Volume Title: A Disequilibrium Model of Demand for Factors of Production

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Volume Publisher: NBER

Volume ISBN: 0-87014-261-5

Volume URL: http://www.nber.org/books/nadi73-1

Publication Date: 1973

Chapter Title: Characteristics of the Data

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Chapter URL: http://www.nber.org/chapters/c1250

Chapter pages in book: (p. 40 - 54)

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CHARACTERISTICS OF THE DATA

IDEALLY, estimation of model (2.7) requires time-series data for input stocks and their rates of utilization, expectational variables, and input prices. As is usual with most econometric studies, the ideal data are unavailable and various compromises must be made. In section A, we describe the construction and limitations of the data used for estimation. The major characteristics of these series are presented in section B.

A. CONSTRUCTION OF THE VARIABLES

The data used in this study are quarterly time series for total manufacturing and seventeen two-digit subindustries for the period 1948I to 1967IV. The details of the industry classification used in this study are described in Appendix A. For aggregates—total manufacturing, durables, and nondurables—the forecast period is 1968I–1970II. The data are for employment of production and nonproduction workers, hours worked per production worker, capital stock at the beginning of the period, a measure of utilization, total inventories, wage rates, rental price of capital, and sales. A set of auxiliary data is also used to generate certain expectational series, such as new orders and unfilled orders. All series are seasonally adjusted.

Some series are taken directly from published sources, and others have been constructed by procedures described below.

The employment, hours, and wage variables come from U.S. Department of Labor, *Earnings and Employment* [1965] and various issues of U.S. Department of Commerce, *Survey of Current Business*. Sales, inventories, and new orders are taken from U.S. Department of Commerce, Bureau of the Census, *Manufacturers' Shipments, Inventories, and Orders, 1961–68* [1968] and the *Survey of Current Business*. Output price deflators

are wholesale prices for the various industries, which are compiled by the Bureau of Labor Statistics and reported in the *Survey of Current Business.*

Measures of capital stock, capital rental prices, and utilization rates are not readily available and have been constructed, as follows:

Capital stock is generated by using seasonally adjusted and deflated investment on new plant and equipment, published in the *Survey of Current Business.* The deflator used was the implicit fixed investment deflator (1954 = 100). Capital stock was calculated by the recursive formula,

$$K_{t+1} = I_t + (1 - \delta)K_t,$$

where K is net capital stock, and δ is the rate of depreciation. The benchmark capital stock and the rate of depreciation were obtained from Jorgenson and Stephenson [1967]. Rental price was constructed by the formula stated in Hall and Jorgenson [1967]:

$$c = \frac{(1 - k)(1 - \omega z)}{1 - \omega} p_k(r + \delta),$$

where $z = (1/d\tau)(1 - e^{-d\tau})$, assuming straight-line depreciation. The following assumptions were made about the parameters: δ is the constant depreciation rate for each manufacturing industry, taken from Jorgenson and Stephenson; ω is the corporate income tax rate, assumed to be constant over the period at 52 per cent; τ is the lifetime of capital for tax purposes, taken to be 72 quarters; d is the discount rate (= 0.035); k is the rate of tax credit, assumed to equal 0.06 in 1962 and 1963, and zero for other dates. The measure used for r, the cost of capital, is the government bond rate, taken from various issues of the *Federal Reserve Bulletin.* The stock price of capital, p_k, is the implicit fixed investment deflator obtained from the *U.S. National Income and Product Accounts, 1929–65* [1966] and subsequent July issues of the *Survey of Current Business,* converted to the 1954 base.

A measure of utilization was constructed by a procedure similar to that used for the Wharton capacity index (Klein [1951]). The procedure is to compute trend output by drawing a tangent line from one cyclical peak to the next highest one. The index is the ratio of actual output to its trend value and takes a value of unity at the highest cycle peaks. Output is measured as the sum of deflated sales and changes in deflated total inventory. Wholesale price indexes are used as deflators. In cases

where the cyclical peak lies beyond the sample period and the last output observation is greater than the previous peak, the later point is assumed to correspond to full utilization.

