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2 Quality Adjustment in the Producer Price Indexes

John F. Early and James H. Sinclair

The Producer Price Indexes (PPI) (formerly called Wholesale Price Indexes) measure price change at the primary market level. They refer to prices received by mines, manufacturers, farmers, importers, and electric utilities for commodities at all stages of processing—crude, intermediate (or semifinished), and finished. The objective of the price indexes is to measure pure price change for a fixed production mix. In practice, the set of commodities cannot remain unchanged. Some commodities are discontinued. Others are modified. And new commodities are added to make the price set more representative of the current economy.

When one variety of a commodity is discontinued in the index and replaced with another variety, the pure theoretical structure of the index is violated. These substitutions are necessary, however, and it is the task of the index maker to make substitutions in a way that will distort as little as possible the measure of pure price change. This process of calculating the index across the discontinuity which results from substitution is usually called quality adjustment. The purposes of this paper are to (1) provide the conceptual background on the way quality adjustment is made in the PPI, (2) describe the methods currently used for quality adjustment, (3) analyze the practical results of the application of these methods, (4) explore other methods that may be available for quality adjustment, and (5) note some of the major improvements that have begun for these indexes.

2.1 The Conceptual Background

We do not propose to determine here what the proper theoretical treatment of quality change in the PPI is. That task is currently in process.

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We seek in this section to document the logic and model that underlie the current practice. The PPIs have suffered, to a degree, from the lack of a clear conceptual definition. They can be conceived as output price indexes from the farms, mines, and factories of the U.S. economy. They may also be viewed as input price indexes to personal consumption at the earliest stages of distribution. The current revision efforts will put an end to that confusion, but the focus here is on the existing data.

Since there are different implications for quality adjustment in these two concepts, the result has been a hybridized methodology for handling quality adjustment. In general, quality adjustment consists of three steps. The first is identifying the physical changes in the item being priced. The second is characterizing each change as an improvement, deterioration, or no change in quality. The third is evaluating each change in dollar terms. In the second step, each change is characterized according to its expected impact on consumer utility (for consumer goods) or producer productivity (for capital equipment). In the third, the differences in cost of production are used to value the changes. It is then argued that in equilibrium the change in production costs and the change in user utility will be equal. If production costs were lower than the price, then other producers would enter the market and drive the price down until it reached the level of cost. If production costs were higher than the price the user was willing to pay, then production of the change would cease.

An interesting anomaly occurs in this methodology when an improvement is made in a product at a lower cost. Quite clearly one cannot give an improvement a negative value. In such cases, the value of the quality change is assumed to be zero.

There has been one major departure from this standard methodology. Antipollution devices that are required by law have been treated per se as quality improvements, even though their previous availability as options may have demonstrated no significant value being placed on them by users. This decision was reached by the special Interagency Committee on the Treatment of Anti-Pollution Devices in Price and Quantity Indexes. The persuasive argument for them was that, by virtue of the government requirement for the device, it was being valued by fiat for the population as a whole at its cost of production.

2.2 Quality Adjustment Procedures

In calculating the change in production costs between two varieties of a product, companies are asked to supply for each change cost data which reflect the differences in the amounts and kinds of labor and material inputs used in the production of the two. The difference in cost should be based on the cost differences in inputs under the cost structure and technological regimen that existed at the time of the introduction of the new variety. The company's standard markup for return to investors and entrepreneurship is also included.

In some cases a new feature is added to an item when that feature has previously been available as an option. The value of such a feature is calculated as the weighted average of the producer's cost and the market price of the option. The market price is weighted by the installation rate of the option, and the producer's costs is weighted by the remainder.

Of course, not all physical changes are quality changes. Changes which are not related to the ability of the component or the item as a whole to perform its function better are not considered quality changes. In particular, changes for the sake of style, such as changes to automobile grill designs, are not considered to be quality changes.

In addition to the producer's cost procedures, two other methods are widely used for dealing with quality changes. The first is the link. In this method the new variety is brought into the index showing no price change from the previous month. The implication of the link procedure is that all the difference in price between the two varieties is due to quality change. It is used when producer-cost data are not available and there are substantial quality differences between the two varieties. It is also used when the changes between the two varieties are so great that a feature-by-feature cost comparison is either impossible or likely to be highly inaccurate. The link procedure, therefore, becomes the tool for introducing totally new products.

The second alternative to the producer-cost procedure is the direct comparison. In this procedure, the prices of the two varieties are directly compared, that is, the price change is equal to the difference between the observed prices. The implicit assumption is that the difference in quality between the two is zero. This method is used when producer cost data are not available for small physical changes.

There is a fourth method which could theoretically yield very good results. This is the overlap method. In this method, both varieties are priced in the same time period. The difference in the market price between the two can then be taken as the valuation of the quality difference. This method works well only if there is a previously stable relationship between the two prices. Normally, substitutions occur between subsequent models or versions of the same item. If any of the older models are still being sold, it is frequently at a discounted clearance price which distorts the market valuation of the quality change. (The reverse case of a premium for the discontinued model may also occur.) No identifiable cases of this procedure were discovered in the data examined later in this paper.

We can express the three procedures used for quality adjustment in symbolic notations as follows:

Let P_t = the price of the new variety at month t, P_{t-1} = the price of the old variety at month $t-1$, L_{t-1} = the link price of the new variety, Q_t = producer cost of the quality changes between the two varieties.

The ratio $P_t/(L_{t-1})$ is the relationship which is used in the calculation of the price index for month t. It is in the derivation of L_{t-1} that the three procedures differ from each other as follows: producer-cost method, $L_{t-1} = P_{t-1} + Q_t$; link method, $L_{t-1} = P_t$; direct comparison method, $L_{t-1} = P_{t-1}$.

It should be noted that, since Q_t is valued in dollars at time t, the formula for the producer-cost method will overstate the link price during a period of rising prices. Since we want to set $P_t(L_{t-1}) = (P_t - Q_t)(P_{t-1})$, the proper expression for the producer-cost method would be:

$$L_{t-1} = \frac{P_t}{(P_t - Q_t)} P_{t-1}.$$

This formula adjusts the $t-1$ price by the ratio of quality change rather than the dollar value. The improved formula is now being used in the PPIs, but for the period under study the first formula was used.

2.3 Results of Quality Adjustment in the PPI

During 1976 the Bureau of Labor Statistics (BLS) obtained more than 100,000 observations for the monthly calculation of the PPI. We have identified all cases of product substitution in the PPIs during 1976. There were 455 such cases, or slightly less than one-half of 1% of the total number of price observations, during the year. The following analysis is based on that set of substitutions. Further analysis is also presented for a subset of commodities covering the time span 1970–76.

In analyzing the results of the different methods, we have used the following two measures: pure price change (or price change), $(P_t/L_{t-1} - 1) \times 100$; quality change, $(L_{t-1}/P_{t-1} - 1) \times 100$.

In the producer's cost methodology, the observed percentage change in prices is factored into both a pure price change and a quality component. In the case of links to show no change, the pure price change is zero and the observed price change is implicitly set equal to the quality change. In the direct comparison cases the observed and pure price changes are equal and the quality change is zero. Tables 2.1–2.5 and figure 2.1 summarize the results of quality adjustment in 1976.

2.3.1 1976 Quality Adjustment Classifications

Out of the 108,756 price observations used in the PPI in 1976, there were 455 quality adjustments using one of the three quality adjustment methodologies. As table 2.1 shows, 129 were evaluated by producer-cost changes (28% of all quality adjustment in 1976), 184 were links to show no price change (40% of 1976 quality adjustments), and 142 were direct comparisons (31% of 1976 quality adjustments). Column 5 of table 2.1 shows quality adjustments of each PPI group as a percentage of total prices reported for that group in 1976. The producer cost methodology is perhaps the most interesting from a research point of view, since it incorporates a combination of both price and quality changes. Frequency distributions of quality and price changes by size of change are listed in tables 2.2 and 2.3, respectively. By glancing at table 2.1, one can see that the pattern of adjustments is not uniform among commodity groups. PPI group 14 (transportation equipment) stands out as having a large proportion of producer-cost observations (68%). This is partly a function of greater BLS emphasis in these industries as well as the reporters' willingness to provide cost breakouts on items that affect the performance or physical characteristics of these commodities.

