Incentives and Prices for Motor Vehicles: What has been Happening in Recent Years?

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Abstract

We address the construction of monthly price indexes for motor vehicles from 1998 to 2003 using a unique dataset collected from a large national sample of motor vehicle dealerships. The dataset contains monthly data on prices and quantities of individual models of light vehicles, along with information on customer cash rebates, financing incentives, and much more. The dataset also allows us to directly observe prices for different vintages of new vehicles at the same point in time. Using these data, we establish several empirical findings: First, we demonstrate that a price measure that takes into account the discount implied by reduced-rate financing is critical for understanding aggregate price movements in recent years. In addition, we observe that vehicle prices drop rapidly over the model year. Using a hedonic regression model that controls for differences in quality across models using both fixed effects and vehicle characteristics, we are thus able to decompose the price change into two components, obsolescence and the pure time effect. We find that obsolescence accounts for much of the within-year price declines of new vehicles.

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1. Introduction

Although motor vehicle manufacturers have used various types of incentives to boost consumer sales for some time, incentives have become both more generous and more widespread in recent years. We address the construction of monthly price indexes for motor vehicles from 1998 to 2003 using a unique dataset collected from a large national sample of motor vehicle dealerships. The dataset contains monthly data on prices and quantities of individual models of light vehicles, along with information on customer cash rebates, financing incentives, and much more. We are able to observe and examine the within-year pattern of vehicle sales and prices at a highly disaggregate level. We measure the incidence of interest subvention at this level as well, and to our knowledge, no prior study has addressed the measurement of new motor vehicle prices and incentives based on such a wealth of information.

We first calculate and present monthly matched-model price indexes by model year. The indexes display an interesting pattern in which vehicle prices drop significantly over their model-year life cycle, in large part a consequence of the use of marketing incentives. Because vehicles undergo frequent and/or recurring upgrades, changes, and redesigns, the logic of user-cost suggests the purchase price of a vehicle will fall over its selling lifetime. However, we also establish that a key feature of retail vehicle markets is the simultaneous marketing of newly produced vehicles from different model years. The prevalence of marketing incentives and the simultaneous selling of different vintages of current production presents challenges for measuring vehicle purchase prices: How should financing incentives be captured and treated? How does variation in the "age" structure of new vehicle sales affect vehicle prices? How should the monthly model level prices be aggregated to yield a quality-adjusted measure of overall new vehicle prices? We explore these issues in sections 2 and 3 of this paper. In addition, we provide an overview of the dataset in the next section that we constructed from information supplied by J.D. Power and Associates.

Information on transactions of different vintages of production being sold at a given point in time can be used to help identify and measure price change, as suggested could be done with data on used prices long ago (Burstein 1961, Cagan 1965, and Hall 1971; see also Griliches 1971a). Moreover, because we observe different vintages of *current* production, our data can be used to determine how much a vehicle depreciates due to obsolescence alone, as recently suggested could be done with high frequency observations on new prices (for PCs; Wykoff 2003). Accordingly, in section 4 we present results of hedonic price regressions in which we use the "age" of newly produced vehicles as a characteristic. The term accounts for obsolescence and is needed (along with the usual considerations) to accurately determine price change when applying the hedonic technique to monthly transactions data on vehicle purchase prices. We also examine the role of "newness" and "fashion" in vehicle markets using alternative specifications of the age term in the regressions. All told, we find that new vehicles lose value at a rate of about 7 to 8 percent per year.

2 Incentives and Overview of the Database

2.1 Popular consumer price incentives

Chart 1 shows two types of popular consumer incentives: cash rebates and reduced-rate financing. Rebates are cash provided directly to the buyer and can come from the dealership, the original equipment manufacturer (OEMs), or from both. Consumers are offered reduced-rate financing usually through the financing arm of the OEMs. Some examples include GMAC, Ford Financial, Chrysler Financial, Toyota Financial Services, and Honda Financial Services. The top panel displays the average level of cash rebates calculated as the total nominal value of cash rebates in a period divided by the total number of sales in that particular period. The top panel also shows the average present discounted value of reduced-rate financing. This is referred to as interest rate subvention or simply, interest subvention. The key to having subvented interest is that consumers who take advantage of financing incentives through the OEM's financial services companies receive a lower interest rate than they would have received elsewhere.

As seen in the chart, the two types of incentives have grown in value significantly in recent years. After varying little on balance from early 1998 through most of 2001, interest subvention shot up in October 2001. Following the attacks of September 11, General Motors announced a program that offered purchasers either zero percent financing for up to 60 months or a cash rebate. This proved to be immensely popular. In response, most other motor vehicle manufacturers also offered zero percent financing or boosted their incentive programs. In recent years, cash rebates have steadily moved higher.

The bottom panel of chart 1 shows two measures of how widely used the incentives have become. Recently, cash rebates are estimated to have been used in more than 60 percent of sales, and interest subvention occurred in more than 70 percent of purchases. Most incentive programs allow the consumer to take either the rebate or the special interest rate incentive but not both. However, it is possible that a buyer could accept the cash rebate and still receive a below market finance rate, although not the special rate offered in the incentive program. This may help explain the rather startling results in chart 1, which suggests that an overwhelming number of motor vehicle retail purchases since late 2001 received some type of sales incentive.

2.2 The Overview of the Database

The data shown in chart 1 and the data that we use in our analysis are from a database constructed by J.D. Power and Associates called the Power Information Network Explorer (PIN) database. This database contains daily information on motor vehicle transactions from dealerships around the country. The data are uploaded daily directly from the dealerships' finance and insurance (F&I) systems. The data are then checked for reporting or clerical errors before being made available to subscribers. The database is incredibly rich and includes a plethora of information on the type of vehicle sold, its cost, and its price. Two demographic variables, consumer age and gender, are also collected. The type of data collected in PIN are shown in table 1A. Categories that are in bold are used to generate our estimates and are explained a little later. According to J.D. Power, the PIN sample represents 70 percent of the geographical markets in the United States. Within those markets, J.D. Power collects data from roughly 1/3 of the dealerships and, all told, captures 15 to 20 percent of national retail transactions.[1] To examine motor vehicle incentives and prices, we used monthly transactions

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[1]PIN collects data in 26 U.S. markets in addition to Canada. The geographic markets as of late 2003 were Boston, New York, Philadelphia, Pittsburgh, Baltimore/Washington DC, Charlotte, Atlanta, Orlando, Tampa, Miami, Houston, Dallas/Fort Worth, Houston, Tulsa/Oklahoma City, St. Louis, Indianapolis, Cleveland, Memphis/Nashville, Chicago, Detroit, Minneapolis/St. Paul, Denver, Phoenix,

data on both purchased and leased new motor vehicles by model and by model year, e.g., 2001 Mercury Sable for a total of more than 35,000 observations.[2] Table 1B provides examples of the model-level detail as well as our nomenclature. For example, although we generally refer to the various observations as model-level data, for many vehicles the observations are at a more detailed level, what is commonly referred to as "trim level." For example, we include in our sample the model, Buick LeSabre. The trim level appellation is Buick LeSabre Limited. However, for some models in our sample (for example, the Mercedes ML320 or the BMW 325XI in table 1B), no further level of detail is available. Thus, our sample includes these models at essentially the trim level. We believe that our unit of observation, vehicles by model and model year, is at a sufficiently detailed level to accurately estimate the matched-model price indexes.[3]

Table 2 shows the number of models by model year. All told, we have observations on almost 500 models. We also collected information on the number of vehicles that are completely new to the market as well as the number that have received a major redesign. In 2001, the number of new models jumped by more than 60 and has since continued to show strong gains. Thus, our dataset is capturing an important development in vehicle markets during this period, when manufacturers were rapidly expanding the number of models in an attempt to fill various "niches" in the market. This assumption is supported by data from Ward's Communications (chart 2 and table 2), which also shows the number of unique models rising over time.

Table 3 summarizes other variables in our dataset. As shown in line 1, the average vehicle price before incentives in the sample is $30,293. This is above the implied average price

Los Angeles/San Diego, San Francisco/Sacramento, and Seattle/Tacoma/Portland.

[2]This is the number of observations before editing the original data pulled from PIN. Some observations were dropped from the matched model price indexes because they represented an extremely small number of sales transactions in a given month, and others were dropped from the hedonic regressions because of missing data in some other series that we used (such as market segment or door style).

[3] The PIN system classifies transactions at an even more detailed level, a level that PIN terms "trim-level." We have done some experimentation with these data, and have found that working at this level roughly doubles the size of the database while not materially changing results.

for automobiles and light trucks of about $26,000 used by the Bureau of Economic Analysis (BEA) in the NIPA accounts. However, the median vehicle price in our dataset is a little over $25,000, which is closer to the NIPA average.

Vehicle price less cash rebate (line 2) is a concept closest to what the Bureau of Labor Statistics (BLS) attempts to measure in the CPI for new motor vehicles. In general, customers are given a choice of either cash back or a reduced-rate financing when purchasing a vehicle. When this occurs, the BLS incorporates the value of the cash rebate into the price of the vehicle regardless of what the buyer actually chose.

Cash rebates (line 3) by model and model year were taken directly from the PIN database and the mean is the difference between the series in lines 1 and 2. As shown in line 4 of table 3, the average value of interest subvention ($1,131) in recent years has exceeded the value of cash rebates ($562).

If one believes that the value of all consumer incentives should be reflected in any measure of new vehicle prices, then the CPI as currently constructed has likely overstated consumer prices.[4] In contrast, the PPI, as a measure of the price received by the manufacturer net of any discounts, reflects the value of both cash rebates and interest subvention. Our series, price less cash rebates and subvention (line 5 of table 3) is the price series closest to the PPI concept.

