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"PRICE HEDONICS: A CRITICAL REVIEW"

by

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July 2002

Paper prepared for the Federal Reserve Bank of New York conference Economic Statistics: New Needs for the 21th Century, July 11, 2002. This draft is preliminary.

Price Hedonics: A Critical Review

I. Introduction

Price hedonics is a statistical technique introduced more than 70 years ago to deal with issues of product quality. It has enjoyed a quiet and respectable life since coming of age in the early 1960s, but has gained a certain amount of notoriety in the last few years through a series of highly visible assessments of the Consumers Price Index. This attention has prompted a reassessment of the technique itself and its role in the CPI, and important new dimensions have been added to the study of price hedonics. These developments that are the subject of the current paper.

The new debate began with testimony by Federal Reserve Board Chairman Alan Greenspan before the Senate Finance Committee in early 1995. Greenspan let drop the comment that he thought the Consumer Price Index was biased upward "by perhaps 1/2 to 1 1/2 percent per year." This remark did not surprise specialists who understood the technical difficulties involved in constructing accurate price indexes, but it created a small sensation in the political arena. Here, at last, was a chance to get around one

of the most difficult issues in the tendentious debate over balancing the federal budget: what to do about the Social Security program. Here was a way to reduce expenditures in order to balance the federal budget and rescue the Social Security Trust Fund from insolvency in the next century. And the beauty of it all was that the solution did not involve raising new taxes or changing benefit formulas. Instead, it involved "fixing" a biased method of adjusting Social Security benefits for the effects of price inflation, that is, by fixing the way BLS handles problems like the one posed by the arrival of a new improved tube of toothpaste.

These political considerations may seem tangential to the subject of price hedonics, but events following from Greenspan's remark have linked the two issues. First, a blue-ribbon panel of experts was consulted by the Senate Finance Committee, and their Delphic consensus supported Greenspan's estimate. The Advisory Commission to Study the Consumer Price Index (better known as the Boskin commission after its chair) was subsequently established by Congress to pass judgment on the magnitude of the CPI bias. It produced an estimate of 1.1 percent per year for the bias, almost identical to Greenspan's estimate, and approximately half of the average bias was attributed to product innovations missed by the CPI (0.6). A parallel study by Shapiro and Wilcox arrived

at the same conclusion, putting the overall bias at 1.0 and the bias due to quality change and new goods at 0.45. They also observed that this bias was the most difficult to correct, likening the quality adjustment process to house-to-house combat.

Price hedonics enters this picture because it currently offers the best hope for dealing with the bias due to product innovation. While the Boskin commission report did not explicitly recommend that the BLS expand the use of this technique in the CPI program (as had the 1961 Stigler committee report), BLS has moved in this direction by increasing the number of items in the CPI treated with price hedonics techniques. The BLS also requested in 1998 that the Committee on National Statistics of the National Research Council empanel a group of experts to investigate the conceptual issues involved in developing a cost-of-living index, including the use of price hedonic methods. This committee (here called the "Schultze panel") released its report earlier this year. The panel did not provide unanimous support underlying philosophy of the CPI as a pure cost-of-living index, and, in its own words, it differs from the Stigler committee and the Boskin commission in this regard.[1]

The Schultze panel was cool to the BLS's expanded commitment

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[1] National Research Council (2002), page 3. The panel's report "At What Price" will be referred to as AWP.

to price hedonics. One the one hand, the report endorsed hedonic techniques as a research tool, commenting that they "currently offered the most promising approach for explicitly adjusting observed prices to account for changing product quality", and recommending that "BLS should continue to expand its experimental development and testing of hedonic methods ... (Recommendation 4-2)". However, the panel recommended against immediately expanding use of hedonics in constructing the CPI itself: "Relative to our view on BLS research, we recommend a more cautious integration of hedonically adjusted price change estimates into the CPI (Recommendation 4-3)". The apparent disconnect between the two recommendations is explained by a "concern for the perceived credibility of current methods." The panel went on to say "While there is an established academic literature on estimating hedonic functions, researchers are much less experienced using them across a wide variety of goods".[2]

The "perceived credibility" standard is something new in the critique of price hedonic methods and, more generally, in the discussion of price measurement. It asserts a higher standard of acceptability for results that have a significant impact on policy (and, by extension, on the well-being of the public) than for "academic" research. This idea has been implicit in policy

[2] These quotes are from pages 6 and 7 of AWP.

analysis (and in statistical agency policy) for a long time, and the explicit appeal to the perceived credibility standard may well the most enduring intellectual contribution of the Schultze panel. However, the panel did not go on to spell out what additional requirements were implied by this standard. They urged further research and recommended the creation of an advisory panel of experts to help guide this research (Recommendation 4-8). The goal was to "provide an analytic basis for proceeding sensibly in the face of external pressures to proceed quickly in this area (AWP, page 7)".