As noted above, some of these measures are far from perfect. Some of their shortcomings should be noted at the outset:

i. Labor Variables

User costs of labor (s_n and s_p) have been omitted due to lack of data. As a proxy for s_n, quit rates were used, but the results proved unsatisfactory in preliminary investigation and are therefore omitted. Neither hours worked by nonproduction workers nor their wage rates are available, forcing the assumption that their hours and wage rates are either fixed or vary proportionally with those of production workers. The employment measures are not true stock variables, since they are a count of all names appearing on payrolls during a week near the middle of the month. Similarly, hours per man are averages for that week. Moreover, wage rates reflect overtime to a small extent, since overtime data were not systematically collected until 1956.

ii. Capital Stock

Measurement of capital stock and its depreciation rate do not take into account changes in capital utilization rates, due to lack of information concerning the depreciation-utilization function. Similarly, c' $(= \partial C/\partial Y_4)$ cannot be constructed from available data, and is omitted.

iii. Rental Prices

The rental price of inventories, c_I, cannot be constructed and is assumed to vary in proportion to the rental price of physical capital, c. Our measure of c excludes capital gains. Preliminary tests indicated that inclusion makes little difference to the estimates of the parameters.

iv. Inventories

Strictly speaking, the model requires inventory data according to stage of fabrication, which are unavailable prior to 1953 for total manufacturing and virtually nonexistent for many of the disaggregated classifications. Consequently, total inventories are used instead.

v. Utilization Rates

An appropriate measure of capital utilization would be an index of

"hours per machine," comparable to that used for labor. Unfortunately, such measures are not available on a quarterly and disaggregated basis. Our constructed utilization measure is a *generalized* utilization rate for all inputs. It captures the unmeasured components of labor utilization that are not included in hours per man, as well as "true" capital utilization. To maintain symmetry of notation, the constructed utilization variable is denoted by Y_4 throughout. However, the real differences between this measure and a genuine capital capacity measure should always be kept in mind.

Due to these shortcomings in the measurement of prices, capital stock, and, especially, utilization rates, all the hypotheses embodied in model (2.7) cannot be tested exactly. These assumptions about prices preclude stringent tests of the price effects on the dependent variable. Therefore, only certain statements about the direction of these effects can be made. Only one relative price variable, wage divided by rental (w/c), is used in the estimation. We feel it is reasonable to hypothesize that, in general, w/c should affect all labor inputs in a negative direction, and capital stock positively. The effects on the utilization rate are likely to be small, while the effect on inventories (Y_5) is uncertain.

B. PROPERTIES OF THE DATA

Since most of the time series in disaggregated industries are broadly similar to those of total manufacturing, it is sufficient to discuss the data characteristics of the total manufacturing sector. The precise classification of industries used in this study is listed in Appendix A. Descriptive statistics such as mean, standard error, and the time trend of the variables for this sector are indicated in Table 3.1. Similar statistics for disaggregated industries are reported in Tables B.1 to B.6. The variables are identified, by name and symbol, in the first two columns of Table 3.1. The symbols are used throughout the study. The remaining columns of the table are self-explanatory, except the last, which contains the regression coefficient of the logarithm of the variable against calendar time, taking the origin as 1948I. A graphic description of these data are presented in Charts 3.1 to 3.13 (pages 46–54, below).

The number of production workers (Y_1) fluctuates around a slight upward trend of 0.75 per cent per quarter. The amplitude of these fluotuations is very pronounced, judging from the coefficient of variation. From Chart 3.1 it is seen that Y_1 is a coincident series, leading at peaks

TABLE 3.1

DESCRIPTION OF DATA: SEASONALLY ADJUSTED QUARTERLY AVERAGES FOR TOTAL MANUFACTURING

(sample period: 1948I–1967IV)

Variable Symbol	Variable Name	Mean	Stand. Dev.	Coeff. of Var.	Trend Coeff.
Y_1	Production workers (millions)	12.993	0.713	.0549	.0075
Y_2	Average weekly hours worked by production workers	40.277	0.623	.0150	.0097
Y_3	Capital stock (billions of constant 1954 dollars)	88.540	15.372	.1735	.6168
Y_4	Constructed utilization rate (constrained between 0 and 1.0)	0.931	0.062	.0674	.0015
Y_5	Inventories (billions of deflated 1954 dollars)	48.600	14.827	.0350	.4647
Y_6	Nonproduction workers (millions)	3.8583	0.7209	.1868	.0306
S	Total shipments (billions of 1954 dollars)	85.724	45.011	.3000	.8059
w	Average hourly wage, production workers (undeflated, dollars per hour)	2.017	0.471	.2335	.01931
c	Rental price of capital (undeflated index)	0.113	0.035	.3165	.00145
P	Wholesale price index (1954 = 100)	0.951	0.827	.0869	.00298
N	New orders (billions of 1954 dollars)	86.277	26.396	.3059	.8117
ou	Stock of unfilled orders (billions of 1954 dollars)	161.82	45.011	.2781	.779

