

Andrew Court and the Invention of Hedonic Price Analysis

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Although popularized by Griliches in the early 1960s, the pioneering hedonic price analysis dates back to a 1939 article by Andrew Court which receives, at best, only perfunctory citations. This article revisits and extends Court's 1939 analysis. By many standards of contemporary hedonic price analysis, Court's work stands up quite well. It addresses problems of nonlinearity and changes in underlying goods, with circumspect analysis and interpretation. The article evaluates Court's work, extends his analyses using data from his unpublished papers, and conjectures as to why the hedonic price method was unused for so many years. © 1998 Academic Press

INTRODUCTION

One of the more unusual episodes in econometric work regards the invention, disappearance, and subsequent re-emergence of hedonic price analysis. Although popularized by Zvi Griliches in the early 1960s, the pioneering work, and apparently the coining of the term "hedonic," dates back to a 1939 article by Andrew Court. Court's work generally receives, at best, a perfunctory citation in most articles.

It deserves better. By many standards of contemporary hedonic price analysis, Court's work stands up quite well. It deals with problems of nonlinearity, and with changes in underlying goods bundles. It addresses a substantive methodological problem with circumspect analysis and interpretation. Given the circumstances, it is useful to revisit the analysis and to re-examine the model, and to ask why it was unused for 20 years after its inception.

This article describes and evaluates Court's work by the standards of contemporary hedonic price analysis. It then extends the work using data

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from Court's unpublished papers. After a discussion of the revival, due largely to the work of Zvi Griliches, it conjectures as to why the method was unused for so many years.

WHAT COURT DID

Andrew Court was an economist for the Automobile Manufacturers' Association in Detroit from 1930 to 1940. He then worked for General Motors until retiring in 1966. Eight volumes of his professional papers were donated to the Walter P. Reuther Library at Wayne State University in December 1980 and were opened for research in December 1989. These papers indicate that he focused on labor cost issues for the industry during the period that he worked on hedonic prices.¹ There is no indication that he did any hedonic price analysis subsequent to his 1939 publication.

Court's papers suggest that he was interested in automobile price indices as early as 1935. His papers include three data spreadsheets for 1925, 1930, and 1935 model automobiles. In these spreadsheets, Court examines measures of dollars per pound, or dollars per unit of horsepower, to compare to Bureau of Labor Statistics measures. The spreadsheets apparently served as the source for some of the regressions presented, and they will be discussed in more detail in the following text.

Examining many price index procedures and finding them wanting, Court [3] notes "Passenger cars serve so many diverse purposes that such a single, most important specification can not be found (like rated tonnage in the case of trucks). The simple method is inapplicable, but why not combine several specifications to form a single composite measure? (p. 107)." The term hedonic (in capitals) was used to describe the weighting of the relative importance of various components, such as horsepower, braking capacity, and window area, among others in constructing an index of "usefulness and desirability." Prices per vehicle would be divided by the hedonic index to adjust for changing vehicle specifications.²

Court's statistical model is familiar to hedonic price students. He recognized the necessity of a well-specified model (including horsepower, braking capacity, window area, seat width, and tire size), but chose to concentrate on the dry weight w , wheelbase f , and advertised horsepower h . The

¹ Subsequent discussion will refer to Court's papers as Court [2].

² In a footnote, he cites *Webster's New International* that "'Utilitarianism, seeking the good in the greatest happiness of the community as a whole, is the chief hedonistic doctrine.' Thus, Hedonic price comparisons are those which recognize the potential contribution of any commodity, a motor car in this instance, to the welfare and happiness of its purchasers and the community."

fundamental equation (simplifying his notation) for a three period model is

$$p = k + b_w w + b_f f + b_h h + b_1 t_1 + b_2 t_2, \quad (1)$$

with conventional time period shifts t_1 and t_2 .

