TIME, CHANGE AND COMPLEXITY:

LUDWIG M. LACHMANN'S CONTRIBUTIONS TO THE THEORY OF CAPITAL.

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Published in *Advances in Austrian Economics*, Vol. 3, 1996

PART ONE: LUDWIG LACHMANN AND THE AUSTRIAN THEORY OF CAPITAL

Introduction

[T]he long retreat from Böhm-Bawerk's classical objectivism in the theory of capital, which started with Professor Hayek's reply to Knight in 1936, was continued in his *Pure Theory of Capital* of 1941 and to which I endeavored to give provisional expression in my book *Capital and its Structure* in 1956, reaches [here] a new stage. (Lachmann, 1986, p. x).

The most famous Austrian capital theorist, Eugene von Böhm-Bawerk, produced a three volume (multiple edition) tomb on *Capital and Interest* (Böhm-Bawerk, 1959). This work generated considerable controversy among many eminent economists, both during and after Böhm-Bawerk's lifetime. Hayek considered the issues raised in capital theory important enough to attempt to continue, and, hopefully, complete Böhm-Bawerk's project. In addition to numerous articles (Hayek 1939), he published *The Pure Theory of Capital* in 1941 (Hayek 1941). This was a rigorous and intricate extended exercise in aspects of intertemporal production, primarily under equilibrium conditions. It was intended to be the first of a two volume work, the second of which was to be an examination of capital issues in a dynamic *disequilibrium* world. Volume two was never produced (as Hayek moved onto other projects). However, in 1956, Ludwig Lachmann, who was a student and colleague of Hayek's at the London School of Economics, published *Capital and its Structure* (Lachmann, 1956). In the preface he stated:

> The chief object of this book is thus to rekindle interest in the fundamental problems of capital .... to outline a new approach and to show that it can be applied ... to a number of problems ....I am painfully aware of the fact that this book leaves many questions unanswered. It could hardly be otherwise. But its is my hope that others will follow and make their contributions to the theory of capital. There can be few fields of economic inquiry today which promise a richer harvest than the systematic study of the modes of use of our material resources. (p. xvi).

In his preface to the unrevised second edition, published in 1978 he noted, "[t]he theory of capital, alas, has made little progress since 1941"(vii). In fact, probably the only notable work on Austrian capital theory in the interim was Kirzner's *An Essay on Capital* (Kirzner, 1966).

Lachmann had moved to the University of the Witwatersrand in Johannesburg, South Africa after the war, where he stayed for the rest of his life (though for some years after retiring he held a visiting appointment at New York University for one semester every year)[1]. By the time he moved to Johannesburg, capital theory was already going out of fashion in the wake of the Keynesian ascendancy. *Capital and its Structure* was really the culmination of his earlier work on capital (Lachmann 1938, 1944, 1947, 1948)[2].

As a professor in Johannesburg, Lachmann lectured on a variety of topics. He was, in fact, responsible for teaching the "core" courses for second and third year economics.[3] These courses included

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[1]The reader interested in Lachmann's biography may consult Grinder 1977, Lavoie 1994 and Mittermaier 1992.

[2]Lachmann's views on capital, and on economics in general, show a remarkable stability and consistency over a long period of time from about 1950 until his death in 1989. His views on capital seem to have been formed during the approximate period 1938-1948. During this period his views seemed to have changed notably. By 1948 (Lachmann 1948) however, he appears to have reached essentially the viewpoint that formed the basis for his book (Lachmann 1956). The spark of inspiration appears to have been Hayek's 1937 article (Hayek 1937), "The ideas set forth there by Professor Hayek have been the main inspiration of this paper" (Lachmann 1948, p. 308, n1).

[3] Under the South African system of higher education courses take an entire academic year rather than a semester or a quarter as in the United States. They are thus designated Economics I, Economics II and Economics III for each of the three years of a three year undergraduate bachelors degree. An economics major would complete all three years. There were related courses like Money and Banking, International Economics and so on, which also lasted a full year. Lachmann's lecture notes reproduced here are from

subsections on monetary economics, Keynesian economics, international economics, economic growth and, of course, capital theory. That there was a section on capital theory at all must be assumed a result of Lachmann's own special interest in the subject. It was surely not the standard fare of undergraduate economics at that time. As might be expected then, this course was heavily influenced by his own work. He attempted, however, to place his work in a wider perspective within the history of capital theory. Part two below contains my lecture notes from the course in capital theory delivered in 1968[4]. It is reproduced here (apart from any independent interest it might generate) to provide a supplement to Lachmann's published work on capital to which it is closely related. This paper is divided into three Parts. The rest of Part One supplies some background context to the lectures, briefly surveys aspects of Austrian capital theory originating with Carl Menger and outlines the basics of Lachmann's own approach. Against this background the lecture notes produced here in Part Two, which are sometimes quite terse (reflecting in part the limited ability of the note taker to capture every elaboration) may be easier to follow and to appreciate. In Part Three I attempt to place Lachmann's contributions in a wider context, considering the relationship of capital to time, complexity and change. A relatively neglected construct of G.L.S. Shackle is examined.

Professor Lachmann's Course on Capital Theory

Ludwig Lachmann as Teacher

Ludwig Lachmann was an unusual teacher. To the average student he seemed a formidable figure, intimidating and highly inaccessible[5]. This impression was created primarily by his way of lecturing. His lectures inevitably followed a set form. Lachmann would sit in front of the class and deliver his lecture in perfectly punctuated prose, (for the most part) without notes. Only very occasionally would he rise to use the board. His manner of articulation was very eccentric. He spoke with a deep, guttural German accent and lingered on particular words for emphasis. He also used an unusual intonation for emphasis; he would frequently interrupt his sentences with something like "eh eh" followed by short pregnant silences and quick intakes of breath. When students first heard him their immediate inclination was to laugh.

They soon found out, however, that he was deadly serious. He would tolerate no disruptions. He always began right on time and finished his remarks just before the sound of the final bell. Each lecture, though apparently spontaneous, was perfectly crafted. Each sentence was connected to the previous one and the succeeding one in such a way that a logical progression was created from beginning to end. If one were able to follow every nuance, one would find his remarks replete with subtle references and allusions

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Economics III. This course was divided up into a number of subsections all of which were taught by Lachmann.

[4]Being a subsection of Economics III. See the previous footnote.

[5]This contrasts sharply with the following statement:

> Indeed, my personal experience with the man convinces me he had no illusions of grandeur. Here was this cultured European gentleman inviting ill-trained and ill-mannered American graduate students into his office for hours of casual conversion about economics. His manner with brash young students was to treat us as equals, to listen to our arguments, and respond to them patiently. He was just a regular guy. (Lavoie 1994, p. 299, n19).

It is difficult to reconcile this impression with my experience in South Africa. After Economics III, I continued as a student of Lachmann's in his private and restricted 'honours' seminar which met every Thursday evening for tea in his office. It included, in addition to students, other faculty and interested lay people from the community (for example prominent journalists). While he was always courteous to and considerate of and even patient with students and others, it never seemed to me that he treated his intellectual subordinates as equals. He retained an impenetrable formality that evidently did not work as comfortably in a very different American environment.

as well as numerous, but frequently missed, examples of dry humor. It is not to be expected that the lecture notes of a rather average senior undergraduate would be able to reflect any of these notable qualities. For this I make no apologies though I do regret being unable to share more of the flavor of the lectures.

It is probably true that most of his students were ill prepared for his classes. The material he chose and the level at which he presented it was beyond them. They were, as a rule, too immature and unsophisticated to comprehend the full meaning of much of his discourse. His concerns were remote from theirs. They were often preoccupied with the always threatening and frustrating South African political dilemmas. Most of his students were part of the white, politically liberal establishment (which in a U.S. context would be in the center of the political spectrum). If Lachmann had any political opinions they never showed in his economics classes. He left it to the students to draw whatever political implications they could, and most did not see any.

It is clear, though most of his students did not share his feelings, that Lachmann thought his subject matter was vital and compelling. For him the important issues in the world concerned rival schools of thought. He frequently employed metaphors of combat to describe his mission to advance the cause of Austrian economics. He was intensely concerned about resisting the dangers posed by classical formalism to the integrity of economics and this concern permeated all of his courses. For him a course was more than the teaching of concepts and techniques. He was concerned to convey the historical context of the subject and the alternative ways of looking at things.

For his students, this was mostly a mystery. They came to the course to learn about economics, which they were required to take and which they understood to mean a body of received doctrine much like a course on physics. There was something profoundly unsettling about finding ‘mere opinion’ where one expected to find formulas for truth. Where they succeeded in his courses it was usually by taking careful notes and memorizing the key ideas without understanding, or caring to understand, their full significance. There were notable exceptions, students whose sophistication and interest were sufficient for them to relate to the material. They were the select few who seemed able actually to communicate with Professor Lachmann.

The Course on Capital

The lecture notes below are probably typical of those taken by Lachmann's students. Therefore, as explained, they miss much of the subtlety that a fuller understanding might have captured and they certainly miss the elegance of expression that characterized the original performance. Nevertheless, after a period of a quarter century they present a remarkably coherent picture, a picture that has gained clarity with time and maturity. In fact it has been a profoundly satisfying experience to find, in the editing of these notes, that ideas that had been considered forever mysterious suddenly became crystal clear. The entire course on capital assumed a unity in my eyes as editor that had been absent from my view as a student.

Lachmann's course on capital theory is, in essence, an extended examination of the legacy of the ideas of Böhm-Bawerk on capital. He was of the opinion that Böhm-Bawerk, though a disciple of Menger's, had inadvertently laid the groundwork for a disastrous wrong turn in the development of capital theory and, by extension, of economic theory in general. Böhm-Bawerk's framework had been used by economists with a Ricardian way of thinking to develop a formalistic approach based on the ideas of long run equilibrium. In this respect, Lachmann sees himself as a descendant of Adam Smith and of Joseph Schumpeter, with Ricardo constituting the entry to the wrong turn.

Thus, the course begins with an attempt to lay out for the student the rival schools and the issues between them. Perspective, method and historical context are elucidated. The main body of the course was composed of an outline of the development of capital theory with special attention devoted to the issues identified at the outset of the course. Adam Smith is the founder of the *compositive school* and Ricardo is the founder of the *classical school*. Lachmann is not unsympathetic to Ricardo. What was appropriate for Smith's world was no longer appropriate for Ricardo's. Ricardo mistakenly applied the ideas appropriate to a predominantly agrarian world to a largely industrialized one. Böhm-Bawerk is

characterized as a Ricardian, a precursor to the latter day Ricardians led by Joan Robinson. Wicksell was the first to move back in the direction of the compositive school, which Hayek and later Lachmann were to develop.

This historical outline teaches the student some of the main ideas necessary to understand the concept of capital and its role in economic life. But, at the same time, the student also learns about how this concept has developed over time and, most interesting for our purposes, how Lachmann envisaged his own contribution to fit into the grand scheme of things. So, whereas most of the main themes of his work on capital to be found in his published work are dealt with here, they are abbreviated and related to the broader context of capital theory from Adam Smith to modern times. To my knowledge, he never published these ideas.

Lachmann refers to Clark, Knight, Fisher, Robinson, Kaldor and others in relation to the two schools of thought he identifies, but he never refers to Menger. This is his most striking omission.[6] A reading of Böhm-Bawerk reveals an uneasy amalgam of the ideas of Menger and Ricardo. Capital theorists, in general, have chosen to emphasize the Ricardian elements. The Mengerian elements in Böhm-Bawerk could easily be fitted into the compositive school as developed by Lachmann. Also, the course would have profited from an appreciation of Menger's original development of all of the essential ingredients of a disequilibrium theory of capital.

Carl Menger's Theory of Capital

As indicated, though Lachmann traces his ideas back to Adam Smith, and, indeed, bases his reconstruction of Böhm-Bawerk's "third ground" on Smith's concept of division of labor, he does not acknowledge the importance of Carl Menger as a member of the "compositive" school, i.e. as contributing to an analysis of capital in terms of its compositive structure rather than in terms of its size. Menger's pioneering approach is, in fact, responsible for our thinking of capital in terms of a *time structure* reflecting the structure of capital goods employed in the production process. Menger's framework is a good place to start in thinking about capital.

Menger characterizes production as a sequential process in which *goods of higher order* (capital goods) become transformed into *goods of lower order* (consumption goods). Capital goods are varied in nature but can be classified by where they fit, along a time continuum, into the production process. The lowest, or first, order goods are, as noted above, consumption goods. The lowest order capital goods are second order. The next highest are third order and so on. With this model, he makes clear that the element of time is inseparable from the concept of capital. Any theory that treats the process of production as instantaneous necessarily misrepresents reality in an important way.[7]

> The transformation of goods of higher order into goods of lower order takes place, as does every other process of change, in time. The times at which men will obtain command of goods of first order from the goods of higher order in their present possession will be more distant the higher the order of these goods (Menger 1871, p. 152).

And the rewards to saving result only if more time consuming methods of production are adopted.

> ...[B]y making progress in the employment of goods of higher orders for the satisfaction of their needs, economizing men can most assuredly increase the consumption goods available to them

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[6] It is possible that the notes fail to reflect some passing references to Menger because, at that stage of my life I was insufficiently familiar with Menger's contributions and such references went unnoticed and unnoted. But Menger certainly did not feature as a key figure in Lachmann's account of the development of capital theory.

[7] I try, in this paper, to ignore methodological questions. Lachmann frequently refers to 'the real world' by contrast to the models of the theorists he was criticizing. He was, of course, aware that all theory involved the need to abstract form reality in important respects, as, equally obviously, was Menger. The criteria by which one decides on the appropriateness of abstractions and metaphors is a question about which both had opinions but which we do not consider here.

> accordingly - but *only* on condition that they lengthen the periods of time over which their activity is to extend in the same degree that they progress to goods of higher order. (Menger 1871, p. 153 italics added).

The higher order goods that men come to own must allow greater production if there is to be progress. That is, they must (in combination with other goods) be able to produce a greater volume of consumption goods in the future or, in other words, they must be able to extend consumption further into the future. It is interesting to note that, while Böhm-Bawerk's later discussion of the greater productivity of more "roundabout" methods of production is clearly drawn from Menger, the latter was clear that there is nothing mechanical about the relationship between saving (diverting consumption from the present to the future) and productivity. "Saving" may be neither *necessary* nor *sufficient* for economic progress. He envisaged the time consuming creation of specific capital goods to be a necessary condition for achieving economic progress. Menger first introduces these ideas in connection with processes in nature. Men find the fruits of nature valuable. But at an early stage in the development of civilization they learn that they "can do more than simply await nature's yield. By intervening in the natural processes, individuals can have an effect on the quantity and quality of the subsequent yield....To understand the objectives of the 'producers' is to understand that the earlier a producer intervenes, the greater are the opportunities to tailor the production process to suit his own purposes. This provides an intuitive basis for the notion that the more 'roundabout processes' tend to have a greater yield in value terms" (Garrison 1985, p. 165).

At any point in time there is a capital structure characterized by capital goods of various orders whose value is determined by the values attributed by consumers to the consumption goods they are expected to produce. "The value of goods of higher order is always and without exception determined by the prospective value of the goods of lower order in whose production they serve" (Menger 1871, p. 150). These values manifest in the market as prices. As long as the these prices remain (and are expected to remain constant) and as long as there are no technical changes in methods of production, the capital structure will remain constant. But if there should be a permanent change in the price of even one consumption good, this will almost always imply the need to change the capital structure in some way. As on theorist has recently put it, for example "if the demand falls for a particular lower order consumer good, the higher order capital good used to produce the consumer good would not necessarily lose its value, but would fall to its next best *marginal* use.... If people stopped smoking the price of all final tobacco products would fall to zero.... those [capital goods] of *exclusive* or specialized use, such as tobacco seeds, would lose their entire value. But because farms and machinery have other uses they do not lose their value completely. Their value falls to the next best *marginal* use" (Skousen 1990, 19).

