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Chapter Author: H. Jerome Cranmer

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Canal Investment, 1815–1860

H. JEROME CRANMER
DREW UNIVERSITY AND BANKERS TRUST COMPANY

IN THE United States, more than 4,000 miles of canals were built between 1815 and 1860 at a cost of nearly $200 million. The present paper describes my attempt to develop a method of estimating annual expenditures for particular canals, which are then combined to yield regional and national totals and the relative investment of government and private enterprise. I also touch on the economic significance of the statistical findings.

Method of Estimation

Failure to keep adequate records, the destruction or loss of many records, refusal to adhere to homogeneous categories in the analysis of expenditures, and the use of the annual reports to obscure rather than clarify the fiscal operations of a company all have produced gaps in the primary sources. My study is based largely upon published materials which include reports of internal improvement commissions and state auditors, annual reports and other documents of private companies, contemporary surveys of internal improvements such as Armroyd, Mitchell, Tanner, and Poor; Purdy's survey in the 1880 census, the valuable tables in Whitford's *History of the Canal System of the State of New York*, and many monographs on particular canals or canal systems. The estimates, therefore, must be considered as only preliminary. More definitive estimates must await meticulous examination of manuscript sources, such as the records of individual companies.[1]

Canals were classified according to the availability of information about them. The first category contained projects about which all necessary information was available: total cost, annual expenditures, construction put in place but not paid for, and dimensions of the canal —mileage, lockage, area of prism, and so forth. In these happy cases it was necessary only to assemble the annual expenditures, adjust them for construction put in place but not paid for, and aggregate. This category accounted for $154 million, or some 79 per cent, of total canal investment.

The second category consisted of projects for which only partial expenditure information was available. Dimensions, total cost, or perhaps total expenditures to a particular date were known but not

[1] See Appendix A for a list of sources.

annual expenditure figures. This category provided about $33 million, or 17 per cent, of total canal investment. Here it was necessary to devise some means of apportioning total cost over the period of construction in order to get the desired annual estimates. For this purpose a typical pattern of annual expenditures was developed from a sample provided by twenty-four canals in the first category.

The third category consisted of canals for which virtually no costs were known. Dimensions, as well as years of construction, were usually available however. For such projects it was necessary to develop a way of estimating total cost which then could be distributed over the years of construction by means of the typical pattern mentioned above, which was done by a multiple regression analysis based on a sample of forty-four canals provided by the first and second categories. This category accounted for less than $6 million, or less than 3 per cent, of canal investment.

The fourth category consisted of a miscellany of canals about which only the most fragmentary information was available. Two factors were essential: mileage and years of construction. When either was missing the canal could not be included in the estimates. Fortunately the category was small, amounting to less than $2 million of total canal investment.

The typical pattern for annual canal investment was developed by an averaging process applied to the experience of a sample of twenty-four canals for which annual expenditure figures were available.[2] Several preliminary operations were required.

1. The annual expenditure figures for each canal had to be adjusted to take account of construction put in place but for which contractors had not been paid at the end of the fiscal year. Usually state boards of internal improvement and private canal companies withheld a percentage from each voucher as a performance bond against the contractor. Moreover, vouchers for work completed might be in process of being approved or paid and thus not appear in expenditures for the fiscal year in which the work was accomplished. A further adjustment was necessary to convert fiscal years into calendar years.

2. To be able to present both total expenditures and years of construction in comparable magnitudes, they had to be converted into percentages. Adjusted annual expenditures were converted into annual percentages of total cost, and calendar years of construction into annual percentages of the total number of years of construction.

3. The next step was the computation of "*C*" coefficients—the ratio of the annual percentages of total cost to the annual percentages of total years of construction (Table 1).

[2] See Appendix B for a list of these canals.

TABLE 1

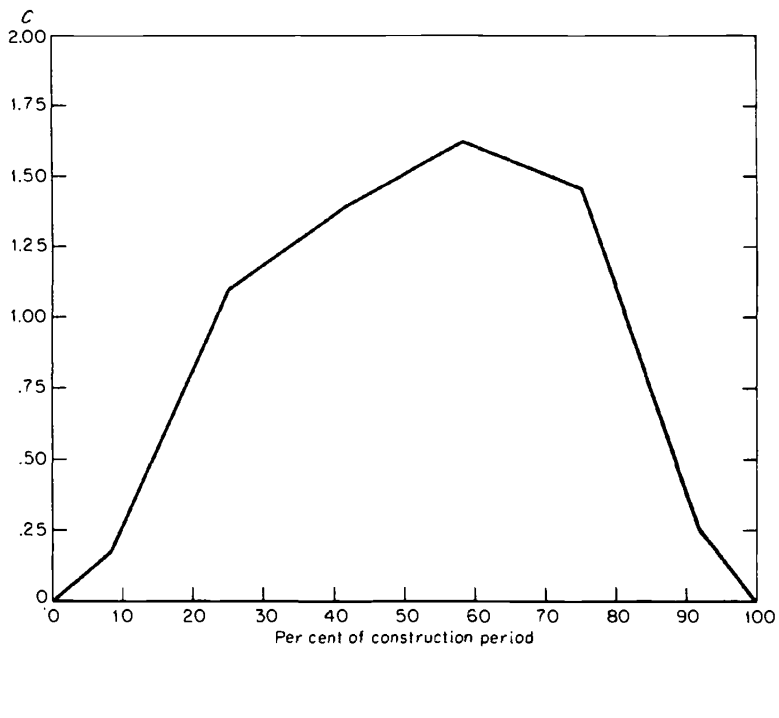
Development of a Sample Construction-Expenditure Profile, The Pennsylvania and Ohio Canal, 1835-1840
(dollar figures in thousands)

Year	*Construction Expenditures Adjusted*	*Percentage of Total Cost*	*Percentage of Construction Period*	*C Coefficient*
1835	$ 32.1	2.8%	16.7%	0.17
1836	207.5	18.3	16.7	1.10
1837	264.1	23.2	16.7	1.39
1838	308.1	27.1	16.7	1.62
1839	277.3	24.4	16.7	1.46
1840	46.1	4.1	16.7	0.25
	$1,135.2	100.0%	100.0%	6.00

Source: Annual Reports of the Pennsylvania and Ohio Canal Co., 1836-1841.

