British Industrialization And The Profit Constraint Hypothesis:

The Case Of A Manchester Cotton Enterprise, 1798-1827

Harvey S. James, Jr.

Department of Economics
University of Hartford
200 Bloomfield Ave.
West Hartford, CT 06117
(860) 768-4864
hjames@uhavax.hartford.edu

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Abstract: This paper test the hypothesis that capital market imperfections constrained the growth of British firms during the Industrial Revolution. Using data on the cost structure of a representative British cotton manufacturer during the 1798 to 1827 period, this paper shows that the scale of operation was too small. The findings suggests that industrialization could have proceeded more rapidly if firms would have had access to alternative sources of capital financing. (JEL N2)

Keywords: Industrial Revolution, capital markets, cotton manufacturing.

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I. Introduction

Most scholars of the Industrial Revolution agree that British firms relied primarily on internal sources to finance long-term fixed investments. However, there is general disagreement about the causes and consequences of internal financing. In discussing the nature of capital formation during the British Industrial Revolution, Mokyr argues that imperfections in the capital market resulted in the suboptimal use of internal financing for long-term fixed investment. The consequence was that investment activities may have been constrained by the rate of growth of profits. Specifically, Mokyr states that "the capital market's imperfection meant that from the outset the rate of profit set a ceiling on the rate of accumulation" (1985, p. 38).

In this paper I examine the validity of the profit constraint hypothesis. In particular, I present evidence in support of the profit constraint hypothesis. Using data on the cost structure of a representative cotton manufacturer during the 1798 to 1827 period, I show that the scale of operation of British firms was inefficient and that industrialization could have proceeded more rapidly if firms would have had access to alternative sources of capital financing.

The paper is organized as follows: section II examines the background of studies on the British capital market and firm investment decisions during the Industrial Revolution. Section III presents a brief discussion of the nature of the British cotton industry. Sections IV and V outline the model, methodology, and data used in this study. Finally, sections VI and VII present a discussion of the results as well as suggestions for future research.

II. Background

The causes and consequences of the internal financing of long-term investment by British firms during the Industrial Revolution has been intensively debated. While few scholars would argue that the British capital market was imperfect, many question the extent to which problems in the capital market affected the performance of British firms and thus industrialization. That is, the issue concerns the degree to which British capital markets operated imperfectly in supplying the capital needs of a growing industrial base, as well as how firms responded to such market conditions.

The debate seems to center around two camps. One, manned almost exclusively by Crouzet, states that while capital markets may have been problematic, they did not adversely affect industrial development in England. As Crouzet explains:

> [O]ne does not have the impression that the pioneers of the Industrial Revolution came up against insurmountable problems in raising the long-term capital they needed ... On the whole, the eighteenth-century capital market seems to twentieth-century eyes, badly organized, but the creators of modern industry do not seem to have suffered too much from its imperfection. We shall reach the same conclusion when we consider, after the problem of the initial outlay for the founding of enterprises, that of financing their expansion. (1965, p. 187-188)

Gattrell (1977) presents a similar argument. He provides evidence that Lancashire cotton manufacturers were "small to middling" in size, not because of capital market inefficiencies, but rather due to preferences for small-scale production. That is, size had nothing to do with considerations of scale economies. Instead, early British entrepreneurs felt that the cotton spinning technologies were simply better suited for small facilities.

The other camp, championed by Mokyr and others, contends that industrial performance could have improved if capital markets operated more efficiently. Their thesis is that capital market imperfections caused firms to rely on inferior methods of supplying their fixed investment requirements.

Chapman's (1970, 1979) studies of Lancashire cotton firms is illustrative. Chapman shows that, although the fixed capital needs of British manufacturers were lower than previously considered, cotton manufacturers were too small and suffered higher-than-average bankruptcy rates as the result of shortages of long-term capital supplies.

One of the shortcomings with these studies is that they attempt to address the problem of how the capital market affected British firms using aggregated data. Thus, they suffer from the problem of the choosing the appropriate method of aggregation, as well as that of determining the appropriate price of capital. If capital markets were inefficient, the estimates of the overall value of capital based upon "market" prices would reflect the biases in the capital market. This paper improves on the earlier analyses by examining the behavior of individual firms and then inferring to the entire population based upon the results and established economic theory. It also utilizes a methodology that does not require the valuation of capital employed.