Vehicle cost (line 6) measures the cost of the vehicle at the time of sale. It includes transportation charges and the cost of dealer add-ons such as roof racks and paint sealants. Ideally, vehicle cost would only include the cost of manufacturing and transporting the vehicle to the dealership. However, our cost measure also includes the value of factory-to-dealer cash incentives and dealer advertising allowances.

Cylinders (line 7) simple refers to average number of cylinders in each vehicle, and displacement (line 8) is included as a measure of engine size and measures the total volume (in liters) of all a vehicle's cylinders. As shown in line 10, the average age of consumers in our

[4]The CPI no longer includes the line item, "automobile finance charges" that was separate from the index for new vehicles. One could argue that interest subvention should not affect new vehicle prices, but should reduce overall consumer prices (Lebow, 2001). However, currently the overall CPI does not reflect the value of new motor vehicle interest subvention.

sample is 45 years, and the majority of purchases are made by men (line 11).

2.3 Estimating interest subvention

In our sample, we have the average interest rate received by those that obtained new vehicles (line 10 of table 3).[5] To generate subvention we first calculated the present discounted value of payments assuming a loan term of 48 months and using the average interest rate received for each model and model year. This allowed the interest rate for each model to vary. We then generated an alternative payment stream using the 48-month commercial bank motor vehicle loan rate as estimated by the Federal Reserve Board (FRB).[6] Benefits of using the FRB motor vehicle bank loan rate include its ready availability. However, a downside is that it assumes that everyone faces the same alternative interest rate. Data in table 4 from the 2001 Survey of Consumer Finances (SCF) suggests that this assumption may not be too egregious, although certainly further work is needed. Table 4 displays a few key characteristics of individuals who received loans for new automobiles or light trucks from the four largest providers of these services: commercial banks, finance companies, credit unions, and auto finance companies (GMAC, Ford Credit, etc.). Together these four types of institutions provide more than 90 percent of consumer vehicle loans. As can be seen in the table, customers vary little in terms of age and educational attainment across institutions. However, those who take out loans from finance companies (column 2) have lower home ownership rates than at the other institutions. In addition, those with loans at *auto finance* (column 4) companies have substantially higher mean wage income. Nevertheless, as shown in parentheses in the table, the standard errors for the wage measures is enormous, which makes it difficult to interpret the differences in wages across institutions.

As shown in table 4, the commercial bank interest rate (column 1) in the 2001 SCF

[5]We only have the purchase interest rate if the transaction was done through the dealership. Interest rates obtained by Individuals from outside sources are not in the PIN database.

[6]The FRB motor vehicle bank loan rate appears each month in the Consumer Credit (G. 19) release. For the survey, banks are asked to report "the most common" interest rate for new 48-month motor vehicle loans. The aggregate is the average of these reported rates.

averaged 9.2 percent, which is roughly midway between the rates charged by finance companies (column 2) and credit unions (column 3). Individuals with loans at auto finance companies (column 4) had the lowest rates.

One other downside of using the 48-month FRB commercial bank loan rate as the alternative in the subvention calculation is that it does not vary with the length of the loan, and the average loan term in our sample has gradually drifted higher over time. As shown in the top portion of chart 2, the average term length in our sample has increased from an average of about 48 months in early 1998 to about 58 months in January 2004. Since longer loans frequently carry higher interest rates, interest subvention may be understated in more recent periods. In order to mitigate this effect to some extent, we adjusted the FRB loan rate in cells with average terms of 60 months or more based on the average wedge between the 48-month and 60-month new auto loan rates in a sample of large commercial banks as reported in the Bank Rate Monitor.

The bottom portion of chart 2 shows the average interest rate in our sample (referred to here sample rate) and the FRB 48-month commercial bank rate. As shown in chart 2, the FRB commercial bank and sample rates followed each other reasonably closely until late 2001, when a sizeable gap opened up. Over the past year or so, the sample rate has held steady while the FRB bank rate has edged lower. Although the gap between the two has narrowed, the sample rate remained below the FRB commercial bank rate by roughly one percentage point at the turn of the year. This is consistent with the top panel of chart 1 which shows that subvention has changed little on balance since early 2003 while cash rebates have climbed higher.

3. Vehicle Sales and Prices over the Model Year

This section establishes several features of retail light vehicle markets that are important considerations for measuring light vehicle purchase prices over a model year. These features both interact and overlap with the need to fully capture interest subvention and cash-back incentives in the resulting price measures, and they underscore the utility of viewing the demand for consumer goods that undergo recurring changes, upgrades and/or redesigns in a user cost framework.

We first review model year trends in vehicle sales, production, prices, and costs by model year, and then we consider how conventional index number theory can be used to develop aggregate price measures for purchases of light vehicles in recent years.

3.1 Retail vehicle markets

Table 5 reports the number of continuing, entering, and exiting models per period, and by model year, in the dataset we constructed from the J.D. Power and Associates' PIN Explorer Database. These figures illustrate three properties of our data and retail vehicle markets: First, in any given month, as indicated by the row labeled "continuing" models, a significant number of the total number of marketed models are available for computing price change from one period to the next. Second, as seen in the columns that break down the more than 400 continuing models per month by model year, these models—all newly produced vehicles—are from more than one model year. Third, as indicated on the rows labeled "entering" models and "exiting" models and illustrated in chart 4, most new model-year vehicles are introduced in the third quarter (August and September), reflecting the model year changeover in production. The clearing of "old" model-year vehicles from dealers' lots, however, occurs relatively smoothly over the calendar year.

All told, the table indicates that *newly produced* vehicles of a given model year are almost always marketed simultaneously with *newly produced* vehicles of an adjacent model year. Chart 5 plots the monthly expenditure shares by model year over time. As may be seen, the key model year selling-period for newly produced vehicles runs roughly 18 months (from July of the calendar year preceding the model year designation through about December of the following year) and thus overlaps with the selling-period of the preceding- or following-year vehicles for a considerable time. Moreover, while spending does shift noticeably to new model year vehicles during the late summer/early fall (August, September, October), unlike the abrupt model year changeover in production, the transition in spending by model year occurs relatively smoothly. These differential production and spending patterns by model year show through in the composition and "age" of dealers' inventory by model year. As noted earlier, the average value of days-to-turn by model year increases over the model year, with the increase especially sharp *after* the production changeover to new model year vehicles.

The within-year pattern of prices by model year is shown in chart 6. The upper panel shows matched-model price indexes calculated for each model year using the price measure after customer cash rebate and interest subvention. Because our dataset has both prices and transactions counts, and because a nontrivial number of monthly observations are for essentially identical vehicles whose prices are observed in adjacent periods, these indexes were computed using a superlative index number formula. In the chart, each model year price index is set equal to 100 in July of the year at introduction and is plotted through the end of following calendar year. As may be seen, our data show that vehicle prices after cash rebates and interest subvention drop steadily over the 18-month selling-period plotted in the graph.

Matched-model price indexes by model year were computed for our other price measures (price after customer cash rebate and price before customer cash rebate) and are shown in the bottom half of the chart. As may be seen by comparing the behavior of the different measures in the chart, as well as the results shown in the in-text table below, the magnitude of the within-year drop in vehicle prices increases as the price concept is broadened to capture all forms of incentives.

As shown in table 6, the effect of the sharp increase in the value and incidence of interest subvention shows through in the divergence between the broadest price measure (line 1) and the measure that just excludes cash rebates (line 2). The price indexes diverge noticeably in 2001 and 2002. The underlying quantity data used for weighting all indexes in the table and chart are the actual quantities sold per period, and the results suggest that these magnitudes have been affected by the average size, prevalence, and type of incentive offered for each vehicle. When General Motors offered zero interest finance rates on their makes in the wake of 9/11, and then again in the fall of 2002 to clear unwanted stocks, consumer expenditure patterns shifted noticeably toward these models. When these expenditure patterns are applied to price measures that do not include interest subvention, as may be seen in the chart, the resulting price indexes post a temporary increase.

As previously indicated, the J.D. Power data also contain information on dealers' vehicle costs, and we can use this information to calculate matched-model indexes of vehicle cost by model year. The indexes of vehicle cost, which are shown as a memo item in the in-text table, change little over the model year and suggest that the downward trend in light vehicle prices over the model year does not stem from changes in underlying producer costs. As a result, we interpret the decline in vehicle purchase prices over the model year as largely a demand-driven phenomenon.[7]

The retail price differentials by model year could reflect consumers' valuation of the change in vehicle quality in moving from one model year to the next: Each model year, the makers redesign and improve the models they produce, which creates a "vintage" effect that can be controlled for by holding constant the appropriate (physical or other) characteristics of the individual models, such as is being done the matched-model indexes by model year. Alternatively, the simultaneous marketing of *newly* produced vehicles of different "ages" could be causing the cross-sectional variation in prices according to vehicle model year. The advent of the next model year's production induces obsolescence (through loss of "newness") and a loss in value over the year. This suggests the "within-year age" of a newly produced vehicle is an important characteristic determining its price over the course of the model year.

Whatever the underlying cause, the within-model year price drops are more readily understood from the perspective of the user cost model of durable goods. A rental price, derived from the user-cost approach, represents the payment per unit of time for the services of a unit of the good, and it incorporates information about financing, expected depreciation (or resale value), and the purchase price of the good. Ignoring taxes, the implicit rental price of a vehicle for a year (RP_t) is the opportunity cost of holding the vehicle plus the expected loss of value of the vehicle over the year:

$$RP_t = r_t P_t + [P_t - EP_{t+1}]$$

where r_t is the rate of interest, P_t is the purchase price, and EP_{t+1} is the expected value of the purchase after a year. If consumers are indifferent between the instantaneous (transportation) services yielded by a given, newly produced model sold in a given model year selling-cycle (at

[7] The relative supplies of vehicles by model year at the beginning of the selling-period and the dealers' need to manage inventory may also be a contributing factor. Comparing the results for the price measure after cash rebates and interest subvention, the price before incentives, and vehicle cost, about two-thirds of the downward trend in consumer prices stems from marketing incentives that are paid for by the makers, and, by implication, about one-third of the intra-year variation is accounted for by dealer markups.

any time), and if the expected loss of value of the vehicle is associated with the vintage of production (rather than physical age) of the vehicle, then the user-cost approach suggests the purchase price of vehicles will fall over the model year.

