A consumption measure for automobiles

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In this article, we estimate consumption of automobiles by using a user-cost approach and data from the Consumer Expenditure Surveys Interview Survey (CE). The user-cost approach is a method for valuing the flow of services from long-lived goods. A key input into user cost is the depreciation of the good, which we estimate by using purchase data from the CE.

Consumption measures of long-lived items are an important part of measuring the economic well-being of households. These long-lived items include owned housing and durable goods. Measures of expenditure sometimes are used to approximate consumption, but the expenditure on goods and the consumption of goods differ for items that are purchased infrequently and used for several years. Other than housing, automobiles are the most expensive durable good that households purchase. The economic literature assumes that automobiles depreciate slowly over a long period; this assumption implies that the consumption of automobiles is spread over multiple years. Thus, consumption and expenditures on automobiles take place at different times and may exhibit different patterns over time. We calculate the consumption of automobiles by measuring their depreciation, opportunity cost, and the recurring costs of ownership. We follow a user-cost approach to sum these three amounts. This sum is the consumption value for the flow of services from an automobile. Data from the Consumer Expenditure Surveys Interview Survey (CE) are used in our analysis.

The three amounts that produce a consumption value for automobiles are individually derived. First, we estimate depreciation by comparing the purchase price of similar automobiles of different ages across time periods with CE data.[1] Our preferred depreciation specification is an estimate of nonparametric depreciation; that is, the depreciation rate can vary by automobile age. We also estimate constant geometric depreciation as a comparison with nonparametric depreciation. The nonparametric approach is preferred because automobiles of different ages depreciate at different rates, as documented in the literature. Second, the opportunity cost is derived from estimated current market values and interest rates. Third, we use CE data on vehicle maintenance and related costs to produce ownership-cost values. Thus, the two estimated values and the ownership-cost values are summed to create a consumption value for automobiles.

Expenditures on automobiles fluctuate much more than the consumption of automobiles. Our research suggests that consumers buy automobiles when the economy is growing, and expenditures on automobiles decline during recessions as consumers postpone purchases. Consumption follows a similar pattern because new automobiles depreciate more quickly than older automobiles, but the decline in the consumption of automobiles is substantially smaller than the decline in expenditures during recessions.

Our approach allows us to measure consumption for individual consumer units (CUs).[2] We combine information on automobile ownership with estimates of depreciation rates for automobiles (both datasets are from the CE). Real (inflation adjusted) 10-year treasury yields are used to calculate opportunity costs. Other components of user cost (the recurring costs, which include maintenance and repairs, insurance, licensing, etc.) cannot be uniquely matched to CE data. However, we accommodate this matching problem by adjusting the recurring costs for other vehicles by the number of automobiles and other vehicles owned by CUs. For example, if a CU owns a car, a truck, and a boat with a motor, and if the average recurring costs for CUs with two automobiles is only 80 percent of the average recurring costs for CUs with two automobiles and one other vehicle in the same year, then we assume that the recurring costs for the car and truck equal 80 percent of total recurring costs for the CU. Using these data, we estimate automobile consumption individually for all CUs. These consumption estimates are positive in each period for all CUs that own automobiles. In contrast, expenditure estimates for the purchase of automobiles are $0 for most CUs in each period.[3]

Our work is similar to approaches used to measure the consumption of owned housing and other durable goods. There are two main approaches to valuing the consumption of durable goods. One is the acquisition approach, which assigns the full value of the good to the period it which the good was acquired. A limitation of the acquisition approach is that it ignores that durable goods provide value over an extended period. An alternative to the acquisition approach is to value the flow of services received over the lifetime of the durable good. The flow-of-services approach is generally recommended for measuring the consumption value of durable goods.[4] There are two options to value the flow of services from durables. The first is called rental equivalence; it uses the rental price for a similar good to value the flow of services. The other is to estimate the user cost. While rental equivalence is the most common method used to value the flow of services from owned housing, it is not feasible for valuing motor vehicles because vehicles are rarely leased past the first few years of their life. Thus, the user-cost approach is the only approach used to value the flow of services from vehicles. There has been substantial prior work estimating consumption from owned vehicles that uses a user-cost approach.[5] Also, research has been conducted on estimating the depreciation rate of automobiles. Bruce Meyer and James Sullivan use a constant depreciation rate estimated by comparing the purchase prices of similar vehicles, and Jonathan D. Fisher and David S. Johnson use an estimated constant depreciation rate of 10 percent for all automobiles.[6] In this paper, we use the basic methods developed by Meyer and Sullivan, but we allow the depreciation rate of automobiles to vary by age.

The issue of how to value durable goods also arises in the context of price indexes. Currently, the U.S. Bureau of Labor Statistics (BLS) uses different methods to value different types of goods and services in the construction of price indexes. The acquisition approach is used for most goods and services, including automobiles and other durable goods. However, rental equivalence is used for owner-occupied housing. Introducing the user-cost approach to value the flow of services from automobiles is in line with the Committee on National Statistics (CNSTAT) recommendation for measuring the prices of durable goods: “The prices of durable goods should be converted to user cost before being aggregated into a price index, whether a basket price index or a COLI [cost-of-living index].”[7] Additionally, CNSTAT has recommended that the number of owned automobiles be used as the quantity weight associated with automobiles in a cost-of-living-based price index. The value of the stock of owned automobiles is an immediate outcome of our approach and can be used to construct the quantity weight. However, a major limitation for implementing a user-cost approach in the production of price indexes is the lack of user-cost data in real time. Our estimates of depreciation rates are average values over a long period of time, but current values would be needed for a timely price index.

In this article, we review how automobile consumption and expenditure can be estimated. To show this, we first discuss how the value of automobile consumption can be measured with a flow-of-services approach. Second, we describe the data available on automobiles in the CE and our methods. Third, we estimate the depreciation rates of automobiles listed in the CE. Fourth, we show how the current market value of automobiles can be imputed with CE data. Fifth, we present a national series of average automobile consumption based on the two depreciation methods and compare them with expenditure on automobiles. Sixth, we estimate the consumption value of automobiles at the level of the CU. Finally, after we summarize our findings, we discuss data sources and the calculation steps for the consumption value of automobiles in a data appendix.

Measuring automobile consumption

We measure the value of automobile consumption by using a flow-of-services approach that combines automobile depreciation with the other costs of owning an automobile. We estimate depreciation by using the difference in the purchase prices (as reported in the CE data) of similar automobiles of different ages. Purchasing an automobile is similar to an investment in which an opportunity cost is incurred as a forgone return to investment. We estimate the opportunity cost of owning an automobile by using an inflation-adjusted market yield on 10-year U.S. Treasuries as a proxy for the real interest rate. As noted earlier, we also use CE data on recurring costs, such as automobile repairs and maintenance, insurance, and registration costs. The sum of depreciation, opportunity cost, and recurring costs equals the user cost, which approximates the flow of services from owned automobiles.

We restrict our analysis to cars, sport utility vehicles (SUVs), and trucks because of the lack of detailed information about other types of vehicles. Throughout the remainder of this article, we refer to cars, SUVs, and trucks as automobiles, and we do not include in our analysis other motorized vehicles, such as aircraft, boats, and motorcycles.

We estimate two measures of depreciation. One measure assumes a fixed depreciation rate over the life of each automobile, and the other measure allows the depreciation rate to vary nonparametrically. A nonparametric measure estimates separate depreciation rates for each age of an automobile. Varying depreciation rates are calculated and used because several sources suggest that automobiles depreciate at different rates throughout their life cycle.[8] As we noted earlier, Meyer and Sullivan use a constant depreciation rate estimated by comparing the purchase prices of similar vehicles, while Fisher and Johnson assume a constant depreciation rate of 10 percent.[9] In this paper, we essentially use Meyer and Sullivan's method, but we allow the depreciation rate of automobiles to vary by age.

