A TEST OF CAPITAL-LABOR SUBSTITUTION USING CAPACITY DATA

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I. INTRODUCTION

Despite the large amount of research that has been done in the field of investment behavior, there still appears to be no general agreement on how investment expenditures are determined and in particular no general agreement on the degree to which relative factor prices are important in determining investment expenditures.[1] There are a number of possible reasons for this lack of agreement. One reason is the aggregative nature of much of the empirical work in this field. It may be asking too much of the aggregative data to expect that the data can distinguish, for example, among hypotheses that are based on different assumptions about the degree of substitution between capital and labor. A second reason is the questionable nature of most of the capital-stock data. Capital-stock data are usually constructed from deflated investment data, and this procedure may lead to large errors in measuring the stock of capital because of possible inaccuracies in the price deflators used and because of the restrictive assumptions that usually have to be made about how the stock of capital depreciates.

A third possible reason for the lack of agreement is the fact that there may be more than one way in which capital-labor substitution can take place. Consider, for example, a putty-clay technology, where at any one time

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[1]This lack of agreement is perhaps best reflected in the extensive debate between Robert Eisner and his collaborators on the one hand and Dale Jorgenson and his collaborators on the other. See Eisner [3] for one of the latest in the series of comments and replies.

different types of machines with differing worker-machine ratios can be purchased. Assume that the worker-machine ratio is fixed for each type of machine and that technical progress is reflected in new types of machines. The standard way in which capital-labor substitution can take place in this case is for the ratio of the wage rate to the cost of capital (to be called the wage-rental ratio) to have an effect on the types of machines purchased. A high wage-rental ratio should cause firms to purchase high-priced machines with low worker-machine ratios, and vice versa. Salter [7], however, has pointed out two other ways in which capital-labor substitution may take place in this case.[2] First, the direction that technical progress takes may be a product of changing factor prices rather than of new knowledge. To the extent that, say, a rising wage-rental ratio causes technical progress to be biased toward labor-saving techniques (i.e., labor-augmenting technical progress growing faster than capital-augmenting technical progress), this can be considered to be a form of capital-labor substitution. Second, capital-labor substitution may come about by speeding up the rate of replacement investment. If, for example, technical progress is on average biased toward labor-saving techniques, then speeding up the rate of replacement investment will result on average in the purchase of machines with lower worker-machine ratios than the machines being replaced. To the extent that one ignores the different forms that capital-labor substitution may take, one may be led to make erroneous conclusions regarding the degree of substitution.

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[2]Salter [7], pp. 24, 71.

A fourth possible reason for the lack of agreement is that the cost of capital may affect investment in ways that have nothing to do with capital-labor substitution in the usual sense. Consider the firm in an optimal control context as maximizing the present discounted value of expected future after-tax cash flow, given an expected sales path. Assume the same technology as above. Whatever production path is chosen in this process, investment in new machines must be sufficient to meet the production requirement each period. If production fluctuates during the year, the number of machines on hand must be sufficient to meet the peak production requirement during the year. The choice of the optimal production plan, given an expected sales path, should be a function, among other things, of inventory costs, of costs of changing production (including employment-fluctuation costs), and of costs of holding idle machines and workers during slack periods. Costs of changing production and costs of holding idle machines and workers should induce a firm to smooth production relative to sales, whereas inventory costs should have the opposite effect. Costs of holding idle machines and workers during slack periods should induce a firm to smooth production relative to sales because the more production is smoothed during, say, a year, the fewer machines and workers will be needed to meet peak production requirements during the year. Therefore, since the cost of capital has a positive effect on the cost of holding idle machines, a rise in the cost of capital should induce a firm, other things being equal, to smooth production more and reduce the number of machines held and thus reduce investment. A rise in the cost of capital may thus lead to a decrease in investment even if capital-labor substitution in the above three senses does not take place. In other words, even if there were only one type of machine in existence, the cost of capital may still affect the number of machines held and the wage rate may still affect the number of workers employed by affecting the firm's production-smoothing decision.[3] The fact that the cost of capital may affect investment in this way is another possible reason why there has been so little agreement on the importance of the cost of capital in determining investment expenditures. In Bischoff's work [1], for example, it is not possible to separate the effects of the cost of capital on investment expenditures that are due to capital-labor substitution from those that are due to other causes. Bischoff assumes, among other things, that the desired capacity-output ratio is constant (p. 71) and that replacement investment is a constant proportion of existing capacity (p. 73). Because of these and other assumptions that Bischoff is required to make, it is really not possible to interpret his estimates of the elasticity of substitution as estimates of the degree of capital-labor substitution. At best the estimates relect some average effect of the cost of capital on investment expenditures.