Column 5 in table 2.1 reflects the number of annual quality adjustments as a percentage of all the prices reported to BLS for each commodity group during 1976. Four-tenths of 1% of these reported prices required some type of quality adjustment before they were used in calculation of the Producer Price Index. The high relative frequency of quality adjustments in transportation equipment can be traced to the annual model changes for automobiles and, to a lesser extent, for trucks. High relative frequencies for household durables reflect frequent model changes in appliances, while frequent style and construction changes in footwear account for the high rate among leather products. On the other hand, farm products, processed foods, fuels, and nonmetallic minerals are mostly highly homogeneous primary products that rarely, if ever, undergo any measurable quality shift.

The great majority of producer-cost quality adjustments fell in the 0%–10% range, with a few extreme quality adjustments in PPI groups 10, 11, and 12. Perhaps a more meaningful analysis involves a consideration of the direction of quality and price changes under the producer-cost methodology. In figure 2.1, all points that deviate from both the vertical and horizontal axes are producer-cost estimates of quality adjustments. (In fig. 2.1, 19% of all cases lie beyond the scale.)

It is apparent that the majority of changes occur in the price and quality increase quadrant (+ +). The price and quality decrease quadrant (− −) had the fewest (five) number of observations. The price decrease and quality increase quadrant (− +), that is, a better product with a pure price decrease, had 11 observations. Most of these cases either include an addition of the product or are an increase in the size or quantity.

On the other hand, the effects of price increase with quality decrease show up in 34 observations. Due to their large number they will not be listed individually. Out of the 39 observations, 18% were in group 11 (machinery and equipment), 13% in group 14 (transportation equip-

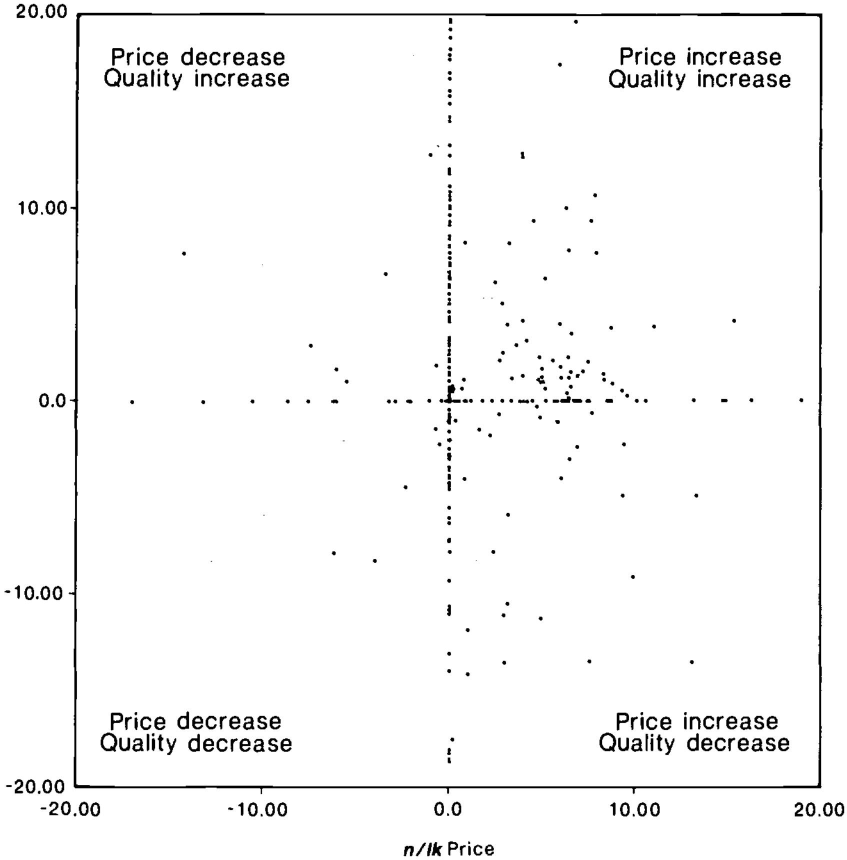

Fig. 2.1 Quality adjustment plot (vertical axis = all price change due to quality; other observations = change due to price and quality; horizontal axis = direct comparison = only price).

ment), and 6% in group 10 (metals and metal products). There were no extraordinary reasons for the producer-cost estimates of quality decline with price increase only that less was offered at a higher price (e.g., more expensive, smaller beer bottles, and thinner gauged, higher priced copper pipes).

Within the link-to-show-no-price-change area, the greatest number occurred in machinery and equipment (PPI group 11), furniture and household durables (PPI group 12), and metals and metal products (PPI group 10).

Table 2.4 breaks out the PPI classifications into negative and positive magnitudes of link-to-show-no-change quality adjustments. A little less than half of the link observations occurred in the ± 0%–9.9% range, but there was a considerable number of large price changes in the machinery and equipment section. Since on average this group is made up of very expensive commodities, one would think that the change in quality as a proportion of the absolute price change would be relatively small. As evidenced by table 2.4, there were 34 cases of quality change that were 30% or higher, some of them as large as 60%–80%. Changes this large almost inevitably are handled with the link-to-show-no-change technique.

The direct comparisons were fairly significant, accounting for 31% of all 1976 quality adjustments. It should be remembered that direct comparisons, by definition, reflect only price changes. Although quality changes may be associated with these price changes, no allowance is made for them because they cannot be identified explicitly. On average, these adjustments usually reflect "minor" specification changes, but there are 15 observations in table 2.5 that represent price changes above 20%, and two that are above 100%. Such large price changes at least suggest that they may include some quality change. As table 2.1 shows, PPI groups 10, 11, and 12 accounted for the major share of direct comparisons in 1976. These same three groups accounted for a similar share of the links. In PPI group 3 (textile products and apparel), most of the changes in specifications have resulted in direct comparisons. For these products the ability of BLS to obtain and use producer-cost adjustments for quality change has been limited.

Another point about table 2.5 to consider is that even the large number of zero price changes may be a result of either the proper handling of small specification changes or a price that is reported as unchanged that is really masking some sort of quality change. The observations under analysis in this paper are the results of changes in the detailed specifications of products. A decrease in quality could be masked by a seller offering a lower quality good at the same price. Conversely, quality improvements not matched with a price increase would tend to be hidden. The machinery group includes cases of this type embodying technological advances at lower costs. By way of contrast, the zero price changes in other groups, such as textiles, apparel, and leather, reflect style changes for the most part. There may have been a change in the detailed specification, but since the BLS procedure is to treat most style changes as not being quality changes, these changes were directly compared.

During 1976, less than one-half of 1% of the observed prices represented specification changes. Since price changes occur in less than one-third of the observations and since price change and specification change frequently occur together, the effect of quality adjustment is probably somewhat larger than this frequency alone might suggest. Nevertheless, the effects of the quality adjustment methodology are not likely to be very large in the short run. Even though the data shown in this section may seem low at first glance, the small number is consistent with a number of features of the index: (1) the large number of crude materials (cattle, natural gas, iron ore, etc.) do not undergo specification change, (2) capital equipment models change very infrequently—often going several years without change, (3) the current BLS practice of pricing volume sellers usually means that the items least likely to be dropped or radically changed are included in the index.

The exclusive use of the link-to-show-no-change methodology would clearly impart a downward bias to the price index. Similarly, the exclusive use of the direct comparison methodology would impart an upward bias. Since neither method predominates and since the size distribution of each is generally consistent with the assumptions on which it is based, these data provide no clue to the direction of any quality adjustment bias in the indexes.

2.3.2 1970–76 Quality Adjustment Classifications for 10 Selected Commodity Groups

This section focuses on changes over time in quality adjustment techniques used in the PPI. Ten specific groups of commodities were selected at the PPI subproduct (six-digit) level for the time-series study. They were selected after looking at a frequency distribution of the three types of quality changes for all PPI groups for 1976. Care was taken to incorporate each type of quality adjustment and several different commodities to see if the same distribution observed in 1976 held for earlier years. Because of time constraints and the difficulty of obtaining the original pricing forms, the time period under investigation was limited to the years from 1970 to 1976. Some data were missing for 1970 and 1974, which may result in an undercount of direct comparisons for those years.

Table 2.6 depicts the breakdown of the types of quality changes by specific years and the total number of prices reported for the same period. Even though the number of reported prices remained relatively stable for these groups over the seven-year period, the number of quality adjustments generally increased. It would certainly be unlikely that the number of actual product changes in the economy increased so greatly during the period, although the expanding government requirements for additional health, safety, and environmental design changes may have played a role. Some of the increased quality adjustment can be attributed to the greater resources that became available to the BLS program during these years; these were used in part to update and revise the items priced for the indexes. There is no clear evidence of either business cycle or price control effects on the frequency of substitution. Nor is there a clear trend in the relative use of each of the methods of adjustment.

