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CHAPTER ELEVEN

Communication and Electric Utilities

11.1. Introduction

This chapter details the estimation of the current-price and constant-price (1860) capital stock on a decadal basis from 1840 to 1900 for communication and electric utilities. These include, in turn, telegraphs, telephones, and electric light and power. These estimates involve the use of perpetual inventory methods, and confront the problems of dealing with new goods.

11.2. Telegraph

11.2.1. Introduction

The early book value figures for the telegraph are unreliable. The frequent mergers before 1870 often caused book values to reflect acquisition cost, not construction cost. To make matters worse, in the 1860s Western Union declared a 100 percent stock dividend, and set it up on the books by doubling the value of "franchise and equipment" (Thompson 1947, 409).[1] In addition, no clear distinction was made between tangible and intangible assets.

Fortunately, there are sufficient data to construct a constant value series based on physical inventories. Estimates of the cost of constructing telegraph lines and equipping offices are available for 1860 and 1866.[2] With this information, and the physical count of miles of poles, miles of

The substance of this chapter was written by Gallman. "We" and "our" refers to Gallman and Howle.

wire, and the number of offices, estimates for 1850 through 1900 can be developed.[3]

11.2.2. Improvements

First, an index of resource content was developed. In 1866, W. Dennison, postmaster general, estimated that the construction of telegraph lines covering the principal mail routes (22,741 miles) would cost, for improvements alone:[4]

one-wire line	$150 per mile
three-wire line	$300 per mile
six-wire line	$580 per mile

Presumably these figures are for a quality of telegraph line superior to what then existed, but we can use them to develop an equation relating cost to miles of poles (pole line) and miles of wire.

$$I = K(P + 1.3w)$$

I = cost of improvements per mile

K = a dollar value to be developed from 1860 cost data

P = miles of poles

w = miles of wire (one to six per mile)[5]

Using K = $65, this equation fits the Dennison estimates fairly well:

Dennison estimates	Equation
one-wire $150	$65(1+1.3) = $150
three-wire $300	$65(1+3.9) = $319
six-wire $580	$65(1+7.8) = $572

Second, we developed estimates of K, expressed in 1860 prices, for each census year. George Prescott estimated that in 1860 the construction

TABLE 11.1 **K value based on 1902 book values, in millions of dollars**

1	1902 improvements and equipment	162
2	Less 10% (a minimum deduction for equipment and intangibles)	16
3	Maximum book value of improvements	146
4	Price index	118
5	Maximum book value in 1860 dollars	124
6	$124 = K(.238 + 1.3 × 1.318)	
7	K = 64	

Sources: Line 1: US Bureau of the Census 1915, 159. Book values are not depreciated. Line 2: a guess; see text. Line 3: line 1 - line 2. Line 4: The life of telegraph improvements was slightly over ten years in 1900. The price index (table 11.8, line 6) shows a gradual decline from 126 in 1880 to 118 in 1890 and 115 in 1900. Since we are dealing with book values, 118 is approximately correct. Line 5: 100 × line 3 ÷ line 4. Line 6: value of improvements from line 5; miles of line and miles of wire from US Bureau of the Census 1915, 159. Line 7: solution to line 6.

cost for a line of the quality then existing was $61.80 per mile (US Senate 1865/66, 4). He went on to emphasize the inferior construction of these lines. It is likely that his estimate was for a one-wire line, because this was the most common kind in 1860. The Prescott estimate indicates a value of K = $27: $27(1+1.3) = $62.00.

A joint letter from the presidents of the three leading telegraph companies estimated that a good quality line of six wires would cost $665 or slightly more in 1866, for improvements only (US Senate 1865/66, 12). This is roughly confirmed by Dennison's estimate of $580 (US Senate 1865/66, 1). Deflating the $665 estimate by our price index yields an 1860 cost of $354 (see table 11.6, line 6.) We may therefore say that the 1866 cost of a "good quality" six-wire line was $354, expressed in 1860 prices, implying a value of K of a little more than $40;[6] that is, $40.2(1 + 7.8) = $354.