CHART 1

Construction Expenditure Profile, Pennsylvania and Ohio Canal, 1835-1840



Source: Table 1.

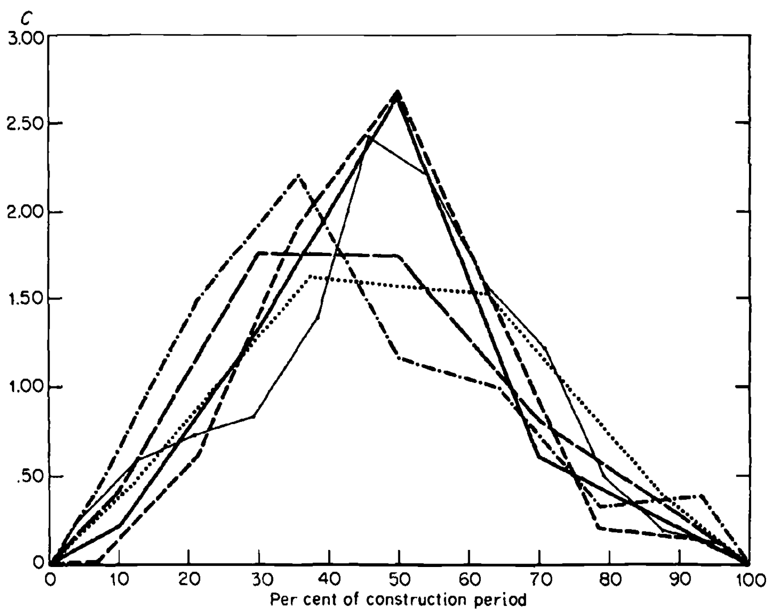
4. The coefficients were then plotted for each canal as in Chart 1, which provided a profile of its expenditure pattern.

Where canal expenditures were proportionately distributed over the period of construction, for example, 10 per cent of the cost incurred in 10 per cent of the time, or 50 per cent of the cost in 50 per cent of the time, the *C* coefficient is 1.00 throughout and the profile a horizontal line. However, as with the Pennsylvania and Ohio (Mahoning) Canal Company, used as an illustration in Chart 1, annual expenditures were by no means in proportion to period of construction. Rather the typical pattern was for a small beginning, a crescendo to a peak about the middle of the period, followed by a gradual decrescendo to the completion of the canal.

Profiles were constructed for each of the twenty-four canals of the sample and plotted on a single chart similar to Chart 2. The values of the *C* coefficients at each 5 per cent stage were then determined by inspection of each profile, and the mean value for each 5 per cent stage

CHART 2

Construction Expenditure Profiles, Six New York State Canals, 1817–1844



Source: Computed from Annual Reports (variously titled) of Controller of the State of New York re expenditures on canals, 1817–1844.

was computed. The result was a curve of means representing the average expenditure profile of the twenty-four canals. To smooth this curve, and particularly to round off a fairly sharp peak at the 50 per cent stage, a five-term moving average was applied. The resulting curve, shown in Chart 3, was taken as the typical pattern of canal construction expenditure, which provided a means of distributing the total cost of a particular canal over the period of construction, as illustrated in Chart 4 and

TABLE 2

Sample Distribution of Total Cost by Means of Construction Expenditure Pattern, The Pennsylvania and Ohio Canal, 1835–1840

(dollar figures in millions)

Year	*Percentage of Construction Period*	*Coefficient*	*Percentage of Total Cost*	*Annual Expenditures Estimated*	*Annual Expenditures Actual*
1835	16.7%	0.45	7.8	$ 89	$ 32.1
1836	16.7	1.18	20.6	234	207.5
1837	16.7	1.65	28.8	327	264.1
1838	16.7	1.50	26.2	297	308.1
1839	16.7	0.75	13.1	149	277.3
1840	16.7	0.20	3.4	39	46.1
	100.2		99.9	1,135	1,135.2

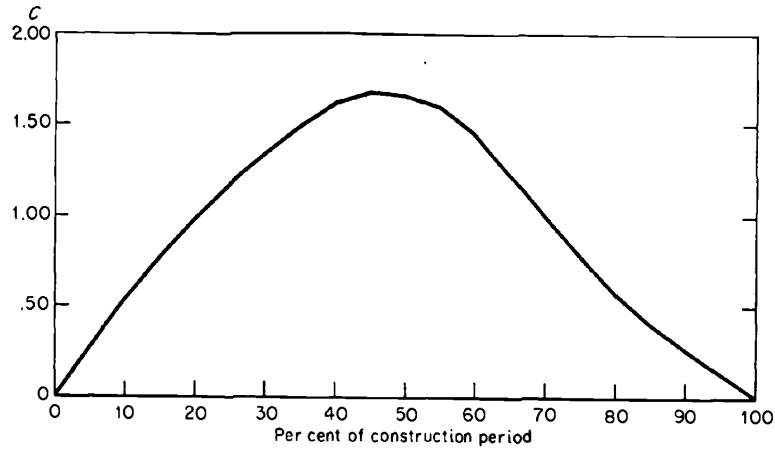
Source: Chart 4 and Table 1.

Table 2. In this way estimates of annual expenditure were developed from total cost figures.