In this paper a somewhat different approach than usual is taken to try to test for the effects of capital-labor substitution. For two three-digit United States manufacturing industries--Cement and Steel--rather good data on capacity are available, and the purpose of this paper is to use these data to try to determine the importance of capital-labor substitution. Many of the problems associated with investment and capital-stock data are avoided by using capacity data, and this study should be able to provide

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[3]See Fair [5] for a model of firm behavior encompassing price, production, investment, and employment decisions in which the cost of capital may affect the investment decision of the firm in ways that have nothing to do with capital-labor substitution.

information regarding the importance of capital-labor substitution that cannot be provided merely from using investment data. In addition, the availability of capacity data allows one to distinguish between decisions of the firm regarding how much capacity to install and decisions regarding the types of machines to purchase to meet the capacity requirements. Given capacity data, one can concentrate only on the second decision. The effect of the cost of capital on the desired level of capacity (through its effect on the production-smoothing decision and the like) can thus be separated from its effect on capital-labor substitution.

Any attempt to determine the degree of capital-labor substitution must take account of short-run fluctuations in capacity utilization. The results in Fair [4] indicate that most firms hold a considerable amount of excess labor during slack periods, and the monthly data on capacity utilization for the Cement and Steel industries indicate that firms operate well below 100 percent capacity much of the time. Part of the present study, therefore, is concerned with trying to separate the short-run determinants of capacity utilization from the longer-run determinants of capital-labor substitution.

Although the test carried out in this paper is somewhat crude and is based on a small sample, the results do indicate that capital-labor substitution has taken place. Unfortunately, the test is not able to distinguish among the three different ways in which capital-labor substitution may take place and is not able to estimate the size of the substitution effect. The test is also heavily dependent on the assumption of a putty-clay technology. Clearly more work is needed in testing for substitution effects and in determining investment expenditures, and it is hoped that the theoretical framework and empirical approach of this paper will stimulate further work along this line.

II. THE THEORETICAL FRAMEWORK

Introduction

A firm is conceived of as making two basic kinds of investment decisions, the first regarding the desired level of capacity and the second regarding how many machines to replace and what types of machines to purchase to meet the desired level of capacity.[4] The technology is assumed to be putty-clay. At any point in time there are assumed to be available a certain number of different types of machines that can be purchased. The machines are assumed to differ in price, in the number of workers that must be used with each machine per unit of time, and in the amount of output that can be produced per machine per unit of time. The worker-machine ratio is assumed to be fixed for each type of machine. Technical progress is assumed to be reflected in new types of machines.

With respect to relative factor prices, let W_t denote the average wage rate at time t and let C_t denote the average cost of new capital at time t. The cost of capital will be different for each type of machine since the cost of capital is a function of the price and length of life of the capital good in question in addition to being a function of the cost of borrowing funds and of tax and depreciation laws. In what follows, however, it will be assumed that the prices of the various types of machines, while differing from each other at any one time, move together over time. If this is true, then an average cost of capital can be defined based on the average price of the various types of machines. Since the main concern is with how the cost of capital changes relative to the wage rate, the use of the concept of an average cost of capital should not pose any serious difficulties in the present analysis. The ratio W_t/C_t will be referred to as the wage-rental ratio.