Prescott also stated that the quality of telegraph construction had already shown considerable improvement from 1860 to 1866, so we might safely assume that by the terminal date of our series, 1900, the quality and resource content of lines would justify a K value at least as high as $40 (US Senate 1865/66, 5).

We can attempt to justify this by using book values that are available for 1902 (see table 11.1). Even in 1902 it is likely that the value of "construction and equipment" included intangibles, such as patent rights and goodwill resulting from mergers. We may therefore consider the K value based on the 1902 "construction and equipment" figure to be an upper bound.

Our assumption was that the K value might have increased from $27 in 1860 to $40 in 1900 as a result of the use of more resources for better quality construction. The K value obtained from 1902 book values

TABLE 11.2 **Values for K and m, 1850–1900**

	1850	1860	1866	1870	1880	1890	1900
K	$24	$27	$29	$30	$34	$37	$40
m	45	49	53	55	62	68	73

Sources: See text for sources of 1860 and 1900 values. All others are based on straight-line interpolation and extrapolations. It is assumed that m moves with K.

TABLE 11.3 **Value of telegraph improvements, 1860 prices, 1840–1900, in millions of dollars**

		1850	1860	1870	1880	1890	1900
1	K	24	27	30	34	37	40
2	Miles of wires	12,000	60,000	150,000	291,000	849,000	1,166,000
3	Miles of poles	8,600	35,000	72,000	111,000	225,000	236,000
4	Value of improvements	0.58	3.05	8.01	16.64	49.16	70.07

Sources:

Line 1: For all years, table 11.2.

Line 2, 1850: Thompson 1947, 241–42. 1860: Prescott estimated that there were more than 50,000 miles of wire in 1859 (US Senate 1865/66, 4). 1870: The ratio of the miles of wire owned by Western Union to the miles of wire owned by the rest of the industry was interpolated between 1866 and 1880. The 1870 ratio was then divided into the miles of wire owned by Western Union in 1870. 1866: Based on the capitalization figures on pp. 21 and 22 of document 49 and the Western Union mileage figure after consolidation (Thompson 1947, 426), with a rough allowance for the fact that Western Union was heavily overcapitalized (Thompson 1947, 414, 424). The capitalization of Western Union after consolidation was $41 million (Thompson 1947, 426), which is 80 percent of the capitalization of all telegraph companies in 1866 (US Senate 1965/66, 21–22). But document 49 omits seven companies for lack of data, and innumerable local companies. Also, Western Union capital figures are inflated. With allowance for these factors, Western Union is likely to have had nearer 70 than 80 percent of total capital. Rounding yields a figure of about 105,000 miles of wire in 1866, of which Western Union had 76,000. Our estimate is 105,000 miles in 1866, of which Western Union (after consolidation) had 76,000. Prescott gives a figure of over 150,000 miles, but he attributes more than 110,000 to Western Union and American, which, after consolidation with United States, had only 76,000, as mentioned above (US Senate 1965/66, 4). 1866, 1870, and 1880: Western Union data are from US Bureau of the Census 1960, series R-44; 1880 industry data are from US Census Office 1883b, 784. 1890 and 1900: Same procedure as 1870, with the ratio interpolated between 1880 and 1902. The ratio was in fact .80 in 1880 and in 1902. Western Union data are from US Bureau of the Census 1960, series R-44; industry data from US Census Office 1883b and US Bureau of the Census 1906, 159.

Line 3, 1850–1900: The ratio of miles of poles to miles of wire is available for the industry for 1850 (0.72)] in US Census Office 1853a, 113, for 1880 (0.381), and for 1900 (0.202). It is also available for Western Union in 1866 (0.494) and 1880 (0.367) (Thompson 1947, 426). We interpolated between the industry-wide ratios for 1880 and 1900 to obtain the 1890 figure (0.265), adjusting this ratio downward so as to assure that the estimated miles of poles in 1890 were less than the actual miles in 1900. We extrapolated from 1880 to 1866 on Western Union data, interpolated to 1870 (0.48) from 1866 and 1880, and interpolated to 1860 (0.59) between 1866 and 1850.

Line 4: For all years, lines 1, 2, and 3 are applied to the formula $I = K(P + 1.3w)$, where I = Improvements, P = miles of poles, and w = miles of wire.

