Econometrica, Vol. 5, No. 3, July 1937

ANNUAL SURVEY OF ECONOMIC THEORY: THE RECENT CONTROVERSY ON THE THEORY OF CAPITAL

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THE LAST FEW YEARS have witnessed the emergence of a tremendous literature on the theory of capital and interest—stimulated, no doubt, by the urgency of finding the appropriate theoretical criteria for a policy designed to mitigate economic instability. A large part of this literature has been directly concerned with the question how far the concept of the "period of production" is relevant for an analysis of industrial fluctuations. Another part, digging deeper into the problem, dealt with the *prima facie* question how far traditional capital theory, formulated under the hypothesis of a stationary state, still retains its validity in essential features once this hypothesis is abandoned. These writings were mainly concerned with the problems of expectations foresight, uncertainty. Finally, largely owing to the offensive launched by Professor F. H. Knight, there was a revival of the discussion on the fundamentals of capital theory itself, comparable in nature to the famous controversy between J. B. Clark and Böhm-Bawerk in the first decade of the century. In this controversy the problems introduced by dynamic changes were not so much in question as the legitimacy of the "investment period" theory of capital even within the narrow framework of static assumptions. Professor Knight's attack[1] has been taken up and supported by other writers,[2] has been fre-

[1] The following articles by Professor Knight deal mainly with this question: "Capital Production, Time and the Rate of Return," *Economic Essays in Honour of Gustav Cassel*, London, 1933, pp. 327–342; "Capital, Time and the Interest Rate," *Economica*, August, 1934, p. 257; "Professor Hayek and the Theory of Investment," *Economic Journal*, March, 1935, p. 77; "The Ricardian Theory of Production and Distribution," *The Canadian Journal of Economics and Political Science*, February, 1935; "The Theory of Investment Once More: Mr. Boulding and the Austrians," *Quarterly Journal of Economics*, November, 1935; "The Quantity of Capital and the Rate of Interest, Part I," *Journal of Political Economy*, August, 1936; "Part II," *ibid.*, October, 1936. (The last of these appeared too late for consideration in the present article.)

[2] The following authors could be regarded as supporting Knight's criticism in varying degrees: M. F. Joseph and K. Bode, "Bemerkungen zur Kapital und Zinstheorie," *Zeitschrift für Nationalökonomie*, Vol. 6, June, 1935; H. S. Ellis, "Die Bedeutung der Produktionsperiode für die Krisentheorie," *Zeitschrift für Nationalökonomie*, Vol. 6, 1935; Nurkse, "The Schematic Representation of the Structure of Production," *Review of Economic Studies*, June, 1935.

The following articles, recently published, deal with more or less the same problems though they are not directly related to the issues of the present controversy: C. H. P. Gifford, "The Concept of the Length of the Period of Production," *Economic Journal*, December, 1933, p. 611; "The Period of Production

quently reiterated by Professor Knight himself, and, on the Austrian side, has been answered by Professor F. Machlup and Professor F. A. von Hayek.[3] It is with this particular controversy that the present article will be concerned.

The literature created by this discussion is already sufficient to fill volumes, and most of it makes very difficult and often tedious reading. Yet a perusal of the more recent publications does not suggest that much progress has been made towards mutual understanding. While Professor Knight's position and those of other critics is not entirely acceptable in the view of the present writer, it appears that on the Austrian side none of his chief points have yet been fully understood or effectively answered.

For this state of affairs, I think Professor Knight is partly responsible. A serious reading of his numerous articles on this particular subject does not make it easy to discover the essential points of departure. He makes so many points that one is apt to get lost among them, not knowing how to distinguish between the primary and secondary, the important and the unimportant; while the conclusions are frequently clothed in paradoxical sentences which are intended to challenge the

under Continuous Input and Point Output in an Unprogressive Community," *Econometrica*, Vol. 3, April, 1935, p. 199; K. E. Boulding, "The Theory of a Single Investment," *Quarterly Journal of Economics*, Vol. 49, May, 1935, p. 475; "Time and Investment," *Economica*, May, 1936, p. 196; J. Marschak, "A Note on the Period of Production," *Economic Journal*, Vol. 44, March, 1934, p. 146; J. Marcus Fleming, "The Period of Production and Derived Concepts," *The Review of Economic Studies*, Vol. 3, October, 1935; A. Smithies, "The Austrian Theory of Capital in Relation to Partial Equilibrium Theory," *Quarterly Journal of Economics*, Vol. 50, November, 1935; V. Edelberg, "Elements of Capital Theory, A Note," *Economica*, August, 1936; Karl H. Stephans, "Zur neureren Kapitaltheorie," *Weltwirtschaftliches Archiv*, January, 1935; "Zur Problematik der Zinstheorie," *Zeitschrift für Nationalökonomie*, Vol. 7, 1936; Richard von Strigl, "Zeit und Produktion," *Zeitschrift für Nationalökonomie*, Vol. 6, 1935; E. Schneider, "Das Zeitmoment in der Theorie der Produktion, I," *Jahrbücher für Nationalökonomie und Statistik*, 1935; "II," *ibid.*, 1936; A. Mahr, "Das Zeitmoment in der Theorie des Produktivzinses," *Zeitschrift für Nationalökonomie*, Vol. 7, 1936; Carl Iversen, "Die Probleme des festen Realkapitals," *Zeitschrift für Nationalökonomie*, Vol. 7, 1936; O. Lange, "Interest in the Theory of Production," *Review of Economic Studies*, Vol. 4, June, 1936; H. Gaitskell, "Notes on the Period of Production," *Zeitschrift für Nationalökonomie*, Vol. 7, 1937.

[3] F. Machlup, "Professor Knight and the 'Period of Production'," *Journal of Political Economy*, Vol. 43, October, 1935, p. 577 (together with Professor Knight's comment), and a further Rejoinder, *ibid.*, December, 1935, p. 808; F. A. von Hayek, "The Mythology of Capital," *Quarterly Journal of Economics*, Vol. 50, February, 1936, p. 199. Reference should also be made to another article by Professor Hayek, dealing with earlier criticisms and a further elucidation of his views, "On the Relationship Between Investment and Output," *Economic Journal*, June, 1934, p. 207.

mind but without a sufficient indication of where to turn in order to uncover those mental processes which must have led up to them.

The aim of the present article is to review the essential points in Professor Knight's argument, to examine them in the light of other criticisms which have been put forward, and, finally, to analyse to what extent and in what respects they destroy the validity of traditional theory. Since this reconstruction of Knight's views has involved some "filling in" of gaps in the printed argument at certain stages, it is not necessarily a "correct" version of his views; it should be considered as an interpretation rather than a summary; and it is possible that it will be repudiated by the author himself.

II

Professor Knight's criticism of the "Austrian" doctrine can, I think, be summarized under three headings: First, that it is impossible to distinguish between permanent and nonpermanent resources (or "original" and "produced" means of production) or between the services of those resources; Second, that it is irrelevant, and in many cases, impossible, to distinguish—analytically or physically—between expenditures incurred in "maintaining" resources and those incurred in "replacing" them; Third, that there is no necessary correlation between the "period of production" and the quantity of capital. Among these, perhaps, the second is most open to criticism and at the same time, least important; whereas the third is certainly the most important and at the same time the most inadequately explained. But let us deal with each of these points in turn.

1. *Permanent versus Nonpermanent Resources.*—Here Professor Knight makes use of two separate arguments. In the first place he sharply distinguishes between the services of resources and the resources themselves (the actual physical objects from which the services flow). The former, in his view, cannot be thought of except as a rate of flow in time: like light or electricity (but unlike water) they flow, but cannot exist as a stock, or have their use transferred to any other period. Just as one cannot "bottle up" sunshine—except in the sense of transferring its energy into some other object, like oranges, which means "consuming" it by creating value in that object—today's labour hours cannot be deferred until tomorrow: they must be used immediately or lost. As regards the latter—pieces of land, labourers, and machines—no distinction can be drawn between permanent and nonpermanent resources, simply because permanent resources—apart from a few and insignificant exceptions—do not exist. It is essentially a fiction that there are "permanent" resources which exist without being maintained and whose services are therefore forthcoming at a rate inde-

pendent of their price. This fiction is admissible in static or stationary-state analysis, where it does not affect the immediate issues involved; but it is inadmissible to treat it as a relevant *fact* upon which a theory may be built. That it is fiction and not fact is shown by the reflection that neither land nor labour services would continue to flow (from the same resources) without the application of current services for their maintenance. No type of natural resources truly possesses "indestructible powers"; the best that can be expected is that the flow of services can be kept up permanently by continued maintenance.[4] A piece of land can be kept permanently in good condition by careful husbandry; but its "consumption" (in the same sense that capital goods can be consumed) is certainly possible by reducing its value to nil through nonmaintenance. In fact some types of resources (such as sources of coal and oil) cannot be kept intact however much is spent on their maintenance, though how long they last and the amount of services yielded may be influenced by expenditures on their upkeep.[5]

The point is equally obvious in the case of labour. The services flowing from a labourer could not be forthcoming unless he is given food nor could he be replaced after his death unless children are "maintained" until they reach the age when valuable services begin to flow from them (during their "construction period"). This way of looking at the matter would not sound so ridiculous but for the historical accident of the abolition of slavery. In a slave state, investment in human labour is in all respects identical with investment in machinery. And even in the nonslave state there is a minimum price necessary to maintain the labourer, while the Malthusian theory of reproduction applies, in certain countries and periods, to a considerable extent.

