Δ *quality for forced (BLS)*	0.7	0.7	3.2	17.8
	Δ *quality for forced (BLS)* $+ \pi_{sample\ rotations}$	2.9	2.8	7.5	20.7
	$\pi_{unit-price} - \pi_{matched}$	6.1	7.4	10.3	19.6
	Substitution rate	11.8%	15.3%	15.0%	31.3%
	Number of quotes	966,242	170,480	114,450	20,844

Data: *CPI Commodities and Services Survey*

Table 3: Response of Unit−price Inflation, CPI Price Inflation net, and Market Share of Units Sales to Substitution Rate for Cars and other Light Vehicles

Dependent Variable ↓	Automobiles	Vans, Pickups, and SUV's
Δ Ln(Unit Price)	5.1 (.09)	4.5 (.13)
Δ Ln(CPI Price)	4.4 (.08)	4.1 (.11)
Δ Ln(Market Share of Sales)	14.2 (2.0)	1.2 (2.3)
Number of model−month observations	21,344	8,336

Data: *CPI Commodities and Services Survey* and *Ward's Automotive Sales Data*, both for January 1988 to January 2005. Independent variable is the monthly rate of forced substitutions for that vehicle model. Standard errors are in parentheses. Regressions include monthly time−period dummies.

Table 4: Dynamic Responses of Market Share to Substitutions for Vehicles

Dependent variable is Δ Share of Sales

	Automobiles	Vans, Pickups, SUV's
Δ Ln(Market Share of Sales) at t−1	−0.24 (.007)	−0.24 (.011)
Δ Ln(Market Share of Sales) at t−2	−0.18 (.008)	−0.17 (.012)
Δ Ln(Market Share of Sales) at t−3	−0.12 (.008)	−0.10 (.012)
Δ Ln(Market Share of Sales) at t−4	−0.06 (.007)	−0.05 (.011)
Substitution rate at t	14.2 (2.3)	−1.8 (2.5)
Substitution rate at t−1	6.3 (2.4)	5.3 (2.6)
Substitution rate at t−2	3.3 (2.4)	3.9 (2.5)
Substitution rate at t−3	6.6 (2.2)	1.6 (2.4)
Substitution rate at t−4	1.9 (2.1)	−0.1 (2.2)
Adjusted R^2	.26	.40
Number of observations	18,747	7,946

Data: *CPI Commodities and Services Survey*, *Ward's Automotive Sales Data*, both January 1988 to January 2005. Standard errors are in parentheses. Regressions include monthly time-period dummies. The p−value for the set of substitution variables for autos is < .0001. For other vehicles it is .02. Estimated impulse response in market share to a substitution for autos is 14.2% the first month, 17.2% in month 3, and 20.3% in month 6. For other vehicles the estimated response is −1.8% in month one, 6.7% in month 3, and 5.5% in month 6.

Table 5: Scanner Data—Goods' Shares and Monthly Entry/Exit Rates

Good	# Obs.	Share	Entry Rate	Exit Rate	Matched Inflation (monthly)
Color TV's	19,399	38.6	4.4%	4.2%	−1.1%
Remote controls, web browsers, caller ID	2363	0.7	3.2	3.5	−0.5
DBS Satellite, TV box−decoders	2089	1.8	3.5	4.6	−1.9
TV combinations	3361	2.7	4.2	4.1	−1.0
VCR's	6161	4.5	4.3	6.1	−2.3
Camcorders, personal video Recorders	5420	11.0	4.6	3.4	−2.2
DVD players	4468	8.6	5.3	2.1	−2.1
CD players	10,408	5.2	3.5	4.2	−1.0
Portable radios, radio/cassettes	3493	0.9	3.4	3.5	−0.8
Portable tape recorders, Solid−state voice recorders	1628	0.4	3.4	2.7	−0.6
Headset stereos, stereo Headphones	6770	1.4	3.8	3.6	−0.2
Receivers, cassette decks	7490	3.9	4.2	4.1	−1.3
Home speakers	13,829	4.6	3.9	3.3	−0.9
Rack or shelf systems	6391	5.0	4.1	4.5	−1.3
Corded phones	2661	0.9	3.1	3.4	−0.8
Cordless phones, 2−way radios	6033	5.3	4.8	3.1	−2.0
Answering devices	3808	4.1	4.0	3.3	−1.7
Headsets	1821	0.5	7.6	3.0	−1.6

Data: NPD Scanner data for video, audio, and telecommunications products, Monthly for March 2000 through February 2002