Table 2.7 provides a summary of each of the 10 selected groups for the years 1970–76. Each of the three methods was used for quality adjustments within each of eight of the 10 groups. The method selected was usually the result of the type of change and the availability of data.

Women's footwear (PPI code 043201) is a commodity with frequent model changes. Fashion tends to dictate both the style and materials used in producing such goods. Quite often the new models are so radically different from previous models that comparisons have not been feasible. Most price changes associated with style changes in this group were also accompanied by quality change, so most of the quality adjustments in this group have been handled by a link-to-show-no-price-change, which is not entirely consistent with the general policy of not allowing quality adjustments for style changes. The overall frequency of quality change in this area is much lower than might be expected, since most of the shoes priced are very standard items not subject to style change. Even the more fashionable items are fixed as to material and method of construction.

During the 1972–75 period many changes took place in farm harvesting machinery (PPI code 111206) to meet federally mandated Occupational Safety and Health Administration (OSHA) requirements. A link-to-show-no-price-change was generally used by BLS for significant (i.e., large cost) changes of this type; most others were treated using the producer-cost methods. In PPI group 14 (transportation equipment), most legally required changes were valued at producer cost.

In PPI group 123101 (soft surface floor coverings), the lack of producer cost information and the dissimilarity between old and replacement models caused a large number of links. New carpets, with different blends, pile depth, etc., were introduced replacing discontinued carpets. Since it is difficult to make quality adjustments for such products, BLS resorted to the large number of links-to-show-no-price-change.

The transportation area (PPI group 141101, passenger cars; and 141102, motor trucks) quality adjustments were of the producer-cost variety. The isolated direct comparison cases were due to the lack of quality change information (generally imports of trucks produced by some individual companies). When a link-to-show-no-price-change occurred in passenger cars or motor trucks, it occurred because a brand new or radically altered model was introduced in the index.

Tables 2.8–2.10 contain frequency distributions by magnitude for each type of quality adjustment. The producer-cost quality adjustments were generally in the 0%–20% range, with the exception of PPI code 101501 (gray iron castings) of which four cases were in the 30% or higher category. Links-to-show-no-change, contained in table 2.9, were more dispersed across all percentage change categories, most notably among soft surface floor coverings. Direct comparisons showed up primarily in the 0%–10% range, with the exception of PPI code 114901 (valves and fittings).

2.4 Regression Techniques for Quality Adjustment of Crane Prices

There is a substantial and growing body of literature on the use of regression techniques to estimate the value of quality changes (Griliches 1971; Triplett 1971, 1975). The term "hedonic" is normally used in reference to this technique but carries no special implication for the theory behind its use. It is not the intention here to provide any special discussion of the technique. The results of our application of the technique to construction cranes will be reported as an example of how independent checks can be made on the quality adjustment in the indexes. Some discussion of the errors in hedonic estimates is provided.

The regression or hedonic technique of quality adjustment begins by transferring the analytical focus from the priced item as a single entity to the item as a collection of characteristics. Thus the price of an individual item (p) is viewed as being a function of the prices for each of its n characteristics (x_k). The x_k variables are either nominal dummy variables or continuous variables, such as physical performance characteristics. Each unit of each characteristic has an implicit price (b_k) associated with it. In linear form this becomes $p = b_o + b_1 \times_1 + b_2 \times_2 + \ldots b_n \times_n$. The hedonic approach uses regression techniques to estimate the implicit characteristic prices of an item from the observed values for the price and characteristics of the item.

Most hedonic studies have used the data from which their regressions were estimated to then estimate a price index adjusted for quality change. In this study we have followed Triplett and McDonald (1977) and estimated the regression coefficients from a large, independent source of data, and then used the regression coefficients to quality adjust the actual prices used in calculating the corresponding PPIs. This approach permits one to identify the impact of the hedonic adjustment technique as compared to the standard methodology without statistical interference from the use of a different sample, and possibly even a different universe for estimating the index.

Construction cranes (hydraulic, crawler, and truck-mounted) were selected for this study because (1) relatively little work has been done in the capital goods area, (2) this is an important part of the PPI structure, (3) enough substitutions occurred over the 1971–77 period to make the effort fruitful, and (4) a good data source was available from which to estimate the regression coefficients.

2.4.1 Data Source

Since the PPI data were limited in the number of available models, the Equipment Guide Book Company "Green Guide" was used as the source of data to estimate the hedonic equation. This price book is widely used in the construction equipment industry. The Green Guide provides prices and summary specifications for a 10-year period. The prices are new manufacturers' list prices, f.o.b. factory, the same type used in the PPI for this product. Cranes are generally sold at list price with no discounts applicable. The same company produces specification data books that give detailed information on every crane produced. These data are in effect reproductions of manufacturers' specification sheets providing information on lifting capacities, overall dimensions, and performance capabilities.

The next task was to select the variables which might be price determining and to compile a cross-section data base that divided cranes into three distinct groups: hydraulic, crawler, and truck cranes. Initially it was thought these three divisions were homogeneous, but further along in the study hydraulic cranes were divided into self-propelled and carrier-mounted because of their heterogeneous nature. Care was taken in the compilation of the independent variables so there would be no proliferation of variables which potentially could cause double counting in the determination of quality characteristics, that is, those that are likely to be highly correlated with each other.

Theory is of no help in determining the best functional form for the regression equation. A simple criterion was used in which the proper functional form would be the one which maximizes the explanatory power of the regression equation (i.e., minimizes the unexplained variance or the residuals) while still satisfying the assumptions of the ordinary least-squares estimating procedure.

2.4.2 Determination of the Independent Variables

The crane characteristics used in the regression equation (independent variables) included both performance (e.g., lifting capacity and lifting speed) and dimensional (e.g., crane weight, length, and width) types. A large list of potential explanatory variables was compiled initially. A list of these variables, for each type of crane, can be seen in tables 2.11–2.13. All characteristics listed were regressed against the prices (and natural log of prices) for each crane.

Probably the most challenging data base, with reference to problems encountered, was that for hydraulic cranes. The dimensional characteristics (e.g., weight, height, length, width, etc.) were all insignificant, which means either they were not price determining or that their effect was included in the performance characteristics. The first problem with performance characteristics dealt with the choice of a lifting capacity characteristic for use in the equation: retracted or extended. When both characteristics were included in the equation the signs of the regression coefficients between boom extended and retracted lifting capacity were opposite. This problem is to be expected when two variables express the same function. The interrelationship (multicollinearity) was borne out by the simple correlation coefficients (see table 2.14). Lifting capacity (both retracted and extended, nos. 3 and 6, respectively, in table 2.14) seemed to be highly correlated with most of the other independent variables as well as with each other. The retracted boom lifting capacity variable explained approximately 97% of the variability in the dependent variable price. This was greater than the extended lifting capacity variable or any other independent variable.

The statistics on how much a crane can lift is a function, basically, of three parameters: radius (the number of feet the boom is extended from the center of rotation), angle, and height. The parameters were couched, however, in terms of safety standards applied by a trade association: the Power Crane Shovel Association (PCSA). The lifting capacity of an extended boom was expressed at a wide variety of radius, angle, and height values among the cranes. The retracted lifting capacity was always expressed with a constant value of radius or angle across all cranes.

Because the retracted lifting capacity variable provided both a more consistent measure and greater explanatory power, it was used in the equations.

Hydraulic cranes have a functional performance feature that is unique and differs from the other two data sets. Torque or horsepower mechanically drives a winch that lifts an object in crawler and truck cranes. However, hydraulic cranes lift an object from a position driven by hydraulic pressure derived from the horsepower of the engine. The hydraulic pump horsepower is more indicative of what the crane can lift than the engine horsepower. Consequently, a hydraulic pump horsepower variable was created to explain this performance function. Pump hydraulic horsepower is basically a function of the gallons per minute of hydraulic fluid that flows through the hydraulic lines, the pounds per square inch of fluid, and a horsepower constant. It turned out, however, to have low explanatory power.

One other problem encountered was that, although two cranes produced by one company had identical prices, one of the cranes had a one-ton greater lifting capacity. The problem seemed to be associated only with hydraulic cranes and was isolated. The company was contacted for an explanation, and its reply was that when there is so small a change in lifting capacity the only change required is an increase in the counterweight. If this were the case, the lifting capacity regression coefficient should be very small; in fact the exact opposite was true. Most other companies indicated, however, that even a small increase in lifting capacity could entail a change in the structure of the boom either by changing the gauge of the steel, by increasing the incidence of double welds, by adding more cross members, or by having stronger joint connections. Because this was an isolated case and the sample of hydraulic cranes was large (92 before it was further divided into carrier-mounted and self-propelled), its influence on the regression coefficients was probably minimal. However, this example does illustrate clearly that individual transactions may not conform to a rational model.

