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MEASURING PRICE DIFFERENCES BY REGRESSION METHODS

IN THIS CHAPTER we set out the rationale for the use of regression methods in international price comparisons and discuss the problems encountered in using this technique. The bulk of the chapter is devoted to the development in considerable detail of regression-based index numbers for automotive diesel engines as an illustration of the problems and alternative solutions. The use of regressions for other commodities in the study as a whole is also summarized.

Regression methods of price measurement are applicable to many commodities that are difficult or impossible to price by traditional methods, and can be used for time-to-time as well as place-to-place comparisons. They were first applied to domestic price indexes, and we used them for intertemporal international price indexes in a number of commodity classifications. We also extended their use to international price comparisons where they had not been used before, and we dwell on this application in the present chapter. However, our tests of the effect of alternative techniques on the final price measurement should be relevant to domestic price measurement as well.

The basic problem in international price comparisons, whether their purpose is to compare the purchasing power of currencies or to measure price competitiveness in international trade, arises from international differences in product specifications. Not only are many products highly differentiated among the producers within each country, but there are often significant international differences in the characteristics of products that serve the same general purpose. As a result, it is frequently

Note: A shorter version of this chapter was published in the *International Economic Review*, June 1969.

impossible to find identical products in two countries, even though products performing the same function are manufactured in both countries.

A similar problem of comparability over time has troubled compilers of domestic price indexes. In recent years the main problem has been a suspected upward bias in price indexes due to insufficient accounting for improvements in quality. It has been suggested that the failure to measure quality change adequately is the most important defect in existing price indexes.[1]

The construction of "hedonic" price indexes, using multiple regression, was suggested by Andrew Court in an article in 1938,[2] but the idea was neglected for many years and only recently revived by Richard Stone, Zvi Griliches, and others.[3] The method has now been applied not only to automobiles, as originally proposed by Court, but also to farm tractors, electrical generating and transmission equipment, and single-family house prices.

The Rationale of Regression Analysis in Price Comparisons

The application of regression analysis to price measurement rests on the hypothesis that price differences among variants of a product in a particular market can be accounted for by identifiable characteristics of these variants.[4] Each of these characteristics is regarded as an element of a complex product; variations in the mix of the elements produces product differentiation at a moment in time and changes in product quality over time. By fitting a regression equation to observations on the price and characteristics of commodity variants, typically in a cross section of the market at a given time, the characteristics associated with the price of the commodity and their relationship to the price can be determined. If the relevant characteristics have been correctly identified, the coef-

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[1] Stigler Committee Report, p. 35 (Price Statistics Review Committee, *The Price Statistics of the Federal Government*, New York, NBER, 1961).

[2] "Hedonic Price Indexes with Automotive Examples," *The Dynamics of Automobile Demand*, New York, General Motors Corp., 1939.

[3] For a bibliography of such studies see Zvi Griliches, "Hedonic Price Indexes Revisited: Some Notes on the State of the Art," *Proceedings of the Business and Economics Section, American Statistical Association*, December 1967.

[4] Cf. Richard Stone, *Quantity and Price Indexes in National Accounts*, Paris, 1956, Chap. 4. For the extension of the theory of consumption to deal with the conception of goods as bundles of characteristics see K. Lancaster, "A New Approach to Consumer Theory," *Journal of Political Economy*, April 1966.

ficients of the equation can be interpreted as prices for the characteristics. These prices are then used in comparisons among markets or time periods in which the commodity differs in quality (i.e., has different specifications or combinations of elements). Court, for example, computed regressions of automobile prices against weight, wheelbase, and horsepower in order to measure price changes over time.

Cost vs. Utility

Most discussions of the meaning of price indexes derived by regression methods, and the very name, "hedonic," applied to them, have stressed measures of utility to the consumer. Court, for example, spoke of "the potential contribution of any commodity . . . to the welfare and happiness of its purchasers and the community" and of ". . . establishing an objective composite measure of usefulness and desirability. . . ."[5]

The Bureau of Labor Statistics and other producers of major price indexes rely on production relationships rather than on consumption relationships. The BLS "finds equivalence of quality in equal production cost. . . ."[6] The adoption of production cost rather than utility as a measure of quality does not preclude the use of regression methods, since valuation in terms of production cost and valuation in terms of utility may be viewed as alternative means of assessing the relative qualities and hence the relative prices of variants of a complex product each having a different mix of elements.[7] On a single market in competitive equilibrium, the two valuations should be identical. As Adelman and Griliches have pointed out, if the ratio of the marginal rates of substitution between two quality dimensions is smaller than the ratio of the costs exacted for them, both price and consumer purchases will adjust until

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[5] *Op. cit.,* p. 107.

[6] Stigler Committee Report, p. 37.

[7] Cf. in *loc. cit.* the Stigler Committee position on producers' goods. Regression analysis, it may be added, can be regarded as a means of inferring statistically the prices of elements of a product for which the total price is determined by what is sometimes referred to as unit or component pricing. In component pricing, which may be found in industries as different as men's apparel and residential construction, the costs (assumed constant) of particular units of work (such as making a buttonhole or providing and installing a window frame) are used to build up the cost and price of a particular product (such as a suit or house).

It would, however, be unduly confining to restrict regression analysis to the variables that form the building blocks used in industrial price formation. These are sometimes difficult to discover, and in any case performance characteristics may sometimes better explain price differences, particularly where different producers achieve given performance by using different physical components.

equilibrium is reached, provided that price is not administered. If prices are administered, and therefore not free to vary, equilibrium between the marginal rates of substitution and the cost of the quality dimensions will be reached by a change in the ratios of quantities purchased.[8]

Thus, in the regression analysis of prices, we may formulate the elements entering into a complex product either in terms of the cost of characteristics such as horsepower and fuel economy or in terms of their utility to consumers at a particular place and time.

Use of Regression Coefficients for Price Measurement

In a regression in which price is taken as the dependent variable, the coefficient of each element (that is, each independent variable) shows its price (that is, the cost per unit for additional units) in the mix of elements included in the complex product.[9] These regression coefficients may tend to change over time. To the extent that such changes reflect economic rather than statistical factors, they may be interpreted in the same way as the changes shown by other kinds of prices. For example, the lowering of the price of power over time accompanied by a shift toward more powerful machines that we have found in regressions for such products as railway locomotives and aircraft engines may be interpreted either as supply-based changes or as demand changes under conditions of decreasing supply price.[10]

International differences in the regression coefficients may also be expected, particularly if each country's market is isolated from the others. They could arise, for example, from differences in relative factor prices which would produce interspatial differences in the relative prices of the

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[8] Irma Adelman and Zvi Griliches, "On an Index of Quality Change," *Journal of the American Statistical Association*, September 1961, p. 547. As between two situations at different times, however, the cost and utility approaches, as they are sometimes defined, will yield different results when there are cost-free improvements in the second situation that were not present in the first. This outcome depends on the assumption that costs may be defined in terms of the physical characteristics of a product independently of the utility the product yields. The issues raised in this connection are not a special problem connected with regression methods and will not be pursued here.