Court did several "modern" things. Looking at the data, he determined that a semilog form should be used "since preliminary analysis indicated that this gave more nearly linear and higher sample correlations (p. 110)." Second, he "chained" the index. With data for 1920, 1925, 1930, 1935, 1937, and 1939, he estimated five sets of adjacent-period indexes. This allows the implicit prices to adjust slowly over time without constraining them to be constant (in logs), as would occur with a single set of coefficients and five time dummies. Third, he addressed the question of whether given models are actually being purchased by noting that one could weight the observations by number (or log of number) of cars sold.

His results appear in Table 1. Neither the constant, the actual coefficients, nor significance levels are reported; results are expressed as percentage change per unit impact of the explanatory variable. The regressions provide excellent correlations (reported rather than R^2 's). The reported results indicate a falling hedonic impact of wheelbase, a relatively constant hedonic impact of weight, and a relatively constant, albeit smaller impact of horsepower. Court annualized the price changes over the intervals estimated. The regression results show that the index price fell from 100.00 in 1920 to 23.10 in 1937, rising then (by 2.5% per year) to 1939.

He does not appear to have adjusted prices in constant dollars. The Consumer Price Index fell from 100.00 to 83.33 between 1920–1930, most of the change representing a return from 1920's post-war inflation. It fell another 16.8% (from 83.33 to 69.33) between 1930 and 1939. Thus Court's rates of price decrease were overstated. Adjusting for inflation indicates

TABLE 1
Court's Hedonic Price Specifications

| Period | Percent change in price | | | | <i>r</i> |
|-----------|-------------------------|--------------|------------|--------------|----------|
| | Per inch (%) | Per cwt. (%) | Per HP (%) | Per year (%) | |
| 1920–1925 | 2.01 | 2.35 | 0.80 | –12.4 | 0.96 |
| 1925–1930 | 1.82 | 4.02 | 0.30 | –7.1 | 0.96 |
| 1930–1935 | 0.31 | 5.66 | 0.55 | –7.4 | 0.95 |
| 1935–1937 | 0.01 | 5.76 | 0.53 | –2.5 | 0.97 |
| 1937–1939 | 0.15 | 2.95 | 0.71 | 2.5 | 0.93 |

Source: Court [3]: p. 111.

that 1939 quality-adjusted car prices were 35.0% of their 1920 value in constant dollars, rather than 24.3% of the current dollar value.³

REPLICATING AND EXTENDING COURT'S ANALYSES

Court's spreadsheets for 1925, 1930, and 1935 contain the same variables that appear in Court [3]. They almost certainly served as the sources for the regressions, and they offer an opportunity to examine alternative hedonic formulations. The data refer to five passenger-four door sedans. There are 74 models in the 1925 sample, 90 in the 1930 sample, and 58 in the 1935 sample.⁴

Table 2 replicates Court's 1925–1930 and 1930–1935 paired regressions. They have comparable simple correlation coefficients, and they show wheelbase and weight to be important. The replications indicate per year decreases of 7.4 and 6.8% respectively, compared with Court's reported decreases of 7.1 and 7.4%. Without knowing exactly what other data manipulations Court conducted or whether he omitted any observations, the replications appear plausible.

³To simplify comparisons with Court's work, I conduct subsequent analyses in current dollars.

⁴Court [3] notes the possibility of weighting the observations by numbers of sales. This would be particularly important for 1925 in which the Model T Ford accounted for 1.24 million of the 2.89 million cars sold. He had information on registration by car (Court [2]), but he apparently did not have information on registration by model, although the spreadsheets indicate that he tried to guess the shares of the different models.

TABLE 2
Replications of Court's 1925–1930 and 1930–1935 Paired Regressions*

| Variable | (1) 1925–1930 | (2) 1930–1935 |
|----------------|--------------------|--------------------|
| Intercept | 4.1256 (13.64) | 4.2340 (16.01) |
| Wheelbase | 0.0161 (4.27) | 0.0101 (3.14) |
| Hundredweight | 0.0461 (8.03) | 0.0484 (11.48) |
| Horsepower | –0.0003 (0.21) | 0.0015 (1.59) |
| Time | –0.3852 (10.30) | –0.3503 (11.81) |
| N | 164 | 148 |
| SER | 0.1693 | 0.1388 |
| R ² | 0.9013 | 0.9425 |

* (*t*-statistics in parentheses).

