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CHAPTER 8

Goods in Process

As we use the term, 'goods in process' refer to the inventories a manufacturer considers to be 'in process' from the viewpoint of his own activities. That is, they are goods the manufacturer who owns them has processed in some fashion but has not yet put into the form in which his goods are finally sold. They are to be distinguished, on the one hand, from materials purchased from others but which a manufacturer has not yet manipulated and, on the other hand, from finished goods ready for sale to other manufacturers, distributors, or final consumers. As we have just seen, goods in process account on the average for about 20 percent of manufacturers' total stocks.

1 Conformity to Output Cycles

It is characteristic of goods in process that the mechanics of the production process make for a fairly close tie between their volume and the rate of production. In many industries the connection is quite rigid. In leather tanning, for example, hides must remain in the tanning liquid for a certain fairly definite period. Hence to sustain a certain rate of production of tanned hides, a certain number of hides must be kept in process. The chemical and petroleum refining industries are similar. In the steel industry, as carried on by the large integrated corporations, the economy of keeping metal hot requires that the process from pig iron to finished rolled steel be continuous. The output of steel depends upon the quantity of metal going through this whole production process. Again, in the canning of fruits and vegetables, the final packing must immediately follow its preparation. More obvious illustrations are afforded by one-process industries such as textile fiber spinning or flour milling. Only when more cotton is being spun or more grain milled can production in these industries increase. In other industries technical considerations may be less demanding; nonetheless, there may be no convenient form in which to hold goods between the raw and finished stages. Thus, in clothing manufacture, once the cloth has been cut, there is no point in keeping the garments unassembled. Goods in process and rate of production tend to go hand in hand.

The chief exceptions occur among industries that combine the operations of making and assembling parts into a finished product. Among the nonferrous metals too there are stocks of partly refined ores which may be drawn down when the production of refined metal is to be enlarged. The same is true of cement making. In such industries a stock of parts or of semifinished goods may be kept 'between stages'. When a higher rate of production is desired, this stock may be reduced while the quantity of goods 'within' the various stages, that is, being made into parts and assembled into finished goods, increases. In such cases, therefore, it is not strictly necessary for goods in process as a whole to rise when production rises. Of course, even when it is technically possible to keep such a 'surplus' stock of semifabricated goods 'between stages' it will not always be done. Many of the goods, even at an early stage of fabrication, may not be of a sort that can be carried over from one year to the next. In manufacturing automobiles whose models change from year to year, parts that do not often change may be stocked but other parts must be made as required.[1] Again, some parts are bulky and, therefore, uneconomic to store and to handle more often than necessary.

Moreover, even when a stock of partly fabricated goods is drawn down as the rate of production rises, the total stock of goods in process may still rise. It will do so if the rate of increase in the value of the goods 'within stages' exceeds the ratė of fall in the value of the 'surplus' stock 'between stages'. And even in industries in which the stock of goods in process as a whole falls in such circumstances, it will hardly do so at the same rate as it rises in industries that do not keep any 'surplus' stocks of partly

[1] Parts that change from model to model may still be carried for a long time for sale as replacements. Such inventories, however, are properly classified as 'finished' goods.

fabricated goods.[2] For in the former the drop in stocks 'between stages' will be offset by the increase in the volume of parts and other materials 'within stages'. In the latter there is no offset to the increase of goods in process.

Thus the presence of industries that can store partly fabricated stocks seems to put merely a minor qualification on the statement that stocks of goods in process rise with output. Industries in which this relation is not technically necessary are, as we shall see, probably not more than half the total. And when it is not technically necessary that goods in process move together with production, they will still do so when surplus stocks of partly finished goods 'between stages' are unimportant or, if important, when the drop in these stocks is more than offset by the increase in the volume of goods being manipulated. And finally the drop in stocks of goods 'between stages', when it occurs, is always offset in some degree by the increase in goods 'within stages'. It is reasonable to conclude, therefore, that while goods in process in some industries may move counter to production for a short interval, a sustained expansion of output in any industry will normally require an increase of goods in process.

2 *Goods in Process in Continuous and Discontinuous Industries*

As the preceding section indicated, the degree of probability we attach to the hypothesis that goods in process and manufacturing output move together in business cycles depends in part upon the proportion of all goods in process held in industries where it is either technically necessary or highly convenient to maintain a fairly constant relation between partly fabricated stocks and the rate of activity. We call these 'continuous' industries. Others we call 'discontinuous' industries.