Even if the maintenance of labour does not proceed on strictly economic grounds in a world where everyone owns his own labour—since the preference for life over death cannot be expressed in marginal terms—maintained (and replaced) it must be; and therefore all re-

[4] The most important exception to this is sunshine which—given static weather conditions—flows at even rate without anything being done to the sun. But since neither sunshine nor the sun can be made subject to human property rights and thus market valuation, this exception is irrelevant. It might be argued also that sheer area (involving exposure to light and rainfall and power to support structure) *is* an "original and indestructible power of the soil" in the Ricardian sense and the only one; but even here we must qualify that area may shrink in some cases (e.g., on river banks) without maintenance.

[5] Professor Knight would go further and say that such nonexhaustible resources can also be "maintained" permanently by creating resources whose services provide a substitute for them. This view is justified, only in so far as *perfect substitutes* can be found (which is by no means always the case; not all uses of coal can be equally replaced by water power).

sources (i.e., *all* scarce objects, including human beings) must have some input or maintenance stream in order to have a permanent output stream (both of which are, of course, to some extent variable). No distinction can be drawn along this line; and the criticism urged against Professor Knight,[6] that he regards capital as maintaining itself permanently without maintenance expenditure, misses its point. From one standpoint all resources are "permanent"—which merely implies that, if they are maintained, they are maintained; while from another standpoint, none are permanent—since none will remain unconsumed unless maintained. What matters is that no distinction can be drawn between permanent and nonpermanent resources, whichever standpoint is adopted.[7]

Professor Knight's second argument in this connection refers to the analogous, but by no means identical, distinction between "original" and "produced" factors. Even if the distinction between permanent and nonpermanent resources is invalid, this latter distinction would still be valid, if it were true that the services of one set of resources—the "original factors"—produce another set of resources, the services of which—either by themselves, or with the aid of the services of the former—produce want-satisfying service flows. But there is no such one-way causation as is assumed by the Austrian theory. Resources are produced with the aid of the services of all kinds of resources; and it is even conceivable that the services of produced resources *by themselves alone* and without any aid from the services of "nonproduced" resources, should produce an endless succession of further produced resources. (It is "conceivable," but I think Professor Knight will admit that such an eventuality is not very likely.)

I hope to show later on that the importance of this latter point has been rather exaggerated—at any rate if it still remains true that the services of "produced" resources always require the co-operation of

[6] Cf. Hayek, "The Mythology of Capital," *op. cit.*, p. 214. "The very concept of capital arises out of the fact that, where nonpermanent resources are used in production, provision for replacement of the resources used up in production must be made, if the same income is to be enjoyed continually, and that in consequence part of the gross produce has to be devoted to their production." But are there any resources for which this is not true?

[7] Moreover, even if it were true that some resources are permanent (in the sense of requiring *no* maintenance) whilst others are not, this fact would not really be relevant from the point of view of capital theory. As will be shown below, "permanent resources" might very well be "capital goods," so long as they are augmentable in quantity; while there are various "nonpermanent goods" which are not part of capital (in the sense that they do not enter into the determination of the rate of interest) for the simple reason that their quantity cannot be augmented. In any case, the distinction between permanent and nonpermanent goods cannot be used to demarcate capital from other resources.

the services of "nonproduced" resources in further production. Professor Knight is quite right in insisting, however, that it destroys Böhm-Bawerk's concept of a "period of production." If the services of produced resources become embodied in further resources (and so on, in endless succession) there is no definite time lag between the investment of a "service unit" and the corresponding emergence of another service unit which is instantaneously destroyed by consumption. The "investment period" for certain services invested on a particular date (or, rather, for a small portion of those services) might be infinity. But this does not imply, in our view, that it is impossible to attribute an "average investment period" for the services *embodied* in a given stream of consumption goods.

It might be argued that the services of the resources *accruing at the present moment* might be regarded as "original factors" as against the services of resources accruing at any subsequent moment. Such a distinction, however, would be meaningless when applied to the time continuum of static equilibrium; and it is questionable whether the periods for which the services accruing at a single moment are invested, are in any way definite in the absence of stationary conditions. For the inputs of different dates jointly produce the outputs of different dates; and it is impossible to separate out the contribution to the output of different dates of the input of a single date.[8,9] This is the chief objection against the concept of an "investment period of currently accruing services" (as against the investment period of the services embodied in a given stream of consumption goods) which Professor Hayek now regards as relevant.[10] Another (alternative) objection is

[8] It is only under the assumption of stationary conditions, where both the output stream and the input stream are constant over time, that an investment period can be imputed to the input of a particular date; since in this case, this period will equal the investment period of the services *embodied* in the capital goods. Cf. also p. 212.

[9] This has already been stated by Wicksell, *Lectures on Political Economy*, English edition, Vol. I, London, 1934, p. 260. Wicksell was considering the analogous problem (or, rather, the same problem from the "other end," so to speak) whether the amount of labour disinvested by the "annual use" of a machine can be measured. ". . . fundamentally it is just as absurd to ask how much labour is invested in either one or the other annual use as to try to find out what part of the pasture goes into wool and what part into mutton. It is only at the margin of production that these quantities can be differentiated and have a concrete significance attached to them." Assuming variability at the margin, it is possible of course to determine by how much the output of various dates can be increased by a *marginal increment* of the input of a single date. But this does not imply, as Machlup appears to believe ("Professor Knight and the 'Period of Production'," *op. cit.*, p. 587) that it is possible to evaluate the contribution of the input of a given period to the output of different future periods.

[10] "The Mythology of Capital," *op. cit.*, pp. 206, 218–219.

that, in the absence of stationary conditions, this measure would be correlated with changes in the scale of new investment, rather than changes in the quantity of capital. It might easily remain constant while the quantity of capital is increasing if accumulation proceeds at a steady rate; while it could actually diminish if the rate of accumulation slowed down.

2. *Maintenance versus Replacement.*—Professor Knight argues in the second place that the maintenance expenditure (which we have seen is necessary for all resources) cannot be distinguished from expenditure incurred to replace worn-out capital goods. The usual distinction between replacement and maintenance is based on the idea that the former does (while the latter does not) bear a definite ratio to the service life of particular capital goods. This is best elucidated by an example. If the investment in a particular stock of houses is not maintained—the amortization funds are not put aside year by year—the amount thus "released" will bear a mathematical relation to the service life of the houses (a relation varying with the rate of interest, but definite at any given rate). If, on the other hand, "maintenance expenditure" in the narrower sense is not incurred (the roof leakages are not stopped, etc.) the house may become immediately useless and the destruction in value caused thereby bears no relation to the amount "released." Now, in the case of many capital goods no definite "replacement" ever occurs; the maintenance may consist only in the periodic replacement of "individual bits"; but that type of replacement need bear no relation to the shortening of service life (or, rather, the reduction in the discounted value of future services) caused by a reduction in maintenance expenditure. A railway locomotive, for example—apart from changes in knowledge, causing technical obsolescence—is never entirely replaced although every single part of it might be exchanged in the course of time, as this becomes necessary. But the sum of such maintenance expenditures cannot be brought into any simple relation with the cost of the locomotive as a whole; and failure to incur such expenditure in any particular respect (e.g., the replacement of a piston) will not destroy *part* of the value of the locomotive; it will destroy its entire value.[11]

[11] This, I believe, is also the reason for the view, which most people found so puzzling, that the "investment period" of the services of resources must be either zero or infinity; i.e., zero for the services engaged in producing current output-streams (from existing capacity) and infinity for the services employed in creating new "capacity." It does not imply a denial that capacity requires maintenance, but merely the view that no definite investment period can be attributed to the services employed in such maintenance for the simple reason that such expenditure is the absolute condition of the "functioning" of the capacity rather than the cause of a definite prolongation of its service life. In the above

Moreover, if "replacement" occurs regularly and continuously—and we shall see presently Professor Knight's reasons for regarding it as if it did—"replacement expenditure" becomes undistinguishable from "maintenance expenditure" in the narrower sense; and, therefore, according to Professor Knight, *the two should be lumped together, and not treated separately.*[12] I am not sure that even so, with a little mental effort, it would not be possible to forge a criterion for an analytical distinction, but I certainly do not think it would be worth the trouble. As we shall see later on, the essential point of the "Austrian" theory of capital does not really depend upon the validity of this distinction.

3. *The Optimal Length of the Investment Period.*—None of the points mentioned so far affect the fundamental assumption of the Austrian theory: the law of roundaboutness. Now we come to the argument with which Professor Knight seeks to prove that this law, irrespective of whether it is true in reality or not, is irrelevant from the point of view of capital theory, for it cannot be shown that an increase in the quantity of capital in a community will necessarily imply the adoption of more "roundabout" processes.[13] In order to show that this argument is independent of the previous objections, we shall assume for the present that "maintenance" does consist of periodic replacement of capital goods, as the Austrian theory apparently assumes, and that capital goods are exclusively produced by the services of other resources, i.e., labour. Let us revert therefore to the traditional situation exemplified by a world where only houses are produced and only labour is required to build (or replace) such houses. The only consumption good will then be the services flowing from houses, i.e., "room-years"; and we might assume the coexistence of different types of room-years. We shall defer for a moment the question how the "degree of round-

case of the locomotive, the labour engaged in building it remains invested for an infinite period, if the locomotive is kept in repair, but only for a very short period—perhaps a day—if the necessary repairs are not made good. Similarly with the labour engaged in making repairs. It is impossible to say by how much the service life of a locomotive is prolonged by the replacement of a worn-out piston. If it is not replaced, the future service life of the locomotive becomes zero, while if it is (and all other "pistons" are also replaced in the course of time) its lifetime might be infinity.

