Volume Title: The Measurement of Durable Goods Prices

Volume Author/Editor: Robert J. Gordon

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-30455-8

Volume URL: http://www.nber.org/books/gord90-1

Conference Date: n/a

Publication Date: January 1990

Chapter Title: Other Products

Chapter Author: Robert J. Gordon

Chapter URL: http://www.nber.org/chapters/c8317

Chapter pages in book: (p. 383 - 416)

9 Other Products

9.1 Introduction

This chapter contains shorter studies of three product categories within PDE that do not fit into the other chapters. The three studies have in common only that their exposition does not require the length of a full chapter. By far the most radical results, and among the most important in this book, are obtained for communications equipment, which has emerged in the 1980s as the single most important industry group within PDE. Also included here is railroad equipment; while my results are based on fragmentary data, they represent, I believe, the only academic study that has ever been carried out on price trends for this type of equipment. The third product group is tractors, both the wheel and the crawler types, which are used within agriculture and construction. The studies of railroad equipment and tractors are based on primary data newly collected for this study, while the results for communication equipment are based entirely on a pathbreaking recent study by Kenneth Flamm (1989), who in turn assembled a variety of price data from industry sources. Because the analysis of tractor prices is based on the hedonic regression technique and is similar in many respects to the examination of auto prices in the last chapter, the tractor results are presented as an "appetizer" for the more exciting findings on communication equipment as the chapter's "main course," leaving railroad equipment for dessert. Those readers who are most interested in those product categories where the new results differ radically from the official government price indexes may want to turn first to the study of communication equipment in section 9.3 below.

9.2 Tractors

The new evidence on tractors consists of hedonic regression equations estimated for new and used wheel and crawler tractors. The time periods covered by the hedonic regressions are 1947–76 for new and used wheel tractors, 1950–70 for new crawler tractors, and 1950–74 for used crawler tractors. As will be evident from the description in this section, the need to adjust prices for changes in equipment attachments makes a hedonic regression study of tractor prices a time-consuming enterprise. In order to obtain a tractor price index for the full 1947–83 period covered in this book within the available time constraint, the indexes are extended after the end of the regression sample by constructing matched model indexes for identical new and used wheel tractor models in pairs of adjacent years. For crawler tractors, a paucity of available data dictated a shift from the hedonic to the matched model method for new crawler tractors in 1971 and for used crawler tractors in 1974.

9.2.1 Hedonic Methodology in This and Previous Studies

One of the earliest hedonic regression studies was performed by Lyle Fettig (1963a, 1963b) for farm tractors on data for the periods 1950 and 1953–62. His results indicated only a modest disagreement with the PPI; the overall price increase between 1950 and 1962 was 23.4 percent for his hedonic index and 28.9 percent for the PPI.[1] A new study of tractors seemed warranted not only to extend the sample period beyond Fettig's eleven years to the much longer time interval covered in this book, but also to examine the relation between used and new tractor prices, both as a means of providing a comparison with my study of new and used auto prices in the last chapter, and as a means of determining whether deviations between transaction and list prices have been important in the market for tractors.

A second major regression study was performed by John Muellbauer (1971a) for the period 1958–69 on a very large sample of used tractor prices. Taken together, the Fettig and Muellbauer indexes when spliced together cover about half the thirty-seven year 1947–83 sample period, that is, 1950 and 1953–69. However, this spliced index cannot be used to study either cyclical variations in prices or shifts in the secular growth rate of prices between the decade of the 1950s and the decade of the 1960s, because the two studies differ in their methodology in two major respects. First, Fettig's dependent variable is the list price of the model when new, whereas Muellbauer's is the price of a used model observed at a particular age. This allows Muellbauer to estimate coefficients not only for the various quality characteristics and for the passage of time, but also for depreciation that occurs with age (one to ten years in his data). Second, Fettig adjusts the list prices for changes in the value of attachments and accessories included as standard equipment, whereas Muellbauer does not.

1. The increase cited in the text is for the average of the linear and semilog indexes from (Fettig 1963b, 50), as compared with PPI index 11-11-01 for "wheel-type tractors."

The methodology of the hedonic study follows the guidelines set down in chapter 3 above and followed in chapter 8 on automobiles. The dependent variable is the price of late-model used items, which should be a good proxy for the true transaction prices of new items, if late model used tractors are close substitutes for new models. In a period of weak demand, one would expect to observe a decline relative to the list price of new models both in the actual transaction price of new models, as a result of discounting, and in the price of used models. Regression equations are estimated below both for the list prices of new models and for used one-year-old and two-year-old models, and the behavior over time of the used/new ratio is interpreted as evidence of cyclical fluctuations in tractor demand.[2]

While this study follows Muellbauer in its use of prices for used items, it follows Fettig in its adjustments for the value of attachments and accessories. A hedonic regression equation with engine power as its only right-hand quality variable will tend to exaggerate the increase in tractor prices, since the price of a 1976-vintage tractor with a given horsepower engine includes as standard equipment a substantial number of attachments that were absent from a 1947-vintage model of the same horsepower. While the value of these attachments may in principle be estimated by separate dummy variables in the hedonic regression equation, in practice multicollinearity results in erratic and insignificant coefficients. The discussion in chapter 3 above recommends the direct adjustment of the dependent price variable for the value of attachments, and this approach has been carried out for auto accessories in chapter 8. Fortunately, the used tractor guides contain lists of prices suitable for adjusting the dependent price variable in the hedonic regressions. The attachment prices are listed for new tractors. The total value of the attachments on a given model is summed and then subtracted from the list price of the tractor in the same year to yield a "stripped" list price. Then the ratio of the stripped to the actual list price is multiplied by the price of used versions of that model to obtain the "stripped" price of the used model.

Although most readers have personal experiences with the automobile accessories that have been gradually converted from options to standard equipment—heater, outside mirror, multispeed window washers, sun visors, tinted glass, seat belts, head restraints, automatic transmission, power steering, and power brakes—the tractor attachments may be less familiar. Whereas a 1947 tractor was equipped simply with starter, lights, and "power takeoff" (i.e., a drive shaft to connect attachments to the tractor's engine), with even basic equipment like tires priced on some models as an optional

2. *The Official Tractor and Equipment Guide* is issued twice each year. Since the vast majority of tractor sales are made in the spring, all prices were copied from the spring edition. I am grateful to F. Wakefield for his hospitality during my visit to the St. Louis headquarters of the National Farm and Power Equipment Dealers Association, where these data were copied in February 1973. Data for the years 1971–83 were obtained by mail from the same source.

extra, by the 1960s the list of standard equipment had grown to include hydraulic systems equipped with sensors to detect changes in terrain and soil conditions, allowing a tractor operator to preset and maintain the draft of ground-working tools. Transmissions also became more complex, with more speeds and the introduction of both semiautomatic and automatic types. Other developments included independent power takeoff, which continues to drive an attachment even when the tractor clutch is disengaged, and the addition of fenders, deluxe seats, and, more recently, enclosed and air-conditioned cabs, as well as electronic monitors that measure and regulate the rate of chemical and seed application. The standard equipment on a 1975 forty-five horsepower International Harvester model 464 gas tractor included, according to the *Official Tractor and Equipment Guide,* "adjustable front axle; fenders; hydrostatic power steering; starter and lights; independent PTO; 8-speed transmission; 3-point hitch with hydraulic draft control and rockshaft; swinging drawbar." Fully 26.4 percent of the price of the average 1970 wheel tractor in my sample was accounted for by equipment that was not included on the average 1947 model.

The procedure of stripping tractors of attachments was performed separately for each model, since the price of a given attachment often varies with the overall size of the tractor. Since the calculation was performed only once when the model was introduced, the price of attachments in years after the model introduction is implicitly assumed to have behaved in the same manner as the price of the stripped tractor. Clearly, this technique requires the willingness to accept the maintained hypothesis that depreciation of used attachments proceeds at the same rate as for the used basic tractor itself. In some cases, when the prices of attachments are not listed separately in the *Guide,* it was necessary to estimate prices for them by finding the current price of an attachment of similar description on a comparable size tractor of the given manufacturer, and if this was not available, of another manufacturer.

9.2.2 Results: Wheel Tractors

Considering that the prices of some attachments had to be estimated in both this study and Fettig's, that the worksheets for Fettig's detailed calculations are unavailable, and that the sample in this study is smaller, the two studies arrive at remarkably similar adjustments for the time interval that both have in common, as illustrated in table 9.1. The ratio of the actual price to the stripped price in this study rises by 19.9 percent from the average 1950 model to the average 1962 model, whereas in Fettig's study the same ratio rises by 19.7 percent. The year-to-year behavior of the ratios in table 9.1 is also reasonably similar, with little change during 1950–57, a very rapid increase during 1957–60 for this study and 1957–59 for Fettig, and then approximate constancy until 1962. Overall, the 1947–70 increase in the ratio in this study

Table 9.1 **Ratio of Actual List Price of Wheel Tractors to Price "Stripped" of Attachments, Average over All Models in Sample in Each Year, 1947–70**

Year	This Study (1)	Fettig (2)	Ratio, This Study/Fettig (3)
1947	0.923	. . .	. . .
1948	0.931	. . .	. . .
1949	1.012	. . .	. . .
1950	1.012	1.012	1.000
1951	1.021	. . .	. . .
1952	1.032	. . .	. . .
1953	1.013	1.064	0.952
1954	1.013	1.091	0.928
1955	1.023	1.076	0.950
1956	1.050	1.068	0.983
1957	1.042	1.073	0.972
1958	1.126	1.141	0.986
1959	1.178	1.218	0.967
1960	1.214	1.205	1.007
1961	1.211	1.206	1.004
1962	1.214	1.211	1.002
1963	1.251	. . .	. . .
1964	1.297	. . .	. . .
1965	1.239	. . .	. . .
1966	1.239	. . .	. . .
1967	1.237	. . .	. . .
1968	1.290	. . .	. . .
1969	1.268	. . .	. . .
1970	1.244	. . .	. . .