2.4.3 Estimating the Characteristic Price Equation

Cross-section regressions were run on all four data sets (self-propelled and carrier-mounted hydraulic cranes, truck cranes, and crawler cranes) using prices for 1976. The results can be seen in tables 2.15–2.18 for the final functional form in each case. It is possible that some of the price variation may be due to real or perceived differences among companies. These company effects were checked for each equation. First, company influences were investigated by inspecting the plot of regression residuals for each company. There were several marked differences in each data set that suggested one or two companies had consistently higher or lower prices (even though each crane had essentially the same characteristics) relative to the other companies in each data set. A more explicit investigation was needed to measure the "unexplained" company effects; consequently dummy variables were introduced into the regression equation for each company. When the regression coefficients were estimated, a Chow Test was administered to test the company effects against the previously selected characteristic coefficients (e.g., lifting capacity, horsepower, etc.). The F-ratio for crawler and truck cranes was greater than the F-critical ratio at .01; therefore, the regressions for crawler and truck cranes include the company effects. The significant company variables may have actually captured the effects of unmeasured characteristics such as durability of service. They may also have captured a type of brand identification effect. Since substitutions in the PPI are not made across companies, these variables will not affect directly the price index to be estimated using these equations. However, the magnitude of the other coefficients are changed as a result of introducing the dummies, and, therefore, the inclusion of these variables does not have an effect.

2.4.4 Selecting Functional Form

The best functional form was identified using the Box-Cox technique which standardizes the sum of squared residuals between the linear and log forms (Zarembka 1974). The linear form used price as the dependent variable; the semi-log used the natural logarithm of price as the dependent variable, and the double-log used the log of both the price and the independent variables, except the dummies, which remained linear. To determine the optimal functional form, the linear sum of squared residuals was standardized and compared to the unexplained variance of the log forms using the following standarization formula:

$$c = \exp\left(\frac{-\Sigma \log Yi}{n}\right), \tag{1}$$

(1.1) $(c^2) \cdot (\Sigma e_i^2 \text{ linear}) = \text{standardized residuals.}$

Also, to test for a significant difference between the three functional forms investigated (linear, semi-log, double-log), an ordinary χ^2 likelihood ratio test was used: the functional forms were significantly different from each other in all cases.

(1.2)
$$\chi^2 = \frac{n}{2} \left| \ln \frac{c^2 \, \Sigma ei \text{ linear}}{\Sigma ei \text{ semi-log} \quad \text{or double-log}} \right| .$$

As can be seen in table 2.19, the functional forms with their respective unexplained variance is presented. With the exception of self-propelled hydraulic cranes, in which the linear functional form was the most appropriate, the double-log was the functional form with the lowest sum of squared residuals after transformation for all the data sets.

2.4.5 Hedonic Quality Adjusted Price Indexes

The quality adjusted price changes for the substitutions in the crane indexes (point estimates) were calculated using the implicit prices as estimates of the specific characteristics of each of the four types of cranes. Quality adjusted price changes and confidence intervals to measure the degree of statistical error were calculated for each functional form (linear, semi-log, and log-log) in order to analyze the effect on the choice of functional form on the actual quality adjusted price changes. Only the best functional form was used to reestimate the price index. Since the coefficients for this project were based on 1976 observations, quality adjustments using the linear form for years other than 1976 must be adjusted by a price relative to correct for price changes from the data base period 1976. The coefficients for the other cases were expressed in percentage terms (log-log), therefore, no adjustment had to be made. The formula for the linear estimation of the quality adjusted link price is rather straightforward:

(2)
$$\hat{P}_j = P_i + \sum_{k=1}^{n} \hat{b}_k \cdot \Delta x_k,$$

where $\hat{P}_j$ = quality adjusted link price for model j; P_i = previous month base price for model i; $\hat{b}_k$ = regression coefficients of characteristics k that changed in the commodity specification; $\Delta x_k = (x_{jk} - x_{ik})$, characteristic change from the old to the new model; and n = number of characteristics in the equation.

The confidence intervals for the estimated quality changes are:

(2.1)
$$\hat{P}_{i \pm t_{\alpha/2}} \cdot \sqrt{S^2 \Delta x' (x'x)^{-1} \Delta x} \; ,$$

where S^2 = variance of regression equation, $x'x$ = cross product of observation matrix, $\hat{p}_j$ = quality adjusted price, $t_{\alpha/2}$ = Student's

t-statistic for a two-tailed distribution at the α confidence interval, and Δx = vector of characteristic changes from the old model to the new model.

When only one characteristic changes, (2.1) reduces to:

$$(2.2) \qquad \hat{P}_{j \pm t_{\alpha/2}} \cdot S_{b_k} \cdot x_k,$$

where S_{b_k} = standard error of the regression coefficient for characteristic in question.

However, when one goes from a linear distribution to a log-normal distribution, the expected value of the exponent is not the same as the exponent of the expected value; therefore, a correction factor must be used. For both the semi-log and double-log equations, the formula for the quality adjusted link price is:

$$(3) \qquad \hat{P}_j = P_i \exp\left(\sum_k z_k b_k - 1/2\, S^2\, z'(x'x)^{-1}\, z\right),$$

where b_k = the estimated coefficient of the kth characteristic, S = estimated standard error of the regression equation, z_k = ln (x_{jk}/x_{ik}) if the independent variables (x's) are in the double-log form, and z_k = $(x_{jk} - x_{ik})$ if the independent variable are in the linear form.

If only one variable changes in the estimating equation, (3) becomes:

$$(3.1) \qquad \hat{P} = P \exp\left(z_k b_k{}^{-1/2} S_{b_k}^2 Z_k^2\right),$$

where S_{b_k} = standard error of regression coefficient.

The confidence interval for the calculated point estimate of quality adjusted price is:

$$(3.2) \qquad P_\alpha = \hat{P} \exp\left(\pm\, U_{\alpha/2} \sqrt{S^2 z'(x'x)^{-1}\, z}\,\right),$$

where U = critical value for the normal curve $\alpha/2$ distribution.

During the period for which data were available (1971–77), five specific cases of specification change occurred for cranes, all of which were evaluated using the producer-cost methodology. The net specification changes for each case are in table 2.20. In cases 4 and 5, even though there was a model substitution in which the new model was a more powerful crane, the Boom Swing Speed and the Boom Point Height decreased in value. The slowing of Boom Swing Speed is understandable, since a heavier boom structure may take more time to revolve. In the fifth case, the Boom Point Height was less for the new model.

Table 2.21 presents the results of recalculating quality adjusted prices for five cases. Column 1 (labeled Producer Cost) contains a measurement of quality adjustment, expressed in percentage terms, for the producer-cost methodology. Column 3 also measures quality change; however, in this column the link prices (L_{t-1}) are not derived from the producer-cost information but from the implicit prices estimated from the hedonic equation with the best functional form. Columns 2 and 4 contain confidence interval limits of these estimates. Columns 5, 6, and 7 show estimates for each functional form. By comparing column 1 with column 3, one can readily observe that relative to the hedonic approach the producer-cost methodology understates the quality change in cases 1, 2, and 4 that actually occurred during the measurement period. The opposite was true for cases 3 and 5. In case 1 the producer-cost evaluation of quality actually was within the 95% range of the hedonic quality adjustment. Further, it is interesting to note substantial differences in columns 5, 6, and 7 associated with different functional forms. In some cases the differences are large enough to alter the direction of difference from the producer cost method.

Table 2.22 depicts the differences between the index calculated with the producer-cost methodology and the revised index employing hedonic quality adjustments. The letters indicate when the actual quality change took place. This comparison brings out differences in both size and direction of change. The hedonic quality adjustments caused the range of the differences in the month of the change between the actual and revised indexes to be between −5.4% and +2.7%. However, one should keep in mind that this table represents the finest level of detail and consequently gives rise to the greatest quality differences between the two types of indexes. Note also the counteracting influences of cases 2 and 3 in 1976.

A more relevant yardstick for measuring the impact of substituting new quality adjustments based on the hedonic approach is to observe the impact of the quality adjustments on "all" cranes. What this implies is that we are including all different sizes and types of cranes that were included in the PPI. Table 2.23 reflects the influences of the five cases on the "all" cranes index. The percentage change from December 1970 to December 1977 between the original and revised index is very small indeed, only .11%. However, differences are somewhat larger during particular months or subperiods.