The absence of explicit criteria is not surprising, because the political economy of statistical measurement is largely *terra incognito* in the practice of economics. However, the Schultze panel report forces the debate in this direction. The main objective of this paper is to make a start in evaluating price hedonics from this expanded perspective. Since the credibility of price hedonics depends in part on the current state of academic research, the next section describes the hedonic model and reviews its main uses. This is necessarily a brief overview, and the interested reader is directed to excellent treatments of the subject in Berndt (1991), Triplett (1987), and the extensive expository material in AWP. I then turn to some of the standard criticisms of price hedonics, and then move into the uncharted

realm of the political economy of price measurement.

II. The Structure and Interpretation of the Price Hedonic Model

A. The Hedonic Hypothesis

Product variety is the *raison d'être* of the price hedonic model. Certain types of commodities are differentiated into sub-types: different models of autos, different species of petunia, personal computers with different configurations, different brands of toothpaste, and so on. Each sub-type could be treated as a good in its own right, with its own price and quantity. This is appropriate for some purposes (e.g., industrial organization studies), but it is inefficient in macro studies of inflation and growth if the number of underlying characteristics or attributes defining the item is small relative to the number of varieties in the market place. In this case, a more tractable way of proceeding is to characterize each sub-type in terms of its characteristics, $X_{j,t}$. Each variety can then be defined by the n-tuple of its component characteristics, $X_t(X_{1,t}, \ldots, X_{n,t})$.

This formulation leads naturally to a definition of product quality in terms of the amount of characteristics each variety possesses.

The empirical link between a variety and its constituent attributes is established, in the hedonic model, through its price, not its quantity. The price of a variety j at time t, $P_{j,t}$, is assumed to be a function of its defining characteristics, $h_t(X_{j,t})$, plus a random error term. In econometric applications, the hedonic function is assumed to have a linear, log-linear, or semi-log form, although more complicated forms like the translog or Box-Cox can be used.[3] The linear specification of the hedonic function can be written

$$P_{j,t} = \beta_0 + \beta_1 X_{1,t} + \ldots + \beta_n X_{n,t} + \epsilon_t \qquad (1)$$

The hedonic weights, β_i, are the portion of an item's overall price attributable to a given characteristic, and are usually interpreted as the price of the corresponding characteristic.

There are two basic approaches in the literature to understanding the characteristic price. One tradition relates

[3] Berndt (1991) cites the Waugh (1928) study of fresh asparagus in Boston markets as being the earliest known empirical example of the technique. The first hedonic regression analysis is attributed to Court (1939), who studied passenger cars. However, the growth in the field began in 1961 with the work of Zvi Griliches.

this price to consumer's willingness to pay for the characteristic. This utility-based interpretation is reflected in the use of the term "hedonic" to describe the approach, and was the original view of the matter adopted by Court and other early practitioners. Lancaster (1966) proposed a theory of consumer utility based on characteristics rather than goods, and Diewert (2001) has described the rather restrictive conditions under which the hedonic function can be derived from an underlying utility function.

The second approach, due to Rosen (1974), has become the generally accepted paradigm of the hedonic approach. Rosen relates the hedonic function to the supply and demand for individual characteristics: to the demand curves of consumers with heterogeneous tastes for the different combinations of characteristic embodied in each variety; and to the corresponding supply functions for each characteristic. In this view, the price hedonic equation (1) is basically an envelope linking the various equilibria, although, as Rosen emphasizes, the link also requires restrictive assumptions. This view was advanced by many authors, including Triplett (1983), Epple (1987), Feenstra (1996), and Pakes (2002).

B. Price Inflation and Quality Change

The concepts of price inflation and quality change have a straightforward interpretation in the hedonic model. Inflation leads to an upward shift in the hedonic function because some or all characteristics become more expensive (i.e., β "prices" increase). The case of quality change, on the other hand, is somewhat more complex. Quality change can arise from two sources: product innovation, which introduces new varieties into the market place that were not feasible in prior years; and composition change, which brings new varieties into the CPI sample which were technically feasible but were not produced for economic reasons, or were produced but were not present in the CPI sample.