Sources: This study (see text), and Fettig (1963b, table 10, p. 40). The level of the index is arbitrary, depending on what equipment is included on the "stripped" model, and is set equal to Fettig's index in 1950.

is 35.8 percent, that is, hedonic regressions estimated from data on unadjusted prices and engine characteristics would exaggerate inflation in tractor prices by 35.8 percent relative to regressions based on adjusted prices.[3]

The treatment of attachments changed after 1970, simply because many items previously listed as attachments became standard, and attachment prices were no longer available. As stated above, for the period after 1970 the new results are based on hedonic regressions for wheel tractors over 1970–76 and matched model indexes over 1976–83. For crawler tractors, all results are for matched models, except for hedonic regressions estimated over 1970–74. All results after 1970 have in common that the only models included in pairs of adjacent years are absolutely identical in model numbers and in the details of standard equipment listed in the used tractor manuals. This feature of the study may make control for quality change better after 1970 than before, for

3. The ratio for this study falls below unity in 1947 and 1948, because models in those years had smaller tires than in 1950; the level of the index is set to equal Fettig's in 1950.

no attempt is made to limit comparisons to observations with identical model numbers before 1970.

While the methodology of this study combines the better features of the previous work by Fettig and Muellbauer, a possible handicap is a much smaller sample size. To minimize the burden of data collection, given the large number of products included in the coverage of this book, tractor price data were collected for only one large manufacturer—International Harvester—and for only two ages of used equipment, one and two years old. Fortunately, Muellbauer's results indicate that the change in tractor prices is virtually identical across manufacturers, and so it would appear that little is lost by the decision to economize on data collection.[4] Similarly, the closely parallel ratios of unadjusted to adjusted prices in table 9.1 indicate that attachments were added to International Harvester tractors to the same extent and at about the same time as for the eight manufacturers included in Fettig's study.[5]

As pointed out in chapter 3, adjustments for attachments must be applied not only to price, but also to any quality characteristics that interact with the attachments. When weight is a quality characteristic included in a hedonic regression, for instance, both price and weight must be "stripped" of the value and weight of attachments. If only the price is adjusted, the coefficient on weight will be biased downward. Fortunately, this problem does not arise in the case of tractors, since the only quality characteristics included in the regressions are horsepower and a dummy variable for diesel engines, and weight is not included.[6] It would be desirable to make an adjustment for improvements in fuel economy, as was so important in the case studies of commercial aircraft and steam-turbine generators earlier in the book, because quality-adjusted fuel economy appears to have improved during the postwar period, but a lack of data precludes explicit fuel economy adjustments.[7]

4. Muellbauer (1971, 26) states, "This latest piece of information shows that brand effects do not simultaneously dominate price and depreciation behavior. This suggests that features that might be associated with market imperfections, such as strong brand advertising and brand loyalty more generally, are probably not very powerful."

5. The sample contains all International Harvester wheel-type gas and diesel tractors listed in the *Guide* except for "duplicate models," i.e., models in a given series having differences from included models only with respect to front-end design, high clearance features, special equipment for canefield or orchard operations, or steel wheels in place of rubber tires.

6. Experiments with other variables were conducted by Fettig, who supported the decision to eliminate variables other than belt horsepower and engine-type dummy variables "for either or a combination of two reasons. The first of these is non-significance of the estimated coefficient for the variable and the second is very high correlation with belt horsepower, so that the variable adds to additional explanation of price variance" (Fettig 1963b, 36).

7. Fettig (1963b, 37–38). Barger et al. (1963, 437) explain this phenomenon as follows: "It would appear, superficially, that the efficiency of tractor engines has not increased since 1940. Actually the engine efficiency has increased, but so has the number of power-absorbing accessories and equipment such as hydraulic systems, generators, and more complex transmissions. The result of the addition of accessories to tractors since 1940 has been to offset the increase in engine efficiency since that time." This implies that constant-quality fuel economy

Table 9.2 **Adjacent-Year Logarithmic Regressions for Used Gas and Diesel Wheel Tractors, Prices Adjusted for Attachments, 1947–76**

Year Pair	Horse power (1)	Dummy = 1 if Diesel (2)	Dummy = 1 if Two Years Old (3)	Time Dummy for Second Year (4)	$\bar{R}^2$ (5)	S.E.E. (6)	Number of Observations (7)
1947–48	0.87**	0.27**	−0.08*	0.19**	0.954	0.092	35
1948–49	0.84**	0.25**	−0.08*	0.19**	0.952	0.081	31
1949–50	0.92**	0.25**	−0.11**	−0.12**	0.951	0.086	31
1950–51	0.91**	0.33**	−0.11**	0.22**	0.974	0.068	35
1951–52	0.85**	0.33**	−0.10**	0.02	0.979	0.057	36
1952–53	0.88**	0.33**	−0.10**	−0.06**	0.976	0.063	37
1953–54	0.93**	0.31**	−0.07**	−0.04	0.965	0.077	34
1954–55	0.89**	0.27**	−0.06	−0.17**	0.947	0.092	23
1955–56	0.49**	0.37**	−0.11**	0.06**	0.981	0.046	18
1956–57	0.60**	0.33**	−0.12**	0.03	0.985	0.057	16
1957–58	0.78**	0.28**	−0.10**	0.10**	0.988	0.042	16
1958–59	0.87**	0.26**	−0.09**	0.09**	0.980	0.064	23
1959–60	0.85**	0.22**	−0.07	−0.07	0.890	0.140	31
1960–61	0.82**	0.19**	−0.10	0.01	0.900	0.131	34
1961–62	0.85**	0.18**	−0.10**	0.06**	0.978	0.064	34
1962–63	0.85**	0.13**	−0.08**	−0.03	0.977	0.063	34
1963–64	0.88**	0.11**	−0.05**	0.04*	0.981	0.053	35
1964–65	0.90**	0.13**	−0.05*	−0.04*	0.972	0.060	37
1965–66	0.88**	0.11**	−0.06**	0.00	0.967	0.068	34
1966–67	0.83**	0.10**	−0.10**	0.05*	0.976	0.062	36
1967–68	0.84**	0.09**	−0.08**	0.05*	0.954	0.085	42
1968–69	0.93**	0.11**	−0.09*	0.03	0.931	0.116	41
1969–70	0.92**	0.12**	−0.10*	0.05	0.914	0.129	36
1970–71	0.79**	0.05*	−0.09**	−0.01	0.960	0.082	44
1971–72	0.81**	0.07*	−0.09**	0.04	0.958	0.091	50
1972–73	0.83**	0.08**	−0.09**	−0.00	0.950	0.100	52
1973–74	0.85**	0.08*	−0.08*	0.05	0.958	0.097	40
1974–75	0.95**	0.05	−0.10**	0.48**	0.977	0.100	51
1975–76	0.98**	0.10**	−0.10**	0.05*	0.979	0.081	60

*Indicates significance at the 5 percent level.

**Indicates significance at the 1 percent level.

The detailed regression results for twenty-eight pairs of adjacent years are listed in table 9.2. As in previous studies in this book (e.g., electric generating equipment, appliances, and electronic computers), all regressions are fitted in double-log form. The tractor equations fit reasonably well, with an average standard error for 1953–62 of 0.0781, as compared to 0.0986 for Fettig's semilog-adjacent-year equations for the same time interval. Compared to the previous equations for appliances in chapter 7, the coefficients on quality characteristics in the tractor regressions are more stable, which may at least partly be a consequence of the larger sample size (which ranges between sixteen and sixty). With the exception

improved, but to take this into account it would be necessary to carry out a study like that of Wilcox (1984) for automobiles, running a regression of fuel economy on a host of quality characteristics. Unfortunately, my data do not permit this additional step.

of the three years when the sample size falls below twenty, the coefficient on horsepower lies in the relatively narrow range of 0.8 to 1.0, with no discernible trend over the postwar period.[8] The coefficient on the diesel dummy declines fairly steadily from an average of 0.29 in the earliest five equations to 0.07 in the last five. The depreciation coefficient (i.e., the dummy variable for two-year-old models) fluctuates between −0.05 and −0.12 but has an average value that agrees closely with Muellbauer's estimate.[9]

Table 9.3 compares the hedonic price index for used tractors derived from the coefficients on the time dummy variables in table 9.2 with three indexes for new tractors—a parallel set of regression equations for new list prices from this study, Fettig's results, and the PPI index for new wheel tractors. Recall that a time constraint led us to extend the hedonic indexes after 1976 with an index of matched models for both new and used tractors. These should be quite reliable, as they are based on a large number of models for both new and used tractors (again, used tractor prices are recorded only for ages of one and two years). Another change made after 1976 is to recognize the supplanting of International Harvester by John Deere as the market leader; all prices for wheel tractors over the period 1977–83 are for John Deere models ranging from the smallest to the largest. The post-1976 matched model index for new wheel tractors is based on as many as seventeen models in a single adjacent-year price comparison, and as many as fifteen for used tractors (i.e., thirty comparisons including both ages, one and two years).

As is shown by the ratios displayed in columns 5–7, the overall rate of secular price change measured by the two hedonic indexes is similar to that of the PPI and, for his limited sample period, to Fettig's index. In contrast to many of the price indexes developed elsewhere in this book for other products, the drift of the three ratios shown in columns 5–7 proceeds at a trivial rate over time. Given the substantial difference in sample size and detailed implementation of the hedonic technique, it is reassuring to find that the ratio of the new list price hedonic index to that of Fettig (col. 6) remains within the narrow range of 0.95–1.04 during the common 1950–62 sample period. We would expect a hedonic price index to exhibit greater fluctuations in price change than the PPI, and indeed such fluctuations are evident in the new/PPI ratio displayed in column 7.

Fluctuations in the ratio of the used hedonic index to the new hedonic index, displayed in column 5, are caused both by variations in the ratio of used prices to the true transactions prices of new tractors, and by variations in transaction relative to list prices. We observe in column 5 greater fluctuations

8. The coefficient averages 0.878 in the first five equations displayed in table 9.2 and 0.884 in the last five equations.

9. For 1958–69, Muellbauer (1971, 26) estimates an average rate of depreciation between one- and two-year-old models of International Harvester wheel tractors of 0.074, with the coefficient constrained to be fixed over the entire time period. The average of my depreciation coefficients for his sample period is 0.078.