[9] The existence of the constant term presumably indicates that the assumption of linearity in element prices, even where it is satisfactory within the range of observation, does not apply outside it, particularly near the zero level. The explanation might be that there are elements in the product (including overhead costs) which we do not try to account for in the equation.

[10] An illustration of a supply-based change is the lower price of horsepower in automobile engines which has been attributed to engine redesign (F. Fisher, Z. Griliches, and C. Kaysen, "The Costs of Automobile Model Changes Since 1949," *Journal of Political Economy*, October 1962, pp. 441 f.).

elements unless the factor mix required for increments in each quality element did not vary from one element to another in any of the countries.

In the case of diesel engines, for example, additions to weight (taken either as an element of cost or as a proxy for durability and/or reliability) might require a high materials content while additions to horsepower might require a relatively high labor content. In these circumstances the ratio of the U.S.-to-U.K. coefficient or "price" for weight would be smaller than the ratio for horsepower. If, on the other hand, it took more labor to build a sturdier engine and high weight were achieved through high labor content, the difference might be in the opposite direction. Or, again, the relative prices might differ if one country's industry specialized in a narrow range of the product (e.g., low horsepower) while another produced a wide range.

If there were truly competitive and frictionless international markets, we would not expect to find international differences in product prices, and if quality elements could be varied independently of each other, with no interdependence in utilities or costs, we would not expect to find international differences in their prices either. Any price that was out of line would bring a fall or rise in market share, changing cost and price until price equality was established.

International markets for most products probably fall between the extremes of complete national isolation and complete international integration. For many products, transport costs, tariffs, and other isolating factors are sufficiently strong to permit the production in different countries of the same products or elements of products at different costs, and their sale at different prices.

Specification Differences and Regression Strategies

Some of the problems encountered in comparing prices in two situations are set out in a series of pictorial cases below. The examples are very simple, involving only one quality variable, and omit the complexities arising from the use of several variables, such as those from intercorrelations among quality characteristics and interactions between them. However, these illustrations introduce and catalog some of the problems referred to later.[11]

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[11] For an exploration of these problems in a different context see James N. Morgan and John A. Sonquist, "Problems in the Analysis of Survey Data and a Proposal," *Journal of the American Statistical Association,* June 1963.

In the simplest price measurement case, the price of the product is uniformly higher or lower in situation II than in situation I, over the whole range of the quality characteristic (Figure 5.1). The slope of line II, in other words, is equal to that of line I.

If there are observations at the same level of the characteristic, say horsepower (*HP*), in both situations, the price difference can be measured in the traditional way by comparing identical engines in the two places or two years.

If the same range of engines is produced in both situations, but no pair is identical in horsepower, the conventional method, relying on identical specifications, is useless, because there are no comparable items produced in both situations. Producers of index numbers probably meet this difficulty (if they do not drop the commodity from their indexes) by interpolating between two observations in situation I, for example, to estimate a price for the item produced in situation II. The method is a very crude version of the regression technique, involving fitting equations to individual pairs of points rather than to the whole set. It could give erratic results if the points were scattered around the line instead of being on one line as in Figure 5.1.

In the more typical case, particularly if the years are some distance apart or the places very different, the bulk of the observations of the characteristic fall in different ranges in the two situations. Although the *HP* observations of the two situations usually overlap, let us consider for the moment the extreme case shown on Figure 5.2 in which

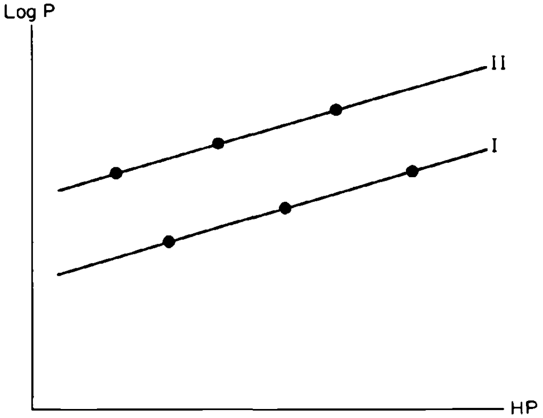

Figure 5.1

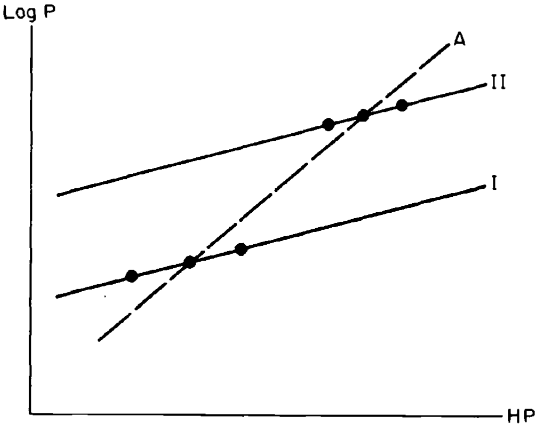

Figure 5.2

they do not. Here again, no index could be calculated by conventional methods, because there are no identical products to compare.

If a regression equation were fitted to each set of observations the regression line for II would be above that for I, and we would calculate that prices were higher in II. The same result would follow from fitting a line to pooled data for I and II, with a dummy variable for II.

If we fitted a single equation to pooled data (A) and measured the price level in each situation by comparing actual prices with the equation, we would calculate that there was much less price difference. In the extreme case, when the line passed through the means of the two groups, we would make a finding of no price difference ($P_{\text{II}}/P_{\text{I}} = 1.00$).

All the examples up to this point have had one characteristic in common: In the two situations being compared the slope was the same. There is no index number problem, since all prices have changed, or differ, by the same amount. Thus if there are any overlapping observations, both conventional methods and regression analysis can easily cope with the measurement problem.

If the slopes differ in the two situations, an index number must be calculated by selecting particular points within the range of the characteristic and measuring the price relationship for those points. The simplest case to picture is that of Figure 5.3, where the range of observations is the same for both countries but the slopes differ.

In this case, if the data were pooled and a single regression line were

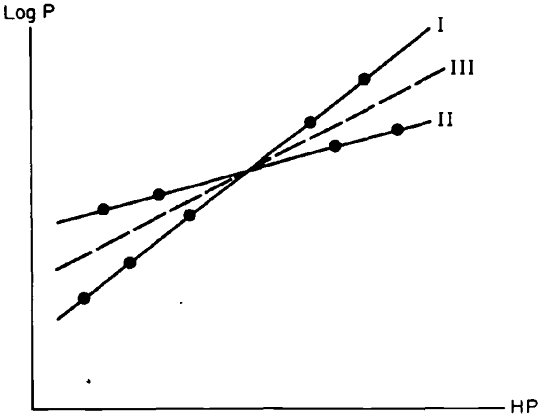

Figure 5.3

fitted, its graph would look like curve III. The conclusion would be that situation I and situation II do not differ in price if an index were calculated from the coefficient of a dummy variable representing one of the countries, since neither country is consistently above or below line III. The same inference would be drawn, provided each observation were given equal weight, if the equation were fitted without dummy variables and the index measured from each country's residuals, or if the price difference were estimated from separate equations for I and II. However, the result from an index calculated by weighting each price comparison by the importance of the engine to which it referred would depend upon the product mix.[12] If smaller engines were more important, situation I would be considered lower in price; if larger ones predominated, situation II would be lower. For measuring export price competitiveness, for example, the weights would be determined by the relative importance in international trade of engines of different horsepower.