We consider three sets of recurring costs. Maintenance and repair costs include spending on service and parts, oil and other fluids, and auto service policies. Insurance costs include all spending on insurance payments. Registration costs include all expenditures needed to obtain and maintain license plates on the automobile. The recurring costs are adjusted for business use because our primary focus is the consumption of households. We do not include fuel purchases in this measure because they are not considered part of user cost in the literature.

We produce a service-flow value of an automobile by combining the estimated depreciation rate of an automobile, the estimated current market value of the automobile, an interest rate representing the opportunity cost of capital, and the recurring costs of automobile ownership. The service flow of an automobile i of age a at time t ($SF_{i,t}$) is calculated with the following formula:

$$\text{SF}_{i,t} = (r_t + \delta_a) \times \Pi_{j=0}^{a-1}(1-\delta_j) \times P_{i,0} + \text{RC}_{i,t} \ , \quad (1)$$

where r_t refers to the interest rate at time t, δ_a refers to the estimated depreciation rate for an automobile of age a, $P_{i,0}$ refers to the purchase price of automobile i at 0 years of age, and $\text{RC}_{i,t}$ is the incurred recurring costs of the automobile i at time t. We use the all-item series of the Consumer Price Index for All Urban Consumers (CPI-U) to adjust the purchase prices of automobiles into constant dollars (1982–84 dollars) in all intermediate steps. Next, we adjust the purchase prices back to the reference-period-dollar level for final measures. Total depreciation over the life of the automobile is equal to its purchase price in constant dollars. In our model, if the interest rate is 0 percent, then the automobile service flow without recurring costs is equal to the original purchase price or acquisition cost. The only difference between the acquisition approach and the sum of the user cost over the vehicle lifetime would be the timing of when costs are recognized. That is, current total expenditure should equal the sum of the depreciation over the life of the vehicle.

Because our primary goal is to measure the automobile consumption of households, we also adjust all three components of depreciation, opportunity cost, and recurring costs for business use. In addition, not all automobile purchases are made through dealers. Nondealer purchase prices may not accurately represent current market prices because of personal relationships, such as those of family members or friends. If the constant dollar purchase price of an automobile is less than $2,000, then we disregard it as an invalid price; instead, we use an imputed price based on the characteristics of a similar automobile.[10]

Data description and method

Our primary data sources are information on household ownership of automobiles from the CE. In our study, we use data collected from the second quarter of 1996 (Q2 1996) to the first quarter of 2022 (Q1 2022). The availability of relevant data is limited for the years prior to 1996 (in particular, maintenance and repair variables are absent from the series). We observe the makes and models of owned automobiles through vehicle descriptions or vehicle codes. These data are internal to BLS. While Public Use Microdata (PUMD) are available for the stock of automobiles owned, details on automobile make and model needed for our estimations are not available for all years of PUMD. As noted earlier, we restrict our analysis to cars, SUVs, and trucks; thus, we do not include observations of other types of vehicles, such as recreational vehicles (RVs), boats, and aircraft. Also, based on purchase information reported in CE vehicle data, we exclude automobiles purchased as a gift for someone outside the CU. We exclude these gift purchases because these automobiles do not generate a service flow for the purchaser. About 0.7 percent of all owned automobiles in the weighted sample are gifts for someone outside the CU. These criteria leave us with more than 1 million automobiles reported in CE interviews from all quarters and all years. If we assume that quarterly data are independent, then the total number of vehicles is a simple sum of automobiles reported in CE data across quarterly surveys. For example, an automobile surveyed in Q1 2021 is treated as a different automobile in Q2 2021. This assumption of the independence of data is necessary because our goal is to produce a value for the flow of services from automobiles for each quarter.

To estimate automobile depreciation, we need information about the original purchase price paid by the consumer of the automobile, whether the automobile was purchased new or used, and the automobile's characteristics (make and model). Among all automobiles that are listed in the stock of owned automobiles, only 24 percent include a valid purchase price in the CE.[11] This means that we can only produce depreciation rates for this subset of all automobiles. For those automobiles with no original purchase prices reported, we impute their current market values based on the average values of automobiles with reported purchase prices and similar characteristics (such as make, model, year, age, and condition). Using CE reporting, we find that approximately 39 percent of all owned automobiles were purchased new and 61 percent were purchased used. The reported purchase prices are converted into constant dollars by using the CPI-U for all items. We estimate depreciation in constant-dollar terms to remove the effect of varying inflation rates on changes in the nominal value of the vehicle. After estimating depreciation and current market values, we convert all consumption measures in constant-dollar terms back to reference-period dollars by using the CPI-U for all items. Also, we convert all consumption measures into prices from 2 months before the interview month to represent consumption for the current period (this is defined as the quarterly reference period). For example, if the interview took place in February 2021 (Q1 2021 in the CE), then the flow of services was assigned to the period Q4 2020. Next, we use the CPI-U for all items from the middle of the quarter as a deflator for the quarterly consumption measure.

We estimate constant-geometric-depreciation rates separately for new and used automobiles. Additionally, we also allow for nonconstant depreciation of automobiles 0 to 10 years of age. A new automobile depreciates substantially in its first years of life before the estimated depreciation rate stabilizes.

To estimate the age-specific depreciation rates for automobiles, we regress the log of the real purchase price of an automobile on an age indicator. Also, we control for make, model, and model year in our regression. The regression equation for automobiles of age a is as follows:

$$\ln(P_{i,a}) = \beta_0 + \beta_a \text{age}_{i,a} + f_{\text{make}} + f_{\text{model}} + f_{\text{year}} + \epsilon_i \ , \quad (2)$$

where the coefficient β_a can be interpreted as an annual average geometric-depreciation rate for automobiles of age a. To be exact, we calculate the depreciation rate as $\delta_a = 1 - \exp(\beta_a)$, where β_a is the coefficient of age in the regression for the subgroup of automobiles of age a and age $a + 1$. We estimate the constant-geometric-depreciation rate for all automobiles at different ages by using this equation. Also, we estimate age-specific depreciation rates by using this equation 11 times for automobiles 0 to 10 years of age. These estimates include only automobiles of age a and age $a + 1$ in each regression for the nonparametric estimates. There are few transactions of older automobiles. Accordingly, the sample size of older automobiles is not large enough to reliably estimate age-specific depreciation rates for these older automobiles. So, we estimate a constant-geometric-depreciation rate for automobiles 11 years of age and over.

Next, we calculate the current market values of automobiles in the CE with two different treatments that are described below. One treatment has a purchase price, and the other treatment does not have a purchase price. For automobiles with a reported purchase price, we calculate the current market value of an automobile at time t as follows:

(3) $$\mathrm{CMV}_t = P_0 \times \Pi_{j=0}^{a-1}(1 - \delta_j),$$

where P_0 denotes the real purchase price (in constant 1982–84 dollars) of an automobile at the time of acquisition, and a is the age of the automobile. About 24 percent of all owned automobiles with a valid purchase price reported in the CE from 1996 to 2021 have a current market value derived from the depreciation approach, and the remaining 76 percent of the automobiles (which have no reported purchase price) are mapped to an imputed market value based on the similar characteristics of the automobiles.

These estimated current market values are adjusted for survival rate and business use. Our depreciation-rate estimates from equation (3) represent the expected loss in market value of an automobile of a given age conditional on the continuing operation of the automobile. Automobiles may cease to be operable for a number of reasons, including damage and mechanical failures. A portion of the yearly service-flow value of an automobile is the expected depreciation. The calculation of expected depreciation is conditional on the probability that the automobile survives the year. This probability that an automobile survives in a specific year is called the survival rate. We estimate the survival rate by using the age distribution of automobiles in the CE. For example, the ratio of the weighted total number of automobiles of age a to the number of automobiles of age $a + 1$ in the CE data is the survival rate for automobiles of age a.