> Goods of higher order thus do not lose their goods-character if but one, or if, in general, but a part of these needs ceases to be present (Menger 1871, pp. 65-66).

We see here an anticipation of Lachmann's notion of "multiple specificity".

The level and pattern of the employment of resources (including labor) is determined and thus depends on *the strong link between the structure of consumption and the structure of production.* Changes in the demand for one (or some) consumption good(s) (*relative to others*) cause changes in the evaluation and use of *particular* capital goods and in employment. The implication in Menger is that the market can accomplish this smoothly. Time is inseparable from the notion of capital. Since the value of higher order (capital) goods depends on the prospective value of the consumer goods they are expected to produce, the elapse of time, and with it the arrival of unexpected events, implies that some production plans are bound to be disappointed and thus affect the value of specific capital goods will thus be affected. The economic consequences of human error are implicit in Menger's view of capital but (unlike Keynes) he does not see them as destabilizing.[8]

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[8]Menger was aware of the possibility of error and of the importance of expectations. He says "[T]he prospective value of goods of lower order is often - and this must be carefully observed - very different from the value that similar goods have in the present." (1871, p. 152). It is thus possible to say, "[T]he 'correctness' of the valuations of higher order goods depends completely on entrepreneurial abilities...." (Garrison 1981, p. 21).

Menger and Böhm-Bawerk

From the above discussion it is evident that Menger laid the groundwork for a comprehensive theory of capital. However, as explained earlier, it is to his most famous disciple, Eugene von Böhm-Bawerk that most economists look when thinking about capital. Such a detailed and voluminous work as Böhm-Bawerk's, lent itself to many possible interpretations. The later Austrians came to see it as an attempt to extend Menger's insights on capital in a way that was not wholly true to Menger's vision. In particular, it seemed to them that Böhm-Bawerk had departed from Menger's subjective theory of value. For John Bates Clark, however, the issue was quite different. Böhm-Bawerk had attempted to incorporate Menger's vision of time in the production process using a quantifiable concept - the "average period of production". As Lachmann explained Clark (and later Knight) attacked this concept as meaningless and indefensible and, in the process, suggested a view of capital in which time as we know it seemed to play no real part at all.

It is important to note, however, that Böhm-Bawerk's characterization of a capital using economy is, in many ways, very similar to Menger's.[9] He adds a geometric devise to Menger's reasoning. The production process is viewed as a series of concentric circles, with time progressing outward from the center. The outermost ring represents the value attained by consumption goods, while the center represents the origin of the production process. The respective rings, starting at the outside and progressing toward the center, thus correspond to Menger's first, second and higher order goods. In a world without change, a stationary state, the rings have two interpretations: "(1) The area of the rings can represent the amount of the different kinds (maturity classes) of capital that exist at a given point of time, or (2) the initial inputs of the production process can be seen as radiating outward through the several maturity classes until they finally emerge at the outermost ring as consumers' goods." (Garrison 1981, p. 24). Though this is the view that was to surface in the debate with Clark, the stationary state was not central to Böhm-Bawerk's view. He was concerned with the question of how an increase in capital occurs and what that meant for economic events.(1884, p. 109). His recurring theme is "that real saving is achieved at the expense of the lower maturity classes (the outer rings) and that the saving makes possible the expansion of the higher maturity classes (the padding of the inner rings) and the creation of higher maturity classes than had previously existed." (Garrison 1981, p. 24). The point to be stressed is that, for Böhm-Bawerk, as for Menger, an increase in capital, a condition we normally associate with the progress of a capital using economy, involves a change in the *time structure of production* in some way. It is not simply an augmenting of each type of capital good at each level of maturity. Once again, this anticipates Lachmann on the inextricable connection between capital accumulation and changes in the capital structure. It is somewhat at odds, however, with Lachmann's characterization of Böhm-Bawerk or at least with his emphasis.

Böhm-Bawerk tried to capture the relationship between the various maturity levels with a single number, "the average period of production". This concept was designed to measure the amount of time on average that is took to produce the product or, alternatively, the amount of time on average that the inputs in the production process spend in production before emerging as outputs. In this way he hoped to have found the illusive element that would cement the heterogeneous elements of the capital *structure* into a single measurable *stock*. The element of measurement was time - "embodied time". This involved a radical departure from Menger's forward looking vision which featured time in an inescapable but different way. In Menger, the amount of time embodied in any capital good is of no particular consequence. The time that mattered was the expected production time in the mind of the entrepreneur who created the capital good at the point in time that he was creating it. Or more generally, the time that matters is the time period relevant to the decision maker-producer in any production project, the time from beginning to end of the particular project. Beginnings and endings are points in the mind of the decision maker that enter, with all other relevant factors, into the decision maker's calculations. There is

[9]We rely heavily here on Garrison's (1981, pp. 23-29) summary.

no way to go from these individual (subjective) reference points to a measure of "production time" for the economy as a whole, in order to arrive at an "objective" measure of the size of the capital stock.

As Lachmann explained in his lectures, in order to calculate the average period of production, one is required not only to identify definite starting and ending points for each production process, one is also required to formulate each production process in terms of physically defined inputs, physically defined outputs, and the elapse of calendar time between them. This is only possible in a world where unexpected change is absent, where all production techniques are known. This implies that all production plans are consistent with one another - where plans are inconsistent some must fail and this implies the occurrence of unexpected events. In such a situation, it is impossible to unambiguously derive an average period of production for all production processes and, therefore, for the economy as a whole. So, in this respect, though not in his essential vision of capital, Böhm-Bawerk departed from Menger and the Austrians who came after him. But it was this specific aspect of Böhm-Bawerk's work that Clark attacked from an entirely different point of view.

Clark and Böhm-Bawerk

Clark attacked Böhm-Bawerk's emphasis on the importance of time for understanding capital by targeting his "average period of production". The essence of his criticism can be understood as follows. We have seen that the average period of production can only be calculated when the production process is describable in a very particular way. A favorite example in the literature is the case of wood production from a forest in which a fixed number of young trees is planted while the same number of trees is cut down each period. It should be clear that it is possible to say, that since production[10] and consumption go on steadily each period, they are in effect simultaneous[11]. Production and consumption are synchronized and occur together all the time (Clark 1893, p. 313). In this case, it *is* possible to calculate the period of production. It is the time that it takes, on average, for a tree to grow from a seedling into a mature tree ready to be cut. If we assume that this time is the same for each tree we have an even clearer measure. Clark' s criticism can be understood to say that this time period is irrelevant since the forest is, after all, a permanent source of wood. Since production and consumption are in effect simultaneous, the relevant period of production is zero. This is the kind of vision one is offering in suggesting that capital should be thought of as a "permanent" fund yielding a flow of income. A "capitalist" economy is then one in which capital plays this role.

As indicated above, however, from the Austrian (Mengerian) perspective, this view is valid only for an economy that has reached a state of stationary equilibrium - a situation in which the capital stock has been built up, is suitably maintained and yields a continuous income (net of maintenance cost). In terms of the forest example the forest is already grown and yielding a steady output when our analysis begins. It tells us nothing about the decisions to grow the forest in the first place, when questions relating

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[10]In this case, as in many others, "production" consists in harnessing the processes of natural biological growth for economic purposes. These were the first and, in some ways are the most fundamental, capital processes. Consequently, much economic theorizing about capital proceeds from these first cases to argue by extension and, more often, by analogy to other, more complex cases.

[11]In this example "consumption" is equated with the harvesting of trees. Of course, in reality, trees are inputs for further production processes that result in consumption at a later date, for example the manufacture of pencils. The essential point, however, is that the woodlot example above provides a case of perfectly synchronized inputs and outputs that, in principle, could characterize other processes where inputs lead ultimately to consumption. Once such a process is completely established and becomes "permanent", an endless and unchanging succession of inputs and outputs results making it appear that production and consumption are indeed simultaneous. As explained in the text, however, this way of looking at the world is superficially valid only as long as there are no changes in the patterns of consumption and production. At any point of time, in any real capital using economy, the capital structure that exists will be only partially adapted to the ever changing pattern of consumption.

to the "period of production" must have been important. Consequently it can tell us nothing about the effect of changes to the structure of production and the decisions that motivate them, or, indeed, what types of (consumption and production) decisions are necessary to expand or contract the production flow. In a fundamental sense, production and consumption only appear to be simultaneous to the observer who does not care about the production plans which gave rise to the production process in the first place. One plants seedlings today not in order to cut trees today but in order to cut trees some years from now. One cuts trees today only because one planted seedlings some years ago. One cannot ignore the time element. Unless we are able to relate the production process to these production decisions, we will not be able to understand changes in that process. Furthermore, in the real world, where the capital structure and the array of consumption goods is continually changing, production and consumption frequently do not even appear to be simultaneous.

Even where we have a simultaneous and perfectly synchronized production process, however, considerations of the time structure and the decisions related to it must enter. "The posited simultaneity of inputs and outputs literally leaves no time for an equilibrating process to take place" (Garrison 1985, p. 129).

Clark's (and after him Knight's) emphasis on the technical and logical aspects of "period of production" concepts had the effect of making capital debates appear to be about abstract technical issues rather than about real economic issues. To concentrate on Böhm-Bawerk's (and later Hayek's) way of measuring production periods was to divert attention away from his (and Menger's) vision of the capital structure as involving time in the *decisions made by producers.* It is these decisions, after all, that are the roots of the changes in the capital structure and in the level of employment. When macroeconomics was born, these technical capital debates had nothing to contribute to an understanding of these macroeconomic policy issues. Lachmann's contribution can be seen as (a failed) attempt to reintroduce capital as a relevant element in policy issues. In some ways, his perspective is even more relevant today.

Lachmann's conceptual framework

The lecture notes that follow in Part Two provide a quick overview of the development of the theory of capital as Lachmann saw it. While his critical eye is present throughout the lectures, he arrives at his own theory (his variation of Böhm-Bawerk's theme) only a few pages from the end. He summarizes there his views as they had developed to that point. In this section I briefly summarize his approach by outlining the key concepts that he uses.

Capital and Capital Goods in Disequilibrium

> The generic concept of capital without which economists cannot do their work has no measurable counterpart among material objects; it reflects the entrepreneurial appraisal of such objects. Beer barrels and blast furnaces, harbor installations and hotel room furniture are capital not by virtue of their physical properties but by virtue of their economic functions. Something is capital because the market, the consensus of entrepreneurial minds, regards it as capable of yielding an income....[But] the stock of capital used by society does not present a picture of chaos. It's arrangement is not arbitrary. There is some order to it. (Lachmann, 1956, p. xv).

A distinction must be drawn between the terms *capital goods* and *capital*. The former refer to physical items (constructed or inherited from nature) that are capable, in combination with labor and other capital goods, of producing valuable consumer goods. Capital, by contrast, has no physical measure. It refers to the total *value* of all of the capital goods under consideration. The values of the individual capital goods are derived by discounting the value of their expected future production. Referring as this does to expected future values, the result is subjective and varies across individuals. The value of the capital stock, being dependent on individual expectations and evaluations (time preferences included) is not an objectively verifiable phenomenon. Only in equilibrium, *where all individuals had the same correct expectations*, would this not be the case. Lachmann therefore chooses to develop his analysis in a disequilibrium framework.

The Heterogeneity of Capital Matters Only in Disequilibrium

Lachmann thus emphasizes the *heterogeneity* of the capital stock. The fact that capital goods are physically very dissimilar is significant precisely because of the existence of disequilibrium. Physical heterogeneity could be reduced to value homogeneity if the values of the various capital goods could be simply added together. Where disequilibrium means that individuals have different and *frequently inconsistent* expectations, one cannot simply add together individual valuations. Even so, the physical heterogeneity is not the essence of the matter. Different physical goods that perform the same economic function could be counted as the same good. It is the difference in *economic function* that matters. For the most part different capital goods look different because they are *designed* to perform different functions. Heterogeneity in use is the key.

The heterogeneity of the capital stock is something that is obvious to anyone. The assumption of homogeneity, made for mathematical and analytical convenience, is never meant as a literal description of reality. It is made in the belief that that is the only way to sensibly incorporate capital into an analytical model, that to do otherwise would condemn one to reduce one's theorizing to providing an unhelpful description of complex reality. Lachmann, in effect, denies that this is the case. Though the capital stock is heterogeneous, it is not an amorphous heap.[12] The various components of the capital stock stand in sensible relationship to one another because they perform specific functions together. That is to say, they are used in various *capital combinations.* If we understand the logic of capital combinations, we give meaning to the capital stock and, in this way, we are able to design appropriate economic policies or, even more importantly, avoid inappropriate ones (for example, Lachmann, 1956, p. 123).

Production Plans involving Capital Combinations can be understood in terms of Complementarity and Substitutability

Understanding capital combinations entails an understanding of the concepts of *complementarity* and *substitutability*. In neoclassical microeconomics, these concepts are developed within a market equilibrium framework. Production goods are substitutes or complements for one another to the degree to which, and in the manner in which, their marginal products are related. The marginal products of complements are positively related while those of substitutes are negatively related. What is envisaged is a situation in which production goods are combined in a technological relationship of known and well understood inputs and outputs. The values of all possible outputs are known with certainty (or with probabilistic certainty) and from this it is possible to calculate the values of the marginal products under all conceivable circumstances. These are treated as objective. Hence, we have the picture of a given budget line (or hyperplane), formable out of the given *equilibrium* prices of the production goods and the quantities used, confronting a given isoquant. Substitution is then simply a matter of moving around the isoquant in two dimensional or multidimensional space. Substitution occurs because of a change in the price of a production good. There is no analysis of any events that occur in disequilibrium i.e. of events that occur between the time that a price change occurs, is perceived, is acted upon and results in the establishment of a new equilibrium. The same sort of analysis is applied to changes in technology, which are analyzed as changes in the positions or shapes of the isoquants.

As a mental picture of a single production plan at a point of time, the isoquant diagrams (or algebras) may be enlightening. They summarize a certain "logic of choice". But they have little to do with Lachmann's conception of what substitution and technical progress mean in reality. His concepts pertain to a world in which perceived prices are actual (disequilibrium) prices in the sense that they reflect inconsistent expectations and in which changes that occur cause protracted visible adjustments. Capital goods are complements if they contribute together to a given *production plan.* A production plan is defined by the pursuit of a given set of ends to which the production goods are the means. As long as the plan is being successfully fulfilled *all* of the production goods stand in complementary relationship to one

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[12]This is an allusion to the words of Shumpeter quoted by Lachmann in the lectures below. We examine this further is Part Three below.

another. They are part of the same plan. (It is not inconsistent to say that their perceived marginal products are positively related, in the sense that their joint outputs depend on each others' performance. An increased availability, reduction in price, of any one input, raises the potential outputs of the plan attributable jointly to all of the inputs and may increase the (joint) demand for all of them.) The complementarity relationships within the plan may be quite intricate and may involve different stages of production and distribution. Substitution occurs when a production plan fails (in whole or in part). When some element of the plan fails a contingency adjustment must be sought. Thus some resources must be substituted for others. This is the role, for example, of spare parts or excess inventory. Thus, complementarity and substitutability are properties of different states of the world. The same good can be a complement in one situation and a substitute in another.

Lachmann uses the example of a delivery company (1947, p. 199 and 1956, p. 56). The company possesses a number of delivery vans. Each one is a complement to the others in that they cooperate to fulfill an overall production plan. That plan encompasses the routine completion of a number of different delivery routes. As long as the plan is being fulfilled this relationship prevails, but if one of the vans should break down, one or more of the others may be diverted in order to compensate for the unexpected loss of the use of one of the productive resources. To that extent and in that situation they are substitutes. Substitutability can only be gauged to the extent that a certain set of contingency events can be visualized. There may be some events, such as those caused by significant technological changes, that, not having been predicted, render some production plans valueless. The resources associated with them will have to be incorporated into some other production plan or else scrapped - they have been rendered unemployable. This is a natural and predictable result of economic progress which is driven primarily by the trial and error discovery of new and superior outputs and techniques of production.