(undepreciated), converted to 1860 prices, is $64. In view of what we know about telegraph book values, such a disparity does not seem unreasonable.

We next interpolated the K values ($27 and $40) between 1860 and 1900, and extrapolated to 1850 (see table 11.2). This assumes a relatively constant increase in resource use over the period. On this basis we estimated telegraph improvements, in 1860 dollars, for all years (see table 11.3).

11.2.3. Equipment

Telegraph equipment during this period accounted for a small fraction of the value of capital. In 1866, for example, the presidents of the three major telegraph companies said that they had an investment of $760,000 in "office equipment."[7] Assuming that one-third of the equipment was purchased at prewar prices, this would be the equivalent of roughly $565,000 in 1860 dollars—only about one-tenth of our computed investment in improvements (interpolated on miles of wire).[8]

We also have an estimate, from the same source, of the cost of equipping an office in 1866, according to the number of wires in the line served by the office (US Senate 1865/66, 13):

one-wire line $150 six-wire line $350

The following formula fits these data:

$$E = mn(1.1 + 0.4w/P)$$

E = total undepreciated value of equipment

m = a dollar multiplier to be determined

n = number of offices

w = miles of wire

P = miles of poles.

For the 1866 per office cost data just quoted, an m value of $100 would be indicated, or $53 when deflated to 1860 dollars. We can compare this with the estimate we previously cited of the cost of office equipment of the three main telegraph companies: Setting $565,000 = 5,700 m (1.1 + 0.4 × 100,000/51,000), yields m = $53.[9]

We do not know how the value of m changed over time. Later office equipment was probably more complex than that existing in the 1860s. For lack of better information, we allowed m to change over time in proportion to the change in K, the improvements multiplier, as indicated in table 11.2.

The only remaining task was to estimate the number of offices in existence. To do this, we interpolated and extrapolated a ratio of the number of offices per mile of poles from 1880 (0.113) and 1902 (0.115) data for the

TABLE 11.4 **Background information for calculation of value of telegraph equipment, 1860 prices, 1840–1900, in millions of dollars**

		1850	1860	1870	1880	1890	1900
1	Multiple (m)	$45	49	55	62	68	73
2	Miles of poles	8,600	35,000	72,000	111,000	225,000	236,000
3	Offices per mile of poles	0.110	0.111	0.112	0.113	0.114	0.115
4	Number of offices (n)	946	3,885	8,064	12,543	25,650	27,140
5	Wire/poles	1.4	1.7	2.08	2.62	3.77	4.94
6	Equipment	0.07	1.34	0.86	1.67	4.55	6.09

Sources: Line 1: See text, above. Line 2: table 11.3. Line 3: See text, above. Line 4: line 2 × line 3. Line 5: table 11.3, line 2 ÷ line 3. Line 6: from line 1, 4, and 5 according to the formula $E = mn(1.1 + 0.4w/P)$.

industry to derive the following estimates: 1850, 0.110; 1860, 0.111; 1870, 0.112; 1890, 0.114; and 1900, 0.115. The 1880 ratio is from the US Census Office (1883b). The 1902 data are from the US Bureau of the Census (1906). The ratios for all other years were interpolated or extrapolated.

We then estimated the value of equipment, in 1860 dollars, for all years (see table 11.4).

11.2.4. Depreciation

The depreciation of telegraph assets is somewhat complicated because we have not developed an annual capital stock series. To develop a depreciated series, we first converted our stock estimates to estimates of the average total output of telegraph assets during each decade. Centering each estimate on the midyear of the decade, and assuming a constant rate of increase in the gross output of telegraph assets between decade mid-years, we developed an estimate of the average age of telegraph equipment. From this estimate, a ratio of depreciated to undepreciated assets values was developed.

The life of telegraph improvements and equipment was taken to be ten years.[10] Investment gross of replacement (hereafter, "gross investment") in year (t) is equal to investment net of replacements (hereafter, "net investment") in year (t) plus gross investment in year (t-10), investment being expressed in constant prices:

$$g_{(t)} = n_{(t)} + g_{(t-10)} = n_{(t)} + n_{(1-10)} + \ldots tn_{(t-10m)}$$

where (t-10m) is in the first decade of significant telegraph asset production.