The second major problem encountered in estimating annual canal investment was posed by canals for which no total cost figures could be found. Fortunately, descriptive information was available for most of these. The most important item was, of course, the length of the canal. Other variables—the kind of terrain traversed by the canal, the size of the canal, the years in which the canal was building—also seemed significant. Total mileage figures were available for nearly all of the projects. However, they were complicated by such considerations as whether or not the total mileage included "feeders" (canals for bringing water to the main line), as for the Delaware and Raritan Canal and the Union Canal of Pennsylvania. Total mileage figures were further complicated where the canal consisted of slack water navigation, as with the Lehigh Navigation Company; or where total mileage included railway or turnpike extensions, as with the Delaware and Hudson or the early James River and Kanawha canals. It was generally impossible to find detailed information about the terrain traversed by a canal—whether sand, clay, rock, marsh, or whatever. The amount of lockage

CHART 3

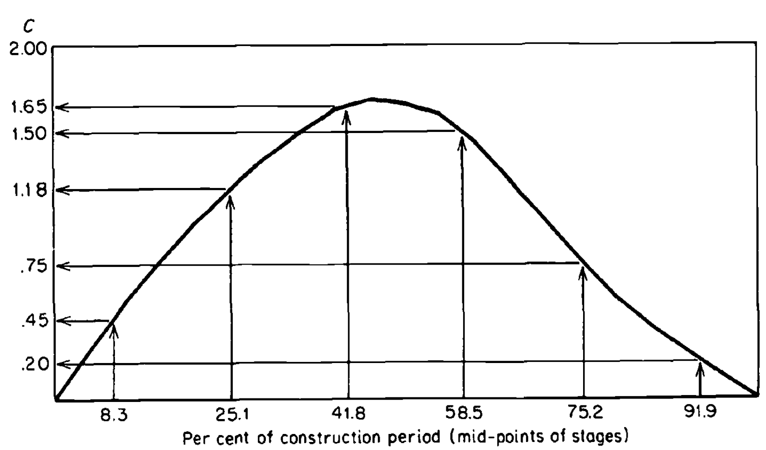
Construction Expenditure Pattern, Twenty-four Canals



See Appendix B for listing of canals included in the sample.

CHART 4

Sample Distribution of Total Cost by Means of Construction Expenditure Pattern, Pennsylvania and Ohio Canal, 1835–1840



Source: Table 2.

(the total rise and fall) indicated whether the route was mountainous or flat and very likely influenced total cost, although this was complicated by the resort to short railways to overcome elevations in projects such as the Morris Canal and the Pennsylvania main line. Further, the size of the canal clearly affected costs and, while it might be estimated by determining the area of the prism, frequently a single canal varied in width and depth, and often it was not possible to determine how many miles were of one size and how many of another.

Analysis relating cost and mileage, however, yielded promising results in the form of a correlation coefficient of 0.71. When the factors of lockage and size were included, the coefficient of multiple correlation rose to 0.81. Curiously, inclusion of years of construction made no significant improvement in the correlation and so this variable was not used in the determination of total cost. The analysis was based on a sample of forty-four canals of widely varying characteristics.[3] Their total cost was more than $100 million, or more than half of all canal investment during the period. The equation of multiple regression was:

$$X_1 = -35.1 + 1.7574X_2 + 0.5176X_3 + 0.0818X_4$$

where X_1 = total cost in tens of thousands of dollars
X_2 = mileage
X_3 = area of prism in square feet
X_4 = lockage in feet.

By substituting in the equation, estimates of total cost were made for large canals (50 miles or longer). Because the longer canals dominated the sample, the equation did not provide a good fit for the shorter canals. However, simple correlation between total cost and mileage, based upon a sample of canals of less than 50 miles in length, provided a satisfactory means of estimating the total cost of the shorter projects. Moreover, all the canals for which only years of construction and mileage were available were short, and the simple correlation was used to estimate total cost for each.

The Estimates

Adjusted estimates of annual expenditures were made for every canal or canal system undertaken between 1815 and 1860. Expenditures for river and harbor improvements were not included, or for slack water navigation except when the expenditures were part of a canal project. For example, the Monongahela Improvement undertaken in Pennsylvania in 1838, consisting of 57 miles of slack water navigation, was not included, but the Lehigh Navigation Company's works, consisting

[3] See Appendix C for a list of these canals.

of 36 miles of canal and 12 miles of slack water navigation was, since expenditures for the canal were indistinguishable from total expenditures. The estimates were then aggregated by region and by agency of enterprise within each region. The regional estimates were then aggregated to provide estimates of annual investment in canals for the entire United States, together with estimates for state and private enterprise. The estimates appear in Table 3.

The data indicate three major cycles in canal investment over the period. From less than $50,000 in 1815, the first cycle cumulates through the twenties reaching a peak around 1829 and declining to a trough in the thirties. By 1831, $50 million had been spent, and most of the projects had been completed or were nearing completion. New canals were being projected, and construction expenditures continued moderately high through the early thirties but not at the level reached earlier.

If profitability and life span be the test, the canals undertaken during this first wave were by far the most successful. This is particularly true of the private canals. Led by the Delaware and Raritan, the list includes the Delaware and Hudson, the Chesapeake and Delaware, the Lehigh and the Schuylkill navigations, and the Morris Canal. The same cannot be said of all private projects, however. The Farmington, the Hampshire and Hampden, the Union, and others enjoyed a far less happy fate and soon were abandoned. The state projects undertaken during the first wave also compare favorably to the projects of the later periods.

The second cycle began in 1836; the expansion phase continued to the 1840 peak and was followed by a precipitate drop to a trough in 1844. From more than $14 million in 1840, canal investment fell to less than $1 million in 1843 and again in 1844. Thus, while 1840 had the greatest volume of canal investment of the entire period (twice the earlier peak and nearly three times the subsequent peak), within four years investment had fallen to the lowest level since 1819. During this nine-year cycle some $70 million were invested in canal construction.

The second wave was distinguished from the earlier and later cycles by a greater degree of public investment and of building in the West. Public investment constituted less than 60 per cent of total investment in cycles one and three; in the second cycle it grew to almost 70 per cent. And western investment, which did not reach 10 per cent of total canal investment in cycles one or three, was over 30 per cent in cycle two. The greater amplitude of the second cycle probably is attributable to these two characteristics.

The third cycle began with an upturn in 1845, increased gradually to a mild peak in 1855, and then declined, once again gradually, to its end in 1860. This cycle was by far the mildest of the three in terms of amplitude of fluctuations. With its termination came the end of significant canal investment in the United States.