The estimated current market values and recurring operational costs are also adjusted for business use to generate the depreciation and opportunity-cost components for CUs. Next, they are combined with the recurring-costs component to construct a complete series of user cost. Rewriting equation (1), we have the following equation:

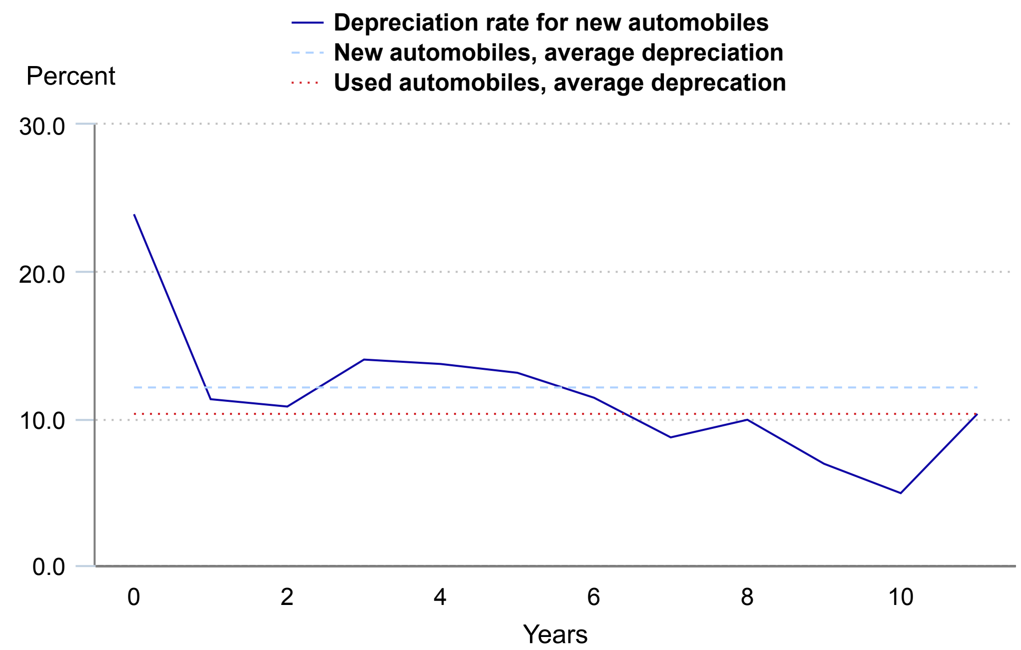
(4) $$\mathrm{SF}_t = (r_t + \delta_a) \times \mathrm{adj\_CMV}_t + \mathrm{adj\_RC}_t \;,$$

where SF_t refers to the service flow at time t, r_t refers to the interest rate at time t, δ_a refers to the estimated depreciation rate for an automobile of age a, $\mathrm{adj\_CMV}_t$ refers to the estimated current market value adjusted for business use and the survival rate of an automobile, and $\mathrm{adj\_RC}_t$ refers to the combined recurring costs of the automobile adjusted for business use at time t.

Depreciation-rate estimates

Chart 1 shows estimated depreciation rates as annual percentages by automobile age from the owned-automobiles data series of the CE. We present rates based on the age of the automobile and constant geometric depreciation. Automobiles purchased as new depreciate faster on average than automobiles purchased used. The depreciation rate of new automobiles is 12.1 percent, and the depreciation rate of used automobiles is 10.3 percent. Not surprisingly, automobiles depreciate much faster in the earliest years of their useful life. If they are purchased as new, automobiles lose almost 40 percent of their original value over the first 3 years. After 5 years, the depreciation rate declines to 5 percent by 10 years of age. This finding is consistent with estimates from Edmunds and Hardesty.[12] These sources state that a new automobile can lose more than 20 percent of its initial value in its first year and may lose almost one-third of its initial value within 3 years of purchase. The estimated depreciation rate for used automobiles is on average close to the fixed depreciation rate (10 percent) used by Fisher and Johnson.[13]

Chart 1. Annual depreciation rates by automobile age



Click legend items to change data display. Hover over chart to view data.
Note: The date range for this dataset is from the second quarter of 1996 to the first quarter of 2022.
Source: U.S. Bureau of Labor Statistics.

View Chart Data

Imputed current market values of automobiles

Similar to Meyer and Sullivan, we impute the current market values of automobiles in the CE either by applying the depreciation rates demonstrated above to the reported purchase price of an automobile or by mapping those automobiles with no reported purchase price to similar automobiles with reported prices in the CE.[14] As noted earlier, we find that about one-quarter of automobiles in the CE data have reported purchase prices. We calculate the current market values in real terms by directly applying annual depreciation rates to the reported real purchase prices. Those current market values are converted back to the current-period-dollar level by using the all-item CPI-U. For example, if an automobile was reported as purchased in January 2010 during a CE interview in the second quarter of May 2020, then the original purchase price is first converted into a price of constant dollars. Next, the current market price in constant-dollar terms is calculated after applying the annual depreciation rate by age (as explained in the previous section). Finally, we use the all-item CPI-U to convert the current market price of the automobile in 1982–84 dollars into March 2020 dollars to reflect the first quarter of 2020 consumption measure.

For the three-quarters of the automobiles in the CE with no reported purchase price, we first impute their current market values in constant dollars by averaging similar automobiles in the pooled data by either full or partial match. The summary statistics of these imputation results are reported in table 1.

Table 1. Imputation results of the current market values of automobiles in the Consumer Expenditure Surveys, 1996–2022

Data condition	Imputation method	Number of automobiles	Percent share of automobiles	Comments
Purchase price is reported.	Depreciation adjusted purchase price	256,741	24	Nonconstant depreciation is used for new automobiles; constant depreciation is used for used automobiles.
Purchase price is not reported.	Average market value of same automobiles	280,420	26	All five variables (make, model, year, age, and condition of new or used automobile) are matched.
Purchase price is not reported.	Average market value of similar automobiles	550,062	50	Partial matches are made based on available characteristics.
Total	[1]	1,087,223	100	[1]

[1] Not applicable.
Note: Calculations use data from the Consumer Expenditure Surveys.
Source: U.S. Bureau of Labor Statistics.

To validate our imputation procedure, we compare data from the 2018 National Automobile Dealers Association (NADA) used-car guides (the only data available for research purposes) with the estimated current market values of the stock of owned automobiles in the 2018 CE.[15] We were able to map a total of 8,596 CE automobiles with the same make, model, and year as a NADA automobile. The correlation is 0.74 between NADA prices and the estimated current market values from the CE for both methods of depreciation. Also, we ran a simple regression (without an intercept) of NADA prices on the estimated current market values from CE data. The coefficients of the CE price from this regression are 0.91 for nonparametric depreciation and 0.85 for constant geometric depreciation. Discrepancies between the two measures are at least partially attributable to differences in body type (this information is not available in the CE) and the condition of the automobile (NADA retail prices are adjusted for mileage). Overall, the NADA prices validate our estimates of CE current market values.

Example: expenditure versus consumption for households

We estimate the consumption of automobiles by spreading expenditures on them (a sum of estimated depreciation and the additional costs of ownership) over many years. If a household buys a new automobile, then the net present value of consumption (excluding additional costs of ownership) is equal to the expenditure on that purchase. We show this result with an example of a new automobile purchased for $30,000 in table 2. We compare consumption values based on constant geometric depreciation (DEP_cg), nonparametric depreciation (DEP_np), and expenditure measures over the operating life of this automobile. We calculate both current market values (CMV_cg, CMV_np) and depreciation by using our estimation of δ from CE data. In table 2, we show that the total values of the three measures differ, but not by substantial margins, from one another because of the age restriction on owned automobiles in the CE. We estimate that automobiles that are over 25 years of age in the CE would have the same current market value as those that are 25 years of age. Automobiles are assumed to generate a flow of service until they are completely totaled. A totaled automobile is one for which the cost to repair exceeds the current market value of the automobile. Thus, the combined consumption value over the entire lifespan of the automobile would be closer to $30,000 as the automobile operates beyond 25 years of age.