The same results as from separate equations for I and II could be obtained from a single equation pooling the data for the two situations but adding variables to differentiate for the level (i.e., intercept) and slope of situation II as compared to the level and slope of I.[13]

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[12] Assuming that the regression were not also weighted.

[13] This method is discussed further below. Other examples of this technique are given in S. Ben-David and W. G. Tomek, "Allowing for Slope and Intercept Changes in Regression Analysis," Department of Agricultural Economics, Cornell University, A. E. Res. 179, November 1965, mimeo.

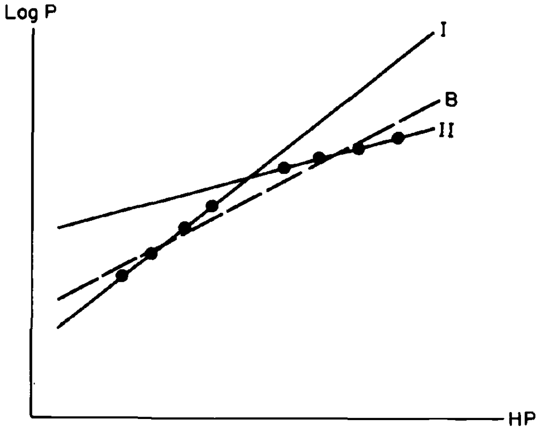

Figure 5.4

Figures 5.4 and 5.5 represent more difficult cases, in which the fitting of the equation or equations involves additional assumptions about the nature of underlying, but incompletely observed, relationships.

One assumption, represented by Figure 5.4, is that there are two price-horsepower relationships for the two situations, as I and II in Figure 5.3, but that all the engines for which prices are known for situation I are below the mean *HP* and all those for situation II are above. Such a case might evolve from Figure 5.3 if each country specialized in that *HP* range in which it was superior, and drove the other from the market in that range.[14] The outcome of the calculation here would again depend on the weighting of the different *HP* sizes. In a weighting based on that of one of the two situations (one country's exports or production, for example) that situation would be found to have the lower prices.

If a single equation (*B*) were fitted to the data of the case represented by Figure 5.4, with price indexes calculated from residuals or from country dummy variables, but with no country-slope interaction terms, the conclusion would be biased toward finding that there was no price difference between situations I and II. This would be true even if the price comparisons used only the horsepowers observed in one of the two situations, because the regression line would tend to pass near the means of the observations of each of the situations. However, the intro-

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[14] Note that the collection of offer prices, in addition to transactions prices, might fill out the other end of the range for each country.

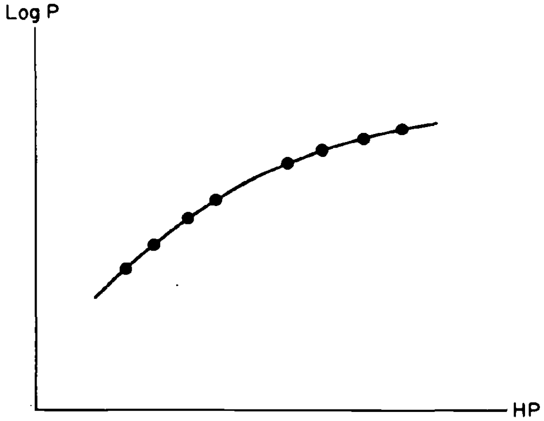

Figure 5.5

duction of an intercept and a slope interaction term would restore the conclusions derived from I and II.

As long as we restrict our consideration to linear functions, the estimation of separate equations or the use of country and slope interaction terms seems clearly superior to the fitting of a single function. Once we lift this restriction, we must consider the possibility that the two situations lie on the same price-horsepower function. If such were the case, as in Figure 5.5, we would have to conclude that the prices of I and II are the same, whether we compared prices on I's products, II's products, or a combination of both of them. However, when there is no overlapping, the data do not show us whether one function (as in Figure 5.5) or two functions (as in Figure 5.4) should be fitted. In these circumstances, we would need other information about the nature of the shape of these functions. Fortunately, we have not had to face such extreme cases in which there were no overlapping observations.

We are thus left with the alternatives of estimating separate equations or, what will yield the same price comparisons, using pooled regressions with situation (intercept) and slope dummies. A compromise between these two alternatives, which retains advantages of each, is "flexible pooling." In this technique we begin by estimating an equation in which there is a dummy variable for each situation[15] and a situation-interaction

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[15] Actually, a dummy variable is used for each situation except the base. See D. B. Suits, "Use of Dummy Variables in Regression Equations," *Journal of the American Statistical Association*, December 1957, pp. 548–551.

term for each combination of situation and characteristic. If situation I is taken as the base, the situation dummy variable distinguishes the intercept of situation II from that of situation I; the interaction term distinguishes the slope in situation II from the slope in the base situation. By dropping the dummy and interaction terms that do not prove to be significant and retaining those that do, we use the whole size and range of the combined sample for the two situations to estimate the coefficients which seem to be common to them while permitting the estimation of separate coefficients for the two situations where these appear to be warranted.

In order to simplify the foregoing outline of alternative regression strategies, we posed the pricing problem in terms of a single independent variable. In fact, of course, it is necessary to take into account more than one product element in explaining the price differences between two situations. Indeed, for a complex product such as an automobile or even a diesel engine, product differentiation between models, brands, times, and places turns upon a very large number of elements. However, most of these tend to be highly intercorrelated, so that it is frequently possible to account for 90 per cent or more of the price variation by including as few as three or four elements as independent variables.

It should be mentioned that both our purpose and the price data we employ differ in several ways from the simple examples described above and from those of other experiments with regression techniques. One difference is that the data relate to several different markets connected, to some degree, by international trade. They can, therefore, contain price differences for whole commodities and for particular quality characteristics which we would not expect to find within a single market. Another point is that the list of specifications could not be enlarged to take account of the regression results. Ideally, such an analysis should provide opportunities to test more thoroughly the effects on price measurements of alternative combinations of independent variables. We could also have examined more closely the cases in which such results as negative coefficients for features apparently useful and costly to produce suggested that the variables were acting as proxies for others not covered. However, since the data were originally collected for conventional price comparisons we were obliged to do as well as we could with the variables that seemed important in advance.