The proportions of goods in process in these two categories of manufacturing can be roughly estimated. The basic data are the ratios of goods in process to total inventories for individual industries in the augmented Federal Trade Commission sample (see Ch. 7 and App. C). The industries were first classified as continuous,

[2] This statement assumes that aside from surplus stocks of partly fabricated goods, the relation of goods in process to production is the same in the industries compared.

discontinuous, or mixed (App. D). They were classified as continuous if their manufacturing operations make it either technically impossible or highly inconvenient to store surplus stocks of partly fabricated goods, or if the industry is a one-process industry. An example of the first type is the steel works and rolling mills industry; the second type is exemplified by the rayon industry and the dyeing and finishing of textiles. Industries were classified as discontinuous if several processes are involved and there seems no urgent necessity for completing all without interruption; for example, the furniture industry. Finally, in some industries, such as cotton textiles, some firms perform only a single process whereas others combine several processes and may keep semifabricated stocks at each stage. Such industries were classified as mixed.

For each category we computed an average ratio of goods in process to total inventories by weighting the ratio of goods in process to total stocks in each industry by the census value of total stocks held. Next, each census industry was similarly classified (App. D), and the value of total inventories held in continuous, discontinuous, and mixed industries computed. Finally, to get an estimate of the value of goods in process held by each category the average ratio of goods in process to total inventories in each was applied to the value of total inventories in its category estimated from census data. Calculations were confined to 1939, for which the FTC sample is somewhat more satisfactory than for 1938 (Table 41).

Roughly one-half of all inventories are held by continuous process industries. A quarter are held by mixed industries and only a slightly higher proportion of all inventories are held by industries following predominantly discontinuous processes.

As might be expected the ratio of goods in process to total inventories in continuous industries is lower than that in mixed industries, and the ratio in the latter is lower than in discontinuous industries. Continuous industries either cover only one stage in fabrication or when they cover more than one stage do not hold surplus stocks between stages. Discontinuous industries involve two or more stages and can hold surplus stocks between stages. Hence their goods in process tend to be more important relative to total stocks. In consequence at the end of 1939 discontinuous

TABLE 41

Goods in Process, Continuous, Discontinuous, and Mixed Industries, December 31, 1939

	TOTAL STOCKS[a] ($ mil.)	AV. RATIO: GOODS IN PROCESS TO TOTAL STOCKS[b] (%)	GOODS IN PROCESS Est. Value ($ mil.)	GOODS IN PROCESS % Distribution
(1)	(2)	(3)	(4)	(5)
1 Continuous	4721	16.1	760	37.7
2 Discontinuous	2672	27.3	729	36.1
3 Mixed	2239	23.6	528	26.2
4 Total mfg.	9632	20.9	2017	100.0

[a] Census of Manufactures, 1939. See Table 39, note. The distribution of industries by categories is shown in App. D.

[b] Percentages estimated from augmented FTC sample (App. C). Ratios for individual industries weighted by inventories to get average for category. Average for total manufacturing computed by using weights from column 2; cf. Table 40.

industries appear to have held about the same quantity of goods in process, something over 36 percent, as continuous industries, nearly 38 percent. If inventories in the mixed industries are divided about evenly between the two main classes, we may say that about half of all goods in process is held in each.

Like so many findings in this difficult field this one too is subject to a considerable margin of error. The classification of industries is often arbitrary; the sample from which we judge the importance of goods in process is inadequate;[3] the information is for a single year. It is a calculation that should be checked as soon as better data are available.

If something like half of all goods in process belong to firms

[3] Some small degree of assurance about the representative character of the augmented FTC sample upon which these estimates are based is gained by comparing the average ratio of goods in process to total manufacturing stocks as calculated in Tables 40 and 41. The two ratios are remarkably similar, 20.6 and 20.9 percent. In the first, the ratios for each industry in the sample are weighted simply by the total stocks of the sample industries as shown by the census. In the second, weighted averages for the three categories of industries are combined in a weighted average; the weights are the census totals of stocks in the three categories. Aside from the possibility of offsetting errors, the two results would not be similar unless the relative importance of industries of the three types is about the same in the sample as in manufacturing at large. The distribution is, in fact, very similar; see App. D.