[12] Cf. especially "The Theory of Investment Once More: Mr. Boulding and the Austrians," *op. cit.*, p. 59: "the process of amortization and replacement is precisely the continuance of an old life and not a new birth"; also "particularly with reference to increments of value, capital as capital, it seems truistical to say that if it is kept in existence there is no amortization and replacement but only continuous maintenance."

[13] I am indebted to Mr. Milton Friedman, of the National Resources Committee, Washington, for helping me to understand Knight's argument in this connection.

aboutness" is to be measured; under these assumptions it will obviously vary with the lifetime of the houses. The famous Jevons-Böhm-Bawerkian law is satisfied if we assume that for each particular type of house (i.e., a type of house is one which provides a given kind of room-year) it is always possible to increase service life in a given proportion by increasing the construction costs of the houses in a lesser proportion.

We shall make two further assumptions, which, in my view, are also implicit in Knight's analysis. The first is that there is perfect competition and constant returns to scale (i.e., the production function is homogeneous in the first degree). The second is that investors have static foresight regarding the future, which implies that they expect the continuance of the same prices in the future as are ruling at present.

Under these assumptions the "optimum degree of durability," i.e., the optimum length of service life of houses, will be the one which maximises the rate of return on a given quantity of investment. In case of resources, such as houses, which are assumed to be periodically replaced, it is not immediately clear how this rate of return is obtained. It will obviously depend on the building cost of the houses (on the price of labour) and on the price of room-years; but it will also depend on the way amortization is provided. The representative investor, in deciding upon the degree of durability he should adopt, will deduct from the expected annual (gross) income of the house a sum sufficient for its replacement when it falls due. The net return of the investment will thus depend on the annual amount of this deduction, i.e., the annual amortization quota. It is only when the relative costs of amortization of the different types of houses are known that it is possible to determine the optimal length of service life.

But the amount of this annual deduction, given the length of service life, will obviously depend on the rate of interest at which the amortization quotas are accumulated. The higher this rate the lower the annual sum required to secure a given "replacement fund" at the end of a definite period; and the higher, in consequence, the rate of return on the investment itself. Now the rate of interest at which the amortization quotas are accumulated can certainly not be higher than the rate of return on the investment, since this would imply the existence of an investment opportunity which is superior to the one in question, in which case that particular investment would never be adopted. For similar reasons, it cannot be lower than the rate of return, since this would imply that the amortization quotas are invested in an investment opportunity which is inferior to the one in question, and the investor always has the choice of reinvesting his capital in the same uses in which it was originally invested. *Consequently the two must be*

equal to one another: and this condition makes the rate of return on a particular type of investment uniquely determinate. *The real rate of return on a particular type of investment is therefore that rate which satisfies the condition that the rate at which the amortization quotas are accumulated is identical with the yield of the investment itself.*[14] The optimum "degree of durability" is the one which maximises the rate of return, calculated in this manner.[15]

This can be elucidated by the following example. Let us assume that the same house (i.e., a house having the same number of rooms, of exactly the same type) can be built in three different degrees of durability. The first costs 1000 units to build and lasts thirty years. The second costs 1100 units and lasts forty years. The third 1200 units and lasts fifty years. We shall calculate first the net yield of the three houses by assuming that the amortization quotas are accumulated at various "given" rates of interest, and second, we shall calculate the real rate of return for each type by assuming that the amortization quotas are accumulated at the same rate as the "net yield" itself. The following table shows the comparative rates of return under the two assumptions:—

Rates of Interest Used in Calculating Amortization	Net Yield (per cent) of		
	Type I	Type II	Type III
per cent			
2	4.8	5.0	5.0
3	5.4	5.5	5.4
4	5.7	5.8	5.5
5	6.0	6.0	5.7
6	6.2	6.2	5.8
(7	6.4	6.3	6.0)*
Real Rate of Return	6.35	6.2	5.9

* At seven per cent none of the investments would be undertaken, since none would have a yield equal to that rate.

[14] The real rate of return, as defined above, is necessarily the same as the one which equates the sum of the discounted *gross* returns of a house (with no deduction for amortization) with its costs of reproduction. It is identical therefore with Professor Fisher's "rate of return over cost" (*The Theory of Interest*, pp. 155 ff.), Wicksell's "real" or "natural" rate, and the "internal rate of return" of Mr. Boulding. ("The Theory of the Single Investment," *op. cit.*, p. 479.) But it is only under the assumption of constant (value) returns to scale (from the point of view of the individual investor) that the optimal mode of investment can be determined by the condition that the real rate of return is maximised. Under conditions of diminishing returns to scale the determination of the optimal method of investment is more complicated and presupposes that the rate of interest is already known.

[15] This conclusion is true, irrespective of whether the output or input streams

It is easily seen that for each type of house the net yield will be at its maximum at the "real rate of return." This is the return which the investment yields if the amortization quotas are reinvested in the same use as the one represented by the original investment. This in turn implies that the investment—after a certain lapse of time, at any rate—is so arranged that the amount of capital invested in a given use is kept at an (approximately) steady and even level over time; this means, in real terms, that the age distribution of houses of each type remains constant in successive periods of time. If individual houses last, e.g., 30 years, a "house investment" will consist of a series of 30 houses, varying in age between 0 and 29 years, one of which is replaced every year. The gains from the investment of a certain amount of capital are therefore only maximised if the time quantity of the investment is stabilised: unless it pays to do the latter it does not pay to undertake the investment at all. Such a "staggering" of capital is thus an indispensable condition of a state of equilibrium.[16]

There need be no difficulty in arranging a maintenance scheme of this type, at any rate under the idealized conditions assumed in the theory. "Houses" may be big; (too big for the individual investor to buy a series of 30 houses), but, if not houses, at any rate the ownership titles in those houses are divisible: and so it ought to be possible for anybody to arrange his investment in such a way as to keep the amount of the investment per unit of time constant. To achieve this end may be considered, therefore, as one of the functions of the capital market.[17] All that is necessary to assume is that the indivisibilities do not go so far as to prevent the coexistence of a sufficient number of houses of each type and age.

This is the meaning of Professor Knight's repeated assertions that capital goods ought to be treated as if they were permanently and continually maintained, that capital is perpetual or a "permanent

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are uniform over time (as assumed in the text) or not. Whatever the time shape of output and input streams, there is only one rate of interest, corresponding to any given constellation of outputs and inputs, which makes the discounted value of all outputs minus the sum of the discounted values of all inputs (including the initial input, or construction cost), for any given date, equal to zero. And since all possible constellations of the time shapes of output and input streams are given by the production function, there will be (normally) only one possible time constellation of inputs and outputs which makes this "internal" rate a maximum. Cf. also Knight, "The Quantity of Capital and the Rate of Interest, Part I," *op. cit.*, p. 445.

[16] This has been stated by Wicksell and set out at length by Åkerman, *Realkapital und Kapitalzins*. Cf. also Wicksell, *Real Capital and Interest*, Lectures, I, pp. 258 ff.

[17] Moreover, it is sufficient to assume that this is possible for *some* investors, since they, through the workings of competition, can prevent the others from investing anything at all in that particular type of investment.

fund." Investing in 30 houses, one of which falls due for replacement and is *planned to be replaced* every year *ad infinitum*, is the same thing as investing in a house which lasts forever, while a certain sum has to be paid out every year to keep it in repair. This sum can be looked upon as "maintenance cost"; it can also be looked upon as the contribution of the services of other resources needed to produce the room-year service which is instantaneously consumed.[18] Thus every investment should be regarded as the source of a certain output stream and the consumer of a certain input stream (both of which are, of course, to some extent variable), in addition to which it will have a certain "initial input" or construction cost. As Professor Knight has shown, in the case where these streams are constant over time, the relation of output value to input value determines the investment period (in his terminology, the turnover period[19]).[20] Since the annual net income

[18] This is also the meaning, I believe, underlying Knight's statements that "maintenance is merely a detail of administration," or that "capital is an integrated, organic conception." What it means is that, in a state of equilibrium, all capital, however durable or perishable are the individual capital goods of which it consists, must be regarded as a fund which is continuously maintained—it cannot be thought of otherwise—since its yield can only be maximised on this basis.

[19] "The Theory of Investment Once More," *op. cit.*, p. 55. According to Professor Knight, this turnover period has only meaning "provided it is taken as an accumulation period and not as a period of investment." I confess I do not understand the meaning of this distinction, since in the context output value and input value represent permanent time streams, while input is regarded as "provision for maintenance or as payments for the other agencies co-operating with the particular capital good . . . or as including elements of both" (*ibid.*, p. 56). The "period" clearly cannot refer merely to the time during which the capital stock is accumulated (which is the sense in which the term "accumulation period" is generally used).