3.2 Aggregate vehicle purchase price indexes

We now consider the application of a conventional index number formula to our dataset. The availability of prices, quantities, and a nontrivial number of monthly observations on essentially identical items whose prices are available in adjacent periods suggests an aggregate price index—not just indexes by model year—can be computed using a matched-model superlative index number formula.

The matched-model Törnqvist price index, for example, is a weighted geometric mean of price ratios of homogeneous items, denoted by the subscript "j", in two periods using an average of each item's revenue share in the two periods as weights. In logs the aggregate price, P^*, from t-1 to t is expressed as

(1) $$ln\, P^*_t - ln\, P^*_{t-1} = \sum_{j \in Mt/t-1} s_{j,t} \,(ln\, P_{j,t} - ln\, P_{j,t-1}) ,$$

where $$s_{j,t} = ½\,[PQ_{j,t} / \sum_{j \in Mt/t-1} PQ_{j,t} + PQ_{j,t-1} / \sum_{j \in Mt/t-1} PQ_{j,t-1}] .$$

Summation over matched models is denoted as $\sum_{j \in Mt/t-1}$, where the number of homogeneous varieties produced or sold in each period is given by M_t, and the number produced or sold in adjacent periods is $M_{t/t-1}$, (that is, $M_t \cap M_{t-1}$). When the results of (1), as well as results using the closely related Fisher formula, are chained together over T periods, the price index will be exact for periods before and after changes in the composition of $M_{t/t-1}$ (Diewert 1987).[8]

In view of the discussion in the previous section, however, it's not entirely clear just how the observations in our dataset should be "matched." For example, two alternatives for "matching" are as follows:

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[8] Although this procedure makes no special allowance for entry and exit, when entering and exiting items are essentially perfect substitutes for continuing items (and under certain assumptions about consumer preferences), the resulting aggregate price index approximates an exact index for all periods (Feenstra 1994).

(I) Because the physical characteristics of a vehicle only change with the advent of a new model year, match adjacent month prices of a given model in a given model year, and treat models at the close of one season versus those at the beginning of another as separate items in (1),

(II) Because the intra-year change in the valuation of a vehicle (with otherwise fixed attributes) is a systematic, recurring phenomenon, match adjacent *year-and-month* observations of a given model (irrespective of model year), thus viewing vehicles as "weakly seasonal" commodities.[9]

Note that to implement alternative (I), the formula (1) is applied to all months and all model years in our data, which yields an aggregate price index that can be built in two steps: First, monthly matched-model price indexes by model year are calculated by applying (1) to the data *in each row* of table 5, yielding the model year price indexes previously shown in chart 5. Second, the monthly model year price indexes are aggregated, also according to (1), using the expenditure shares by model year, also previously shown, in chart 6.

The second alternative (II) compares prices of models from one model year to the next, holding the month in the year constant. In effect, a model in each season of the year is treated as a separate "annual" commodity. To implement this alternative, we need a variant of the year-over-year indexes suggested by Diewert (1998, 2003) that accounts for the model-year dimension in our data. Denote the number of models from model year *v* being sold in month *m* in year *t* as $M_{v,t,m}$, and denote the set available from one year to the next *and* from one model year to the next as $M_{v/v-1,t/t-1,m}$ (that is, $M_{v,t,m} \cap M_{v-1,t-1,m}$). Define the expenditure share for model *j* of model year *v* in month *m* in year *t* as

$$s_{(j,v),(t,m)} = PQ_{(j,v),(t,m)} / \sum_v \sum_{j \in Mv/v-1,t/t-1} PQ_{(j,v),(t,m)}$$

[9] The treatment of seasonal commodities in index numbers has a long history, summarized and extended by Diewert (1998, 1999, and 2003); see also Balk (1980). The term "weakly seasonal" refers to seasonality that originates from custom, rather than climate – a classification that Diewert (2003; 1) notes dates back to Wesley Mitchell (1927; 236) at least.

and apply the following formula to all months and all model years in the data:

$$(2) \qquad ln\, P^{*}_{t,m} - ln\, P^{*}_{t-1,m} = \sum_{v} \sum_{j \in Mv/v-1,t/t-1} [\, (s_{(j,v),(t,m)} + s_{(j,v-1),(t-1,m)})/2 \,] * [ln\, P_{(j,v),(t,m)} - ln\, P_{(j,v-1),(t-1,m)}\,].$$

The summation over model years and models picks up all of the models being sold in a given period for which a year-over-year/model-year to model-year comparison can be made. Although this notation is not explicit about the month that the model year advances compared with the advancement of the calendar year, we could note that V=T +1 (or T, or T-1) if m=7..12, whereas V=T (or T-1, or T-2) if m=1, 6, and so on.

This year-over-year index applies (2) to all available observations on continuing models, where continuing refers to the matching of model year/month-year price observations with those from the previous year. Observations on new models are thus not in $M_{v/v-1,t/t-1,m}$ until the *end* of their introductory model-year selling-period, when the production of the next model year begins to be marketed—a procedure that implicitly ignores changes in quality (and price) that accompany the introduction of new models. For models that continue from one year to the next, even when redesigned (but with no name change), all changes in price are included in the aggregate price measure.

Aggregate indexes for the price measure after cash rebate and interest subvention under the alternative matching assumptions are shown in rows 1 and 2 of table 7. As may be seen, the index calculated under alternative (I) drops noticeably over time, with the twelve-month percent change averaging -6 percent for the periods shown. This large cumulative drop essentially reflect the chaining together over time of the recurring within-year price declines shown earlier. By contrast, the aggregate year-over-year index calculated under matching assumption (II) is about flat, on balance, for the years shown. In view of our earlier discussion of the importance of the intra-year "age" of a vehicle as a determinant of its price, the alternative (I) index clearly would seem to overstate the overall decline vehicle prices. However, the relative flatness of the year-over-year index likely stems from its inherent inability to account for quality change in newly introduced or redesigned vehicles, suggesting that neither matching alternative can be used to construct an accurate monthly price measure for light vehicles.

Turning to rows 3 through 8 of the table, and stepping back from the issue of how to match, aggregate price indexes for each price concept using two index number formulations —the Törnqvist, and geometric mean—are shown.[10] The geometric mean indexes we calculate use (1) with $s_{m,t}$ replaced by $1/M_{t/t-1}$. Notice that, when the weighted formula, the Törnqvist, is applied to prices before cash rebates and prices after cash rebates, the resulting indexes fall noticeably more slowly than the indexes that use the geometric mean formulation. However, when the alternative index formulations are applied to prices after cash rebates *and interest subvention*, the results are not materially different from one another, suggesting that price movements for vehicles that are close substitutes to one another are highly similar once subvention is taken into account.[11]

In the next section we employ a regression approach to determine the aggregate price change for motor vehicles using our broadest price measure, the price excluding cash rebates and interest subvention. When the typical hedonic regression is applied to a dataset in which earlier and later varieties overlap with currently marketed items for much of the time (as was shown in table 5), the dominant term in the estimate of aggregate price change is a geometric mean of price change for continuing varieties (Triplett and McDonald 1977; Aizcorbe, Corrado, and Doms 2000). Thus, a hedonic price index applied to our broadest price measure will not need to be weighted to obtain an appropriate measure of price change.

4. Hedonic Regressions

Motor vehicles have long been a popular subject for the application of the hedonic technique. Many studies of car prices have employed hedonics ever since Zvi Griliches (1961) revived the work of Andrew Court (1939), who computed a regression of automobile prices

[10] The Fisher formulation was also computed, and the results were identical to the Törnqvist.

[11] The geometric mean formulation produces pretty much the same result as a weighted, or superlative, formulation when the prices of the items being aggregated move in pretty much the same proportions, as one might expect if the items are close substitutes (Abraham, Greenlees, and Moulton 1998), such different brands of essentially the same sport utility vehicle, for example.

against weight, wheelbase, and horsepower in order to measure price change over time.[12] For the most part, the empirical hedonic technique is a simple one, and studies rest on the breadth and ability of attribute data to explain cross-sectional variation in prices over time. In this regard, several aspects of some of these early studies should be noted for our work: First, the new car price measures used in prior studies are almost always manufacturers' *list prices at the start of the model year*. Second, "make effects" – whether representing omitted physical characteristics, differential market power, or brand loyalty considerations – have been found to be a powerful determinant of the cross-sectional variation in car prices (Dhrymes 1971, Ohta and Griliches 1975). Lastly, the literature has also cautioned that, as the automobile has evolved over time, the physical attribute data that worked so well in the hedonic models used by Court and Griliches[13] could not continue to adequately represent what the automobile "does" for its buyer (Triplett 1990).

Numerous studies of vehicle demand have speculated or documented that the "newness" of a new vehicle is a demand characteristic. In particular, Wykoff (1970) and Ohta and Griliches (1975) estimated higher rates of depreciation in the first year, compared with rates for the second and later years. Although these studies suffer from having had to rely on list, rather than transactions, prices for new vehicles, there is no reason to believe that vehicle deterioration (or physical decay) occurs in this fashion. It thus seems more plausible that obsolescence accounts for the rapid early loss in value (Wykoff 1973). Relatedly, and more recently, Pashigian, Bowen, and Gould (1995) examined the within-year decline in the not seasonally adjusted CPI for new cars by segment, which is based on transactions prices. They found that the within-year percentage declines are larger for segments that undergo more frequent styling changes, suggesting that obsolescence accounts for much of the cross-sectional variation in new vehicle prices across model years.