and troughs by less than a quarter on average. Nonproduction worker employment (Y_6) has grown rapidly: about 3.06 per cent (Table 3.1) per quarter with some fluctuation around this trend. It follows a cyclical pattern similar to that of Y_1, but with a lag of one or two quarters. This series is characterized by downward rigidity during business cycle contractions. The coefficient of variation (0.17) of the capital stock (Y_3) indicates considerable sluggishness of this variable during the postwar period. Although capital stock is on the whole a trend-dominated variable,

the slope of the trend seems to vary over the span of time studied. Capital stock increased at a rapid rate during 1949–57, but its momentum was checked during the slow-growth phase of the economy (1958I–1960IV) and this sluggishness continued until the end of 1962. Capital stock rose very steeply in the expansionary period 1963I–1967IV. There is some minor retardation of the series at peaks, and it seems to lag behind business cycle turning points by about three to four quarters.

The stock of total inventories (Y_5) fluctuates considerably and has a pronounced trend of 0.465 per cent per quarter. Fluctuations of this variable coincide with the business cycle. During expansions, inventories are drawn down as sales expand, and the reverse often occurs during contractions. But this cyclical behavior, as indicated in Chart 3.5, does not always hold. Part of the reason is that our measure of inventories includes finished, semifinished, and raw materials. The sales-inventory ratio will be affected by how rapidly and by how much the firm replaces its stock of semifinished and raw materials.

The flow variables exhibit interesting behavior. Average hours worked (Y_2) fluctuates around a narrow band of values, displaying a very small trend and at least a two-quarter lead in the early phase of the business cycle. This lead seems to have increased in the latter part of the period. Hours worked are a well-known leading indicator of business cycle activity (Bry [1959], Hultgren [1965]); our measure reflects that fact. The generalized utilization rate (Y_4) fluctuates greatly, but with no real trend (0.0015 per cent per quarter). It leads by one to two quarters at business cycle turns, though its fluctuations have been very small during the long expansionary phase of the economy in the 1961–67 period.

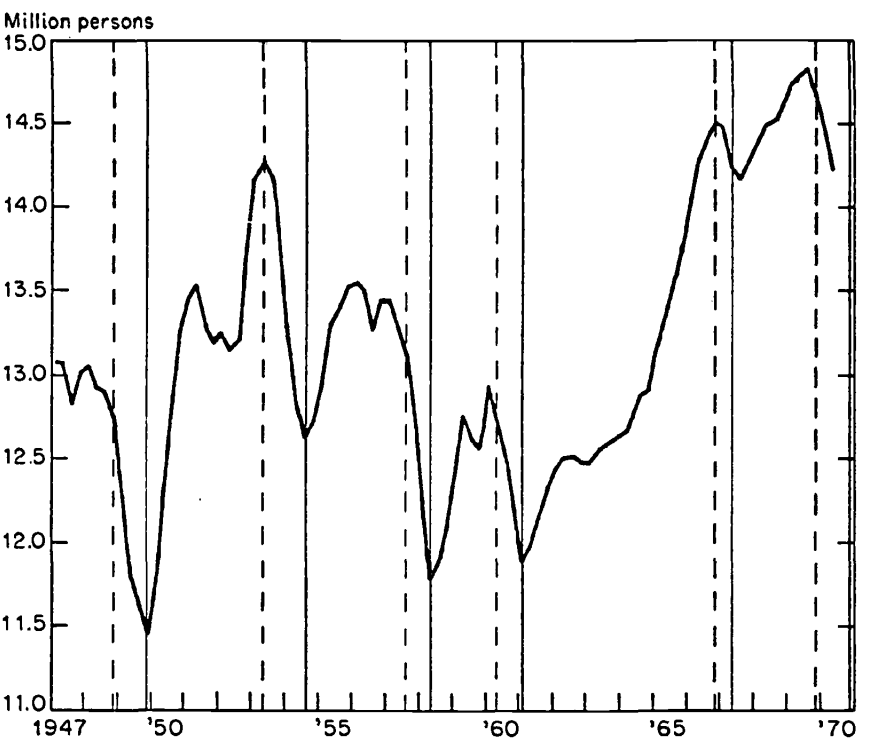
The deflated sales variable fluctuates considerably around a rising trend of 0.81 per cent per quarter and lags behind at peaks and troughs of the business cycle by one to two quarters. The wage variable, w, is largely trend-dominated with little fluctuation; it leads at troughs and coincides at peaks of the cycle. The rental price of capital, c, on the other hand, has an upward trend and fluctuates considerably, mainly reflecting movements in the interest rate. Generally, it leads by about one quarter at turning points of the cycle. The relative price variable, w/c, the ratio of wages to the rental price of capital, has a downward trend of about -0.06 per cent per quarter and fluctuates considerably, rising in the troughs and falling during the expansionary phases of the economy. This phenomenon is due both to downward rigidity of money wage rates