[20] If a is the value of the annual input, b the value of the annual output, t the average period sought, their relation will be given by the equation

$$a(1 + i)^t = b. \tag{1}$$

The rate of interest in question, however, is the investment's "real rate of return," which is given by the equation

$$i = \frac{b - a}{C}. \tag{2}$$

where C is the value of current services needed to produce (or reproduce) an "investment" capable of yielding an output stream b at an input stream a. Since the production of resources also takes a certain time, this construction cost will itself include an element of interest. This, however, causes no logical difficulty; for the construction cost (including interest) will still have a unique value if we impose the further condition that interest during construction must be identical with the interest earned on the investment itself. In other words, given the input of all dates (including the series of initial inputs, representing

of the investment is merely the difference between the two and since, under our assumptions (i.e., constant returns to scale), every unit of capital in that investment is assumed to earn interest at the same rate, the relation between output value and input value will also determine the relation between "construction cost" and "annual maintenance cost." For investments which are continuously maintained at an even rate of time, the degree of roundaboutness can be measured by the ratio of the initial or construction cost to the annual maintenance cost (assuming that the expected future prices of productive services are the same as present prices).[21,22] The "law of roundaboutness" then

"construction") and the outputs of all dates, the rate of return on the investment will be uniquely determined.

[21] We use the expression "the degree of roundaboutness" rather than "the investment period," since the ratio of construction cost to annual maintenance cost gives us an *index* to the period of investment, rather than the period itself. It will correspond to the average period (as defined above) only if the rate of interest is small and compound interest can therefore be neglected. Neglecting compound interest, the above equation (1) becomes

$$a + (a[1 + i] - a)t = b,$$

from which

$$t = \frac{b - a}{ai}.$$

But

$$C = \frac{b - a}{i} \text{ (from (2))};$$

$$\therefore \quad \frac{C}{a} = \frac{b - a}{ai} = t.$$

This is also the definition of the "time spread of the investment" given by Mr. Boulding ("Time and Investment," *op. cit.*, pp. 212–213) who appears to have reached it by a different route; and also of Mr. Smithies ("The 'Austrian' Theory of Capital in Relation to Partial Equilibrium Theory," *op. cit.*, p. 81). Its merit is that it enables us to make use of the concept also in those cases where the lifetime of individual capital goods comprising the investment cannot be evaluated.

In the case of our three types of house investments, the relation of annual output to annual input will be 225/100, 273/100, and 312.5/100 respectively, while the ratio of "initial cost" to "annual maintenance" cost will be (approximately) 2000/100, 2800/100, and 3600/100. Since on account of compound interest the value of individual houses does not diminish at an even rate in time, the "replacement cost" of a stock of houses with an average age equal to half their lifetime will not equal half their total cost of construction, but will be higher than this amount. This ratio will therefore only approximate to Böhm-Bawerk's "average period of production" (=half the lifetime of the houses) when the rate of return is so small that compound interest becomes negligible.

[22] The "annual maintenance cost" of a resource (or good) includes the value of *all* services consumed in producing whatever is regarded as the output stream of that particular resource. It is determinate therefore only if the output

simply says that it is always possible to reduce annual maintenance cost by increasing initial construction cost, in producing a given permanent output stream.

Now, according to Professor Knight, this concept of the investment period, or "degree of roundaboutness," is without significance for capital theory; for "the average investment period and the quantity of capital may perfectly well be affected in opposite ways."[23] The argument, if I rightly understand it, could be summarised as follows: The optimum degree of roundaboutness, on any single investment, is the one which maximises the rate of return on that investment. A change in the quantity of capital could only lead to a shift in the optimum degree of roundaboutness by affecting the relative rates of return on different degrees of durability. It is usually assumed that this will be the case because an increase in the supply of capital will lead to a fall in the rate of interest. But in the case of "continuous maintenance" the *rate of return*, on any single investment, will be independent of the rate of interest. It is only by assuming that the amortization quotas are accumulated at some "outside" rate of interest that this "internal rate" will be affected; in which case a given fall in the rate of interest would reduce the return from less "durable" investments to a greater extent. In the numerical example we have given above, the reduction in the interest rate to 4 per cent would make Type II houses more profitable than either of the other two types. But this method of calculation is obviously mistaken since it overlooks the fact that, by reinvesting the amortization quotas in the same uses, a much higher net return is obtained than by reinvesting them at the current interest

stream of the particular good is regarded as given. Since, however, the resources themselves can only be unequivocally defined by their output streams, this problem ought to cause no difficulty. To elucidate our concept by an example: if the output stream of certain boot-manufacturing machines is regarded as a certain quantity of machine services per unit of time (assuming that these services are capable of physical measurement, in terms of machine-service-hours, like labour-hours), the "annual maintenance cost" or "input value" of those machines will consist of the expenditures—in the form of upkeep and replacement—continuously incurred in securing a permanent flow of these services. If, on the other hand, not "quantity of machine-service-hours, per unit of time" but "quantity of boots per unit of time" is regarded as the output stream of those particular machines, "the annual maintenance cost" will include, in addition to the above, also the cost of the services of the factors (labour, etc.) normally regarded as co-operating with the machines in producing the boots. The ratio of construction to maintenance cost—which, perhaps, should more properly be called *the ratio of the initial input to the annual input flow*, the former, as distinct from the latter, being a singular expenditure which is incurred only once, at the beginning of the investment—will of course be different in the two cases: but so will the "investment period," if measured in any other manner.

[23] *Ibid.*, p. 45.

rate outside. It is not true, therefore, that a fall in the interest rate would make it profitable to shift to more durable houses. In the above example, the least durable house (Type I) has the highest real rate of return—6.35 per cent—and so long as the price of room service and the rate of wages remain the same, this is the type that will be preferred, irrespective of how much the rate of interest might fall.

An increase in the quantity of capital, therefore, will not change the "degree of roundaboutness" involved on *already existing* investments; and there is no reason to suppose that this "degree of roundaboutness" will be higher on new investments than the average on already existing capital goods. What happens when the rate of interest falls is that investments whose real rate of return was lower than the previous interest rate become profitable. More houses will be built. But the houses which have only just become profitable on account of the lower rate of interest need not be "more durable houses"; they may be houses with a different quality of room service. It is the relation between net return and cost of construction which must be lower. But the kind of houses which have a lower net return may very well have a lower ratio of construction cost to maintenance cost and thus a lower "period of production." The two are not related to each other at all—durability, as Knight contends, is merely one of an "infinite number" of considerations that affect the net return of investments.

III

Before we proceed to a criticism of this argument, we might attempt to piece together these various aspects and give a general picture of the world as Professor Knight sees it. It consists of a collection of resources, which, like heavenly bodies, emanate light and absorb light. All these resources have to be "maintained"; i.e., they all absorb a quantity of services at every unit period which is the absolute condition of their continuing to radiate another stream of services, which is their "output." No distinction can be made between maintenance and replacement, or even between production for immediate consumption and production for "maintenance"—or future consumption—since all that we know is that during a certain period a certain quantity of all kinds of services have been "put in" (into each particular "resource" or "factor") and a certain other quantity of services has been "put out." It is impossible to say "how much" of the input served to produce the immediate output, and how much served to maintain the resource itself. And since, in a well-organised competitive world, for each particular resource both input stream and output stream must be constant, per unit of time (if the ruling prices are

expected to remain in operation),[24] the question itself is meaningless. Looked at in one way, all production is "instantaneous"—if the input stream is regarded as "producing" the output stream. If the resources themselves are regarded as producing the output stream, all input is to be regarded as producing output in an indefinite future. The output stream of all resources in so far as they do not directly consist of consumption service and in so far as they are not actually creating some *additional* resource—must therefore be input or "maintenance cost" for some other resources. Even consumption can be looked upon as the input of the resources called "labourers." Not all consumption, of course. For on the one hand labourers' consumption falls short of total consumption by the consumption of the owners of other resources —on the other hand, the labourers' consumption must itself include the net return from the investment of owning themselves. This difference (property owners' consumption plus the difference between labourers' income and maintenance cost) can be regarded as the "net return" from the whole system. It is precisely the extent to which all inputs fail to cancel out all outputs.

In a growing system some of the service stream (of all types of resources) will also be engaged in producing further resources. To the extent that such services are obtained by reducing the input-stream of other resources—and this is the only way of obtaining them if a world of "full employment" is contemplated—these other resources, will, for the period of construction of the new resources, be "under-maintained"—their input stream will be temporarily reduced. Not all the resources "lent" will be repatriated, of course, at the end of the construction period. Some of them will permanently remain with the new resources, as their permanent input flow. This deficiency, however, will be more than offset by the output stream from the new resources, which directly or indirectly will also help to maintain the old ones.[25]

As the quantity of capital is increasing, the rate of return falls, since this implies the adoption of progressively inferior investment opportunities. It is at the margin of investment that the rate of interest

[24] I believe this assumption underlies the whole of Knight's analysis. When he mentions "perfect foresight" he uses this word in a different sense from the one in which Professor Hayek uses the term. Professor Knight, I believe, merely implies that the markets are sufficiently perfect to adjust themselves immediately to any given change—they are "Walrasian" markets. It is "perfect foresight" only under the static assumption that no further changes occur in the future.

[25] The whole situation is analogous to the case of a hydroelectric plant, which lends part of its water power for the construction of another plant. Once the new plant is constructed, the old plant's power will no longer be required except for "maintenance," which is a small proportion of the construction cost and, if I rightly interpret Professor Knight, could easily be less than the additional net output of the new plant.

is determined; capital quantity itself is a "marginal concept." Accumulation implies the conversion of current income into additional streams of permanent income; it implies an increase in "resources" in general, in the capacity to produce output streams, and in this sense *every* addition to the stock of capital should be considered as a permanent improvement. Accumulation requires abstinence (in the sense that abstaining from a part of the current product is the price of creating an additional output stream) but there is no "waiting period" involved in the maintenance of a given stock of resources,[26] and, since the services of all resources equally contribute to the creation and maintenance of each other, no definite meaning can be attached to the term of an investment period itself. This concept is in any case *irrelevant;* for even under the most favourable assumptions it could not be substantiated that an increase in capital will necessarily imply the adoption of "lengthier" processes.