Table 9.3 **Alternative Price Indexes for New and Used Wheel Tractors, and Selected Ratios among Indexes, 1947–83**

	This Study, New List Price[a] (1)	Fettig, New[b] (2)	This Study, Used Price[a] (3)	PPI (4)	Ratio, Used/New (5)	Ratio, New/Fettig (6)	Ratio, New/PPI (7)
1947	43.5		51.4	46.9	1.181		0.928
1948	47.8		61.9	52.2	1.294		0.916
1949	54.3		74.7	55.0	1.377		0.987
1950	54.7	57.7	66.1	55.8	1.208	0.948	0.980
1951	68.4		82.3	59.2	1.203		1.156
1952	69.2		83.9	60.0	1.213		1.153
1953	67.6	65.2	78.7	60.3	1.164	1.038	1.121
1954	63.3	63.3	75.4	59.2	1.192	1.000	1.068
1955	60.8	61.3	63.9	58.3	1.050	0.993	1.043
1956	64.7	64.0	67.6	59.7	1.045	1.012	1.084
1957	69.1	66.3	69.9	62.8	1.012	1.041	1.100
1958	70.0	73.8	77.5	65.8	1.107	0.949	1.064
1959	70.2	72.2	84.4	68.3	1.203	0.972	1.028
1960	68.2	72.0	78.7	69.2	1.154	0.947	0.986
1961	73.9	74.5	79.4	70.6	1.074	0.992	1.047
1962	74.9	74.9	84.3	72.5	1.125	1.000	1.034
1963	73.5		81.8	73.3	1.114		1.002
1964	69.9		85.3	74.7	1.220		0.936
1965	75.3		81.8	76.1	1.086		0.990
1966	76.2		81.6	78.6	1.071		0.969
1967	79.1		85.4	81.1	1.079		0.976
1968	85.0		90.0	84.4	1.059		1.007
1969	91.2		93.1	88.3	1.021		1.033
1970	96.5		92.3	92.8	0.957		1.040
1971	100.0		96.1	95.3	0.961		1.049
1972	100.0		100.0	100.0	1.000		1.000
1973	108.5		99.9	101.9	0.921		1.065
1974	120.4		104.8	117.2	0.871		1.027
1975	163.6		169.3	138.6	1.035		1.180
1976	182.9		177.5	150.6	0.971		1.214
1977	200.1		197.3	164.3	0.986		1.218
1978	200.1		215.4	176.8	1.076		1.132
1979	214.4		243.6	194.9	1.136		1.100
1980	233.6		257.8	224.2	1.104		1.042
1981	265.2		294.2	253.3	1.109		1.047
1982	308.2		299.6	277.9	0.972		1.109
1983	322.5		293.4	294.1	0.910		1.097

Sources: Column 3 is constructed by cumulating and taking antilogs of time dummy regression coefficients shown in table 9.2. Column 1 is index calculated in the same way from coefficients in an analogous regression equation for new list prices, not shown separately. Column 4 is PPI index 11-11-01, from App. table B.11.

[a]Indexes for this study in cols. 1 and 3 are matched model rather than hedonic regression indexes for 1976–83.

[b]Fettig index is the average of linear and semilog indexes in Fettig (1963b, 50) and is linked to my new list price hedonic index in 1962.

Table 9.4 **Adjacent-Year Logarithmic Regressions for Used Gas and Diesel Crawler Tractors, Prices Adjusted for Attachments, 1950–74**

Year Pair	Horse-power (1)	Dummy = 1 if Diesel (2)	Dummy = 1 if Two Years Old (3)	Time Dummy for Second Year (4)	$\bar{R}^2$ (5)	S.E.E. (6)	Number of Observations (7)
1950–51	1.35**	0.15**	−0.11**	0.20**	0.945	0.052	16
1951–52	1.13**	0.09*	−0.09*	−0.02	0.929	0.068	17
1952–53	1.15**	0.08	−0.10**	−0.01	0.952	0.073	19
1953–54	1.21**	0.08**	−0.12**	0.08**	0.976	0.057	20
1954–55	1.22**	0.09**	−0.10**	−0.07**	0.981	0.051	20
1955–56	1.20**	0.12**	−0.11**	0.04	0.979	0.053	20
1956–57	1.05**	0.12*	−0.11*	−0.09	0.908	0.099	16
1957–58	0.59**	0.20**	−0.11**	0.17**	0.968	0.047	12
1958–59	0.82**	0.17**	−0.10**	0.06**	0.999	0.005	12
1959–60	0.81**	0.19**	−0.10**	0.05**	0.999	0.003	12
1960–61	0.79**	0.18**	−0.09**	0.08**	0.998	0.012	12
1961–62	1.25**	0.10	−0.09*	−0.00	0.949	0.095	18
1962–63	1.40**	0.08	−0.10**	−0.05	0.956	0.088	23
1963–64	1.53**	0.07	−0.11**	0.02	0.953	0.080	21
1964–65	1.74**	0.06*	−0.10**	0.02	0.966	0.063	20
1965–66	1.82**	0.03	−0.10**	0.00	0.967	0.059	19
1966–67	2.42**	−0.04	−0.08	0.04	0.956	0.077	15
1967–68	3.30**	−0.11**	−0.10**	−0.01	0.999	0.086	12
1968–69	1.42**	0.11	−0.13	0.07	0.852	0.168	16
1969–70	1.33**	0.08	−0.12	0.05**	0.998	0.13	18
1970–71	0.74**	. . .	−0.09	−0.02	0.665	0.19	12
1971–72	0.74**	. . .	−0.09	0.02	0.663	0.19	12
1972–73	0.69**	. . .	−0.13	0.04	0.689	0.184	11
1973–74	0.50*	. . .	−0.14	0.05	0.708	0.166	8

*Indicates significance at the 5 percent level.

**Indicates significance at the 1 percent level.

in the ratio of the two hedonic indexes than in the ratio of the new hedonic index to the PPI: the used/new ratio in column 5 displays a substantial bulge at the beginning of the sample period and then a gradual downdrift. This ratio averages 1.252 in the first five years and 1.046 in the last five years of the sample period. The overall pattern of the used/new ratio for wheel tractors mirrors many of the features of the used/new hedonic ratio for automobiles discussed in the previous chapter (see table 8.9), except that the immediate postwar bulge in the used/new ratio is greater for automobiles, and the used/new ratio for automobiles increases in 1971–72 to a level about 10 percent higher than that observed in the 1960s, whereas a similar jump for tractors occurs somewhat later, over the 1978–81 interval.

9.2.3 Results: Crawler Tractors

Separate regression equations were estimated for crawler tractors and are exhibited in table 9.4. All methodological details, including the adjustments for attachments, are identical to those for wheel tractors, and the average standard error is similar for the period 1950–70 (0.0681 compared to 0.0781 for wheel tractors), after which the standard error for crawler tractors is larger, probably due to a much smaller sample size. The smaller average sample size may also explain the less stable coefficients on horsepower and the diesel dummy. Most of the instability occurs in the period 1964–70, when the range of horsepower covered in the sample is quite narrow, only 27–40 hp. In most earlier and later years, larger models are included and help stabilize the coefficient on horsepower. As compared to the wheel tractor regressions, the depreciation coefficients for crawlers are more stable and fluctuate in the relatively narrow range −.09 to −.14.

The hedonic index implied by the regression coefficients of table 9.4 is displayed in column 2 of table 9.5 and is compared there to an analogous hedonic price index based on new list prices (col. 1) and the PPI for crawler tractors (col. 3). Recall that small sample sizes force a switch to the matched model (specification) method for new crawler tractors in 1970 and for used crawler tractors in 1974. Only International Harvester models are included until 1976 but all manufacturers after 1976. The matched model pairs for adjacent years during 1976–83 cover a total of six manufacturers, and those for used crawlers cover three firms (this occurs because the tractor books give new list prices but no used prices for several small firms, probably indicating a small used market for these brands). Until the final decade (1973–83), there is no net drift in the ratio of the hedonic index for new list prices to the PPI, as shown in column 5. This ratio is almost identical in 1947 and 1972, rises above unity during 1951–56, and falls below unity during the period 1957–71.

The sharp decline in the ratio of the new-list-price crawler index to the PPI during 1972–78 is startling. In contrast to the 76 percent increase in the PPI over this six-year period, my index increases only 17 percent. For most of the period, this index is based on two large models (International Harvester TD-15-C and TD-20-C), which exhibited list price increases over 1973–77 of just 11 and 17 percent, respectively. To check on the plausibility of this new list price index, we can examine the price history of these models in the used tractor market, for, if they were underpriced in later years, any price differential compared to similar models should have been eliminated by arbitrage in the used market. Yet we find an increase over 1974–79 of just 31 percent for a one-year-old TD-20-C and just 32 percent for a two-year-old version of the same model, in contrast to an increase of 75 percent in the PPI over the same interval.