in the postwar period and greater flexibility of capital costs over the cycle, at least since 1953.

It is obvious that the input variables mentioned often move in the same direction and tend to reinforce each other. At other times, some variables move counter to others in order to meet output or sales requirements. The lead and lag relations among the inputs suggest the desirability of explicitly taking into account joint responses of inputs to changes in sales, prices, and other exogenous variables in a unified theoretical and empirical framework. Model (2.7), as specified in Chapter 2 and estimated below, is our attempt in this direction and stands in sharp contrast to the usual practice of analyzing the behavior of each input independently of the others.

CHART 3.1

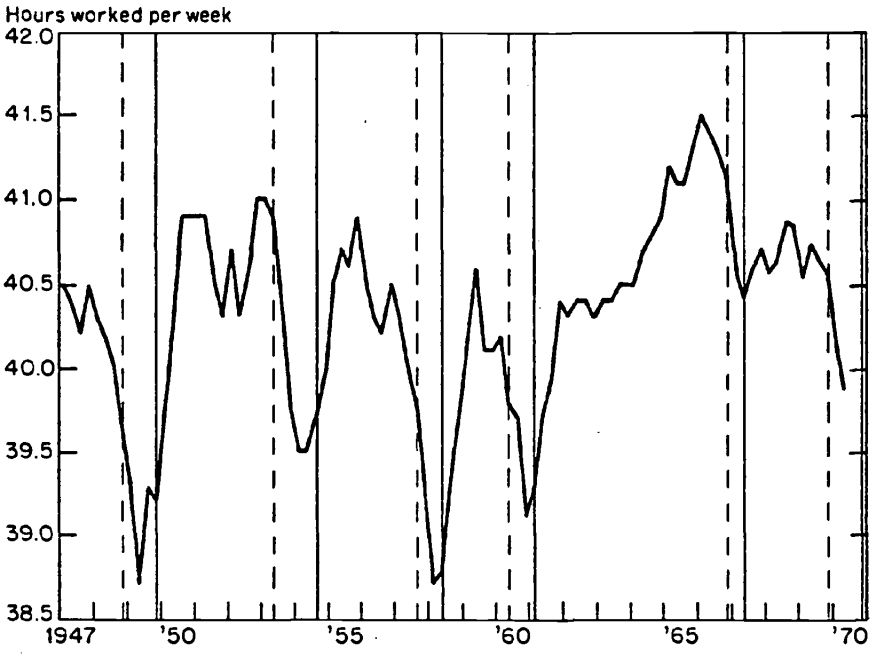
STOCK OF PRODUCTION WORKERS (Y_1), 1947I–1970II



SOURCE: U.S. Department of Labor [1965] and U.S. Department of Commerce, *Survey of Current Business*.