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[4]Bischoff [1], p. 64, makes the same kind of distinction between investment decisions.

A Test for Capital-Labor Substitution

In order to see how data on capacity output can be used to test for capital-labor substitution, consider first the following extreme case.[5] Assume that there is only one type of machine in existence. Let λ_ν denote the amount of output that can be produced per worker hour on machines of this type that were purchased in time ν, and let μ_ν denote the amount of output that can be produced per machine hour on these machines. Let $I_{t\nu}$ denote the number of machines that were purchased in time ν that are actually operating in time t, let $M_{t\nu}$ denote the number of workers working in time t on these machines, let $H_{t\nu}$ denote the number of hours worked per worker and machine in time t on these machines, and let $Y_{t\nu}$ denote the amount of output produced in time t on these machines.[6] The machines will be assumed not to be subject to physical depreciation, so that λ_ν and μ_ν are not a function of t. This assumption and the constancy of the worker-machine ratio imply that

$$(1) \qquad Y_{t\nu} = \lambda_\nu M_{t\nu} H_{t\nu} = \mu_\nu I_{t\nu} H_{t\nu} \quad .$$

Let m_t denote the age of the oldest machine that is being used in time t. Then the total amount of output produced in time t, Y_t, is

$$(2) \qquad Y_t = \sum_{\nu=t-m_t}^{t} Y_{t\nu} \quad .$$

[5]The assumptions made here about the basic underlying technology of a firm are similar in many respects to the assumptions made by Johansen [6], Salter [7], and others who have analyzed putty-clay models. Some of the notation used here is similar to the notation used by Solow, Tobin, von Weizsacker, and Yaari [8].

[6]$M_{t\nu}$ and $H_{t\nu}$ are meant to refer only to the number of workers actually working and the number of hours actually worked per worker. Idle workers and hours are not counted in $M_{t\nu}$ and $H_{t\nu}$.

In other words, the total amount of output produced in time t is the sum of the amount of output produced on each of the machines that are operating in time t.

Although equations (1) and (2) refer to the actual amount of output produced, they can also be written in terms of capacity output. Let I_ν denote the total number of machines that were purchased in time ν (regardless of whether they are actually operating in time t or not), let $\tilde{M}^c_\nu$ denote the number of workers that are required to work on the I_ν machines, and let H^c denote the maximum number of hours that can be worked per worker per period on these machines. H^c is assumed not to be a function ν. Capacity or maximum output per period on these machines, $\tilde{Y}^c_\nu$, is

$$(3) \qquad \tilde{Y}^c_\nu = \lambda_\nu \tilde{M}^c_\nu H^c = \mu_\nu I_\nu H^c \quad .$$

If m denotes the age of the oldest machine in existence in time t,[7] then total capacity output in time t, Y^c_t, is

$$(4) \qquad Y^c_t = \sum_{\nu=t-m}^{t} \tilde{Y}^c_\nu \quad .$$

Likewise, the number of workers required in time t to produce Y^c_t, M^c_t, is

$$(5) \qquad M^c_t = \sum_{\nu=t-m}^{t} \tilde{M}^c_\nu \quad .$$

Equations (3) and (4) imply that

$$(6) \qquad Y^c_t = H^c \sum_{\nu=t-m}^{t} \mu_\nu I_\nu \quad ,$$

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[7] m is assumed for now not to be a function of t, and machines of the same age are assumed to go out of existence all at the same time.

and equations (3) and (5) imply that

$$(7) \qquad M_t^c = \sum_{\nu=t-m}^{t} \frac{\mu_\nu I_\nu}{\lambda_\nu} .$$

Lagging equations (6) and (7) one period and subtracting each lagged equation from the respective unlagged equation yields

$$(8) \qquad Y_t^c - Y_{t-1}^c = H^c(\mu_t I_t - \mu_{t-m-1} I_{t-m-1}) ,$$

$$(9) \qquad M_t^c - M_{t-1}^c = \frac{\mu_t I_t}{\lambda_t} - \frac{\mu_{t-m-1} I_{t-m-1}}{\lambda_{t-m-1}} .$$

