Heredity and Environment: Causes of Postwar Movements
In Automobile Longevity

By
Bruce W. Hamilton
Molly K. MaCauley

Over the past 25 years there has been a dramatic increase in the longevity of automobiles. The mean age of the domestically manufactured fleet rose from about 5.5 years in calendar year 1970 to over 7 years in 1991. About 7% of 1960 cars survived beyond age 15; over 45% of 1976 cars did. *Ex post* life expectancy (calculated out to age 15) was 9 years for 1958-vintage cars and rose to over 11 years for 1977 cars.

Figure 1

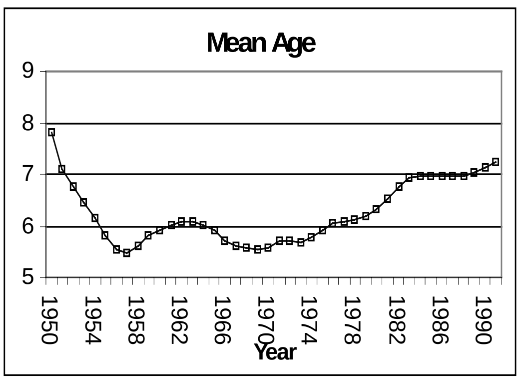


Figure 2

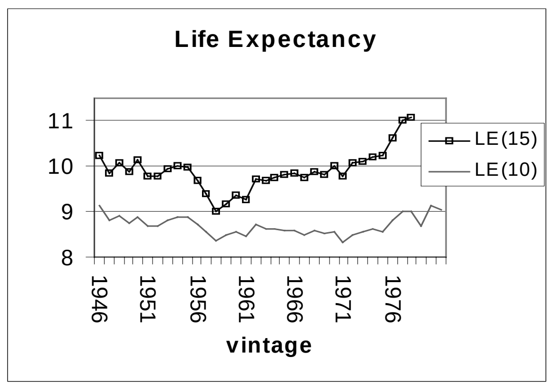


Figure 3

Two natural questions come to mind:

- Do today's cars last longer than their ancestors because the cars themselves are inherently more durable, or because of some change in the external environment causes them to last longer?
- What are the forces which caused cars to become more durable, or to last longer despite constant durability, as the case may be?

The main purpose of this paper is to answer the first question – to disentangle the rise in longevity into an inherent-durability effect (which we will refer to as the **embodied** effect), and an effect driven by something external to the cars (which we will refer to as the **disembodied** effect). Examples of disembodied effects are reduced accident rates and reductions in the prices of repair parts. We estimate respectively the embodied and disembodied effects upon car longevity, by year, from 1950 through 1991. We find that the entire rise in auto longevity (and then some) is due to some force disembodied from the cars themselves. Recent vintages of cars are actually **less** durable than 1962 cars.

A hint of this result can be seen in Figure 3. The life expectancy of 1970-71 cars, calculated out to age 10 (that is, built up from the *ex post* death rates from age 0 to 10) is about a half-year **less** than that of 1962-63 cars. But the life expectancy calculated out to age 15 is a half-year **more** for 1970-71 than for 1962-63 cars. This reflects the fact, explored below, that the 1980s represented a particularly benign environment for cars of all vintages. Conditional on living to age 10, 1970-71 cars did very well over the next 5 years. This suggests that it is the external environment of the 1980s, not the quality of 1970-71-vintage cars, which explains the secular rise in longevity.

Data

Our data come from R. L. Polk and Company. Since the end of World War II Polk has gathered auto registration data, by make and vintage. With these data we generate life tables for the domestically produced automobile fleet, and for various individual makes of domestic cars.[1] Thus with the Polk data we generate a matrix of age-specific automobile death rates; $\mathbf{d}^{\mathbf{a}}_{\mathbf{v}}$, the death rate of vintage-v cars at age a.

Estimation Model

Suppose that cars die according to a logistic:

[1] Polk began to record information on imported cars in 1958, giving too short a time series to meaningfully estimate our model for imports.

Equation 1

$$d_v^a = \frac{1}{\alpha + EXP(\beta + \gamma \cdot age)}$$

We model any changes in the shape of the logistic as operating through the age coefficient γ:

Equation 2

$$\gamma = \gamma_0 + \sum \gamma_i \cdot X_i$$

where the X's are regressors which might influence the longevity of cars.