CHART 3.2

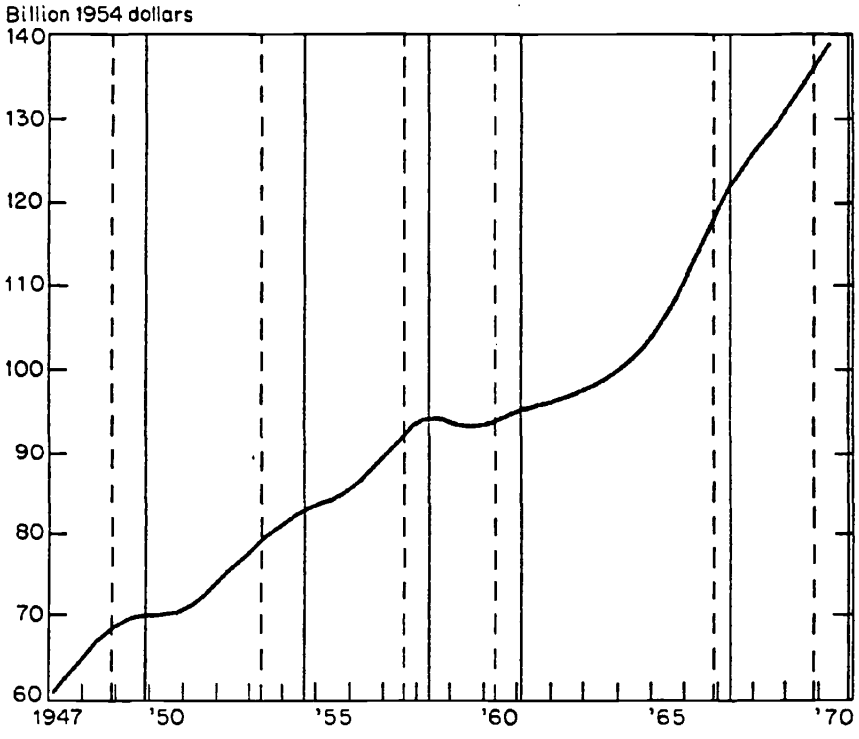
HOURS OF WORK PER WEEK OF PRODUCTION WORKERS (Y_3), 1947I–1970II



SOURCE: Same as Chart 3.1.

CHART 3.3

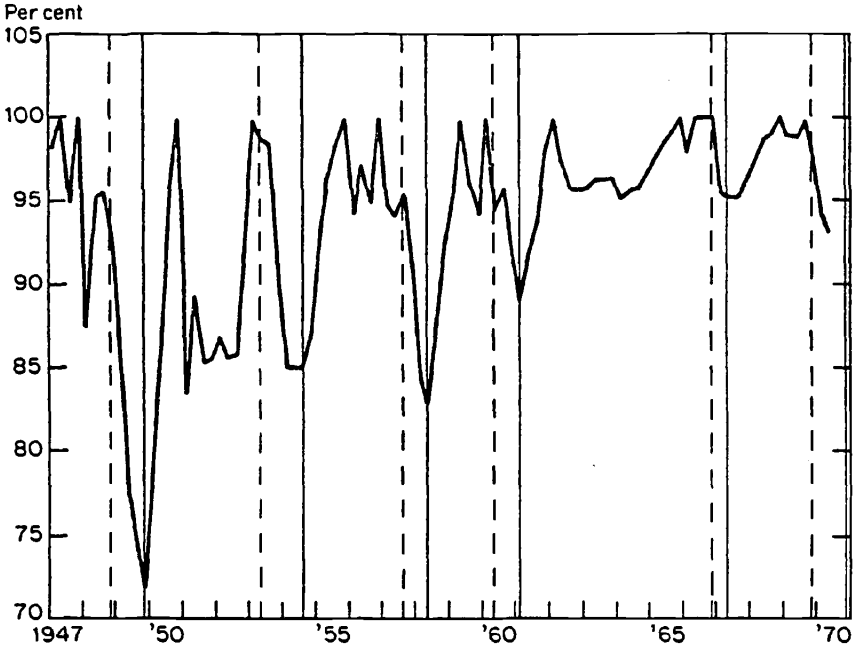
DEFLATED CAPITAL STOCK (Y_3), 1947I–1970II



SOURCE: Based on *Survey of Current Business*; for details, see section A, above.