in continuous industries (and in continuous branches of mixed industries), our conclusion that stocks of goods in process as a whole vary positively with output is reenforced. Within the continuous branches, we may expect the relation between production and the volume of goods in process to be quite rigid. In other manufacturing industries, the relation need not be rigid; yet even here there is a bias in favor of a positive relation between production and goods in process. For only surplus stocks between stages can move inversely to output. The stocks within the various stages of discontinuous industries must still move together with activity in their respective stages. Since activity in these stages is closely bound together, so must output and goods in process within the various stages. Finally, it must be remembered that surplus stocks between stages need not move inversely to output; they only may do so. We may conclude, therefore, that there is, in fact, a very powerful set of forces impelling goods in process, as here defined, to move together with output in manufacturing as a whole.

3 *Timing Relative to Turns in Output*

In a general way it is clear that when production is relatively high, the quantity of goods in process will also be high. But when will stocks of goods in process reach their peaks as compared with production? An answer can be given for continuous industries, that is, for industries in which goods remain in a partly fabricated state for a specified interval that does not change. And our conclusions will apply as well to the relation between goods in process within any stage of a discontinuous industry and activity at that stage.

As a first step we must assign a more precise meaning to the term, goods in process. To this end we define 'output' as the number of physical units of a commodity that reach a finished state during a given period. We define 'input' as the number of units of potential output on which fabrication begins during a given period. Now let us suppose that in a certain continuous industry, c days elapse between the time goods are put into process and the time they emerge in finished form. This interval we shall call the production period. Suppose further that for each unit of potential output b_1 dollars are expended in fabricating costs (raw materials, labor, etc.) during the first day, b_2 dollars during the second day, and so on. Then if a units of input are gradually fed into the fabricating process during the first full day of processing, this batch will attain a value of $\frac{ab_1}{2}$ by the end of the first day, since the average unit will have received half of a full day's processing. By the end of the second day, the value of the batch will have grown to $ab_1 + \frac{ab_2}{2}$. Its value will be $ab_1 + ab_2 + \frac{ab_3}{2}$ at the end of the third day, and $ab_1 + ab_2 + ab_3 + \ldots \frac{ab_c}{2}$ at the end of a production period. In other words, the total stock of goods in process on a given day equals the sum of the value to which the input c days before has grown and the value to which input $c - 1$ days before has grown, and so on, the total being the sum of the values to which inputs made during an entire production period have grown by the given day.

These relations may be illustrated by an arithmetical example. Consider an industry in which $10 of costs, including costs of raw materials, are incurred for each unit of input per day and in which the production period is four days. Let input be constant at 100 units per day. The value of goods in process at the end of successive days is shown in Example 1.

Example 1

Value of Goods in Process when Input and Output are Constant

Assumptions: Production period is 4 days
Cost of fabrication, including materials, is constant at $10 per day per unit

DAY	INPUT IN PHYSICAL UNITS	VALUE ATTAINED BY INDICATED INPUT AT END OF SPECIFIED DAYS									
		1	2	3	4	5	6	7	8	9	10
1	100	500	1500	2500	3500	4000					
2	100		500	1500	2500	3500	4000				
3	100			500	1500	2500	3500	4000			
4	100				500	1500	2500	3500	4000		
5	100					500	1500	2500	3500	4000	
6	100						500	1500	2500	3500	4000
7	100							500	1500	2500	3500
8	100								500	1500	2500
9	100									500	1500
10	100										500
Total value		500	2000	4500	8000	12000	12000	12000	12000	12000	12000
Minus finished goods		...	...	...	...	4000	4000	4000	4000	4000	4000
Goods in process		500	2000	4500	8000	8000	8000	8000	8000	8000	8000

When input is constant, the value of goods in process reaches a maximum at the end of one production period and thereafter remains at the same level. The values in the table are, of course, calculated according to the formula set forth above. When a and b have constant values of 100 and $10 respectively the batch fed into process during the first day has a value of $\frac{ab}{2}$ or $500 at the end of the first day. At the end of the second day, its value is $ab + \frac{ab}{2}$ or $1,500; and so on. At the end of the fourth day, the value of the first batch is $3,500; this sum plus the values attained by units fed into the process of fabrication on later days is the total value of goods in process, $8,000.