I am not sure whether this brief picture does justice to Professor Knight's views. But if it is a correct interpretation of his theory, it fails to account for a number of factors which it is the fundamental task of a theory of capital to explain. In the first place, it does not explain how the rate of return, on different investments, is kept at a level of equality. Under the conditions postulated, the rate of return should correspond in equilibrium to the current rate of interest not only on the marginal unit of investment, but on all units. It can be argued that "inframarginal" investments will earn rents which, in terms of money costs, will equalise this difference; but then the question still arises: why should "rents," if they arose, not be eliminated by competition? In the second place (and this is closely linked up with the first) it

[26] Among Austrian theorists, the "waiting period" is sometimes measured by the extent to which current consumption has to be reduced (below some technical maximum) in order to permit the maintenance of the existing stock of capital, i.e., in order to secure the continuance of the same rate of consumption permanently. Now it is perfectly true that at any time, given the technical composition of the system, the rate of consumption could be stepped up a certain extent if all productive services were devoted to producing for immediate consumption—given the length of time for which the increased rate of consumption-output is supposed to last. But the extent to which this can be done will depend on the type of capital goods used as well as on their quantity; and it is quite possible that with an increase in capital, the possibility of expanding consumption by not maintaining capital goods should decrease rather than increase. In any case, the extent to which this can be done will certainly have no relation to the *value* of capital in terms of current income, except in those simple cases where the capital consists exclusively of circulating capital, physically homogeneous with the final product. (E.g., if capital consisted of the stock of grain annually reinvested—in the form of seed and advances to labour—the quantity of consumption could be expanded in precisely the same ratio as the value of the capital stock in terms of the annual product.)

does not really explain why an increase in capital should lead to a fall in interest. To say that resort must be had to inferior investment opportunities does not in itself meet the problem. Diminishing returns necessarily presuppose the existence of some "fixed factor" as their cause; and there is no room for such "fixed factors" if we regard, as Professor Knight apparently regards, capital accumulation as an increase in the quantity of resources in general. In the last place, this theory contributes little to an explanation as to how *interest as a distributive share* is determined, along with other distributive shares. The great merit of the Austrian capital theory—at any rate of Wicksell's version of this theory—is that it explains the interrelation between wages and interest; and thus makes it possible to extend the general marginal productivity theory so as to include capital. So far as this problem is concerned, the critics of the traditional theory can hardly be said to have offered an alternative explanation.

We shall attempt to demonstrate in the following that the crucial argument concerning the irrelevance of the "law of roundaboutness" ignores the all-important effect of a change in the quantity of capital on price relationships; and that an interpretation can be given to the theory which allows it to survive most of the other criticisms that have been brought forward. Finally we shall endeavour to show that the "law of roundaboutness" itself is merely a derivation from the general law of nonproportional returns; while the Austrian view of capital merely implies an attempt to measure the quantity of variable resources by the average productivity of the services of "fixed" resources, which is possible so long as the latter are homogeneous in kind and the composition of the final output stream can be considered as given.

IV

1. In the first place, let us go back for a moment to the question of the definition of resources. Here Professor Knight appears to have overlooked one distinction which survives the strictures levelled against the traditional classification. Even if all resources require to be maintained and the services of all resources contribute to the production of new resources, it is still not true that *all* kinds of resources can be *produced*. It is not possible to produce "land"; and, in a capitalist economy which no longer knows the institution of slavery, it is not even possible to "produce" labour. The quantity of labour, through a change in the birth rate, can certainly be increased, but to regard this quantity as being a function of saving or the rate of interest is turning an analogy into a falsehood.

If the services of producible resources provided "perfect substi-

tutes"[27] for the services of the nonproducible resources this difference would not constitute a "relevant economic fact"—the prices of the services of nonproducible resources would be entirely governed by the services of produced resources. In reality, however, the services of capital goods provide merely an imperfect substitute to services of labour; the one can be substituted against the other in any sort of production only at continuously increasing marginal rates of substitution. Thus even if the distinction between "permanent" and "nonpermanent" resources or between "original" and "produced" resources were untenable or irrelevant, there is still a distinction to be drawn between "producible" and "nonproducible" (or rather, "augmentable" and "nonaugmentable" resources).

Given this distinction, we must immediately make note of another factor, which in this paper has so far been left in the background: that in a position of equilibrium, assuming perfect competition, the value of producible resources must always correspond to their cost of reproduction (to the value of the quantity of services needed to produce another, "identical" resource). The value of nonproducible resources, on the other hand, need not conform to any such criterion simply because they have no costs of reproduction.

Now, what Professor Knight's own theory has not explained—or at any rate the present interpretation of his theory has not explained so far—is the problem, how this correspondence between the value of producible resources and their costs of reproduction is achieved, or if achieved, how this correspondence is again re-established, once equilibrium has been for any reason disturbed. A fall in the rate of interest, e.g., will raise the discounted value of *all* future income streams, and thus the present value of all resources whose ownership can be bought and sold (that is to say, all resources except labour). Moreover, if it is assumed that all resources are "continuously" maintained, it must raise the market value of all investments in the same proportion. If their value was previously equal to their costs of reproduction, they will now exceed these costs by the proportion which the fall in the rate of interest bears to the new rate of interest. How will this correspondence be re-established?

2. In order to analyse the interrelation of different factors let us return to the simplest hypothetical situation, where the stock of capital consists of houses which are built exclusively by labour, while "room-years" represent the only kind of consumption good. In order to avoid monetary complications which are not relevant in the present discus-

[27] In the sense of their having infinite "elasticities of substitution" with the services of the other resources, i.e., that this rate of substitution did not vary with the proportions in which they were combined.

sion, we might also assume that "room-years" serve as a *numeraire* in terms of which debts are contracted, wages are paid, and property is valued. In this society "savings" imply a desire to convert current income ("room-years") into "houses"—in other words, an increased desire for "holding" houses. If this increased demand can be satisfied by an increased supply (when, e.g., unemployed labour is available for additional house building) there need be no change in the value of houses in consequence. But if *all* the labour is already engaged in building (or rather "replacing") houses, it is the value of houses that will rise (which is merely another way of saying that the rate of interest, in terms of room-years, will fall); and, as the value of houses rises, wages will rise. For the value of existing houses cannot be higher than their costs of reproduction; and a rise in costs of reproduction must imply a rise in wages.

Alternatively one might say that saving first leads to a fall in the room-year rate of interest (which is "determined" in the annuity market), this creates the rise in the value of houses, which in turn increases wages. The rise in wages increases construction costs; but it will also reduce the value of houses (i.e., below their new level, which they reached after the fall in interest). For the rise in wages, by raising expected future wages, increases maintenance costs, relatively to gross incomes (input values relatively to output values) and thus reduces the "net incomes" on the basis of which capital values are calculated. Thus, while costs of construction rise, capital values fall, and "somewhere in the middle" they again meet, thus bringing the movement to an end. In either case, it is the change in wages which brings the real rate of return on individual investments into equality with the rate of interest.

It would seem to follow from this that in this society "savings" merely resulted in a transference of income from the capitalists to the labourers.[28] There would be no increase in aggregate real income; and (save for changes in relative demand arising out of changes in distribution) there would be no changes in composition. In particular, it is difficult to see how investment opportunities which were previously ultramarginal (which were previously not adopted because their real rate of return was lower than the prevailing interest rate) would, as

[28] This transference would not be temporary, but permanent, (even if "savings" were temporary). For it would be financed, so to speak, out of two sources: first, the increase in the supply of capital, coming from the savers; second, the reduction in interest (in the return on investments) which the increase in the supply of capital creates (and which would thus be shared equally by all capitalists). The reduction in the interest rate, following upon a given increase in capital, would be precisely such as would enable the same transference of real income per time unit permanently as the volume of savings (per time unit) which was originally responsible for it.

a result of savings, become inframarginal. For the rise in wages would have offset the effect of the reduction of interest; and in the new situation, they would still be below the margin of profitability. Continued capital accumulation under such circumstances would merely lead to the complete expropriation of the capitalists, by reducing the rate of interest to zero and making the value of annual labour input identical with the value of room-year output.[29]

3. But fortunately for the capitalists this will not be so—not even under our rigid assumptions. For the rise in wages in terms of house-room creates something which by itself tends to check the tendency of the level of wages to rise and the income from capital to fall. It necessarily increases the optimum degree of roundaboutness.

Let us return to our numerical example of the three types of houses and see how their respective rates of return will be affected by varying increases in wages. Since the rise in wages must always be such as to equalise the rate of interest with the real rate of return, this will also show the level of wages corresponding to different rates of interest (represented by the italicised figures):—

Increase in Wages (per cent)	Real Rate of Return (per cent) of		
	Type I	Type II	Type III
0	*6.35*	6.2	5.9
10	5.42	*5.45*	5.24
20	4.65	*4.83*	4.68
50	2.69	3.29	*3.37*

We can see from this that not only does Type II become the most profitable investment if the increase in wages is 10 per cent, but the differences in profitability, expressed as a percentage, continuously increase with every increase in wages.[30] Assuming that there is a con-

[29] This sounds rather like a rehabilitation of the classical theory of the Wages Fund—which in a sense it is meant to be. If conditions were postulated under which an increase in the supply of capital would *not* lead to an increase in aggregate real income (when, e.g., the technical coefficients between "capital" and labour—the services of produced and nonproduced resources—are fixed and the quantity of labour is given) the supply of capital would determine—in a linear fashion—the rate of wages. There is no reason to assume that in such a society the rate of interest will be necessarily zero—it will be determined at the point where the demand for "annuities" (in exchange for current income) is equal to its supply. (The rate will be zero only if at any positive rate the demand for annuities exceeded the supply.) The rate of interest thus determined will determine the level of wages and the share of labour in the product.