It should be emphasized that our main purpose has not been to analyze the economic factors underlying price changes or to account for differences in price levels. For that reason we had no real interest in the element coefficients themselves. The price indexes, and therefore the country dummy variables from which they were derived, were the object of the experiment. The other coefficients were important only as they affected the price estimates.[16] Our major question in using regression methods was whether the price indexes which they produce would be sensitive to choices among equally justifiable alternative equation forms and explanatory variables. Indexes computed by more traditional methods are not immune to similar problems, but the ranges of indeterminacy involved in the two approaches have not been compared.

Automotive Diesel Engine Price Regressions

Data on 1962 price, horsepower, revolutions per minute, engine displacement, and weight were obtained for seventy-three automotive diesel engines produced in four countries (see Table 5.1). What we refer to as the "average" engine has the mean specifications (unweighted) of the seventy-three engines. The specifications of the "export" engine were derived by weighting each country average by the relative importance of that country in automotive diesel engine exports.

The American firm that was the main source of information had gathered the data in a market survey, presumably including the variables considered important. We had no opportunity to enlarge the list of specifications, even though a longer list would have been desirable for our purposes.

Specification of the Relationship

The main utility sought by the purchaser of a diesel engine is power. The concomitant considerations include durability, frequency and ease of repair, fuel economy, and smoothness of operation. These qualities

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[16] Since we are not interested in the coefficients themselves it has been suggested that factor analysis or principal components analysis would have been appropriate techniques for dealing with the problem of multicollinearity. The drawback of these methods is that the independent variables lose their identity. It is then impossible to impose any criteria for the reasonableness of the relationships. For an application of principal components analysis see Phoebus J. Dhrymes, "On the Measurement of Price and Quality Change in Some Consumer Capital Goods," *Discussion Paper No. 67,* Department of Economics, University of Pennsylvania, September 1967.

Table 5.1
Summary of Data for Automotive Diesel Engines, 1962

	U.S.	U.K.	Germany	France[a]	Total or Average	"Export" Engines[b]
No. of producers	4	6	5	1	16	
No. of engines	22	22	23	6	73	
Averages:						
Price (dollars)	3,470	1,593	2,023	2,394	2,360	2,250
Horsepower	190	147	163	184	168	164
RPM	2,182	2,191	2,367	2,050	2,232	2,217
Displacement (cu. in.)	517	539	488	590	520	524
Weight (lbs.)	2,117	1,531	1,509	2,123	1,749	1,715

Note: The U.K., German, and French data were supplied by an American firm; the U.S. data came from that firm and three others. Prices are mainly those charged to distributors in the country of manufacture but include also some on sales directly to truck manufacturers.

[a] In addition, information was available on price, horsepower, and revolutions per minute but not on weight and displacement for five engines of two other French producers. The averages for all eleven French engines were: price, $2,147; horsepower, 166; and rpm, 2,273. Only the six engines for which complete information was available were included in the pooled regressions; all eleven were included in the separate regressions for France.

[b] The "export" engine is the average of country-type engines weighted by the estimated share of each country in automotive diesel exports. The weights used were: United Kingdom, 50 per cent; United States, 30 per cent; Germany, 18 per cent; and France, 2 per cent.

may also be viewed as being related to components of the total cost per unit of freight delivered (for a truck) such as driver time, repair and fuel costs, and costs of delayed delivery.

The variables at our disposal—horsepower (H), displacement (D), revolutions per minute (R), and weight (W)—are summary variables in the sense that they are determined by other elements such as the number and size of cylinders, inlet pressure and temperature, fuel-air ratio, and spark advance. Neither our summary variables nor the more detailed specifications behind them directly measure the various facets of delivery costs which may be important to the buyer. Indeed, only H is a direct measure of a major utility to the diesel engine consumer. The other variables are proxies for performance characteristics we are unable to measure.

Three of the variables—H, D, and R—are parts of an engineering relationship that may be expressed as follows:

$$H = \frac{M \times D \times R}{k}$$

where M is mean effective pressure (the amount of pressure that operates on each cylinder) and k is a constant.[17] While M was not specifically included in our data, it is obvious that we can easily calculate it, since we know the values of the other variables in the relationship.

The relationship indicates that a given horsepower can be achieved by means of different combinations of M, D, and R. Each has its advantages and disadvantages. For example, as between two engine designs with the same H, the one with the higher R will be smaller and may cost less because it uses less materials. On the other hand, it may vibrate more, thus requiring more servicing, and may have poorer combustion, thus consuming more fuel.

The relation of weight to the other variables is more difficult to specify. On the one hand an engine that is too light may not be durable; indeed, one industry source suggested that in a cross section of engines at any one time weight could be taken as a rough guide to the reliability and durability of an engine. On the other hand, weight per se is a disadvantage, and costly effort such as more careful casting may be undertaken to keep down weight.[18] Furthermore, since W is highly correlated with D and (inversely) with R, it may be expected to add little to the explanation of price variation. In fact $\bar{R}^2$ was substantially reduced when weight was eliminated, and there were some large differences in the price relatives. Since weight may contribute to the durability of an engine, and is statistically significant in the explanation of price variation, equations that include it are clearly preferable.

To explain the variation in diesel engine prices, W and any three among M, H, D, and R can be taken, because any three of them

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[17] The constant is 792,000 for a four-stroke-cycle engine and 396,000 for a two-stroke-cycle engine. See A. R. Rogowski, *Elements of Internal-Combustion Engines*, New York, 1953, p. 53; and B. H. Jennings and E. F. Obert, *Internal Combustion Engines*, Scranton, Pa., 1944, p. 40. All of the engines in our sample are, to the best of our knowledge, four-stroke-cycle engines.

[18] The relationship of weight to utility may be positive across models at a given time but negative over time.

determine the fourth. We chose to eliminate H, partly because it is more highly correlated than M with the other variables and partly because the coefficients of the other variables make more sense when M is used. H is the one variable we are certain represents a utility to the purchaser of diesel engines. Leaving it out of the function permits us to measure the value of additions to the other elements when they result in additions to horsepower. Including H produces coefficients of the other variables whose meaning is ambiguous because an addition to any other variable, holding H constant, involves a subtraction from whichever variable is omitted (M, D, or R). For example, if H is used, the coefficient for D represents the price of an addition to displacement that does not add to horsepower, and therefore involves a reduction in M. It is difficult to say what sign such a coefficient should logically have. On the other hand, if M is used, the coefficient for D represents the price of an addition to displacement which does add to horsepower, clearly implying a positive sign.

The relation between an equation in M, D, and R and one in H, D, and R can be expressed as follows:

$$P = aH^bD^cR^d$$

implies, given $H = MDR/k$, that

$$P = \frac{a}{k^b} M^bD^{b+c}R^{b+d}$$

The coefficients in this formula represent the price of additions to horsepower through additions to each of the other variables. Since weight is not included in the function, the addition to displacement and horsepower will probably involve an increase in weight, too, and thus represent essentially the value of a larger engine minus the drawbacks attendant on increased size. However, if weight is included in the function the D coefficient represents the price of increased horsepower through greater size without any weight penalty, presumably through the use of lighter materials or other engineering changes. We would expect this D coefficient to be larger than the one which allows for increased weight, since higher power is more desirable if it does not bring greater weight.