TABLE 3

Annual Investment in Canals by Region and by Agency of Enterprise, 1815–1860
(millions of dollars)

	UNITED STATES			NORTHEAST			SOUTH			WEST		
Year	*Total* (1)	*State* (2)	*Private* (3)	*Total* (4)	*State* (5)	*Private* (6)	*Total* (7)	*State* (8)	*Private* (9)	*Total* (10)	*State* (11)	*Private* (12)
1815	a											
1816	a											
1817	0.2	0.1		0.2	0.1							
1818	0.7	0.6	0.1	0.6	0.6	0.1						
1819	0.8	0.6	0.2	0.7	0.6	0.1	0.1		0.1			
1820	1.1	0.8	0.2	0.8	0.7	0.1	0.3	0.2	0.1			
1821	1.6	1.3	0.2	1.3	1.1	0.2	0.3	0.2	0.1			
1822	2.7	2.3	0.3	2.2	2.0	0.3	0.4	0.4	0.1			
1823	2.8	2.2	0.7	2.4	1.8	0.6	0.4	0.4	0.1			
1824	2.5	1.8	0.7	1.9	1.3	0.6	0.6	0.5	0.1			
1825	2.7	1.5	1.2	2.2	1.0	1.2	0.4	0.3	0.1	0.1	0.1	
1826	4.0	1.5	2.5	3.0	0.6	2.4	0.3	0.2		0.8	0.7	0.1
1827	5.6	2.3	3.3	4.3	1.4	2.9	0.4	0.1	0.2	0.9	0.8	0.2
1828	7.8	4.0	3.7	6.0	3.2	2.9	0.7	0.1	0.7	1.0	0.8	0.2
1829	7.0	3.7	3.2	5.2	2.9	2.3	0.8	0.1	0.8	0.9	0.7	0.2
1830	7.5	5.1	2.4	6.1	4.2	1.9	0.5		0.4	1.0	0.8	0.1
1831	3.7	2.2	1.5	3.0	1.6	1.3	0.1		0.1	0.7	0.6	
1832	4.6	2.9	1.7	4.2	2.6	1.6	0.1		0.1	0.4	0.4	
1833	5.3	2.7	2.6	4.9	2.5	2.4	0.2		0.2	0.2	0.2	
1834	4.4	2.8	1.6	3.9	2.4	1.5	0.1		0.1	0.4	0.4	
1835	3.5	2.0	1.5	2.9	1.6	1.3	0.1		0.1	0.5	0.4	0.1
1836	4.4	1.8	2.6	2.9	1.2	1.7	0.3		0.3	1.2	0.6	0.5
1837	8.2	3.9	4.3	4.4	2.0	2.4	1.2		1.2	2.7	2.0	0.7
1838	12.3	7.2	5.1	6.0	3.4	2.6	1.9		1.9	4.4	3.8	0.6
1839	13.6	9.5	4.1	7.3	5.4	1.9	1.9		1.9	4.4	4.1	0.4

continued on next page

TABLE 3 concluded

Year	UNITED STATES Total (1)	UNITED STATES State (2)	UNITED STATES Private (3)	NORTHEAST Total (4)	NORTHEAST State (5)	NORTHEAST Private (6)	SOUTH Total (7)	SOUTH State (8)	SOUTH Private (9)	WEST Total (10)	WEST State (11)	WEST Private (12)
1840	14.3	11.3	3.0	8.4	6.7	1.7	1.2		1.2	4.7	4.6	0.1
1841	11.7	9.8	1.9	8.8	7.4	1.3	0.5		0.5	2.4	2.4	
1842	3.1	2.6	0.6	1.8	1.5	0.3	0.3		0.3	1.1	1.1	
1843	1.0	0.7	0.3	0.3	0.2	0.1	0.1		0.1	0.6	0.5	0.1
1844	1.0	0.7	0.3	0.2	0.1					0.8	0.6	0.2
1845	2.0	1.1	0.9	0.7	0.3	0.4	0.3		0.3	1.0	0.8	0.2
1846	1.8	0.8	1.0	0.5	0.2	0.3	0.7		0.7	0.7	0.6	0.1
1847	4.7	1.1	3.6	3.5	0.4	3.1	0.6	0.6	0.6	0.6		
1848	4.5	1.5	3.0	3.9	1.1	2.7	0.3		0.3	0.3	0.3	
1849	3.4	1.9	1.6	2.9	1.7	1.2	0.4	0.4	0.1	0.1		
1850	4.9	2.3	2.5	4.2	2.3	1.9	0.7		0.7			
1851	4.7	2.0	2.8	3.8	1.9	2.0	0.8		0.8	0.1	0.1	
1852	3.4	1.9	1.5	2.8	1.8	1.0	0.5		0.5	0.1	0.1	
1853	3.8	2.4	1.4	3.3	2.1	1.2	0.2		0.2	0.3	0.3	
1854	4.7	3.8	0.9	4.0	3.3	0.6	0.3		0.3	0.5	0.5	
1855	5.3	4.2	1.1	4.6	3.8	0.8	0.3		0.3	0.4	0.4	
1856	4.2	3.2	1.0	3.6	3.0	0.6	0.4	0.4	0.2	0.2		
1857	3.5	2.9	0.7	3.0	2.8	0.2	0.5		0.5	0.1	0.1	
1858	2.8	1.6	1.1	2.3	1.6	0.7	0.4		0.4	0.1	0.1	
1859	1.9	1.4	0.5	1.7	1.4	0.3	0.2		0.2			
1860	1.2	1.0	0.1	1.1	1.0	0.1	0.1		0.1			
	194.6	121.1	73.5	141.3	88.8	52.5	19.7	2.5	17.2	33.5	29.8	3.8

[a] Less than $50,000.

Detail may not add to totals due to rounding.

Economic Significance

In recent years economic historians have been particularly interested in the circumstances governing economic growth and the question of the best agency for promoting growth. Much discussion has revolved around the relative roles of government and private enterprise. In considering decisions for public or for private enterprise in canal construction, it is useful to recall a distinction drawn by writers at the time. The distinction lay in the economic function to be performed by the canal. A canal was considered worthwhile if it stimulated the economic life of an otherwise isolated region. Such a canal may be characterized as a "developmental" project. On the other hand, a canal was also considered justified when the geographic and economic circumstances provided a profit opportunity. This may be considered an "exploitative" canal.