Changes in the composition of varieties seen in the market place can occur because changes in income, individual tastes, or demographics dictate a change in the product mix within the feasible set of possible varieties. For example, rising incomes in an particular area may cause some supermarkets to introduce upscale brands of food. A change of this sort is equivalent to a movement along the hedonic function from X_0 to another X_1.

Product innovation, on the other hand, occurs when technological innovation in product design or production lead to a reduction in the cost of acquiring a given amount of a

characteristic (or more characteristics for the same price). Improvements in personal computers fall into this category. This sort of quality change is equivalent to a downward shift in the hedonic function. A variant of this theme occurs when quality innovation leads to the introduction of varieties which have a greater amount of one or more characteristics than previously feasible, without lowering the cost of existing varieties. Aircraft with larger capacity are an example of this possibility. This case can be represented in our figure as an extension of the feasible portion of the existing hedonic function.

Figure 1 portrays the case of a linear hedonic function with a single characteristic. The hedonic surface for the reference time period t=0 is designated $h_0(X)$; the variety sampled in this period has X_0 units of the characteristic, and costs $P_{0,0}$. This price deviates from the hedonic line by the error ϵ_0. The hedonic surface for the comparison period shifts upward to $h_1(X)$, and a new variety is sampled with X_1 units of the characteristic. It costs $P_{1,1}$, with a deviation from the hedonic line of ϵ_1. The upward shift in the hedonic function indicates that inflationary pressures dominate any cost-reducing product innovation, but it is not possible from the data shown in the figure to separate the two effects (or even tell if product innovation has occurred). The replacement of variety X_0 with X_1 signals a change in the

market basket, but, again, this may be due to pure composition change (if X_1 were potentially available in the reference period), or otherwise due to innovation.

C. Uses of the Hedonic Method

Price hedonics has been applied to a wide range of issues in a variety of fields of economics. At the risk of some over-simplification, it is useful to group these studies into two broad groups: those which are mainly concerned with adjusting observed prices on the left-hand side of the hedonic regression for changes in product quality, and those which focus on issues relating to the individual characteristics and β-coefficients on the right-hand side of the hedonic regression.[4] Much of the recent debate has been about the first of these objectives.

Indeed, the main mission of price hedonics has been, since its inception, to isolate the quality component of price changes

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[4] Although this paper is essentially about "left-hand side" issues, it is worth noting that a number of interesting economic problems are naturally formulated in terms of individual characteristics and their β 's. For example, when the (log) price of used producers' durable equipment is regressed on two characteristics, the year in which the equipment was sold and its age at the time of sale, the β-coefficient of age can be interpreted as the rate of economic depreciation (indeed, this is the theoretical definition of depreciation). This approach formed the basis for my own work with Frank Wykoff which estimated rates of depreciation for a wide variety of business fixed capital, and which has come to be embedded in the National Accounts estimates of the capital consumption adjustment. Another example comes from human capital theory. The determinant of wage rates have been studied using price hedonics by putting the wage on the left-hand side of (1) and worker characteristics on the other. Other examples include the use of hedonics to study such diverse items as housing values and fine wines.

to achieve better measures of price inflation. This was the objective of the original Waugh and Court studies, and was recognized by the Stigler report. Price hedonics has influenced official price statistics in two ways: through the decision by BEA to adjust computer prices for quality change using price hedonic techniques from the studies by Cole et. al. (1986), and through the quality-adjustment techniques used by the BLS to adjust the CPI and the PPI.

The "matched-model" method is the principal procedure used to construct the CPI. A representative sample of consumption goods and retail outlets is drawn and, once a given type of good is selected, the BLS price-taker attempts to find a match for the reference good and price it each month. The individual price matches are aggregated into the CPI using a two-stage procedure. In 1995, an "exact" match was made almost 98 percent of the time each month (AWP, page 117, based on Moulton and Moses (1997)). In the 2.16 percent of the cases where a sample item was replaced, two-thirds of the replacement items were deemed to be comparable substitutes for which no adjustment for quality was necessary. For the remaining one-third, a quality adjustment to price was made, using a variety of techniques including price hedonics. Hedonics thus played only a small role in the big picture in 1995, affecting about 0.2 percent of the items priced

each month (though it had a slightly larger impact on the price index).