What determines the fate of any capital good in the face of change is the extent to which it can be fitted into any other capital combination without loss in value. Capital goods are *regrouped*. Those that lose their value completely are scrapped. That is, capital goods though heterogeneous and diverse are often capable of performing a number of different economic functions. Lachmann calls this property *multiple specificity*.[13]

Capital Structure *as distinct from Capital* Stock

Lachmann's world is consciously similar to Schumpeter's world (Shumpeter, 1911) of "creative destruction", except that for Lachmann the innovating entrepreneur is not disrupting some preexisting general equilibrium. His world is one in which a continuous evolutionary process of changing patterns of capital complementarity is occurring. At any point in time different entrepreneurs will have different and frequently incompatible production plans. Over time the market process will validate some and invalidate others. Lachmann sees the market process as tending to integrate the *capital structure.*

The concept of the capital structure (to be explained below) is built out of the notion of capital complementarity. A production plan is a construction of the human mind. As such it exhibits a necessary internal consistency . From the point of view of *the individual planner*, it might be said (although Lachmann did not use this terminology) that the plan is always in equilibrium. The plan is always in equilibrium in the sense that every planner, being rational, may always be counted on to do the best he/she can given all the relevant constraints, where such constraints include the time available to adjust to any unexpected changes. That is to say, at any given point of time any individual planner is in equilibrium with respect to the world as he/she sees it at that point of time. All productive resources employed in that plan stand in complementary relationships to one another. *Between* any two points of time, during which unexpected changes will necessarily have occurred, resource substitutions will have been made in an

[13]He seems to have invented this term fairly late in the development of his ideas on capital. In his 1947 article he never uses it and instead uses the term "versatile" which he credits to G.L.S. Shackle.

attempt to adjust to the changes.[14] Complementarity is a condition of plan equilibrium (stability), substitutability is a condition of plan disequilibrium (change).

The notion of the capital structure encompasses a sort of economy wide equilibrium as an ideal type. At the individual level disparate elements of the production plan are brought into consistency by the planner. These elements are all present in a single human mind. There is no such mechanism guaranteeing consistency between different production plans. The market process does, however, tend to eliminate inconsistencies between plans in so far as not all of them can succeed. In this way plans that are consistent with (complementarity to) one another tend to prevail over those that are not.[15] So whereas the individual planner ensures the complementarity of all of the resources within a production plan, the market process tends towards a situation of overall *plan complementarity*.[16] This is what constitutes the capital structure. The heterogeneous assortment of capital goods stand at any time in a kind of ordered structure defined by their functions and by the relationships that the various plans have to one another. The latter is a result not of any supra plan, but of the market process. A capital structure in which this tendency were complete, in which every capital good and every production plan was complementary to every other, would be a completely *integrated* capital structure. In summary:

> In a homogeneous aggregate each unit is a perfect substitute for every other unit, as drops of water are in a lake. Once we abandon the notion of capital as homogeneous, we should therefore be prepared to find less substitutability and more complementarity. There now emerges at the opposite pole, a conception of capital as a structure, in which each capital good has a definite function and in which all such goods are complements. It goes without saying that these two concepts of capital, one as a homogeneous fund, each unit being a perfect substitute for every other unit, the other as a complex structure, in which each unit is a complement to every other unit, are to be regarded as ideal types, pure equilibrium concepts neither of which can be found in actual experience. (Lachmann, 1947, p. 199).

Lachmann chose to describe the world in terms of a capital *structure* rather than a capital *stock.* This choice reflects a judgment that to obscure capital complementarity through aggregation would result in an inaccurate and misleading picture of the role of capital in the economy. This can be seen in his account of how the market process works.

The Capital Structure is changed by Capital Gains and Losses

At any moment in time individual planners hold inconsistent expectations. This means that the passage of time must disappoint some of them. Some production plans must fail (in part or in whole) while others, of course, may succeed beyond their expectations. This is reflected, according to Lachmann, in two crucial ways - in capital reevaluations (capital gains and losses) and in changes in cash balances.

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[14]Thus, whether we characterize the individual planner as being continuously in equilibrium or else as continuously adjusting to disruptions of his/her production plan would seem to be more an issue of semantics than of substance. Strictly speaking, if we visualize an individual adjusting to a disruption of equilibrium, then there must have been an instant, however short, during which the individual was out of equilibrium by his/her own assessment. So an "equilibrium always" characterization does not appear to be logically tenable for a world in which unexpected changes occur. The important point, however, is that Lachmann did think that the notion of individual equilibrium was a sensible one and that it could be applied within the context of the individual plan.

[15]This would seem to imply that the production plans of individual firms are identical with the plans of one or other individual in that firm. This is not necessarily the case however. Firms must find a way to harmonize the different visions of its various planners. Presumably the larger the firm the more difficult this is. But those firms that do so more successfully and adopt successful supra plans will tend to survive. The market process works its way into the firm in this way.

[16]As Lachmann was to emphasize in his later work, if unexpected changes occur rapidly this tendency may be overwhelmed. This was not something he stressed in his work on capital however.

Whereas the "wealth effects" of neoclassical economics are sometimes assumed to be small enough to be neglected, the capital gains and losses of Lachmann's world are the most important forces driving changes in the capital structure. These market evaluations of the prospects of success or failure of the firm and its capital combination are reflected in the financial assets associated with the firm. The financial assets (for example, debt and equity) form a superstructure over the capital assets of the company and constitute its *asset structure*. They are claims to the physical assets of the company and as such reflect their value (or others' opinions of their value, which amounts to the same thing). Thus, there is a *financial structure* that is related to the capital structure of the economy. The capital structure and the capital combinations of which it is composed are in turn related to the plan structure. A vitally important institution in this financial structure is the Stock Market. On the Stock Market assets are valued and revalued every day in accordance with companies' performances. The Stock Market thus reflects a daily balance of expectations concerning earning prospects of companies. It is probably fair to say that Lachmann considered the Stock Market to be the most important institution of the market economy (he did *not* share Keynes' view that it was basically random in nature, (Lachmann 1956, pp. 68-71)) and the one, more than any other, that differentiated it from socialized economies - the institution that, together with others in a private financial capital market, was responsible for facilitating the adoption of those capital combinations that produce economic progress (see Lachmann 1992).

Capital gains and losses provide entrepreneurs with feedback from the market. Ventures that continue to sustain capital losses will eventually have to regroup or stop operating. In this way the financial structure and the capital structure interact to produce a continuing reshaping of the latter (Lachmann 1956, p. 94).

A more immediate form of feedback comes in the form of changes in the cash balances of the company. The company holds cash as a form of "excess capacity" in order to preserve flexibility. In a sense, cash is the most substitutable of the company's capital assets. Thus changes in cash balances, like changes in inventory, provide an important indicator of the results of the operation over a period of time. A negative cash flow is the ultimate long term discipline and often also the first indicator of a problem. Lachmann sees the traditional neoclassical portfolio approach to cash balance and financial asset holding as misleading. While it is true that production plans must include decisions about financial asset mix (the perceived optimum manner of financing), to assume that *observed* cash and asset portfolios reflect optimal choices is to loose sight of the feedback process discussed above. That is to say, empirically observed changes in cash holdings and asset values reflect not only intended outcomes, they also reflect results that are *unintended* (mistakes or surprises - good and bad). In the portfolio equilibrium view, the portfolio reflects the results of portfolio selection based on underlying preferences and shared knowledge. In Lachmann's market process view, the portfolio value reflects portfolio results which are often different from what was intended and cannot be assumed to accurately reflect the preferences and intentions of the planners. Rather it is a barometer of the viability of the overall plan.

> Capital gains and losses .... [E]ssentially ... reflect in one sphere events, or the expectation of events, the occurrence of which in another sphere is indicated, and knowledge of which is transmitted, by changes in money flows. (Lachmann 1956, p. 95).

This view of financial portfolios, especially of money holdings, is treated at some length in *Capital* (see chapter VI "Capital Structure and Asset Structure"). But in the lectures it is hardly mentioned.

There are far reaching implications in a disequilibrium approach

Perhaps the most important general implication of a disequilibrium approach to capital is the proposition that *all capital accumulation entails a changing capital structure.* This follows from the (primarily empirical?) observation that most technical change is embodied in new (improved) capital goods and/or involves the production of new consumption goods. Capital accumulation that accompanies economic growth as we know it, is not simply the addition of the same kinds of capital goods doing the same things. Lachmann's view of capital accumulation and economic progress is in many ways very prophetic of the revolutionary kind of economic change that has characterized the twentieth century,

including the later quarter of that century. It is, in this view, impossible to separate the phenomena of technical progress and capital accumulation. That is to say, capital accumulation always proceeds hand in hand with technical change. By the same token failed production plans imply "holes" in the capital structure that signal investment opportunities for others. An approach to economic growth that visualizes capital as a homogeneous aggregate to which investment expenditure adds in an indiscriminate way, so that a government policy adding directly to investment expenditure, is, in essence no different from an increase in private entrepreneurial investment expenditure, is not only untenable, it has far reaching consequences. The capital structure will be irreversibly different in these two cases. It is very likely that government expenditure "crowds out" not only private sector expenditure but also private sector induced technical progress. The shape of the capital structure will be different and, because capital assets are heterogeneous, specific and durable, will remain different from what it would otherwise be. It takes a lot of faith in the abilities and integrity of the government agents involved to imagine that no sacrifice in entrepreneurial discovery is involved. Lachmann's capital theory framework blends nicely with Kirzner's views on entrepreneurship and Hayek's views on information to yield some very specific insights on "investment policy".

Lachmann's approach also implies that the phenomena of capital accumulation and economic fluctuations are intimately related. The final chapter of *Capital* is devoted to what were then called trade cycle issues. The flavor of this chapter suggests that it was written with 1930's type issues (of depression and recovery) in mind. We find continued use to terms like "strong boom" and "weak boom", while terms like "recession" and "stagflation" were not yet invented. By the time he delivered his lectures on capital theory he appeared to have moved beyond these considerations and they appear nowhere in his course materials. Nevertheless, the basic approach contains much that is relevant to a structural view of fluctuations in employment and economic activity today.

PART TWO: A SHORT COURSE IN CAPITAL THEORY[17]

The Subject Matter

In our discussion of money[18] we concluded with a general theory of financial assets. Here we are dealing with non-financial assets. There is a fairly clear cut distinction between these two types of assets. Some items may raise questions, for example, industrial shares (stocks). Shares are, in fact, claims to non financial assets i.e. capital goods. If there were no capital goods, shares would have no value. Thus, although capital goods are reflected in the sphere of financial assets, the distinction is nevertheless still fairly clear cut. Capital goods in their original capacity are just that. They are held to give their owners a steady income stream. Shares exist on a different level and may change hands fairly often, though their nature stays the same. Changes (maintenance, repairs, etc.) take place on the real capital assets, but the shares stay the same. The borderline is fairly clear cut.

When it comes to the borderline between capital and growth, this is not so clear cut. The accumulation of capital is a very important concept in economic growth, in fact it is a vital indicator of progress. To a very large extent, economic growth is a phrase for all the concomitants of capital accumulation, though it is not the same thing. Since the accumulation of capital appears in both the second and third parts of our course (the theory of capital and the theory of economic growth), a clear cut border may be difficult to draw. Our examination here will help us to understand some fallacies in growth theory.

Conceptual Background

Two schools of thought

In capital theory there are *two schools of thought*. They are very different, often contradictory and are really incompatible with one another. We will have to go into this in some detail. Here is a preliminary description at this stage.

The first school of thought is fundamentally interested in the distribution of incomes. Economists belonging to this school raised the question: Why are owners of material wealth able to receive an income, which the classical economists, called *profits*? What is it that determines the magnitude of these profits or, more technically, the rate of profit? We shall call this the *classical* school of thought. It is linked to Ricardo and until recently has been most prominent in the theory of capital.

For those interested in the distribution of income between owners of material wealth and others (we will expand this later) the magnitude and composition of capital is a secondary, if interrelated, consideration. The rate of profit, the primary object of study to these economists, is a flow of incomes received by the owners of wealth divided by the stock of capital. Hence, with the rate of profit being the prime focus of interest, the size of the capital stock had to be considered by implication. If we are to have a fraction, total profit/ total capital, we have to know the size of capital, the denominator - this has to be estimated. This is how capital came within the vision of the classical school. The theory of capital to them was of secondary interest, however, to their prime interest in the rate of profit.

The other school of thought is more difficult to describe. The economists who belong to it are those who consider capital as their main interest. What largely interests them is the character of the capital stock. They share a common interest with the other school in the magnitude of the capital stock, changes in it, etc. But there is one respect in which they are clearly distinguished. The first and most important question to the classical economists was: what was it that determined that part of the income flow received as profits?, whereas the other school is interested in *why there are capital goods that are*

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[17][Being notes from Ludwig M. Lachmann's lectures to economics majors: *The Theory of Capital* - delivered second quarter 1968. Editorial comments in this Part appear in square brackets.]

[18][Delivered earlier in the year.]

being used in the particular way they are. This latter view looks at the agglomeration of existing assets (buildings, machines, etc.) as heterogeneous entities that nevertheless have meaning in that they have been put there by human actions and are used in a certain way corresponding to a decision to do so. Decisions relating to *existing* capital goods are considered important - as distinct from investment decisions. The most recent of these economists have tried to link the existing components of capital to the plans involved with them. This relationship is by no means constant. Plans change all the time. For example, in older cities of Europe there are buildings serving all kinds of uses not originally intended by their designers. Stables have been turned into garages, schools into assembly halls and so on. Often very durable capital goods are turned from one use to another. (Kirzner 1966). We must try to determine of what plan is any capital good *now* a part. This *compositive* school emphasizes the composition of the capital stock, that vast agglomeration of pipe lines, hotel room furniture, etc. that reflects plans which may be inconsistent with one another. If we assume consistency we would not be understanding the essence of the structure of capital.

Despite what has been said about the incompatibility of the schools there are some common interests, for example, the accumulation of capital accompanying economic growth. How does this affect the distribution of incomes? In some ways this has made it more difficult to see that we are talking about two different things in the history of capital.

There have been attempts to fuse the two approaches. The most famous are the Marxists. They fused the distribution of income with the accumulation of capital using simple and crude "laws". In a capitalistic economy owners exploit the workers. Wages can never rise above the minimum of subsistence. The whole of the excess over this bare minimum of gross social revenue steadily increases and has to be used somehow. So it is accumulated by the owners of capital. Thus the accumulation of capital is linked to the distribution of incomes. It follows therefore, that once the exploitative motive comes to an end, after the revolution, so will the accumulation of capital and technical progress alone will provide for economic progress. It would probably shock Marx today if he knew of modern communist doctrine stressing the accumulation of capital as a prerequisite to economic progress. (He denied this vehemently). Whatever our view, we, by and large, accept the fact that for economic progress, technical progress has to be embodied in the accumulation of capital - the two go together.

Marx's idea of fusing was carried over to the present. One of the latest contributions to the theory of capital (sophisticated in a way) - 1956 - is Joan Robinson's. According to her, the accumulation of capital depends to some extent on the distribution of incomes between owners and workers. But what of the capital gains and losses that are bound to occur? These are not thought of as part of savings or investment.

Measuring capital

An important aspect of the dichotomy to be considered is the heterogeneity of the capital stock. This has been emphasized already (coal mining equipment and hotel room furniture) as an aspect stressed by the compositive school while the classical school does the opposite. Simply because a fraction is looked for in *the* rate of profit we need a concept of capital as a homogeneous substance. While not denying the heterogeneity of capital goods, the classical school would argue that for the economically significant purposes of calculation these can be reduced to a common denominator.