Embodied and Disembodied effects

If vintage v* cars are inherently more durable than pre (or post) v* cars, this vintage should have lower death rates at all ages, relative to other cars. A dummy variable equal to 1 for vintage = v* will pick up this effect. Similarly, if year t* was unusually good to cars of all vintages, a dummy variable equal to 1 for year = t* picks up this effect. In principle, we can trace out the entire history of embodied and disembodied effects by including a complete set of year and vintage dummy variables in equation 2.

The Estimating Equation

As there is no way to linearize equation (1), the model must be estimated via nonlinear least squares (NLLS). And of course, with NLLS and a large number of coefficients, convergence becomes a problem. The functional form which most readily converges is

Equation 3

$$\frac{1 - d_v^a}{d_v^a} = \alpha - 1 + EXP\left(\beta + \left(\gamma_0 + \sum_v \gamma_v \cdot D_v + \sum_t \gamma_t \cdot D_t \right) \cdot age \right)$$

We were unable to get equation (3) to converge with a complete double set of dummy variables; thus we grouped both vintages and years into two-year intervals (e.g., a dummy variable for t = either 1950 or

1951). The equation is estimated over all vintages[2] and all years from 1950-1991. Excluded were ages less than 4 years and any other observations with negative reported mortality rates.[3] The omitted years and vintages are both 1960-61. Results for the domestic fleet are given in the table below.

Next we convert the parameter estimates into life expectancies. For the omitted year and vin (1960-61) the estimated parameters are given in the top panel of the table. Plugging these parameters into the logistic survival function we recover predicted age-specific death rates, from which we calculate life expectancy, calculated out to age 19. For these parameter values the life expectancy is 10.26 years.

The contributions of the embodied (vin) and disembodied (year) effects are displayed as follows:

- For vin, we ask what would be the life expectancy for a non-1960-61 vehicle, living in the 1960-61 external environment. For example, the vin(1962-63) dummy coefficient is .0502; we calculate life expectancy for a car for which $\gamma = -.6288 + .0502$. As γ falls from -.6288 to -.5786, life expectancy rises from 10.26 years to 10.83 years. The incremental life expectancy, 0.57 years, is attributable to some inherent difference between 1960-61 cars and 1962-63 cars. When we carry out this calculation for all of the vin dummy coefficients, we obtain a time series which shows the life expectancy that each vin would achieve, living in the 1960-61 external environment.
- For year we do the analogous calculation. The 1962-63 year dummy coefficient is -.0074, taking γ to -.6326 and yielding a calculated life expectancy of 10.18 years. This says that a 1960-61 vintage car could expect to live 10.26 years in the 1960-61 environment but only 10.18 years in the 1962-63 environment. Carrying out this calculation for all of the year dummy coefficients, we get a time series showing the life expectancy of a 1960-61 vintage car in the economic environments from 1950-51 through 1990-91.

The results of both of these calculations are shown in Figure 4.

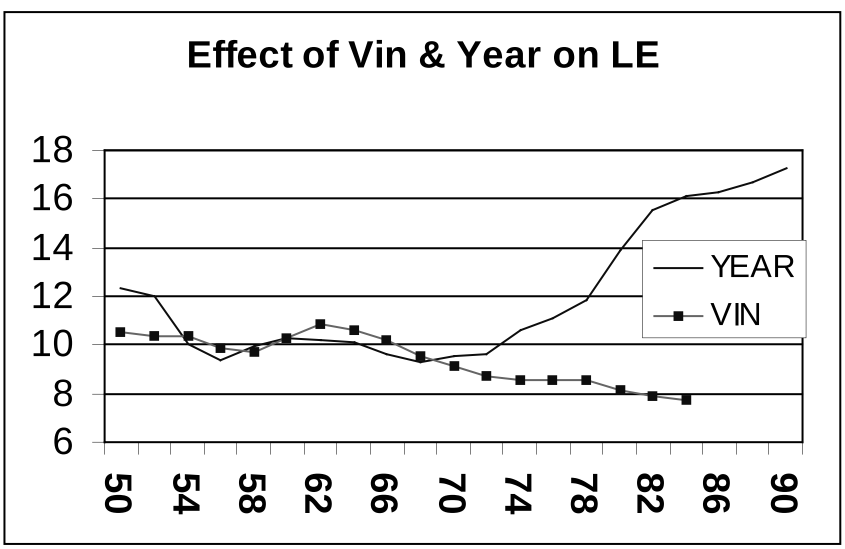
[2] All vintages prior to 1952 are lumped into the 1950-51 dummy variable; prior specifications with separate dummies for earlier clusters of vintages were generally insignificantly different from results reported here.
[3] "Mortality" is the difference between the number of vintage-v registrations in year t and year t-1. Sometimes the entire stock of a given vintage does not get sold (hence registered) for a few years; these "post-mature births" lead to negative calculated deaths.