Table 6: Scanner Data—Matched−good Inflation and Share Changes

Good	$\ln(P_{in}/P_{out})$ (X 100)*	$\ln(Q_{in}/Q_{out})$ (X 100)*	$\ln(Q_{in}/Q_{out})$ (X 100), wider window*	Change in Matched Share
Color TV's	62%	174%	233%	−1.9%
Remote controls, browsers, caller ID	87	79	128	−0.8
DBS Satellite, TV box−decoders	68	143	161	−2.0
TV combinations	53	176	170	−3.1
VCR's	26	225	259	−1.9
Camcorders, video recorders	83	210	290	−2.5
DVD players	57	183	213	−2.9
CD players	54	229	239	−2.4
Portable radios, radio/cassettes	46	62	105	−1.8
Portable tape/voice recorders	37	175	85	−2.0
Headset stereos, stereo headphones	17	116	135	−1.4
Receivers, cassette decks	38	240	290	−1.8
Home speakers	36	104	104	−1.2
Rack or shelf systems	42	157	149	−3.0
Corded phones	60	189	151	−1.3
Cordless phones, 2−way radios	46	142	214	−2.3
Answering devices	84	326	345	−2.1
Headsets	12	141	119	−4.6

Data: NPD Scanner data for video, audio, and telecommunications products, Monthly for March 2000 through February 2002

* P_{in}/P_{out} denotes the ratio of the average price of entering models relative to those exiting. Similarly, Q_{in}/Q_{out} denotes the ratio of units sold. Q_{in}/Q_{out} for wider window is same, except sales for those exiting is based on the next−to−last month for the item and sales for those entering is based on the second month that the item appears in the scanner data.

Table 7: Response of Price Increase Over Full Model Cycle to Price Increase at Substitution

	Cars, Vans, Trucks, SUV's		Video, Audio, Telephones		43 Other Durables	
	(1)	(2)	(3)	(4)	(5)	(6)
Regression Results*						
Price Change at Model Change	0.79 (.005)		0.83 (.006)		0.81 (.004)	
BLS Quality growth at Model Change		0.87 (.006)		0.89 (.006)		0.88 (.005)
CPI price increase at Model Change		0.63 (.008)		0.58 (.010)		0.59 (.0065)
Adjusted R^2	.67	.68	.76	.79	.70	.72
Importance of Quality Growth in Higher Price Increases at Model Changes**						
α		0.89		0.91		0.91
ρ		0.62		0.57		0.59
$q/(\pi_{changes} - \pi_{matched})$		0.64		0.74		0.62

* Data: *CPI Commodities and Services Survey*. The number of observations equals 13,431 for vehicles, 7,818 for video, audio, and telephones, and 14,831 for the other durables. Dependent variable is $\Delta Ln(p^i_{v,t} / p^i_{v-1,t-12})$. Regressors are, rows one to three, $\Delta Ln(p^i_{v,t} / p^i_{v-1,t-1})$, $s^i_v(\Delta)\Delta Ln(p^i_{v,t} / p^i_{v-1,t-1})$, and $(1-s^i_v(\Delta))\Delta Ln(p^i_{v,t} / p^i_{v-1,t-1})$.

**Across the three categories, calculations employ values for λ_ε of 0.11, 0.10, 0.11, for ϕ_ε of 0.76, 0.69, 0.60, and for s of 0.14, 0.53, 0.13.

Table 8: Annual Quality Growth from Forced Substitutions by Competing Measures

Quality growth measured by	Cars, Vans, Trucks, SUV's	Video, Audio, Telephones	43 Other Durables	All Durables
(A) BLS methods	0.7 %	3.2 %	0.2 %	0.7%
(B) Price change net of matched−model inflation	5.2	6.0	1.6	3.8
(C) Price effect that persists over the model cycle	3.3	4.4	1.0	2.5

Table A1: BLS treatment of Price Increases with Forced Substitutions, Durable Consumer Goods, January 1988 to December 2006

	Percent of Quotes (Weighted)	Price Increase	Inflation (BLS methods)	Quality Growth (BLS methods)
All Quotes	100 %	0.02 %	−0.08 %	0.10 %
No Substitution	88.2	−0.5	−0.5	0
Substitution	11.8	4.2	3.4	0.8
–– treated as same quality	4.2	2.7	2.7	0
–– direct quality adjustment	4.4	4.6	4.1	0.5
–– other adjustments	2.1	7.4	5.1	2.4
–– omitted in calculating Inflation	1.1	2.3	−0.1	2.4

Total number of quotes equals 966,242.

Data: *CPI Commodities and Services Survey*. Computer equipment excluded

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