There is clearly more work that needs to be done in determining the specific nature of problems within the British capital market and how that affected firm performance. However, this paper is not an attempt to provide evidence for or against the proposed imperfections of the British capital market. Furthermore, a determination of the extent to which firms relied on internal financing for long-term fixed investments is also beyond the scope of this paper. Instead, the purpose of this study is to test the specific hypothesis that the growth of British cotton manufacturers was constrained by the rate of growth of profits.

III. British Cotton Manufacturing

The cotton industry was one of the most dynamic sectors in British economic growth. Between 1770 and 1831, cotton's influence on British industry changed from relative unimportance to the most important industry next to building, in terms of value added (Crafts, 1985). Indeed, production of cotton yarn increased over 500 percent during the first three decades of the nineteenth century (Shapiro, 1967).

Cotton production in England became centered in Lancashire, particularly at Manchester, although cotton production was also established in Yorkshire, Cheshire, as well as in parts of Scotland and Ireland. However, Lancashire remained the primary location of the cotton industry. Of the 934 estimated cotton mills in England in 1833, 657 were located in Lancashire (Baines, 1835, p. 389). Between 1780 and 1800, raw cotton imports into Lancashire increased nearly eightfold, from 5 million pounds per year to over 50 million pounds (Lee, 1972). In addition, the growing cotton industry resulted in money wages in Lancashire typically exceeding those in London, sometimes by more than 50 percent (Shapiro, 1967).

The nature of production in the cotton industry changed over time as developments in the spinning process became available. While the jenny and mule worked reasonably well in both the workshop and factory settings, the Arkwright process and water frame required larger outlays on fixed capital and thus more extensive production facilities (Honeyman, 1982). Economies of scale, which were clearly recognized from the late eighteenth century (Chapman, 1979), as well as the need to ensure an adequate quality of output, further influenced the desire to utilize larger production facilities.

There are few sources on the total value of capital invested in British cotton manufacturing during the Industrial Revolution. Chapman and Butt (1988) report that in 1788, capital investment is estimated at roughly L1.9 million. By 1811/12, they estimate that capital investment increased over 400% from 1788 levels.

Data on initial capital outlays are somewhat more accessible. Small-scale cotton operations typically required an initial capital requirement of about L1,000-L2,000. Larger mills, utilizing the more advanced Arkwright technology, often required more than L3,000 as an initial investment. These firms usually began with approximately 1,000 spindles, although some mills started at twice the size (Honeyman, 1982).

These figures suggest that the cotton industry was important to British economic development, although the specific contribution to aggregate output remains uncertain (see Craft, 1985). Nevertheless, a study of the cotton industry will provide meaningful insights into the role capital markets and firm investment activities played in British industrialization.

IV. The Model

To test for the possible presence of a profit constraint affecting investment activities in British firms, I estimate the economies of scale for a representative manufacturer by examining the firm's cost structure over a period of time. A measure of economies of scale would provide a reasonable test of the profit constraint hypothesis. Specifically, if a firm is forced to rely primarily on internal sources of financing, because manufacturers cannot access external capital markets or because the firm chooses to do so for other reasons, the rate of capital accumulation may be constrained by the rate of profit growth. If the profit constraint is binding, then the firm may not be able to expand efficiently and its capital to labor ratio will be too low.[1] Thus, increasing economies of scale would exist throughout the relevant range of output.

Of course, capital markets could be operating imperfectly but the firm not be profit constrained because internal financing is able to meet the investment needs of the firm. However, this implies that the profit constraint is not binding on the firm's optimization problem over time, which suggests that internal sources were sufficient to provide an efficient level of productive capacity.

The methodology of estimating cost functions for an individual firm follows that of Braeutigam, Daughety, and Turnquist (1982), who estimated a variable cost function using monthly data for a single railroad company. The alternative would be to estimate cost functions for a cross-section of British firms. However, complete data does not exist to permit an adequate examination of cost structures for the early nineteenth century. The results of this analysis are generalizable because I assume that the firm examined is representative of a typical early nineteenth century British manufacturer.

