

The Capital-Using Economy

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Introduction

It is no exaggeration to say that Capital Theory is fundamental to everything else in Austrian Economics. It lies at its core, implicit in discussions of monetary policy, the business cycle, the entrepreneur, and the subjectivity of value and expectations. Prior to the Keynesian revolution it was Capital Theory for which the Austrian School was most known among mainstream economists. With the advent of Keynesian macroeconomics, interest in Capital Theory all but disappeared. But it has recently been the subject of increasing attention. After a brief overview of the main ideas in Austrian Capital Theory (ACT) from its origins and extensions through the middle of the last century, this chapter will note this rekindled interest and survey recent applications.

The Austrian Theory of Capital

Production refers to the process of transforming physical resources into more useful forms. This is how *value* is created. A series of activities must occur in a specific context and sequence, in order for the production project to be successful. Carl Menger (1871) spoke of higher-order (intermediate) goods used in the service of producing first-order (consumer) goods. Böhm-Bawerk (1959) has a similar image of concentric circles – the outermost being most remote from the final product. Hayek (1931) used the image of a production triangle, with the base indicating time and the height indicating value-added. All of these visions see production as a process in time involving sequential, related activities. (For a survey of the history of ACT see Lewin 2011 [1999] and Lewin 2005.)

The Austrian economists emphasize that production takes time, and, other things constant, the longer the (linear) supply-chain, the more “time” it takes. Thus, modern production is much more “roundabout” (Böhm-Bawerk’s term) than older, more rudimentary production processes. Rather than picking the fruit in our back yard and eating it, most of us today get our fruit from fruit farms using complex picking, sorting, packing machinery and specialists to process carefully engineered fruit products. Consider the amount of “time” (for example in “people-hours”) involved in setting up and assembling all the pieces of this complex production process from scratch – from before the manufacture of the machines, etc. – and this gives us some idea of what is meant by production methods that are “roundabout.” Intuitively, what is being asserted is that doing things in a more complicated, specialized way is more difficult – loosely speaking it takes more “time” because it is more “roundabout,” more indirect – involving the construction of more intermediate products (or services) before moving to the next step in the process.

The scare quotes in the previous paragraph are used because, even for simple linear processes, there is no perfectly rigorous way to define the length of a production process in purely physical terms. This essential fact is at the heart of the three capital controversies that have occurred over the last one hundred years – the first in the late nineteenth and early twentieth century involving Böhm-Bawerk and his critics (notably J. B. Clark, 1893, 1988 [1888]), the second in the 1930’s and 1940’s involving Friederich Hayek and his critics (notably Frank Knight, 1936), and the last in the 1970’s onwards, lingering until today, known as the Cambridge-Cambridge debate, involving respectively protagonists from Cambridge England and Cambridge Massachusetts (for a summary see Blaug 1974). ACT was explicit in the first two controversies and implicit in the third. All involved the essential nature of production in a capital-using economy. Böhm-Bawerk was tackled because of his use of a simplifying, inconsistent theoretical construct – the “average period of production.” It can be easily shown that any attempt to calculate such a magnitude is fraught with insurmountable difficulties, except for the simplest of cases – and, even there, is impossible if we consider, as we should, the interest rate implicit in the formula to be compound interest (see the appendix to this chapter for a formal discussion) [reference]. Böhm-Bawerk’s lengthy, intuitive discussion of the nature of capitalist production as an increasing reliance on produced means of production in specialized production processes became associated with this rather specific and limited formula. Though in actuality a small

part of his work as a whole, and arguably an aberration in his breadth of vision, it became the focus for the prolonged and energetic debate in capital theory.

A similar story was repeated in the later debate between Hayek (1936) and Frank Knight (1936). Hayek (1935) had tried to use a very stylized version of ACT in his debate with Keynes over the business cycle – Hayek’s famous triangles. Subsequently Hayek tried to flesh out ACT for an English speaking audience and to do so in a way that avoided Böhm-Bawerk’s errors. This project was both incomplete and unsuccessful (Hayek 1941). By this stage interest in capital theory was passing.