Now provided cycles in input proceed smoothly from trough to peak, the cyclical turns of goods in process cannot lead the turns in the rate of input in industries of the type in question, although they may occur at the same time. They may lag behind the turns in input, but the lag cannot exceed one production period. Furthermore, since it is self-evident that for industries of the type in question output must reach its peaks and troughs exactly one production period after input reaches its peaks and troughs, the above statements imply that the cyclical turns of goods in process cannot lag behind those of output though they may be synchronous. Goods in process may turn before output but the lead cannot exceed one production period.

The validity of these statements may be seen from the fact that the value of goods in process on a given day depends upon the number of units fed into fabrication on each day of the production period ending with the day in question. Now if the rate of input increases steadily from its trough to its peak, the inputs made on each day from the first to the last of a production period ending with a peak of input must exceed the inputs made on the corresponding days of any production period ending before input reaches its peak. Consequently, when the rate of input reaches its peak the goods in process must have a higher value than on earlier days during the expansion. Hence the peak of goods in process cannot precede the peak of input.

Goods in process may, however, lag behind input on both the upswing and downswing and, indeed, are likely to do so, but the lag cannot be longer than one production period. That they are likely to lag can easily be seen by considering a second arithmetical example. Example 2 is concerned with an industry in which the

Example 2

Value of Goods in Process when Input Varies Symmetrically about a Cyclical Peak

Assumptions: Production period is 4 days
Cost of fabrication, including materials, is constant at $10 per day per unit

Day	Input in physical units	Value attained by indicated input at end of specified days: 1	2	3	4	5	6	7	8	9	10	11	12	13
1	90	450	1350	2250	3150	3600								
2	100		500	1500	2500	3500	4000							
3	110			550	1650	2750	3850	4400						
4	120				600	1800	3000	4200	4800					
5	130					650	1950	3250	4550	5200				
6	120						600	1800	3000	4200	4800			
7	110							550	1650	2750	3850	4400		
8	100								500	1500	2500	3500	4000	
9	90									450	1350	2250	3150	3600
Total value					7900	12300	13400	14200	14500	14100				
Minus finished goods						3600	4000	4400	4800	5200				
Goods in process					7900	8700	9400	9800	9700	8900				

production period and the daily costs of fabrication per unit are the same as in Example 1, but input rises and falls in a symmetrical pattern about a cyclical peak. Although the pattern is symmetrical about the peak and the rate at which fabricating costs are applied is uniform throughout the production period, goods in process reach a peak two days later than input. This occurs for two reasons. The first may be illustrated by comparing goods in process at the end of the fifth day, when input reached its peak, and at the end of the eighth day. In both cases, goods in process result from previous inputs of the same number of units. But the order of the inputs is reversed. When input is at its peak, the small inputs precede the large. After the peak, the opposite is true. The difference between the two cases then lies in the fact that in the earlier it is the small inputs that have grown to their maximum values; in the later, it is the large inputs. The second reason is illustrated by comparing goods in process at the end of the fifth day, when input is at its peak, with goods in process at the end of the sixth day. Not only do the relatively large inputs come somewhat earlier in the latter case, but they are somewhat larger.[4]

The lag of goods in process behind input tends to be longer the more slowly input declines after the peak and the more rapidly input rises before the peak (Example 3, Parts A and B). In both parts production costs are applied at the same rate as in the pre-

Example 3

Value of Goods in Process when Input Varies Asymmetrically about a Cyclical Peak

Assumptions: Production period is 4 days
Cost of fabrication, including raw materials, is constant at $10 per day per unit

DAY	INPUT IN PHYSICAL UNITS	VALUE ATTAINED BY INDICATED INPUT AT END OF SPECIFIED DAYS: 1	2	3	4	5	6	7	8	9
					PART A					
1	90	450	1350	2250	3150	3600				
2	100		500	1500	2500	3500	4000			
3	110			550	1650	2750	3850	4400		
4	120				600	1800	3000	4200	4800	
5	130					650	1950	3250	4550	5200
6	129						645	1935	3225	4515
7	128							640	1920	3200
8	127								635	1905
9	126									630
Total value					7900	12300	13445	14425	15130	15450
Minus finished goods						3600	4000	4400	4800	5200
Goods in process					7900	8700	9445	10025	10330	10250
					PART B					
1	40	200	600	1000	1400	1600				
2	50		250	750	1250	1750	2000			
3	70			350	1050	1750	2450	2800		
4	100				500	1500	2500	3500	4000	
5	130					650	1950	3250	4550	5200
6	120						600	1800	3000	4200
7	110							550	1650	2750
8	100								500	1500
9	90									450
Total value					4200	7250	9500	11900	13700	14100
Minus finished goods						1600	2000	2800	4000	5200
Goods in process					4200	5650	7500	9100	9700	8900