These figure do not seem to imply a large enough role to justify all the attention it has recently been given. However, the BLS expanded the role of price hedonics after the Boskin Commission report, and is considering further expansion. This reflects in part, the technical virtues of the hedonic method, but it is also motivated by a dissatisfaction with the other quality adjustment techniques used in the CPI.

These issues can be illustrated in the context of Figure 1. The matched-model method starts with the selection of a variety (say X_0) to price each time period. The expected price change between the reference and comparison periods is simply the ratio $h_1(X_0)/h_0(X_0)$. If the variety X_0 remains in the market place in a purely static world, the matched-model strategy will continue to price this variety. A problem arises if the variety disappears from the sample. A replacement must be found, and if a new variety X_1 is selected whose observed price is $P_{1,1}$, the BLS must consider the possibility that some part of the observed price increase $P_{1,1}/P_{0,0}$ may be due to a change in quality.[5] At this point, the BLS must decide if the new variety is a comparable or

[5] This is one way quality change affects the CPI sample. Another occurs when the sample is "rotated" to include new items.

noncomparable substitute. If the former, X_0 and X_1 are deemed to be equivalent and the observed price ratio $P_{1,1}/P_{0,0}$ is not adjusted for quality. If this is wrong and the new variety is really a noncomparable substitute, the ratio $P_{1,1}/P_{0,0}$ overstates the true rate of pure price increase when $X_1 > X_0$ (one source of the Boskin Commission's quality bias). More generally, the price ratio is the product of a pure price term and a quality term: this ratio can be written from the standpoint of the comparison period t=1 as

$$\frac{P_{1,1}}{P_{0,0}} = \frac{P_{0,1}}{P_{0,0}} \times \frac{P_{1,1}}{P_{0,1}} \qquad (2)$$

where $P_{0,1}$ is the unobserved price of original variety X_0 in the comparison period (the price that would have been paid in t=1 for X_0 had it been available for sampling). In Figure 1, the expected price term is the vertical distance between the price $P_{0,0}$ and the point b, and the expected quality term is the vertical distance between b and d.

A parallel quality adjustment can be made from the standpoint of the reference period t=0:

$$\frac{P_{1,1}}{P_{0,0}} = \frac{P_{1,1}}{P_{1,0}} \times \frac{P_{1,0}}{P_{0,0}} \qquad (3)$$

where $P_{1,0}$ is the unobserved price of variety χ_1 in the comparison period (the price that would have been paid in t=0 for χ_1 had it been available for sampling then). In Figure 1, the expected price term is the vertical distance between the price $P_{1,1}$ and the point c, and the expected quality term is the vertical distance between a and c

The price-quality decomposition in (2) and (3) requires estimates of the missing prices $P_{0,1}$ and $P_{1,0}$. The BLS has several methods for doing this: the overlap method, where these prices are, in fact, observable somewhere (useful when the sample is intentionally changed and new items are "rotated" into the sample); the link and class-mean methods, where the missing prices are imputed by averaging the prices of similar products (historically the dominant method); and the "direct" adjustment methods, which impute the missing prices $P_{0,1}$ or $P_{1,0}$ by their cost of production, or by using price hedonics. The hedonic solution is simply $P_{0,1} = h_1(\chi_0)$ or $P_{1,0} = h_0(\chi_1)$. This is the most intellectually satisfying of the various quality-adjustment methods, because it appeals to an underlying economic structure rather than to opportunistic proxies. A case for using hedonics can be made on these grounds alone: hedonics regression analysis inevitably involves statistical error, but so do the other

methods. The current consensus appears to be that the dominant link and class-mean approaches are subject to a greater degree of error, but more research is needed on the accuracy of all methods. Some of the common problems associated with hedonic regressions are reviewed in the next section, but this critique must be viewed with the larger picture in mind.[6]

III. A Critique of the Hedonic Regression Model

A. Fact versus Inference in Price Measurement

The portrait of price hedonics painted in the preceding section is rather flattering, particularly in comparison to competing alternatives. Why, then, the conservative Recommendation 4-3 from Schultze et. al. and an ambient skepticism on the part of some users? One of the leading developers and practitioners of price hedonics, Triplett (1990), found it necessary to devote an entire paper to the analysis and refutation of common criticisms of the hedonic method. I believe

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[6] This section has focused on the use of price hedonics in the CPI program. However, the most quantitatively important use of hedonics up to now has probably occurred on the "real" side of official statistics, through the BEA's computer price adjustment that was based on the study by Cole et. al. (1986). The BEA adjustment redefines the units in which output is measured from computer "boxes" to effective units of computer power, reflecting the fact that new varieties of computer pack more capacity into each box. This, in turn, increased the measured growth rate of real GDP and enhanced the perception of the emerging "New Economy".

that a large part of the problem reflects a lower degree of confidence in data that are imputed using regression analysis. Price estimates collected directly from an underlying population are generally regarded as "facts". When the price is inferred using regression techniques, it becomes a "processed" fact subject to researcher discretion.