Schumpeter has a succinct statement of the compositive school approach. Whenever we are talking about a *given* situation - meaning given tastes, resources and technology - resources must exist in a certain stock of *inherited* goods i.e. goods provided in the past. They are simply there, like land. These resources are limited in the way that they can be used. The stock of existing goods constitutes a constraint on human action going forward. The stock of capital "is neither homogeneous, nor is it an amorphous heap"[19]. Its components complement one another. Some goods must be available for the operation of others. The nature of the composition of the stock is vital - it constitutes a given "structure".

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[19][This quote from Schumpeter is investigated further in Part Three below]

We have shown so far the dissimilarity in approach between the two schools, a common theme in the history of scientific endeavor. Does it go further? For instance, has incompatibility been proved? Have we shown that they are not merely dissimilar, but that the only kind of world in which one is valid makes nonsense of the other? It is, indeed, when we consider the question of measuring the capital stock that we see that our two schools of thought are not merely different but have incompatible views of the world.[20]

If we are interested in finding out about the distribution of income in the way the classical economists were, we will find that the principles we adopt must assume a recurrent, unchanging world; in part a world in which everyone adjusts to an existing situation. Marginal productivity was accepted as a principle governing the distribution of income and, therefore, the marginal product of capital is used. This presupposes a quantity of capital that is measurable unit by unit in an inclusive way. We know, however, that in the real world, the value of *all* the various forms of equipment is a matter of opinion. Expectations differ about it. The value of each unit of capital depends on the expectations of those who hold or trade it. If we don't rule out expectations, we cannot have a marginal product of capital and we cannot have a universal principle governing the distribution of income.

The classical school uses the *static* method; decisions within a period of time are viewed in isolation. The world must be one of adjustment to an existing situation. They do not take account of the future or the past - that is they exclude expectations and differences of opinion. These would cause the concept of marginal product of capital to collapse. The classical economists got round this by the assumption of the stationary state. Capital lasts more than one period and is calculated to do so. But if we assume the future to be like the present - an unchanging world - today is like yesterday and tomorrow, then expectations will always be identical and correct. The Austrian school is concerned, conversely, with changes over periods of time and an uncertain future is part of this. Capital means we must bear in mind yields in the future which are expected but not known. Capital problems are *dynamic* problems (involving divergent expectations). This has very far reaching implications and bears further examination.

When we say capital cannot be measured, what do we really mean? It cannot be denied that it is often possible to reduce capital to certain common characteristics like horse power. This could provide a basis for counting. But it has no economic significance. The physical heterogeneity of capital presents us with a problem of accounting for the *value* of each component. If we were willing to assume an equilibrium for the whole economy, then, for each capital good, the discounted future earnings must be equal to the value of the good. Also, in perfect equilibrium, the discounted future earnings must be equal to the cost of production of the good. As long a the discounted value of future earnings of capital goods exceeded their cost of production, a capital gain could be made and no equilibrium could exist. Similarly, where discounted future earnings fell short of "production costs", goods would not be maintained. The non replacement and repair of goods, because their discounted future value is less than their cost of production, is incompatible with equilibrium. So, in a situation of general equilibrium, which precludes investment as well as disinvestment, present and expected future earnings are just enough to maintain the existing number of capital goods. Capital goods can then be measured by their costs of production. Any situation not like this, therefore, presents problems of measurement. In the real world, characterized by unexpected changes, there is no unambiguous way to measure the capital stock. No simple criterion of measurement exists. Only in the unlikely event that expectations of future earnings are identical across individuals could we talk of *an* expected future earnings value. If different people have different expectations, a future earnings value as such disappears. In a world of change in which there is a difference between discounted expected future earnings and costs of production for some producers

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[20][At this point Lachmann dictated a list of references]:
Classical School: Irving Fisher (1930), Dewey (1965) (deals with certain modern discussions), Knight (1936), Knight (1946).
Compositive School: Hayek (1941), Hayek (1936) Hayek (1937), Lachmann (1956), Kirzner (1966), Kaldor (1960) (reprint of his 1937 survey of capital theory controversies).

(entrepreneurs), we cannot measure the stock of capital as such. The return to capital is a subjective estimate.

Some attempts have been made at measurement. In Britain an attempt was made in terms of insurance value i.e. measures corresponding to the views of those best fit to judge. But this still implies a subjective estimate embodying a certain set of expectations.

We must dispel any misconceptions about the relationship between our two schools of thought. They are not to be thought of as warring factions denying each other's point of view. They are interested in completely different things i.e. income distribution and the stock of capital versus the structure of capital. We have seen that they do clash, however, on one point, i.e. the possibility of measuring capital. The proof of the impossibility of measuring the capital stock has been widely accepted (even by some classically oriented economists). The conflict remains important in the field of growth. In a growth context, we can only talk of a stock of capital if we can construct a type of growth equilibrium. If it can be shown that this is an impossibility then the theory of growth is seriously threatened. Talking about capital becomes much more difficult.

It is interesting to note the impact of this idea of the immeasurability of capital on some classically oriented economists. For example, Joan Robinson(1956 [1932]) is reluctant to accept it. In chapter 11 of her 1956 book she shows that the marginal product of capital is non existent, but in the main text of her book she dodges the problem by assuming a required stock of capital fully adapted to the demand for specific goods i.e. an equilibrium. She thus keeps at bay the Austrian compositive criticism. In Chapter 11, on the measurement of capital, she says toward the end that, while admitting what we have said above about measurability and equilibrium, the fault lies in the use of words and that we, of course, all know what capital is after all. However, it is not simply a matter of linguistic use. It is a matter of physical reality and change.[21]

In the second part of Hicks's *Value and Capital* expectations are brought in. But in all respects he remains within classical lines. In particular, a homogeneous capital stock is assumed. In *Capital and Growth* he talks about a world of change and puts forward a compositive argument. In 1958, in his paper for the International Economic Association conference on *The Theory of Capital* on the measurement of capital in relation to the measurement of other aggregates, (Lutz and Hague 1961) he was aware of the problem of measurement. But he fails to see that the same problems would arise in measuring National Income. He admits the heterogeneous nature of output, but says, since it is possible to reduce it to a common money base, why not do the same thing for capital? In a market economy anything that is held is, in principle, salable. Income streams and elements of income streams are sold as well as stocks (stocks and flows are sold for one another). Capital can always be sold against consumption goods. Therefore, we can measure that way. However, as already noted, this assumes a system of equilibrium prices exists for anything in the economy.

After this paper and sometime before 1965 (*Capital and Growth*), Hicks had a change of heart. In 1962, when reviewing a book by Meade, he surprised his readers by criticizing Meade for failing to see the difference between income streams (a flow) and the concept of capital (a stock). Only in a static world are these equivalent. And, in so far as goods that endure beyond the single short period are concerned, the static method is invalid![22]

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[21][See also Lachmann's (1958) review of Robinson (1956).

[22]One sees this also in Hicks's later repudiation of the concept of the "accelerator" found in his book on the trade cycle (1950). Producers had been assumed to respond to increases in current demand for output by increasing capital investment by a certain multiple of that increase. This obviously assumes uniform, identical and correct expectations on the part of the producers as to what the demand increase signaled for the future. In a world of divergent expectations the accelerator makes no sense. Professor Kaldor (1957) has a growth model in which capital is treated as a measurable concept. (In another article (1962), capital as a variable is dropped). We will return to Hicks's *Capital and Growth* (1965) when we come next term to the theory of economic growth.

Historical context

Historically speaking, the second school is the older. Before economics became a 'science', certain aspects of the problem of the accumulation and the composition of capital invited interest, for example, by the Mercantilists. This is related to the rise of the nation state and the nature of the struggle for power. This struggle implied, among other things ideas about capital. The rising middle class favored rapid industrialization. In our terms, this means that they thought that the composition of the capital stock would be better having components in industry rather than in agriculture, i.e. those favoring industrialization were, by implication, favoring a certain type of capital stock. The same holds for their opponents, the Physiocrats, who favored land and agriculture as against the sterile urban classes. Both expressed views about the nature of the stock of capital. Conclusions followed about what was a favorable type of capital stock by pointing to what they thought was the key sector of the economy. Therefore, this approach is actually older. It is found even in Adam Smith who, though he was an opponent of Mercantilism, shared the idea that the composition of the capital stock matters.

The rise of the classical school is clearly marked in the work of Ricardo. He asks about the distribution of income between two classes of factors of production. From his time onwards, this approach overshadowed the composite or "Austrian" school. (This should not be understood to imply that the Austrians did not examine the question of the distribution of incomes in their own way.) The classical approach focused on the role of interest. Capital was a secondary consideration - a receiver of income.

The Austrian school arose again and can be found in Wicksell, one of the most important followers of Böhm-Bawerk. Wicksell was, at first, enthusiastic about Böhm-Bawerk's work but gradually came to see its weaknesses. He became somewhat disillusioned with Böhm-Bawerk's doctrines. Wicksell is really the start of the modern compositive school.

We now examine some of the important ideas in the history of capital theory in more detail.

The Development of Capital Theory

Adam Smith

When we turn to the early economists we find capital theory implicit in their work. Economic theory as we know it didn't exist. Often it appears in Adam Smith that we are dealing with a static world. It is not clear whether we are dealing with the past, the future or a hypothetical model. Although he was living in the age of the Industrial Revolution, we find little to suggest that he knew it. Writers of economics seemed to pay little attention to the world of thirty years before their time. Also, Scotland was relatively undeveloped. Whatever the historical reasons, it is difficult to know what Mercantilist policies he (Smith) was denouncing as, by that time, policy was already fairly liberal.

[Though he did not publish much additional work on capital after the 1956 book, Lachmann maintained his interest in capital theory as evidenced by his review and discussion articles in Lachmann 1977. In particular see his review article of Hicks's *Capital and Time* (Lachmann 1973). Through Hicks Lachmann appears to have had some influence on the debate in capital theory, for example, Hicks 1973. In an article published in 1976 Hicks wrote:

> Most of my critics have been ... equilibrists; but there is one, for whom I have the greatest respect, who has opened fire from the other flank. Professor Ludwig Lachmann, is (like Professor Hayek) a chief survivor of what I distinguished as the Mengerian sect of the Austrian school. It is clear that his view of me is like Menger's view of Böhm-Bawerk. He cannot of course abide the steady state. Even the modest uses of it which I have made ... fill him with dismay. Even the explanations which I have not been giving (and which are meant, incidentally, to assure him that I am more on his side than on the other) will I fear, fail to placate him. His ideal economics is not so far away from my own ideal economics, but I regard it as a target set up from heaven. We cannot hope to reach it; but we must just get as near as we can (Hicks 1976, p. 275, footnote omitted).]

What matters to us is his particular way of looking at capital in a largely still agrarian society. The model implicit in his ideas on capital and growth survived the immediate circumstances of his time. Both the assumptions of a homogeneous capital stock and the use of the static method, concerned primarily with today and not tomorrow, underlie a lot of classical economics. An agrarian economy largely depends on harvests, for example, the Irish potato famine in the 1840's was very serious in such an economic climate. Next year's harvest will depend, to a large extent, on how much of this year's harvest is plowed back in seeds and, even more, on how much corn there is this year. This year's harvest, which keeps the working population growing, the animals alive and the seeds for next year's harvest, must be considered as a type of *capital stock*. The inhabitants of industrial societies are used to the idea that not all capital goods are used. We are familiar with obsolescence and changing uses of capital. Not all elements of the capital stock are necessary to keep the population alive or allow it to make progress. By contrast in an agrarian society all capital (1) is important (2) is homogeneous and (3) is turned over in one period (year). Though other forms of capital (buildings, machinery, fences, dams - "fixed" capital) are not turned over, Smith seems to have neglected these. Perhaps they were considered of secondary importance in determining the wealth and progress of nations. (Smith regarded himself as a moral philosopher trying to establish the best policy for the nation. Economics as a separate study did not exist. His "model", therefore, is our own interpretation of him. Ricardo was much more consciously a model builder. So our task is much harder with Smith.)

We have a certain harvest, a certain population working the land, the possibility of a harvest next year - dependent on the labor and its productivity (there is no indication of an awareness of diminishing returns at this stage). What is the magnitude of the wage rate? It is not clear what Smith has in mind. It is easiest to assume a conventional one near the minimum of subsistence. He knew nothing of Malthus's law of population.

There is a crucial relationship between this year's harvest and next year's harvest. This year's output is Y_0 - our capital stock for this year. We divide it up into seed corn, fodder and food production (real wages). In the simplest model Y_0 can all be regarded as capital stock, whatever of the three purposes it is used for - it is a subsistence fund to be used variously for man, animals and soil for next year's harvest. The capital stock comprises a wages fund necessary to keep society until next harvest[23].

$Y_0 = Nw$; N= number of workers, w = real wages per man.

Then $Y_0/w = N$ = the number of workers who can be employed. Growth will depend on this i.e. that the harvest in successive years grows - the extent of which will depend on the productivity of workers (p = labor productivity, the amount of corn produced by one laborer).

$Y' = pY_0/w$ or $Y'/Y_0 = p/w$. Thus the rate of growth is equal to p/w-1.

The growth rate is inversely proportionate to the wage rate ceteris paribus. The faster production grows in relation to the wage rate the faster the economy grows and vice versa. And since labor is limited and wages must rise so must p.

In this crude manner of expression we have neglected to account for all sections of the agrarian economy, e.g. the towns and land owners. This can be expressed by $k<1$ of actual output of the agrarian sector being set aside each year to feed the other classes. From the point of view of economic growth in this context, this is a drag on growth. The larger k the slower growth will be.

It is quite wrong to interpret Smith as thinking p, w, and k as constants. There are strong hints that he thinks they would not be constant. Smith appears to assume that there is generally a reserve of labor. Economic growth then means that the subsistence fund grows and needs to grow as long as population is not constant. A larger population can be fed with economic growth. So the economic

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[23]In other words, the whole of the corn that the laborer uses for his consumption plus his planting may just as well be counted as his "wage". [See the note following below].

conditions of population growth determine naturally the subsistence rate of economic growth. This is consistent with a type of steady growth where w, p and k are all constants. Smith, however, does *not* assume this and, in fact, was interested in situations that were not so steady. What would happen if population grew at a rate lower that the subsistence rate? Then the wage rate will increase - he did not believe in the Malthusian story. Smith believed that p would increase over time as a result of the division of labor, thus causing a rise in w, and he quotes cases to this effect. Thus p and w would grow together even if not at the same rate. "Productive" versus "unproductive" labor is interpreted as agricultural (p) versus labor in the towns (k). This interpretation is not exactly what Smith says - he says that labor is productive when its efforts becomes embodied in the good produced i.e. the worker adds some net value to the good. So servants, for example, are unproductive. This implies that a large number of "productive" laborers are desirable for economic growth which would mean to us a minimum of service. This gave rise to the loudest protests of his critics. We, however, can ignore his distinction and use the above interpretation - i.e. that productive labor is that labor that is in the agricultural sector on which growth depends, the other labor is "unproductive".