[4] Arthur F. Burns suggests that the same point may be made more forcefully if we consider that goods in process bear the same relation to input as a weighted moving total (plotted at the end of the moving period) does to an original series. If the original data vary in symmetrical cycles, the maxima and minima of a moving total will lag behind those in the original data even if the items in the total are unweighted. If weights of diminishing order are applied, as in our problem (that is, the latest input is given the smallest weight), the tendency to lag is even more pronounced.

ceding examples, but in Part A input declines more slowly after the peak, although it rises before the peak at the same rate as in Example 2. The peak of goods in process comes a day later than in Example 2, a difference that can be due only to the relatively slow decline of input after the peak. In Example 3, Part B, the same result emerges because input rises more rapidly before the peak than it does in Example 2, although it declines at the same rate.

The lag of goods in process behind input tends to be longer also if production costs are applied more heavily in the later stages than in the earlier stages. In Example 4, as in Example 2, it is assumed

EXAMPLE 4

Value of Goods in Process when Input Varies Symmetrically about a Cyclical Peak

Effect of Non-uniform Application of Fabricating Costs

Assumptions: Production period is 4 days
Costs per unit of input are $4 on first day; $8 on second day; $10 on third day; $18 on fourth day.

DAY	INPUT IN PHYSICAL UNITS	VALUE ATTAINED BY INDICATED INPUT AT END OF SPECIFIED DAYS 1	2	3	4	5	6	7	8	9
1	90	180	720	1530	2790	3600				
2	100		200	800	1700	3100	4000			
3	110			220	880	1870	3410	4400		
4	120				240	960	2040	3720	4800	
5	130					260	1040	2210	4030	5200
6	120						240	960	2040	3720
7	110							220	880	1870
8	100								200	800
9	90									180
Total value					5610	9790	10730	11510	11950	11770
Minus finished goods						3600	4000	4400	4800	5200
Goods in process					5610	6190	6730	7110	7150	6570

that a unit of goods put into process reaches a value of $40 when it is finished; but unlike Example 2 in which a unit grows $10 each day, in Example 4 a unit grows $4 the first day, $8 the second, $10 the third, and $18 the fourth. In both examples the pattern of the input rate is the same. In Example 4 the peak of goods in process comes later than in Example 2.

The length of the lag of goods in process behind input depends then upon the pattern of the input rate and upon the pattern according to which the costs of fabrication, including raw materials costs, are incurred during the production period. But no matter what assumptions are made about these two variables, the lag cannot be longer than a single production period because, barring random fluctuations, the inputs of the production period that begins with the peak of input must exceed those of any production period beginning later.

Finally, since output must lag behind input by exactly one production period, the discussion above serves to make clear also the relation between goods in process and output. Stocks of goods in process cannot lag behind output. They are likely to lead, but the lead cannot be longer than one production period.

These conclusions, of course, apply strictly only to goods in process in continuous industries. In other industries the timing relation may well be different; in extreme cases stocks of goods in process and output may move in opposite directions. It seems justifiable, however, to think that for goods in process as a whole, the argument set forth above has a fairly high degree of relevance. Although short lags are possible, goods in process and output are likely to move together, with some tendency for the former to lead.

4 *Length of the Production Period*

These timing relations indicate the desirability of estimating the average length of the production period in manufacturing industries. Consider a period in which output, measured in terms of cost,[5] is steady at z dollars per day, and assume that goods in process, p, increase in value at a steady absolute rate from 0 to their cost as finished output during a production period of c days.

The goods put into process during any given day, then, have a value which is equal to $\frac{z}{2c}$ by the end of the day, that is, they will have had on the average one-half day's processing. At the end of the second day, they will, on the average, have received one and one-half days' processing and will be worth $\frac{3z}{2c}$. At the end of the third day, this value will be $\frac{5z}{2c}$, and at the end of the c^{th} day,

[5] Cost in this context should include only such items as are usually entered into the accounts in establishing the cost of the inventory of finished goods.