Table 2. Simulation of current market value and depreciation over the life of an automobile

Age, in years	Depreciation rate (percent)	Current market values		Consumption values		Expenditure
		Constant geometric depreciation	Nonparametric depreciation	Constant geometric depreciation	Nonparametric depreciation	
0	23.9	$30,000	$30,000	$3,633	$7,178	$30,000
1	11.3	26,367	22,822	3,193	2,590	0
2	10.8	23,174	20,232	2,807	2,194	0
3	14.0	20,367	18,038	2,467	2,517	0
4	13.7	17,900	15,520	2,168	2,130	0
5	13.1	15,732	13,391	1,905	1,754	0
6	11.4	13,827	11,637	1,675	1,325	0
7	8.7	12,153	10,312	1,472	897	0
8	9.9	10,681	9,415	1,294	930	0
9	6.9	9,387	8,484	1,137	583	0
10	4.9	8,250	7,901	999	390	0
11	10.3	7,251	7,511	878	775	0
12	10.3	6,373	6,736	772	695	0
13	10.3	5,601	6,041	678	623	0
14	10.3	4,923	5,418	596	559	0
15	10.3	4,327	4,859	524	501	0
16	10.3	3,803	4,358	461	450	0
17	10.3	3,342	3,908	405	403	0
18	10.3	2,937	3,505	356	362	0
19	10.3	2,582	3,143	313	324	0
20	10.3	2,269	2,819	275	291	0
21	10.3	1,994	2,528	242	261	0
22	10.3	1,753	2,267	212	234	0
23	10.3	1,540	2,033	187	210	0
24	10.3	1,354	1,824	164	188	0
25	10.3	1,190	1,636	144	169	0
Total	[1]	[1]	[1]	28,954	28,533	30,000

[1] Not applicable.

Source: U.S. Bureau of Labor Statistics.

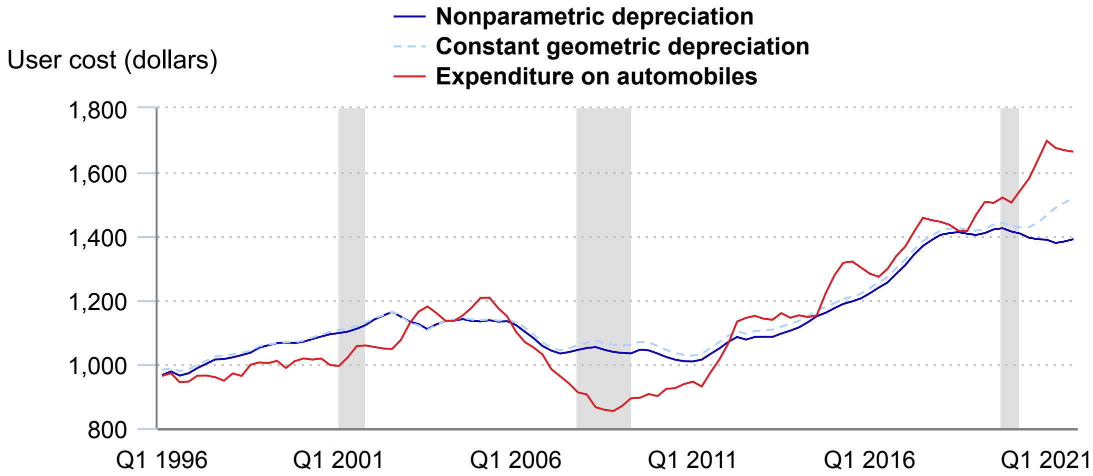
Average automobile consumption at the national level

In this section, we present a national series of quarterly average automobile consumption based on the two depreciation methods and compare them with automobile expenditures. Averages are based on population-weighted quarterly aggregate consumption, population-weighted quarterly aggregate expenditure, and the total number of CUs owning or purchasing automobiles during the reference period. Results are presented by adjusting consumption or expenditure for business use. This is in accordance with the BLS publication of average automobile expenditures that are adjusted to reflect only nonbusiness use.[16] One difference between the consumption-based averages and BLS-published average automobile expenditures is that consumption accounts for not just the previous purchase of automobiles but also the receipt of these as gifts or other transfer and without payment. In contrast, CE-published average expenditures reflect what is purchased in the reference period; this is the case whether or not the purchase is for the consumption of the CU or for someone living outside the CU. The latter are referred to as “gifts given” in CE data files. A discrepancy can arise in the two measures as the total number of vehicles purchased as gifts may not equal the total number of vehicles received as gifts in the sample in a given period.

To compute averages, we first estimate the value of consumption for each CU with an automobile. Next, we average those values across all CUs (including those CUs that do not own automobiles) to obtain a national average series. For comparison, we construct a series with actual net purchase expenditures (this is the amount paid for a vehicle after subtracting any trade-in allowance and any costs paid by an employer) in the CE interview reference period of the previous 3 months. We also construct a time series based on the average expenditures for all vehicles purchased within the interview reference period. The total expenditure series includes the purchase price and the recurring costs, but the opportunity cost (interest component) is not included (the opportunity cost is included in the flow-of-services approaches).

Chart 2 compares consumption estimates of the three methods. Both the nonparametric-depreciation series and the constant-geometric-depreciation series include depreciation, interest (opportunity cost), and recurring expenditures. The two series that use depreciation to measure consumption have relatively smooth quarter-to-quarter changes, while the expenditure series is more variable. Consumption estimated with nonparametric depreciation tends to track consumption estimated with constant depreciation closely, but the two series diverged during the pandemic. It is likely that this divergence between the two series is due to the decline in new automobile production. This production decline led to an increase in the average age of automobiles and an increase in the purchase of used automobiles. Also, the results of the nonparametric-depreciation approach show higher consumption of automobiles in the first years of their lives.

Chart 2. Household consumption and expenditure on automobile purchases, quarterly averages, 1996–2022