Capital is thus all circulating, and is homogeneous (corn). There are no investment decisions to make save for the planting on corn one period ahead. We can do nothing about the harvest two or three years hence.[24]

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[24][This model, interpreting Smith, comes from John Hicks, *Capital and Growth* (1965), pp. 36-42). For example,

> The single period is the agricultural year. The initial capital stock is last year's harvest, a certain quantity of 'corn'. The 'productive' sector (in Smith's sense) transforms that corn into more corn. It does so ... in two ways: by natural reproduction (the use of corn for seed), and by employing labor in cultivation. But it is not in fact of much importance to distinguish between these uses. For we can simply add the corn which the laborer sows to that which he consumes; the total is the amount of corn that is used up in employing him. He is himself (in terms of the model) simply a part of the process by which the harvest of one year is transformed into that of the next. So that the whole of the corn that the laborer absorbs may just as well be reckoned as his *wage.*
>
> If the wage (in this sense) is given, the number of laborers who can be employed will be determined by the size of the capital stock - which is therefore, in this model, a wage fund. If they were all employed in growing corn, the whole economy would be reduced to its productive sector, and that sector would reduce to an apparatus for making corn out of corn. Consider the working of the economy in period (year) *t*. Let X_{t-1} be last year's output of corn; let *w* be the given wage (measured in terms of corn); the number of laborers employed will then equal X_{t-1}/w. If *p* is labor productivity (the amount of corn produced by one laborer), this year's output will be pX_{t-1}/w; so that $X_t = (p/w)X_{t-1}$. The growth rate of the economy (measured in terms of this *gross* output) accordingly (p/w)-1.
>
> This is what happens when the whole of the corn output is used as a (direct or indirect) input into corn production; when nothing escapes outside. But that is no more than a limiting case. Ordinarily there will be a 'leak'. Some part of the corn output will be used for paying wages to non-corn producers ('unproductive laborers'); some may even be consumed directly by non-laborers. The capital that is used in corn production in year *t* (K_t) will then not be the whole of the previous year's production, but only a part of it. Write $K_t = kX_{t-1}$(where $k<1$). The number of laborers employed in corn production will now be K_t/w. So $X_t = (p/w)K_t = k(p/w)X_{t-1}$. The growth rate of the economy is now no more than $k(p/w) - 1$ so that the growth of the economy is slowed down by its unproductive consumption. [pp. 37-38]

The rest of Lachmann's remarks on Adam Smith likewise follow Hicks's treatment very closely.]

Ricardo

We now turn form Smith to Ricardo. From the point of view of our interests, Ricardo's "achievement" consists in having "saved" and extended the capital theory, in essentials, taken over from Smith, and applying it to his (Ricardo's) circumstances. In doing so he exposes the weaknesses of the theory.

Smith's model is essentially a subsistence fund theory. There is a stock of food to maintain workers from one harvest to the next. What capital does for the owner is to facilitate the employment of a certain number of workers for the production of a certain output, etc. All economic considerations are such that we never have to look beyond this one year horizon. This makes the application of the static method possible. This excludes the consideration of expectations. Adjustment is simply a response to a given situation. Real economic action is excluded.

Ricardo was writing forty years after Smith (1817). Nevertheless, he was living in a different world (London not Scotland; the Industrial Revolution arrived in London sooner). Ricardo, whose original source for economic education had been Smith (it was not an academic education), took over, in all important details, Smith's theory. This is especially true with regard to the subsistence fund and the use of the static method. But Ricardo's was a different society form Smith's. He had to face certain problems that Smith was able to avoid. In the third edition of his book he found it necessary to add a chapter on machinery and had to withdraw certain previous statements. This is significant for us. It has a bearing on the way we look at the capital stock. Once machinery plays a large part in the economy, it becomes apparent that Smith's assumption of a homogeneous capital stock was no longer applicable. However, he managed to overcome this difficulty, and maintain his predecessor's theory in all important respects, and this is his greatest "triumph" .

The labor theory of value (which is what Ricardo regarded as his most valuable contribution) served to bring *all* economic goods within a common denominator. Everything economic is expressed in some way (usually money), but for purposes of comparison we need a measuring rod not subject to inflation and deflation. This was Ricardo's purpose. He used "labor hour" as a unit of measurement and this seemed the answer to him. Labor time is the common standard of comparison. It incidentally then served the purpose of reducing capital to the same common denominator as well. Machines, corn and cattle all cost labor and are seen to be comparable in those terms.

One problem which he had to solve at first looked formidable. We can, if we have a stock of circulating capital (e.g. a stock of corn), ask how many hours of labor it took to produce it and get an input-value. *But* if we have a machine lasting fifteen years, although we can say that its production took x man hours, the total input value is not used up in one year and enters successively into the output over fifteen years. This was not obvious to Ricardo. Smith distinguished fixed from circulating capital but only used it for descriptive purposes. Ricardo (in his genius) used it for analytical purposes i.e. fixed capital is that which simply circulates more slowly. Both circulating and fixed capital are capital goods. They only differ in their period of circulation. Fundamentally there is no difference. All capital stocks rotate. It is only a matter of degree.

Smith's wheel turned once a year. Ricardo has many more various wheels rotating at different rates. Ricardo's real interest was in the distribution of income between the various categories of goods. Is this arbitrary? What determines the periods of circulation of different goods? Realizing the fact of heterogeneity, what determines the equilibrium composition of the capital stock and the speed at which the various elements change?

For an answer he turns to *the rate of profit*. The tendency for this rate to be equalized provides a mechanism for determining flows of capital to various types of production. He uses the static method with perfect competition. The doctrine that a Capitalistic economy tends to establish a uniform rate of profit is fundamental to Ricardo. This is what explains the distribution of wealth. In equilibrium all ventures earn the same rate of profit.

This can be regarded as a great triumph in his "difficult" situation. It was a vindication of Smith's subsistence fund theory and an extension of it to more complicated circumstances. On the other hand, this really exposes for us the weakness of his theory. The main force on which we have to rely for

integrating various elements of the capital stock is at best a very long run force, for the only way in which capital can flow from one venture to another is by non-investment. If some venture becomes non-profitable capital can be withdrawn from it only slowly. We have to assume that no matter how unprofitable it is we can still earn our depreciation quota on the capital. Net revenue must still be positive if capital transfers are to take place. If this is not the case, the process (of equalization) will last even longer. Clearly there will be changes which will happen while capital is in the process of being shifted from areas of low to areas of high profitability. In a world in which unexpected changes occur and flows of capital cannot keep track of all the changes, equalization will never occur. A uniform rate of profit will only be brought about if the period of flow necessary for correction is not longer than the time between unexpected changes. In a world where this is not so, i.e. where uniform rates of profit do not emerge fast enough, prices of the various capital goods will be such that the original labor value invested in them has no enduring meaning. The whole Ricardian position begins to lose its basis.

Another way to make the point is to note that when talking of fixed capital the static method becomes inapplicable. Investment decisions have to cater for the whole life of the capital asset (profit and depreciation). Ricardo would argue that even if we are wrong we will still get our capital back, even if at a lower profit and having made the mistake once we won't do so again. But we know that continuing malinvestment may take place and this will affect the value of the capital invested. This means that labor-hours of production for any asset is totally irrelevant. Expectations matter in a way that labor-hours do not. This is what we mean when we speak of the weaknesses in his theory.

Smith's model is only acceptable in Smith's very special conditions - a "static" agricultural society. All relevant economic decisions have to be taken with respect to given conditions and for the immediate future. This is more or less satisfied in Smith's one year agricultural society. But Ricardo's society, which has many machines, has to bring in a long run tendency to bring about a uniform rate of profit. This might take a very long time and might *never* come about. The point is that expectations play a vital role. Ricardo, in vindicating Smith's theory, had to move into an exposed position, one where the static method is invalid. But it is important to note that in drawing a distinction between fixed and circulating capital (saying that it is a matter of degree) Ricardo was the first to stress the relevance of time in the context of capital.

Böhm-Bawerk

In the 1880's Eugene von Böhm-Bawerk published his important work on capital and interest. His rate of *interest* means rate of *profit*. Interest is that accruing to capital owners. Böhm-Bawerk followed Ricardo very literally on income distribution (land, labor and capital earn rent, wages and profits). He adds that one should not fail to distinguish between "original" factors (land and labor) and "man-made" capital. Therefore, in volume 1 of his work, he takes as his objective to explain why capital gets an income at all if, in reality, capital is a composite product of land and labor. Why don't rent and wages rise to incorporate this?

He gives three answers. Each exists independently of the others and would account for the existence of interest by itself. The first two deal with the scarcity of capital. They deal with the question: Why do lenders demand a rate of interest? The third deals with the demand price and looks at borrowers. (1) There is a temporal division of wants. All those who believe that future wants will be better provided for than present wants, have an incentive to equalize future and present satisfaction of wants at the margin. This implies a rate of interest will emerge. But the conditions in which this explanation of interest are convincing are not the ones that Böhm-Bawerk postulates. He assumes a stationary world in the sense that unexpected change (technological change for example) is absent. Capital is, however, being accumulated by individuals. In such a world a higher future income stream cannot reasonably be expected. While some people will dis-save for consumption, there will be others who are at the peak of their earning power and will, therefore, do the opposite with their declining future in mind. And in a static world these two tendencies must, by assumption and implication, cancel out. A uniform age distribution is, therefore, implied. So, under Böhm-Bawerk's conditions, a positive rate of interest *might* not emerge. (2) Böhm-Bawerk identifies a "psychological law". Most men underrate their future

satisfaction of wants. This implies that they are inclined to save "too little" because of the pressure of immediate wants. This is the "systematic underestimation of future wants". Böhm-Bawerk was criticized for this assumption on the grounds that it assumes irrational conduct. Such behavior is incompatible with the general assumption that people act reasonably. Some *may* well act like he says, but almost certainly others will go to the other extreme. There is, therefore, no reason to assume that the loan market between the two will end up with a positive rate of interest. This pertains to the supply of savings and how it depends on the array of people with different inclinations - some will be net suppliers of savings, some net demanders (borrowers). The rate of interest would appear to be indeterminate! It is whatever equates supply and demand.

(3) On the whole capital is productive. One can obtain a future income from it. The "higher productivity of round-about processes of production" was approximately the way he put it. Instead of using only the original factors of production, the productivity of human beings can be increased as some output is devoted to producing more efficient *means* or instruments of production. For this we need the accumulation of a certain stock of food to feed those specializing in the production of means of production. Some people must "waste their time" now for the benefit of greater future production. (The idea of "food" relates to the idea of a subsistence fund, which now does not rotate as it used to - food is turned into capital goods which become a means to a means .... to an end. The end is increased production).

Böhm-Bawerk assumes that all capital can be measured in a time dimension i.e. using labor services now for higher productivity in the future. This is the whole point of capital, the deflection of labor is made worthwhile by the gain in productivity. He proposed a measure of capital - the average period of production. For example, a ship producer takes 3 years and uses 2 units of labor in each of the first and third years and one unit of labor in the second year. When the ship is finished he has used 10 man years:

Year:	I	II	III
	L	L	L
	L		L

2Lx3yrs. + 1Lx2yrs. + 2Lx1yr. = 10Lyrs.

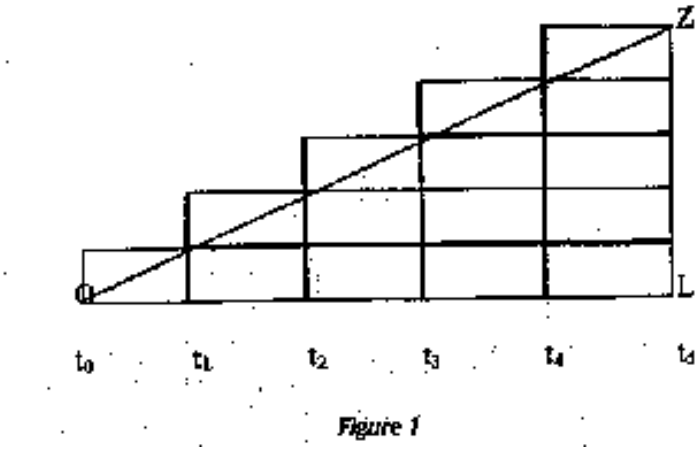

Figure 1

Five units of labor are used. Therefore, the average period of production is two years.

All capital goods are fundamentally unfinished consumption goods - consumption goods that are unfinished are fundamentally capital. This fits the conception of circulating capital and fits easily into classical subsistence fund theory. There are intermediate products at various stages of production. This invites the conception that the status of a capital good can be defined by its distance from the consumption stage. Capital is a stock of unfinished consumption goods at different stages of production. In a stationary economy this stock replaces itself continuously. Its distribution over time (stages of production) is constant. It represents a continuous and balanced flow. The labor force is distributed over the various stages of production. The input of any actual production good, however, becomes available as output at a

certain definite time. Fundamentally all capital is circulating. (There is a question about durable consumption goods. Should they be thought of as consumption or capital?)

What Böhm-Bawerk was trying to find was a measure of the capital stock defined in terms of time. The simplest example (see Dorfman 1959) is that of a water reservoir. Assume a water reservoir in a stationary situation i.e. where the inflow = the outflow. This implies a constant water level. Clearly then we can express the quantity of water in terms of time. For example, 10 gallons of water, with 2 gallons per hour flowing in and out, would imply that the average drop of water was in the tank for 5 hours. The ratio of stock to outflow = 5. This is the period of retention of each drop. This basic logic can be applied to the capital stock. The average period of production is then T = (total capital/rate of flow) = K/f. What is the
economic significance of f? Clearly it is a consumer good and must be measured in value terms. If we accept Böhm-Bawerk's labor theory of value then the amount (value) of goods that become ready at the end of each short period of time depends on the number of workers we have and the wage we pay them. This defines the value of the output = Nw. Value is being added as goods pass through production stages. Then

(1) $T = K/Nw.$

We have (in figure 1 above) 5 man hours emerging at the end of the process + 4 man hours at stage four + 3 man hours at stage three + two man hours at stage 2 + one man hour at stage one = 15 man hours.

We should think not in terms of 5 but in terms of 100's of stages of production plus 100's of units of labor. But this general model provides us with a simple measure of the capital stock. When there are only a few stages of production the diagonal line is in reality the broken connection between the north east corner of so many (in this case five) rectangles. When we increase the stages to the 100's the diagonal line will gradually straighten out as shown. Then we can measure the capital stock in terms of the area of the triangle, i.e. OLZ = 1/2tLZ, (where t is the period of production, OZ) = 1/2tNw (where Nw is consumption emerging). So:

(2) $K = 1/2\ tNw$

and

(3) $T = 1/2t$ from (1)

i.e. the average period of production equals half the total period of production. This can be used as our description of the capital stock. Any increase in the average period of production must imply an increase in the capital stock. (Note: this relationship was established for a *flow input-point output*[25] case, a case of continuous, uninterrupted production.)

Wicksell

[25]The input continues for five years and matures into an output at the end of that time. This is a case of flow input-point output. We should note, therefore, that the input is measured as a flow while the output is measured as a stock. As we will see below Wicksell extended Böhm-Bawerk's reasoning to the case of a stock input and a stock output (*point input-point output*). In such a case the logic of average period of production still makes sense. But when we move to other possible cases, particularly *flow input-flow output*, the situation becomes much more complicated. Needless to say, this last case most closely resembles reality.

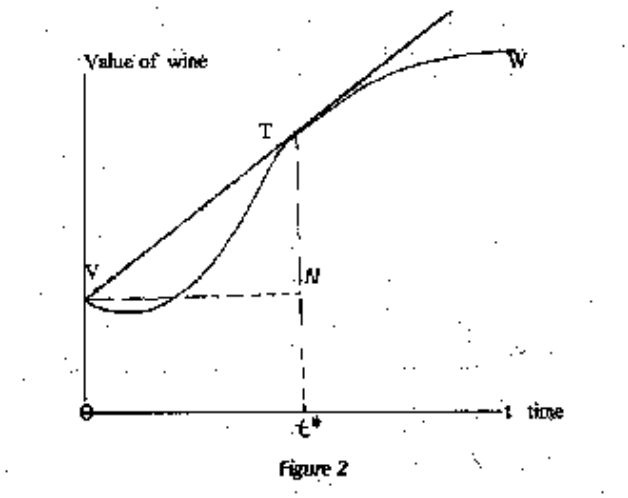

Figure 2

Wicksell at first was an enthusiastic defender of Böhm-Bawerk's view's and tried to vindicate Böhm-Bawerk's theory. His shifted to another case, namely, *point input-point output.* He uses a particular example, the example of wine making. The wine merchant buys grape juice and keeps it stored. Value is added merely by the passage of time. The question is: How long must he store it in order to maximize profits? We assume that the price of wine is independently set in the market and beyond the control of this wine merchant. His only choice variable is storage time. There are different prices for different maturities. So profits are a function of (storage) time. The solution is to sell when the rate of return on the grape juice has reached its maximum.