Table 1
Regression Results

		3.181 (.0486)
β		6.472 (.0504)
γ_0		-.6288 (.1040)
R^2		.9237

	VIN EFFECT	YEAR EFFECT		VIN EFFECT	YEAR EFFECT
1950-51	.0247 (.0302)	.1561 (.0189)	1972-73	-.1791 (.0238)	-.0632 (.0564)
1952-53	.0900 (.0512)	.1320 (.0329)	1974-75	-.2120 (.0296)	.0317 (.0545)
1954-55	.0063 (.0446)	-.0237 (.0430)	1976-77	-.2048 (.0468)	.0697 (.0151)
1956-57	-.0373 (.0157)	-.0913 (.0471)	1978-79	-.2081 (.0299)	.1223 (.0405)
1958-59	-.0614 (.0001)	-.0031 (.0367)	1980-81	-.2803 (.0239)	.2359 (.0390)
1960-61	(omitted)	(omitted)	1982-83	-.3186 (.0211)	.3118 (.0357)
1962-63	.0502 (.0012)	-.0074 (.0373)	1984-85	-.3598 (.0207)	.3378 (.0269)
1964-65	.0294 (.0312)	-.0173 (.0188)	1986-87		.3464 (.0280)
1966-67	-.0091 (.0163)	-.0667 (.0282)	1988-89		.3685 (.0398)
1968-69	-.0709 (.0349)	-.1022 (.0328)	1990-91		.4039 (.0461)
1970-71	-.1238 (.0159)	-.0797 .0276)			

Figure 4



From 1950 through about 1966 inherent durability (vin) moved in a very narrow band from life expectancy (evaluated in the 1960-61 external environment) of about 10 to 11 years. But from the peak vintage (1962-63) there commenced a virtually linear decline in inherent durability, from a peak of 10.8 years to a final value of 7.71 years. It certainly does not seem that the recent increase in longevity of domestic cars is attributable to the cars themselves.

The year effect shows the life expectancy of a 1960-61 car in the external environments represented by the various years. Note first that the year coefficients pick up something that we would expect to see: From 1950 through 1953 people took very good care of their cars. Holding car quality constant, cars lasted about 2 years longer in 1950-53 than over the next several years. This is surely the legacy of the World War II production hiatus and the subsequent slowdown during the Korean War. After the war legacy, the external environment for automobiles was quite stable until the early 1970s. But beginning in 1973 there was a steady and dramatic improvement in the external environment for automobiles. A 1960-61 vintage car would have survived about 10 years had it lived its entire life in the 1972-73 environment, but the same car would have survived 16 years in the 1984-85 environment and almost 17 years in the 1990-91 environment.

What is in the "External Environment?"

The distinction between vintage and environmental effects rests on the notion that a vintage (embodied) effect affects a given vintage in all years, but a year effect (disembodied) affects all vintages in a given year. Thus for example, the year effect going from 1972-73 to 1974-75 (almost a full year rise in life expectancy) is generated by a decline in the age-specific death rates of all vintages of cars between 1972-73 and 1974-75.