The ratio of the used hedonic to new hedonic index (col. 4) displays a substantial downdrift over time, like the used/new ratio for wheel tractors discussed above in table 9.3, but the timing is different. The used/new ratio for wheel tractors exhibits most of its decline during 1949–55, while that for crawler tractors declines mainly between 1967 and 1975, with another decrease during 1979–83 after a temporary increase in between. The final two columns in table 9.5 exhibit the ratio of the crawler to the wheel tractor

Table 9.5 Alternative Price Indexes for New and Used Crawler Tractors, and Selected Ratios among Indexes, 1950–83

	This Study, New List Price[a] (1)	This Study, Used Price[a] (2)	PPI (3)	Ratio, Used/New Crawler (4)	Ratio, New Crawler/ PPI (5)	Ratio, New Crawler/ New Wheel (6)	Ratio, Used Crawler/ Used Wheel (7)
1950	38.5	54.4	37.4	1.411	1.030	0.705	0.823
1951	45.6	66.2	41.1	1.453	1.108	0.666	0.804
1952	47.6	64.7	42.6	1.358	1.119	0.688	0.771
1953	49.1	64.0	45.4	1.303	1.082	0.727	0.813
1954	51.4	69.1	46.9	1.345	1.096	0.812	0.916
1955	53.0	64.8	48.6	1.223	1.091	0.871	1.014
1956	58.1	67.2	54.0	1.157	1.075	0.898	0.994
1957	51.4	61.4	58.6	1.195	0.877	0.744	0.878
1958	56.6	72.8	61.4	1.287	0.921	0.808	0.939
1959	56.7	76.9	63.7	1.357	0.889	0.807	0.911
1960	62.7	80.5	65.7	1.284	0.954	0.920	1.023
1961	66.6	86.7	66.9	1.301	0.996	0.902	1.092
1962	62.2	86.6	67.4	1.391	0.923	0.831	1.027
1963	63.7	82.2	68.9	1.291	0.925	0.866	1.005
1964	64.4	83.9	71.4	1.303	0.902	0.921	0.984
1965	63.9	85.1	73.1	1.331	0.874	0.849	1.040
1966	68.9	85.5	74.9	1.241	0.920	0.904	1.048
1967	69.3	89.1	78.3	1.285	0.886	0.877	1.043
1968	71.4	88.2	84.3	1.235	0.847	0.840	0.980
1969	84.4	94.8	88.6	1.123	0.953	0.926	1.018
1970	84.4	99.8	92.3	1.182	0.915	0.875	1.081
1971	84.4	98.1	96.6	1.162	0.874	0.844	1.021
1972	100.0	100.0	100.0	1.000	1.000	1.000	1.000
1973	105.8	104.5	104.0	0.988	1.017	0.975	1.046
1974	108.7	109.4	122.9	1.006	0.885	0.903	1.044
1975	116.5	116.3	149.7	0.998	0.778	0.712	0.687
1976	116.5	121.5	160.6	1.044	0.725	0.637	0.685
1977	116.5	149.4	176.2	1.283	0.661	0.582	0.757
1978	116.5	152.8	194.3	1.312	0.600	0.582	0.710
1979	116.5	148.0	214.9	1.270	0.542	0.543	0.569
1980	116.5	146.6	239.0	1.259	0.487	0.499	0.569
1981	147.2	151.9	260.7	1.032	0.565	0.555	0.516
1982	159.3	161.2	286.2	1.012	0.557	0.517	0.538
1983	165.1	155.2	295.8	0.941	0.558	0.512	0.529

Sources: Column 2 is constructed by cumulating and taking antilogs of time dummy regressions coefficients shown in table 9.4. Column 1 is index calculated in the same way from coefficients in an analogous regression equation for new list prices, not shown separately. Column 3 is PPI index 11-28-02, from app. table B.11. Column 4 is the ratio of col. 2 to col. 1; col. 5 is the ratio of col. 1 to col. 3; col. 6 is the ratio of col. 1 to col. 1 of table 9.3; col. 7 is the ratio of col. 2 to col. 3 of table 9.3.

[a]Indexes for this study in cols. 1 and 2 are matched model rather than hedonic regression indexes for 1974–83.

hedonic indexes, both new and used. Here we find substantial changes in relative prices that are mimicked in the new and used index ratios, with a substantial increase in the relative price of crawler tractors over the period 1950–60, followed by a sharp decline after 1973.

As in Chapter 8's study of used and new automobile prices, changes in the ratio of the used to new hedonic price index are interpreted as an indicator of shifts in transaction prices for new models relative to list prices. Anecdotal evidence suggests that new tractors have sold for substantial discounts off list price in some periods, and it is plausible that they may have sold for premiums over list price during the farm export boom after World War II, as did automobiles.[10] For this reason, the alternative price index for the tractor component of PDE developed in chapter 12 utilizes the hedonic price indexes for used wheel and crawler tractors displayed in tables 9.3 and 9.5. Any tendency of the used tractor index to overstate the downdrift of true transaction prices relative to list prices should be more than offset by the incomplete adjustment for quality change in the hedonic regression equations. First, no adjustment at all is made for improved "constant-quality" fuel economy or, second, for the types of improvements in riding and handling quality that have occurred in the auto industry.[11]

9.3 Telephone Transmission and Switching Apparatus

In recent years, communications equipment has been the largest single industry group within PDE and accounted for 12.7 percent of nonresidential PDE in 1986, more than either the office and computing (OCAM) or the trucks and busses categories. Within communications equipment, almost all the weight in the PDE deflator is applied to equipment installed by telephone companies for the purpose of transmitting and switching local and long-distance telephone calls.[12] The communications equipment category is of central interest in any study of durable goods prices, not only because of the importance of the category within PDE, but also because of the unusually high rate of R&D spending by manufacturers of telephone equipment and the resulting rapid rate of technological change. Western Electric (hereafter abbreviated WE), the AT&T-owned manufacturing subsidiary, spent 5.8

10. There is no evidence that used late-model tractors sold for more than the list price of new tractors, as was true for autos in 1947–48. However, regarding discounting, a dealer is quoted in 1977 as stating, "Our biggest seller is the 135-hp tractor, which lists for $26,000 . . . but many dealers are selling it for $22,000, just to move tractors off the lot and make enough cash to keep the doors open." This amounts to a discount of 15.4 percent (see "Farm Equipment Sales Go Slow," *Business Week,* 25 July, 1977, 49).

11. In a story about relatively inexpensive imported Russian tractors, a reporter for *Forbes* magazine took a ride both on the 70 hp Russian Belarus and a 65 hp Deere model: "The Deere is quiet, smooth-shifting, with a short turning radius, a steering wheel that responds to one finger and push-button four-wheel drive. The Belarus, by contrast, is loud, smoky and cantankerous; Richards had to play with the gearshift for almost a minute to get it into neutral" (Zweig 1988, 108). I take this to be indirect evidence that the handling characteristics of the 1988 American model are superior to a 1947 American model on the logic that, however far behind the Russians may be, surely the 1988 Russian model is superior to the typical 1947 American one.

12. The weight in App. table A.1 for 1967 is 95 percent (this is the sum of the weights applied to the AT&T index used for annual deflation; the other indexes designated by n. b in that table are used for quarterly interpolation). For 1986, the BEA list of price indexes used in the PDE deflator indicates a weight of 74 percent applied to the PPI for switchgear and the Engineering-News-Record wage index for skilled construction labor.

percent of net sales on R&D during the 1961–70 decade, substantially more than the chemical (3.8 percent), electrical equipment (3.6 percent), or total manufacturing (2.0 percent) industries (Billingsley 1973, 19). Partly as a result of the R&D spending, many types of equipment used in telephone transmission and switching have been subject to order-of-magnitude improvements in performance. For instance, the capacity of coaxial cable systems increased from 600 simultaneous conversations in 1941 to 132,000 in the late 1970s.[13] The introduction of electronic switching systems in the mid-1970s increased speed by an order of magnitude, provided more flexibility in routing calls, and reduced requirements for electricity, maintenance labor, and space.[14] Because of the sharp increases in the carrying capacity of transmission lines and the introduction of electronic switching equipment, it is quite likely that a "true" price index for telephone equipment would exhibit a decline in price over the postwar period, although probably at a rate considerably slower than the 20 percent annual rate of price decline experienced by electronic computers (see chap. 6 above). However, the existing PDE deflator for telephone equipment registers a substantial postwar increase in price rather than a decline and may fail to capture much of the technological change that has occurred.

9.3.1 Existing Price Indexes for Telephone Equipment

Over the postwar interval through 1983, the PDE deflator for telephone equipment is set equal to a component of the AT&T telephone plant and equipment price indexes (TPI) called "inside plant." Since 1983 the AT&T index has been unavailable, and the BEA has switched to a crude approximation, deflating the entire telephone equipment category by the PPI for "Switchgear" (with a two-thirds weight) and an index of skilled construction labor (with a one-third weight), making no adjustment at all for productivity change. This assumption of no productivity increase in telephone equipment is ironic, in view of the fact that the communications industry itself (as distinguished from the portion of manufacturing that makes communications equipment) exhibits the fastest postwar increase in productivity of any major industry group. As one example of a significant rate of productivity improvement within Western Electric, the main manufacturer of telephone equipment, a Bell publication (Billingsley 1973, 22) shows that, in the manufacture of rotary telephone sets over 1955–71, an increase in wage rates at an annual rate of 5.2 percent was largely offset by a reduction in labor

13. Bell Lab/Western Electric advertisement, *Commentary* magazine, July 1977, 2. Ellinghaus (1970) cites figures of 480 simultaneous messages for coaxial cables in 1941, 5,580 in 1953, and 32,400 in 1970.

14. Heralding the introduction of the no. 4 Electronic Switching System, McElheny (1976) compared it to its electromechanical predecessor 4-A Crossbar system: "The No. 4 E.S.S., costing far less per unit of capacity than its predecessor, using only 60 percent as much electricity, and requiring small maintenance and operating crews, also occupies so much less space . . . that virtually all the No. 4's can go into existing telephone buildings" (37).

Table 9.6 Annual Growth Rates for Telephone Equipment, 1947–80

	Annual Growth Rates
1. BEA PDE deflator for communications equipment	2.09
2. AT&T TPI for inside plant	2.57
3. WE index for all manufactures	1.13
4. WE index for apparatus and equipment (excludes cable and wire)	0.65
5. PPI for Switchgear, 11-75-04 (used by BEA after 1982)	4.54
6. BEA compensation per hour in construction industry (1948–80; analogous to construction wage index used by BEA after 1982)	5.91
7. AT&T average embedded cost per circuit mile	−5.35

Sources by row: (**1**) Table 9.7, col 1. (**2**) Table 9.7, col. 4. (**3**) Table 9.7, col. 2. (**4**) The Western Electric embedded cost index is available only through 1980. (**5**) PPI for Switchgear is from the PPI file described in chap. 12. (**6**) BEA compensation per hour is from NIPA table 6.4A divided by table 6.11. (**7**) AT&T embedded cost is from Flamm (1989, fig. 5, p. 28), available only through 1980.

content per set at an annual rate of 3.6 percent, resulting in an annual increase in labor cost per set of 1.6 percent rather than the 5.2, percent that would be implied by the BEA's post-1982 method.