The typical hedonic regression expresses the prices of models in terms of the quantities of

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[12] These studies include, among others, Triplett 1969, Dhrymes 1971, Griliches 1971b, Ohta and Griliches 1975, and Gordon 1990 (Chapter 8).

[13] See also Raff and Trajtenberg 1997, who studied pre-WWII prices.

characteristics contained in each model in the period and dummy variables in time. While our empirical strategy blends various strains of the literature, the basic model we use follows Ohta and Griliches. They specified the hedonic function for vehicle prices in terms of measurable and unmeasurable characteristics of each model, and included make effects—to account for markup pricing that was assumed to dominate the new car market—and terms to capture depreciation when the sample included used, as well as new, vehicles.

The measurable physical characteristics that we have include indicators of engine performance (number of cylinders, engine displacement) and door style (represented by eight dummy variables for "cargo", "crew cab", "2-door", etc.) of each model. The unmeasured (fixed) physical characteristics are represented by a dummy variable for each unique model in the sample. Because the characteristics of a vehicle are fixed over its selling cycle, and because each model of vehicle has many observations, these dummy variables account for much of the cross-sectional variation in prices. In particular, they capture the "make (or segment or brand) effects" as model-specific values for coefficients on the unmeasured characteristics.[14]

The presence and significance of within-year obsolescence is captured by including dummy variables for the different vintages of current production being sold at a given point in time. The dummy variable is designed to represent the "age" of the model in years so that, with the hedonic regression in semi-logarithmic form, its coefficient represents the rate of depreciation (loss of value) in a vehicle after being marketed for a year. Specifically, we define age as a function of the model year: In the first half of each calendar year, all vehicles with model years equal to the current calendar year are considered the newest vintage, while in the second half of the year, all vehicles with model years one greater than the current calendar year are defined to be age zero. Thus, a 2001 model introduced in September of 2000 will be age zero in the second half of 2000 and the first half of 2001, and then will increase to age one after being on the market for a

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[14] When there are nontrivial sets of overlapping data on homogeneous models (or varieties) from one period to the next, and the coefficients on each characteristic are allowed to vary by model, the hedonic regression can be expressed as a fixed-effects model in which each unique model is assigned a dummy variable that captures the average value of its unique characteristics on its price (Aizcorbe, Corrado, and Doms 2000). Note that the fixed-effects model is very demanding of the data (Aizcorbe, Corrado, and Doms 2003), but as discussed and illustrated in sections 2 and 3, abstracting from within-year effects, our data conform to the demands of this model.

year. In practice, given the average 18 month selling cycle of each model-year vehicle, nearly all transactions are for models of age zero or one; we therefore treat observations of new vehicles of age greater than one or less than zero as outliers and drop them from the sample.

The general form of the hedonic regression we estimate is then as follows:

(3) $$\ln P_{m,t} = {}_{m}\,{}_{m}\, MD_{m} \quad {}_{k}\,{}_{k}Z_{k,m,t} \quad \alpha A_{m,t} \quad {}_{t}\,{}_{t}TD_{m,t} + {}_{m,t}$$

where $\ln P_{m,t}$ = natural logarithm of the price of model m at time t (divided by the NIPA PCE price index for nondurable goods and services).

$MD_{m,t}$ = 1 if the price is for model m, and
= 0 otherwise.

$Z_{k,m,t}$ = the value of characteristic k for model m at time t.

$A_{m,t}$ = the age of model m (in model years) at time t.

$TD_{m,t}$ = 1 if a price for model m is observed at time t, and
= 0 otherwise.

and where ${}_{m}$, β_k, α, ${}_{t}$, and ${}_{m,t}$ denote econometric estimates. Changes over time are identified by the coefficients on the time dummies for each time period in the sample.

For comparability with previous studies, and to test several alternative specifications, we first run regressions on annual data only, using the observations in October of each year (a month in which many new and old vintages are sold at the same time). The estimated coefficients from the baseline hedonic regression are shown in the first column of table 8. As can be seen in the table, the physical characteristics are marginally significant. Although we do not report the estimates for the dummy variables that were included in the set of regressors, they are strongly significant and appear to capture the large portion of cross-sectional variation in vehicle performance. The time dummies are also significant, and as illustrated by the annual listed in the bottom of the table, they imply a negative pure price change over the sample period. Near the bottom of the table we report the coefficient on age, which provides a measure of the within-year obsolescence effect. In the baseline regression, the coefficient implies that new vehicles experience a loss in value of percent per year.

In a second regression, we attempt to refine the set of characteristics by treating models that were redesigned without a name change as separate models. We accomplish this by including additional dummy variables for the model-year vehicles that experienced a major design change.[15] An example is the Honda Accord, which went through major redesigns in the 1998 and 2003 model years. In this case, we would include two dummy variables for the Accord, one for the first design sold from 1998 to 2002, and another for the design introduced in 2003 and sold through the end of the sample. Allowing for separate dummy variables for redesigned models relaxes the assumption of no quality change between successive model years other than that captured by the observed physical characteristics (cylinders, displacement, and door style). All told, there are 595 model/platform dummy variables.

The results of this regression with model and platform dummies are reported in the second column of table 8. The overall explanatory power of the regression is a bit higher than in the baseline regression, though the estimated coefficients on age and the physical characteristics are not very different. The age coefficient implies a slightly smaller rate of obsolescence, about 7.5 percent per year, and it is significant with 95 percent confidence. The time dummies, which are also jointly significant, imply a larger overall decline in prices over the sample period.

In a third regression, we allow the coefficient on age to vary for vehicles of different market segments. Table 9 illustrates that new vehicle introductions and redesigns occurred with much greater frequency in two of the eight J.D. Power market segments, namely, SUVs and luxury vehicles. One might expect that the rates of obsolescence in these two categories would be different than for other vehicles that undergo less frequent styling changes or new product introductions. To test whether the effects of age vary by market segment, we add separate age variables interacted with these two market segments to the regression. The results are reported in column 3 of table 8. Two of the three age variables are statistically significant. Although SUVs appear to depreciate at the same rate as other vehicles after they are introduced, the positive sign on the luxury variable interacted with age implies that, all else equal, new vehicles in the luxury segment depreciate *less* over the model year than other vehicles. While the other vehicles appear to lose their value at an annual rate of 8.7 percent, luxury vehicles decline by just 2.5 percent

[15]Using data on vehicle platforms by model year obtained from Ward's Communications, we identified models that had been through a major redesign as those that had changed platforms from one year to the next. We verified the accuracy of these data using new vehicle reviews and summary articles on vehicle redesigns obtained from http://www.edmunds.com.

(-8.7+6.2) per year.

Finally, we turn our attention to the implications of the hedonic regressions for the pattern of price change over time. In order to construct a monthly hedonic price index that spans the entire sample period, we adopt the final specification presented above and run the regression on all of the available monthly data from January 1998 to December 2003.[16] Figure 7 plots two of the resulting hedonic price indexes—one for the price after cash rebates, and the second for prices net of both cash rebates and interest subvention. Over the entire five-year period, prices net of rebates and subvention decline an average of one percent per year. And as discussed earlier, the effects of financing incentives are striking—in late 2001 and early 2002, prices after cash rebates and interest subvention drop sharply, while prices without interest subvention actually rise for some time before dropping back in mid-2002.

5. Conclusions

In this paper we document several interesting empirical observations in aggregate prices for motor vehicles based on a rich dataset of both monthly quantities and transaction prices. First, we show that financing incentives play in integral role in understanding recent movements in aggregate prices. We also find that in retail vehicle markets multiple vintages of the same models are sold simultaneously, a feature that presents challenges for measuring vehicle purchase prices. We examine within model-year price movements and find that vehicle prices drop rapidly in the months following their introduction, often in large part through the use of marketing incentives.

Finally, by employing a hedonic regression, we are able decompose the overall price change into two components, obsolescence and the pure time effect. We find that, in addition to the usual characteristics, the "age" of newly produced vehicles is an important characteristic that is needed to accurately determine price change. The resulting monthly hedonic price index drops roughly one percent per year over the period from 1998 to 2003.

[16] In the monthly regression, age is expressed as the number of months that have elapsed since June of the year in which a given model has been introduced. We drop those few observations that have a negative age in months, i.e. that were introduced before mid-year.

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Table 1A. Information available in the PIN database on new retail motor vehicles

Model	Engine	AH insurance premium	Trade in amount
Model year	Transmission	Life insurance premium	Trade in over/under allowance
Vehicle price	Fuel	Lease/finance or cash purchase	Trade in equity
Vehicle price less customer cash rebate	Aspiration (turbo)	monthly payment	Vehicle gross
Vehicle cost	Origin	amount financed	Vehicle profit margin
Days-to-turn	Make	Down payment	Vehicle profit markup
Cash rebate	Nameplate	term	Buy rate APR/IRR
Interest rate received	Drive type	Money factor, lease	Finance reserve
Doors	Exterior color	Residual, lease	Service contract costs
Cylinders	Fuel type	Cap reduction, lease	Service contract income
Displacement	Segment (compact car)	Lender/lessor name	AH insurance cost
Trim/series	Subsegment (premium compact car)	Captive flag	AH insurance income
Body type	Service contract premium	trade in cash value	Buyer age and gender

Source: J. D. Power and Associates, 2002. Includes purchased and leased vehicles.

Table 1B. Examples of Nomenclature in the Authors' database

Manufacturer	Nameplate	Model	Trim level	Model year
General Motors	Buick	LeSabre	LeSabre Limited	2001
BMW Group	BMW	325XI	n.a.	2003
Ford	Mercury	Sable	Sable GS	2000
DaimlerChrysler	Mercedes-Benz	ML 320	n.a.	1998

Source: Extracted from J. D. Power and Associates' PIN database.

Table 2. Number of models by model year.