The distinction between developmental and exploitative canals casts light upon the attitude toward the role of government. If the waterway was to open up a new region to trade and commerce, clearly profits would have to await the anticipated development. The development might proceed slowly, and many years might pass before the canal could pay off its debt and begin to earn a profit or even meet current operating costs. Indeed the canal might never prove profitable and still be justifiable for the economic development it precipitated. The principal example was the great case of the Erie, which was begun in 1815 with slight prospects of reimbursing the state, quite apart from producing a revenue. The dominating purpose was to open the Mohawk Valley and western New York to settlement and development, and not until the canal was completed some ten years later did its amazing profitability become apparent. The Erie was widely imitated and contributed to the "canal mania" of the twenties and thirties. Its importance was not merely as a stimulus to internal improvement in general but as a stimulus to improvement by state enterprise. The great benefit brought to New York State through the enlightened action of its government provided a powerful incentive to other state governments.

On the other hand, it might be immediately and convincingly apparent that a particular canal would be a profit-making project virtually from the moment of its completion. Such was likely to be true if the waterway would help existing trade or connect two major commercial centers. Here it was merely a matter of determining the volume of the trade likely to use the canal and balancing the estimated revenue against the anticipated costs. If the results were particularly favorable, private capital might be expected to undertake the project. Or, as was repeatedly suggested in New Jersey for the Delaware and Raritan Canal, the state might build the canal and thus secure the revenues for itself. Thus the exploitative canal might be the creature of either private or public enterprise while the developmental canal could not be built without public action or public aid.

When I undertook this paper, I thought that a quantification of the roles of public and private enterprise in canal investment might be valuable and also that a regional distribution was in order. Accordingly, I aggregated the data by three major regions: the Northeast, South, and West, and provided a breakdown between state and private investment for each region (Table 3).[4]

Quite apart from the timing of participation, the data indicate the general magnitudes of participation by regions and by state and private enterprise. Thus, of the $195 million spent on canal construction during the period, $121 million (about 60 per cent) was spent by state governments, $74 million by private companies.[5] Of total canal investment almost three-fourths (73 per cent) took place in the Northeast, 10 per cent in the South, and 17 per cent in the West.

Public action predominated in the West, 89 per cent of canal expenditure being accomplished on state account. In the South, however, the opposite was true; 87 per cent of investment was by private companies. These figures support the presumption that public action characterized the underdeveloped frontier region, private enterprise the more mature regions. However, the Northeast, with two-thirds undertaken on state account and one-third by private companies, can by no means be said to provide a good fit. The most highly developed region in the United States was dominated, though less so than the West, by public enterprise.

The apparent contradiction presented by the Northeast is resolved by a recognition of the frequent difference between economic boundaries and political ones. By aggregating the data on a statewide basis we accepted the Pennsylvania–Ohio line as the boundary between the developed and the underdeveloped regions of the early nineteenth century. An alternative line suggests itself at once—the line of the Allegheny Mountains. Accordingly, canal investments by state and private enterprise were aggregated for two regions, the Seaboard (which includes canals lying entirely east of the ridge) and the Trans-Allegheny

[4] The Northeast consists of the New England and Middle Atlantic states, including Maryland and the District of Columbia. The South encompasses the area south of the Potomac and Ohio rivers. The West is the region north of the Ohio River. A single exception to the regional classification is provided by the Louisville and Portland canal which, though actually located in Kentucky, south of the Ohio River, is included in the West rather than the South.

[5] Since the estimates are of final expenditures only, inclusion of aid to private companies by local, state, or federal government would have involved double counting. Also, because funds are indistinguishable, it would not have been possible to apportion the government contributions over the years of construction. Consequently "mixed enterprises" were treated as private companies unless a clear-cut distinction could be made, with the result that government participation is underestimated wherever such aid was provided.

(which includes canals crossing or lying entirely west of it). I believe these regions to be more nearly homogeneous in stage of economic development than those established by state lines.

When canal investments are aggregated for the new regions, a somewhat different picture emerges (Table 4). Of total investment, $63.5 million (32.5 per cent), was in canals lying east of the Alleghenies. Of this, less than $4 million (6 per cent) was the work of state governments. Private undertakings made up 94 per cent of canal investments in the relatively more developed Seaboard region. Of a total investment of $131.7 million in the Trans-Allegheny region, $117.6 million (89.3 per cent) was by state government while only $14 million was by private enterprise.

Further insight may be gained by examining the individual canals that made up the minority groups. The canals constructed on government account in the Seaboard region were the Delaware Division of the Pennsylvania system, the Champlain Canal in New York, and a group of small canals undertaken by South Carolina. The Delaware Division canal was included in the Pennsylvania system through logrolling, as a device to gain the support of the northeastern corner of the state for the entire system. The Lehigh Coal and Navigation Company was prepared to undertake the project itself as a private enterprise should the state fail to build it. The Champlain Canal and the South Carolina canals are exceptions for which I found no explanation.

The major private canals of the Trans-Allegheny region were the Chesapeake and Ohio, the Louisville and Portland, the Pennsylvania and Ohio, the Sandy and Beaver, and the Cincinnati and Whitewater. The Chesapeake and Ohio and the Louisville and Portland received aid from the federal government, and the Chesapeake and Ohio, the Pennsylvania and Ohio, and the Cincinnati and Whitewater received state aid. Except for the Chesapeake and Ohio, all of the canals enjoyed some exploitative features. The Louisville and Portland was built to by-pass the falls of the Ohio and provide continuous steamboat navigation of that river. The Pennsylvania and Ohio provided a northern connection between the canal systems of Ohio and Pennsylvania, the Sandy and Beaver provided a southern one. The Cincinnati and Whitewater was designed to intersect the canal being built by the state of Indiana up the Whitewater Valley, the most populous section of the state, and to divert the traffic of that canal to Cincinnati.