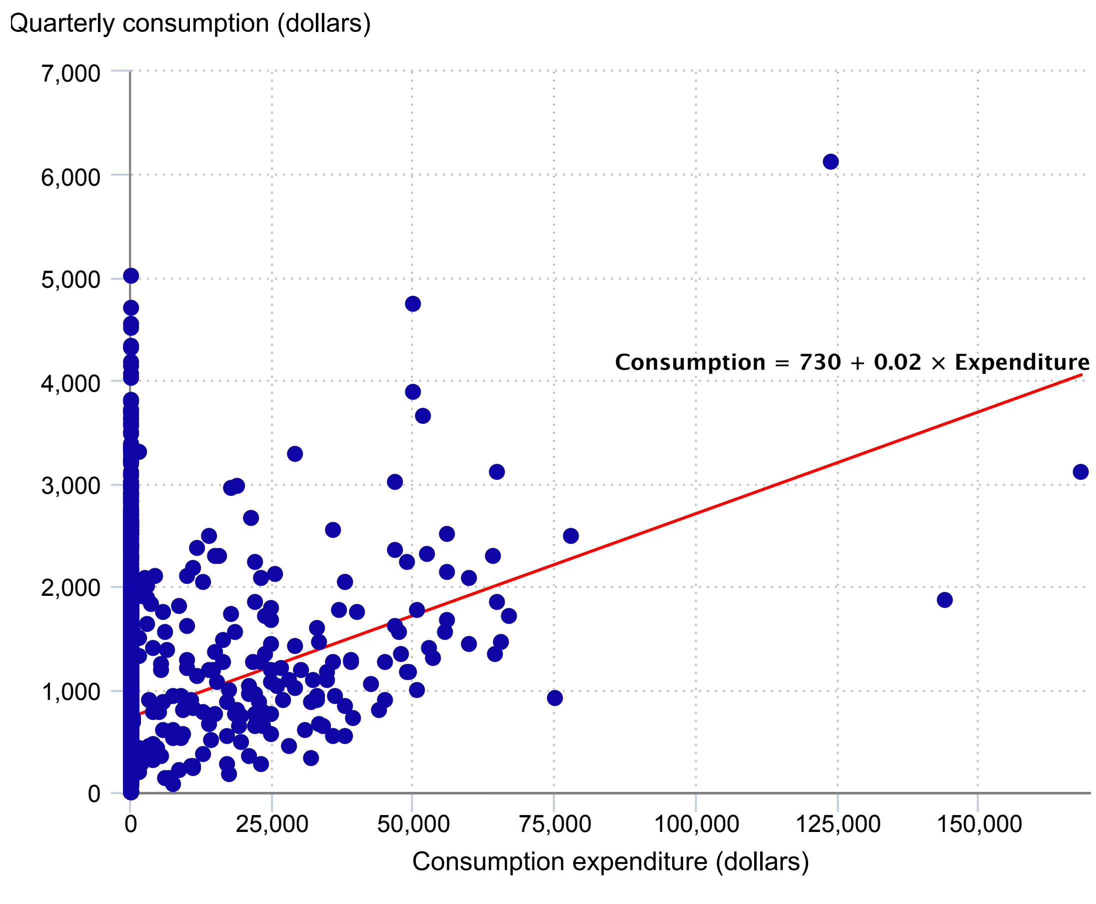
Click legend items to change data display. Hover over chart to view data. Shaded areas represent recessions as determined by the National Bureau of Economic Research. Note: All national average series are based on authors' calculations using data from the Consumer Expenditure Surveys. Both the nonparametric-depreciation series (nonlinear) and the constant-geometric-depreciation series (linear) include depreciation, interest components (opportunity cost), and recurring expenditures, such as maintenance and repair, vehicle insurance, and other operating costs spent on inspection, registration, and property tax. The expenditure series includes automobile net purchase prices and recurring costs, but the interest component is not included for comparison purposes. These data sets are seasonally adjusted and adjusted for business use.
Source: U.S. Bureau of Labor Statistics.

View Chart Data

Consumer-unit consumption

Despite the similarities between average automobile consumption and expenditure, the picture at the CU level is quite different. Most CUs that own automobiles have $0 in expenditures on automobile purchases in any quarter, although expenditures for recurring costs would be positive. Chart 3 plots the estimated parts of consumption, depreciation and opportunity cost, and expenditures that represent the purchase of automobiles for all CUs participating in a CE interview in October, November, or December 2021 (this is referred to as collection period Q4). Because both the consumption and expenditure series include the same recurring costs at the CU level, these are excluded from chart 3. The depreciation and opportunity cost of consumption are calculated on the basis of the stock of vehicles reported as owned during the interview reference period. Automobile purchase expenditures refer to those made in the same reference period (the 3 months prior to the interview month). Adjustments to reflect nonbusiness use are only made in the calculations of consumption and expenditure. Unlike in our automobile consumption measure, here we include purchases of automobiles given to someone outside the CU in the expenditures measure.

Chart 3. Consumption versus expenditure without recurring costs, fourth quarter 2021



Note: Consumption is the sum of depreciation and opportunity cost without recurring costs added at the consumer unit level. Expenditure is the net purchase price after subtracting the trade-in allowance of new and used automobiles reported in data from the Consumer Expenditure Surveys at the consumer unit level.
Source: U.S. Bureau of Labor Statistics.

View Chart Data

Some CUs have purchase expenditures over $50,000, and no CU has estimated automobile consumption above $10,000 that excludes the recurring costs. The positive correlation between expenditure and consumption is limited to the sum of depreciation and opportunity-cost components because automobiles depreciate the most in the period in which they are purchased.

Approximately 4 percent of automobiles are either purchased as a gift to someone outside the CU (0.7 percent) or received as a gift (3.2 percent). When an automobile is given to someone outside of the CU, the consumption value for the purchaser of the automobile is $0. However, expenditures are positive if a gift is purchased. Automobiles purchased for someone outside the CU are excluded in the consumption series, but these purchases are included in the expenditure series that uses purchase information reported in CE vehicle data.

Summary

In this article, we use a user-cost approach to compare estimates of the consumption of owned automobiles at the national level and the CU level, but each comparison uses different depreciation assumptions. Over time, consumption in the average series is less volatile than in the expenditure series, although the levels of consumption and expenditure are similar. But there are a few exceptions between the series. For example, at the national level, average expenditure was relatively lower than consumption during the recessionary period just before and after 2008 and relatively higher during the COVID-19 pandemic period. At the CU level, consumption was positive in each period for all households that owned automobiles, although in each period there were CUs with no expenditures.

Currently, economists at BLS are using automobile consumption values to construct a comprehensive consumption measure. Although additional research is needed, a flow-of-services estimate of automotive consumption could replace the acquisition approach for the pricing of vehicles in the CPI.

Appendix

In this appendix, we discuss data sources and the steps to calculate the consumption value of automobiles.

Data sources

We use CE data from Q2 1996 to Q1 2022 to estimate consumption values from 1996 to 2021. Unlike other consumer products, automobiles are not expected to be consumed immediately. The stock of automobiles is measured by asking a CU if they have any vehicle during the interview time period. Because there is no clear determination of the month in the last 3 months the CU owned the vehicle, we use CE data in the following quarter to measure the consumption value of the stock of automobiles for any reference quarter. For example, consumption values for the first quarter of 1996 are calculated from Q2 1996, for the second quarter from Q3 1996, for the third quarter from Q4 1996, and for the last quarter from Q1 1997.

The quarterly estimated-average consumption series for CUs is again seasonally adjusted by taking a rolling average of measures from the two previous quarters, the current quarter, and the following quarter. The rolling-average equation is as follows:

$$\text{Consumption}_t = (\text{Consumption}_{t-2} + \text{Consumption}_{t-1} + \text{Consumption}_t + \text{Consumption}_{t+1})/4 \quad ,$$

where t denotes the reference quarter of a year. Seasonal adjustments are made to smooth out large fluctuations across quarters.

It would have been ideal to use PUMD so outside researchers could reproduce our results, but not all relevant characteristics of an automobile, such as vehicle make, model, and fuel type, are available in PUMD. Instead, we use CE data that are internal to BLS. We assume that each quarterly survey is independent and that CUs are unique across surveys. We count a total of 1,281,071 motor vehicles from 689,811 CUs that are surveyed in the data. In any period, a CU owns an average of 1.86 vehicles, which includes 1.58 cars, SUVs, or trucks. We only include cars, SUVs, and trucks in our current calculation, and we exclude other types of vehicles, such as aircraft, boats, RVs, trailers, and kayaks, because not enough information about these other types of vehicles is available for depreciation-rate estimation. Many other types of vehicles, such as aircraft and boats, have no purchase prices reported, and it is difficult to impute a current market value from limited information. For example, a CU reported that it has a boat without other specific details. A boat can have a market value ranging from $1,000 to over $1 million. Although we can apply some fixed depreciation rate, such as 5 or 10 percent, imputing a current market price is challenging in the first place.

The following tables provide more detail on the exact number of vehicles and CUs by type. We also list all variables used in this article, along with a brief explanation of each. Table A-1 shows the total number of vehicles surveyed in the CE data; we assume that quarterly data are independent of one another. About 85 percent of all types of vehicles are automobiles (cars account for 47 percent, and SUVs and trucks account for 38 percent).

Table A-1. Surveyed automobiles in the Consumer Expenditure Surveys, assuming quarterly reports are independent, second quarter 1996 to first quarter 2022

Vehicle category	Total number of vehicles in the Consumer Expenditure Surveys	Percent share
All vehicles	1,281,071	100
Cars and trucks	1,087,223	85
Cars	605,906	47
Trucks	481,317	38
Source: U.S. Bureau of Labor Statistics.		