Model Year	Total	New	Major Redesigned	**Memo: Wards Communications[1]**
1998	234	–	–	237
1999	256	28	16.	245
2000	262	33	24	248
2001	290	61	16	252
2002	310	45	14	270
2003	311	43	15	266
2004	308	35	13	278
Total, all years[2]	480	245	98	n.a.

Source: Authors' database constructed from J.D. Power and Associates' PIN Explorer Database; information provided by Rod Tadross, Banc Securities; and Edmunds.com.

1. Number of models as of December in the year indicated.
2. The figures for all years are net from the beginning of the 1999 model year.

Table 3. Summary Statistics on Vehicle Database[1]

	Variable	Mean	Median	Standard deviation	Minimum	Maximum
1.	Vehicle price	$30,293	$25,324	$16,780	$7,690	$152,176
2.	Vehicle price less cash rebate	$29,731	$24,525	$16,940	$5,610	$152,176
3.	Cash rebate	$562	$170	$844	0	$6,751
4.	Interest subvention	$1,131	$335	$1,035	0	$5,976
5.	Vehicle price after cash rebate and mean subvention	$28,600	$23,395	$16,941	$4,740	$152,176
6.	Vehicle cost	$29,098	$24,565	$16,009	$7,350	$168,152
7.	Cylinders	6	6	1.5	3	12
8.	Interest rate received (percent)	7.3	7.4	2.7 (pct. pt.)	0	27.6
9.	Displacement (liters)	3.7	3.3	1.4	1	8.3
10.	Customer age (years)	45	44	7.1	18	100
11.	Percent male (percent)	68	68	–	38	87
	Memo:					
	Total number of available observations	35,764				

1. Values are calculated over all models and model years. Current dollars. Data were extracted from J. D. Power and Associates PIN database.

Table 4. Key Characteristics of Buyers by Loan Originator (standard deviations are in parentheses)

	Loan Originator			
	Commercial Banks (1)	Finance Companies (2)	Credit Unions (3)	Auto Finance Companies (4)
Mean:				
Age (years)	43.5	42	43	45
	(12.7)	(12.4)	(12.7)	(13.3)
Educational attainment (years)	13.5	13.2	13.9	14.1
	(2.8)	(2.4)	(2.2)	(2.2)
Wages (thousands of current dollars)	77	65	60	102
	(316)	(82)	(63)	(243)
Percent:				
Who own their home	70%	56%	71%	70%
Average interest rate	9.2%	10.9%	8.7%	7.6%
Memo: Share of new vehicle loans[1]	29%	29%	22%	11%

1. The remaining sources of loans include savings and loans, savings banks, the dealer, or the prior owner.
Source: The Survey of Consumer Finances, 2001, Board of Governors of the Federal Reserve System.
Observations total 1,093 respondents.

Table 5. Number of continuing models by model year, average monthly rate per quarter, 1998Q4 to 2003Q4

Model Year	1998	1999				2000				2001				2002				2003			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1998	182	130	58	15																	
1999	201	246	248	238	202	152	75	18													
2000		1	9	63	219	250	257	247	209	161	97	38	7	1							
2001						4	20	88	250	277	284	272	249	172	94	30	2				
2002											13	80	274	301	303	289	244	165	99	39	6
2003														4	18	85	261	299	303	293	261
2004																		3	25	102	272
Total Continuing	382	377	315	316	421	406	352	353	460	449	394	390	530	477	415	404	508	467	427	435	539
Memos: Entering	29	4	6	58	18	9	7	64	17	7	7	71	21	5	9	67	20	9	12	63	24
Exiting	16	18	26	17	17	17	30	20	20	16	23	25	18	30	28	25	24	26	26	23	22
Total marketed	411	381	321	374	439	415	359	417	476	446	401	461	551	482	424	471	538	476	439	498	563

Note: Components may not sum to totals due to independent rounding. Exiting models are counted in month t+1, i.e., the period in which a match cannot be made. Total marketed is the sum of continuing plus entering models.

Source: Authors' data set constructed from J.D. Power and Associates' PIN Explorer Database. In the authors' data set, PIN transactions for a model in a month that preceded or trailed the primary selling period for the model by more than one month were not include

Table 6. Percent change in model year price index, September to September

Measure	Model year of index (and ending year for percent change) 1998	1999	2000	2001	2002	2003	Average
1. Price after cash rebate and interest subvention	–5.1	-4.6	-5.1	-7.2	-5.7	-8.5	-6.0
2. Price after cash rebate	-3.7	-3.9	-3.3	-4.7	-3.0	-7.7	-4.4
3. Price before incentives	-2.2	-2.2	-1.5	-2.5	-2.2	-2.3	-1.9
Memo: 4. Vehicle cost	-1.6	-.1	-.3	-.3	-.4	-.4	-.2

Source: Authors' calculations using a data set constructed from J.D. Power and Associates' PIN Explorer Database.

Table 7. Percent change in aggregate vehicle price index, December to December

Measure	Ending year of change 1999	2000	2001	2002	2003	Average
Price after cash rebate and interest subvention, Törnqvist formulation						
1. Alternative (I)	-2.9	-6.1	-6.3	-7.1	-8.3	-6.1
2. Alternative (II)	1.1	.2	-.5	-.1	.3	.2
Price after cash rebate and interest subvention, Alternative (I)						
3. Törnqvist	-2.9	-6.1	-6.3	-7.1	-8.3	-6.1
4. Geomean	-3.3	-5.6	-6.5	-7.4	-8.3	-6.2
Price after cash rebate, Alternative (I)						
5. Törnqvist	-3.2	-3.8	-3.5	-5.6	-7.9	-4.8
6. Geomean	-4.2	-5.1	-4.9	-7.4	-9.0	-6.1
Price before incentives, Alternative (I)						
7. Törnqvist	-1.6	-2.1	-2.4	-2.5	-3.1	-2.3
8. Geomean	-3.1	-4.1	-4.8	-5.6	-5.9	-4.7
Memo:						
9. CPI for new vehicles	-.5	.0	-.1	-2.0	-1.9	-.9

Table 8. Hedonic Regression Results, Price After Cash Rebate and Interest Subvention

log(cylinders)	0.22	0.09	0.09
	(0.10)*	-0.11	-0.11
log(displacement)	0.27	0.40	0.38
	(0.11)*	(0.12)**	(0.12)**
2 door	-0.05	0.43	1.15
	-0.33	-0.34	(0.35)**
4 door	-0.14	0.43	1.14
	-0.32	-0.34	(0.35)**
4 door extended cab	0.00	0.00	0.59
	0.00	0.00	-0.37
Cargo	-0.23	-0.22	-0.12
	-0.35	-0.35	-0.07
Crew cab	-0.01	-0.02	0.57
	-0.06	-0.09	-0.37
Extended cab	-0.06	-0.08	0.52
	-0.06	-0.08	-0.36
Extended cargo	-0.08	-0.09	0.00
	-0.35	-0.34	0.00
Extended passenger	-0.07	-0.09	0.00
	-0.32	-0.32	-0.13
Passenger	0.73	0.74	0.85
	(0.37)*	(0.37)*	(0.14)**
Regular cab	-0.20	-0.18	0.42
	(0.07)**	(0.08)*	-0.36
1999 dummy	-0.02	-0.02	-0.02
	-0.02	-0.02	-0.02
2000 dummy	-0.07	-0.08	-0.08
	(0.02)**	(0.02)**	(0.02)**
2001dummy	-0.12	-0.13	-0.13
	(0.02)**	(0.02)**	(0.02)**
2002 dummy	-0.12	-0.14	-0.14
	(0.02)**	(0.02)**	(0.02)**
2003 dummy	-0.16	-0.18	-0.18
	(0.02)**	(0.02)**	(0.02)**
Age	-0.08	-0.08	-0.09
	(0.01)**	(0.01)**	(0.01)**
Age*luxury segment			0.06
			(0.02)**
Age*SUV segment			0.00
			-0.02
Observations	3191	3191	3190
R-squared	0.88	0.89	0.89
Implied time index:			
1998	1.000	1.000	1.000
1999	1.014	1.011	1.012
2000	0.996	0.988	0.990
2001	0.957	0.946	0.947
2002	0.968	0.951	0.953
2003	0.952	0.933	0.933