It is certainly true that sampling techniques involve a degree of discretion in sample design. In the CPI, decisions are made about which items are included in the matched-model samples, which outlets are visited, the sample size, when a substitution is comparable and noncomparable, and so on. The resulting price estimates involve a sampling variance and a potential for bias, and are no different is this regard than estimates obtained using regression analysis. There is, however, an important difference from the standpoint of perceived credibility. The CPI sample is constructed directly from an underlying population of consumption goods in retail outlets whose prices are "facts". Full enumeration of the population is conceptually possible, lending verisimilitude to the sampling process.

On the other hand, the researcher discretion involved in regression analysis is not so well anchored. The old saw about regression analysis applies here: "if you torture Mother Nature long enough, she will ultimately confess to anything you want."

This quip reflects a widely understood but seldom emphasized truth about applied econometrics: researchers rarely complete their analysis with the very first regression they try. The first pass through the data often produces unsatisfactory results -- poor statistical fits, implausible coefficient estimates, etc. Rather than stop the analysis at this point, researchers typically use the same data to try out different functional forms and estimation techniques, and to drop weak explanatory variables, until plausible or satisfactory results are obtained (or the project is abandoned). The Schultze panel report cites instances of these practices during the incorporation of price hedonics in the CPI program.[7]

This "learning by doing" approach has a pragmatic justification: theory is rarely a precise guide to practice and experimentation with alternative techniques and specifications is both normal and necessary. Ideally, a fresh sample should be drawn for each new try, but resampling is usually expensive and sometimes unfeasible. However, the resulting estimates may lack the statistical power to discriminate among competing models.

B. Rounding Up the Usual Suspects

The economics profession has been moving along the price

[7] AWP, page 142.

hedonics learning curve for some time, and it may be useful at this point to review, briefly, the current state of progress (a more detailed account is given in Chapter 4 of AWP). Three general issues will be examined. First, price hedonics is subject to the problem of all product differentiation models: where does a good stop being a variety of a given product-class and become a product on its own? It is intuitively reasonable to group all Toyota Corollas in the same class and treat different equipment options as characteristics. Is it as reasonable to group included near-substitutes like Toyota Camrys, or all Toyota passenger cars into the same product class? Or, perhaps the product classes should be functional: sub-compacts, compacts, luxury sedans, SUVs, etc., regardless of brand.

Theory gives only the following guidance: items should be grouped according to a common hedonic function. For example, if equation (1) is the correct specification, all items in the hedonic class must have the same list of characteristics and the same β's. This implied grouping seems reasonable for different configurations of a Toyota Corolla, but increasingly less so as the range of included items is expanded. It should be possible to test for homogeneity of items included in a hedonic class, but it is not clear how often this is actually done. Dummy variables for different brands within a given class can be used in some

cases, but this is essentially an admission that some important characteristics are missing or that the β's differ in at least one dimension.

This problem is attenuated in the CPI, since the items included in the matched-model design are rather narrowly specified. However, while the narrowness of matched-model item specifications helps with the problem of heterogeneous β's, it exacerbates the problem of representativeness. Learning a lot about inflation and quality change in one narrowly defined class like Toyota Corollas may not be indicative of the experience of the broader class of autos.

A second general class of issues involves the selection of the characteristics. Hedonic theory suggests that a characteristic should be included in the analysis if it influences consumer and producer behavior. It implicitly assumes that consumers and producers have the same list, but this is far from obvious (Pakes (2002)). The consumer may be interested in performance characteristics like top speed and acceleration, while the seller may focus on product attributes like engine horsepower, and the design engineer on technical characteristics like valve design. And, different consumers may base their spending decisions on different sets of characteristics or assign them different weights, meaning that the β-coefficients in an

equation like (1) are really not fixed parameters, but weighted averages. As a result, estimated parameters may not be stable over time, and the implied estimates of price and quality may shift simply because of changes in the mix of consumers.