The variable cost function allows estimation of returns to scale at the level of output during the period examined. The test is at the point of output and not along the efficient expansion path because I am testing the hypothesis that the firm's capital to labor ratio is too small.[2] Thus, factor prices for the level of capital are not required.[3] In addition, capital is assumed to be the fixed factor. The method of examining variable costs is appropriate because, although capital would certainly be expected to change

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[1] The derivation of the capital to labor ratio under profit constraint is presented in the appendix.
[2] See Braeutigam and Daughety (1983) for a discussion of the two methodologies.
[3] This approach has the additional advantage of avoiding the problem of determining the appropriate price of capital. This is important because I wish to avoid a priori assumptions on the completeness of the capital market, since market imperfections are assumed to exist if firms are profit constrained.

over time, the hypothesis is that accumulation is not efficient.

The general representation of the short-run cost function is as follows:

$$c_v(y, p_l, p_c; k), \tag{1}$$

where c_v represents the short-run costs of the firm; y represents the quantity of output produced annually; p_l and p_c are the exogenously determined factor prices for labor and cotton inputs respectively; and k represents the level of the fixed factor of production.[4]

According to Braeutigam and Daughety, returns to scale, estimated at the point of operation from the variable cost function, is given by the following formula (where r is returns to scale):

$$r = [1 - (\delta \ln c_v / \delta \ln k)] / (\delta \ln c_v / \delta \ln y) \tag{2}$$

A linear representation of the Cobb-Douglas function is used to estimate the variable cost function (1) using econometric methods. The equation is defined as follows:

$$\ln c_v = a_o + a_y \ln y + a_k \ln k + \Sigma a_i \ln p_i \tag{3}$$

where $p_{i,}$ i=1,2 represents the factor prices of the variable inputs and a_o, a_y, a_k, and a_i are the parameters to be estimated.

The Cobb-Douglas functional form is restrictive in the sense that it does not allow the returns to scale to vary with output. Thus, estimated returns to scale will be greater than, equal to or less than one over the entire relevant range of output. Nevertheless, the use of the Cobb-Douglas will allow a general approximation of the scale economies which for the particular firm examined.

To ensure that the estimated cost function is well-behaved, economic theory specifies that it be homogenous of degree one in input prices. This condition is accomplished by restricting the parameters on input prices to sum to one. That is, Sai=1 for i=1,2.

Furthermore, to complete the estimation requirements, an error structure is added to (3) because of the possibility of random errors in the measurement of the data or the result of uncertainties in the firm's optimization problem. I assume the errors are identically and normally distributed, with a mean of zero. However, because the data is a time series, I will correct a priori for possible autocorrelation by using generalized least squares techniques.

V. Data

The data for this study are taken from the records of the M'Connel & Kennedy company, a cotton manufacturer located in Manchester, Lancashire, England. The records were compiled and published by Lee (1972), who also added a short history of firm.

M'Connel & Kennedy was formed by James M'Connel and John Kennedy, who went into partnership with Benjamin and William Sandford in 1791. The main business was in the making of spinning machinery, with mule spinning and yarn production as a second line. The original partnership dissolved after four years, but M'Connel and Kennedy formed a second partnership under the same name. Their initial capital outlay totaled approximately L1,700. While the firm continued to promote its machinery making operations, it gradually moved to emphasizing the more profitable cotton spinning business. The partnership was very successful. The firm was of the largest employers in Manchester, and typically paid above average wages to its spinners and mechanics. Furthermore, between 1796 and 1810, the firm's net worth increased almost 13 fold, with an average of 19 percent return on capital invested (Lee, 1972; Shapiro, 1967).

Annual data for the 1789-1827 period were taken from Lee (1972), as well as from other published sources.[5] Physical output is calculated from the valuation of yearly sales of yarn divided by the price of an average quality of mule yarn, as reported from the M'Connel & Kennedy records (see Lee, 1972, pp. 157-158, 176). Number of mules and number of spindles were taken from the inventory of the firm's spinning machinery (Lee, 1972, p. 162) and are used as the measure of the fixed factor. The number of mules grew from 38 in 1798 to 400 in 1827. The number of spindles ranged from almost 7,500 to well over 124,000 during the same time period.

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[4] A more detailed discussion of the data is given in section V.