To demonstrate the sharp divergence among alternative indicators that have been or might be used as deflators for telephone equipment, annual growth rates are contrasted over the 1947–80 interval in table 9.6. Annual data for the indexes shown in the first three rows are displayed in table 9.7, columns 1, 2, and 4. These growth rates raise several questions. I have no explanation for the small discrepancy between the BEA PDE deflator and the AT&T TPI, since the former is supposed to be composed of the latter with a weight of 95 percent prior to 1983.[15] The substantially slower rate of price increase recorded by the WE index reflects the fact that the AT&T TPI includes an installation labor component, while the WE index refers to manufactured products only. The much faster rates of increase shown by the Switchgear PPI and construction wage index suggest that the BEA deflator may be biased upward after 1982, even if the AT&T TPI is correct. Finally, the rapid decline in the AT&T embedded cost index suggests the possibility that technological progress may have reduced effective capital cost in ways that are not captured by either the AT&T TPI or the WE indexes. Any such finding would be important not only for our primary focus, the secular rate of change of the PDE deflator, but also for microeconomists interested in the production process within the telephone industry and who have in the past used the AT&T TPI to measure capital costs (see, e.g., Nadiri and Schankerman 1981).

For perspective on the new evidence discussed below, a review of the available data can begin with the methodology of the AT&T TPI and WE equipment indexes. The TPI includes separate components for transmission

15. The 95 percent weight comes from app. table A-1 (see also n. 12 above). The information that the particular AT&T TPI chosen by the BEA is the "inside plant" category comes from Flamm (1989, 30).

systems (circuit and radio equipment in central offices, cable and wire, pole lines, and underground conduits) and switches (manual, panel, step by step, crossbar, and electronic) and is based on the standard BLS specification methodology. No allowance is made for changes in price per unit of the desired quality characteristic, that is, per circuit mile for transmission equipment or line capacity for a switching system. In effect, only price changes following the initial introduction of a new model have any effect on the aggregate TPI. We learned in studying computer prices that much of the rapid rate of price decline measured by hedonic price indexes occurs with the introduction of new models, and the evidence of Cole et al. (1986) was cited showing that a matched model index for computer processors declined during 1972–84 at a much slower rate than a hedonic regression index. It would be surprising if price declines in telephone equipment did not also occur with the introduction of new models.

The WE index, compiled annually from 1920 to 1980, is a "chain index" compiled by specification methodology and thus differs from the PPI in its use of current sales weights, which change annually, as compared to the fixed weights and infrequent weight changes in the PPI.[16] It measures changes in the level of prices charged to Bell System customers for products sold to them by WE and differs from the AT&T TPI indexes by excluding any costs incurred by the Bell customers in the installation of the equipment. All significant items in each division ("sales class") of WE are included, and "the sum total of the item individually priced for the indexes is in the order of 90–95 percent of the total sales in most cases." Thus, the WE index introduces new products faster than is typical in the PPI and also has unusually complete coverage. However, the WE index suffers from the same basic defect as the TPI, and this is the failure to measure price change at the time that new models are introduced. The description of the index states explicitly that, "frequently, redesigned or new products have to be introduced into the indexes. When this is necessary the redesigned or new product is 'linked' into the index in a manner which does not change the level of the index at the time of introduction.[17]

9.3.2 Technological Innovation: A Brief Historical Review

The pace and timing of new model introductions that might incorporate unmeasured price declines have differed between transmission and switching equipment. Improvements in transmission technology have included a

16. I am grateful to S. Dale Jones, manager, Corporate Analysis, Western Electric Co., for providing me in 1973 with the Western Electric price indexes and background on their methodology. Updates through 1980 were provided by T. F. Clifford, manager, Corporate Analysis, Western Electric.

17. Details on the WE index included in this paragraph come from a mimeographed document obtained in 1973 from WE entitled "Basic Characteristics of the W. E. Selling Price Indexes."

hundred-fold increase in the carrying capacity of coaxial cables, the introduction of microwave transmitters and satellite transmission, and, more recently, optical fiber cable. Evidence examined below suggests that a substantial decline in the cost of transmission capacity occurred in two stages, the first between the early 1950s and the mid-1960s, and the second beginning in the late 1970s and extending into the mid-1980s. Indirect evidence is provided of further rapid price declines before 1950.

The technology of switching equipment was purely electromechanical until 1965, and the transition to electronic switches did not begin in earnest until the mid-1970s. The three main types of electromechanical switches were step by step, panel, and crossbar, serving, respectively, 47.5, 5.6, and 49.1 million telephones in 1970 (Brand 1973, 5). These were progressively more sophisticated in their programming ability: the first could send a call only through a fixed path and returned a busy signal if that was unavailable; the second and third allowed a limited ability to reprogram the calling path from a central location independently of the sequence dialed by the customer. The first full-scale central office electronic switching system was introduced in 1965, followed by the first fully digital electronic system in 1976. The transition to electronics also included the upgrading of old crossbar equipment to include limited electronic programming capability.[18]

9.3.3 New Evidence on Secular Price Movements

The new evidence presented in this section is all based on Flamm's (1989) pathbreaking study, which assembles evidence on costs and prices from a variety of sources, including internal Bell System records.[19] My contribution is to distill this evidence into a single price index for telephone transmission and switching equipment that can be used to replace the inadequate TPI on which the official PDE deflator is now based. Flamm's evidence is of three basic types. All have in common that they are measures of capital cost divided by some measure of the productive capacity of a capital good (e.g., circuit miles or lines handled by a switching system). Thus, these measures are analogous to the indexes for computer processors developed in chapter 6, where the unit of capital is taken to be the "quality characteristic" (e.g., memory, speed) of the computer rather than the number of computer boxes. In the same way, here I take the unit of measurement to be a circuit mile or telephone line rather than a "wire mile" (independent of handling capacity) or "switching system box."

18. Details in this paragraph come from Flamm (1989, 19–27), who emphasizes the much slower diffusion of electronic technology in the telephone industry than in the electronic computer industry.

19. Some of my source notes also refer to Flamm (1988), the working paper version of Flamm (1989), which contains several data series in appendix tables that were not reprinted in the published 1989 version.

Flamm's first measure is the AT&T embedded capital cost per circuit mile, which is a measure of the book value of installed capital in the AT&T Long Lines Department (i.e., excluding local service) divided by the number of circuit miles in the system at the same time. Because this concept measures the unit capital cost embedded in the current capital stock over all past vintages still on the books, its timing is inappropriate to represent the price of currently produced investment goods. Only if price change proceeded at an absolutely unchanged geometric rate would an embedded stock measure yield the same rate of price change as a price index based on current production. A further problem is that the depreciable lifetime of capital for accounting purposes may well be different from the actual lifetime over which the capital is counted in the cumulation of "circuit miles," the denominator of the AT&T ratio. Because of its disadvantages, this measure is used only to extrapolate the new index from 1952 back to 1947, a period for which no other adequate information is available.[20] A precedent for adopting a measure of the unit capital cost embedded in the current capital stock as part of a price index is provided by Jack Triplett, who as part of his "best practice" price index for computer processors attached a sizable weight to Flamm's (1987) price index of the installed capital stock of computers (in the case of computers measured at market prices rather than historical cost).

The second type of evidence taken from Flamm is a measure of incremental capital cost for new transmission and switching capacity. For transmission equipment, capital cost is the annual change in the net book value of central office circuit and radio equipment, as well as in that of toll and exchange lines, and the change in capacity is measured in circuit miles. For switching equipment, capital is measured by the annual change in the net book value of central office switching equipment, and switching activity is assumed to be proportional to total local calls plus ten times long distance messages. The resulting ratios of incremental capital cost to incremental capacity have a zigzag appearance and are exhibited in table 9.7, columns 5 and 6, as three-year moving averages. The rapid decline in transmission cost between 1952 and 1968 is striking, as is the reversal between 1969 and 1978. Incremental switching cost declined much more slowly than transmission cost until the mid-1960s and increased less from then until the mid-1970s.

Flamm suggests three defects of the incremental capital cost measures. First, there is a time lag between an investment and the completion data of the resulting increase in capacity. Second, the denominator in the switching measure is actual traffic, rather than capacity, and thus incremental cost for switching moves inversely to capacity utilization, and vice versa. Third,

20. In discussing Flamm's evidence, I omit his measure, taken from Phister (1979), of the cost of data communication per bit transferred, following his own verdict that this mainly reflects improvements in interface technology (i.e., cheaper modems) rather than lower line costs. To the extent that modems are treated as a computer peripheral in PDE within the OCAM category, lower modem costs are already taken into account in the PDE deflator.

Table 9.7 **Alternative Price Indexes for Telephone Transmission and Switching Equipment, 1947–84**

	NIPA Deflator for Communi-cations Equipment (1)	Western Electric All Manu-factures (2)	AT&T TPI General Equipment (3)	AT&T TPI Inside Plant (4)	AT&T Marginal Capital Cost Trans-mission (5)	AT&T Marginal Capital Cost Switching (6)	Bellcore 6 Switching Equipment Types (7)	AT&T Bellcore Transmission and Switching Equipment (8)
1947	68.4	97.7	47.8	63.3				273.9
1948	68.4	96.4	52.2	63.9				256.7
1949	66.4	96.3	54.2	63.3				240.6
1950	68.4	93.0	56.0	64.8				225.5
1951	78.7	104.9	60.8	67.9				211.6
1952	73.1	94.6	62.2	65.9	265.8	100.0		198.6
1953	68.7	87.2	62.7	60.9	178.1	101.9		164.1
1954	66.4	87.3	63.4	64.4	190.4	83.5		153.5
1955	71.2	87.9	65.6	64.6	233.3	61.2		145.5
1956	68.4	89.6	70.0	66.3	253.5	65.0		156.4
1957	74.3	88.6	72.8	69.1	207.9	77.7		141.6
1958	75.5	91.4	76.3	70.7	163.2	69.9		119.0
1959	76.7	92.1	77.9	71.2	129.8	58.3		96.9
1960	76.4	90.3	78.2	71.0	128.1	68.0		104.0
1961	74.8	88.7	78.2	70.9	115.8	71.8		101.7
1962	72.2	85.7	77.9	71.0	118.4	79.6		108.2
1963	75.3	85.0	76.7	72.0	107.0	68.0		95.1
1964	74.4	84.0	78.3	73.5	106.1	68.9		95.4
1965	75.5	81.7	78.7	73.8	82.5	60.2	74.8	78.5
1966	75.5	81.9	79.4	75.4	82.5	65.0	78.0	80.2
1967	77.5	83.2	81.5	78.2	72.8	68.9	81.3	76.9
1968	81.3	88.1	84.5	81.7	71.1	68.0	84.7	77.6
1969	85.3	90.5	86.9	86.1	71.1	72.8	88.3	79.2
1970	87.6	94.4	90.7	90.0	78.1	88.3	92.0	84.8
1971	94.1	96.2	94.8	94.9	92.1	101.0	95.9	94.0
1972	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1973	102.6	100.8	99.9	104.0	100.0	96.1	99.4	99.7
1974	104.1	110.9	111.1	113.9	113.2	116.5	105.8	109.4
1975	117.6	120.0	125.1	124.7	131.6	115.5	92.5	110.3
1976	126.3	128.0	130.3	132.3	149.1	109.7	76.6	106.9
1977	130.0	130.7	132.3	137.4	152.6	76.7	72.7	105.3
1978	130.1	130.9	132.3	137.9	159.6	75.7	69.0	104.9
1979	132.9	134.7	138.4	141.5	137.7	82.5	66.4	95.6
1980	136.1	141.6	147.0	147.8	105.3	106.8	65.2	82.9
1981	149.5		163.0	160.4			67.4	85.6
1982	166.1		176.9	176.0			70.0	88.9
1983	176.6		183.9	185.4			59.8	76.0
1984	183.7						51.2	65.0