Equation (8) can then be solved for $\mu_t I_t$ and this expression substituted into equation (9), yielding

$$(10) \qquad M_t^c - M_{t-1}^c = \frac{Y_t^c - Y_{t-1}^c}{H^c \lambda_t} + \left(\frac{1}{\lambda_t} - \frac{1}{\lambda_{t-m-1}}\right) \mu_{t-m-1} I_{t-m-1}$$

If λ_t is the same for all t, then equation (10) merely states that the change in the number of workers required to produce capacity output is proportional to the change in capacity output. If λ_t equals $\beta(1+\lambda)^t$ -- exponential labor-augmenting technical progress -- and if firms never purchase any but the newest machines, equation (10) becomes

$$(11) \qquad M_t^c - M_{t-1}^c = \frac{Y_t^c - Y_{t-1}^c}{H^c \beta(1+\lambda)^t} + \left[\frac{1}{\beta(1+\lambda)^t} - \frac{1}{\beta(1+\lambda)^{t-m-1}}\right] \mu_{t-m-1} I_{t-m-1} .$$

Equation (11) states that the change in the number of workers required to produce capacity output is directly proportional to an exponentially decreasing function of the change in capacity output, except for a factor that takes into account replacement investment. I_{t-m-1} is the number of machines retired at the end of period t-1.

Now consider estimating the following equation,

$$(12) \qquad M^c_t - M^c_{t-1} = \left(\frac{1}{H^c \beta}\right) \frac{Y^c_t - Y^c_{t-1}}{(1+\lambda)^t} + \gamma_1 \frac{W_t}{C_t} + u_t \quad ,$$

where u_t is an error term. If there is only one type of machine, if labor-augmenting technical progress is exponential, and if replacement investment is not a function of the wage-rental ratio, then estimating equation (12) should not result in a significant estimate of γ_1. From equation (11) it can be seen that if there is only one type of machine and if labor-augmenting technical progress is exponential, then the only way in which the wage-rental ratio can have a nonzero coefficient in equation (12) is if replacement investment is a function of the wage-rental ratio. Consequently, if replacement investment is not a function of the wage-rental ratio, the coefficient γ_1 in equation (12) should be zero.

If, on the other hand, the wage-rental ratio affects capital-labor substitution in any of the three possible ways mentioned in Section I, then the coefficient γ_1 should be nonzero in equation (12). Consider first the case in which more than one type of machine can be purchased per period, the machines differing in price and in the size of the λ coefficients. In this case a high wage-rental ratio should cause firms to purchase the more expensive machines with lower worker-machine ratios, and a low wage-rental ratio should cause firms to purchase the less expensive machines with higher worker-machine ratios. A changing wage-rental ratio should thus cause the change in the number of workers required to produce capacity output not to be directly proportional to any simple function of the change in capacity output, which in turn should cause the wage-rental ratio to be a significant explanatory variable when an equation like (12) is estimated. The purchase of machines with low worker-machine ratios should cause $M^c_t - M^c_{t-1}$ to deviate from $\left(\frac{1}{H^c \beta}\right) \frac{Y^c_t - Y^c_{t-1}}{(1+\lambda)^t}$ by a negative amount, and the purchase of machines with high worker-machine ratios should have the opposite effect. The wage-rental ratio in equation (12) should thus have a negative effect on $M_t^c - M_{t-1}^c$ if the purchase of different types of machines is influenced by the wage-rental ratio.