Input prices for labor and cotton wool were taken from Wood (1910, p. 127) and Baines (1835, pp. 313-314) respectively. The yearly wage bill was computed assuming a 200 workday year. Annual wages ranged from a low of 399 pounds to a high of 26,954 pounds. Moreover, the value of cotton inputs per year for the 1798-1827 period ranged from 3337 pounds to 29,381 pounds.

VI. Results

Two equations were estimated. One equation used the number of mules as the yearly level of the fixed factor; the other used the number of spindles as the capital measure. The results are shown in table 1.

(Table 1 about here)

The estimated returns to scale for the cotton manufacturer is computed using Braeutigam and Daughety's formula $(1-a_k)/a_y$. Returns to scale using the number of mules as the measure of capital is 1.503. Similarly, returns to scale utilizing spindles as the fixed factor measure is 1.533. These indicate that over the relevant range of output, the British cotton firm M'Connel & Kennedy was operating in an increasing returns to scale region. That is, the firm generally utilized an inefficient level of capital. Consequently, these results cannot reject the hypothesis that capital accumulation was constrained by the use of internal sources of financing.

An examination of the elasticity of cost with respect to output (read directly from the coefficients in the table) confirms this finding. Cost elasticity with respect to output is 0.604 and 0.628 for each model estimated respectively. Thus, short-run marginal cost is below short-run average cost, or average cost is falling.[6]

VII. Conclusion

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[5] Averages were used for missing data for the independent variables where appropriate and reasonable.

[6] According to Braeutigam, Daughety, and Turnquist (1982), this can be shown as $dc_v/dy=(0.604)*(c_v/y)$ at the point of means.

The evidence presented lends support to Mokyr's prediction that the profits of British firms set a ceiling of the rate of capital accumulation. Thus, it appears that output could have expanded and that firms could have likely enjoyed relatively higher profit rates if they were able to employ higher levels of capital. Additional research is necessary to determine the extent to which profits constrained the growth of British firms by limiting their ability to acquire capital.

Appendix

To show how a binding profit constraint results in a capital to labor ratio that is too small (capital is under-utilized and the scale of operation is too small), I follow the methodology of Averch and Johnson (1962). In their seminal paper, they showed that for regulated firms, when the rate of return on capital is allowed to exceed the true cost of capital, too much capital will be employed and the capital to labor ratio will be too low.

Suppose a firm maximizes profits, subject to the constraint that capital investment does not exceed profits.[7] The constrained optimization problem facing the firm is:

$$\text{MAX } Pr^* = P\ f(K,L) - c(P_k,P_l,K,L)$$

$$\text{s.t. } P_k K <= Pr^*,$$

where Pr* is profits; P is the price of output; f(.) represent the production or output function, with inputs of capital, K, and labor, L; c(.) is the cost function, with costs a function of the prices of inputs as well as the quantity of inputs employed. The constraint represents the presumption that capital expenditures are constrained by the level of profits.

Differentiating using Kuhn-Tucker techniques yields the following first order conditions:

w.r.t. K: $P\ f_k - c_k + y(P\ f_k - c_k - P_k) = 0,$

w.r.t. L: $P\ f_l - c_l + y(P\ f_l - c_l) = 0,$

w.r.t. y: $P\ f(.) - c(.) - P_k K = 0,$

where y is the shadow price and f_a and c_a represent the marginal valuation, a=k, l.

The complimentary slackness condition is:

$$y(P\ f(.) - c(.) - P_k K) = 0.$$

Rearranging terms gives for labor $MRP_l=P_l$; but for capital, $MRP_k>P_k$. Similarly, one can show:

$$(P_k/P_l) < (f_k/f_l).$$

[7] For simplicity, I assume a one-period model and output price exogenously determined. These assumptions do not affect the results qualitatively.

This indicates that the capital to labor ratio is too low, or that too little capital is being utilized.

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Table 1. Estimates of the Cobb-Douglas Variable Cost Function

Coefficient	Equation 1 (Mules)	Equation 2 (Spindles)
a_o	6.958	6.805
	(0.518)	(0.918)
a_y	0.604	0.628
	(0.072)	(0.068)
a_k	0.092	0.004
	(0.142)	(0.119)
a_1	0.657	0.664
	(0.134)	(0.135)
a_2	0.343	0.336
	(0.134)	(0.135)
RHO	0.207	0.181
	(0.179)	(0.180)
R2	.94	.94

Standard errors are in parentheses