Sources by column: (**1**) NIPA implicit deflator, table 5.6, row 5, divided by table 5.7, row 5, rebased to 1972. (**2**) From Western Electric prior to divestiture (see text). (**3, 4**) From Flamm (1988, app. A). (**5, 6**) Three-year moving averages of Flamm (1988, app. B, cols. 3 and 4). (**7**) Constructed by cumulating and taking antilogs of annual log changes displayed in table 9.8, applying equal weights to each piece of equipment. (**8**) Törnqvist index of cols. 5 and 6 for 1952–65 and cols. 5 and 7 for 1965–82, extended to 1984 by col. 7, and extended before 1952 by Flamm (1989, fig. 5, p. 28), reading off the graph annual growth rates of −6.47 percent for 1947–50 and −6.37 percent for 1950–55.

Table 9.8 **Annual Growth Rates of Prices for Six Types of Telephone Switching Equipment, 1965–84**

	Small (1)	Medium (2)	Large (3)
	2,500 lines	5,000–20,000 Lines	80,000 Lines and Over
Local office switches:			
1972–73	4.14	−25.92	5.56
1973–75	4.14	18.05	2.31
1975–76	−8.87	1.81	−0.87
1976–78	−8.87	0.30	−0.87
1978–79	1.78	−1.79	−0.66
1979–80	11.37	−4.94	4.77
1980–81	11.37	13.26	4.77
1981–82	6.45	13.26	13.58
1982–84	−22.20	−10.20	−14.65
	15,000 Trunks	30,000 Trunks	60,000 Trunks
Toll and tandem switches:			
1965–72	4.15	4.15	4.15
1972–74	4.26	4.26	4.26
1974–76	−25.26	−36.53	−43.25
1976–80	−6.11	−7.46	−8.47
1980–82	−4.81	−3.31	−2.08

Source: Calculated from Flamm (1989, app. B, pp. 404–5).

capital cost per mile is inversely proportional to route length, so a reduction in average route length would spuriously raise the transmission incremental cost measure, and vice versa. However, the first two factors will mainly contribute year-to-year fluctuations in the incremental cost measures rather than creating a secular bias; the bias caused by changing route length is unknown. The Flamm incremental cost measures are greatly superior to the WE and TPI indexes, which omit all price changes associated with the introduction of new models and new products.

Flamm's third set of evidence, and doubtless the best, consists of estimates by Bell Communications Research (''Bellcore'') specialists of the cost of representative central office switches per line served in offices of varying sizes. These estimates are also available for toll and tandem switches. Displayed in table 9.8 are the annual rates of price change over the intervals spanning the estimated prices. The price changes are erratic, with substantial price declines concentrated in particular years. Trunk line switches plummet in 1974–76, reflecting an assumed shift from the No. 4 crossbar system to the No. 4 Electronic Switching System (ESS). To the extent that the transition of overall Western Electric production from crossbar to ESS switches did not occur instantaneously, the indicated rates of price change may exaggerate the price decline in 1974–76 and overstate it in other periods.

Because the Bellcore estimates are closer in principle to true prices than are the incremental capital cost measures, the final price index (displayed in table 9.7, col. 8) is based on the Bellcore switch estimates for their period of availability, 1965–84. The six Bellcore size classes are combined into logarithmic chain indexes (i.e., Törnqvist indexes), using equal weights, and then are combined again with the incremental capital cost measure for transmission equipment (available only through 1980), again with equal weights. Since Flamm provides data on cost per circuit mile, number of circuit miles, switching cost per line, and number of lines, it is possible to aggregate the implicit transmission and switching capital stock, and this calculation yields 1973 shares of transmission and switching equipment in the capital stock of 49.3 and 50.7 percent, respectively, thus validating the choice of equal weights for the two components of telephone equipment.[21] From 1952 to 1965, the final index is an unweighted Törnqvist index of incremental capital cost for transmission and switching, and prior to 1952 is based on Flamm's embedded capital cost per circuit mile measure. The annual growth rate of the final index over 1947–52 is −6.4 percent, over 1952–65 is −7.1 percent, and over 1965–84 is a mere −1.0 percent.

As was true for many of the indexes developed in other chapters, there are numerous unmeasured aspects of quality change that are not taken into account in the final index, thus supporting the verdict that it understates the "true" rate of price decline. First, reduced maintenance cost and energy use in electronic switching systems creates value for the user beyond the sheer carrying capacity of the switches. We found in chapter 7 that saving in maintenance cost and energy use was important for several types of appliances and were able there to develop rough adjustments for the value of these improvements, but here we do not have quantitative evidence and must rely on qualitative descriptions.[22] In addition to these savings, electronic switching equipment has made possible radical reductions in equipment space occupied per line served, thus allowing many telephone companies to eliminate whole multistory buildings that would have been required with the previous technology to accommodate today's calling volumes.[23] Second, for switching equipment, the basic measurement unit is taken to be the "line,"

21. The calculation for 1973 is 550 million circuit miles times $18 average cost, or $9.9 billion, and 62 million lines at about $165 switching cost per line, or $10.2 billion. These figures are taken from Flamm (1989, figs. 4 and 5); and Flamm (1988, app. C).

22. See, e.g., the McElheny (1976) quote in n. 14 above.

23. In addition to McElheny (1976), an additional citation on space-saving is Urquhart (1985), who states that, as a result of space-saving equipment, Bell Canada was able to eliminate plans to build a third office building in Toronto, and was able to sell a regional headquarters building with 660,000 square feet of office space: "The company has also realized that the introduction of compact digital switching equipment that requires one-quarter as much space as old electro-mechanical equipment,is freeing up all sorts of existing space for other uses. As the old equipment was replaced, Bell said, 'Holy smoke, look at all that valuable real estate' " (29).

but a telephone line is not the same as it was twenty or forty years ago. Today's switches allow calls to be completed much faster than before, saving time for customers, and the programming capabilities of modern switches allow the equipment to search for alternative routings, thus reducing the incidence of "circuit busy" signals. Third, today's digital switches (by converting analog voice signals into digits) reduce distortion and provide a clearer line. Finally, modern switches allow the provision of additional services, including the routine provision of itemized bills for subscribers, as well as paging and electronic call transfer services.[24]

Regarding transmission equipment, there are fewer dimensions of unmeasured quality change, but no doubt that transmission quality has improved over the postwar period. People calling their relatives across the continent who in earlier decades may have sounded "far away" now sound as if they were "next door," and the difference in sound quality between local and transcontinental calls, and even for some types of international calls, is rapidly disappearing. A further indication that the final index may understate the rate of decline in telephone equipment prices occurs after 1980, when the index is entirely based on switching equipment, with no contribution from transmission equipment. If anything, the transition to fiber optic cable must have created a decline in the effective cost of transmission equipment during this period even more rapid than that of switching equipment. As one specific piece of evidence, Flamm (1988) exhibits a chart indicating a rate of price decline for fiber optic cable of 45 percent *per year* from 1980 to 1985. This piece of evidence is not included in the final price index, however, because it refers to the cable itself, not the complete transmission system, which contains an unknown mix of other equipment besides cable.

9.4 Other Types of Communication Equipment

This book develops alternative price indexes for components of PDE and, in chapter 12, combines the alternative and current official price indexes with an identical set of weights, that used by the BEA at present in combining its own set of detailed official price indexes (mainly PPIs) into deflators for the separate industry groups within PDE. There seems to be some indication that the 95 percent weight applied (before 1973) by the BEA to the AT&T TPI index of telephone transmission and switching equipment is excessive, simply because the remaining 5 percent (about $1.6 billion in 1984) seems to leave too little room for other types of communication equipment.

Contrasting evidence is given by *Current Industrial Reports,* which lists 1984 shipments of telephone switching and switchboard equipment ($5.5

24. On the last two points, see "Princes and Pumpkins at the Digital Switching Hour," *Economist,* 29 August 1987, 74–75.

billion), other telephone equipment ($8.1 billion), nontelephone nonbroadcast communications systems and equipment ($8.5 billion), and broadcast and studio equipment ($1.4 billion). Thus, there is clearly a substantial production of communications equipment other than telephone equipment, and the broadcast/studio category alone amounts to almost as much ($1.4 billion) as the entire amount ($1.6 billion) that the BEA allocates to communications equipment other than telephone.

This section provides some qualitative and anecdotal evidence on several of the other types of products involved. Previously, in chapter 6 on computers, in the section of chapter 7 on home television sets, and in the previous section on telephone equipment, quantitative evidence has been provided to show that prices of electronic equipment have uniformly fallen over the postwar period. And, as we found for telephone switches and as we shall find again for typewriters in chapter 10, the transition from electromechanical to electronic components for a given product can easily involve a discrete decline in price to one-third or less of the previous price, not counting the additional dimensions of quality (spellcheckers on typewriters, call forwarding by telephone equipment) that were previously unavailable. In discussing these additional types of equipment, this section implicitly assesses the validity of the PPIs to which the BEA applies the remaining 5 percent weight in the PDE deflator for communications equipment; these are the PPIs for magnetic tape, home tape recorders, home television sets, and phonographs.