2.5 Quality Adjustment and the Revised PPIs

The study of quality adjustment in the crane indexes show a small, negative revision in the index when regression techniques are used for quality adjustment. While the average effect is a downward revision of the index, some observations were revised in each direction. A study of the refrigerator component of the PPI is the only other study that has used regression techniques to quality adjust the actual observations on which an official index is based. Triplett and McDonald (1977) found that the application of regression techniques produced an index that declined 23% over the 1960–72 period compared with a decline of 17% in the official index. Like our crane study, they found that the direction of revision was, on average, consistent with the hypothesis that there is a positive quality error in price indexes but that for individual observations and particular subperiods the reverse was true.

The variety of evidence examined in this paper suggests any quality error in the Producer Price Indexes is a very complex phenomenon with no clear evidence of overall magnitude or direction. We certainly do not wish to minimize the potential difficulties involved in providing proper quality adjustment. But such occurrences are infrequent in the index. They show a reasonable distribution of price and quality magnitudes. Hedonic techniques provide a useful check on the ongoing quality adjustment process but still seem to be too complex to be generally applicable in a production environment. The evidence in this paper is that the impact of a hedonic technique seems to be relatively small in the short run and variable over time in both size and direction. However, the evidence is too sparse to draw any general conclusions. Two interesting problems have been identified that will require further research: the relatively large statistical error in the hedonic estimates, and the sensitivity of the results to the selection of the functional form.

PPIs are currently undergoing a comprehensive revision. The first experimental results were released in August 1978, and the full results will be released on an industry-by-industry basis between January 1980 and April 1985. Some of the improvements being made by the revision include probability sampling, net output weighting, and better transaction prices. Also as part of this effort, more resources will be devoted to quality adjustment (Early 1978). Further research will be conducted on alternative methods for quality adjustment in an index-production environment. And appropriate theory and methods will be developed for measuring error from all sources, including quality adjustment. As part of the improved index system, a complete, automated file on all substitutions will be maintained, which will make possible a more complete and prompt analysis of the effects of substitutions on the indexes.

Table 2.1 Classification of Quality Adjustments, PPI, 1976

PPI Major Commodity Group	Cases of Quality Adjustment as Percent of All Quality Adjustments[a] Total (1)	Producer Cost (2)	Link, No Change (3)	Direct Comparison (4)	Total Quality Adjustments as Percent of All Prices in Each Commodity Group in 1976[b] (5)
01. Farm products	0	0	0	0	0
02. Processed foods and feeds	1.32	.22	.44	.66	.07
03. Textile products and apparel	3.96	.66	.88	2.42	.34
04. Hides, skins, leather, and related products	2.64	.44	1.54	.66	1.04
05. Fuels and related products, and power	0	0	0	0	0
06. Chemicals and allied power	3.08	.44	.66	1.98	.12
07. Rubber and plastic products	2.64	.22	1.10	1.32	.28
08. Lumber and wood products	.44	0	.22	.22	.05
09. Pulp, paper, and allied products	2.20	0	1.10	1.10	.25
10. Metals and metal products	12.97	2.42	6.37	4.18	.38
11. Machinery and equipment	37.36	10.77	14.51	12.09	.49
12. Furniture and household durables	13.63	1.98	7.69	3.96	1.27
13. Nonmetallic mineral products	.44	.44	0	0	.05
14. Transportation equipment	14.73	9.89	3.08	1.76	2.38
15. Miscellaneous products	4.62	.88	2.86	.88	.44
	100.00	28.40	40.40	31.20	.40

[a]455 total cases.
[b]108,756 total price observations in 1976.

Table 2.2 **Frequency Distribution of Quality Change for Producer Cost Method, PPI, 1976**

	Percent Change													
	0–9.9		10–19.9		20–29.9		30–39.9		40–49.9		50–99.9		>100	
PPI Code	+	−	+	−	+	−	+	−	+	−	+	−	+	Total
01														0
02					1									1
03	2	1												3
04														0
05														0
06	1	1												2
07				1										1
08														0
09														0
10	3	4		2		1					1			11
11	23	5	8	6				1				2	3	48
12	5	2			1								1	9
13		1											1	2
14	35	9		1	1		1					1		48
15	3				1									4
Total	72	23	8	10	4	1	1	1	0	0	1	3	5	129

Table 2.3 **Frequency Distribution of Pure Price Changes in Producer Cost Method, PPI, 1976**

	Percent Change														
	0–9.9		10–19.9		20–29.9		30–39.9		40–49.9		50–99.9		>100	>100	
PPI Code	+	−	+	−	+	−	+	−	+	−	+	−	+	−	Total
01															0
02		1													1
03	2	1													3
04															0
05															0
06	2														2
07	1														1
08															0
09															0
10	8	2	1												11
11	36	3	5				1					1			46
12	7	1			1										9
13	2														2
14	44	2	3			1									50
15	2	1		1											4
Total	104	11	9	1	1	1	1	0	0	0	0	1	0	0	129

Table 2.4 **Frequency Distribution of Links to Show No Price Change, PPI, 1976**

	Percent Change													
	0–9.9		10–19.9		20–29.9		30–39.9		40–49.9		50–99.9		>100	
PPI Code	+	−	+	−	+	−	+	−	+	−	+	−	+	Total
01														0
02		1									1			2
03	1	1	1			1								4
04	3	1	2					1						7
05														0
06		1	1					1						3
07	1	2		1						1				5
08													1	1
09	1	4												5
10	6	6	2	3	1	1	1	1	2	1		3	2	29
11	25	6	14	2	4	1	4	1	2	1	5		1	66
12	11	3	7	2	4	4	1	1	1			1		35
13														0
14	4	6			1	1						1	1	14
15	1	1	4	2		2		1				1	1	13
Total	54	31	32	10	10	9	5	7	5	3	6	6	6	184

Table 2.5 **Frequency Distribution of Price Change for Direct Comparisons, PPI, 1976**

	Percent Change														
	0	0–9.9		10–19.9		20–29.9		30–39.9		40–49.9		50–99.9		>100	
PPI Code		+	−	+	−	+	−	+	−	+	−	+	−	+	Total
01															0
02	3		1				1					1			6
03	11	2					1					1			14
04	1	2							1						4
05															0
06	5	1	1	1		1			1						10
07	1	2	1					1			1			1	7
08	2														2
09	2	2	1												5
10	11	8													19
11	28	5	5	4	3	1	2	1	1						50
12	12	3	2											1	18
13															0
14	4	4													8
15															0
Total	80	29	11	5	3	2	4	2	3		1	1		2	143

Table 2.6 **Classification of Quality Adjustments, for Ten Selected Commodity Groups, PPI, 1970–1976**

Type of Quality Adjustment	Cases of Quality Adjustment Per Year						
	1976	1975	1974	1973	1972	1971	1970
Producer cost	45	59	40	54	23	4	27
Link	47	23	18	31	11	14	0
Direct comparison	16	0	6[a]	2	3	2	0[a]
Total no. cases per year	108	82	64[a]	87	37	20	27[a]
No. reported prices	4,128	4,224	4,284	4,284	4,284	4,272	[b]

[a]Some data not available.

[b]Comparable figures not available.

Table 2.7 **Cases of Quality Adjustment for Ten Selected Commodity Groups, PPI, 1970–1976**

PPI Code	Number Producer Cost Adjustments	Number Link Adjustments	Number Direct Comparison Adjustments	Total Adjustments	Total Price Obser-vations
043201 (women's and misses' footwear domestic)	2	16	2	20	1,848
101501 (gray iron castings)	12	8	2	22	7,092
104101 (builder's hardware)	1	15	5	21	3,648
111206 (harvest-ing machinery)	16	18	3	37	2,148
112802 (tractors, crawler type)	23	20	1	44	1,728
114901 (valves and fittings)	2	8	6	16	3,108
117837[a] (optoelec-tronic devices)	0	2	2	4	276
123101 (soft sur-face floor coverings)	0	31	4	35	2,748
141101 (passenger cars)	107	11	2	120	1,260
141102 (motor trucks)	89	15	2	106	1,620
Total	252	144	29	425	25,467

[a]Began in 1975.