Consider next the case in which labor-augmenting technical progress is not exponential, but is a function of the wage-rental ratio. Assume in particular that it is the deviation of the rate of labor-augmenting technical progress from an exponential trend that is a function of the wage-rental ratio. In this case a high (low) wage-rental ratio should cause the deviation of the rate of labor-augmenting technical progress from an exponential trend to be positive (negative), which should in turn cause $M_t^c - M_{t-1}^c$ to deviate from $(\frac{1}{H^c \beta}) \frac{Y_t^c - Y_{t-1}^c}{(1+\lambda)^t}$ in equation (12) by a negative (positive) amount. The wage-rental ratio in equation (12) should thus have a negative effect on $M_t^c - M_{t-1}^c$ if the rate of labor-augmenting technical progress is a function of the wage-rental ratio.

Consider finally the case in which replacement investment is a function of the wage-rental ratio. This involves relaxing the assumption made above that the age of the oldest machine in existence, m, is not a function of time, for if m is constant, then replacement investment is merely a function of the number of machines purchased m periods ago. If replacement investment is a function of the wage-rental ratio, then from equation (11) it can be seen that replacement investment should have a negative effect on $M_t^c - M_{t-1}^c$, since the term in brackets in the equation is negative. Therefore, if the wage-rental ratio has a positive effect on the rate of replacement investment, as it should have if technical progress is biased toward labor-saving techniques, then the wage-rental ratio should have a negative effect on $M_t^c - M_{t-1}^c$ in equation (12).

In summary, then, if the wage-rental ratio affects capital-labor substitution in any of the three possible ways described above, estimating equation (12) should result in a significantly negative estimate of the coefficient γ_1. Otherwise the coefficient estimate should be insignificant. Even if the rate of labor-augmenting technical progress is not exponential, so that equation (12) is misspecified, it still should not be the case that estimating equation (12) results in a significant estimate of γ_1 if in fact the wage-rental ratio has no effect on any of the three possible ways of capital-labor substitution. It should be noted, of course, that the above test cannot separate out the three possible ways in which the wage-rental ratio may affect capital-labor substitution, nor can the test rule out possible effects of spurious correlation. Because of the somewhat indirect nature of the test, there also appears to be no obvious way in which one can relate the size of the estimate of γ_1 to the amount of substitution that has taken place. In the next two sections equation (12) will be estimated for the Cement and Steel industries. The equation is nonlinear in the parameter λ and so must be estimated by a nonlinear technique.

III. THE DATA AND RESULTS FOR THE CEMENT INDUSTRY

The Data

The period of estimation used for the Cement industry is 1947-1966. Yearly data on capacity in the Cement industry are available for this period from the Bureau of Mines. In an annual survey of the Bureau of Mines, Cement companies are asked the following question: "Assuming no problem of storage, transportation, or plant labor force, report total rated maximum 24 hour kiln capacity to produce clinker at this plant as of December 31." The answers are given in barrels of 376 pounds, and by adding the answers for all plants for each year the Bureau of Mines has been able to construct a yearly series on total Cement capacity. Also available from the

Bureau of Mines are monthly data on Cement shipments for the entire period and monthly data on production for the 1947-1964 period. All of these data are in physical units. From the monthly data on production and the data on capacity, a monthly series on capacity utilization can be constructed, and such a series was published by the Bureau of Mines through 1964. Monthly data on employment in the Cement industry are available for the entire period from the Bureau of Labor Statistics. The employment data used in this study refer to the employment of production workers only.

Short-run fluctuations in shipments and production are fairly pronounced in the Cement industry, due in large part to seasonal factors, and the work in [4] indicates that excess labor is held in this industry during slack months. For present purposes, however, what is needed is not a series on excess labor, but rather a series on the number of workers that are required to produce capacity output. For the 1950-1959 period, the Cement industry operated at or near 100 percent capacity during at least one month of the year. For the 1947-1949 and 1960-1964 periods, the peak operating rate each year was about 92 percent of capacity. For the 1965-1966 period, it also looked like the peak operating rate was about 92 percent of capacity, although this impression had to be gathered from looking at monthly shipments data rather than monthly production data. For some of the years 1950-1959 the peak operating rate was about 110 percent of capacity.