OV (figure 2) is the price of grape juice. The maturity price structure is such that the value obtained can be considerably increased if one simply waits. The product productivity curve shows how much the value of grape juice increases over time. At first the value falls, then it rises at an increasing rate and then, finally, rises at a decreasing rate. The straight line from V measuring the rate of return on capital is at its highest point when it is tangent to the productivity curve[26]. At that point (T) the storage time is $Ot^* = VN$. Also at T the marginal revenue = the average revenue. Any point to the right of T must be below the curve and therefore below VT. The slope to VT is TN/VN and this is the average (net) revenue (over the period). Therefore T is the optimum point.

A simple modification of our formula is instructive for the theory of distribution. Both Wicksell and Böhm-Bawerk had this in mind. It is a classical problem. Remember:

(2) $K = 1/2\ tNw$

or

(2') $K/N = (t/2)\cdot w$ (this is the form in which it is most instructive).

[26]Where the productivity curve is such that there are two (or more) tangents, the highest one is chosen.

Figure 3 here

Given our capital stock, the number of workers and the wage rate, if w rises the average period of production will fall and vice versa. If w fell it would become possible to extend the period of production. The classical idea is that, given the subsistence fund and given the technique of production (a particular way of bringing consumption goods to maturity), the shorter the period the less productive it is. Equation 2' assumes the left hand side is given. As long as K and N increase proportionately nothing will change. The sizes of the capital stock and the labor force will have no effect on t and w. But if K and N do change relative to each other - for example, if K increases relatively - w will rise or t will rise or both. Thus, an increase in the capital stock puts an upward pressure on wages and the period of production. If the rise in w were small t could be lengthened more. Alternatively a rise in N will cause a fall in w unless t is shortened.[27]

Assessment

Böhm-Bawerk's contribution

Böhm-Bawerk, in his later years, made certain points which elucidate the general assumptions he was making. He made clear that when he talked of increasing the period of production he did *not* mean technical progress (though he had spoken before in terms that seemed to imply that he did). Therefore, the world of Böhm-Bawerk is a peculiar one. It is a stationary world in which the quantity of capital can increase (in this way it is similar to Smith's). Progress means accumulation of capital and a more complex division of labor. In Böhm-Bawerk there is the possibility of progress in otherwise stationary conditions. It is not technical progress, but capital accumulation in excess of the growth in population. He did not mean to say that a lengthening of t would need to lead to an increase of productivity. Techniques must be wisely chosen from a set of *known* techniques. One may be more productive but is not being used owing to lack of sufficient capital, i.e. if there is a way to lengthen the period of production, there is a way to increase productivity.

This whole aspect of Böhm-Bawerk's framework is open to some criticism. We are asked to accept a world in which higher productivity as a result of a higher t does not imply technical progress. We need to note that t/2 applies to the economy as a whole. So, if as a result of technical progress, it becomes possible to shorten t, then this would imply that some capital is set free to be used elsewhere. So, once all capital is re-employed t may be higher or lower. We have to understand it as it applies to the economy as a whole. J. B. Clark and Frank Knight criticized the whole concept of period of production. According to them the concept was mistaken. A strict Böhm-Bawerkian view assumes a continuous flow of inputs maturing into a stock of consumption goods, whereas Wicksell assumes a *point input-point output* process. But both assume that at a certain point in time capital matures into consumption goods. In the economy as a whole, part of current income is investment (not necessarily net investment, some of it is for maintenance of the existing capital stock). According to Knight's criticism, the period of production, as applied to the economy as a whole, is always infinite or always zero, depending on the perspective one adopts. In the former case, there is no such thing as an origin to the period of production. The infrastructure of capital goods dates back to Adam and Eve. There must always have been production with the help of some capital goods and part of gross output was always used to maintain current capital goods and produce others. Output is a continuous flow that never ends. All social production is continuous. In the second case (where t = 0), time intervals are seen as irrelevant. Clark and Knight

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[27]In Böhm-Bawerk it is clearly assumed that the input of the services of labor adds continuously to the value of the product. The rate of interest calculated by Böhm-Bawerk is inconsistent with this assumption. He calculates it as a periodic payment (value of product/time labor). But Böhm-Bawerk's interest accrues continuously. Therefore, as Wicksell pointed out, this involves *compound interest*. As long as the rate of return remains constant, capital owners should be indifferent between the various period lengths since profits can be reinvested. If we use compound interest then we should have a logarithmic scale on the y axis of figures 1,2, and 3.

argued that it is quite wrong to say that there are time intervals in production. Consumption and Investment take place *at the same time*, the two are concurrent, simultaneous. The whole thing is a misconception.

Another criticism argues that there is really no reason why an increase in productivity should have anything to do with *time*. For example, for increases in the scale of production, the opposite may apply. A theory explaining interest in terms of production time is misconceived.

Beyond Böhm-Bawerk

We now have two possible ways to react. One is to accept the objections and give up the Böhm-Bawerkian doctrine. The other strategy is to make Knight's objection an occasion for reconstruction i.e. keep the essence of Böhm-Bawerk. Therefore, we have to identify what that essence is.

It is not too difficult to show that Knight's points of concern do not relate to the kernel of the matter. His first argument is that capital has *always* been necessary for production. This is not really illuminating of Böhm-Bawerk's essential theory. Böhm-Bawerk was trying to show that in making investment decisions there are a number of alternatives to be considered. *Time* is one of the dimensions of the alternatives. Arguments about the length of production periods are not really that important. Knight's second argument, that production never begins or ends is also not illuminating. In the real world decision makers are concerned with investment operations that have visible results at certain identifiable points or time. There is always a very long time horizon identifiable, but where this is beyond our personal horizons it is irrelevant. We talk about and work with finite periods of time.

Knight's formulation in terms of an average period of production that is either infinite or zero[28] is strictly speaking true only for a stationary economy. Only then is the production and consumption of goods simultaneous. In a stationary state no capital is ever consumed. It is maintained all the time. Therefore, by assumption, no consumption depends on any action concerning capital. We must remember that we can differentiate between different types of equilibrium. Knight means a stationary state. Production and consumption are a synchronized, simultaneous flow. By contrast. in a world where there are net additions to the capital stock, capital production precedes acts of consumption.

There is no reason, therefore, why we should regard Knight's strictures as really destructive of the core of Böhm-Bawerk's vision. Nevertheless a reconstruction is necessary. (1) We need to stop talking about the period of production. Böhm-Bawerk has exposed his theory to objections by using this formulation. (2) We need a word to express the fact that certain outputs accrue at certain points of time - an investment period. The way we must look at it is not as starting with the original factors of production. We must place ourselves at a certain point in time arbitrarily. The past is essentially irrelevant. We look forward in time when we make decisions. Therefore, we should really use *point input-flow output* formulations. The inherited capital stock can be used in various ways. We have a present stock of capital (consisting mainly of durable goods) from which we can obtain certain future outputs. We must choose among prospective output streams. For example, a building may have multiple possible uses - a factory, a cinema, a restaurant, etc. But how should we choose? In some cases the income stream will decline more quickly than in others, in some it will start low and then rise. The possible variations are infinite. Income streams differ in patterns. What are our choice criteria?

A formal analysis was given by Irving Fisher. He showed that the decision essentially involves two elements - (1) The transformation constraints, which describe the amounts of future income that would become available at different points of time as a result of investing income today and (2) relative preferences for income at different points of time i.e. time preference. In each case we must compare the *present values* of the income streams in question. Fisher uses an indifference curve diagram to investigate the case of two periods:

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[28]That is, we can either think of the production process as stretching back from the beginnings of human history and forward into the unending future, or we can think of the production process as essentially timeless since production occurs simultaneously with consumption.

We contrast preferences with the opportunities available. The tangency of the highest indifference curve with the intertemporal budget curve give us individual equilibrium. The shapes of the indifference curves reflect the extent of our time preference and the slope of the budget curve is determined by the relevant rate of interest. If we were completely indifferent between x and y then our indifference curves would be completely symmetric. If we assume that we always prefer present (x) to future (y) goods then the slope along the y axis will be steeper. For an individual the rate of transformation of present into future goods is given. So the budget constraint would be a straight line. We are concerned with the more general situation (for example, the situation for society as a whole) where the constraint shows diminishing returns. It is an intertemporal "production frontier". If it were completely symmetrical this would mean that the best we could do is maintain our present wealth. There would be no opportunity to get more y by sacrificing a bit of x. For productive capital it must be asymmetrical as with ORQ. The larger OR relative to OQ the more productive. E is the highest point of tangency. The general rate of exchange of x for y is given by the slope

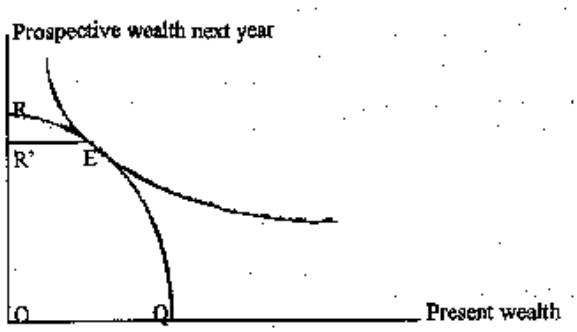

Figure 3

of the tangent to both curves at this point (i.e. slope AB = 1+r, where r = the rate of exchange (interest)). The same sort of analysis can be performed for 2, 3, ... n years into the future. Böhm-Bawerk must be interpreted as asserting that the longer the period the steeper the frontier becomes - i.e. greater productivity of roundabout production. OR rises along the y axis as we move further into the future.

We have so far assumed a given OQ. If, in the course of time and because of a positive income stream, we become richer, will this not affect the length of time for which we invest our present wealth? It should be clear that intertemporal allocation will only be affected if the shape of the indifference curves changes with increasing wealth. But in order to get Böhm-Bawerk's result an increase in the capital stock must mean an increase in the period of investment. Thus we would have to assume that OR is rising for later periods. If we do not accept this Böhm-Bawerk's conclusion does not necessarily follow.

In our examination of Böhm-Bawerk we have said that a theory asserting a relationship between capital and time would have to be in the form of a *point input.flow output* to be valid - only then would we be able to choose the optimal flow. Any analysis must be in terms of comparative statics - comparing one equilibrium to another. Here the problem of heterogeneity raises its head. As long as we assume homogeneity of our existing stock of capital and of the flow which it yields, time is the only distinguishing factor. We have simply an operation by which we turn given resources into an essentially similar flow.

Böhm-Bawerk's work is neither stationary nor fully dynamic. No technological progress takes place, technical knowledge is given, but the accumulation of capital goes on. This implies the lengthening of the period of production. As soon as we allow for heterogeneity, however, we introduce a new set of problems. In particular we have to determine what kind of *composition* this capital stock that we have actually has.

Beyond Homogeneity

As long as we maintain the assumption of homogeneity and look for the optimum yield and optimum investment period we do not really have much of a capital problem. Investment is sufficient to ensure that out of our income stream we shall be able continuously to add to our capital stock. The only difference between two points of time is that we become progressively richer over time. The only difference between present and future situations is that in the future we shall be in possession of a larger stock of resources. But with heterogeneity this can no longer be valid. The problem now is to what extent we should change the composition of our existing stock that is being accumulated. Future wealth might be in a very different form from present wealth. We have to be very careful abut what units we add. To what extent in a growing economy will it be necessary (and possible) to transform even the *pre-existing* stock?

We may ask: What does it mean to allow for heterogeneity? Physical heterogeneity is *not* the essence of the matter. Suppose some type of material had the useful property that one could build anything at all with it. Such physical homogeneity would not solve our problem. We are concerned with the *homogeneity of use*. Certain capital goods can be used with others only in varying quantities. There are limits to how many trains can run over a track at one time. The existing capital goods have to be used together in certain varying proportions (proportions that vary within limits). This imposes a constraint. It means that typically the capital goods available to a productive unit will have certain known forms.

Thus, as Schumpeter says, capital is neither homogeneous nor an amorphous stock, i.e. it has a certain form.[29] Thus what we mean when we speak of equilibrium must be an equilibrium composition of

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[29][This is an allusion to the words of Shumpeter 1954. In a section entitled "The Structure of Physical Capital", Schumpeter seems to anticipate much that is relevant to Lachmann's viewpoint. Schumpeter's book was completed (or at least interrupted by his untimely death) in 1950 and published in 1954. Lachmann's book on capital was published in 1956, but his 1947 article contains most of the essentials. A more extensive quotation is:

> The initial stock of goods is neither homogeneous nor an amorphous heap. Its various parts complement each other in a way that we readily understand as soon as we hear of buildings,

the capital stock. In a situation in which each capital good is replaced by a replica of its own or simply maintained fully intact, we have an equilibrium of sorts. If we want to change the composition of the capital stock we are not in equilibrium. This shows the difficulties of equilibrium analysis as it applies to capital. The fact is that capital analyses do not lend themselves to the static method. The static method assumes a given situation to which people are fully adjusted. But with a heterogeneous capital stock that is changing its composition over time one has to account for the transition from one form to another. What is it that compels (induces) the changes in the type of equipment used or the proportions in which they are used if not a dissatisfaction with the existing form, i.e. a disequilibrium? Equilibrium analysis is ill suited to a changing heterogeneous capital stock.

There is another difficulty. What are the implications of assuming with Böhm-Bawerk and Wicksell the existence of a stationary world except for the lengthening of the investment period over time? If the existing capital stock has an existing equilibrium composition then the owners of the capital goods that compose it must replace them with exact replicas over time. We must further assume that our world has *always* been in equilibrium. If this were not the case, then if at any time in the past a disequilibrium situation had existed and any investment took place (which happens all the time), then the capital goods created in that disequilibrium situation must have been appropriate to (designed for) that situation and, therefore, the capital stock cannot be an equilibrium composition now. This is because capital is durable. The capital goods of today embody the decisions of yesterday. Strictly speaking, the only time we can be in equilibrium is when we have the assurance that we have *always* been in equilibrium. The remnants of former disequilibria cannot exist today. The consequences of any disequilibrium situation will be long lasting. It is very difficult, therefore, to match capital theory with an equilibrium situation in the sense that each element of the composition is in equilibrium.

We shall have to move to *a new theoretical approach*. Heterogeneity of use is the first basic property of capital. Capital goods are used in certain proportions determined in one sense by technology - though there is always a choice of technique which implies a choice of capital combination proportions. These involve entrepreneurial decisions. Capital goods outside of a capital combination are really useless, redundant and, therefore, need to be scrapped. The necessity of combination implies the *complementarity of capital*. This is intrinsically bound up with the value of the capital stock. Some stocks may be kept optimistically (i.e. it might be expected to have a future use), but, except for land and permanent fixtures (e.g. tunnels), there is a tendency for capital goods to disappear over time. Those goods which do not fit into the existing capital combinations will be scrapped.

The complementarity of various resources is reflected in production plans. That is to say complementarity is *planned* complementarity. Production plans encompass labor and consumption as well. But different plans have to complement one another. We can talk of complementarity that goes beyond the firm. In an industrial economy the various activities, like mining, manufacturing, heavy industry, transportation, etc., must, in some way, fit together. There must exist some relationship between the capital invested in these various industries. This relationship comes about, however, as a result of market forces, as distinct from entrepreneurial decisions. Complementarity in the market exists as a result of the fact that "redundant" capital is scrapped.

Complementarity relationships impose constraints on capital choices. Capital goods can only be used together in certain proportions. Regarding this we can draw a distinction between the short term and the long term. The constraints are looser in the latter. There is almost always more than one technique of production. In the short run one is more strongly tied to given techniques. The switching of techniques

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> equipment, raw materials, and consumers' goods. Some of these parts must be available before we can operate others; and various sequences or lags between economic actions impose themselves and further restrict our choices; and they do this in ways that differ greatly according to the composition of the stock we have to work with. We express this by saying that the stock of goods existing at any instant of time is a *structured quantity or a quantity that displays structural relations within itself*, that shape, in part, the subsequent course of the economic process (Schumpeter 1954, pp. 631-632, italics original)]

requires time. For example, the combination of goods a, b, and c may be reshuffled to get rid of c and add d (these symbols represent quantities of goods types a, b, c, etc.). The period required for the reshuffle lies between the Marshallian long and short runs where the criterion of distinction is given by the fixity of the capital stock. With a heterogeneous capital stock we are no longer confined to speaking of adding, subtracting or keeping constant that stock. Now we are *reshuffling*. We have a new dimension. Changing its composition requires some time and the period over which this reshuffling is possible will be somewhat longer than the Marshallian short period with a given capital stock (where only output decisions are made). New capital goods have to be created. As soon as we allow for a variable composition of the capital stock we have to bring in a new period lying between the long and the short periods of Marshall. In the long period the added capital goods are already existent, where this is not so the period of reshuffle becomes identical with the long period.