[30] In the above example, the changes appear numerically slight (relatively to the changes in wage rates) but this is only because the maintenance costs, in the examples shown, were already very low in relation to the construction cost. Generally speaking, the numerical change in relative profitability for a given

tinuous range of alternatives and not merely three distinct types of durability there must be a shift in the optimum ratio of construction cost to maintenance cost (or input volume to output volume) as soon as the price of input units rises relatively to the price of output units. This shift can be thought of as being brought about (for the "representative enterprise") either by a reduction of present "output" with a view of increasing the future rate of output (the input stream remaining the same) or a reduction in present output with a view of reducing future rate of input; or, finally—since the input flow is subject to diminishing returns in terms of output flow—simply a reduction in the permanent rate of input which is followed by a less-than-proportionate reduction of the permanent rate of output. In all of these cases there will be a reduction in the permanent input flow per unit of output flow; which in turn will have three different consequences: In the first place, it damps down the fall in the value of investments, brought about by a rise in wages; since the increase in maintenance cost will no longer be proportionate to the increase in wages. In the second place, it increases the "costs of reproduction" of house investments more than in proportion to the increase in wages (since maintenance costs can only be reduced by increasing construction cost) and thus closes more rapidly the "gap" between the value of investments and the costs of reproduction, caused by a given increase in the supply of capital. (In other words, it closes the gap with a smaller increase in wage rates than otherwise.) All this can also be expressed by saying that the existence of Type II houses as alternative to Type I houses prevents both the rate of interest from falling, and the level of wages from rising, so much—following upon a given percentage increase in "free capital"—as they would have fallen, or risen, had Type II houses not been available as an alternative. In the third place, it creates an increase in the permanent supply of house room, which otherwise could not have taken place, as a result of a fall in the interest rate.[31] If in the above example we further assumed that there was only a single kind of house room in existence (that given in the example)

increase in wages will be greater, the higher is the ratio of maintenance cost to construction cost—(the influence on relative profitability of changes in the interest rate in the case of "discontinuous maintenance" will be *per contra* the more noticeable the lower is this ratio)—and greater the higher is the real rate of interest. With continued increases in wages, the differences generally increase in a diminishing proportion.

[31] Furthermore if we assume that the "degree of roundaboutness" for different types of room-years is different, the rise in wages will change their relative rates of return. For a given rise in wages will affect the rate of return all the more the higher is the ratio of annual maintenance cost to construction cost. The re-establishment of equilibrium (i.e., equalisation of the rates of return) will then require, in addition, a relative fall in the prices of the services of more "durable" resources and a relative expansion of their supply.

the change over to Type II investments from Type I investments will ultimately have increased the volume of available room-years in the ratio of 100(273–225)/225, i.e., by 20.88 per cent. This, divided by the quantitative increase in the investment period, which is involved in this change-over, should give the "marginal productivity of waiting" according to the Jevons' formula, to which the rate of interest must correspond at the point where the two types of investments are equally profitable.[32]

Thus, given the available quantity of labour and the productivity function of capital (the extent to which maintenance cost per unit of output can be reduced by a minute increase in the ratio of construction cost over maintenance cost), the rate of interest determines the relative price of labour service and consumption service. This price ratio in turn determines the "average investment period," i.e., the degree of roundaboutness which maximises the yield of investments. Alternatively, the increase in the supply of capital determines the extent to which the degree of roundaboutness will be changed by changing the ratio of the price of input units relatively to output units, which in turn determines the rate of interest, since in equilibrium the rate of interest must be equal to the "real rate of return" on investments.

All this is merely a simplified and somewhat loose account of the Wicksellian version of the Austrian theory, first put forward in the *Über Wert, Kapital und Rente,* and later in the *Lectures on Political Economy,*[33] and adapted to the case where all capital is "permanently and continuously" maintained. It differs from the Böhm-Bawerkian theory chiefly through the analysis that for the individual entrepeneur the optimal investment period is determined by the production function and the existing price relationships (which are given to him); while the supply of capital "determines" the investment period by determining the ratio of output prices to input prices (i.e., of a unit of consumption service to a unit of labour service).[34]

[32] The two types of investments become (approximately) equally profitable at a wage increase of 6 per cent at which both yield 5.8 per cent. At this rate the "compound investment period" (calculated according to the formula in footnote 20 above) will be 14.73 years for Type I and 17.85 years for Type II. The net increase will therefore be 3.42 years and the "marginal productivity of waiting" $20.8/3.42 = 6.2$ per cent, i.e., approximately the same as the rate of interest. (An exact equality could only result if very small changes were contemplated.) Since, however, in these cases, the "investment period" (in terms of years) can only be evaluated if the rate of interest appropriate to the situation is already known, the concept of the "marginal productivity of waiting" does not seem to be particularly helpful.

[33] Cf. *Lectures,* Vol. I, Part II, Sect. D, "An Alternative Treatment of the Problems of Interest and Distribution," also Appendix 21, "Real Capital and Interest." Cf. also Wicksell's *Finanztheoretische Untersuchungen,* pp. 22–41.

[34] Cf., e.g., *Finanztheoretische Untersuchungen,* p. 33 (my translation): "Given

V

So far we have merely attempted to vindicate the traditional capital theory under the simple assumption that the capital of the world consists of houses produced exclusively by labour; that there is perfect competition, static foresight, and the absence of uncertainty. The real world—for the purpose of the present discussion—differs from this, apart from the last three assumptions, in three important respects: (i) that the maintenance of capital does not have the character of "replacement" of units at definite intervals but rather that of continuous repairs; (ii) that the services of labour are not at all invested in capital but partly co-operate with the services of capital goods in producing consumption services, i.e., the labour force itself is divided, to use Wicksell's expression, between "free" and "invested" labour; (iii) that capital goods are not produced exclusively by the services of labour but also by the services of other capital goods, i.e., the services of capital goods themselves help to produce (or "maintain") each other. How far do these facts modify our results?

(i) The first of these points can be treated briefly. Whether "maintenance expenditure" consists of definite replacement of physical units or merely of repairs, the ratio of initial cost to annual maintenance cost will still provide a measure of the "degree of roundaboutness"; and so long as it is still possible to reduce the annual maintenance charge, of a given service stream, by increasing the initial construction cost, it will still be true that the price ratio between output units and input units will determine the optimum relation between construction cost and maintenance cost, which, in turn, will determine the rate of interest. It will not be possible, of course, to associate a definite "investment period" with the input of any *particular* period; but this, as we have seen, is hardly legitimate in any case, unless the whole contribution of the input of a particular period accrues at some given date in the future (as, e.g., with the storage of wine), which is only true in certain specific cases.

(ii) The second point is more serious. It affects our previous analysis in two ways: (a) In the first place, it is clear that if a part of the labour supply is co-operating with existing equipment in producing current output, simultaneously with savings a certain quantity of labour will be "released" for employment in new construction. If instead of houses we had taken the less unreal example of machines co-operating with

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the general postulate of Böhm-Bawerk's theory [i.e., the law of roundaboutness] one would think at first that the capitalist always aimed at a steadily longer investment period of his capital—at any rate once the loss of interest during the transition period can be neglected. This, however, will by no means be the case; for any given level of wages, there is always an optimal length of the investment period."

labour in producing bread, it would have been at once obvious that savings will not merely increase the demand for "holding" machines, but will also reduce the demand for bread. Corresponding to the increase in the demand for labour in machine-making, there will be a released demand for labour in the making of bread.[35] If machines are produced exclusively by labour, while "bread" is produced partly by labour and partly by machines, there would still be an increase in the *aggregate* demand for labour. But if "labour" and "machines" co-operate in the same way in producing new resources as in producing final output—and this is what Professor Knight's first point really amounts to—there need be no net increase, as far as the *creation* of new capital goods is concerned, either in the demand for labour services or in the demand for machine services. There could thus be an increase in the number of machines even without a rise in wages. It would be wrong to conclude, however, that this would invalidate our previous conclusions. For once the new machines are in existence and "saving" correspondingly ceased, they will require some additional labour for their maintenance and operation which they can only get by reducing the quantity of labour employed in combination with the previously existing resources. This in turn (if machine services are merely an imperfect substitute for labour services) will increase the price of labour services, relatively to other services (which is merely another way of explaining that the relative increase in "other services" increased the relative scarcity of labour services), it will reduce the quantity of labour input per unit of bread output (by reducing either the labour embodied in, or the labour co-operating with, a unit of machine service, or both), which in turn implies an extension of the degree of roundaboutness and a fall in the rate of interest. It still remains true that it is the rise in wages, in terms of final output, which causes the fall in the rate of return; a fall which would be more severe if it were not possible to offset partly the effect of the rise in wages by extending the degree of roundaboutness.