We next determined the average net investment in the telegraph in each decade and centered it on the mid-year of the decade:

$$n_t = 0.1(s_{t+5} - s_{t-5})$$

where s is our undepreciated stock figure.

We now had a means of estimating the average gross investment per annum for each decade, and we centered this figure on the mid-year of the decade. We interpolated changes in investment along a straight line from one decade's mid-year to the next. Thus we could divide the investment within the decade into two parts. Part A corresponds to the level at the beginning of the 10-year period, continued throughout the decade; it is 10 x g_{t-10}. The average age of equipment produced at the constant rate represented by Part A is obviously five years. This corresponds to a ratio between depreciated and undepreciated value of 0.5, assuming straight-line depreciation. Part B represents a straight-line increase in investment during the decade; it is $(10 \times g_t - g_{t-10})/2$. The average age of equipment corresponding to part B is 3.33 years, and the ratio of depreciated to undepreciated value is 0.667 for this portion of the stock.

TABLE 11.5 **Depreciation of telegraph assets, 1860 Prices, 1840–1900, in millions of dollars**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Undepreciated Stock (s)	**Change in s**	**Net Investment (n)**	**Gross Investment (g)**	**Ratio (s_0/s)**	**Depreciated improvement**	**Depreciated equipment**
1840	0						
1845			0.07	0.07	0.67		
1850	0.7	0.7			(0.65)	0.4	0.05
1855			0.27	0.34	0.63		
1860	3.4	2.7			(0.62)	1.9	0.21
1865			0.55	0.89	0.6		
1870	8.9	5.5			(0.60)	4.8	0.51
1875			0.94	1.83	0.59		
1880	18.3	9.4			(0.60)	9.9	1
1885			3.54	5.37	0.61		
1890	53.7	35.4			(0.58)	28.5	2.6
1895			2.25	7.62	0.55		
1900	76.2	22.5			(0.55)	38.5	3.3

Sources: Column 1: The undepreciated stock of capital equals line 4, table 11.3 + line 6, table 11.4. Column 2: From column 1, $\Delta s = s_t - s_{t-10}$. Column 3: From column 2, $n = 0.1\Delta s_t + 5$. Column 4: From column 3, $g_t = n_t + n_{t-10} + tn_{t-10}m$. See text, equation 2. Column 5: From column 4, $s_0/s = (0.667g_{t-10} 0.167g_{t-10})/g_t$. See text, equation 5. The figures in parentheses are interpolations. Column 6: column 5 × line 4, table 11.3. Column 7: column 5 × line 6, table 11.4.

TABLE 11.6 **Price indexes of telegraph assets, 1850–1900, 1860 base**

		1850	1860	1866	1870	1880	1890	1900
1	Pine logs	94	100	200	125	150	150	150
2	Iron wire	98	100	190	127	95	64	60
3	Building trades	82	100	170	186	143	173	182
4	Wet cell batteries	140	100	—	120	74	57	40
5	Electric apparatus	138	100	—	100	88	78	69
6	Improvement index	92	100	188	144	126	118	115
7	Equipment Index	122	100	187	133	100	100	96

Sources:
Line 1: The 1860–1900 index is from the *Aldrich Report* (US Senate 1893, 47). This index seemed the most appropriate to reflect changes in the price of telegraph poles. The index was extrapolated to 1850 and to 1900 according to changes in the building materials index in US Bureau of the Census 1960, series E-8 and E-21.
Line 2, 1860–1900: *Aldrich Report* (US Senate 1893, 40) extrapolated to 1850 and 1900 according to changes in the metal and metal products index in US Bureau of the Census 1960, series E-7 and E-20. In the early 1900s both copper and iron lines were being used. Although it is not known to what extent copper had replaced iron by 1900, the price index of sheet copper (copper wire index not available; US Senate 1893, 40) did not deviate greatly from that of iron wire. Line 3: 1860–90: US Bureau of the Census 1960, series D-577. This index was extrapolated to 1900 by US Bureau of the Census 1960, series D-623, and to 1850 by an index of common labor (Lebergott 1964, 541). The building trades index seemed more appropriate than the other available wage indexes because it follows the skilled labor index (Lebergott 1964, 90) closely for the years of overlap. It also corresponds closely to the illuminating gas wages index, the only utility index that is available for the period.