TABLE 4

Annual Investment in Canals by Region and by Agency of Enterprise
(millions of dollars)

	SEABOARD			TRANS-ALLEGHENY		
Year	*Total*	*State*	*Private*	*Total*	*State*	*Private*
1815	[a]			[a]		
1816	[a]			[a]		
1817	[a]			0.1	0.1	
1818	0.1		0.1	0.6	0.6	
1819	0.2		0.2	0.6	0.6	
1820	0.4	0.2	0.2	0.7	0.7	
1821	0.4	0.2	0.2	1.1	1.1	
1822	0.7	0.4	0.3	2.0	2.0	
1823	1.0	0.4	0.6	1.8	1.8	
1824	1.2	0.5	0.7	1.3	1.3	
1825	1.5	0.3	1.2	1.2	1.2	
1826	2.6	0.2	2.4	1.4	1.3	0.1
1827	3.2	0.1	3.1	2.4	2.2	0.2
1828	3.5	0.2	3.3	4.3	3.9	0.4
1829	2.9	0.4	2.5	4.1	3.3	0.8
1830	2.4	0.7	1.7	5.1	4.4	0.7
1831	1.3	0.1	1.2	2.5	2.1	0.4
1832	1.1		1.1	3.5	2.9	0.6
1833	1.7		1.7	3.6	2.7	0.9
1834	1.1		1.1	3.3	2.8	0.5
1835	0.9		0.9	2.6	2.0	0.6
1836	1.5		1.5	2.9	1.8	1.1
1837	2.7		2.7	5.5	3.9	1.6
1838	3.2		3.2	9.1	7.2	1.9
1839	2.7		2.7	10.9	9.5	1.4
1840	2.3		2.3	12.0	11.3	0.7
1841	1.7		1.7	10.0	9.8	0.2
1842	0.6		0.6	2.6	2.6	
1843	0.2		0.2	0.8	0.7	0.1
1844				0.9	0.7	0.2
1845	0.7		0.7	1.3	1.1	0.2
1846	0.9		0.9	0.9	0.8	0.1
1847	3.5		3.5	1.2	1.1	0.1
1848	2.8		2.8	1.8	1.5	0.3
1849	1.1		1.1	2.4	1.9	0.5
1850	2.3		2.3	2.5	2.3	0.2
1851	2.8		2.8	2.0	2.0	
1852	1.5		1.5	1.9	1.9	
1853	1.4		1.4	2.4	2.4	
1854	0.9		0.9	3.8	3.8	
1855	1.1		1.1	4.2	4.2	
1856	1.0		1.0	3.2	3.2	
1857	0.7		0.7	2.9	2.9	
1858	1.1		1.1	1.8	1.6	0.2
1859	0.5		0.5	1.5	1.4	0.1
1860	0.1		0.1	1.0	1.0	
	63.5	3.7	59.8	131.7	117.6	14.1

[a] Less than $50,000.

Detail may not add to totals due to rounding.

APPENDIX A

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A. GENERAL

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3. Corporate Documents

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APPENDIX B

Canals Employed in Developing the Average Expenditure Pattern

Agency and Name	*Years of Construction*	*Cost* (millions)
New York State:		
Erie	1817–27	$7,144
Oswego	1825–28	565
Cayuga and Seneca	1827–29	237
Crooked Lake	1830–33	157
Chenango	1833–37	2,316
Genesee Valley	1837–44	5,663
Pennsylvania:		
Eastern Division	1826–34	1,347
Juniata Division	1827–34	3,047
Western Division	1826–30	2,760
Susquehannah Division	1828–33	1,039
West Branch Division	1828–33	1,580
Delaware Division	1827–30	1,238
Beaver Division	1828–33	519
South Carolina:		
Drehers	1820–22	78
Saluda	1819–22	157
Columbia	1820–24	211
Broad River	1820–25	111
Landsford	1820–26	130
Catawba	1820–26	164
Wateree	1821–27	158
Ohio:		
Ohio	1825–34	4,245
Miami	1825–31	788
Private:		
Pennsylvania and Ohio	1835–40	1,135
Louisville and Portland	1826–30	1,019

APPENDIX C
Canals Employed in Multiple Regression Analysis

Name	*Cost*[a]	*Length*[b]	*Prism*[c]	*Lockage*[d]	*Year Completed*
Cumberland and Oxford	25	21	104	143	1829
Middlesex	53	27	75	136	1804
Blackstone	60	45	104	451	1828
Hampshire and Hampden	23	22	112	298	1835
Farmington	60	56	112	218	1831
Erie	714	363	136	676	1827
Champlain	92	66	132	188	1823
Oswego	57	38	132	155	1828
Chemung	31	23	136	395	1833
Chenango	232	97	136	278	1833
Genesee Valley	566	114	136	1,045	1857
Black River	231	88	132	1,083	1849
Delaware and Hudson	188	108	96	1,073	1829
Delaware and Raritan	284	65	462	116	1834
Morris	311	103	104	1,674	1831
Eastern Division	135	43	287	132	1834
Juniata	305	130	170	615	1830
Western	276	104	136	471	1830
Susquehannah	104	39	321	68	1833
West Branch	158	72	180	107	1833
North Branch	140	73	158	90	1830
Upper North Branch	564	103	128	259	1850
Delaware	124	60	165	164	1830
Schuylkill	185	110	105	588	1825
Erie Extension	553	163	168	930	1844
Lehigh	156	85	265	353	1829
Susquehannah and Tidewater	326	45	215	233	1840
Chesapeake and Delaware	275	14	504	32	1829
Chesapeake and Ohio	1,011	185	280	610	1850
James River and Kanawha	126	37	119	237	1827
Albemarle and Chesapeake	164	44	595	2	1858
Dismal Swamp	68	30	248	85	1822
Santee	65	22	104	103	1802
Ohio	425	333	132	1,218	1834
Miami	788	244	215	907	1842
Wabash and Erie	633	379	132	505	1851
Illinois and Michigan	656	109	288	141	1848
Wateree	16	4	48	52	1827
Catawba	16	7	48	178	1826
Landsford	13	2	48	32	1826
Broad River	11	3	48	46	1825
Saluda	16	3	48	35	1826
Columbia	21	3	48	36	1826
Rocky Mount	20	5	48	122	1829

[a] Cost—tens of thousands of dollars.
[b] Length—miles.
[c] Prism—square feet of cross section.
[d] Lockage—feet of total rise and fall.

COMMENT

HARVEY H. SEGAL, New York University

Jerome Cranmer is to be congratulated. He has invaded a territory which, until recently, has been the exclusive province of the tow-path antiquarian, the folklorist, the retired engineer, and the nonquantitative historian.