Change affects the two forms of complementarity (firm and market) differently. At the firm level plans will be revised and capital combinations reshuffled. At the market level, the market process works to harmonize different parts of the economy. Input-output tables give a good picture of how goods flow from one section of the economy to another. When unexpected change occurs these relationships are affected. Let us look a little more closely at this. At the firm level, when capital combinations are reshuffled as a result of unexpected change we can draw two implications: (1) To the extent that some kind of unexpected change is expected (i.e. we are aware of real uncertainty), the need for reshuffling may be mitigated. Everybody will carry somewhat larger stocks than would be the case in a stationary state. These perform the role of shock absorbers - spares, cash, excess inventory, etc. Excess capacity is to some extent simply a means of keeping a dynamic economic flexible. (2) Where changes are significant enough to cause reshuffling, they may come in a variety of ways. The most commonly considered is a significant change in the demand for a final product. This will cause a change in the capital combinations producing that product. Alternative uses will have to be found for some of the capital goods. This is because of their *specificity*. Capital goods cannot (as the classicists assumed) simply flow from one industry to another. Second best uses will have to be found for displaced goods - if possible. Less commonly considered, but perhaps more important practically, is a change due to the discovery of some superior use for a kind of capital good (or resource). For example, B and C become useless because of a superior use discovered for A. This kind of thing is going on all the time as a concomitant of economic growth. We see it reflected in the value of land. It pays these days in Braamfontein[30] to dissolve capital combinations of houses and build offices or apartments. The land has become more valuable. A better use for any component of a capital combination alters the combination. It doesn't follow that all other components will be scrapped. Sometimes other uses are valuable. Beautiful staircases can be sold. The dissolution of a capital combination because of one component does not mean a second best use can't be found. As the market process proceeds and capital is reshuffled, some goods are turned to more profitable uses, some are scrapped and some are tuned to second best uses. The scrapping of redundant capital goods proceeds slowly over time.

What does this mean for Investment? The availability of cheap displaced capital goods might be an incentive to investment. If B and A can be used profitably together, then a lower price for B implies a greater opportunity to invest in A. There is no place for this kind of insight in the Keynesian framework.

Can we say anything about the relationship between economic progress to changes in the capital stock? One school of thought analyzes a situation where, although the capital stock is heterogeneous, it increases over time with the proportions of the various goods remaining the same. This is the predominant assumption for growth theory and is the nearest thing to assuming a homogeneous capital stock. In a more sophisticated way Mrs. Robinson (1956) assumes that the capital stock at each moment of time has that composition which the relative for consumption goods needs. But our aim is to find out how such a situation could ever come about? We know that in reality the capital stock changes its form and not merely its "size". It is difficult to say in general in what way it changes over time. But looking at history we see the advantages of an existing infrastructure (railways, roads, equipment, etc.). An existing

[30][The neighborhood in which the university is situated.]

infrastructure means that some capital will at first not have to be added to. For example, in South Africa's history, the under-utilization of the railway (which is, of course, indivisible) was an important factor in economic growth. The existence of indivisible capital is the main source of increasing returns. We can say at least two things about the typical pattern of complementarity. (1) There will not be a simple multiplication of *all* capital goods with growth. It varies, for example, with degrees of utilization. (2) The more the economy grows the more it will pay to invest in *new* capital goods.

Böhm-Bawerk's Third Reason Again

The increasing productivity of roundabout processes identified by Böhm-Bawerk has its counterpart in aspects of the above discussion. In defending his theory he made it clear that he wasn't thinking of technological progress, which he admitted would shorten the period of production. He also did not deny that capital could increase without the period of production increasing e.g. by producing more of each class of capital good already in existence. Returns would increase with technical progress which, however, was limited and couldn't continually combat the downward pressure on rates of return on capital.

We can interpret him in our terms. As an economy grows certain indivisibilities come within its reach. These are known, in the sense that the technical knowledge is available to be used when it is profitable. For example, we could produce a nuclear power plant but it is not yet profitable to do so. We can interpret the lengthening of the period of production concept as a process by which we bring certain indivisible goods within our economic reach. The construction of new indivisible capital goods involves the complementarity of other capital goods under profitable conditions. For example, as the economy grows railway traffic increases. The profitability of the railway depends on the profitability of complementary industries. This is true in every industry. The profitability of the total capital invested depends on the modes of complementarity. When we talk about capital accumulation we mean we can now afford (because of so much complementary capital in existence) to get hold of indivisible capital resources. For example, the building of a power plant depends on the profitability of the coal industry.

When Böhm-Bawerk talks about the time it takes a product to reach the consumption stage we can interpret it in term of stages of processing. Economic progress typically takes the form of processing stages. This becomes more complex because more specific capital goods are invested in them. In a modern industrial economy turning wool into clothes is a long process. At each stage highly specific, highly specialized equipment is used. Spinning, weaving, dying, etc. equipment is needed. The reason why each is profitable is because the throughput, the demand and the raw materials, are all there. We should, therefore, think of economic progress as the multiplication of production stages. The richer the economy is the more of these there are. All this is easier to understand if we remember Adam Smith's division of labor, which for him meant economic progress. Böhm-Bawerk's view is very different. Labor is replaced by capital of many different types. By this we manage to escape the continuous downward pressure on the rate of return on capital. We have a lengthening of the duration of the journey of processing raw materials. There is a basic complementarity between the specific capital goods and the materials that flow through them. Böhm-Bawerk's homogeneity is a defect in so far as it leaves out the essence of complementarity and its relation to the growth of capital. The nature of the throughput changes with each change in the capital structure.

PART THREE: FURTHER CONSIDERATIONS ON LACHMANN'S THEORY OF CAPITAL

Capital and Complexity

The Division of Capital

In his work on capital Lachmann proposed a reinterpretation of a controversial aspect of Böhm-Bawerk's theory, his proposition concerning the productivity of roundabout production. (See the last section of the lectures notes above and Lachmann 1956, chapter V). As he explained at length in his lectures, Lachmann regarded Böhm-Bawerk's use of time as a unit of measurement for the capital stock as untenable and seriously misleading. He felt strongly, however, that Böhm-Bawerk's intuition about the sources of economic progress were correct. "[T]he intuitive genius of Böhm-Bawerk gave an answer [that], to be sure we cannot fully accept and which, moreover, is marred by an excessive degree of simplification, yet an answer we cannot afford to disregard." (1956, p. 73). Therefore he suggested dispensing with the notion "period of production" and replacing it with the notion "degree of complexity". Whereas Böhm-Bawerk argued that the period of production increased with capital accumulation, Lachmann argues that capital accumulation results in the increasing complexity of the production process. In this way he hoped to have given a new and more appropriate meaning to the notion of increased roundaboutness.

Lachmann argued that Böhm-Bawerk's ideas were closely related to those of Adam Smith (Lachmann 1956, p. 79). Both were concerned about the sources of economic progress. Both lived in a world that was "neither a stationary nor a fully dynamic world" (1956, p. 79). Our world is, however, a dynamic world, one in which technical progress is an outstanding feature. For Böhm-Bawerk roundaboutness was not a form of technical progress. "Technical progress requires new forms of knowledge spreading through the economic system while Böhm-Bawerk assumes as given knowledge equally shared by all." (1956, p. 79).

> For Adam Smith the division of labor was the most important source of progress. The same principle can be applied to capital. As capital accumulates there takes place a 'division of capital', a specialization of individual capital items, which enables us to resist the law of diminishing returns. As capital becomes more plentiful its accumulation does not take the form of multiplication of existing items, but that of a change in the composition of capital combinations. Some items will not be increased at all while entirely new ones will appear on the stage.... The capital structure will thus change since the capital coefficients change, almost certainly towards a higher degree of *complexity* i.e. more capital items will now be included in the combinations. The new items, which either did not exist or were not used before, will mostly be of an indivisible character. *Complementary plus indivisibility* are the essence of the matter. It will not pay to install an indivisible good unless there are enough complementary capital goods to justify it. Until the quantity of goods in transit has reached a certain size it does not pay to build a railway. A poor society therefore often uses costlier (at the margin) means of transport that a wealthier one. The accumulation of capital does not merely provide us with the means to build power stations, it also provides us with the means to build factories to make them pay and enough coal to make them work. Economic progress requires a continuously changing composition of social capital. The new indivisibilities account for the increasing returns. (1956, pp. 79-80, italics original).

Böhm-Bawerk's thesis about the higher productivity of roundabout production is an empirical generalization. It can be applied, reinterpreted, to our own world. We have achieved, and will continue to achieve, greater productivity, that is the production of more and better consumption goods and services, by the continuing introduction of new indivisible production goods (which embody new production techniques). This can be cast in terms of Böhm-Bawerk's (and Menger's) idea of "stages of maturity". Böhm-Bawerk argued that capital accumulation will take the form of an increase in the number of stages of production. "The richer a society the smaller will be the proportion of capital resources used in the

'later stages of production', the stages nearest to the consumption end, and vice versa." (1956, p. 82). Lachmann recasts this idea to mean that progress implies that capital accumulation results in an increase in the number of processing stages as capital combinations become more and more specialized. He is careful to point out that this will only imply an increase in the actual time of production (however calculated) if it can be assumed that each "stage" is of equal duration. This is not likely to be the case and so we must give up the hope of measuring production processes in terms of time. The increased number of stages is indicative of increased complexity, which, in turn, is indicative of increased productivity. Increased complexity implies "an ever more complex pattern of capital complementarity" (1956, p. 85).

> We conclude that the accumulation of capital renders possible a higher degree of the division of capital; that capital specialization as a rule takes the form of an increasing number of processing stages and a change in the composition of the raw material flow as well as of the capital combinations at each stage; that the changing pattern of this composition permits the use of new indivisible resources; that these indivisibilities account for increasing returns to capital; and that these increasing returns to the use of capital *are*, in essence, the 'higher productivity of roundabout methods of production'. (pp. 84-5, italics original).

Finally, Lachmann contends that the increased complexity of the capital structure also implies an increased vulnerability. "A household with six servants each of whom is a specialist and none of whom can be substituted for another, is more exposed to individual whims and the vagaries of sickness than one that depends on two or more 'general maids'. Thus an 'expanding economy' is likely to encounter problems of increasing complexity...[among which are] disproportionalities and the resulting maladjustment of the capital structure [which] may give rise to serious problems in economic progress." (1956, p. 85).

What are we to make of these assertions? One way to think about the capital structure becoming more complex is to see an increase in the degree of vertical disintegration. More and more stages of production are associated with any production process. Complexity implies a large number of components - in this case stages. Increasing complexity then implies that the number of stages increases. The production activities become more and more finely specialized. This development is facilitated by the growth in economic activity. As Adam Smith would have it specialization is limited by the extent of the market. Lachmann has given fuller expression to this idea through the idea of capital complementarity. A possible objection to this line of thought is provided by noting that the whole character of production processes changes with technological change. In some instances vertical integration may increase not decrease. For example, in the computer industry, large scale production and consumption of personal computers, peripherals and software has provided economies of scale in the distribution of these products so that it has become possible in many cases to dispense with the services of the distributor middleman. An entire stage in the production-distribution cycle has been cut out. There are undoubtedly other examples of this. New production processes may imply fewer stages. This raises the difficult question of what we should regard as constituting a production stage. There are arguably more components in an old main frame computer than in a modern desk top. However, the number of circuits in a modern microprocessor (CPU) is many times that in the old main frame. Which has more "stages" of production? Another problem is presented by the production of completely new products and the disappearance of old ones. From what perspective could we ever measure, or should we ever try to measure, the number of production stages for the economy as a whole? We seem to be back to capital measurement problems. Yet, there is an inescapable intuitive ring of truth to Lachmann's (and Böhm-Bawerk's) attempt to characterize progress as increasing complexity. This is, in fact, very much in line with recent developments in other fields of inquiry, like biology, physics, population studies, weather, and others. (Waldrop 1992). In each of these fields investigators have turned their attention to what they characterize as *complex systems.* A complex system is one that has a great many independent agents that are interacting with each other in a great many ways. Moreover, the very richness of these interactions allows the system as a whole to undergo spontaneous self organization and to adapt to changes. Notably, "every one of these complex, self-organizing, adaptive systems possesses a kind of dynamism that makes them qualitatively different from static objects". (Waldrop 1992, pp. 11-12). Market economies in general and capital structures, as characterized by Lachmann, definitely constitute complex systems in this sense (See

also Hayek, 1964). In what way are they becoming more complex? Perhaps the key is to be found in the continuing arrival of new information leading to new knowledge. Capital accumulation in the modern world implies the accumulation of information and the addition to knowledge. To be sure, some knowledge may be lost. For example, modern man could not last very long in the wilderness unaided, in the manner of his more primitive forebears. Also certain kinds of "wisdom" may be lost as lifestyles change. However, modern man can, in an obvious sense, accomplish more things. Our current knowledge is of a "higher" order. It rests on the multitude of advances (and mistakes) made across countless generations. In that way we reap the benefits of more "roundabout" production.

Not surprisingly there seems to be a crucial connection between capital and knowledge. And Lachmann has emphasized, in his work on capital and even moreso in his other work, that the knowledge possessed by the members of any society is a crucial determinant in its economic development. The very notion of capital combination rests on the presumption of an active understanding of the functions of individual capital items. Yet, while emphasizing the importance of knowledge in its many manifestations, Austrian economists have said surprisingly little about knowledge as a phenomenon. They have treated it as a sort of "exogenous variable". Lachmann says for example that we cannot imagine the passage of time without there being a change in knowledge. He regarded this as an axiomatic truth and it has elsewhere been called "Lachmann's axiom" (Lewin 1994 p. 236). Yet there is no analysis of the determinants of knowledge, of the various processes that might be expected to generate different types of changes in knowledge. This is a "human" side of capital that has not been integrated into the Austrian view of capital. One wonders whether the large literature on human capital might have something to offer in this regard[31].

The Time Structure of Production

We have seen that Lachmann rejected the notion that the capital *stock* could somehow be reduced to the dimension of units of time, although he had considerable sympathy for Böhm-Bawerk's idea of "roundabout production" being an essential ingredient of modern societies. Therefore he recast Böhm-Bawerk's idea in the form of an ever increasing division of capital, an evermore complex specialization of the individual components of the unquantifiable capital *structure*. But surely Lachmann would not have denied the importance of time in understanding capital. Time is surely important as a factor in the capital formation and maintenance decision, as implying the postponement of consumption; and it is surely important in that the value of capital depends on future yields. But what is the connection between the capital *structure* and time?

It is well known that Lachmann admired the work of G.L.S. Shackle. The relationship of Shackle's work to Austrian economics has been a matter of some (sometimes strongly motivated) dispute. Certainly Shackle's treatment of time has implied a radical subjectivism that some Austrian economists have felt unable to live with. Lachmann had great sympathy with Shackle's approach and even of his characterization of aspects of Keynes's theory. He saw in Shackle's work a connection to his own work on expectations. Less well known, however, is his admiration of one of Shackle's works of a somewhat different nature. In 1965 Shackle published a book entitled *A Scheme of Economic Theory* (Shackle 1965). This was a sort of taxonomic work in which a number of different prominent theories were compared according to the way in which they used, or the implications they had for, time.