$\frac{(2c-1)z}{2c}$. Now since stocks of goods in process on any day equal the sum of the values of goods at each successive stage of production, the value of goods in process on a given day equals the sum of quantities similar to those above: $p = \frac{c^2z}{2c} = \frac{cz}{2}$

That is, on the assumption of a steady rate of production and a steady growth of value in fabrication from zero to total cost, the value of goods in process equals one-half the output (at cost) during a production period.

From this we can determine the number of days in a production period: $c = \frac{2p}{z}$

Under these assumptions the number of days in a production period equals the number required for daily output (at cost) to cumulate to a sum as large as twice the value of goods in process.

The factors in this equation may be roughly evaluated. Approximations to the value of goods in process were presented in Chapter 7. From the Department of Commerce estimates we compute the average value of goods in process held by all manufacturers during 1939 to be $1.69 billion. For the same year, we can find an approximate figure for the value of output at inventory cost. Inventory cost, of course, is a concept of uncertain definition (see App. A). For our purposes we may estimate its magnitude crudely by adding (1) the gross cost of raw materials, fuel and energy used by manufacturers, (2) wages and salaries, and (3) one-half the sum of overhead expenses and profits.[6] The Census of Manufactures puts this figure at $49.35 billion in 1939. The average daily rate of output at inventory cost was, consequently, $135 million. We therefore have: $p = \$1{,}690{,}000{,}000$ and $z = \$135{,}000{,}000$. The number of days in the average production period in manufacturing establishments $\left(\frac{2p}{z}\right) = 25.0$.[7]

[6] Wages of nonmanufacturing employees of manufacturing firms and salaries of officers are here included among overhead expenses.

[7] A minor error in this figure and in those that follow derives from the fact that output was growing during 1939. Since goods in process probably lead output by a few weeks, the average level of goods in process was probably a

This estimate of 25 days is, of course, calculated from crude figures and upon arbitrary assumptions. As regards assumptions, it should be remembered that our definition of inventory cost of output is rough. But the limits of error from this source can be stated. A maximum value for output at inventory cost would be gotten if we assumed that, while profits are never charged to the cost of goods sold, all overhead costs are. The relevant cost of output in 1939 would then be some $52.16 billion (census value of product excluding contract work, $56.25 billion, minus net profit before taxes of manufacturing firms as estimated by the Department of Commerce, $4.09 billion) instead of $49.35 billion. The value of output at cost would be a minimum if we assumed that no part of either overhead costs or of profits is charged to the cost of goods sold. The value of output at cost would then be $42.44 billion. These alternative values may be used to establish lower and upper limits for the average length of the production process in individual manufacturing establishments: lower limit, 23.6 days; upper limit, 29.1 days.

The estimate is subject to a second qualification. It is made upon the assumption that within each manufacturing establishment, the fabricating process is such that goods grow in value at an even rate per unit of time from zero to their full cost when ready for sale. Whether this is a fairly good approximation to the truth or whether fabricating processes are on the whole such that the major part of fabrication costs (including the cost of raw materials consumed) is incurred early in the process, or whether the reverse is true, we do not know. If costs are applied relatively early, the value of goods in process required to sustain a given rate of output will be relatively high; conversely, if costs are sustained relatively late, the value of goods in process required will be relatively small. *Given the cost of output and the value of goods in process,* therefore, early application of costs means a shorter production period; late application means a longer production period.

An extreme case may indicate the bounds to which varying as-

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little higher relative to output than it would be during a year when output was constant. This would tend to make our estimates of the production period somewhat too high.

sumptions about the pattern of the application of costs can drive our estimates. Assume that all purchased raw materials are fed into process at the very beginning, then manipulated without further addition of materials during a number of days equal to a production period. This amounts to assuming a very heavy skew in the application of costs toward the beginning of the production process. The elements of the problem in this case are:

a = value of raw materials fed into process per day
b = fabricating cost per dollar of raw material input
c = number of days in the production period
p = value of goods in process.