Table A-2 presents vehicle ownership at the CU level. About 86 percent of CUs have any type of vehicle (including boats, aircraft, and RVs), and 83 percent of all CUs have automobiles. Thus, 3 percent of CUs have no cars or trucks but only other types of vehicles. CUs without any vehicles account for 14 percent of the unweighted pooled sample.

Table A-2. Surveyed consumer units in the Consumer Expenditure Surveys, assuming quarterly reports are independent, second quarter 1996 to first quarter 2022

Consumer unit (CU) category	Total number in the survey data	Percent share
All CUs	689,811	100
Total CUs with any vehicle	593,339	86
CUs with automobiles	575,641	83
CUs with cars	431,670	63
CUs with trucks	339,973	49
CUs with other vehicles but no automobiles	17,698	3
CUs with no vehicle at all	96,472	14
Source: U.S. Bureau of Labor Statistics.		

Table A-3 lists all the variables we use in our computation of consumption, expenditure, and recurring costs. Some variables are directly extracted from the CE data, and others are intentionally constructed during the estimation process.

Table A-3. Variables included in the internal data file from the Consumer Expenditure Surveys and used in calculations

Source	Category	Variable name	Description	Comment
Variables from CE				
CE interview data	CU characteristics	FAMID	CU identifier up to Q1 2015	[1]
CE interview data	CU characteristics	NEWID	CU identifier since Q2 2015	[1]
CE interview data	CU characteristics	SEQNO	Sequence number for vehicles owned by a CU	[1]
CE interview data	CU characteristics	QINTRVYR	Interview year	[1]
CE interview data	CU characteristics	QINTRVMO	Interview month	[1]
CE interview data	CU characteristics	FINLWT21	Calibration final weight for CU	[1]
CE interview data	Vehicle characteristics	VEHBSNZ	Percentage of the vehicle used for business	To be used for nonbusiness-use adjustment
CE interview data	Vehicle characteristics	VEHICYB	Vehicle type: "100" for cars and "110" for trucks	[1]
CE interview data	Vehicle characteristics	VEHICYR	Vehicle model year	[1]
CE interview data	Vehicle characteristics	VEHPURYR	Vehicle purchase year	[1]
CE interview data	Vehicle characteristics	VEHPURMO	Vehicle purchase month	[1]
CE interview data	Vehicle characteristics	NETPURX	Net purchase price after discount, trade-in, or rebate including destination fee	[1]
CE interview data	Vehicle characteristics	QTRADEX	Amount paid for vehicle after trade-in allowance (NETPURX) minus amount of cost paid by employer	To be used to construct acquisition series based on expenditure in comparison with the user-cost series
CE interview data	Vehicle characteristics	TRADEX	Amount of trade-in allowance	[1]
CE interview data	Vehicle characteristics	MKMDLY	Vehicle make and model code (four-digit number)	[1]
CE interview data	Vehicle characteristics	MKMODEL	Vehicle make and model	[1]
CE interview data	Vehicle characteristics	MKMDESC	Vehicle make and model description	[1]
CE interview data	Vehicle characteristics	VEHBSNS	Where vehicle is used for business	[1]
CE interview data	Vehicle characteristics	VEHBSNZ	Percentage of vehicle mileage for business use	To be used to adjust current market value of automobiles for business use
CE interview data	Vehicle characteristics	VEHGFTC	Vehicle gift code	Automobiles purchased as a gift for someone outside the CU are excluded from consumption
CE interview data	Vehicle characteristics	VEHNEWU	Was it new or used when acquired?	[1]
CE interview data	Maintenance and repair	QVOPEQPX	Quarterly amount paid for vehicle service and parts less reimbursements	[1]
CE interview data	Maintenance and repair	VOPFLUDX	Quarterly amount spent on the following: motor coolant, antifreeze, brake fluid, transmission fluid, gasoline additives, oil additives, radiator cooling system protectors (excluding tune-up), excluding current month	[1]
CE interview data	Maintenance and repair	VOPPLCYX	Quarterly expense for auto service policies, excluding current month	[1]
CE interview data	Insurance	QADINS3X	Quarterly amount paid for vehicle insurance (adjusted for business), reference period	[1]
CE interview data	Property tax, licensing, registration, and inspection of vehicles	VOPREGX	Quarterly expenditure on vehicle licensing, registration, and inspection	[1]
Variables from other sources				
CPI for all urban consumers (CPI-U)	Price level of all items	INDEX	The national level price index for all urban consumers	To be used for converting nominal values in real terms and vice versa
Federal Reserve Bank of St. Louis	Opportunity cost	INTEREST	Market yield on U.S. Treasury securities at 10-year constant maturity, inflation-indexed, percent, quarterly, not seasonally adjusted	To be used to calculate opportunity cost of owning vehicles
Constructed variables				
Constructed as intermediate variable	Vehicle characteristics	VEHAGE	Vehicle's age when surveyed	= QINTRVYR – VEHICYR; replaced by 25 if over 25 years
Constructed as intermediate variable	Vehicle characteristics	PURAGE	Vehicle's age when purchased	= VEHPURYR – VEHICYR; replaced by 25 if over 25 years
Constructed as intermediate	Vehicle characteristics	VINTAGE	Years owned since purchased	= QINTRVYR – VEHPURYR; replaced by 25 if over 25 years

[1] No comment. Note: CE = Consumer Expenditure Surveys; CU = consumer unit.
Source: U.S. Bureau of Labor Statistics.

Source	Category	Variable name	Description	Comment
variable				
Constructed as intermediate variable	Vehicle characteristics	PRICE	Vehicle's purchase price	= NETPURX + TRADEX
Constructed as intermediate variable	Vehicle characteristics	RPRICE	Vehicle's purchase price in 1982–84 dollars	[1]
Constructed as intermediate variable	Vehicle characteristics	MAKE	Vehicle make	Extracted from MKMODEL/MKMDESC
Constructed as intermediate variable	Vehicle characteristics	MODEL	Vehicle model without body type	Extracted from MKMODEL/MKMDESC
Constructed as intermediate variable	Vehicle characteristics	YEAR	Vehicle model year	= VEHICYR
Constructed as intermediate variable	Identification	IMPUTE	Current market value imputation identifier	0: not imputed; 1: Imputed using purchase price; 2: imputed using same characteristics of automobile; 3: imputed using similar characteristics of automobile
Constructed as intermediate variable	Identification	VEH	Vehicle identifier	0: no vehicle; 1: has a vehicle
Constructed as intermediate variable	Identification	AUTO	Automobile identifier	0: other vehicle; 1: automobile
Constructed as intermediate variable	Vehicle characteristics	ACQ	Acquisition identifier	0: not acquired during the last 3 months; 1: acquired during the last 3 months
Constructed as intermediate variable	Depreciation	DEP_RATE	Annual depreciation rate of automobile at specific ages	Estimated from regressions of automobile purchase prices on automobile ages
Constructed as intermediate variable	Depreciation	RMV	Current market value of automobile in 1982–84 dollars	= RPRICE × (1 – DEP_RATE)^{VINTAGE}
Constructed as intermediate variable	Depreciation	SURRATE	Survival rate at a specific age	[1]
Constructed as intermediate variable	Depreciation	CMV	Current market value of automobile	= RMV × INDEX/100
Constructed as intermediate variable	Depreciation	ADJ_CMV	Current market value of automobile adjusted for business-use, survival rate and gift code	[1]
Constructed as intermediate variable	Recurring cost	MREXP	Quarterly expense on vehicle service and parts for owning vehicle	QVOPEQPX adjusted for owning purpose
Constructed as final variable	CU identifier in the pooled data	COMID	CU identifier in the pool data	Either FAMID or NEWID
Constructed as final variable	CU characteristics	CUWT	Quarterly CU final weight	= FINLWT21/4
Constructed as final variable	Reference period	QTR	Calendar quarter	= interview quarter – 1
Constructed as final variable	Reference period	CYEAR	Calendar year	= QINTRVYR if QTR > 1; = (QINTRVYR – 1) otherwise
Constructed as final variable	Identification	N_VEH	Number of all types of vehicles owned by CU	[1]
Constructed as final variable	Identification	N_AUTO	Number of automobiles owned by CU	= N_VEH – number of other vehicles
Constructed as final variable	Expenditure	EXPQ	Quarterly expenditure on automobile purchase	= QTRADEX if purchased in the last 3 months
Constructed as final variable	Expenditure	EXPY	Annual expenditure on automobile purchase	= 4 × EXPQ
Constructed as final variable	Depreciation	DEP	Quarterly depreciation value of all cars and trucks owned by CU	= adj_CMV × DEP_RATE/4
Constructed as final variable	Opportunity cost	INT	Quarterly opportunity cost (forgone interest revenue in flow of service value) of all cars and trucks	= adj_CMV × interest/4
Constructed as final variable	Depreciation	YDEP	Annual depreciation value of all cars and trucks owned by CU	= adj_CMV × DEP_RATE
Constructed as final variable	Opportunity cost	YINT	Annual opportunity cost (forgone interest revenue in flow of service value) of all cars	= adj_CMV × interest