Table 2.8 Frequency Distribution of Change for Producers' Cost Method for Ten Selected Commodity Groups, PPI, 1970–1976

	Percent Change													
	0–9.9		10–19.9		20–29.9		30–39.9		40–49.9		50–99.9		>100	
PPI Code	+	−	+	−	+	−	+	−	+	−	+	−	+	−
	Quality Change													
043201		2												
101501	4	2		1	1			1	1		2			
104101		1												
111206	14	1	1											
112802	13	4	1	3	2									
114901	1				1									
117837														
123101														
141101	87	14	3		2	1								
141102	68	13	7			1								
Total	187	37	12	4	6	2	0	1	1	0	2	0	0	0
	Price Change													
043201	2													
101501	9	1	1		1									
104101			1	1										
111206	10	2	4											
112802	17	4	1											
114901			2			1								
117837														
123101														
141101	75	26	5		1									
141102	60	12	14		1				1					
Total	173	45	28	1	3	1	0	0	1	0	0	0	0	0

Note: Total observations = 252.

Table 2.9 **Frequency Distribution of Links to Show No Change for Ten Selected Commodity Groups, PPI, 1970–1976**

	Percent Change													
	0–9.9		10–19.9		20–29.9		30–39.9		40–49.9		50–99.9		>100	
PPI Code	+	−	+	−	+	−	+	−	+	−	+	−	+	−
043201	9	1	5		1									
101501		1		1		1	2	1	2					
104101	2	1	1	3	1	1			1	1		3	1	
111206	11	2	2		2						1			
112802	12	2	2			1	1				1		1	
114901	1		3	1			1		1				1	
117837			1								1			
123101	6	4	4	3	5	1	1	1	2	1	1		2	
141101	7	3				1								
141102	13	2												
Total	61	16	18	8	9	5	5	2	6	2	4	3	5	0

Note: Total observations = 144.

Table 2.10 **Frequency Distribution of Price Change for Direct Comparisons for Ten Selected Commodity Groups, PPI, 1970–1976**

	Percent Change													
	0–9.9		10–19.9		20–29.9		30–39.9		40–49.9		50–99.9		>100	
PPI Code	+	−	+	−	+	−	+	−	+	−	+	−	+	−
043201	2													
101501	2													
104101	5													
111206	2			1										
112802	1													
114901	1		2		2		1							
117837	2													
123101	2	2												
141101	2					1								
141102	2													
Total	21	2	2	1	2		1							

Note: Total observations = 29.

Table 2.11 Independent Variables for the Hydraulic Crane Data Base[a]

1. Crane type (carrier-mounted or self-propelled)
2. Boom retracted boom length
3. Boom retracted rated lifting capacity
4. Boom retracted at boom radius
5. Boom extended boom length
6. Boom extended rated lifting capacity
7. Boom extended at boom radius
8. Boom maximum angle
9. Boom maximum hook height
10. Maximum height at maximum weight
11. Boom topping speed
12. Boom swing speed
13. Hoist speed
14. Pump hydraulic horsepower
15. Outrigger type
16. Outrigger extended width
17. Crane engine type
18. Crane engine cylinders
19. Crane engine horsepower
20. Crane length
21. Crane height
22. Crane width
23. Crane wheel base
24. Crane gross weight
25. Crane maximum speed
26. Standard carrier engine type[a]
27. Standard carrier engine cylinder[a]
28. Standard crane engine horsepower[a]

[a]These characteristics referred to the carrier-mounted hydraulic crane. It was later decided that the hydraulic crane data base should be divided into carrier-mounted and self-propelled hydraulic cranes. In this way, the dummy variable "crane type" could be dropped.

Table 2.12 **Independent variables for the Truck Crane Data Base**

1. Boom length
2. Boom angle at minimum radius
3. Boom radius minimum
4. Boom lifting capacity minimum radius
5. Feet from hook point minimum radius
6. Minimum load line minimum radius
7. Boom radius maximum
8. Boom lifting capacity maximum radius
9. Feet from boom point maximum radius
10. Minimum load line maximum radius
11. Boom angle maximum radius
12. Maximum boom angle
13. Boom swing speed
14. Maximum single line hoist speed
15. Maximum single line pull main hoist
16. Crane engine type
17. Crane engine cylinders
18. Crane engine horsepower
19. Crane engine revolutions per minute
20. Standard carrier engine type
21. Standard carrier engine cylinders
22. Standard carrier engine horsepower
23. Carrier speed

Table 2.13 **Independent Variables for the Crawler Crane Data Base**

1. Boom maximum capacity
2. Boom on boom length
3. Boom at radius
4. Boom length
5. Maximum hoisting speed on single line
6. Boom type
7. Minimum boom length with type of boom top
8. Maximum boom length
9. Maximum fly-jib length
10. Crawler width retracted
11. Crawler width extended
12. Crawler pad width
13. Crawler pad length
14. Crawler weight
15. Ground bearing pressure
16. Cab height with crawlers
17. Total crane weight with boom and counter-weight
18. Counterweight
19. Tailswing radius
20. Cab length without counterweight
21. Cab width
22. Cab height without counterweight or crawlers
23. Crane engine type
24. Crane engine horsepower
25. Crane engine revolutions per minute
26. Crane engine drive
27. Crane maximum travel speed

Table 2.14 **Simple Correlation Coefficients from Hydraulic Crane Data Base (Includes Both Self-Propelled and Carrier Mounted Cranes)**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
1	1.000	.666	.687	.604	.738	.596	.476	.597	.735	.749	.651	.550	.606	.634	.795	.675	.048	.313	.311	.655	.592	.059	.099	.645	.814	.179	.991
2		1.000	.863	.979	.969	.943	.785	.976	.973	.962	.957	.941	.934	.916	.811	.978	.241	.842	.862	.995	.979	.206	.228	.918	.943	.094	.655
3			1.000	.795	.940	.819	.659	.784	.925	.925	.878	.714	.780	.861	.770	.876	.117	.742	.776	.855	.800	.154	.177	.918	.794	.059	.662
4				1.000	.992	.954	.791	.990	.932	.916	.930	.980	.947	.891	.755	.965	.327	.865	.871	.984	.994	.199	.217	.878	.941	.101	.597
5					1.000	.884	.758	.918	.997	.996	.946	.866	.900	.904	.843	.962	.198	.799	.810	.960	.925	.215	.241	.941	.925	.081	.722
6						1.000	.726	.944	.879	.882	.921	.928	.909	.881	.770	.949	.278	.842	.857	.949	.952	.164	.181	.869	.979	.096	.588
7							1.000	.779	.763	.751	.754	.766	.725	.901	.569	.768	.204	.675	.702	.781	.785	.161	.176	.711	.724	.067	.467
8								1.000	.929	.914	.924	.977	.942	.876	.748	.967	.382	.870	.869	.982	.995	.204	.222	.868	.949	.099	.590
9									1.000	.987	.944	.882	.911	.906	.845	.969	.211	.800	.817	.967	.945	.214	.238	.941	.940	.080	.721
10										1.000	.941	.862	.893	.898	.854	.960	.197	.781	.797	.955	.919	.215	.241	.947	.925	.084	.745
11											1.000	.884	.902	.892	.784	.938	.196	.806	.842	.952	.928	.189	.210	.911	.886	.084	.649
12												1.000	.945	.944	.701	.926	.358	.844	.835	.950	.977	.196	.212	.819	.904	.100	.548
13													1.000	.844	.714	.919	.262	.809	.814	.954	.949	.248	.245	.858	.889	.076	.592
14														1.000	.726	.905	.171	.767	.799	.907	.884	.195	.216	.882	.844	.072	.619
15															1.000	.835	.048	.577	.584	.801	.747	.216	.246	.800	.845	.144	.788
16																1.000	.292	.850	.856	.981	.969	.207	.229	.918	.947	.108	.666
17																	1.000	.454	.324	.274	.356	.246	.326	.970	.295	.154	.645
18																		1.000	.962	.851	.956	.214	.219	.805	.756	.180	.651
19																			1.000	.864	.882	.244	.250	.842	.712	.141	.621
20																				1.000	.984	.147	.157	.892	.942	.086	.645
21																					1.000	.201	.219	.880	.942	.104	.584
22																						1.000	.999	.464	.977	.091	.582
23																							1.000	.485	.941	.117	.641
24																								1.000	.842	.071	.625
25																									1.000	.176	.812
26																										1.000	.216
27																											1.000
28																											

Table 2.15 **Self-Propelled Hydraulic Cranes**
A. Linear Regression Coefficients

Quality Variables[a]	Coefficients	Standard Error	*t*-Statistics
Lifting capacity	2169.2600	201.0189	10.790
Maximum lifting height	31.2995	5.9601	5.251
Boom topping speed	287.6940	121.0072	2.377
Boom swing speed	9193.0200	1608.7750	5.714
Engine horsepower	34.2335	39.4713	0.867

B. Linear Estimate of Intercept and Company Effects from Self-Propelled Hydraulic Crane Regression

Company[b]	Coefficients	Standard Error	*t*-Statistics
Intercept[c]	−9255.4560	19826.890	−.4668
Bantam	81.2964	5825.198	.0140
Broderson	−1671.6920	12078.040	−.1384
Bucyrus-Erie	10713.9900	7140.533	1.5000
Drott	11015.8100	5551.588	1.9840
Galion	14260.3400	9606.422	1.4840
Grove	2156.7110	4549.937	.4740
Hyster	2223.1710	7957.227	.2794
Lorain	2473.0400	7511.479	.3292
P and H	7965.3620	5154.097	1.5440
Pettibone	2367.5810	7340.416	.3225
Warner and Swasey	−6406.1480	9418.650	−.6802

$R^2 = .94331$
Standard error of residual = 845.71
Sample size = 61

Crane price (dependent variable): mean = 111,227
Standard deviation = 62,406

[a]Estimated without company dummies which were, as a whole, insignificant.
[b]These companies were derived from the "Green Guide" and in no way reflect actual companies that are priced in the PPI.
[c]Austin-Western was included in the *y*-intercept.