Alternative formulations might involve including both H and M but excluding D or R. If R were excluded, the H coefficient would represent the price of increased horsepower achieved by raising R, the M coefficient would represent the price of substituting M for R at a given horsepower, and the D coefficient would measure the price of substituting D for R.

The results presented below are based on regressions in which W, M, D, and R are the main independent variables,[19] but these, it should be remembered, only imperfectly and incompletely represent the desired performance characteristics of a diesel engine. Because we do not know how the missing factors are related to the proxies used, we can only speculate as to whether the coefficients are logical. We must depend on the assumption that their relation to the true utility elements does not differ substantially among the countries or on the assumption that if it does, the differences do not affect the price comparisons.

Mathematical Form

Linear, semilog, inverse semilog, and double log regressions were fitted to the data in all the alternative combinations of variables and regression methods we tried. However, the double log regressions were preferred for several reasons. The arithmetic and semilog forms were rejected because the factors that underlie the international differences in price—whether profit margins, labor or material costs, better technology, or more skillful management in one country as compared with another—are more likely to result in a fixed percentage difference between prices for all variants of an engine—large and small, weak and powerful, etc.—than in a fixed absolute dollar difference.[20]

The inverse semilog and double log forms estimate percentage rather than absolute price differences between countries, and it is percentage differences that we wish to express by index numbers. Each of the other forms yields a single absolute difference in price between each pair of countries for all engines, small or large, cheap or expensive.

The choice between the inverse semilog and double log forms was not as clear. The double log form was preferred because it incorporated the character of the technical relationships among the independent vari-

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[19] The statistical results of using other combinations of independent variables, including $(D \times R)$ as a composite variable, were generally inferior to those of the *MDRW* equation.

[20] A related factor is that the equations in which arithmetic price is the dependent variable are fitted by minimizing squares of absolute deviations from actual prices while the inverse semilog and double log forms are fitted in terms of percentage deviations. The latter seems more desirable because a larger absolute error is acceptable in estimating the price of a $5,000 engine than in estimating the price of a $1,000 engine.

ables described in the previous section—a multiplicative rather than an additive relationship.

Types of Regression

Three types of regression analysis were tried, each in several variants differing in the choice of variables and mathematical form. One type involved pooling all data under the assumption of equal element prices in all countries (additive dummy variables). The equation was

$$P = \Phi(M, D, W, R, k, g, f)$$

where P = price of engine
M = mean effective pressure
D = displacement
W = weight
R = number of revolutions per minute (rpm)
k = dummy variable for U.K. engine
g = dummy variable for German engine
f = dummy variable for French engine

A second approach was to fit a separate regression for each country:

$$P_u = \Phi_u(M, D, W, R)$$

$$P_k = \Phi_k(M, D, W, R)$$

$$P_g = \Phi_g(M, D, W, R)$$

$$P_f = \Phi_f(M, D, W, R)$$

where P_u is the U.S. price; P_k, the U.K. price; P_g, the German price; and P_f, the French price.

A third technique was to pool all data but to allow for international differences in the prices of quality elements (additive and multiplicative dummy variables):

$$P = \Phi'(M, D, W, R, k, g, f, kM, kD, kW, kR, gM, gD, gW, gR, fM, fD, fW, fR)$$

We chose this last method of "flexible pooling" as the most appropriate: Where there were no significant differences in element prices among countries, the size of the sample and its range were enlarged. On the other hand, it did allow for differences in element prices where they appeared to be statistically significant.

In pooling without allowances for differences in element prices, the assumption is that the relative prices of the different elements making up the product mix are the same in the different situations involved in the price comparison. This may be a questionable assumption even when the situations involve two different points in time referring to the same country; it seems quite unlikely when prices are being compared for two or more different countries. There are obvious and important differences in relative factor prices from one country to another, and these may affect the prices of the elements in our equations for diesel engines. U.S. labor costs are high relative to those of Europe, but the prices of alloys or certain castings requiring advanced technology are low. Since we did not know what factor mix was required to produce the various elements that made up the product mix and we could not assume that it was identical in each country from element to element, we chose a regression method which did not impose the requirement that all price differences be summarized by a single intercept dummy.

We present, first, the results from our application of flexible pooling, since we used them in the larger price study. These are then compared with the outcomes of the other two methods.

Pooling with International Differences in Element Prices

The pooled regression, in this approach, includes as independent variables not only the several engine characteristics and the dummy variable for each foreign country, but also a dummy for each foreign country for the slope of each continuous variable. In the case of the weight variable, for example, this is accomplished by retaining a basic weight variable and adding a weight slope variable for each foreign country that reflects the country-weight interaction. If the relationship between price and weight in a foreign country is the same as in the United States, the weight *slope* coefficient will be zero or at least insignificantly different from zero. If intercept and slope dummies were included for all variables the results would be the same as those obtained by fitting a separate regression for each country, using the same mathematical form and the same independent variables.

These regressions are based on sixty-seven observations for the United States, the United Kingdom, and Germany, and contain fourteen independent variables.[21] In view of our earlier discussion, we confine ourselves to the inverse semilog and double log forms.

The following rules were adopted to govern the retention and elimination of dummy variables from the equation finally used to compare prices:

1. The slope dummy coefficient for a country was not retained unless the coefficients for both that country and the base country conformed to a priori economic and technical considerations. For example, the slope dummy for U.K. mean effective pressure taken in conjunction with the base coefficient implied a negative relationship between price and pressure in the United Kingdom and was therefore rejected.

2. No intercept or slope dummy was retained unless it was at least as large as its standard error. This choice of a 1-standard-error test in preference to the frequently used 2-standard-error test raises the issue of priority among the independent variables. We preferred to assign priority to quality characteristics in partitioning the observed variation in international prices into quality differences on the one hand and country-to-country differences in prices (for given qualities) on the other. This might imply that the variables which measure price differences (the country and slope dummies) should be retained only when highly significant—i.e., when they met the 2-*S.E.* test. However, this policy would rule out an observed difference in international prices unless the odds were overwhelming (20 to 1) that the difference would not be produced by chance. At the other extreme, by retaining all slope coefficients, however insignificant, we would forego the advantages of pooling.[22]

3. Even if significant in these terms, a slope dummy variable was not retained if its addition to the equation caused the corresponding element variable to lose its statistical significance.[23] The retention of

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[21] If we included all four countries in such a regression there would be nineteen independent variables, four basic ones for the engine characteristic, and one intercept and four slope dummies for each of the three foreign countries. Since we have only six complete observations for France, there is little point in including France in a regression in which it would require five additional independent variables.

[22] The criterion of one standard error, if carried through consistently, would produce the highest level of $\bar{R}^2$. See Yoel Haitovsky, "A Note on the Maximization of $\bar{R}^2$," *American Statistician*, February 1969.