Standard errors in parentheses

* significant at 5%; ** significant at 1%

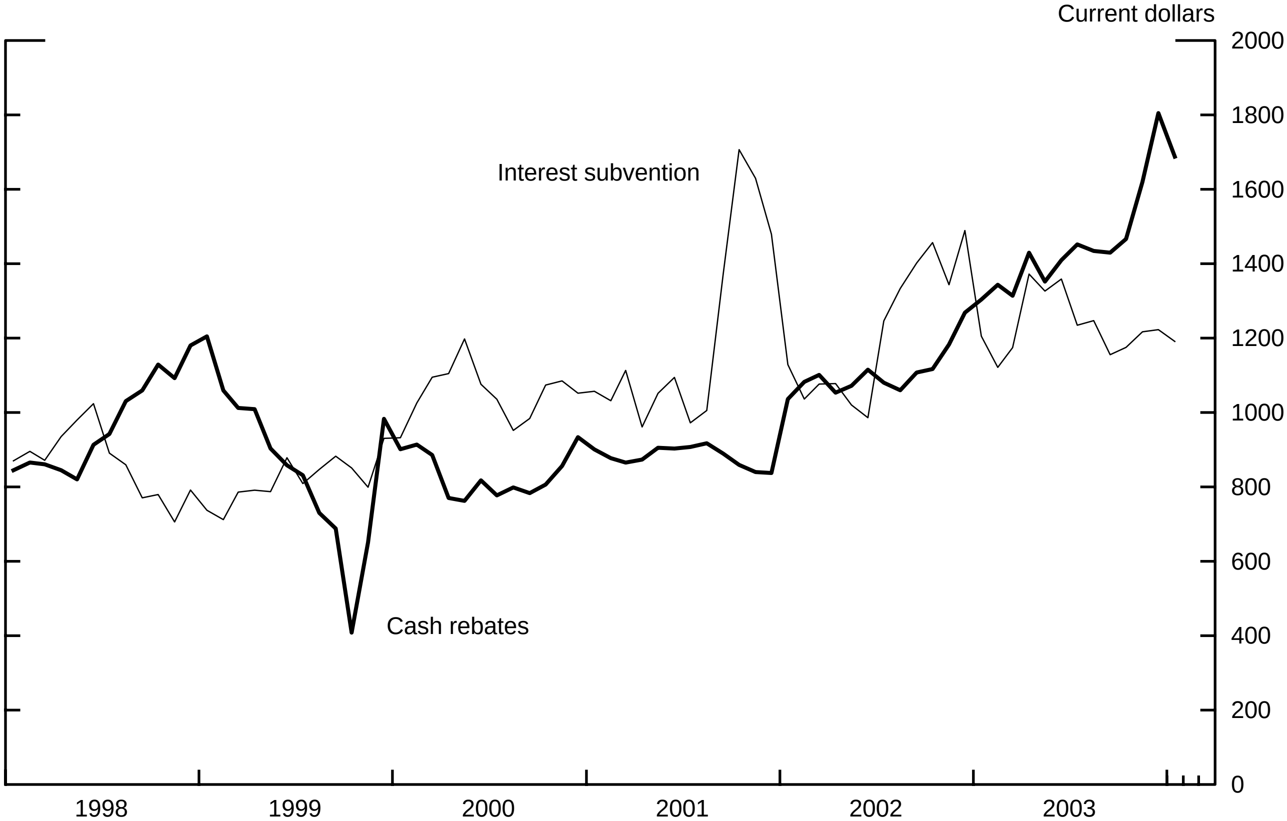
Table 9. New Model Introductions and Redesigns by Market Segment, 1999-2004

Market Segment	Number New or Redesigned	Total
Compact Car	687	3,768
Fullsize Car	76	705
Luxury Car	1,272	7,259
Midsize Car	654	4,462
Pickup	593	3,754
Utility Vehicle	1,321	6,986
Sporty Car	538	3,398
Van	407	3,705