As usual Shackle provides a penetrating and eloquent account of ideas - in this case of his own (particularly on the meaning of equilibrium and the meaning attached to different usages of the concept of "time"), of Marshall, of Keynes, of Harrod-Hicks, of Böhm-Bawerk and of Leontief. In a chapter entitled "The Structure of Production" he provides a characterization and analysis of Böhm-Bawerk's approach that is strikingly in tune with Lachmann's[32] but that, in addition, emphasizes the role of time. He recasts

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[31]This is, indeed, part of this writers current research activities.

[32]Although he does not include any discussion of the increasing division of capital. In this book Shackle was apparently not conversant with Lachmann's work on capital. There is only one reference to

Böhm-Bawerk's "Capital is Time" approach into a "Time Structure of Production" approach that yields some insights not mentioned by Lachmann. It is worth examining this in some detail.

In characterizing "the anatomy of production" Shackle begins by emphasizing the heterogeneity of productive activities (and by implication capital items) that are part of the productive process as a whole.

> Productive activity takes an immense variety of forms, most of which depend, for their means and for their purpose upon each other. Each particular operation is performed with materials and tools which embody the results of many other operations, and helps in its turn to make further objects some fraction of which may serve, more or less indirectly, to make possible the very types of activity that have provided the means of this first operation itself. Productive activities thus belong to and constitute a single whole, within which they are interdependent and from which they draw their means and their meaning....Total production is unity in diversity, and we need some model to represent to ourselves simultaneously both of these aspects of reality (Shackle 1965, 150).

If we characterize each work-place producing a homogeneous product as a productive activity and we assume that the economy consists only of such work-places (i.e. there is no multiproduct production), "our picture of society ... will then consist of a great number of work-places into each of which there will flow supplies of materials and energy of many diverse kinds, each kind the product of some class of other work-place, and from which there will flow out its own product going to yet other work-places which, again, will be of many kinds." (Ibid. pp. 150-151) What we have is "an intricate network of interdependence .... Let us call the pattern of this interdependence the technical structure of production." (Ibid. p. 151) And now Shackle explains an interesting connection between technology and time. "It is clear that the interruption of activity at any one point or in one class of work-places (one 'industry') would be followed only after various lapses of time by the entailed interruptions at other points or in other industries and that thus the *technical structure of production* involves also a *time-structure of production.* The recognition of each of these aspects of production may help to explain some economic phenomena and may furnish guidance on how to give effect to policy." (Ibid. p. 151)

For example, imagine two societies identical in every economic respect in an evenly rotating equilibrium, i.e. in each society, each day, each person duplicates the operations of the previous day, and the list of equipment and goods produced remains the same over time. Expenditure on maintenance is just sufficient to maintain the capital structure intact. Now "let us suppose that in one of these societies, in one particular *activity*...(let us call it activity *j*) there occurs a strike lasting one day, following which, so far as the physical resources available to him allow, every member of the society endeavors still to repeat the former pattern of operations, deviating from it only so far as change in the tools and flows of materials made available to him by other activities technically compels him to....[B]y comparing the size of the output of each activity in Society A with that of the same activity in Society B, in each of the days following the strike in one particular activity of Society A, we can trace the repercussions of that strike through the whole productive system of Society A" (Ibid. pp. 151-152). These repercussions will be widely dispersed over time and space and will be exceedingly complex in nature.

> Since a parcel of *j*'s product dispatched today to activity *k* will not be used by *k* until some later day, and *k*'s output in turn cannot in general ... be immediately processed by *l*, the *technical* network of paths along which the various activities may be conceived to send their products to each other will be, as it were, projected, in a geometrical sense, on to an axis where the sequential location of activities represents the time-sequence in which they will be affected by the one day interruption of output in *j*. It is plain that an activity, say *k*, will appear several times in

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Lachmann on a different subject. Had he known of Lachmann's work on the capital structure it is unlikely that he would have neglected to mention it.

> such an ordering, for its own output, diminished on one date ... may be an essential ingredient for some other of its own suppliers (Ibid. p. 152).

Such a conception though complex understates the actual complexity that is likely in the postulated scenario. In some cases the effects may be felt for the entire lifetime of the durable products involved, as for example when an interruption in the output of industry *j* means that a particular tool which has to be scrapped will fail to be replaced causing the *stock* of tools to remain smaller by one item until the date arrives when the item which was never produced becomes due for replacement.

The time structure, implied by the technical structure, cannot be easily summarized. In particular, the time lag and intensity with which any one sector is affected would in general be different when a different originating sector is involved (Ibid. p. 153). "This still leaves it perfectly possible that the time required for a disturbance of given intensity in a named sector *k* to be followed by the resulting disturbance in another named sector *l*, directly supplied by *k*, might be constant no matter where the trains of disturbance had originated, and that this might be true of all similarly related pairs of sectors. If so we can claim that our apparatus reveals a *time-structure of production*, and gives to this an operational meaning which, perhaps, it has lacked in even the modern formulations of the Austrian theory of capital."(Ibid. p. 153) In the absence of this simplifying assumption the time structure is more complex and though perhaps not "operational" exists in the same sense implied by Shackle. Thus, from the perspective of Lachmann's conceptual framework, the pattern of complementarity that characterizes the capital structure implies a time structure. The capital structure exists *in* and *through* time. At any point of time the *stocks* of capital items exist in capital combinations characterized by complementary relationships. Over time goods and services *flow* between these stocks. In Böhm-Bawerk's scheme goods and services in process flow uniformly from inception to completion facilitating the characterization of the production process in terms of production time. In the Lachmann-Shackle scheme goods and services flow in all directions precluding such a characterization. The role of time as a factor in the production process is nevertheless the same in both worlds. Production takes time, even if at any point of time it may appear as a continuous process. And that fact becomes apparent under various circumstances. One is when the production process is interrupted as discussed above. Another is when an innovation is made to an existing activity or when a new activity (production process) is started and the necessary equipment has yet to be put in place. There will be repercussions on the capital structure essentially similar to those caused by a temporary interruption, except that in the case of innovation the capital structure and its implied time structure will be permanently affected.

This raises an aspect of time that Shackle did not deal with in this context. That is the phenomenon of change. The time structure of production is not only complex it is changing. The practical implication of Lachmann's axiom that time and knowledge belong together (the elapse of time always implying the arrival of new knowledge) and its corollary that capital accumulation implies technological change, is that the structure of capital and its implied time structure (the pattern of leads and lags implied by flows of goods and services within it) are continually changing over time. More specifically, according to Lachmann, economic development implies, for the most part, an increasing specialization of production processes, an increasing division of capital.

Lachmann's assertion that greater complexity implies greater vulnerability can be linked to the time structure of production. An increasingly complex time structure may imply that any interruption of the production process (i.e. any unexpected event) will imply interruptions at various points in the production network as described by Shackle. Increased vulnerability implies that these interruptions will be more far reaching in their effects the more intricate the production network. In general this assertion does not appear to be true. On the one hand, increased specialization does imply increased vulnerability to the extent that more indispensable processes are involved, the interruption of any one of which, if unmitigated, can sabotage the entire structure in some way. On the other hand, to the extent that the trend towards increased specialization is accompanied by an increased redundancy in the structure, for example the proliferation of competing and substitutable technologies, increased vulnerability need not arise. It would appear to depend on the particular case.

Shackle's critical yet appreciative analysis of Böhm-Bawerk's scheme involves a discussion of the various difficulties with which it is associated. This discussion, for the most part, echoes Lachmann's approach to

the same subject outlined above. Basically this consists of variations around the theme of the impossibility of calculating the average period of production in the world as we know it. While acknowledging this, "we may [however] reasonably ask how serious this problem is for a theory which claims only to give insight." The most interesting way, according to Shackle, in which reality differs from the Austrian model is "that so far from there being an isolated, self contained process leading up to each consumable good, there is, instead, an intricate interweaving of all the paths along which we can conceive the results of productive activity to flow through the system. [And he hopes to have shown] that the idea of a time-structure of production is relevant, and can be conceptually made apparent, even where there is an intricate interdependence of industries" (Ibid. p. 168).

A comparison of Böhm-Bawerk's system with the more complex one discussed by Shackle reveals yet another aspect of the relevance of time. Böhm-Bawerk's model hypothesizes that individuals "prefer to consume the fruits of their efforts in a shorter rather than a longer time from the date of those efforts." Indeed this provides a justification for the earning of interest by those who are willing to advance the means of subsistence to those who construct the capital equipment. "Now there are two distinct sets of circumstances in which this 'impatience to consume' could be supposed to operate. The 'impatience' has to be overcome, in some degree and over some period, in order to build up 'from the beginning' a stock of goods suitable to some advanced technology. But when this stock is already in existence, the impatience has still to be held in check, because if it were given free rein the capital stock could be dissipated in an orgy of consumption or of indolence, of consuming more than was currently being produced." (Ibid. pp. 168-169) Shackle then asks whether these two cases are symmetric.

> Could 'building down' the capital stock proceed in an exact mirror image of building it up? May it not be true that the degree of restraint needed to preserve an existing capital stock in being is less than that needed to carry through the latest stages of advance to its present state? There are here a psychological and a technical aspect quite distinct from each other. On the one hand, the instinct to preserve may be more imperious than the ambition to advance. Only a disintegrating or a dying society, except in war, would indulge in general disinvestment. The technical question is more interesting. When the material embodiment of an advanced technology is being built up from small beginnings ... the *means* of making more advanced and specialized tools and machines and materials are themselves *less* specialized. But will it be at all profitable, even in the shortest run, to dismantle the dynamo's, the telephone systems and the computers in order to use the copper of their substance for some more primitive purpose? Any widespread injury to the system as it exists and as it lives may well be fatal... The disinvestment could conceivably be carried through with careful discrimination, leaving at each stage as much, in value terms, of the system still in working order as possible. But to what purpose? The gain in immediate consumption could at best be slight, and would last for only the briefest time. *The growth and evolution of a capital-using, highly specialized economy is virtually an irreversible process* (Ibid. p. 169, Italics added in the last sentence).

Thus an important aspect of the heterogeneity of capital is that its evolution is a one way street. It is an important aspect of the 'arrow of time.' It is an aspect that is not apparent when capital is assumed to be a homogeneous entity, or one that is in continuous equilibrium. At any point of time the capital structure, being composed in part of durable items, will reflect the results of past decisions and will constitute a constraint on present and future decisions. We cannot explain actual decisions without taking this into account.

Shackle's discussion involves the identification of activities that he labels *j, k, l* etc. The picture created is of a lattice or a matrix of activities. And indeed this parallel leads him to a discussion of Leontief's input-output matrices. Shackle's purpose is to show the elegance and beauty of the conception. And something of the complexity of the capital structure is captured, "an essential aspect of modern production, namely, that every plant and industry stands at the confluence of many streams of products which are supplied to it by other firms, and is also the point from which many streams of its own diverge, first to other firms which it directly supplies, and through them to a great part of the whole economy." (Ibid. pp. 170-171) However, an input-output matrix designed to reveal the capital structure by using an array of flows of goods and services expressed in money values, and coefficients of flow (a_{uk}) which are

assumed to be fixed over time, may reveal more through its deficiencies than its parallels. A recording of these matrices over time would show these coefficients to be in a constant state of flux. This reflects not only constantly changing relative prices, but also the continuing mutation of the capital structure in response to the arrival of new knowledge embodied in new technology. The capital structure of a dynamic economy is malleable and any theoretical construct that fails to reflect this misses an important characteristic.

In the final analysis, the capital structure is not merely a list (albeit a continually changing list) of capital items. Rather it consists of these items and the relationships they bear to one another. A consideration of what it would take to describe the capital structure and how it contributes at any point (or during any period) of time to the well being of individuals, reveals that the knowledge implied for such a task cannot possibly be possessed by any one person. And it prompts the further consideration as to how capital structures do indeed evolve when no one could possibly possess the knowledge to design them. The connection between this theme and a discussion of Hayek's (Hayek 1945) should be clear.

Capital and the pace of change

Lachmann was convinced that unpredictable change was an important part of our lives and ought to be part of our theories. The choice of how to characterize capital is dependent on the kind of world in which one lives. In a world in which unexpected changes occur relatively rarely and in which methods of production, distribution and interaction are very stable, it might make sense to characterize capital as an equilibrium stock, a fund of more or less agreed upon value. But in a world in which change is rapid and unpredictable, Lachmann's characterization of capital as a structure of heterogeneous items, becomes more appropriate. In particular, with regard to the effect of change on incomes, employment and life styles, Lachmann's changing capital structure gives insights that are not available from an equilibrium approach.

It is generally agreed that we are living in an age of profound changes - some people have called them revolutions. These changes are in one way or another characterized as "changes in technology". Changes in the variety, quality and type of consumer goods that we have available in our homes are the result of changes in the technology of production and distribution of these goods. Changes in the methods of producing capital goods and in the type of capital goods used are likewise the result of changes in technology. It is not the fact of changes in technology that is revolutionary, it is the speed with which it is occurring that is new. The agricultural and industrial revolutions brought with them tremendous strains and stresses in the wake of the changes that occurred. But, by comparison to the changes occurring in our current age, they were minor ripples. The orders of magnitude have multiplied. Also, the pace of change is not only quicker, it is accelerating. At the same time, however, our ability to absorb and adjust to change has increased many fold.

Underlying virtually all of the major developments of this century is the revolutionary change in the way in which we generate and use information. Some people have already started to call this the "information age". In some respects this is only the latest in a line of similar revolutions, like the emergence of language, writing, accounting and printing. The latest, and to date most profound, development in this line of developments, is electronic communication of which the telephone, the computer and the video and audio recorder are all part. Electronic communication in all of these aspects is responsible for the developments of global markets, of desktop publishing, of fuel injectors for automobiles, of computer aided design of everything from microchips to airplanes, and so on.

The scope and pace of technological change itself is governed by our ability to generate and process relevant information. If technological change is seen as the result of many trial and error selections (of production processes, of product types, of modes of distribution, etc.) then the ability to generate and perceive more possibilities will result in a greater number of successes. It will, of course, also result in a greater number of failures. Lachmann's proposition that capital accumulation, proceeding as it does hand in hand with technological change, necessarily brings with it capital regrouping as a result of failed production plans, appears in this perspective to be particularly pertinent. "[E]conomic progress ... is a process which involves trial and error. In its course new knowledge is acquired gradually, often

painfully, and always at some cost to somebody." (Lachmann 1956, p. 18). Today new knowledge acquisition is not so gradual.

From the perspective of traditional macroeconomics, with its focus on the money value of investment spending as a gauge of productive activity, it must seem curious that the western economies have gone through a period of rapid capital accumulation and technological advancement at the same time as the unemployment of some types of labor remains high. But in an era of rapid technical change this is precisely what one might expect. Capital combinations are made to fit into production plans that assume a particular type of technology. Given that we live in a world where the arrival of the unknown in terms of the technological is almost, paradoxically, to be expected, some flexibility may be built into the plan to accommodate unexpected changes. Whether or not it will be possible to accommodate changes within any production plan, for example by upgrading equipment, depends on how large the change is. When very large changes occur the plan may have to be abandoned. The capital in that plan will have to be reassigned or scrapped. This may have ripple effects in so far as this plan is complementary to others. The process of capital regrouping has implications for labor. Labor will be displaced and will have to slot into other capital combinations. Skills acquired for one purpose may be less suited to others. Unemployment is the natural counterpart in labor of multiple specificity in capital. The concept of "human capital" would appear to have ready application in this context. In particular, like physical capital, human capital should be thought of as heterogeneous and multiply specific.

This kind of structural unemployment, that is to say unemployment caused by the changing of the capital structure as a result of technological changes, is obviously not a new phenomenon. The substitution of capital for labor as a result of automation, for example, is well known. Historically speaking the effects of the displacement of labor by capital have been outweighed by the overall expansion of production activities and we may expect the same trend to continue. In the current situation, however, the process is complicated by the rapidity of change and by the increasing complexity of both capital and labor structures.

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