(b) This brings us to the next point in this connection: the question of durability. We have already mentioned earlier[36] that the input

[35] The reason why this has been apparently overlooked (by the classics and in Wicksell's treatment, cf. esp. *Lectures*, *op. cit.*, pp. 148–149) is due to the assumption that what is saved is the product of past labour and not of current labour, so that the current demand for labour is independent of current consumption; depending only on the current supply of capital. (This is the meaning, e.g., of Mill's statement that the "demand for commodities is *not* a demand for labour"). This again is true if (a) the unit of account is fixed in terms of the final product, so that changes in current consumption do not affect the profitability of investment *via* price expectations; (b) all labour is "invested labour"—as, e.g., in the case of an agricultural community, whose labour requirements consist mainly in sowing seed for the following harvest.

[36] Cf. footnote 22 above.

stream (and thus the ratio of initial input to annual input) of resources will depend on how one defines the "output stream" of resources. In the example just given, either the "quantity of machine services per unit of time," or the "quantity of bread per unit of time" can be regarded as the output stream of the machines. In the first case the "input stream" will consist only of expenditures incurred in the upkeep and replacement of the machines (Wicksell's "invested labour"). In the second case it will include, in addition to the above, also the labour normally regarded as co-operating with the machines in producing the bread. According as the first view is taken or the second, we shall have two different measures of the "degree of roundaboutness." Only the first of these can be regarded as an index of the *durability* of capital goods. But only the second will be necessarily correlated with the quantity of capital.

It is only in so far as the proportion of invested labour to co-operating labour remains constant when the aggregate quantity of capital changes that the degree of roundaboutness will necessarily increase in both senses. And although this follows from Wicksell's analysis of the problem[37] there seems to be no reason that it should be the case if the possibility of a change in the *character* of the machines is taken into account.[38] An increase in the quantity of capital available might even lead to the introduction of *less durable* rather than more durable equipment, if only this equipment is more "automatic" (in the sense

[37] Cf. *Lectures*, Appendix 2, pp. 278 ff., esp. 287–288.

[38] Wicksell's argument could be summarised as follows: Let us suppose that in the beginning the increase in capital only leads to an increase in the number of machines, of the same type as those already in use. This will imply that the amount of invested labour increases and the amount of "free" labour is reduced; which in turn will necessarily raise wages and reduce the price of the services of machines. The rise in wages, as we have seen before, makes it profitable to extend the lifetime of machines, which in turn will imply a reversal of this process: the amount of free labour will increase and the amount of invested labour will be reduced. On Wicksell's assumption this must continue until both regain their former proportion. Meanwhile "the labourers lose part of, but not all of, their recent increases in wages and the capital goods regain part of, but not all, the value they have just lost." (*Ibid.*, p. 288.)

It is quite possible, however, that as a result of the rise in wages, it becomes profitable to introduce not more durable but more automatic—and even less durable!—machines and in consequence there will be a further increase, rather than a reduction, in the amount of invested labour. It is often thought that machines which are both *more* efficient and *less* durable will be preferred irrespective of the quantity of capital. That this is not the case, can best be elucidated by a simple example. Let us assume, e.g., that bread can be manufactured by two different processes. The first involves machines which require an initial expenditure of 1000 units of labour and an annual maintenance of expenditure of 10 units (per unit of bread, per year). These machines will need in addition 50 units of labour to operate them. The second involves machines which require

of requiring less labour to operate it) than the previous equipment. It is not true therefore (except in the special case, like houses, where all the labour used is invested labour) that the increase in the quantity of capital will *necessarily* lead to an increase in "average durability," or that it will lead to the making of "goods of still greater durability in place of those produced before."[39] It *could* imply the opposite of these things. It must necessarily increase the "degree of roundaboutness" involved in producing final output (if co-operating labour and invested labour are taken together); but this is *not* the same thing (except in the special case where the amount of co-operating labour is zero) as an increase in the average durability of capital goods.

(iii) The last point—although it is the one most frequently emphasised by other critics[40]—does not, in our view, affect the theory any more than it has already been affected by previous considerations. It is perfectly true that at no stage of the production process is labour exclusively employed—the services of different types of resources contribute to the "maintenance" (or production) of each other; the output stream of resource A might be the input stream of some other resource B, whose output stream in turn forms part of the input of A. But this does not imply that this "circularity" in production is complete: this would only be the case if consumption itself could be regarded as part of the system's "input."[41] Now all "outputs" (of resources other than labour) which are *not* consumption services must be simultaneously inputs in some other resource. Similarly, all inputs, in so far as they do not consist of labour service, must be the outputs of some other resource. Therefore all outputs which are not consumption service and all inputs which are not labour service, exactly cancel

an initial expenditure of 1500 units and an annual maintenance expenditure of 40 units; but these machines being much more "automatic" only require 10 units of labour to operate them (all per unit of bread, per year). The ratio of initial cost to annual maintenance cost in the *first* sense will be 1000/10, 1500/40 respectively, in the two cases. In the second sense, it will be 1000/60, and 1500/50 respectively. Now, if the price of labour in terms of bread is unity, obviously the first of these methods is preferable to the second—since it will yield a return of 4 per cent while the second yields only 3 per cent. If, however, the price of labour rises, say by 50 per cent, the second method will become preferable to the first; since in that case, the yield on the first method will be reduced to 0.5 per cent while the yield on the second only to 0.83 per cent.

[39] Machlup, "Professor Knight and the 'Period of Production'," *op. cit.*, p. 590; and Hayek, "The Mythology of Capital," *op. cit.*, p. 213.

[40] Cf. Joseph and Bode, "Bemerkungen zur Zinstheorie," *op. cit.;* Nurkse, "The Schematic Representation of the Structure of Production," *op. cit.*

[41] It is possible, of course, to regard that part of the labourers' consumption which is necessary to maintain this productive capacity intact, as the "input" of labour as a factor of production. But only in a slave state would this magnitude have an economic significance.

each other out, if the input streams and output streams of individual resources are added together.[42] By defining the "net output" of resources as the volume of consumption we thereby also necessarily define their "net input" as the quantity of labour.[43] So long as the quantity of annual labour service remains constant with variations in the quantity of capital, and so long as the quantity of no other type of services remains constant, there will be a unique correlation between the rate of interest and the amount of labour input per unit of final output—or, if you like the rate of interest and the average investment period of the services of labour. For, as I hope to show in the next section, the "investment period" of a factor necessarily varies with its average productivity, once it is assumed that the factors themselves have a cost of production and not only the final products.

VI

For a proper understanding of the nature of capital and interest one ought to start by analysing the conditions of equilibrium in a society where *all* goods are capital goods, i.e., where "original" or non-augmentable resources do not exist at all. It is rather unfortunate that, following Böhm-Bawerk and his school, we have been generally accustomed to start with a more specialised set-up, with the picture of Robinson Crusoe engaged in net-making. This Crusoe-approach makes it unnecessarily difficult to single out features which are merely the property of a special case from the demonstration of general principles. Had the analysis started with the "general case"—by imagining a society where *all* resources are produced and the services of all resources co-operate in producing further resources—a great deal of the controversies concerning the theory of capital might not have arisen. As we shall see, it will be much easier to get back from this world to Böhm-Bawerk's world than to make the journey in the opposite direction.

Let us imagine, then, a society where "machines" and "slaves" are the only scarce resources, whose services are required equally for the production of each other and for the production of bread.[44] The owners

[42] Cf. also the "analysis of interactions" in Fisher's *Theory of Interest*, pp. 18–22.

[43] This really follows from selecting "labour" as being distinct from other resources, in which case the input of *all* resources other than labour will consist of labour service. It would also be possible to regard some other factor—"land" —in the same way: in which case the input of all resources (including labour under this head) would consist exclusively of land service. The reason for regarding "labour" as distinct, is twofold: (a) that it is the ownership of labour which is nonalienable and in consequence has no capital value; (b) that it is the quantity of labour service which can be regarded as a constant with respect to "saving." Cf. also the next section, below.

[44] I.e., there is a production function for machines, whose variables are machine service and slave-labour service, a similar one for slaves, and yet another for bread. If we strictly adhered to the terms of our example, it should be added

of slaves and machines (the entrepreneurs) will, under these assumptions, have essentially three degrees of freedom: (1) they can vary the proportions in which the services of machines and slaves are combined in the production of bread; (2) they can vary the proportions in which the machines and slaves themselves are produced, or reproduced; (3) they can decide how much of the "net output" of any period (i.e., the quantity of bread production compatible with maintaining the stock of slaves and machines intact) should be set aside to increase the permanent stream of bread output in the future.

Assuming perfect competition and constant returns to scale, the entrepreneurs will (individually) combine the two factors in such proportions as to maximise the output of a given outlay; and they will tend to produce the factors themselves in such proportions as would maximise the rate of return on a given investment (all in terms of "bread"). Assuming that the law of diminishing productivity operates throughout (i.e., that there is an increasing marginal rate of substitution between machine services and slave-labour services, in the production of bread, machines, and slaves) the problem will have a unique solution. Given the cost function of machines, slaves, and bread, there will be only one proportion between machines and slaves which will maximise the yield of capital: the proportion at which the value of both machines and slaves (calculated by discounting at the same rate their expected net income) is equal to their respective costs of reproduction.[45] It is this yield which in turn will determine the rate of interest. (All this can also be expressed by saying that the yield on capital will be maximised when the real rates of return, on machine investments and slave investments, are equalised.) This rate will represent at the same time the system's "maximum rate of growth": the rate at which the stock of resources would increase, per unit of time, if consumption is reduced to zero and the services of all productive resources were devoted exclusively to their own production.

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that the services of machines and of slave labour are directly required only for the production of machines and of bread. Only "bread" is required for the production of slaves. But bread in turn represents a certain quantity of machine services plus labour services, combined; so that we can say that the services of both resources are needed for the production of both resources.