From the monthly data on employment and capacity utilization, a series on the number of workers required to produce capacity output, M_t^c, was constructed as follows. For each year of the 1950-1959 period, M_t^c was taken to be that level of employment corresponding to a month or months in which capacity utilization was approximately 100 percent. If more than one month in a year had capacity utilization of around 100 percent, then the employment numbers were either averaged to get the number for M_t^c or the most frequently occuring number was taken. There was some subjectivity involved in the choice of the numbers for M_t^c, but in general the choice was fairly straightforward. For each year of the 1947-1949, 1960-1966 period, M_t^c was taken to be equal to a constant, $\bar{M}$, plus that level of employment corresponding to a month or months in which capacity utilization was approximately 92 percent. The choice for the years 1965 and 1966 had to rely on shipments rather than production data. The constant $\bar{M}$ can be determined by the regression equation, as will be seen below. The constant should be positive since fewer than the capacity number of workers are likely to be on hand when capacity utilization is only 92 percent. There may, of course, still be some excess labor held at 92 percent of capacity, but if the amount held at this operating rate does not vary from year to year, then the above procedure is still valid. All that is required is that the capacity number of workers differ from the actual number of workers at 92 percent of capacity by a constant amount. For the years in which the peak operating rate was 92 percent of capacity, the choice of M_t^c always corresponded to the peak level of employment for the year, but this was not always the case for the other years. For the years in which the peak operating rate was near 110 percent of capacity, the peak level of employment was usually larger than the level corresponding to 100 percent operating rates.

Monthly data on average hourly earnings in the Cement industry are available for the entire period from the Bureau of Labor Statistics. For purposes here, the earnings figure prevailing in February of each year was used as the wage rate for the year. February is a month in which very little overtime is worked in the Cement industry, and so the average hourly earnings figure for this month more closely reflects straight time hourly earnings than, say, the average hourly earnings figure for the whole year.

The measure of the cost of capital used in this study is one constructed by Robert Coen and presented in [2], Table 2. The measure is available yearly for the 1947-1966 period and incorporates various tax incentives for investment that have been passed since 1954. The NIA implicit price deflator for nonresidential fixed investment was used by Coen as the estimate of the price of capital goods. Moody's industrial bond yield was used as the estimate of the interest rate. There are a number of fairly restrictive assumptions involved in the construction of Coen's measure, but it appeared to be the best measure available.

<u>The Results</u>

From the above work, data on M_t^c are available for the 1950-1959 period and data on $M_t^c-\bar{M}$ are available for the 1947-1949 and 1960-1966 periods. Taking first differences means that data on $M_t^c-M_{t-1}^c$ are available for the 1948-1966 period except for the years 1950 and 1960. For 1950 data on $M_t^c-M_{t-1}^c+\bar{M}$ are available, and for 1960 data on $M_t^c-M_{t-1}^c-\bar{M}$ are available. The constant $\bar{M}$ can be estimated, and all of the data points used, by constructing a dummy variable, say D_t, which is one in 1950, minus one in 1960, and zero everywhere else, and by including D_t as an explanatory variable in the equation being estimated. For all of the years except 1950 and 1960, D_t will have no effect; for 1950 the coefficient of D_t will be $\bar{M}$ since the dependent variable for 1950 is $M_t^c - M_{t-1}^c + \bar{M}$ rather than the correct $M_t^c - M_{t-1}^c$; and for 1960 the coefficient of D_t will be $\bar{M}$ since the dependent variable for 1960 is $M_t^c - M_{t-1}^c - \bar{M}$. The estimate of the coefficient of D_t in the regression equation will thus be an estimate of $\bar{M}$. The estimate is expected to be positive since $\bar{M}$ is assumed to be positive.