CHART 3.4

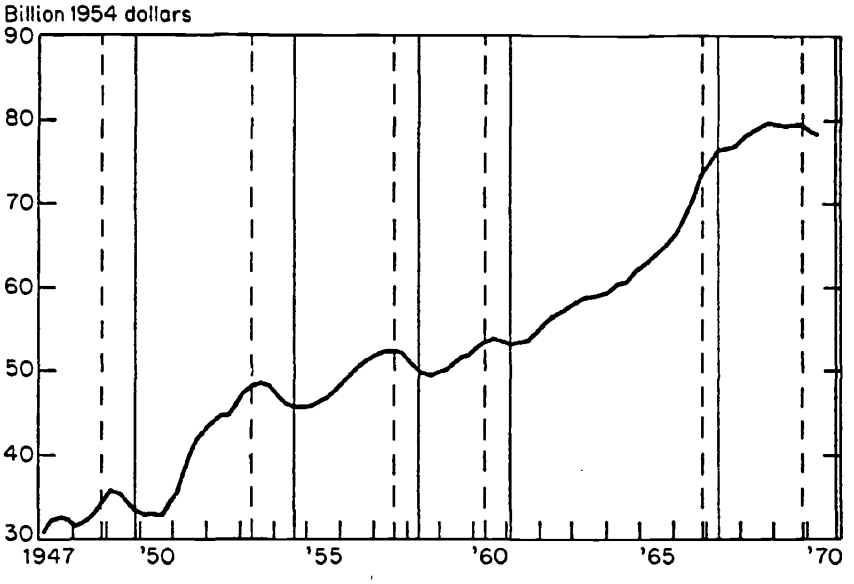
UTILIZATION RATE (Y_4), 1947I–1970II



SOURCE: See section A, above.

CHART 3.5

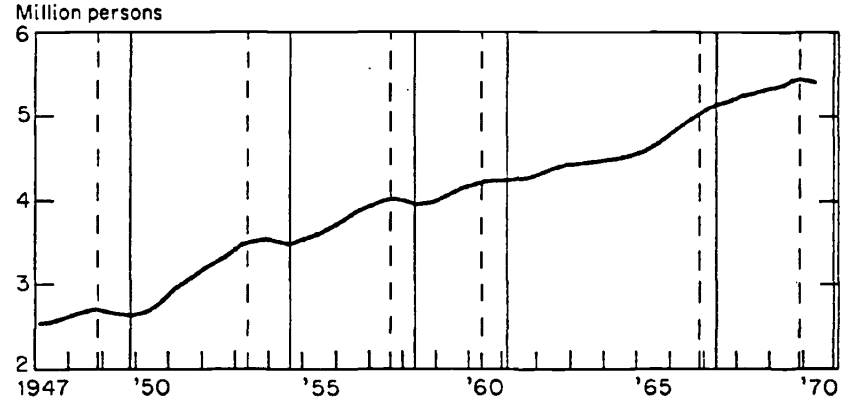
MANUFACTURERS' TOTAL INVENTORIES IN CONSTANT DOLLARS (Y_5), 1947I–1970II



SOURCE: U.S. Department of Commerce, *Survey of Current Business* and *Manufacturers' Shipments, Inventories, and New Orders, 1961–68*; deflated by NBER, using wholesale price data reported in *SCB*.

CHART 3.6

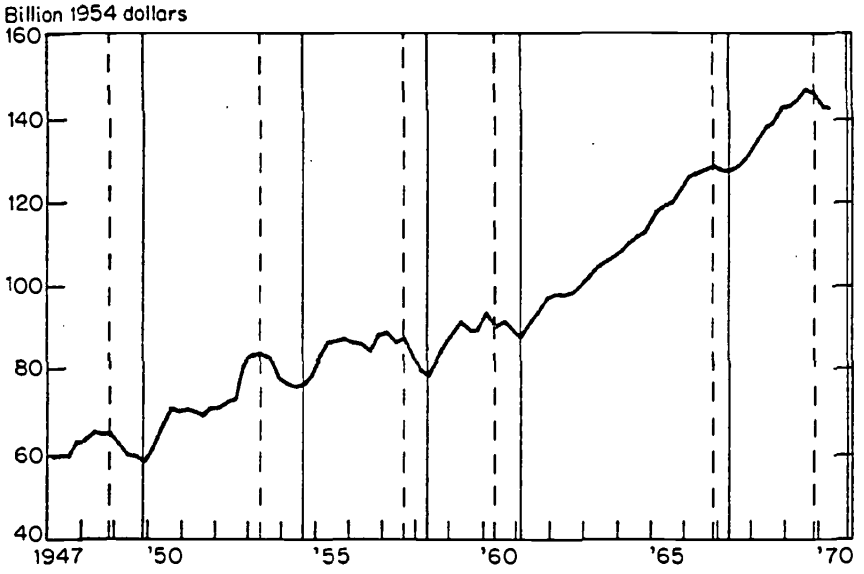
STOCK OF NONPRODUCTION WORKERS (Y_6), 1947I–1970II



SOURCE: Same as Chart 3.1.