One product that experienced a shift to electronic technology beginning in the mid-1970s was the office telephone and internal office switching equipment (PBX, for "private branch exchange"). Until 1968, AT&T had a monopoly and owned the entire installed base of PBX equipment, but the historic Carterfone decision in that year allowed non-Bell equipment to be connected to Bell System lines. Because AT&T had no incentive to introduce modern technology, PBX equipment designs seldom changed, and one telephone company was offering in 1971 a model first introduced in 1937. Competing firms took time to get established in the face of delaying tactics applied by Bell companies to "foreign attachments," but by 1975 these firms were applying intense competitive pressure through the introduction of modern electronic PBX systems.

In the old technology, physical rewiring was required to change the telephone configuration in a customer's office. Electronic PBX devices allowed the addition of numerous features that today are taken for granted, including call forwarding, automatic call back, call waiting, automatic setting up of conference calls, automatic routing of long-distance calls, and restrictions on toll use by some branch extensions. By 1976, prices of full electronic systems had fallen to roughly the level charged by old-fashioned electromechanical PBX equipment lacking all these advanced features. In one case, a new system in a large 1,000-line office saved 26 percent on long-distance charges, and 75 percent on operator costs.[25] It should be noted also that deregulation and divestiture opened the market to new suppliers that undercut Bell system prices, so that an internal Bell price index for PBX equipment, even if one existed, would understate the rate of price decline during the 1970s. More recently, in the 1980s, a study has estimated that PBX prices fell at an annual rate of 10 percent per annum over 1981–84, while smaller PBXs called "key systems" fell at an annual rate of 16 percent over the same period; the same study quotes a decline in central office switching equipment costs over 1980–84 at an annual rate of 7–10 percent, which is somewhat faster than the 6 percent rate of decline used in the final telephone equipment index in the previous section.[26]

In the 1980s, the most dramatic new product innovations have been the cellular telephone and the fax machine. In each of these cases, drastic cost reductions have stimulated exponential increases in use. One estimate is that the price of the least-expensive model cellular phone declined at an annual rate of 23 percent between 1983 and 1987, comparable to the rate of price decline of personal computer equipment over the same period.[27] Until 1985, fax machines were large, cumbersome machines, usually found in the corporate mailroom, which were difficult to operate, often unreliable, and took as long as six minutes to transmit one page of a document. The new generation of fax machines are small, easy to use, transmit a page in fifteen seconds, and are fast becoming ubiquitous in corporate offices and even in universities. According to one estimate, the prices of fax machines have fallen at about 15 percent per year during the 1985–88 period, with signs of an acceleration at the end of the period as small personal units were introduced in the $1,000–$1,500 range having many of the features previously available on more expensive office units.[28]

Broadcast and studio equipment has, of course, been of electronic design throughout the history of the industry, but has benefited from the same transition from vacuum tubes to transistors to integrated circuits that yielded for home television sets a −6.6 percent rate of price change over the 1952–83 period. Much broadcast equipment consists of transmission equipment, the price of which should behave roughly like that of telephone transmission equipment, and of television sets and monitors, which should mimic the prices of home television sets. In the area of transmission equipment, the most dramatic price change has been in satellite earth

25. Details about PBX equipment come from "Technology Changes the Office Telephone," *Business Week*, 19 January 1976, 42–44.

26. These growth rates are from a study by an industry group and are quoted in "Telecommunications Survey," *Economist*, 23 November 1985, 12.

27. *Business Week*, 21 September 1987, 90. On personal computer equipment, see chap. 6.

28. "Faxually Speaking," *Forbes*, 13 June 1988, 114–16.

terminals, which in one three-year period (1975–78) fell in price at an annual rate of 54 percent per year (Cooper 1978, 34). The study of home appliances in chapter 7 above found that the most dramatic rate of price decline, −26 percent per annum over the 1980–85 period, occurred for VCRs. So we should expect that dramatic price declines have occurred for types of broadcast equipment that involve videotape recording technology.

In the early years of television, video cameras weighed hundreds of pounds. They were mobile only in the sense that they were mounted on dollies and rolled into position on the studio floor. As for the equipment that recorded picture and sound, it weighed tons and could not be moved at all. Until the introduction of instant video replay technology in 1957, those of us who lived on the West Coast saw all prime-time television programs not in the original fidelity enjoyed in the rest of the country but through the grainy screen of off-the-screen sixteen-millimeter film reproduction used to achieve the required three-hour time delay. In the 1950s, any outside gathering of television news was accomplished by film cameras, not video cameras, and transmission required the physical transport of the film back to the studio and a time delay required for film developing. Live remote broadcasts, such as sporting events or political conventions, required that portable video cameras be connected by cable to a truck containing the 1.5 tons of equipment required to record on two-inch videotape.

By 1975, the weight and size of portable camera and recording units had been reduced to eighty-five pounds and could be carried by two men; tape width had fallen to one inch. Only a few years later, a broadcast-quality unit had been reduced in weight to fifteen pounds, and one person could operate a single unit housing a camera, complete recording system (on one-quarter-inch tape), and battery.[29] By the mid-1980s, "camcorders" in several tape formats had fallen enough in price to make the transition into the home market, making home movie equipment obsolete. The reduction in television news equipment prices had proceeded far enough by 1988 that hundreds of local television stations sent live transmissions from the floor of the two political conventions.

Overall, the experience of home television sets, with their postwar annual rate of price decline of 6.6 percent per year, may be an acceptable proxy through the mid-1970s, but since then the rate of price decline for nontelephone communications equipment seems to have accelerated. Scattered examples in this section over selected three to five-year intervals since 1975 reported annual rates of price decline for particular products in the rate of 10–50 percent. Even if these examples are atypical, reporting price declines in the particular intervals when technical innovations were concentrated, the

29. Details on size and weight of equipment from an advertisement of Robert Bosch GmbH in the *Wall Street Journal*, 5 April 1982, 12.

implied rate of price decline for all these products could easily have been in the range of 5–10 percent per annum.

9.5 Railroad Equipment

A great deal of information is available on prices of railroad equipment, but time limitations permitted only the assembly of scattered bits and pieces. These, however, cover freight locomotives and several of the most important types of freight cars, which together account for the great majority of PDE in railroad equipment. To capture secular price trends, data collection is limited to the beginning, middle, and end of the 1947–83 coverage period. The aim is to develop estimates of the secular rate of price change for locomotives and freight cars over the intervals 1947–70, 1970–79, and 1979–83.[30]

Just as the new price measures for telephone equipment are developed for a single quality unit, circuit miles for transmission equipment and lines for switching equipment, here the new price measures are based on price per horsepower for locomotives and price per ton of carrying capacity for railroad freight cars. This procedure introduces the implicit assumption that the cross-sectional relation of price to horsepower or price to ton is unit elastic, that is, the plot of price against horsepower at a moment of time is a ray extending through the origin. The unit elasticity assumption has been used in some previous studies, including Flamm's (1987) work on computers, discussed in chapter 6, and telephone equipment, discussed in section 9.3 above. Dulberger's (1989) and this study's hedonic regression equations for computers in chapter 6 tend also to exhibit a unit elasticity of price to the two most important quality characteristics, memory and speed.

The new evidence on railroad equipment prices is based on three different data sources. For 1947 and 1970, tables are listed in the monthly periodicals *Railway Mechanical Engineer* and its successor, *Railway Locomotives and Cars*. These tables, published every month, list almost all orders for new locomotives and freight cars, including for all orders the number of units ordered and the horsepower or ton capacity. For a very small subset of the orders the aggregate price is included, allowing calculation of a per-unit and per-horsepower or per-ton price. For instance, of the roughly 150 order transactions for locomotives and a like number of freight car transactions in calendar 1948, suitable price information was provided for just twelve locomotive transactions and six freight car transactions. Some price information could not be used, because the price provided was the aggregate value of

30. For annual interpolation, the only available source is the single PPI used in the POE deflator for this category. This is PPI index 14-4, which began in 1961. The notes to the BEA list of PPIs have the following ambiguous explanation of the pre-1961 source: "Extrapolated back prior to 1961-I using previously published quarterly series."

an order containing several sizes of locomotives or types of freight cars. Unfortunately, these periodicals eventually suspended publication, and similar information has not been published since the early 1970s. In assessing this new evidence, it is important to note that the prices are *not* sampled; the results are based on literally every shred of usable information published in the sources for the two years 1948 and 1970.

The twelve priced transactions for locomotives in 1948 are particularly valuable information, because the wide range of sizes ordered provides clear evidence of a unit elasticity of price to horsepower. Despite a range of sizes from 1,000 to 6,000 hp, the price per horsepower was in the extremely narrow range of $91.70–$106.10, and most of the locomotives were priced at precisely $100 per horsepower, that is, a price of $100,000 each for an order of thirteen 1,000 hp locomotives and $600,000 each for an order of six 6,000 hp locomotives. Exactly the same information was available in the same format in 1970, although the range of price per horsepower was much wider ($92.50–$150). However, there is no evidence in the 1970 sample to conflict with the assumed unit elasticity of price to horsepower; both the orders at $150 per horsepower were of the mid-range 2,000 hp size, and other order transactions occurred for the 1,000, 2,000, and 3,000 sizes in the narrow range of $92.50–$100 per horsepower. If a larger number of transactions containing price information had been available, one might well have concluded that there was no increase at all in price per horsepower between 1948 and 1970; however, when one averages the price-per-horsepower quotations with equal weights across each order, one concludes that the average price increased 14 percent (see table 9.9, rows 1 and 2).[31]

For freight cars, exactly the same sources are used in the same way. As shown in rows 5 and 6 of table 9.9, prices are collected separately for open and covered hopper cars. (Additional price information was available on gondola and box cars in 1970, but not in 1948.) The prices listed indicate that freight car prices almost doubled over this interval, in contrast to virtually no increase in locomotive prices. This difference in price behavior is consistent with evidence provided from the Sears Roebuck catalog in chapter 10 that simple products fabricated from metal with few moving parts exhibited faster price increases, and benefited less from technological change, than more complex devices, for example, a 1948–70 price increase of 87 percent for steel safes and 131 percent for cast-iron radiators versus an increase of 14 percent for stationary air compressors and 7 percent for centrifugal pumps.