Line 4: Brady's index, received by correspondence. The 1854 figure was used for 1850. Line 5: Brady's index, received by correspondence, unadjusted, extrapolated from 1860 to 1850 along changes in Brady's machine shop products index (table 8.9, line 2). Line 6: A weighted average of lines 1, 2, and 3. US Census Office 1883b furnishes a very detailed list of Canadian Telegraph assets. The total cost of poles and that of wire were about equal. The US telegraph industry had about the same ratio of miles of wire to poles in 1866 as the Canadian industry had in 1880. Considering the price fluctuations in these two items, we assumed that they were of about equal value in the United States in 1870. We weighted the change in relative importance of these two items according to the change in the average number of wires per line. The weighting of labor is a rough estimate. Line 6 was thus obtained by weighting lines 1, 2, and 3, respectively, as follows:

1850	1860	1866	1870	1880	1890	1900
40, 30, 30	40, 30, 30	35, 35, 30	35, 35, 30	30, 30, 30	25, 45, 30	20, 50, 30

Line 7: No detailed account of the components of telegraph equipment was found. To obtain the equipment index, we arbitrarily weighted lines 3, 4, and 5, respectively, as follows:

1850	1860	1870	1880	1890	1900
30, 35, 35	30, 35, 35	30, 35, 35	30, 35, 35	30, 30, 40	30, 25, 45

To obtain the 1866 value, it was necessary to interpolate between 1860 and 1870 according to changes in the Warren-Pearson metal and metal products index (US Bureau of the Census 1960, series E-7).

The depreciated value/undepreciated value ratio therefore corresponds to:

$$(0.5\ g_{t-10} + 0.667g_t - 0.667g_{t-10})/g_t = (0.667g_t - 0.167g_{t-10})/g_t$$

This is subject to the restriction that investment must have first begun at (t-10) or earlier.

We next determined the depreciated/undepreciated value ratio and the depreciated value of telegraph assets for the 1850–1900 period (see table 11.5).

11.2.5. Current Value Estimate

Our price indexes were constructed as indicated in table 11.6. The constant-price series was multiplied by the price index to obtain the current-price series in table 11.7.

It is interesting to compare our estimates with the only other evaluations of telegraph assets that are not based on book values. These estimates, for 1872 and 1880, are found in US Census Office (1883b). They are based on an 1869 report of the president of Western Union. The 1869 data were extended to 1872 and 1880 by considering the change in miles of wire and miles of line during the period. It appears, however, that no adjustment was made for price changes. The series was intended to represent the cost of the assets, not depreciated values. Table 11.8 presents a comparison of our undepreciated estimates with US Census Office (1883b) evaluations.

TABLE 11.7 **Telegraph assets converted to current dollars, 1850–1900, in millions of dollars**

		1850	1860	1870	1880	1890	1900
	Improvement						
1	Value, at 1860 prices	0.4	1.9	4.8	9.9	28.5	38.5
2	Price index	92	100	144	126	118	115
3	Value, at current prices	0.4	1.9	6.9	12.5	33.6	44.3
	Equipment						
4	Value, at 1860 prices	0.05	0.21	0.51	1.0	2.6	3.3
5	Price index	122	100	133	100	100	96
6	Value, at current prices	0.06	0.21	0.68	1.0	2.6	3.2

Sources: Line 1, 4: table 11.5, above. Lines 2, 5: table 11.6, below. Line 3: line 1 × line 2 ÷ 100. Line 6: line 4 × line 5 ÷ 100.

TABLE 11.8 **Comparison of Gallman-Howle and US Census asset evaluations, in millions of current dollars**

	(1)	(2)
Year	**Gallman-Howle (undepreciated)**	**Tenth census**
1870	12.7	—
1872	14.6	11.9
1880	22.6	18.7
1890	62.6	—
1900	86.4	—

Sources: Column 1: Table 11.3, line 4, and table 11.4, line 6 were each inflated by the appropriate price index, table 11.6. The improvements and equipment were then totaled together. The 1872 figure was interpolated between 1870 and 1880 along miles of Western Union wire. Column 2: US Census Office 1883b, 846–49.