The results of estimating equation (12) for the Cement industry are presented in Table I. The equation is a very simple nonlinear equation and was estimated by a standard gradient method. The estimate of the coefficient of the wage-rental ratio is definitely significant in Table I and of the expected negative sign.[8] The estimate of $\bar{M}$ is of the expected positive sign, but it is quite insignificant. It appears that $\bar{M}$ is either quite small or the sample is not large enough to pick up any errors-of-measurement effects. The estimate of $1+\lambda$ in Table I is above one, as expected, and significantly different from one.

The results in Table I thus indicate that capital-labor substitution has taken place in the Cement industry. If more observations had been available, it would have been desirable to experiment with various distributed lags of the W_t/C_t variable to get a better idea of the timing effects of the wage-rental ratio on capital-labor substitution, but the results in Table I are quite consistent with capital-labor substitution having taken place.

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[8] Since equation (12) is nonlinear, tests of significance in the present context must be interpreted with some caution.

Table I: Results of estimating equation (12) for the Cement industry

$$M_t^c - M_{t-1}^c = \bar{M}\cdot D_t + \gamma_o \frac{Y_t^c - Y_{t-1}^c}{(1+\lambda)^t} + \gamma_1 \frac{W_t}{C_t} + u_t$$

Note: For 1950 the left-hand-side variable is $M_t^c - M_{t-1}^c + \bar{M}$.

For 1960 the left-hand-side variable is $M_t^c - M_{t-1}^c - \bar{M}$.

Period of Estimation	$\hat{\bar{M}}$	$(\widehat{1+\lambda})$	$\hat{\gamma}_o$	$\hat{\gamma}_1$	SE	R^2	DW	# of Obs.
1948-1966	.214 (0.04)	1.157 (2.50)*	24.02 (1.96)	-.871 (-3.82)	6.80	.503	1.56	19

(t-statistics are in parentheses.)
*t-statistic based on null hypothesis that coefficient is equal to one.

IV. THE DATA AND RESULTS FOR THE STEEL INDUSTRY

The Data

Yearly data on steel capacity -- blast furnace capacity and capacity to produce ingots and steel for castings -- are available for the 1947-1960 period from the American Iron and Steel Institute (AISI). Monthly data on production and capacity utilization are also available from AISI for this period. Blast furnace production accounts for about 11 percent of SIC industry 331, and production of ingots and steel for castings accounts for about 46 percent. The other 43 percent of industry 331 is composed primarily of production of steel mill products. Monthly data on employment for the 1947-1960 period are not available on any more detailed a basis than for industry 331.

For the work in this study, the data on capacity and production of the ingots-and-steel-for-castings part of industry 331 were used for the capacity and production data, and Bureau of Labor Statistics data on the employment of production workers in industry 331 were used for the employment data. Because of the interrelatedness of the various processes in industry 331, there is a very high correlation between the production (of pig iron) from blast furnaces, the production of iron and steel for castings, and the production of steel mill products. It should thus not matter very much for present purposes that the capacity and production data refer to only about 46 percent of industry 331 while the employment data refer to the entire industry. Only if technological developments and trends were quite different in the various parts of industry 331 would the use of the production and employment data pose a serious problem, and this does not appear to have been the case during the period under consideration. All of the capacity and production data are in physical units.

Production in the Steel industry is subject to very little seasonal fluctuation, but it is characterized by large cyclical swings and large fluctuations because of strikes. Because of the lack of regular seasonal fluctuations, the construction of M_t^c for the Steel industry was somewhat more difficult than it was for the Cement industry. For the 1947-1960 period, only eight months that were separated by a year or more could be found in which the rate of capacity utilization was around 100 percent. The eight months that were chosen to use for the M_t^c data were August 1947, February 1949, January 1951, August 1952, August 1953, December 1955, September 1956, and February 1960. Data on capacity output for these eight months were constructed by interpolating the yearly capacity figures, the yearly figures being available for the beginning of each year. This procedure is to be contrasted to the procedure used for the Cement industry, where there was no real need to interpolate the yearly capacity figures.