Table 3 presents alternative specifications to those that Court described. Court's method does not guarantee that the predicted value from year 2 of the first of the paired regressions equal the value from year 1 of the second of the paired regressions. This restriction is easily imposed; the wheelbase effect is almost identical in the two panels, and there is a slight decrease in the impact of weight. The linkage increases the first period price change slightly from -7.4 to -7.5% per year, while decreasing the second panel price change from -6.8 to -6.6% per year.

Column 2 shows possibly the most common hedonic procedure, in which the 3 years are pooled, with two trend dummies. The trend dummy suggests a larger first period fall than the other procedures, and a similar second period decline. Columns 3, 4, and 5 provide separate estimates for the 3 years, allowing hedonic prices to vary by year. They can then multiplied by an "average" bundle for the 3 years to determine yet another price index.

TABLE 3
Alternative Specifications with Court's Data*

| Variables | (1) Restricted shift | (2) Trend dummies | (3) 1925 | (4) 1930 | (5) 1935 |
|-----------------------|----------------------------|-------------------------|------------------|-------------------|------------------|
| Intercept | 4.3541 (21.01) | 4.2543 (16.99) | 3.4905 (6.48) | 4.2413 (12.31) | 3.8571 (9.67) |
| Wheelbase (WB) | 0.0133 (5.07) | 0.0147 (4.91) | 0.0236 (3.54) | 0.0102 (2.30) | 0.0092 (1.96) |
| Hundredweight (WT) | 0.0488 (10.22) | 0.0448 (10.86) | 0.0367 (3.63) | 0.0523 (7.83) | 0.0424 (9.15) |
| Horsepower (HP) | -0.0001 (0.05) | 0.0012 (1.22) | 0.0007 (0.24) | -0.0003 (0.26) | 0.0048 (4.05) |
| WB shift term | 0.00005 (0.05) | | | | |
| WT shift term | -0.00003 (0.57) | | | | |
| HP shift term | 0.0012 (0.84) | | | | |
| Time 1 | -0.3909 (11.47) | -0.4179 (13.08) | | | |
| Time 2 | -0.3436 (10.46) | -0.3438 (10.63) | | | |
| <i>N</i> | 312 | 222 | 74 | 90 | 58 |
| SER | 0.1557 | 0.1561 | 0.1845 | 0.1536 | 0.1012 |
| <i>R</i> ² | 0.9246 | 0.9259 | 0.8697 | 0.9230 | 0.9697 |

* (*t*-statistics in parentheses).

TABLE 4
Automobile Price Indices by Various Methods—1925–1935

| Price index | List | Court | Court replication | Restricted shift | Pooled with dummies | Separate regressions chain index |
|-------------|--------|--------|-------------------|------------------|---------------------|----------------------------------|
| 1925 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 1930 | 85.34 | 70.97 | 68.03 | 67.65 | 65.84 | 66.78 |
| 1935 | 64.61 | 49.66 | 47.93 | 47.97 | 46.69 | 43.48 |

Table 4 compares results with the various indices. There was considerable price deflation during the 10 year period, so even a comparison of list prices shows an index (with a 1925 value of 100) declining to 85.34 in 1930, and to 64.61 in 1935. Court's index indicates a fall in prices by just over 50%, and the replication (from Table 2) provides a very slightly greater fall.

The various constructions all provide similar results. The greatest fall in prices occurs with the three separately estimated regressions, with the "mean" bundle. These indicate that by 1935, automobile prices, controlling for quality, fell to under 44% of their 1925 value.