Table 2.16 Carrier-mounted Hydraulic Cranes
A. Log-Log Regression Coefficients

Quality Variables[a]	Coefficients	Standard Error	t-Statistics
Lifting capacity	.3443582	.067681250	5.088
Maximum lifting height	.0003310	.000141158	2.346
Boom topping speed	.0136750	.005049586	2.708
Boom swing speed	.2141211	.022945020	9.332

B. Linear Estimate of Intercept and Company Effects from Self-Propelled Hydraulic Crane Regression

Company[b]	Coefficients	Standard Error	t-Statistics
Intercept[c]	10.06874000	.31394700	32.070
Bantam	−.02443212	−.07376190	−.331
Bucyrus-Erie	.24878560	−.06548293	3.799
Drott	.06297117	.09278927	.679
Grove	−.03281932	.06307050	−.520
Link Belt (FMC)	.16683410	.10007760	1.667
Lorain	.14671190	.14406750	1.018
P and H	.08088108	.07017277	1.153
Pettibone	.07826455	.10504100	.745
Warner and Swasey	−.02088442	.07259642	−.228

The dependent variable is the natural logarithm price.

R^2 = .9820268
Standard error of residual = .0751401
Sample size = 31

Crane price (dependent variable): mean = 76,770
Standard deviation = 6,441

[a]Estimated without company dummies which were, as a whole, insignificant. Intercept data came from a different regression estimate.
[b]These companies were derived from the "Green Guide" and in no way reflect actual companies that are priced in the PPI.
[c]Austin-Western was included in the y-intercept.

Table 2.17 Crawler Cranes
A. Log-Log Regression Coefficients

Quality Variables	Coefficients	Standard Error	*t*-Statistics
Lifting capacity	.421730700	.0399051800	10.57
Maximum lifting height	.001109538	.0002065855	5.37
Engine horsepower	.001107087	.0003046310	3.63

B. Log-Log Estimate of Intercept and Company Effects from Crawler Crane Regression

Company[a]	Coefficient	Standard Error	*t*-Statistics
Intercept[b]	6.3136880	.38374550	16.450
Bucyrus-Erie	.1209202	.05201461	2.330
Koehring	−.0169128	.06094477	−.278
Lima	.0033107	.06549748	.050
Link-Belt (FMC)	−.0253000	.04507097	−.455
Lorain	.2443997	.12301540	1.990
Manitowoc	−.1787732	.05913360	−3.020
Northwest	.5968208	.04105696	1.450
P and H	.0182433	.05508285	.331
Unit	.0035194	.12373360	.028

The dependent variable is the natural logarithm price.

R^2 = .9761163
Standard error of residual = .1139354
Sample size = 80

Crane price (dependent variable): mean = 226,080
Standard deviation = 154,189

[a]These companies were derived from the "Green Guide" and in no way reflect actual companies that are priced in the PPI.
[b]American was included in the *y*-intercept.

Table 2.18 **Truck Cranes**
A. Log-Log Regression Coefficients

Quality Variables	Coefficients	Standard Error	t-Statistics
Lifting capacity	.388152900	.0969392800	4.00
Maximum lifting height	.000974499	.0004301725	2.27
Engine horsepower	.001334569	.0006628524	2.01

B. Log-Log Estimate of Intercept and Company Effects from Truck Crane Regression

Company[a]	Coefficient	Standard Error	t-Statistics
Intercept[b]	9.77262500	.43826080	22.300
Bantam	−.62374620	.16769490	−3.720
Bucyrus-Erie	.21800800	.10344780	2.110
Lima	−.05877054	.08425340	−.689
Link-Belt (FMC)	−.25938990	.07657147	−3.390
Lorain	.06346180	.07583306	.862
Manitowoc	.13640830	.17467810	.781
Northwest	−.13694970	.12073060	−1.130
P and H	−.07919773	.08635810	−.917

The dependent variable is the natural logarithm of price.

R^2 = .9638091
Standard error or residual = .1700581
Sample size = 37

Crane price (dependent variable): mean = 247,203
Standard deviation = 138,920

[a]These companies were derived from the "Green Guide" and in no way reflect actual companies.
[b]American was included in the y-intercept.

Table 2.19 Testing for Best Functional Form Using Box-Cox Power Transformation Test[a]

Type of Crane	Standardized Sum of Squared Residuals
Hydraulic Cranes	
1. Self-propelled[b]	
Linear	.4973005
Semi-log	.7321062
Log-log	.5482269
2. Carrier-mounted	
Linear	.2030923
Semi-log	.1976967
Log-log	.1832833
Truck Cranes	
Linear	.9757013
Semi-log	1.7095040
Log-log	.9254327
Crawler Cranes	
Linear	2.2006408
Semi-log	2.6330330
Log-log	1.2611700

[a]A χ^2 test was used to test for a difference between all the functional forms. In all instances the χ^2 value was significant at .01 level.
[b]Notice the linear functional form had the smallest sum of squared residuals for "self-propelled" hydraulic cranes.

Table 2.20 Net Specification Changes from Old to New Model for Five Specific Cases

Case	Lifting Capacity (tons)	Boom Point Height (inches)	Boom Swing Speed (rpm)	Boom Topping Speed (sec)	Engine Horse-power
1[a]					+44
2[b]	+10	+120			+24
3[b]	+10	+ 96			
4[c]	+ 7	+102	−1		
5[c]	+ 5	−16.25	+5	+1.5	

[a]Self-propelled hydraulic crane.
[b]Truck cranes.
[c]Carrier-mounted hydraulic cranes.

Table 2.21 Quality Changes for Producer-Cost Methodology and Three Hedonic Function Forms (Percent)

		Best Functional Form[a]			Point Estimate Other Functional Forms		
Case	(1) Producers Cost	(2) Lower Limit	(3) Point Estimate	(4) Upper Limit	(5) Linear	(6) Semi-Log	(7) Log-Log
1	1.30	−2.71	2.88	8.47	2.88[b]	3.81	.027
2	1.18	4.09	8.12	12.30	20.88	24.08	8.12[b]
3	10.43	3.36	6.69	10.13	18.50	20.19	6.69[b]
4	1.89	6.49	11.33	16.40	16.50	18.88	11.33[b]
5	30.26	8.75	11.68	14.69	21.78	11.17	11.68[b]

[a]The best functional form as determined by Box-Cox test.
[b]95% confidence interval.

Table 2.22 **Actual and Hedonic Crane Index for Five Specific Cases**

	January	February	March	April	May	June	July	August	September	October	November	December
Case 1 (self-propelled hydraulic)												
1971 actual index	119.6	119.6	119.6	119.6	119.6	119.6	119.6	119.6	119.6	119.6	119.6	119.6
1971 hedonic index	119.6	119.6	119.6	119.6	119.6	113.1[a]	113.1	113.1	113.1	113.1	113.1	113.1
Cases 2 and 3 (truck crane):												
1976 actual index	221.0	221.0	221.0	221.0	221.0	226.6	230.1	230.1	230.1	230.1	230.1	230.1
1976 hedonic index	221.0	221.0	221.0	221.0	221.0	226.6	230.1	230.1	232.6[a]	232.6	232.6	225.9[a]
Cases 4 and 5 (carrier-mounted hydraulic)												
1977 actual index	147.4	147.4	147.4	149.8	149.8	150.6	150.6	150.6	150.6	151.6	151.6	151.6
1977 hedonic index	147.4	147.4	147.4	159.0[a]	159.0	154.6[a]	154.6	154.6	154.6	155.6	155.6	155.6

[a]Month in which quality adjustment took place and implicit link price was substituted for producer-cost link price.