Average hourly earnings figures prevailing in February in industry 331 were used for the wage rate data. The hourly earnings figure of the February preceding the month in question was used as the figure pertaining to the month in question. The same cost of capital variable was used for the Steel industry as was used for the Cement industry.

The Results

The results of estimating equation (12) for the Steel industry are presented in Table II. It should be noted that for purposes of estimation the time trend was not taken to be evenly spaced over the 7 observations, but was taken to be evenly spaced across calendar time. The estimate of the coefficient of the wage-rental ratio is negative, as expected, in Table II, but it is not significantly different from zero at the 95 percent confidence level. The estimate of $1+\lambda$ is above one and is significantly different from one.

Table II: Results of estimating equation (12) for the Steel industry.

$$M_t^c - M_{t-1}^c = \gamma_o \frac{Y_t^c - Y_{t-1}^c}{(1+\lambda)^t} + \gamma_1 \frac{W_t}{C_t} + u_t$$

Period of Estimation	$(1\hat{+}\lambda)$	$\hat{\gamma}_o$	$\hat{\gamma}_1$	SE	R^2	DW	# of Obs.
See text.	1.044 (2.31)*	.278 (1.44)	-6.97 (-1.28)	112.7	.668	1.75	7

(t-statistics are in parentheses.)
*t-statistic based on null hypothsis that coefficient is equal to one.

The results in Table II for the Steel industry are thus similar to the results in Table I for the Cement industry, although the estimate of the coefficient of the wage-rental ratio is not significant. With only four degrees of freedom, the results in Table II must be interpreted with considerable caution, but at least the results are not unfavorable to the conclusion that some capital-labor substitution has taken place in the Steel industry.

V. SUMMARY

In this study an attempt has been made to test for the existence of capital-labor substitution by using capacity data. Use of these data avoids many of the problems associated with investment and capital-stock data and allows one to separate the decision of the firm regarding the types of machines to purchase from the decision regarding the total amount of capacity to install. Although the results are based on very small samples, in part because of the adjustments that had to be made to account for short-run fluctuations in capacity utilization, they are consistent with capital-labor substitution having taken place in the two industries. The test is not able to distinguish among the three different ways in which capital-labor substitution may take place.

DATA APPENDIX

Year	M_t^c or $M_t^c - \bar{M}$	Cement Y_t^c	W_t	C_t	t
1947	348*	249107	-	-	1
1948	349*	254272	122.7	12.98	2
1949	350*	258948	132.9	13.17	3
1950	351	268273	139.1	13.62	4
1951	353	281532	151.0	16.01	5
1952	351	284014	157.0	16.83	6
1953	358	291798	170.0	17.76	7
1954	357	298026	178.0	16.84	8
1955	363	315299	183.0	17.42	9
1956	377	349442	191.0	19.26	10
1957	382	380386	207.0	21.85	11
1958	378	402786	222.0	21.99	12
1959	379	420395	236.0	23.83	13
1960	371*	432941	246.0	24.12	14
1961	346*	443022	257.0	24.11	15
1962	341*	468974	266.0	23.42	16
1963	335*	477585	277.0	22.54	17
1964	321*	479618	285.0	22.14	18
1965	307*	482439	293.0	22.35	19
1966	308*	495171	312.0	24.12	20

Month	M_t^c	Steel Y_t^c	W_t	C_t	t
Aug.1947	5852	92986	-	-	8
Feb.1949	6095	96443	152.2	12.98	26
Jan.1951	6249	104230	166.1	13.62	49
Aug.1952	6305	113814	190.0	16.83	68
Aug.1953	6338	121504	212.0	17.76	80
Dec.1955	6321	128152	228.0	17.42	108
Sept.1956	6339	131760	248.0	19.26	117
Feb.1960	6070	148649	304.0	23.83	158

*$M_t^c - \bar{M}$

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