The raw materials fed into process on a given day will on the average be worth $a + \frac{ab}{2c}$ at the end of the first day, $a + \frac{3ab}{2c}$ at the end of the second day, and $a + \frac{(2c-1)ab}{2c}$ at the end of the last day. The sum of these quantities for a number of days equal to the average production period is the value of goods in process. If the rate of input and fabrication is constant:

$$p = ca + \frac{c^2ab}{2c}$$
$$= ca + \frac{cab}{2}$$

That is, the value of goods in process equals the sum of the raw material input plus one-half the value added to raw materials during a production period. The length of the production period thus indicated is: $c = \frac{2p}{2a+ab}$

These factors, too, may be evaluated by use of previously derived figures and additional census data:

p = \$1,690,000,000 = value of goods in process
a = \$82,900,000 = average cost of raw materials consumed per day
b = \$0.631 = fabricating cost per dollar of raw material input = (cost of fuel and energy plus wages and salaries of manufacturing employees plus one-half the sum of overhead costs and profits) ÷ cost of raw materials and supplies.

Substituting these values in the last equation, we get 15.5 days as the average production period in manufacturing establishments. This figure, of course, is only an extreme limit of the range of possible estimates. The true value is certainly higher since some raw materials or supplies are consumed at every stage in the production process.

These computations make it possible to put the argument of earlier sections in quantitative terms. In continuous industries, the stock of goods in process cannot lag behind output. Goods in process may lead output but the lead cannot be longer than one production period; it is likely to be somewhat shorter. For such industries, therefore, the lead cannot be longer than about a month at the most and is probably shorter.

As we have noted, however, in discontinuous industries, stocks of partly fabricated goods are not likely to turn as early, relative to output, as in continuous industries. In discontinuous industries, they may even lag behind output, though for reasons advanced in Section 3, the lags, if any, are likely to be short. We conclude, therefore, that aggregate stocks of goods in process tend to rise and fall almost synchronously with output. The lead that certainly characterizes goods in process in continuous industries and goods 'within stages' in other industries is no longer than a month at most, and is likely to be shorter. This diminutive lead may be further reduced by the offsetting behavior of goods 'between stages' in discontinuous industries.

5 *Total Stocks of Goods in Process, Total Output, and Business Cycles*

The foregoing analysis and the conclusions to which it leads apply directly to the relation between output and stocks of goods in process in individual industries. Subject to one qualification, they apply also to the relation between the total output of manufacturing industries and total stocks of goods in process.

No qualification would be necessary if total output were measured by aggregating the outputs of individual industries each weighted according to the value of goods in process held per unit of output in some base period. Total output, however, is usually measured by adding the outputs of individual industries each weighted by 'value added' per unit of output, that is, by the expenses incurred in processing a unit of goods in a given industry. This is the appropriate measure for our purposes. The nub of the problem, therefore, is whether total output, as measured by the value added method, has cycles that tend to lead or lag behind those that would be found in an output index constructed with goods in process weights.

The two methods would, of course, never yield completely identical results. But whether the differences would often be substantial for our purposes depends upon the answers to two questions: (a) Does the relative importance of value added per unit of output in various industries differ substantially from the relative importance of goods in process per unit of output? (b) Is there a marked correlation between the cyclical timing of output cycles in various industries and the relative importance of either value added or goods in process per unit? If the answer to both questions were affirmative, the virtually synchronous relation between cycles of goods in process and output, which undoubtedly exists in individual industries, would not hold for all industries taken together. Stocks of goods in process might either lead or lag behind output by a substantial interval. For example, if industries in which value added per unit is relatively high tended to turn early, and if the value of goods in process per unit in these industries were no higher than in others, total output, as usually measured, would tend to turn before total output computed by using goods in process weights. Consequently, total stocks of goods in process would tend to lag behind a standard index of total output. On the other hand, if the answer to either question were negative, the cyclical timing of total output as usually measured would be substantially the same as that exhibited by an output index computed by using goods in process weights.

These questions cannot be answered now because we do not have enough information about the value of goods in process by industry. In further argument in this book, I shall disregard the difficulty and assume that total stocks of goods in process rise and fall at about the same time as total output. It seems unlikely that aggregation will produce large differences in timing where these do not exist industry by industry. But the reader should remember that this is not certain.

Subject to the same proviso, we can describe the behavior of goods in process during business cycles. Total manufacturing output tends to reach its peaks and troughs at about the same time as business cycles.[8] If goods in process rise and fall almost synchronously with total output, they must also with business at large.

[8] During the cycles of the interwar period, the FRB index of manufacturing production turned before the National Bureau monthly reference dates four times; it turned later three times, and in the same month four times. The average lead was 1.1 months.