There is also the problem of separability and "inside" and "outside" characteristics. The β-coefficients in (1) may be unstable over time for another reason: the characteristics defining the good are not separable from the characteristics defining other goods. This is a well-known result in aggregation theory and it is hardly unique to price hedonics. But the hedonic hypothesis is a form of aggregation and the stringent conditions for separability may fail, in which case a change in some characteristic outside the set of "inside the hedonic function" characteristics may cause the relation between the inside elements to shift, leading to a change in the β's.[8] A similar problem can arise when some of the relevant characteristics are left out of the regression analysis.

The problem of missing inside characteristics and non-separability with respect to outside characteristics can be subjected to econometric tests. However, the truth is that the

[8] In more concrete terms, the value of extra computer power in a personal computer may shift as new software or applications become available. And, the tradeoff between extra performance and additional comfort in autos depends on the quantity and quality of the nature of the highway system, etc.

selection of characteristics is heavily influenced by data availability, and it is not clear how much progress can realistically be expected in dealing with these conceptual issues.

Choice of appropriate functional form is the third general problem often raised in critiques of price hedonics. The three most common forms -- linear, semi-log, log-log -- do not allow for a very rich set of possible interaction among characteristics. Important complementarities often exist, as for example, between microprocessor speed and storage capacity. The one does not substitute for the other at a given price in most applications. Expanding an auto's performance to race-car levels involves an increase in many characteristics, not just a very large increase in horsepower alone. This suggests the use of more flexible functional forms like the translog. And, as noted in the preceding section, innovations in product quality can take the form of extensions of the length of the hedonic function over time, and this is hard to capture with the usual functional forms.

C. The Pakes Developments and the New Heterodoxy

Many of the problems noted above are generic to many econometric applications, and many can be addressed with

alternative econometric techniques. However, the recent paper by Pakes (2002) suggests that some of these problems are really not problems at all. This paper is a potential paradigm shifter, and deserves special attention.

Pakes advances three important propositions, which I will call Pakes-I, Pakes-II, and Pakes-III. Pakes-I starts with the usual interpretation of the hedonic function as a locus of supply and demand equilibria for heterogenous agents in which the price of each characteristic is equal to its marginal cost -- the standard view inherited from Rosen (1974). Pakes observes that this assumes that producers have no market power over the package of characteristics they offer, and that this is a poor assumption to impose on a world of product differentiation. The product/characteristics space is not continuously dense for most differentiated products, and producers try to differentiate their product so as to achieve a degree of market power. Moreover, product innovation is a part of the product differentiation process, and innovation tends to convey a degree of market power.

Pakes derives an alternative interpretation of the hedonic function in which price equals marginal cost plus a market power term that depends on the elasticity of demand for the characteristic. This is the Pakes-I result and it is surely correct for many of the goods for which price hedonics is

employed. However, the implications of this result are novel to the point of heterodoxy:

"Hedonic regressions have been used in research for some time and they are often found to have coefficients which are "unstable" either over time or across markets, and which clash with naive intuition that characteristics which are generally thought to be desirable should have positive coefficients. This intuition was formalized in a series of early models whose equilibrium implied that the "marginal willingness to pay for a characteristic equaled its marginal cost of production". I hope [the preceding] discussion has made it amply clear that these models can be *very misleading* [author's emphasis]. The derivatives of a hedonic price function should not be interpreted as willingness to pay derivatives or cost derivatives; rather they are formed from a complex equilibrium process (page 14)."

This view clashes strongly with the conventional view, which is summarized in the Schultze panel report in the following way:

"Strange-looking variable coefficients could be indicative of larger problems -- including omission of key value indicators, characteristic mismeasurement, and functional form issues (AWP, page 142)."

And,

"It is hard to know when a hedonic function is good enough for CPI work: the absence of coefficients with the "wrong" sign may be necessary, but it is surely not sufficient (AWP, page 143)."

In the Pakes view of price hedonics, there is no reason to assume that the hedonic function and the β-coefficient should be stable

over time, and the "wrong" sign is not necessarily wrong at all. In fact, the price associated with any characteristic may be negative! In other words, the price of a product can go down when it acquires more of a given characteristic. This result is a corollary of Pakes-I but is so important that it deserves a separate status as Pakes-II. Pakes-II turns conventional wisdom on its head and challenges any notion of perceived credibility based on intuition about parameter instability and "wrong" signs.