[23] If the t-ratio for the basic variable was 2 or more prior to the addition of the slope dummy, the dummy was not retained if with its presence the t-ratio of the basic variable was less than 2. If the original t-ratio was between 1 and 2, the dummy was retained if its addition was not accompanied by a reduction in the t-ratio to a level below 1.

the dummy variable under these circumstances would have had the effect of depriving the base situation of the advantages of pooling in cases in which the unpooled coefficient for that variable was not significant in the base situation.

4. When more than one equation (each with a different set of dummy variables) satisfied these three conditions, the one with the highest $\bar{R}^2$ was chosen.

5. If, for a given foreign country, no combination of dummy variables met the above conditions, all the slope dummy variables were dropped. Rather than read the result as representing no price difference, the coefficients of the intercept dummies were taken as the best measure of the price difference.

The "best" double log equation selected by these criteria has an intercept dummy for the United Kingdom and has German slope dummies for displacement and weight; it yields U.K.-U.S. and German-U.S. price relatives of 70 and 85, respectively. In Table 5.2, these results are compared with those based on alternative criteria for the retention of dummy variables. The U.K.-U.S. relatives range from 68 to 70 and the German-U.S. relatives, from 83 to 85 in those equations which do not contain negative coefficients for pressure.

Table 5.2
Automotive Diesel Engine Price Comparisons Based on Alternative Criteria for Pooling: Double Log Equations

Criteria Met[a]	Dummy Variables[b]	$\bar{R}^2$	U.K./U.S.[c]	Ger./U.S.[c]
All, using 1 S.E.	k, g_d, g_w	.911	70	85
All (1 S.E.) excl. No. 3[d]	k, k_d, g_w	.914	69	83
All, using 2 S.E.	k, g	.909	68	85
All (2 S.E.) excl. No. 3	k, k_d, g	.913	69	84

S.E. = standard error.

[a] See accompanying text for list.

[b] The letters *k* and *g* without subscripts refer to country (intercept) dummies for the United Kingdom and Germany, respectively. With the subscripts *d* and *w* they refer to slope dummies for displacement and weight, respectively.

[c] Dropping criterion 1 produced price level indexes of 61 and 62 for the United Kingdom and 81–84 for Germany.

[d] See text.

The "best" inverse semilog equation yields U.K.-U.S. and German-U.S. price comparisons of 81 and 93, respectively.[24] There is thus a notable difference between the results from the two forms. Statistical criteria such as the $\bar{R}^2$'s and tests for heteroscedasticity [25] do not point to a decisive advantage of one form over the other, but we opt for the double log form on the grounds mentioned earlier.

There is one other complication in taking double log results of the flexible pooling approach. An equation yields different price indexes for each engine specification whenever one or more slope dummies is retained. One way of dealing with such situations is by pricing the "export" engine, for each of the four countries.[26] Averages obtained in this manner for displacement and weight enter, for example, into the computation of the estimate of 85 for the German-U.S. price relative selected as the preferred result of flexible pooling.

An alternative approach to averaging is to make a series of binary price comparisons, one for each country's average engine, and then to average the estimates with the use of export weights. Thus we set out below the German-U.S. price comparisons based on the average specifications of each country (rows 1–4) and export-weighted averages of the relatives in row 7.[27]

Engines with Specifications of	*German-U.S. Relative*
1. United States	81
2. United Kingdom	87
3. Germany	85
4. France	82
5. Average	84
6. Export	85
7. Weighted average of relatives	85

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[24] Unlike the case of the double log form in which only one set of dummy variables met all of the first three conditions given in the text, seven different sets of dummy variables satisfied these conditions in the inverse semilog form. They produced U.K.-U.S. price relatives ranging from 76 to 84 and German-U.S. relatives ranging from 90 to 94.

[25] Each form meets the test performed.

[26] The average specifications for each country are shown in Table 5.1. These averages refer only to the engines in our sample, and we do not know precisely what the true averages are for each country's exports.

[27] The preferred equation contained no slope dummies and only a country dummy for the United Kingdom. The U.K.-U.S. relative thus is 70 for all specifications of engines. See Table 5.1 for specifications for rows 1–6. Row 7 is an average of rows 1–4 weighted by the relative importance of each country in exports.

The rationale for the export-weighted average of relatives is that the average engine of each country is regarded as representing a particular product variant whose importance in international trade is proportionate to the country's share in diesel exports. However, the alternative methods of averaging (rows 5–7) do not, in this and in other cases we have examined, produce very different answers.

A troublesome feature of these data is that in some instances the U.S.-type engine seems to be relatively cheaper in Germany than any of the European-type engines. Either the German producers are foregoing a significant market opportunity, or, what is more probable, if they actually began to make engines with U.S. specifications in larger volume, the coefficients of the German regression would shift so as to make the U.S.-type engine relatively more expensive, compared to U.S. prices, than the average-type engines now being produced in Germany. Actually our estimates of German prices of U.S.-type engines are based on relatively few observations and are probably misleading. Under these circumstances the smaller price differences suggested by the comparisons based on German-type engines might be a better approximation to the true relationship. Another possibility is that we have overlooked some quality elements which make U.S. engines more desirable at the larger end of the scale. In any case, the low German-U.S. ratio for U.S.-type engines shows there is a defect in our analysis. Fortunately, the lighter and lower horsepower German- and U.K.-type engines take up most of the weight, and the export-weighted averages would not be very different if the U.S.-type engine were excluded.

Other Types of Regression

In order to test the extent to which our choice of flexible pooling as a method determined our relative price estimates we ran regressions based on the two other methods described earlier.

Pooling the data without allowance for differences in element prices produced equations which fitted the data well in inverse semilog and double log forms (Table 5.3) and considerably less well in arithmetic and semilog forms. The price comparisons calculated from equations in the two preferred forms were (U.S. = 100):

Form of Equation	*France*	*Germany*	*U.K.*
Inverse semilog (log-arithmetic)	79	93	77
Double log (log-log)	72	85	68

Table 5.3
Regression Coefficients for Automotive Diesel Engine Prices:
Pooled Equations with No Allowance for Country
Differences in Element Coefficients
(figures in parentheses are standard errors)

	Inverse Semilog[a]	Double Log[a]
Pressure (M)	.4418	.9110
	(.0773)	(.1444)
Displacement (D)	.00059	.5045
	(.00021)	(.1260)
Weight (W)	.00038	.4856
	(.00006)	(.1297)
Revolutions per minute (R)	-.00021	-.2831
	(.00010)	(.2111)
France	-.2414	-.3243
	(.0805)	(.0794)
Germany	-.0681	-.1676
	(.0578)	(.0567)
United Kingdom	-.2663	-.3802
	(.0620)	(.0611)
Constant	6.5312	2.9133
	(0.3348)	(1.9512)
Standard error as per cent of mean	3.18	3.16
$\bar{R}^2$	.910	.912
$\bar{R}^2$ (transformed data[b])	.919	.911

Note: Price in dollars, displacement in cubic inches, rpm in units, weight in pounds. Mean effective pressure obtained by dividing horsepower by product of displacement and rpm and multiplying by 10,000. The logs are natural.