It was briefly revived with the Cambridge-Cambridge debate. This did not explicitly involve ACT – it pitted the English (and Italian) Neo-Ricardians against the American Neoclassicals. It was overtly ideological in tone, the former group trying to stake out a respectable theoretical position for a Marxist view of production and the latter trying – rather lamely – to defend against it using the post-war Neoclassical framework. The Neo-Ricardians won the theoretical debate in showing that the Neoclassical concept of capital as a factor of production contained irresolvable contradictions. Capital as an input whose price was the rate of interest is an idea whose coherence cannot withstand careful logical scrutiny. As Ludwig Lachmann (1973) and Israel Kirzner (1993) have shown, however, this is a matter of no relevance to ACT. From an Austrian perspective, interest is not the price of capital, and capital as an input is not quantifiable in physical terms – whether using time or any other physical measure. In the disequilibrium of the real-world market process, capital is a much more complex phenomenon. Both Cambridges were wrong in their understanding of the essential nature of capitalist production.

The difficulties faced by the Austrian capital theorists through to Hayek were the result of a focus on discovering a way to characterize in some quantitative fashion, the total capital endowment of an economy. It was Ludwig Lachmann who realized that this was both impossible and unnecessary. His realization that, in a dynamic innovative economy, the (functional) *heterogeneity* of capital goods precluded the adding up of capital goods into a single aggregate capital-stock, motivated his work in extending the ACT (1947, 1978 [1956]). According to him, though the capital-stock is heterogeneous, it is not amorphous. The various components of the capital-stock stand in sensible relationship to one another because they perform specific functions together – they constitute a *structure* of complex interrelationships. That is to say, capital-goods are used in various *capital-combinations*. If we understand the logic of capital-combinations, we give meaning to the capital-structure (Lachmann 1947, 1978).

Understanding capital-combinations entails an understanding of the concepts of *complementarity* and *substitutability*. 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 another. They are part of the same plan. The complementarity relationships within the plan may be quite intricate and 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 or of alternative suppliers of the same input product. 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 (Lachmann 1947:199; and Lachmann 1978:56). 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 predictable, render some production plans valueless. The resources associated with them will have to be incorporated into

some other production plan or else scrapped—they will have been rendered unemployable. This is a natural 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 or supplier 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.

By the mid-twentieth century then, ACT had been extended and reoriented along a track that made it both more accessible and more relevant. With the turn toward extreme formalization in mainstream economics, however, this revitalized theory could garner no interest outside of Austrian circles. It has become a focus of interest again because of its relevance in macroeconomics and in management studies. This revitalized theory stresses the *complexity* of real world production processes and networks. Real-world production processes are much more complicated than the original simple linear picture suggested by Menger and Böhm-Bawerk and, in his earlier work, by Hayek. Rather, they are non-linear and complex, involving multiple, and multi-level, interactions. Some product-types may be both inputs and outputs (like sugar), some may be inputs at multiple parts of the supply-chain, some firms are substitute providers, some are complementary to others. Rather than straight-line processes, modern capital-structures are more like meandering spider-webs, with multi-directional connections (multi-dimensional, with feedback and feed-forward loops). It is this realization that led Lachmann to his work on Capital Theory and, arguably, Hayek to his work on complex phenomena (Lewin 2013).

Capital-structure and the growing complexity of production

Lachmann points to the increasing number of productive stages as an indication of the growing complexity of the capital-structure. Considering the importance of complementarity (a form of interaction between elements) at multiple levels (capital-combinations, plans, firms), complexity in this context implies an increasingly complicated network of production linkages – a progressively expanding network of complex, multi-level mutual dependencies between increasingly specialized elements. He suggests dispensing with any notion of quantifiable production time and replacing it with the notion “degree of complexity.” “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” (Lachmann 1978:82). 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” (Lachmann 1978:85).

Ludwig von Mises points this out in a particularly graphic way. An increase in the number of stages of production, i.e. an increase in specialization, necessarily implies an increase in complexity in that those stages closer to the final product are more complex than those stages further from it. Complexity is related to specificity – the construction of artifacts for specialized purposes implies more internal structure, and more linkages between the stages. “Iron is less specific in character than iron tubes, and iron tubes less so than iron machine parts. The conversion of a process of production [to another purpose, in response to unexpected change] becomes as a rule more difficult, the farther it has been pursued and the nearer it has come to its termination, the turning out of consumers’ goods.” (Mises 1998 [1949]: 500).