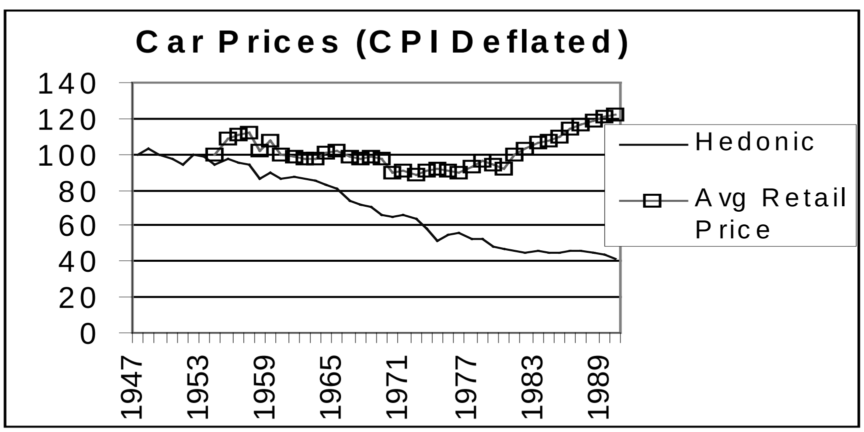
Exactly what are these disembodied year effects and embodied vintage effects? The answer is that embodied effects capture anything which is physically attached to the car (built-in durability) and disembodied effects are everything else. In particular, disembodied effects might include any of the following:

- The price of new cars. If new cars become more expensive it is optimal to maintain them into older age. This effect will be arbitraged into the prices of used cars, and the higher price of used cars will cause them to last longer than before the price increase.

- The price of repair/replacement parts. Anything that makes auto maintenance cheaper, so long as it affects grandfather and new cars equally, induces consumers to maintain their cars, both grandfather and new, into older ages.
- Anything in the **external environment** which reduces the amount of maintenance that cars require (and therefore which affects new and grandfather cars equally). Possibilities are:
  - Improved highway safety. If with the passage of time cars are subjected to fewer hazards, they will live to an older age. Such things as improved highway safety should reduce the death rates of old and new cars alike.
  - Migration to the Sunbelt. If more cars are driven on salt-free roads, then the longevity of both old and new cars will rise.

Only the engineering of cars themselves influences new but not grandfather cars.

Figure 5



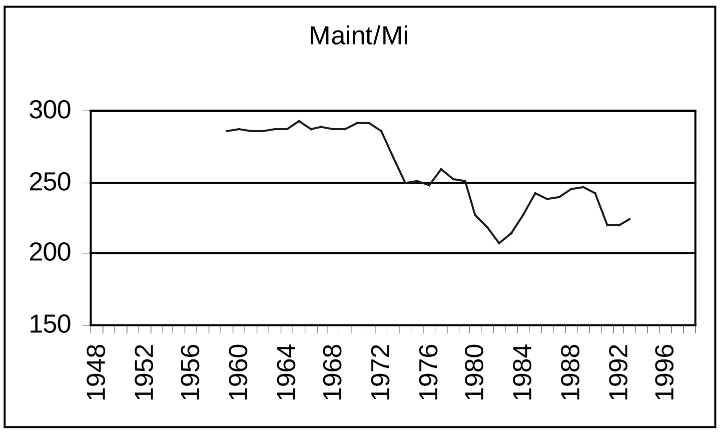
In this section we look at data on new car prices and maintenance cost[4] to see whether we can isolate something which led to the large disembodied rise in life expectancies shown in figure 4. Figure 5 is our evidence on new car prices. The series with square markers is the average retail price of new cars, deflated by the CPI, as reported by Automobile facts and Figures (various issues). The second series is Gordon's

[4] We have not been able to find data that separate maintenance into price and quantity.

(1990) hedonic series[5] also deflated by the CPI. It is the average retail price, not the hedonic price, that enters into equation (3); we show the latter only for comparison. The rise in the disembodied (year) longevity effect predates the rise in new car prices by about a decade (indeed it begins at a time when new car prices were historically low). The 1980s rise in car prices may be responsible for the continued improvement in longevity during the 1980s, but cannot have been responsible for the initial increase.

The next graph shows the history of auto maintenance expenditure per mile driven, by year.

Figure 6



The series shows auto maintenance expenditure (from the Personal Consumption Expenditure component of the National Income and Product Accounts) per vehicle mile,[6] deflated by the CPI. The decline in maintenance cost per mile coincides almost precisely with the disembodied improvement is auto longevity; it seems like a likely suspect for explaining the onset of longevity improvement.