11.3. Telephones

11.3.1. Current Value Series

We accepted Ulmer's (1960) estimates, which were constructed by inflating constant price cumulations of net investment flows.[11] Ulmer's figures refer to 1 January of each year; we interpolated between them to produce approximations to 1 June estimates. The only available breakdown into capital components is in a Federal Trade Commission report that established a breakdown for 1922 (Federal Trade Commission 1926, 30). We adjusted these figures, as explained in the notes to table 11.9. The results appear in table 11.10.

11.3.2. Deflation

We then deflated the telephone series by using our telegraph improvements and equipment indexes from table 11.6. Although telephones did not exist commercially before 1880, our price index extends back to 1860.

TABLE 11.9 **Telephone asset ratios, 1880–1922**

		1880	1890	1900	1922
1	Land	0.04	0.04	0.04	0.03
2	Improvements	0.48	0.46	0.44	0.40
3	Equipment	0.48	0.50	0.52	0.57
4	Fixed assets	1.00	1.00	1.00	1.00

Sources: 1922 ratios were taken from data in Federal Trade Commission 1926. The 1880 ratios were roughly estimated by considering the 1922 ratios and the change in the nature of telephone assets between 1880 and 1922. The ratios were interpolated between 1880 and 1922.

TABLE 11.10 **Value of telephone assets, measured in current prices, 1880–1900, in millions of dollars**

		1880	1890	1900
1	Land	0.3	1.4	8.2
2	Improvement	3.2	16.7	90.5
3	Equipment	3.2	18.1	107.0
4	Total	6.6	36.2	205.7

Sources: Lines 1, 2, and 3 obtained by multiplying Ulmer's (1960, table E-1) adjusted improvement and equipment total (line 4; see text for adjustment) by the ratios in table 11.9.

TABLE 11.11 **Value of telephone improvements and equipment, current and 1860 prices, 1880–1900, in millions of dollars**

		1880	1890	1900
	Improvements			
1	Value, at current prices	3.2	16.7	90.5
2	Price index (1860 = 100)	126	118	115
3	Value, at 1860 prices	2.5	14.2	78.7
	Equipment			
4	Value, at current prices	3.2	18.1	107
5	Price index (1860 = 100)	100	100	96
6	Value, at 1860 prices	3.2	18.1	111.5

Sources: Line 1: table 11.10, line 2. Line 2: table 11.6, line 6. Line 3: 100 × line 1 ÷ line 2. Line 4: table 11.10, line 3. Line 5: table 11.6, line 7. Line 6: 100 × line 4 ÷ line 5.

TABLE 11.12. **Value of electric light and power assets, measured current and 1890 prices, 1890–1900, in millions of dollars**

		1890	1900
	Current prices		
1	Land	2	13
2	Improvements and equipment	41	251
3	Total	43	264
	1890 prices		
4	Improvements and equipment	41	235

Sources: Line 1: Land made up about 5 percent of total fixed assets; see Ulmer 1960, table D-3. Line 2: Ulmer's (1960, table D-1, column 1) estimate, interpolated between adjacent first of year figures. Line 3: line 1 + line 2. Line 4: Ulmer's (1960, table D-1, column 2) constant value series interpolated between adjacent first of year figures and adjusted to an 1890 base.

Therefore, for the sake of consistency with our other categories, we have stated our telephone assets in 1860 dollars (see table 11.11). Readers will notice that two sets of price indexes figure in the estimates: ours and Ulmer's. We run the risk, therefore, of having our constant price series determined in part by irrelevant differences between deflators. Comparison of the changes described between the three census years by the two sets of deflators suggests that the risk is not a great one.

11.4. Electric Light and Power

We used Ulmer's (1960, 293–363) estimates, which were made by cumulating net investment flows, in constant prices, and then inflating them.

The constant-price estimates are on an 1890 base, not an 1860 base. See table 11.12 for details.

11.5. Conclusion

This chapter details the procedures to estimate the capital stock in the communications and electric utilities sectors.