Chart 1

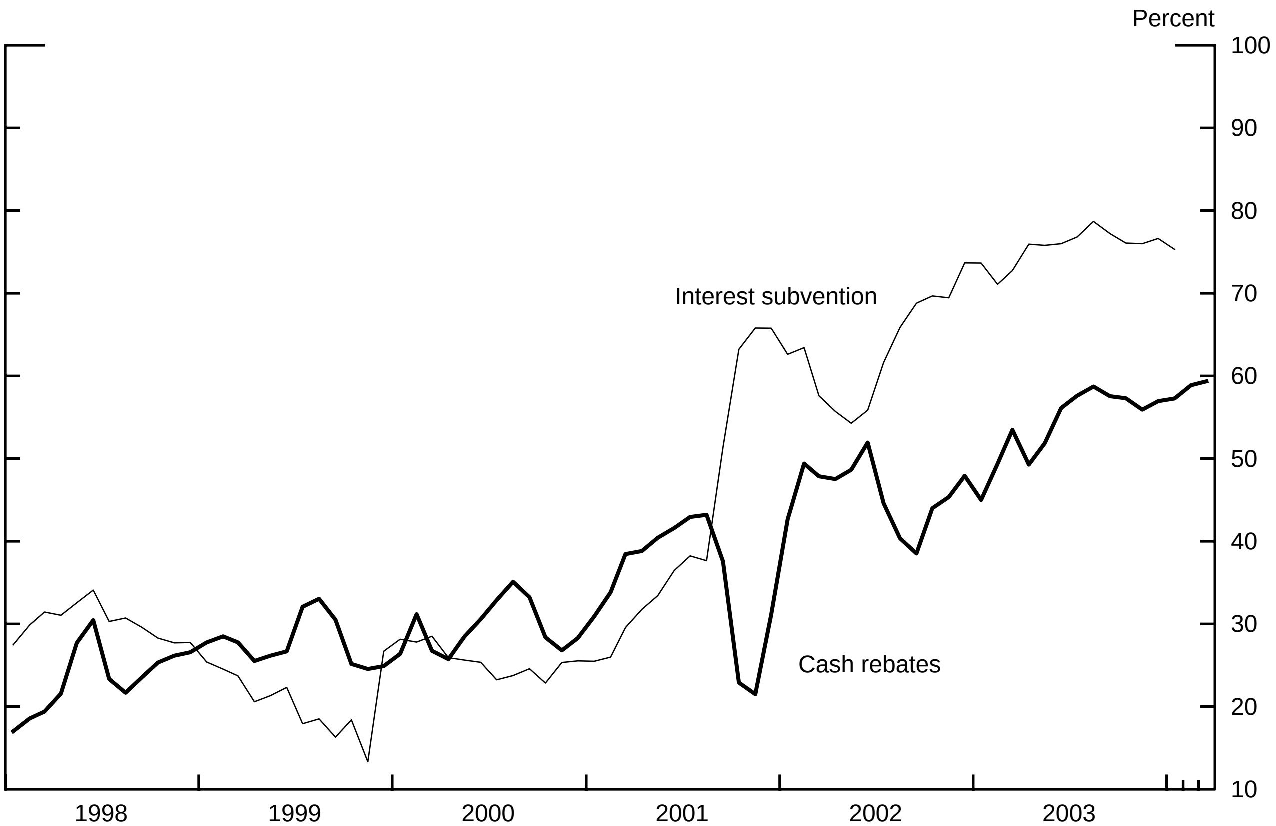
PRICE INCENTIVES FOR AUTOMOBILES AND LIGHT TRUCKS

Average Value of Cash Rebates and Interest Subvention



Constructed using data from J.D. Power and Associates

Measures of Sales Penetration of Price Incentives

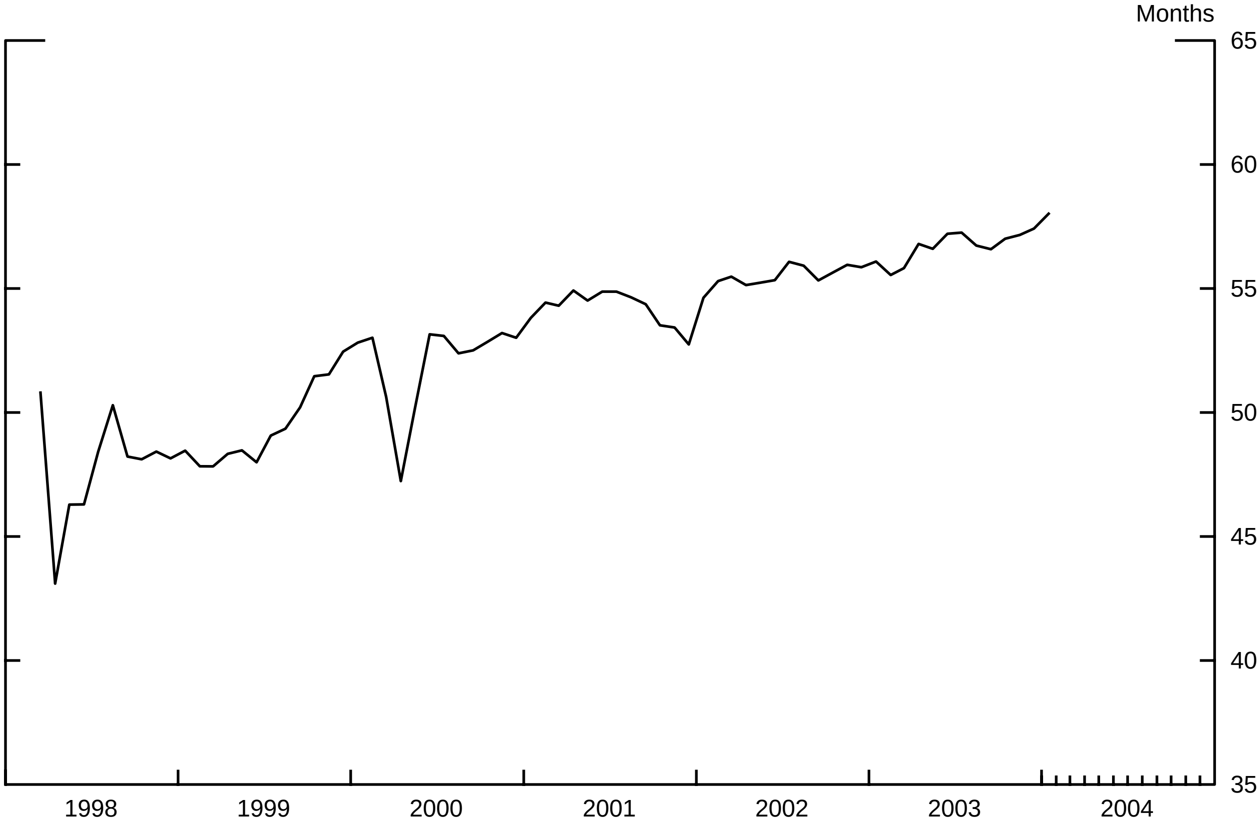


Constructed using data from J. D. Power and Associates

Chart 2

Loan Term Length and Average Loan Rates

Average Term on New Vehicle Loans



Average Interest Rate Received by Consumers and the Commerical Bank Rate

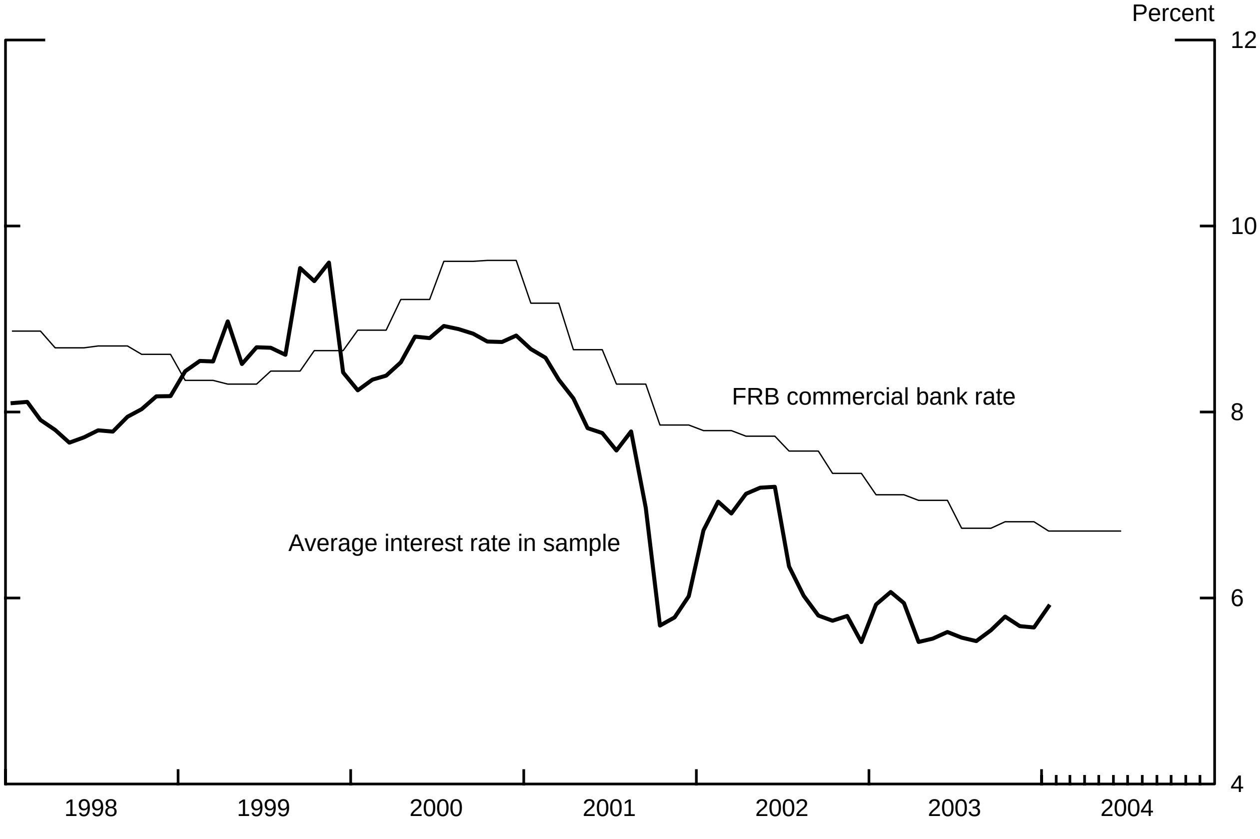
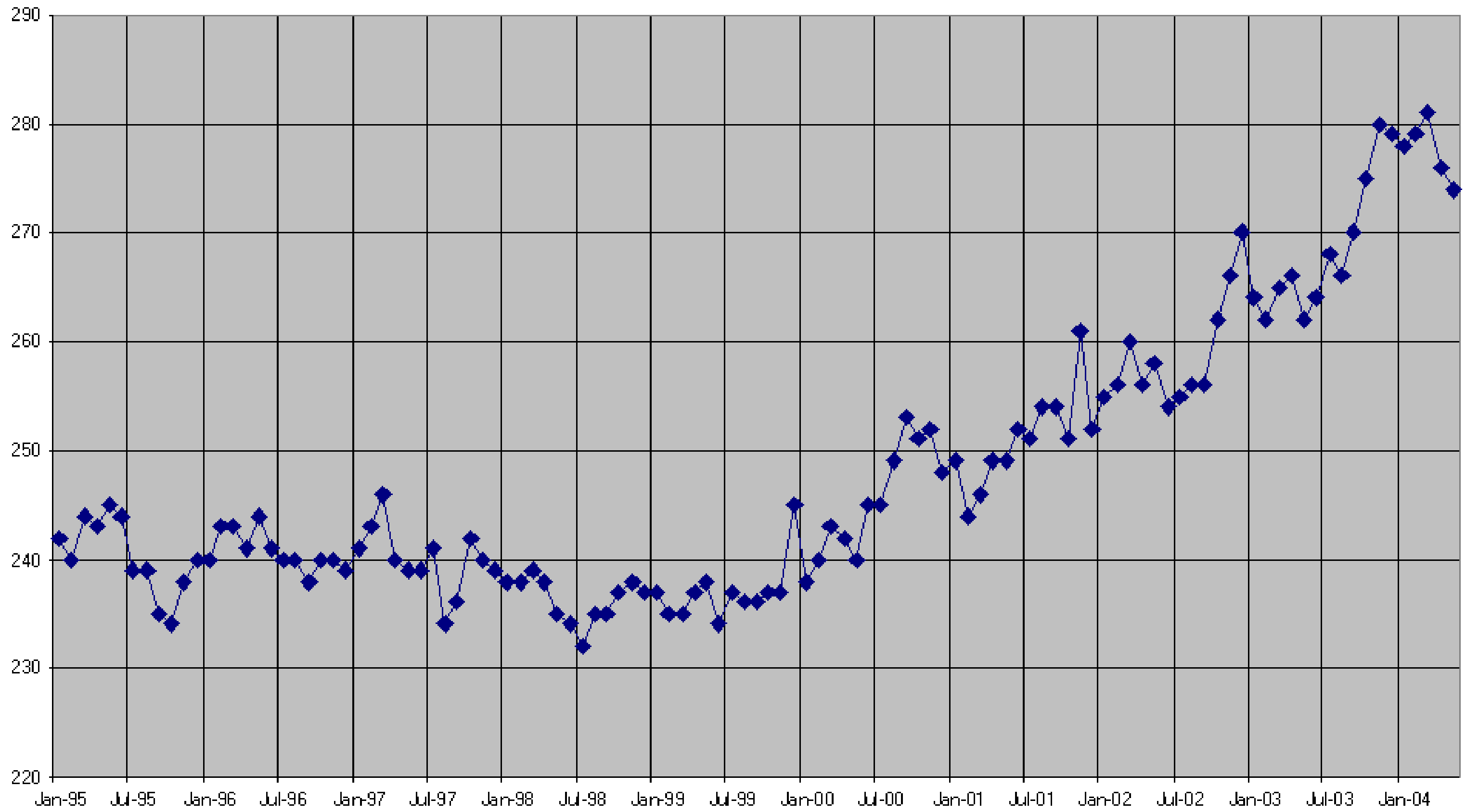


Chart 3. Count of Models Sold by Month, 1995-2004



Source. Ward's Communications.

Chart 4. Entering and Exiting Models

(Number per month, October 1998 to December 2003)

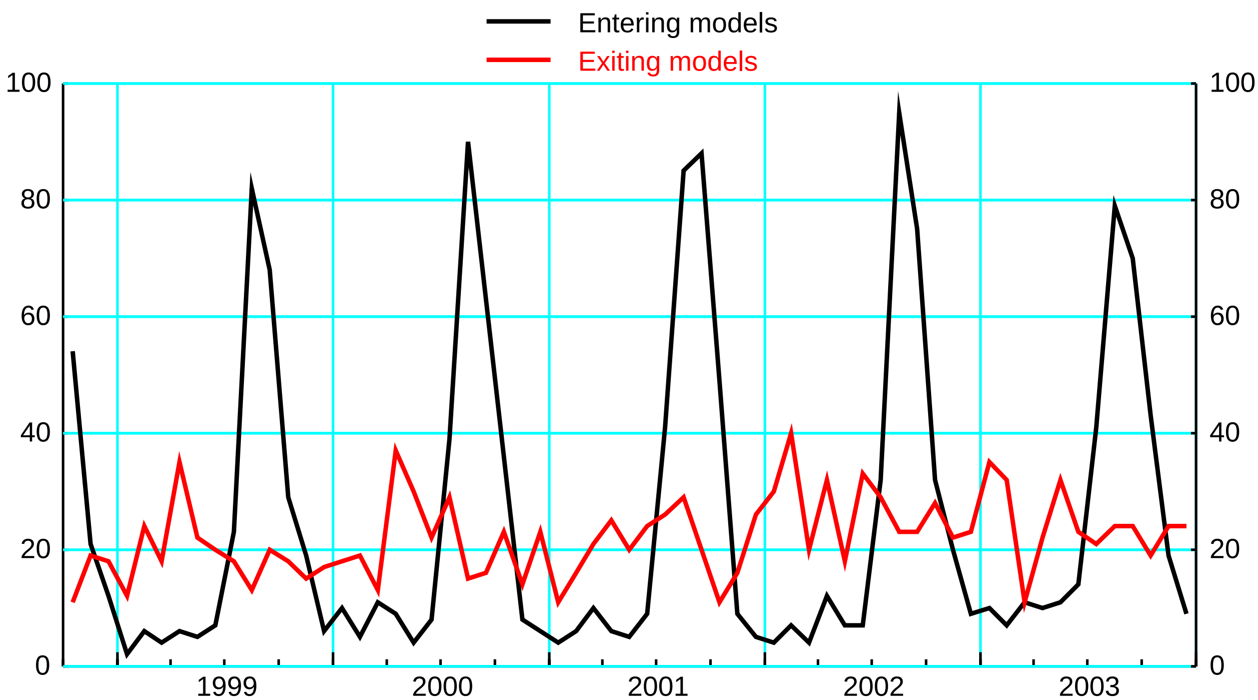


Chart 5. Expenditure Shares by Model Year

(percent of total expenditure, March 1998 to December 2003)