Pakes-III is yet another corollary. This result argues that parameter instability and counter-intuitive signs are irrelevant if the point of the hedonic analysis is merely to correct observed prices for changes in quality (and not to interpret individual coefficients -- recall the two general objectives of price hedonics noted in Section II above). In terms of Figure 1, Pakes-II implies that two hedonic lines need not bear any close resemblance to each other. Pakes-III implies that estimation of either line is sufficient to make a quality adjustment. All that is needed to impute the terms in the price ratios (2) and (3) are estimates of $h_0(\mathbf{X})$ and $h_1(\mathbf{X})$.

These results represent a potential paradigm shift in the field of price hedonics. They have yet to be vetted by the specialists in the field, but some or all of each proposition is

likely to survive scholarly scrutiny.[9] There are a number of issues to be resolved, including, for example, the problem of cross-sectional stability. The same mechanism that causes the hedonic coefficients to be unstable over time may also cause them to be unstable in a cross-section of consumer prices drawn from different locations and different types of retail outlet. In this case, the movement along the hedonic function at any point in time may not be possible. This, and other issues, await further debate.

IV. The Political Economy of Price Hedonics

There is a saying in tax policy that "an old tax is a good tax". This does not follow from any deep analytical insight of optimal tax theory, but from the pragmatic observation that taxation requires the consent of the governed. The public must accept and respect the tax, and this does not happen automatically when a new tax is introduced. There is typically a learning curve as people adjust their behavior in light of the

[9] Indeed, the Pakes-II result has precedent in conventional price-quantity analysis. When the price of a good is regressed on its quantity, it is well known that the underlying supply and demand curves generally cannot be identified separately, and that the regression coefficients will be unstable and can easily have the "wrong" sign. The price hedonic case is somewhat more complex, since the hedonic function contains multiple varieties, but it is also a case in which price is regressed on the "quantity" of characteristics.

new tax incentives, and gainers and losers are sorted out. The tax matures as affected groups negotiate changes, and as unforeseen consequences become apparent and are dealt with.

A similar argument leads to the proposition that "old data are good data". "Old" data, like "old" taxes, involve learning by the public and by policy makers about a new set of facts, and both may involve large economic stakes. In the case of CPI reform, the Boskin commission estimated that the cumulative effects of one percent per year bias would have added $1 trillion to the national debt between 1997 and 2008. If price hedonics were completely successful in eliminating the Boskin commission's quality bias, the growth rate of the CPI would fall by around 25 to 60 basis points per year, with an attendant reduction in cost-of-living payments to individuals.[10] And COLAs -- Social Security, federal civilian and military retirement, Supplemental Security Income, etc. -- are not the only dimension of policy affected by this line of argument, since the CPI is used to index income tax parameters, Treasury inflation-indexed bonds, and some federal contracts.

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[10] The Schultze panel report concludes that the expanded use of price hedonics is unlikely to have a large effect on CPI growth if it is limited to imputing missing prices for non-comparable substitution items. Several recent BLS commodity studies have found that price hedonics did not produce dramatically different results than other quality adjustment methods. However, the impact could be much larger if hedonics were to be applied more broadly.

Moreover, a revision to the CPI also changes the metric that policy makers use to gauge the rate of inflation. They have to assess how much of the change in measured inflation is the result of underlying inflationary pressures and how much is caused by the new methods. This reflects a fundamental truth about the policy process: policy decisions (indeed, most decisions) must be made with imperfect information. There is learning over time about the nature of the data and the useful information they contain. Alan Greenspan's 1995 comment about his perception of a 1/2 to 1 1/2 percent bias in the CPI is a case in point.

The expanded use of price hedonics thus looks different to users who are interested in the "output" of the technique than to expert practitioners, who are interested in developing the technique *per se*. Put differently, there is a policy-user learning curve that is different from the learning curve of researchers. However, the two curves are related. The weaker the professional consensus about a technique, the lower the confidence in its consequences, and the weaker the degree of acceptance by the public and policy makers. This is the essence of the "perceived credibility" standard.[11]

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[11] The "perceived credibility" standard and the notion of "old" data are not well-established in the literature on economic measurement. Most discussions focus on "better" or "more accurate" as the appropriate criteria for comparing new measurement techniques to old: if a new method promises more accurate data, it should be adopted without hand-wringing about gainers

This line of argument has implications for the use of price hedonics in the CPI. Perceived credibility is linked to the degree of professional consensus, and the paper by Pakes has pretty much upset whatever consensus had existed. It will doubtless take time to sort out the propositions advanced by Pakes, and this alone justifies the conservatism of Recommendation 4-3. More research is needed about the robustness of price hedonics results to changes in assumptions about functional forms and characteristics, and about the circumstances under which parameter instability and "wrong" signs occur. Monte Carlo studies in which the true value of the parameters are known in advance could be a useful way of understanding the pathology of the hedonic technique and assessing the accuracy of this technique and its ability to forecast the CPI, both in absolute terms and relative to other quality-adjustment methods.