31. If I had weighted by the dollar value of each order, my conclusion would have been that price did not change at all, since one order of $28.3 million, with an average price per horsepower of just $97.50, dwarfs all other orders combined (adding to $12.0 million).

Table 9.9 **Summary of Information Collected on Railroad Locomotives and Freight Cars, 1948–83**

	1948	1970	1979	1983
Locomotives, price per horsepower:				
1. Twelve transactions, 103 locomotives, range 1,000–6,000 hp, range $/hp $91.7–$106.1.	102.42			
2. Eight transactions, 173 locomotives, range 1,000–3,000 hp, range $/hp $92.5–$150		116.88		
3. Electro-Motive new unit, 3,000 hp model SD-40-2			216.67	
4. Electro-Motive new unit, 3,500 hp model SD-50				342.90
Freight cars, price per ton:				
5. Six transactions, 3,800 hopper cars:				
Open	67.40			
Covered	107.14			
6. Four transactions, 3,500 hopper cars:				
Open		132.50		
Covered		180.56		
7. Average cost per car (size not specified):				
Gondola		14,203	31,760	37,655
Open Hopper		12,726	34,585	39,687
Covered Hopper		16,221	36,858	37,334
Price indexes, 1970 = 100:				
8. BEA implicit deflator for PDE, railroad equipment	52.8	100.0	231.3	293.3
9. Alternative, locomotives	87.6	100.0	176.5	244.6
10. Alternative, freight cars	54.9	100.0	208.8	218.5
11. Törnqvist-weighted alternative, railroad equipment	69.4	100.0	192.0	231.2

Sources by row: (**1, 5**) *Railway Mechanical Engineer*, various monthly issues during calendar year 1948, feature titled "Orders and Inquiries for New Equipment Placed Since the Closing of the [last month] Issue" (**2, 6**) *Railway Locomotives and Cars*, various monthly issues during calendar 1970, feature having same title as in 1948. (**3**) Young (1979, 1). (**4**) "Electro-Motive Gets Big Conrail Order," *Chicago Tribune*, 17 November 1983, sec. 2, 14. (**7**) *Railroad Facts, 1985 Edition* (Washington, D.C.: Association of American Railroads, August), 49. (**8**) NIPA, table 5.6, row 20, divided by table 5.7, row 20, rebased in 1970. (**9**) 1948–70, directly from rows 1 and 2. 1970–79 and 1979–83, adjusted for 5 and 14.2 percent estimated present value of fuel saving (see text). (**10**) 1948–70, directly from rows 5 and 6. 1970–79 and 1979–83, annual percentage change in "Cost of New Freight Cars" (row 7 source, p. 49) is reduced by annual percentage change in "Average Freight Car Capacity" (in tons, from row 7 source, p. 48). (**11**) Törnqvist unweighted average index computed from rows 9 and 10.

Independent evidence to support these results on locomotive prices was obtained directly from the Electro-Motive division of General Motors, which for most of the postwar period had a market share of about 75 percent (thus making its price experience as relevant for a locomotive price index as IBM's experience is for a computer price index).[32] In addition to manufacturing

32. In the early 1980s, Electro-Motive lost ground to General Electric, which in 1983 had gained a market share of 45 percent. See "GM Locomotive Production Lines May Shut," *Chicago Tribune*, 15 July 1982, sec. 4, 1.

locomotive diesel engines for use in its own locomotives, Electro-Motive sells the same engine for a variety of uses, including inland marine use (e.g., tow boats on the Ohio River), for standby emergency power generation, and in oil well drilling. Its standard locomotive engine was gradually upgraded from 1,605 to 3,300 hp between 1950 and 1970 and increased in price per horsepower by 14 percent over that two-decade interval, by coincidence the same percentage increase as is shown in table 9.9 for locomotives between 1948 and 1970.[33]

To update the study for the period after 1970, when the order transaction data are unavailable, I rely on separate sources for locomotives and freight cars. The locomotive data are for the dominant Electro-Motive model sold in 1979 and 1983, as reported in newspaper accounts (see the notes to table 9.9). The freight car observations are the average purchase price, without any adjustment for size, available annually from the Association of American Railroads. The reported annual rate of change in freight car prices is adjusted for the annual rate of change in average freight car size, from the same source, so that the resulting price index calculated in row 10 is on the same per-ton basis as the computed 1948–70 price change. For locomotives, an adjustment is made for improved fuel economy. Railroads achieved a 36 percent increase in fuel economy per ton mile carried between 1971 and 1983; of this, a 20 percent increase is allocated to locomotives, and the rest to some combination of lighter freight cars and improved operating procedures.[34] The present discounted value of the fuel saving is then used to adjust the observed change in locomotive price per horsepower, using the same procedure as in chapter 7, in which the dollar fuel saving is added to the price in the first year and the price change then recalculated. Data on locomotive lifetimes and fuel prices are averages for the railroad industry as a whole. Fuel prices are those at the beginning of each interval (1970 for 1970–79 and 1979 for 1979–83), thus assuming static expectations and greatly underestimating the true fuel savings that were made ex post.[35] The resulting adjustments are 5 percent of the 1970 price over 1970–79 and 14 percent of the 1979 price over 1979–83.

33. The price per horsepower increased from \$20.40 to \$23.33. Price quotations were obtained by phone in 1973 from H. L. Smith, chief engineer of Electro-Motive, McCook, Ill., and are listed in detail in chap. 11.

34. Of the 20 percent increase in fuel economy, 10 percent is allocated to 1970–79 and the remaining 10 percent to 1979–83. Electro-Motive achieved a substantial improvement in fuel economy in shifting from the model SD-40, introduced in 1965, to the SD-40-2, introduced in the mid-1970s. This was "designed to save fuel by idling at lower horsepower, equipped with a better cooling system, and capable of being shut down completely in cold weather when the locomotive is not needed. [One of the biggest headaches faced by railroads is the cost of idling locomotives around the clock in cold weather because of the difficulty in restarting a diesel engine.] 'It's the most reliable unit we own,' said Deane H. Ellsworth, manager of motive power planning and development for Amtrak, of that agency's 71 SDP40-Fs"(Young 1979, 3).

35. The necessary data are obtained from the source listed in table 9.9, row 7, p. 44 for fuel consumed per revenue-ton mile, p. 45 for the average age of locomotives in 1984, and p. 60 for average price paid annually by railroads for diesel fuel.

The resulting price indexes for locomotives and freight cars are shown separately in rows 9 and 10 of table 9.9 and are aggregated into a single unweighted Törnqvist index for railroad equipment in row 11. The application of equal weights to locomotives and freight cars is supported by the PPI, which reports the "relative importance" of its locomotive index (14–41) as 0.146 and of its railroad car index (14–42) as 0.151.[36] Despite the adjustment for improved locomotive fuel efficiency, there is no doubt that the final index for railroad equipment overstates the true quality-adjusted price increase. Two specific pieces of evidence can be cited. First, technical improvements in locomotives have been made that improve hauling ability relative to horsepower. There was little change in average horsepower per locomotive between 1971 and 1984 but an increase in revenue ton miles per locomotive of 38 percent.[37] In the specific case of Electro-Motive, the new model SD-50, introduced in 1979–80, had a 16 percent increase in horsepower (from 3,000 to 3,500) but could haul 33 percent more tonnage, which was accomplished through a newly designed system for controlling "wheel creep," improving the adhesion between wheel and rail by between 18 and 24 percent (Young 1979, 3). I make no adjustment at all for the improved fuel efficiency made possible by lighter freight cars, yet part of the increased cost per ton, counted here as a price increase, actually represents a quality increase. For instance, flat cars redesigned in the 1980s to use lighter-weight materials produced fuel savings equal to fully one-third of their capital cost, evaluated at 1983 fuel prices.[38]

9.6 Conclusion

This chapter has provided new evidence on secular price trends for four different classes of products, tractors, telephone equipment, nontelephone communications equipment, and railroad equipment. The overall secular drift of the new alternative indexes relative to official price indexes covers a wide range, suggesting that there is no alternative to the nitty-gritty business of examining as many products as possible, and that overall conclusions may be sensitive to alternative weighting schemes.

The secular annual rate of price change over the full intervals of available data for the new price indexes developed here are listed in table 9.10. The secular drift exhibited for crawler tractors and railroad equipment is in the range found for many other products in this book, as summarized below in

36. See *PPI Supplement: Data for 1983*, October 1984, table 13, p. 239.

37. See the source to table 9.9, row 7, p. 44.

38. Specifically, Santa Fe railroad designed a new "Ten Packer" train of piggyback-carrying flat cars that saved 6,000 gallons of fuel per trip, or $600,000 per year, for a capital cost of $2 million. "The principal savings on fuel come because the cars are lighter and are designed to reduce aerodynamic drag on trains." (Young 1983, 2).

Table 9.10 **Annual Rate of Price Change for New and Official Price Indexes**

	Interval	Alternative	Official	Alternative/Official
Wheel tractors	1947–83	4.84	5.10	−0.26
Crawler tractors	1950–83	3.18	6.27	−3.09
Telephone equipment	1947–84	−3.89	2.67	−6.56
Railroad equipment	1948–83	3.44	4.89	−1.45

Sources: Alternative/official calculated from alternative and official growth rates. Wheel tractors data from table 9.3, cols. 3 and 4. Crawler tractors data from table 9.5, cols. 2 and 3. Telephone equipment data from table 9.7, cols. 8 and 1. Railroad equipment data from Table 9.9, rows 11 and 8.

chapter 12. Wheel tractors, like automobiles, exhibit virtually no drift, suggesting perhaps that the BLS has devoted unusual attention to purging observed price observations of quality change. Telephone equipment, with its transition to electronics, is an unusual case, exhibiting a rate of secular drift much less than that of electronic computers, but similar to that of noncomputer office machinery.

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III Sources for the Pricing of Numerous Products

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