Both Lachmann and Hayek made the connection between the complexity of the capital-structure and the role of *expectations* (Lewin 2013). The more complex the system, the more complex the disparate *expectations* of the agents that operate within it, and the more difficult managed coordination becomes. Disparate expectations imply error and uncertainty. Thus, capital complexity is related to the (unexpected) change. It is not the fact of change itself that is revolutionary and potentially problematic, it is the speed with which it is occurring. The pace of change in the modern world is not only quicker, it is accelerating. Lachmann’s considerations suggest, however, that *our ability to absorb and adjust to change has dramatically increased* – it must have, or else we would not be able to observe these changes occurring as they do within a well-ordered social framework, a framework that remains intact in spite of the ubiquity and rapidity of change. So an interesting question arises as to how exactly we are able to cope with this increasing complexity. How have changes in organization and management technology

allowed us to absorb and benefit from the ever growing specialization of function that has produced this *complexification* of the production process? We return to this below.

The increasing complexity of the capital structure can be understood in broader terms, especially if we include human capital (as we should). In some respects this is only the latest in a line of similar revolutions like the original emergence of language and the development of writing, accounting, and printing. The latest, and to date most profound, in this line of developments is electronic communication, of which the telephone, the computer, and the video and audio recorder-transmitter, and, of course, the internet, are all part. Electronic communication by all of these means 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; and, of course, has revolutionized the entire supply process in all of its diverse aspects from containers to custom design. Thus to understand the phenomenon of accelerating structural change occurring together with our enhanced abilities to adapt to change, we must realize that 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 1978:18). Today new knowledge acquisition is not so gradual.

The Capital-Based view of the firm

Firms, capital goods and the entrepreneur

Recently this vision of capital has been applied to problems in the literature on the theory of the firm. It sheds light on such questions as the determinants of the boundaries of the firm, product design, internal organization, etc. (this section draws from Lewin and Baetjer 2011 outlining a Capital Based View (CBV) of the Firm).

Capital assets derive their value from the value of the products their services help to produce, in the absence of which they would have no value. Capital value is, thus, the result of forward-looking processes undertaken by the entrepreneurs who plan them. There must be a production plan if the activities of these resources are to have any meaning to anyone. These production plans reflect the knowledge and the expectations of the planners and of the human resources employed by the planners.

Knowledge is thus an important and complex dimension of every production plan. The knowledge dimension is always there. Further, capital accumulation, adding value to the capital structure, involves learning—it involves change—as the knowledge-base of workers and planners is enhanced. Time and knowledge are inextricably connected. One cannot conceive of the lapse of time in real-world situations without a change in knowledge (Lachmann 1978), though, of course, some changes have more economic significance than others. Changes in knowledge often become incorporated in additions to the capital structure. As mentioned earlier, capital accumulation and technological change are thus intertwined (Menger 1871: Böhm-Bawerk 1959; Lachmann 1978: Lewin 2011 [1999]; Baetjer 1998, 2000). This contrasts with economic approaches that imagine a world in which additions to capital occur without changes in technology like standard neoclassical growth models deriving from Solow (1956).

Each capital good may be said to possess a set of attributes that are (potentially) useful in the production process (Barzel 1997). These attributes determine the services that the capital good can yield. Sometimes they are deliberately constructed with these attributes in mind. Other times, these attributes may be fully revealed only after being used in combination with other resources. In either event, the entire set of valuable attributes of

capital goods, and especially combinations of capital goods, is not likely to be obvious to every observer. Different evaluators see them differently. Capital goods combinations have to be subjectively appraised according to the value of the product they are expected to yield, that is, according to the revenue streams they are expected to generate in changing circumstances. Account must be taken of the future actions of both competitors and producers of complementary products (Richardson 1960) as these will affect the value of the product produced. Different appraisers will thus have different expectations. Their cognitive models will be heterogeneous (Klein 2008).