[a] In the inverse semilog equation the dependent variable (price) is logarithmic and the independent variables are arithmetic; in the double log equation all variables are logarithmic.

[b] Correlation between antilogs of actual and predicted prices.

At the opposite extreme from this pooling are separate country regressions, which use no information from one country in the estimate for another of the relation of price to quality characteristics.

The difficulty of basing each comparison on a set of identical elements is that elements which explain a very high percentage of price variation in one country may explain only a low percentage in another. If we use, for each country, all the variables that are significant for any country, the $\bar{R}^2$ for a particular country, corrected for degrees of freedom, may be less than with a smaller number of variables. A frequent concomitant of this defect will be the presence of regression coefficients which seem unlikely on economic grounds. The use of such a coefficient would imply that an element which has a positive value in one country has a negative value in another.

This difficulty is illustrated by the equations for each country using M, D, R, and W in Table 5.4, where the separate regressions produce some striking differences in the coefficients.[28] In particular, the U.K. coefficient for pressure is negative and not significantly different from zero while those of the other two countries are positive and significant (at the .05 level) in both the inverse semilog and double log equations. The most likely explanation for the negative U.K. coefficient is the extent of multicollinearity among the four engine characteristic variables.

A major difference between the United Kingdom and the other two countries is in the narrower range of observation of mean effective pressure[29] and, to a smaller degree, of displacement. Because the U.K. coefficients of M and D are calculated over relatively narrow ranges, we can place less confidence in their values than in those for other countries. Similar problems arise when other combinations of independent variables are employed in U.K. regressions.[30]

Conclusions

The preferred results from double log equations produced by each method can be summarized as follows (U.S. = 100):

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[28] We drop further reference to French prices in this section since we decided against computing separate regressions for the six engines for which complete information was available. It would greatly add to the number of alternative results (all of them inferior) that we would have to present for the other countries if we based comparisons on equations including only H and R, the two variables for which there are eleven French observations.

[29] The ranges for the United Kingdom, the United States, and Germany for $(H/DR) \times 10{,}000$ were 1.14–1.48, 1.20–2.48, and 1.07–2.64, respectively.

[30] One way to deal with these country differences would be to base the comparisons on *unlike* equations; that is, to fit a different equation for each country, using those variables and that mathematical form which produced the closest explanation of price. Prices for engines of given specifications could then be estimated from each country's "best" equation and compared.

The derivation of indexes from unlike equations is based on the assumption that we are warranted in comparing the prices of diesels in terms of a different set of elements in each country. It involves the questionable assumption that a variable not significant over the range of variation present in the sample for country A would not be significant—that is, would have a zero price—over the wider range found in country B, if country A produced that wider range of products.

Table 5.4
Regression Coefficients for Automotive Diesel Engine Prices: Pooled and Individual Country Regressions
(figures in parentheses are standard errors)

	Mean Effective Pressure	Displacement	RPM	Weight	Constant
Inverse semilog (log-arith)					
Pooled	.4418	.00059	-.00021	.00038	6.5312
	(.0773)	(.00021)	(.00010)	(.00006)	(0.3348)
U.S.	.5282	.00076	.00047	.00046	4.6334
	(.1066)	(.00027)	(.00031)	(.00008)	(0.8105)
U.K.	-.2795	.00165	-.00046	-.00007	7.8716
	(.3664)	(.00075)	(.00013)	(.00027)	(0.7290)
Germany	.6469	.00165	-.00016	-.00006	6.1799
	(.1808)	(.00063)	(.00020)	(.00022)	(0.7605)
Double log (log-log)					
Pooled	.9110	.5045	-.2832	.4856	2.9134
	(.1445)	(.1260)	(.2111)	(.1297)	(1.9512)
U.S.	.9973	.4649	.2033	.5652	-1.2311
	(.2598)	(.1780)	(.7250)	(.2149)	(6.2515)
U.K.	-.2622	.7988	-.6544	.2635	5.4689
	(.4706)	(.4294)	(.2954)	(.4644)	(3.2322)
Germany	1.4020	1.1116	.1523	-.1172	-0.1592
	(0.3338)	(0.3287)	(.5605)	(.3024)	(5.3910)

Note: Prices in dollars, displacement in cubic inches, rpm (revolutions per minute) in units, weight in pounds. Mean effective pressure obtained by dividing horsepower by product of displacement and rpm, and multiplying by 10,000.

	U.K.	*Germany*
Flexible pooling (4 types)	68–70	83–85
Pooled regressions	68	85
Separate country regressions		
MDRW		81
HDRW		81

Depending upon the choice of independent variables, the specifications to be priced, and the extent of pooling—but leaving aside regressions rejected for poor fit, unreasonable coefficients (such as some zero or negative coefficients), or heteroscedasticity in the residuals—the U.K.-U.S. price relatives ranged from 68 to 70 and the German-U.S. relatives from 81 to 85. We do not list the U.K.-U.S. coefficients for separate country regressions because they contained negative coefficients for variables which had significant positive coefficients in equations of other countries.

Use of the inverse semilog form yielded a range of 77–81 for the United Kingdom and 87–93 for Germany, the range being wider and the level higher than the results from the preferred double log equations.

The application of regression analysis to diesel engine prices in this chapter was necessarily along simple lines in keeping with the resources of our study and its need to cover a very broad range of products. An obvious extension would be to take account of more engine characteristics, some of which might be continuous variables and others, such as power transmission, on an included-or-not basis (i.e., represented by dummy variables).

A more difficult extension of the work would be to aim at variables which reflect utilities to the consumer. The proxies we have been obliged to use represent these performance characteristics very imperfectly. We are therefore unable in many instances to judge whether the coefficients obtained are logical from an economic standpoint. Indeed, we cannot be certain that we have not omitted some key characteristic that accounts for a significant part of the observed difference in price in the two situations. Thus, it has been suggested to us that in the case of diesel engines the "quality" of the U.S. diesels is higher than that of European makes so that the real difference in price is smaller than our estimates indicate. We cannot rule this possibility out, even though the industry itself competes in world markets with specifications set out mainly in terms of the elements we have used.

Other Applications of Regression Methods

The regression analysis of automotive diesel engine prices is only one of several used in the study. Regression methods for a number of commodity groups in which conventional measures based on common specifications would have been impossible to calculate provided both place-to-place and time-to-time comparisons. These applications are described in the product chapters, but for the convenience of the reader they are summarized here.

In the case of aircraft engines, for example (Appendix to Chapter 12), it was not possible to find American and British engines of identical characteristics, from which conventional price comparisons could be made, although the two countries produced engines in the same weight and power range. Regression equations were fitted to data on twenty engines, relating their prices to take-off thrust, weight, and country of origin. The resulting price comparisons varied within a range of four percentage points, and $\bar{R}^2$ ranged from .85 to .95. The regressions we ran were a simpler version of one performed by a leading aerospace company, on essentially the same data, for predicting the price of new engines.