In principle, the dramatic decline in the cost of maintenance could be either embodied (new-vintage cars require less maintenance than their predecessors) or disembodied (the price of maintenance fell for all vintages, or improvements in highway safety made automobile operation safer). For a variety of reasons, it seems clear that the precipitous decline in maintenance expenditure from the early 1970s to the early 1980s represents a disembodied improvement, not an improvement in auto quality. First, it is consistent with our estimate above that the mortality improvement is disembodied. Second, any embodied

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[5] Gordon's series ends in 1983; we have spliced it to the new-car component of the CPI for subsequent years.

[6] Source for vehicle miles: Automobile Facts and Figures, various issues.

improvement in maintenance requirements would manifest itself in the aggregate numbers much more gradually, as post-improvement cars gradually become a more dominant part of the fleet. (The recovery of maintenance cost in the mid-1980s is likely due to the dramatic aging of the fleet revealed in Figure 1.)

The evidence seems to point to the following immediate causes of the rise in car longevity. The rise was triggered by a substantial fall in the price (not the required quantity) of auto maintenance, which induced owners to maintain cars into older age. The disembodied longevity improvement may have been perpetuated in the 1980s by the rise in new car prices.

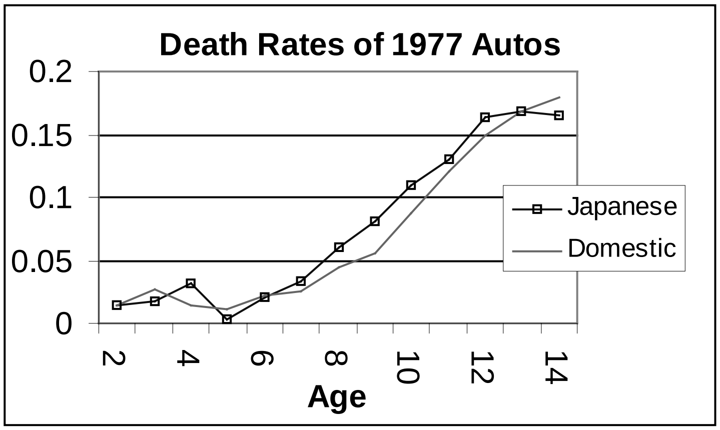
The evidence presented above sheds no light on **why** the price of maintenance might have fallen during the 1970s or why the retail price of new cars rose during the 1980s. And there are far too few observations for any serious statistical work. One possibility is that the secular decline in the industry's market power[7] over this time forced the industry to cut its profit margins more substantially on repair parts than on new cars. Several durable-goods market-power models predict a greater markup on parts than on original equipment.

Not the Japanese-Car Effect

One plausible popular explanation for the rise in longevity of American cars is the competitive effect of Japanese imports. According to this story, the 1970s saw a flood of inexpensive, highly durable Japanese imports, which ultimately forced domestic manufacturers to improve quality. But this explanation seems inconsistent with the central observation of this paper; that improved longevity has nothing to do with improved cars. Also the (disembodied) improvement began in the early 1970s – about 5 years before Japanese imports made major inroads into the United States market. And finally, surprisingly, Japanese cars have not shown superior durability to American cars. Figure 7 shows the age specific death rates for Japanese and Domestic 1977-vintage cars. Domestic death rates were generally slightly **below** Japanese death rates. Patterns for other vintages are generally similar to those of Figure 7; there is rarely a significant difference between domestic and Japanese mortality patterns. Whereas Japanese cars do better for some vintages, American cars do better for approximately the same number of vintages.

[7] The Herfindahl index of concentration in the auto industry was over 3000 in the mid-1960s, and had fallen to under 2500 by the early 1980s.

Figure 7



Conclusion

Of course, it would be most interesting to know what economic forces led to the mild secular decline in inherent durability, and to the very rapid secular improvement in the external environment for automobiles. Unfortunately, any time-series variable which is roughly flat from the mid-1950s until the early 70s and then shows a linear trend is almost perfectly correlated with the year and vin effects depicted above. There seems to be no way to statistically identify the forces at work.

But despite our inability to learn **why** the year and vin effects are as depicted, the evidence seems to strongly support the proposition that the secular improvement in car longevity was brought about not by an improvement in the durability of cars but by a truly dramatic improvement in the environment in which cars live their lives.