CHART 3.7

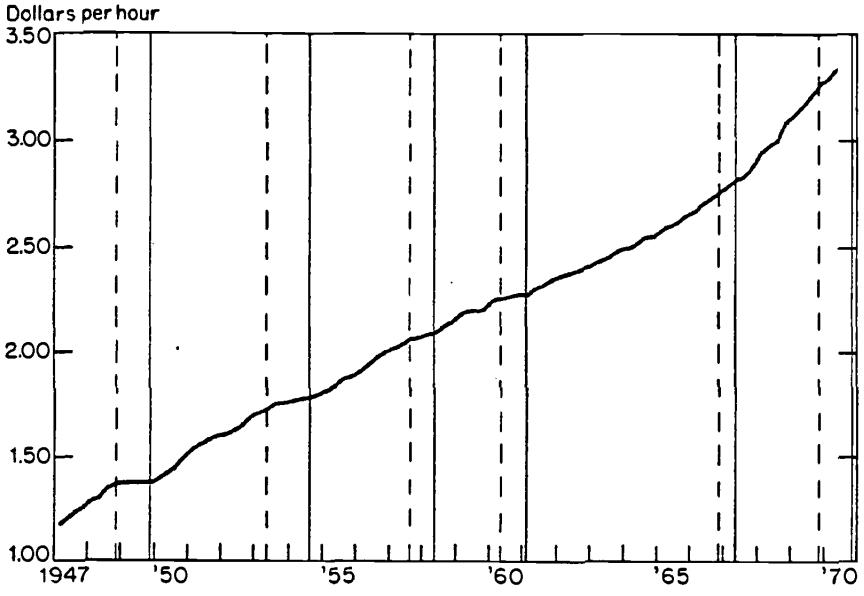
DEFLATED SHIPMENTS (S), 1947I–1970II



SOURCE: Same as Chart 3.5.

CHART 3.8

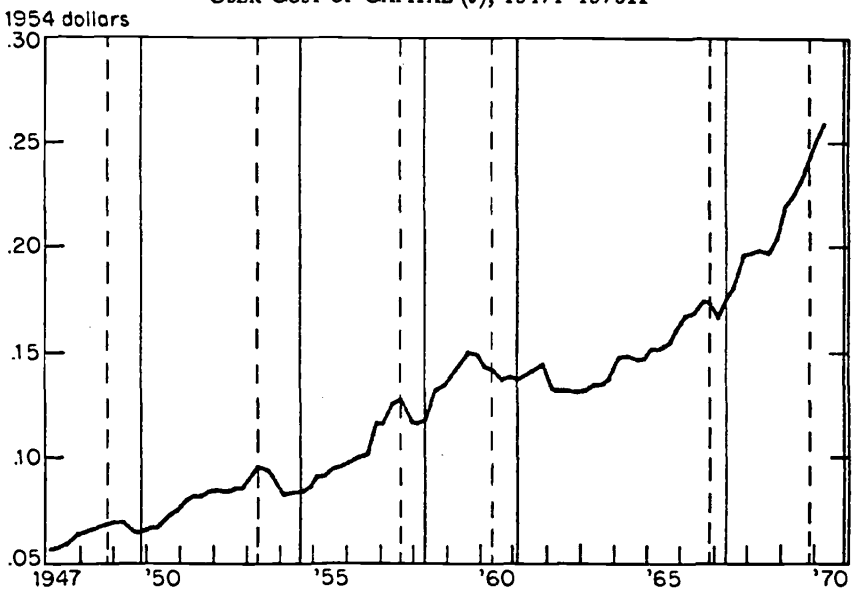
HOURLY EARNINGS PER WEEK OF PRODUCTION WORKERS (w), 1947I–1970II



SOURCE: Same as Chart 3.1.

CHART 3.9

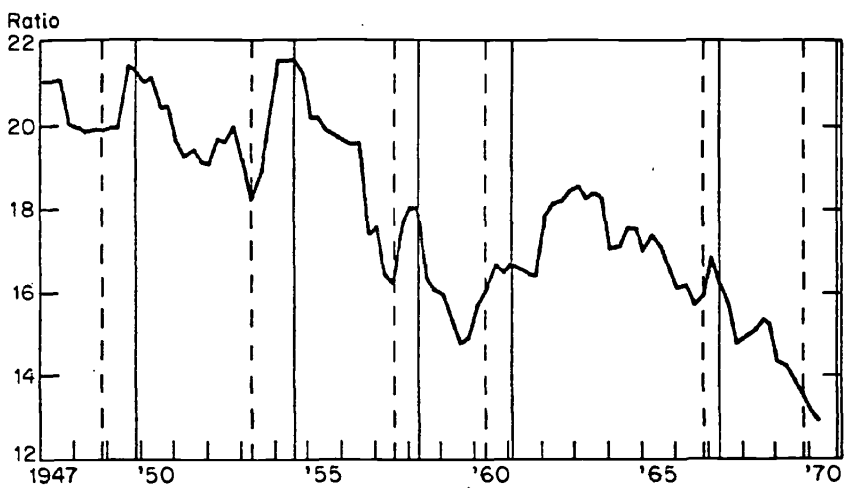
USER COST OF CAPITAL (c), 1947I–1970II



SOURCE: See section A, above.