Another set of place-to-place comparisons was performed by multiple regression for outboard motors (Appendix to Chapter 12). About 100 observations from six countries were available for each of two years, all gathered in a market survey by a large producer. The equations related price to horsepower, country of origin, market of sale, and the presence of an electric starter. The equations produced high levels of $\bar{R}^2$, and the price level indexes were similar (mostly within five percentage points) as between arithmetic and logarithmic forms.

A U.S. price index for tractors, 1953–64, was constructed from data for sixty-one tractor prices, obtained from six U.S. manufacturers. Information for all years was pooled, and the price index was estimated from year dummy variables. Price was related to horsepower, weight, and a dummy variable for type of tractor, as well as the year of sale. The $\bar{R}^2$ were extremely high for both arithmetic and logarithmic equations but lower for mixed equations. The logarithmic equations, however, showed a more rapid price increase in both types of tractors, by nine to twelve percentage points over the eleven years. Almost all the difference was accounted for by the first period, when the sample was extremely thin; the 1957–64 period showed differences of only three percentage points.

In the case of power transformers (Appendix to Chapter 13), there were virtually no time series data on prices. Our prices were from reports by buyers, who would rarely purchase the same product twice, and from bidding documents, which were usually for unique products. We chose to calculate price changes over time by fitting regressions to the lowest prices bid by U.S. companies on approximately 150 power transformers. We used only capacity as a quality variable, and included as dummy variables the year in which the bidding took place and the location of the project (United States or foreign). Slope dummy variables allowed for differences among the years in the slope of the price-capacity relationship. All the logarithmic equations produced high levels of $\bar{R}^2$ but there were some substantial differences in price movement, particularly in 1963–64 when the significant dummy variable for foreign projects was dropped. The price change was taken directly from the equations except for 1963–64, where the change in slope meant that the price movements differed by size of transformer.

The regression, crude as it was, produced price indexes quite similar to others for U.S. domestic prices which were derived by much more elaborate regressions and by other methods involving the use of a greater number of variables. The price change was calculated for several different sizes, and these were then weighted by the importance of each, as estimated from the bidding data.

For railway locomotives a regression-based index was calculated for the U.S. time-to-time index but was used only as a check on the conventionally calculated one (Appendix to Chapter 14). The number of categories available for equation fitting was small, and there were some erratic changes in the coefficients. The method used in this case was to fit a separate regression for each year and to price the 1963 set of locomotives produced in the United States in each year's equation, to produce what was essentially a Laspeyres price index with 1963 weights for locomotive types.

A Japanese ship price index was computed from data for 205 contracts for ships built in Japanese yards. The logarithmic equation finally selected included continuous variables for the tonnage and horsepower of ships, and dummy variables for type of ship (bulk carrier, cargo vessel, or tanker) and for the year of purchase, using pooled data for all years. The indexes computed from this logarithmic equation were similar to those from a semilogarithmic equation and from an arithmetic equation using 1963 ship specifications. The logarithmic equation also produced the best fit, and the price indexes calculated from it were not sensitive to the addition of other marginal variables to the equation.

Regression-based index numbers were used in place-to-place comparisons for truck prices in the United States and the United Kingdom (Chapter 14). Separate regressions were computed for diesel and gasoline-powered trucks. Gross vehicle weight, wheelbase, and displacement were used as continuous variables in both cases with the addition of dummy variables for cowl and forward control.

Both time-to-time and place-to-place indexes for automobiles were derived by regression techniques (Chapter 15). Only in this group was such extensive use made of this method and virtually none of conventional price indexes. The basic data consisted of over 1,000 domestic list price observations for the U.S. and 700 for five foreign countries, covering all six years of the study. The listed makes of car included in the comparisons accounted for 95 per cent or more of national output in every case. The specifications included weight, length, horsepower, engine displacement, number of cylinders, the presence of automatic transmission, number of doors, and volume of production, but not all of them were used in the final regression equations.

The regression equations were calculated by pooling data for pairs of years, permitting coefficients for the two years to differ where the difference was statistically significant (the method of flexible pooling described earlier in this chapter). The price index was derived from a time dummy variable or that variable in combination with others in cases where the characteristic coefficients differed between the two years.

The average $\bar{R}^2$ for the whole period, based on various combinations of explanatory variables, ranged from .85–.88 for the United States and Japan (the lowest proportions explained) to .94–.97 for Italy and Germany. The range of variation in the alternative estimates of price movements was highest in 1953–57, when there were several instances of five and six percentage point differences. After that there were only three cases out of twenty-four in which the range among the price changes calculated from the variants of the equation was greater than three percentage points.

The place-to-place indexes for 1964 were calculated in two ways. The same domestic price data as in the time-to-time indexes were used to calculate equations matching pairs of countries (United States with each other country) instead of pairs of years. The $\bar{R}^2$ ranged from .892 to .967 but the price relatives, in every case, differed widely by type of car, with foreign prices always very high for U.S.-type cars and comparatively low for foreign-type cars. Wide differences in the type of car produced in different countries created serious problems in these price level comparisons. U.S. cars were, of course, larger and more powerful than European cars, and the ranges for some variables hardly even overlapped. The worst instance is the comparison of the United States with France. Because of these wide differences, price comparisons were made for five classes of cars and then averaged on the basis of estimates of the importance of each type in world trade.

In addition to these comparisons of home market prices, comparisons were made of prices in four specific markets, based on a total of over four hundred observations and using the same method of flexible pooling. The pattern of comparative advantage appeared much the same as in the comparison of home market prices, with the United States the lowest-priced seller of large cars and the highest-priced seller of small cars.

In this chapter, we particularly stressed the dependence of the estimates of price change and price differences on the choice of independent variables, mathematical form, and mode of pooling. Regression-based indexes have been criticized because of the indeterminacy caused by this variety of possible methods. However, it is important to realize that the range of indeterminacy in results based on regression methods is not inherently different from that which is embedded in the results of more traditional methods. The difference is that in more conventional methods, indeterminacy is neither avoided nor eliminated but concealed, whereas in regression methods it is made explicit.

Indeed, the former often turn out to be the equivalent of crude regression techniques such as the arithmetic interpolation of prices for a few models on the basis of one or two independent variables. In such cases, many decisions about alternative methods or assumptions are made at disaggregated levels in ways that are difficult, if not impossible, to summarize and present to the index user. An important advantage of the regression technique is that the choices among methods and their results can be described and presented clearly and systematically.

Aside from making explicit the methods and the unavoidable indeterminacy of the results, regression techniques also permit the use of a much wider range of product varieties in price measurement, and make possible price comparisons between different times and places for complex, differentiated products which are usually omitted from price indexes because of the difficulty of applying traditional methods of price measurement to them.

Thus, although much experimentation is still needed to put price measurement by regression methods on anything like a routine basis, even in the present embryonic stage they provide an important and useful tool in the making of price indexes.