DISCUSSION AND CONCLUSIONS

There was little follow-up to Court's hedonic work from 1939 to 1960.⁵ Griliches [9] recalls using his first hedonic regression in a 1958 article (Griliches [6]) on the demand for fertilizer. He related the prices of different fertilizers to their mixes of nitrogen, phosphoric acid, and potash, to derive better weights (existing price indices used equal weights) for the construction of a constant quality fertilizer quantity and price series. The regression, which was "buried in a footnote," yielded weights of 3.5, 2, and 1, respectively, for the three components.

Griliches's work on automobile price indices [7, (1961)], as did Court, used automobile models as units of analysis, with the regressions reported in more modern terms (standard errors of the coefficients, R^2 s). As did Court, he used the semilog form, producing R^2 s in the 0.80s and 0.90s, and his Table 4 similarly presents chained adjacent period regressions. Like Court's work, the Griliches analysis did not appear in a conventional economics publication.⁶ Unlike Court, however, there was considerable response, and hedonic prices moved swiftly into the micro-econometric tool kit.

⁵ Berndt [1] provides an interesting historical perspective on price index work during that time.

⁶ In Griliches [8], he notes that the 1961 article appeared in an "inaccessible" publication.

Why did it take so long? One can list a number of conjectures. The econometrics that took hold in the 1940s and 1950s was fundamentally although not exclusively macro-econometrics, with data collection concentrated at highly aggregated levels. Hedonic price analysis, which is fundamentally a micro-econometric analysis, might have been of less professional interest to those doing quantitative work.

Second, the rudimentary nature of data collection and coding, as well as the time-consuming nature of regression analysis on office calculators and early electronic computers, made the contemporary types of calculation impossible. Real estate records were not computerized, and samples had to be coded and keypunched. Geographic coding was done with pins on a map.

Further, calculating one regression with 100 or more observations and a large number of explanatory variables was a major undertaking. Detailed examination of which variables were important, or what functional form would fit best was beyond the machines (although not the brains) of the early analysts. Griliches [9] himself may phrase it best, referring to the 1961 article:

This paper appeared at a rather opportune moment, just as data, computer resources, econometric training and sophistication, and general interest in this range of topics were all expanding, and a whole literature developed in its wake, influencing the measurement of real estate prices, wage equations, environmental amenities, and other aspects of "qualitative differences." (p. 187).

One other reason may explain the long wait. In discussing hedonic price analyses in the early 1980s, I referred to Andrew Court's work. A colleague vehemently disagreed, noting that Louis Court had written on hedonic prices in 1941. Indeed, Louis Court, a University of Chicago mathematician, had written two articles (Court [4, 5]) in *Econometrica* referring to commodity spectra and consumer demand. These articles are extraordinarily difficult (eliciting an unusual apology from editor Ragnar Frisch)⁷ and any readers looking to use them for any hedonic price work might have been scared away permanently.⁸

It is both enlightening and sobering to close with a last written comment on Court's original article, by Louis Bean of the Agriculture Adjustment

⁷ In the opening footnote Frisch writes:

The present paper by Mr. Louis M. Court is published in *ECONOMETRICA* not because of the novelty of its proposition from the purely mathematical viewpoint... Economic theory is now growing into a stage where much of the work will consist in a combination of mathematical and economic analyses so intimate that it is difficult to say where one begins and the other ends. Mr. Court's paper is a valuable contribution toward this type of work.—Because of its length [note: 83 pages in *Econometrica*] it will be published in two installments, the second dealing principally with consumer demand theory.

⁸ Jack Triplett remembers these articles similarly.

Administration:

Mr. Court's interesting work should be carried much further, as he suggests. We should, however, not be disappointed if neither public agencies nor trade associations adopt the policy of publishing prices, values and index numbers based on the *relatively tricky results that one is sure to get by applying the device of multiple correlation* [italics added]. The only group who would sponsor such a procedure would be the non-existent National Association of Experts in Multiple Correlation, the demand for whose services would be enormously increased.

Empiricists should take note!

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