Table 2.23 "All" Cranes Index Original and Hedonic (1972 = 100)

	January	February	March	April	May	June	July	August	September	October	November	December
1971 original	94.2	94.2	94.2	94.3	94.4	94.4	96.6	96.6	96.6	96.9	96.6	96.4
1971 hedonic	94.2	94.2	94.2	94.3	94.4	94.2[a]	96.4	96.4	96.4	96.7	96.4	96.2
1972 original	97.5	98.8	98.8	98.8	98.8	99.3	99.3	99.4	99.4	99.4	100.0	100.0
1972 hedonic	97.4	98.7	98.7	98.7	98.7	99.2	99.2	99.3	99.3	99.3	99.9	99.9
1973 original	100.1	100.1	101.2	101.5	101.5	102.7	102.8	102.8	102.8	102.8	103.3	106.2
1973 hedonic	100.0	100.0	101.1	101.4	101.4	102.6	102.7	102.7	102.7	102.7	103.2	106.1
1974 original	106.2	107.1	108.2	110.6	114.5	115.3	119.8	121.9	125.1	126.8	129.2	133.1
1974 hedonic	106.1	107.0	108.1	110.5	114.4	115.2	119.7	121.8	125.0	126.7	129.1	133.0
1975 original	135.9	137.9	139.5	143.7	143.7	144.9	146.9	147.2	147.9	150.8	151.0	153.7
1975 hedonic	135.8	137.8	139.4	143.6	143.6	144.8	146.8	147.1	147.8	150.7	150.9	153.6
1976 original	153.7	153.8	153.8	153.8	154.2	156.0	157.8	158.3	159.0	159.6	159.7	159.9
1976 hedonic	153.6	153.7	153.7	153.7	154.1	155.9	157.7	158.2	159.2[a]	159.8	159.9	159.7[a]
1977 original	163.6	163.4	163.4	164.1	164.7	165.9	166.2	167.4	167.4	167.9	168.7	168.9
1977 hedonic	163.4	163.2	163.2	164.5[a]	165.3	165.8[a]	166.1	167.3	167.3	167.8	168.6	168.8

[a]Month in which actual quarter adjustment occurred for cranes under investigation.

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Comment Zvi Griliches

The paper consists roughly of three parts: first, there are some introductory comments explaining the current philosophy of quality and adjustment in the PPI; second, there is a survey of the frequency and type of quality adjustment in 1976 and a more detailed listing of quality adjustments for 10 selected commodity groupings during the 1970–76 period; and, finally, there is a report on an exploratory hedonic regression study of power cranes. The three parts are only barely linked, and I shall comment on each of them separately.

The first section describes current practice in the PPI without necessarily endorsing it. The current practice is based on the assumption that quality change is to be valued by the difference in the cost of production that it induces. I have both conceptual and practical objections to this procedure. First, I believe this to be an inappropriate definition of quality change. The appropriate measure is one based on the utility to the purchaser of the item. I understand that one may use producer cost for lack of anything better or because of the unwillingness to enter the treacherous waters of utility estimation, but I do not understand its elevation to dogma, to the status of a "desirable" definition of such indexes. If such a procedure were followed consistently for all quality

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changes, it would come close to abolishing this source of productivity growth by construction (except for differences between beginning and end period weights) since it would recognize only those changes in output per commodity unit (quality per model) in the producing industry which correspond to measurable changes in production costs. But then output per unit of input will not have changed. The argument that all this will work out in equilibrium does not wash as far as I am concerned. The essence of price and productivity measurement is the evaluation of transitions between equilibria. There are also problems with the empirical implementations of this notion. Conceptually, as far as I can tell, the relevant notion must be of *marginal* production costs. In practice they also include the "standard mark-up for return to investors and entrepreneurship." But that assumes away the possibility of price change that comes from the erosion of such margins over time.

Perhaps an example will help here. Imagine a change in Bayer Aspirin bottles from 50 to 75 pills per bottle and a change in price from 50 cents to 70 cents per bottle. If a true production cost notion were taken, one would use the information that marginal cost of an aspirin pill does not exceed .3 cent and that the difference in the bottle and associated transportation cost is not larger than 5 cents per bottle (all these numbers are, of course, invented but are illustrative of the right orders of magnitude). Thus the total production cost change per bottle due to the new package is 7.5 + 5 = 12.5 cents, implying a 7.5 cents *increase* in the price of a bottle of aspirin. But the actual price per pill has come down (from 1 to .93 cent per pill). Obviously, the BLS will not use the above producer-cost calculation but will rather accept the pill as the relevant unit here. But how does it *know* that the pill *is* the relevant unit without an implicit utility analysis?

I have also a more mundane objection to the producer-cost concept. I believe that it leads to a too great reliance on crude accounting data provided by firms and to a serious downward bias in the index (for *those* items), since it has been in the interest of firms and industries to claim that various changes have been very costly. I do not believe that the BLS has adequate resources for checking and challenging such claims in appropriate detail.

The section on the actual prevalence of various adjustment practices is very valuable in what it describes but falls short of what I would have liked to see. There is no independent examination of a sample of cases to see how many changes were *not* identified and how many of the identified changes were treated correctly. That is, we do not learn anything directly about the *quality* of such quality adjustments. What we do learn indirectly is quite disturbing.

In 1976, out of 108,756 price observations, only 455 were *reported* as creating a comparison problem. The incidence appears to be very low. It implies that out of about 10,000 different commodities and varieties priced one encountered only 455 comparability problems during one year. Either many true comparability problems are not reported or the PPI by design excludes most of the rapidly changing commodity areas from its purview. I assume that both are true. Of those examined 31 percent were presumed not to show any quality change, while 40 percent were assumed to show no improvement in quality relative to price. The remaining 28 percent were adjusted using the producer-cost method with a preponderance of positive quality change estimates (91 out of 129). My guess is that in this period of inflation "quality change" is probably *overestimated* in a sector where it is measured by the producer-cost method and underestimated everywhere else.

Looking at table 2.1 we find most of the producer-cost valued-quality changes concentrated in the machinery and equipment and transportation equipment industries. In the latter industry, many of these changes arise from mandated changes in the products and probably represent a serious overestimate of such change from the user's point of view. Surely the recent laws have led to a significant increase in the cost of automobile ownership, per year or per passenger mile, which is not reflected adequately in the official indexes.

There are other disturbing aspects of these tables. More than half of the "links," of direct substitutions, involve changes in commodities which differ by more than 10 percent in their price. More than a quarter of all links differ by more than 20 percent in their prices. One wonders how comparable such links really are.

Looking at the more detailed data for the 1970–76 period for 10 detailed commodities the same kinds of questions arise. The bulk of the adjustments occur for passenger cars and trucks where the rate of adjustment is roughly on the order of one per model per year. Since the adjustments there are based primarily on producer-cost estimates, I suspect that they overestimate quality change in this particular time period. The other categories (e.g., tractors, valves, and builders hardware) exhibit a rather low rate of adjustment, implying that many changes in quality are not being caught by the current procedures.

The last section shows that it is easier to criticize the PPI than to propose effective alternatives. It presents estimates of hedonic price regressions for several types of power cranes and uses the estimated coefficients to adjust the actual price quotations in the PPI. Since these regressions are based on data for only one year, there is some doubt about the propriety of applying the estimated coefficients to the whole 1971–77 period. Moreover, the instability observed in the estimates of the various coefficients might have been alleviated by expanding the regression sample to cover more years. One can always test, later on, whether such pooling of observations over time is legitimate.

The resulting estimates are used to evaluate five cases of producer-cost adjustments. The individual estimates based on the hedonic regressions are subject to so much uncertainty, however, both because of sampling error and because of ignorance of the appropriate functional form, that little can be concluded from such a comparison. It appears that producer-cost adjustments *underestimate* slightly the quality change that occurred in these particular cases. There were, however, only five such specification changes for *all* crane models in the seven-year period that was examined by them. This is rather surprising and may indicate how little I know about cranes, but it also might lead one to wonder about the representativeness of the crane models being sampled by the PPI.

I learned a great deal from reading the Early-Sinclair paper, and I am grateful to the authors for providing all this information, even as I hanker for more. We need more such studies, however, before we can start generalizing about the role, magnitude, and direction of the "quality error in the PPI."

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