CHART 3.10

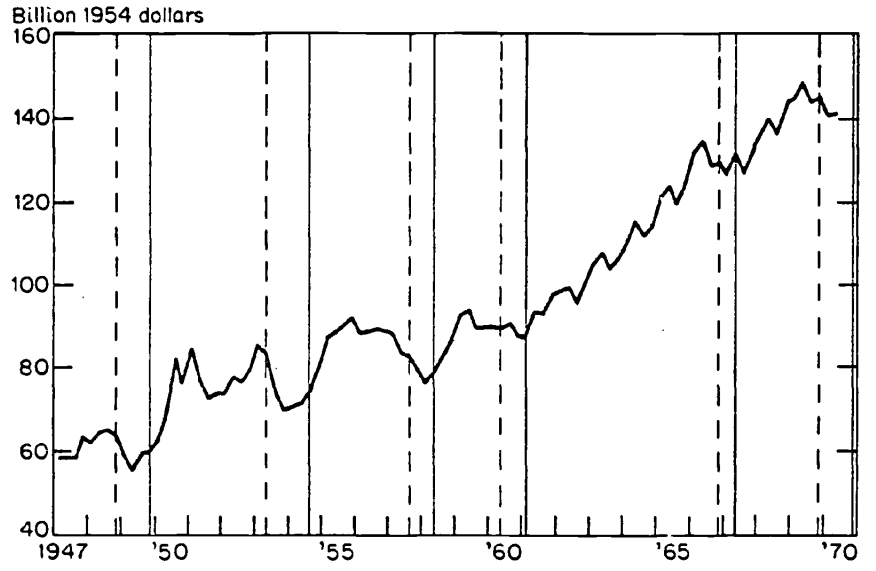
RELATIVE PRICES (w/c), 1947I–1970II



SOURCE: See section A, above.

CHART 3.11

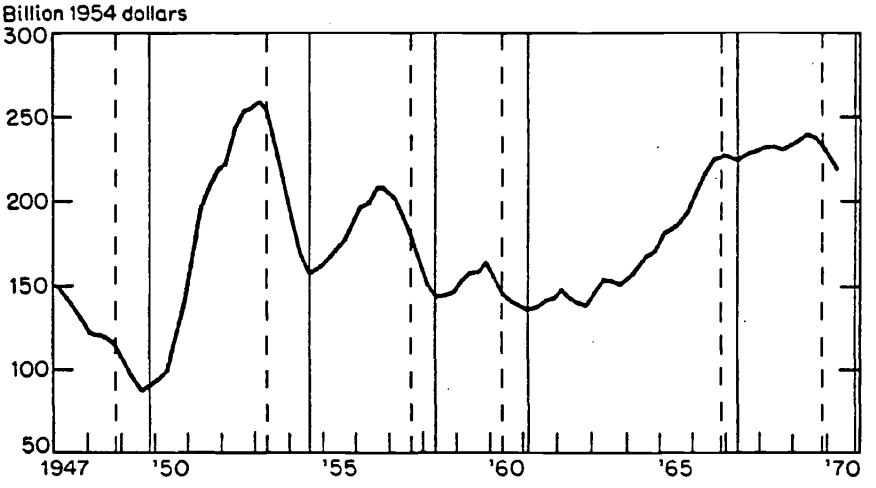
MANUFACTURERS' NEW ORDERS IN CONSTANT DOLLARS (N), 1947I–1970II



SOURCE: Same as Chart 3.5.

CHART 3.12

MANUFACTURERS' UNFILLED ORDERS IN CONSTANT DOLLARS (ou), 1947I–1970II



SOURCE: Same as Chart 3.5.

CHART 3.13

RATIO OF MANUFACTURERS' UNFILLED ORDERS TO SHIPMENTS (*ou/S*), 1947I–1970II