[1] No comment. Note: CE = Consumer Expenditure Surveys; CU = consumer unit.
Source: U.S. Bureau of Labor Statistics.

Source	Category	Variable name	Description	Comment
Constructed as final variable	Maintenance & repair	MR	Quarterly maintenance and repair expense	= MREXP + VOPFLUDX + VOPPLCYX
Constructed as final variable	Property tax, licensing, registration, and inspection of automobiles	REG	Quarterly operating expense	= VOPREGX
Constructed as final variable	Insurance	INS	Quarterly automobile insurance payments	= QADINS3X
Constructed as final variable	Recurring cost	RC	Quarterly combined recurring costs of owning automobile	= MR + REG + INS
Constructed as final variable	Maintenance & repair	YMR	Annual maintenance and repair expense	= 4 × (QVOPEQPX + VOPFLUDX + VOPPLCYX)
Constructed as final variable	Property tax, licensing, registration, and inspection of automobiles	YREG	Annual operating expense	= 4 × VOPREGX
Constructed as final variable	Insurance	YINS	Annual automobile insurance payments	= 4 × QADINS3X
Constructed as final variable	Recurring cost	YRC	Annual combined recurring costs of owning automobile	= 4 × (MR + REG + INS)

[1] No comment. Note: CE = Consumer Expenditure Surveys; CU = consumer unit.
Source: U.S. Bureau of Labor Statistics.

Calculation steps for the consumption value of automobiles

The constant-geometric-depreciation rate (δ_a) is estimated by comparing the purchase prices of the same model automobiles at different ages in the pooled sample data. The regression model for constant geometric depreciation is as follows:

$$\ln(P_{i,a}) = \beta_0 + \beta_a \text{age}_{i,a} + f_{\text{make}} + f_{\text{model}} + f_{\text{year}} + \epsilon_{i,t} \ ,$$

where age denotes an automobile's purchase age. The variable age can take a value from 0 to 25 years. We set a limit for automobile age at 25 years because in many states (including the District of Columbia, Virginia, and Maryland) automobiles over 25 years of age are considered antique or vintage, and these older automobiles may not have a specific pattern of depreciation. The coefficient β_a indicates how much an automobile's value depreciates each year on average as a constant share of its current value. To be precise, we calculate δ_a as $1 - \exp(\beta_a)$.

Similarly, the nonparametric-depreciation rate (δ_v) is estimated by comparing an automobile's purchase price with the purchase price of the same model automobile of age v and age $v + 1$. We assume that an automobile follows age-specific depreciation up to 10 years. After 10 years of age, we assume the automobile follows constant geometric depreciation because of the limited sample size of old automobiles. We estimate δ_v by using age-specific depreciation rates for automobiles 0 to 10 years of age. This is done with a subsample of automobiles of age v and age $v + 1$, in which v takes a value between 0 and 10 years. A total of 11 regressions are run separately on the 11 age-group subsamples. In our estimations, we hold δ_a as constant no matter the age of the automobile (v), and we vary δ_v depending on the age of the automobile (v). The variable v can take a value between 0 and 10 years.

We then calculate the current market values of automobiles after depreciation by separately using the estimated δ_a and δ_v. We calculate the current market value (CMV_t) of an automobile at time t with the constant-geometric-depreciation method as follows:

$$\text{CMV}_t = \text{PRICE}_y \times (1 - \delta_a)^{(x-y)} \ ,$$

where x denotes the current age of the automobile, and y denotes the age of the automobile when it was purchased.

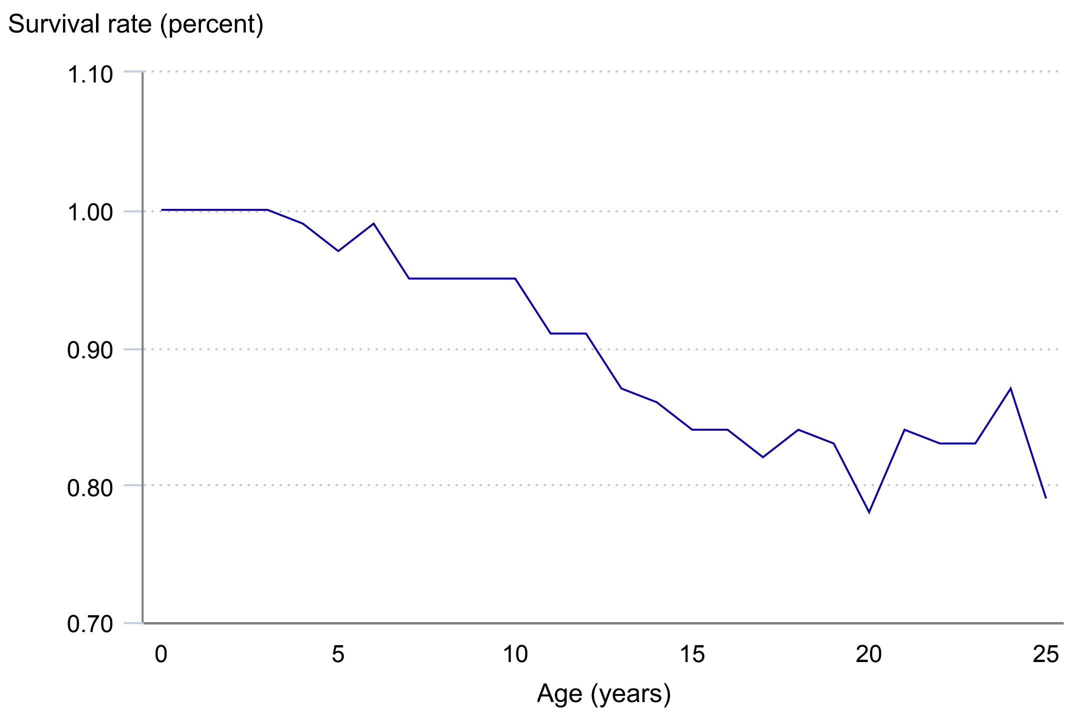
On the other hand, we calculate the CMV_t of the same automobile with the nonparametric-depreciation method as follows:

$$\text{CMV}_t = \text{PRICE}_y \times \Pi_{v=y}^{x-1} (1 - \delta_v) \ ,$$

where δ_v denotes the marginal depreciation rate of an automobile of age v.

Because not all automobiles, old automobiles in particular, are expected to survive to generate a flow of services until the next reference period, CMV_t is age adjusted for survival probability (SURRATE). We aggregate the total number of automobiles of age v and age $v + 1$ by using pooled CE data, and then we divide the two numbers to calculate the survival rate for an automobile of age v. The calculated survival rates are shown in chart A-1.

Chart A-1. Survival rate of automobiles



Hover over chart to view data.
Source: U.S. Bureau of Labor Statistics.