My comments will be directed exclusively to Cranmer's methods of deriving his annual estimates of investment. His principal finding, that there were three long cycles in canal investment, appears to me to be valid. My objections concern the turning points and the amplitudes of those cycles.

Cranmer's estimates of annual investment cover three classes of canals, for which there are (1) annual data on construction outlays, (2) only total cost figures, and (3) no data on construction costs. Canals of the first class—for which there are data on annual construction outlays—account for about 60 per cent of Cranmer's estimate of total investment. About 90 per cent of the canals in that class were constructed by state governments. In his estimates of investment in the state projects, Cranmer relied upon the summary totals of annual expenditures reported periodically by state commissions; he did not examine the accounts for individual projects.[1]

This saved time, but I think the price was rather high. First, the summary totals include items which cannot be properly classified as construction expenditures, and damage payments, which frequently lagged construction operations by years. Thus Cranmer has probably overstated the total investment by some 7 per cent.[2] Second, Cranmer implicitly assumes that annual construction outlays, appearing in the summary accounts, were equal to the value of construction work completed. There were, however, periods of financial difficulty, particularly during the cyclical contraction of 1839–43, when payments to contractors lagged far behind the pace of construction, and outstanding indebtedness mounted. For the canal systems of New York, Pennsylvania, and Ohio, the differences between the annual construction outlays and the value of construction work completed in 1840–44 were very large, as the table on next page indicates (in millions of dollars).[3] Had Cranmer taken these data into account, the second canal cycle would have reached its peak in 1841 instead of 1840, and the ensuing

[1] Cranmer explained his procedure in a letter to the writer dated August 6, 1957.

[2] For the magnitude and composition of such outlays for the canals of the states of New York, Pennsylvania, and Ohio, see Harvey H. Segal, "Canal Cycles, 1834–1861: Public Construction Experience in New York, Pennsylvania and Ohio," unpublished dissertation, Columbia University, 1956, pp. 113, 117, 209–210, and 276–277.

[3] These estimates are based upon state documents relating to outstanding debts due canal contractors. Segal, pp. 119–120, 212, 243, and 278.

Year	New Construction Outlays	Value of Construction Work Completed	Difference
1840	8.2	8.7	−0.5
1841	5.6	9.1	−3.5
1842	3.8	2.4	+1.4
1843	2.5	0.4	+2.1
1844	0.8	0.3	+0.5

contraction would have been more severe.[4] Similar occurrences in the construction of public canal projects in other states should also be investigated.

In his estimates of annual investment for the second class of canals—those for which the only information is on the total cost—Cranmer employed what I shall call the average time-expenditure pattern. The patterns for individual canal projects, from which the average was derived, are based upon the functional relationship between what he called the C (construction) ratio and time (see his Chart 1). The C ratio for the j^{th} year of construction may be derived from the following relationship:

$$C_j = \frac{\dfrac{O_j}{\sum_{i=0}^{n} O_i}}{\dfrac{t_j}{\sum_{i=0}^{n} t_i}}$$

where O = construction outlays
t = time measured in calendar years.

Given the C ratio and the relative construction time elapsed, it follows that the relative construction outlay in the j^{th} year may be derived from the following relationship:

$$\frac{O_j}{\sum_{i=0}^{n} O_i} = C_j\left(\frac{t_j}{\sum_{i=0}^{n} t_i}\right)$$

The C ratios on which Cranmer's average-time expenditure pattern is based (see his Chart 3) were taken from a sample of twenty-four canals, constructed between 1817 and 1854, for which construction outlays are known. Some notion of the degree to which the individual

[4] Cranmer's annual estimates for the years 1857–60 would be altered had he taken into account the following differences between construction outlays and the value of work completed in New York state: 1857, \$−0.3 million; 1858, \$−1.0; 1859, \$0.0; and 1860, \$+1.3 (Segal, pp. 108 and 120).

patterns were smoothed in the single average pattern may be had by comparing Cranmer's Charts 2 and 3. A measure of dispersion, such as the average deviation of value about each *C* point in the average pattern, would have been helpful.

Assuming there were no appreciable payment lags or cessations of construction operations, the average time-expenditure pattern has a certain intuitive appeal.[5] Under certain restrictive conditions, it is reasonable to assume that the average time-expenditure pattern for uninterrupted canal construction will ascribe over time a polygon-like curve skewed to the right. Such a pattern merely indicates that construction outlays are relatively small during the early stages of work, that they reach a peak before half of the construction period has elapsed, and that they decline as the last details of a canal are completed.

However, an average-time expenditure pattern such as Cranmer has employed does not yield tolerably accurate estimates over forty-five years unless one can safely assume that: the time-expenditure patterns for long and short canals have shapes that are essentially alike; no technological changes take place over the period to which the pattern is to be applied; and construction costs remain constant.

I strongly suspect that there may be systematic differences in the shapes of the time-expenditure patterns for long and short canals, and that this accounts for a large part of the variation in the shapes of the patterns for the six New York State canals (Cranmer's Chart 2). The "clean-up" operations on a canal, including the sealing of leaks in the most recently flooded sections, would be an example of different time-expenditure patterns for long and short canals. The range of variation of mileage for the six canals is 358 miles.[6]

While no striking technological changes, such as the use of steam shovels, occurred during Cranmer's period, canal contractors in the late 1840's and the 1850's enjoyed substantial external economies which gave them a decided advantage over their predecessors. Stone quarries became more numerous and transport facilities were often superior. These factors must have affected the shapes of the time-expenditure patterns.

Finally, canal construction costs fluctuated widely, particularly between 1834 and 1860. Data on total construction costs are scarce, but the available evidence indicates that total construction costs rose by at least 33 per cent between 1836 and 1839 and then declined sharply after 1842 when most construction activity ceased.[7] Rising construction costs would tend to truncate the right-hand tail of the time-expenditure

[5] Work on one of the twenty-four canals in Cranmer's sample, the Genesee Valley Canal of New York, was interrupted for six years between 1841 and 1847. It is difficult to appraise the effects of the inclusion of that canal on the average time-expenditure pattern.