[45] If there is a relative increase in the number of machines, and a consequent fall in the yield of machine investments, this would not imply an equivalent fall in the yield of "capital"—as it does in our own society—since the fall in the yield of machines would be largely offset by the corresponding increase in the yield of slaves. But on account of the law of diminishing returns it could never be so offset *entirely* (and vice versa if there is a relative increase in the number of slaves). Thus there will be only one ratio of investment in the two factors which equalises the real rates of return on these two types of investment and this will necessarily be also the arrangement which maximises the return per unit of bread.

Thus both factors will yield a "net product"—i.e., the specific productivity of their services will be greater than the costs of production of these services—and the rate of return merely denotes the size of this excess, per unit of time, as a percentage of the cost. Since this "real productivity," and thus the real rate of return, on any resource will depend upon the relative scarcity of the services of that resource, and since the proportions of the factors are variable, investment will tend to get distributed in such proportions as would equalize the rate of return on all lines of investment.[46] Once this proportion is achieved, capital accumulation or decumulation (in the absence of a change in technical knowledge) will leave the rate of interest unaffected. How rapidly capital will be accumulated will depend, of course, on the rate at which people are willing to save at the given rate of interest; but no amount of capital accumulation could change this rate.[47]

In this society there will be two distinct "investment periods" which cannot be combined for the purposes of an average, since they are alternative ways of describing a single situation. We might either represent the entire bread output as the product of machines whose input consists of slave-labour service; or we might represent the entire bread output as the product of slaves whose input consists of machine service. The average investment period of the services of slave labour will depend on the ratio of the value of the entire labour input (of all machines) to that of the entire bread output. The average investment period of the services of machines will depend on the ratio of the value of the entire machine-service input (of all slaves)[48] to that of the

[46] It would necessarily be true therefore of a slave state that both capital and labour yield a positive rate of return, irrespective of the extent of accumulation (unless there is some third "fixed" factor, like land, in relation to which both become less productive, by an increase in their quantity). But it will normally be true even in a nonslave state that the rate of return will be positive on both "machines" and labour (though the latter, owing to the inalienability of the ownership of labour, can only be calculated on rather arbitrary criteria) although, of course, there will no longer be forces operative which tend to make them *equal*. But the rate of return, on one or the other, could fall to zero in "extreme cases": (1) when the quantity of labour has increased, by multiplication, to the extent that the marginal productivity of labour has been brought down to the labourers' subsistence level (the "stationary state" of Ricardo and the classics); (2) when the quantity of material resources has increased, by accumulation, to the extent that the marginal productivity of the services of capital goods has been brought down to the level of their "maintenance costs" (the stationary state of Professor Schumpeter). There seems to be no reason to assume that in the real world forces are operative which will inevitably draw the system either to the one or the other "extreme" of stationariness.

[47] If this rate is such that people are willing to save at that rate (and this desire, in the absence of a change in psychology, could only be strengthened by continued accumulation) our society would resemble the "expanding universe"; it could never become stationary.

[48] The "machine-service input" of slave capital takes two different forms. (1)

entire bread output. Since both refer to the same bread output, an average between the two is completely meaningless. Both of these investment periods will, of course, remain unaffected by changes in the amount of capital.

If we now assume that, for some reason, the number of slaves is "held constant," when capital is accumulated, the increase in capital can only take the form of an increase in machines. Then the investment period of *labour* will rise, and the real rate of return on *machines* will fall. (Correspondingly, the investment period of machine services will *fall*, and the rate of return on slave labour will *rise*, but not to the same extent.) This "lengthening" of the investment period for slave labour can take various forms. (1) There might be an increase in the number of the *same* machines, and a substitution of machine services for labour services, in the production of bread; this will imply a reduction in the amount of co-operating labour, and an increase in the amount of invested labour, per unit of bread; (2) There might be an increase in the durability of machines, in which case the proportion of invested to co-operating labour can remain the same; (3) There might be a change in the "degree of automatism" of the machines (with or without a change in durability), in which case again the proportion of invested labour is increased and the proportion of co-operating labour reduced. All three cases imply a reduction in current labour input, and an increase in "initial input," per unit of bread output. If we now further assume that the slaves are liberated and in consequence only machines are regarded as "capital," the rate of interest will be determined by the yield of machines only; and we have then arrived at the Austrian theory of capital.

It follows from this analysis that the *Senior-Jevons-Böhm-Bawerkian law of roundaboutness is merely a roundabout way of expressing the law of nonproportional returns.* Once it is realised that the only difference between "produced" and "nonproduced" resources lies in the fact that the one can be augmented by economic disposition and the other cannot, it is clear that the ultimate reason why the rate of interest is falling with an increase in capital is precisely the same as the reason why rents are rising (or wages falling) with an increase in labour. A relative increase in the number of slaves, in the case where "land" and "slave labour" are the only scarce resources, could just as well be said to imply an increase in the "investment period" of the services of land, as a reduction of the marginal productivity of the services of labour; while the material content of the Austrian theory of capital

The services of machines directly co-operate with labour in producing bread. (2) Bread is also required for the maintenance of labour (which must be deducted from the "net output" of bread) and this maintenance bread also represents a certain quantity of machine service. (The same is true the other way round, of course.)

could be equally well expressed by saying that capital accumulation leads to a reduction in the marginal productivity of the services of those factors whose quantity can be augmented by such accumulation, as by saying that it increases the investment period of the services of those resources whose quantity remains constant.

The purpose of the "investment period" approach is to reduce the production function to two variables, substituting "waiting" for the services of all produced (or variable) factors, with interest as the price of "waiting." In this way—and only in this way—can *capital as capital* be treated as a factor of production, commensurate with "labour." This, however, can only be done so long as the services of the "fixed" factors can themselves be regarded as homogeneous, or at any rate sufficiently homogeneous to leave their relative scarcity unaffected by changes in the amount of the services of other resources. In the above example machine services and labour services were the only scarce factors. This enables us, by regarding the quantity of labour as constant, to measure changes in the amount of machine services available by changes in the "investment period" of the services of labour. Had we assumed three factors, say the services of machines, labour and land, among which only the services of machines could be increased in quantity by capital accumulation, neither the investment period of the services of land, nor the investment period of the services of labour would have afforded an unambiguous measure of the amount of machine capital. A combined "investment period" of the services or these "original" or rather constant resources, on the other hand, would have been possible only if the services of machines were assumed to be an "independent good" relatively to the services of land and labour, i.e., if the marginal productivity-ratio between land services and labour services depended only on the relative amounts of land service and labour service, but not on the quantity of machines.[49]

Further consideration shows, moreover, that the same objection which can be brought up as regards the nonhomogeneity of the services of fixed resources also applies as to the nonhomogeneity of final products. So far we have treated consumption goods—"bread"—as if they were a homogeneous entity, or if not homogeneous, at any rate something the composition of which can be regarded as given. It is obvious, however, that except in the special case where all consumption goods contain the services of fixed resources in the same proportions, an increase in the quantity of capital will lead to a change in the relative prices of different types of consumption goods, and thus to a change in the composition of the consumption stream. In that case it

[49] This defect of the Austrian capital theory was first pointed out by F. X. Weiss, "Produktions Umwege und Kapitalzins," *Zeitschrift für Volkswirtschaft und Sozialpolitik*, 1921.

will no longer be legitimate to speak of the degree of roundaboutness involved in producing a unit of "final output," since we no longer have an unambiguous measure of that unit. Nor can one ascertain (once allowance is made for the "circularity" in production) the degree of roundaboutness for each kind of consumption good, taken separately. For the contribution of the services of produced resources are diffused between different industries; and this renders it impossible to impute a definite proportion of the aggregate stream of "labour" to a single kind of consumption good.[50]

So far we have conducted our analysis under purely static assumptions, and found that even under these assumptions the investment-period concept leads into difficulties once allowance is made for the fact that both the relative prices of different kinds of labour (and land) and the relative prices of different kinds of consumption goods might change as a result of a change in the quantity of capital. It is not proposed here to examine the further difficulties that emerge once the static assumptions are, in one respect or another, relaxed; nor even to enquire how far the methods of "comparative statics" are legitimate for dealing with problems of capital accumulation. There can be no doubt that for an analysis of dynamic problems—and especially of the *par excellence* dynamic problem of the trade cycle—the investment-period concept could hardly be of any use. At the same time we hope that we have succeeded in demonstrating that the real objections against the "Austrian" capital theory relate to the *measurability* of the investment period, rather than to its *relevance*. It can be argued on many grounds (some of them emphasised by Knight, some already emphasised by earlier writers, such as Professor Fisher) that the "investment period" ceases to be a quantitatively measurable magnitude once one departs from the level of abstraction of Böhm-Bawerk's and Wicksell's writings. But this is a very different thing from maintaining—as Professor Knight maintained in various articles—that the investment-period concept is also wholly irrelevant, i.e., that even if conditions are postulated under which it can be measured, it will have no correlation with the quantity of capital and the rate of interest. In so far as it is possible to give an index to the "degree of roundaboutness," it can also be shown that an increase in capital, if associated with a lower interest rate, will necessarily imply the adoption of more roundabout processes.

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[50] It is only in cases where (as in our world of houses) the input stream of each single capital good consists exclusively of labour, or where the services of all capital goods are completely specific (i.e., they only contribute to the production of one final good) that the "investment periods" for individual commodities can be *separately* evaluated.