View Chart Data

Our goal is to estimate the consumption value of owning an automobile for nonbusiness use. Therefore, we adjust the estimated current market value of automobiles for business use by using the percentage of the automobiles used for business use as reported in the CE (VEHBSNZ). The formula for survival and business-use adjustment is as follows:

$$\text{Adj\_ CMV}_t = (\text{SURRATE} \times \text{CMV}_t + (1 - \text{SURRATE}) \times (\text{CMV}_t /2)) \times (1 - \text{VEHBSNZ}) .$$

In the equation above, we assume that even if an automobile did not survive until the end of the next period, then the automobile is on average expected to survive halfway through the reference period.

Not all CUs report a purchase price for each owned automobile in the survey. We use the average current market value of a similar automobile in the imputation of the current market value and depreciation of an automobile without relevant information, such as purchase price, automobile purchase age, and model year. When the parties of a vehicle purchase transaction are known or related to each other, such as friends or family members, it is possible that a reported purchase price might not accurately reflect the fair market value. Several sources suggest that there is a minimum price that a consumer has to pay a dealer for a used automobile in working condition.[17] If the purchase price of an automobile is less than $2,000 in 1982–84 dollars, then we assume the transaction was between related parties and use an imputed price based on similar characteristics. The imputation results are shown in table 1.

Next, we impute depreciation (DEP_t) and opportunity cost (INT_t) (forgone investment revenue) of an automobile of age a at time t as follows:

$$\text{DEP}_t = \text{adj\_CMV}_t \times \delta_a ,$$

and

$$\text{INT}_t = \text{adj\_CMV}_t \times r_t ,$$

where r_t denotes the real interest rate at time t. We approximate the real interest rate by using the inflation-adjusted market yield on U.S. Treasury securities at 10-year constant maturity.

Finally, we add together the other recurring costs (RC) associated with operating an automobile to calculate the full user cost of owning an automobile, such as maintenance and repairs (MR); automobile insurance (INS); and registration, property tax, licensing, and inspection (REG). Thereby, the equation for the consumption value of a CU (u) who owns k automobiles at time t ($\text{Cons}_{u,t}$) is as follows:

$$\text{Cons}_{u,t} = \sum_{j=1}^{k} (\text{DEP}_{j,t} + \text{INT}_{j,t} + \text{RC}_{j,t}) ,$$

and

$$\text{RC}_{j,t} = \text{MR}_{j,t} + \text{INS}_{j,t} + \text{REG}_{j,t} ,$$

where $\text{RC}_{j,t}$ denotes the combined recurring costs, MR denotes maintenance and repair cost, INS denotes automobile insurance cost, and REG denotes other registration and licensing expenses for automobile j at time t.

Notes

[1] For a recent reference on the estimation of such depreciation methods in the production of consumption measures, see Giulia Mancini and Giovanni Vecchi, *On the Construction of a Consumption Aggregate for Inequality and Poverty Analysis* (Washington, DC: World Bank Group, 2022), https://documents1.worldbank.org/curated/en/099225003092220001/pdf/P1694340e80f9a00a09b20042de5a9cd47e.pdf.

[2] The U.S. Bureau of Labor Statistics defines a consumer unit as follows: “A consumer unit is defined as either (1) all members of a particular household who are related by blood, marriage, adoption, or other legal arrangements; (2) a person living alone or sharing a household with others or living as a roomer in a private home or lodging house or in permanent living quarters in a hotel or motel, but who is financially independent; or (3) two or more persons living together who pool their income to make joint expenditure decisions. Financial independence is determined by the three major expense categories: housing, food, and other living expenses. To be considered financially independent, a respondent must provide at least two of the three major expense categories.” See *Glossary* (U.S. Bureau of Labor Statistics), https://www.bls.gov/bls/glossary.htm.

[3] Our estimates for automobile consumption are used in the construction of a comprehensive consumption measure. See Thesia I. Garner, Brett Matsumoto, Jake Schild, Scott Curtin, and Adam Safir, "Developing a consumption measure, with examples of use for poverty and inequality analysis: a new research product from BLS," *Monthly Labor Review*, April 2023, https://doi.org/10.21916/mlr.2023.8.

[4] "Report II: household income and expenditure statistics," Seventeenth International Conference of Labour Statisticians (Geneva: International Labour Organization, 2003). https://www.ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/meetingdocument/wcms_087588.pdf; and

OECD Framework for Statistics on the Distribution of Household Income, Consumption and Wealth (Paris: Organization for Economic Co-operation and Development, 2013), https://doi.org/10.1787/9789264194830-en.

[5] For more information, see David M. Cutler and Lawrence F. Katz, "Macroeconomic performance and the disadvantaged," *Brookings Papers on Economic Activity*, vol. 1991, no. 2, 1991, pp. 1–74, https://doi.org/10.2307/2534589; Daniel T. Slesnick, "The standard of living in the United States," *Review of Income and Wealth,* vol. 37, no. 4, 1991, pp. 363–386, https://doi.org/10.1111/j.1475-4991.1991.tb00379.x;

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[6] Bruce Meyer and James Sullivan, "Winning the war: poverty from the Great Society to the Great Recession," *Brookings Papers on Economic Activity*, vol. 45, no. 2 (The Brookings Institution, 2012), pp. 133–200; and Jonathan D. Fisher and David S. Johnson, "Consumption mobility in the United States: evidence from two panel data sets," *The B.E. Journal of Economic Analysis & Policy*, vol. 6, no.1, 2006, pp. 1–38.

[7] *At What Price?: Conceptualizing and Measuring Cost-of-Living and Price Indexes* (Washington, DC: The National Academies Press, 2002), p. 72, https://doi.org/10.17226/10131.

[8] Chris Hardesty, "How to beat car depreciation," *Kelley Blue Book*, September 11, 2023, https://www.kbb.com/car-advice/how-to-beat-car-depreciation/; and "Depreciation infographic: how fast does my new car lose value?," *Edmunds*, September 24, 2010, https://www.edmunds.com/car-buying/how-fast-does-my-new-car-lose-value-infographic.html.

[9] Meyer and Sullivan, "Winning the war: poverty from the Great Society to the Great Recession;" and Fisher and Johnson, "Consumption mobility in the United States: evidence from two panel data sets."

[10] This lower bound shows cases in which vehicles are purchased for low prices because of related party transactions.

[11] The stock of automobiles owned during a reference period may not necessarily be purchased during the previous 3 months but may also include those purchased prior to the reference period.

[12] Hardesty, "How to beat car depreciation;" and "Depreciation infographic: how fast does my new car lose value?," *Edmunds*.

[13] Fisher and Johnson, "Consumption mobility in the United States."

[14] Meyer and Sullivan, "The effects of welfare and tax reform;" and Meyer and Sullivan, "Winning the war: poverty from the Great Society to the Great Recession."

[15] For more information on National Automobile Dealers Association used-car guides, see "Consumer vehicle values" (National Automobile Dealers Association), https://www.nada.org/nada/consumer-vehicle-values.

[16] For more information on published average annual expenditures from the Consumer Expenditure Surveys, see "Table R-1. All consumer units: annual detailed expenditure means, standard errors, coefficients of variation, and weekly (D) or quarterly (I) percents reporting," Consumer Expenditure Surveys (U.S. Bureau of Labor Statistics, 2021), https://www.bls.gov/cex/tables/calendar-year/mean/cu-all-detail-2021.pdf.

[17] Phillip Reed, "Tips on how to find a cheap, reliable used car to buy," *USA Today*, November 12, 2016, https://www.usatoday.com/story/money/personalfinance/2016/11/12/nerdwallet-buyin-a-reliable-used-car/93667546/; and Cara Smith, "How to buy a cheap, drivable used car," *Nerd Wallet*, July 18, 2022, https://www.nerdwallet.com/article/loans/auto-loans/cheap-drivable-used-car.

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