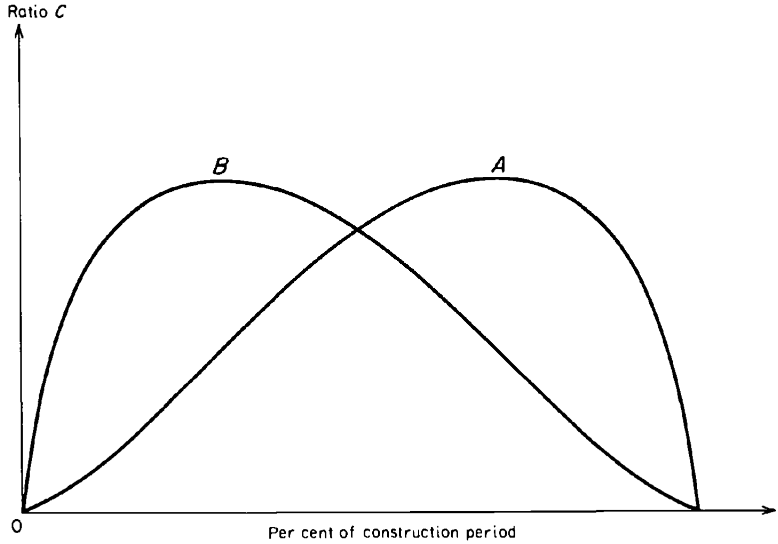
[6] The Crooked Lake canal was only eight miles long; the Erie was 363 miles long.

[7] See Segal, pp. 44, 201, and 296–297.

pattern for an individual canal, producing a left skew as in line *A* of Chart 1; falling construction costs would tend to accentuate the right-skewness, as in line *B*.[8]

CHART 1

Hypothetical Time-Expenditure Patterns Under Conditions of (*A*) Rising and (*B*) Falling Construction Costs



CONSTRUCTION PERIOD

When a nearly symmetrical average time-expenditure pattern, such as Cranmer's in his Chart 3, is used in allocating total cost under conditions of rising labor and material costs, we should expect overestimates of the actual outlays for the early years of the construction period and underestimates for the later years. Opposite errors would obtain when prices were falling.

Cranmer's own material appears to support my contentions. Note that his time-expenditure pattern for the Ohio and Pennsylvania Canal (Chart 1) is left-skewed, a shape we would expect to obtain under conditions of rising prices.[9] In his allocation of total costs of the Ohio

[8] Assuming, of course, that the construction time for individual contracts was short enough for rising prices to affect the cost of a project. When it was not, contractors frequently abandoned their sections or, in the case of state projects, appealed to the legislatures for special relief.

[9] This canal was constructed during a period of rising construction costs. It passed through a lightly populated area in which there was brisk competition for labor.

and Pennsylvania (Chart 4), the pattern of the errors is in accord with my expectations. Also, the errors of estimation for 1837 and 1839 are very large; expressed as percentages of actual outlays (disregarding signs) they amount to 22 per cent and 53 per cent, respectively.[10]

Although Cranmer did not prepare an annual breakdown of the allocated component of his estimates, we may assume that it is approximately equal to the ratio of "private" canal investment to the total (columns 1 and 3 of Table 3). That ratio varied from 16 per cent in 1841 to 100 per cent in 1816, and for the entire period, the ratios were distributed as follows:

Percentage of Private Investment to Total	*Number of Years*
Less than 20	7
20 and less than 30	12
30 and less than 40	5
40 and less than 50	11
50 and less than 60	6
60 and less than 70	2
Over 70	2
Total	45

Given sizable errors of allocation for individual canals, their relative importance in the annual totals will be equivalent to the ratio of the allocated component to the total shown above. The absolute magnitude of the errors will depend upon the total investment in a given year and on the proportion of the total that was derived by allocating total costs. The twenty-one years for which Cranmer estimated 40 per cent or more of the total investment by the allocating method account for $91,240,000, or more than 46 per cent of the grand total of investment. Differences in the direction of the errors could reduce the total error for a given year, but in the absence of detailed information it is impossible to say how important the offsetting might be.

For the last class of canals—for which there was no information on costs—Cranmer first estimated the total cost by means of a multiple regression equation and then used his average time-expenditure pattern to derive annual estimates. In deriving the regression equation, he used data on the physical characteristics of forty-four canals constructed between 1804 and 1857. His dependent variable, total cost, is expressed in current prices, and as a consequence it is difficult to evaluate his estimate of the total costs of canals, for which there is no information. Presumably, the resulting cost estimates represent some weighted

[10] In his Chart 4, Cranmer did not "level-up" the annual C ratios so that they total six. If that correction is made, the errors are 25 per cent and 49 per cent, respectively.

average of the construction cost levels between 1804 and 1857. Also, two of Cranmer's three independent variables, prism size and lockage, are of questionable value. Prism designs varied among canal projects; those lined with masonry benchwalls, as on the enlarged Erie Canal, cost far more than ordinary prisms of the same size. Locks varied in design, construction, and size of lock chambers, with resultant differences in construction costs.

I should like to suggest these improvements in Cranmer's estimates:

1. Construction of a separate annual series of estimates of investment in canals for which annual construction outlays are known, with adjustments for periods in which payments lagged behind the value of construction work completed. Such a series would be valuable in the analysis of cycles, and in dating their turning points. The annual totals would probably represent the bulk of canal investment for most years.

2. Tests of possible systematic variations in the time-expenditures patterns of large and small canals, and of canals of approximately the same size built in different periods.

A more difficult problem is posed by changes in construction costs. First, Cranmer might compile a canal-construction cost index with which to deflate the estimates yielded by the appropriate average time-expenditure pattern. Before applying such a deflator, he would need to know the average duration of construction contracts. Second, if such an index cannot be constructed, he might alter the shape of the time-expenditure curve to make rough allowances for changes in costs where only the direction of the change is known. The accuracy of these manipulations could be tested by applying them to the total costs of canals for which there is information on annual construction outlays.

3. No attempt should be made to estimate the total costs of canals for which there is no information unless the cost data used in the estimating equation can be deflated and the dependent variables can be expressed in a more satisfactory form.