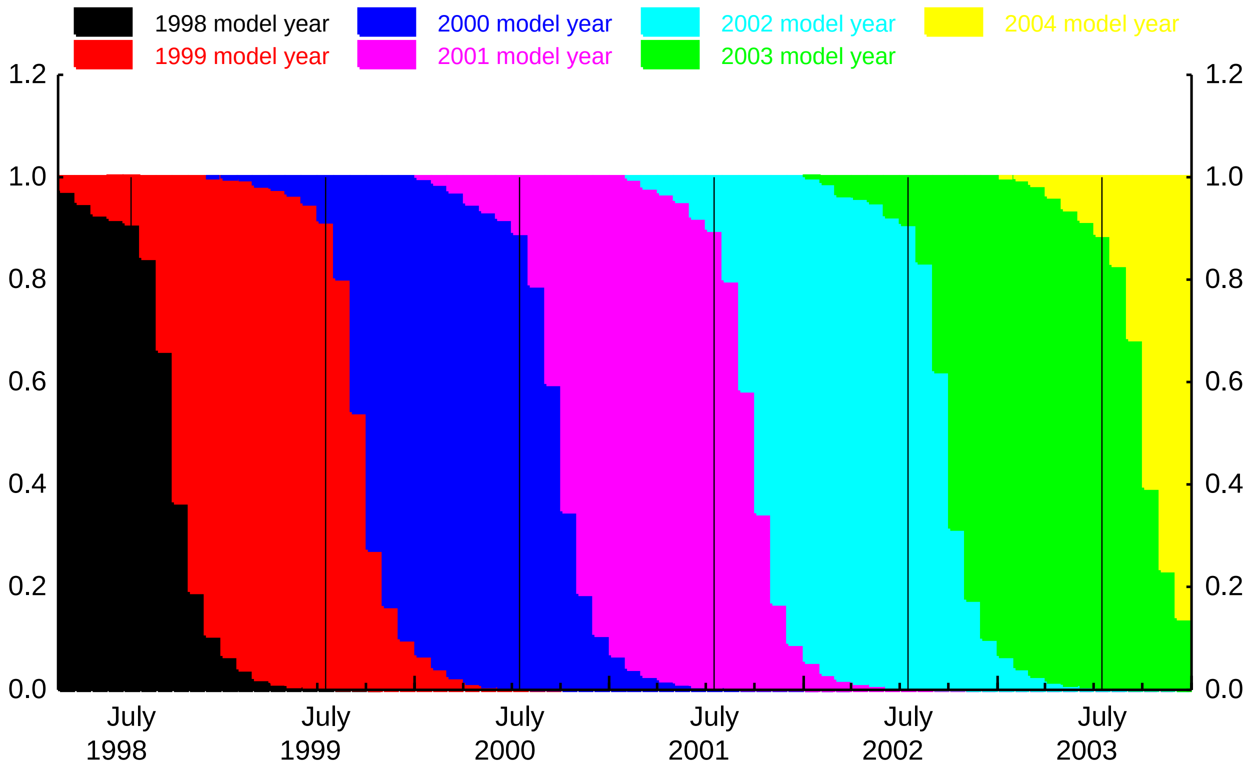
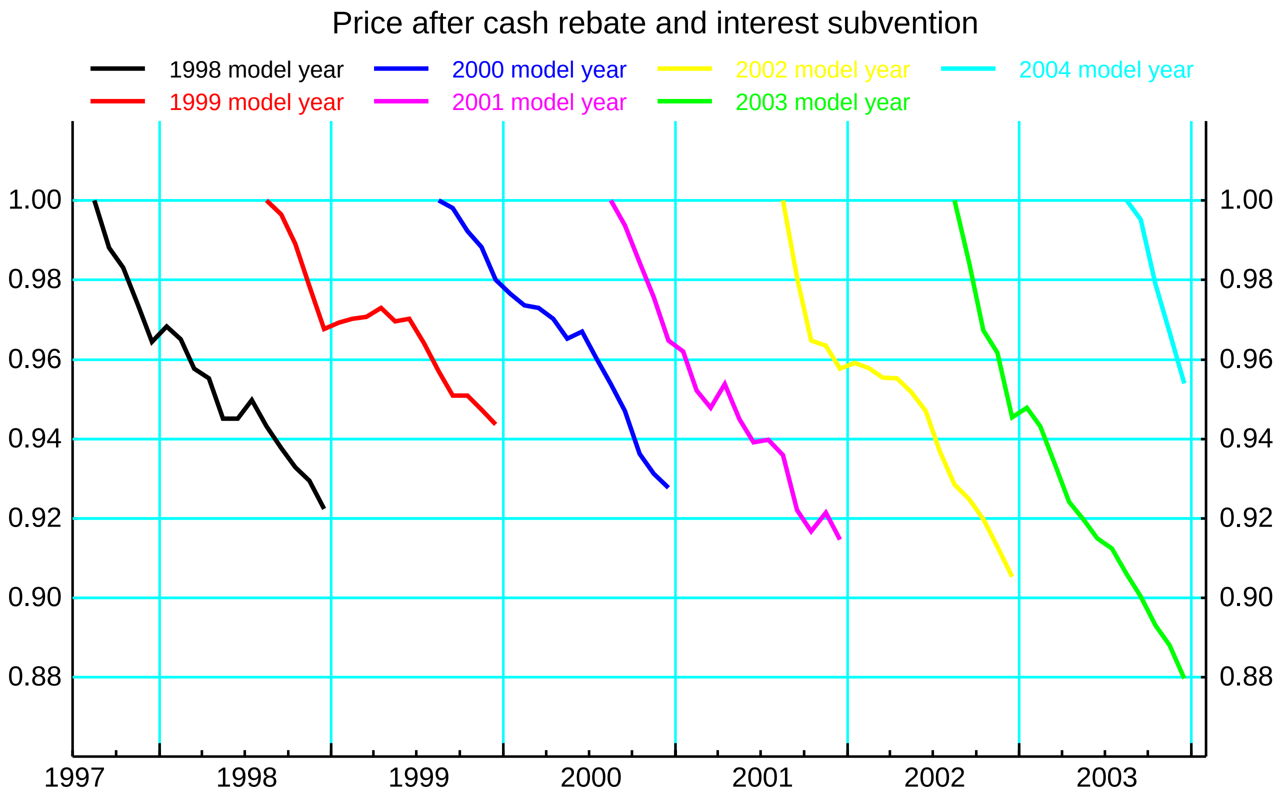


Chart 6. Matched-model Price Indexes by Model Year



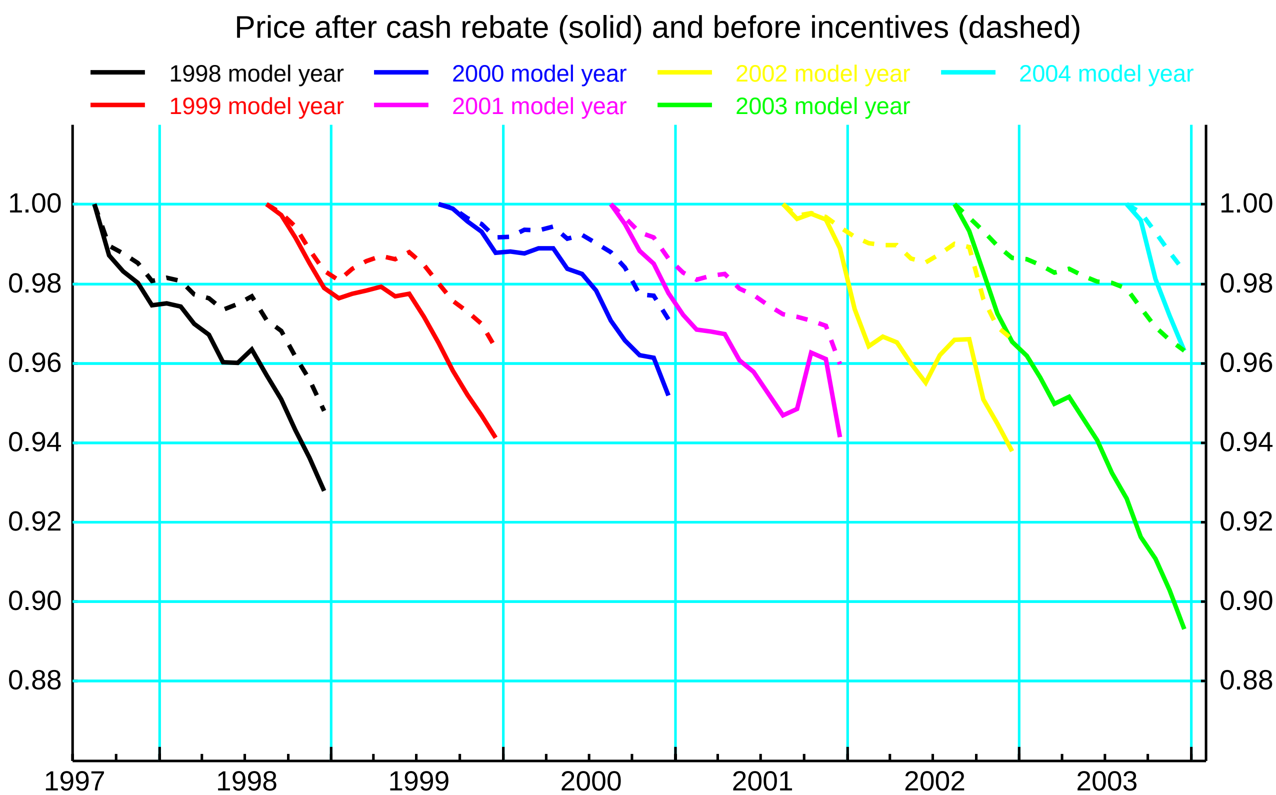


**Chart 7. Hedonic Regression
Price Indexes, 1998-2003**