V. Conclusion

Research at the frontier should be bold and challenging, aimed at convincing peer researchers. However, this is not the

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and losers. The job of the experts, in this view, is to provide the best scientific advice they can and leave politics to the politicians and public. However, this "ivory tower" view of expert knowledge ignores the fact that it is the politicians and the public who asked (and largely paid) for the advice in the first place. Users have a right to demand a quality product from the supplier, and to define quality in their own terms. The perceived credibility standard is part of this quality control.

way good policy is made. Policy ultimately relies on the consent of the public, not the vision of convinced experts. Changes in official statistical policy therefore should be conservative and credible, and the research agenda must include a component aimed at building confidence that the benefits of change outweigh the costs. Viewed in this way, the Schultze panel is right to insist on a conservative approach to the increased use of price hedonics in the CPI. However, the research community is also right to insist that this technique is the most promising way to account for changes in product quality in official price statistics.

They would also be right to point out that part of the credibility issue with hedonics is about the switch to the new technique, and not just about the technique itself. Had the BLS used price hedonics more extensively in the past, rather than relying on the methods of quality-adjustment more commonly in use, hedonics would probably have evolved to the point of perceived credibility by now. Indeed, if positions were reversed and the link, overlap, and class-mean methods were offered as substitutes for an entrenched hedonics methodology, the debate would look very different.

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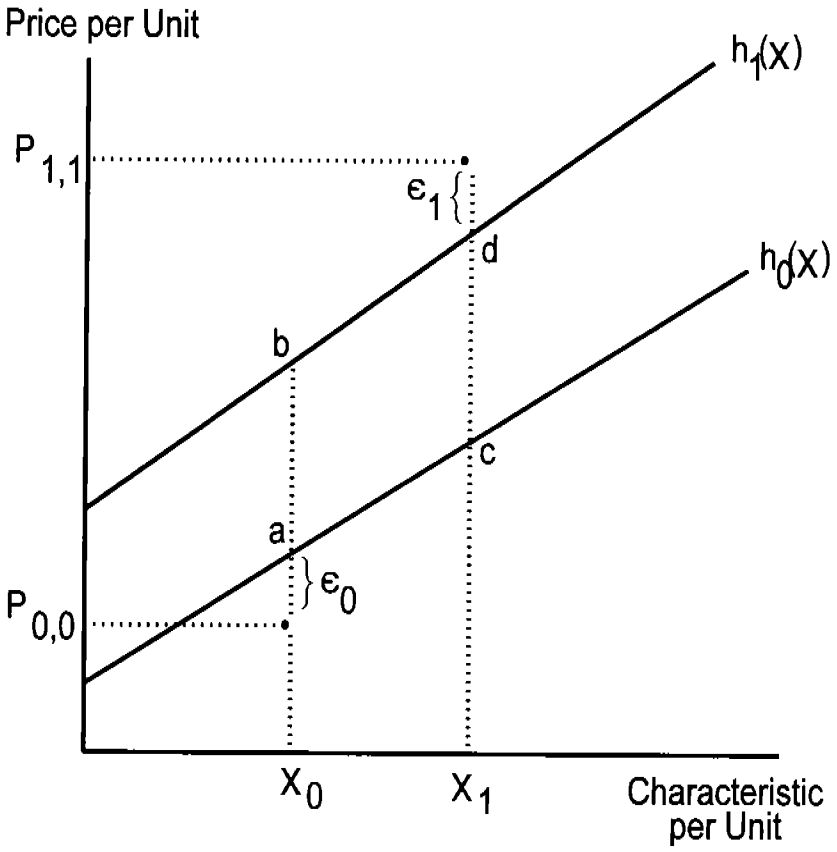
Price per Unit
$h_1(X)$
$P_{1,1}$
ϵ_1
d
$h_0(X)$
b
c
a
ϵ_0
$P_{0,0}$
X_0
X_1
Characteristic per Unit

FIGURE 1