In forming specific capital combinations, it is the role of the entrepreneur to bring to the production process her particular appraisal—her vision (Penrose 1959; Lachmann 1978). It is unavoidable, therefore, that in many spheres of human action, notably in the sphere of economic competition, expectations will be mutually inconsistent. Rival economic models are the essence of the competitive process—for example, in predicting standards, fashions, brand appeal, price–quality trade-offs, etc. And where expectations are mutually inconsistent, at most one person can be right (Lachmann 1978). Disparate expectations mean inevitable errors. They are a normal part of the experimental nature of the market process. Entrepreneurs pit their judgments against each other. Such judgment is necessary in a world where product values are uncertain. The more successful the judgment, the appraisal, the more surplus value will be earned by the entrepreneur—revenue minus the payments (or opportunity costs, implicit prices) of the services of the employed resources. In a world of uncertainty, of heterogeneous capital resources and heterogeneous cognitive models, profit (and competitive advantage) is not difficult to explain (Knight 1921; Mathews 2006: 102, 2010: 225–226).

For entrepreneurial judgment to be effective, it must be exercised within a framework in which the entrepreneur has property rights (use and residual claimant rights) to the capital goods necessary to fulfill his vision (Barzel 1997). In this sense, entrepreneurship implies ownership (Foss and Klein 2011; Foss et al. 2007). It is the entrepreneur’s judgment that is implemented by him or his delegates (in which case the judgment of the delegate is “derived” from him). In sum, production occurs through the formation of capital structures in which heterogeneous capital goods are combined in real time by ambitious entrepreneurs in an uncertain world in the hope of earning a profit as a result of the superior judgment of the value of those combinations—or, equivalently the value of the produced product.

Knowledge about the knowledge in capital

The above discussion provides the basis for a closer examination of the nature of capital and capital goods and the role of knowledge. What kinds of things qualify as capital goods? Should we consider knowledge to be a capital good? And what exactly is the role of knowledge in the production process?

In order to use capital goods, we have to know what they can do. The attributes that a capital good possesses (referred to above) can be thought of as useful (productive) knowledge. Different capital goods “know” how to do different things. Capital heterogeneity (of economic function) is a reflection of the division of labor—we might say it is a “division of capital” (Lachmann 1978). This division of labor, whereby different parts of the production structure are devoted to specialized activities, is an organizing principle (Loasby 2007) based on what Hayek called a “division of knowledge” (Hayek 1945).

In order to understand this principle, one needs to take account of the various ways in which knowledge enters the production process. This is the knowledge dimension of production. There is a fundamental relationship between knowledge and capital. Indeed, capital goods are useful because they embody knowledge about productive processes and how they may be carried out (see Baetjer (1998, 2000) for a fuller exposition). Much of our knowledge is to be “found” not in our heads, but in the capital goods we employ. In particular, capital equipment (tools) embodies knowledge of how to accomplish some purpose or function, as explained above.

It is also true that much of our knowledge of the causal relationships between things, and of how to achieve the changes we desire, is tacit knowledge. Adam Smith speaks of the “skill, dexterity, and judgment” of workers (Smith

1776: 7); these attributes are a kind of knowledge, a kinesthetic “knowledge” located in the hands rather than in the head. The improvements these skilled workers make in their tools are embodiments of that knowledge. The very design of the tool passes on to a less-skilled or less dexterous worker the ability to accomplish good results. Consider how the safety razor enables those of us unskilled in the barber’s craft to shave with the blade always at the correct angle, rarely nicking ourselves. The skilled barber’s dexterity has been passed on to us, as it were, embodied in the design of the safety razor. To emphasize, the knowledge aspect of capital goods is the fundamental aspect. Any physical aspect is incidental. A hammer, for instance, is physical wood (the handle) and minerals (the head). But a piece of oak and a chunk of iron do not make a hammer. The hammer is those raw materials infused with the knowledge embodied in the precise shape of the head and handle, the curvature of the striking surface, the proportion of head weight to handle length, and so on. (We leave aside, for now, all the additional knowledge required to shape the oak into a handle and the iron into a steel head.) Even with a tool as bluntly physical as a hammer, the knowledge component is of overwhelming importance. With precision tools such as microscopes and calibration instruments, the knowledge aspect of the tool becomes more dominant still. We might say, imprecisely but helpfully, that there is a greater proportion of knowledge to physical stuff in a microscope than in a hammer.

The case of computer software provides both a compelling analogy for general understanding and a particular case of the nature of capital. Software is less tied to any physical medium than most tools. Because we may with equal comfort think of a given program as a program, whether it is printed out on paper, stored on a hard drive, or loaded into the circuits of a computer, we have no difficulty distinguishing the knowledge aspect from the physical aspect with a software tool. Of course, to function as a tool, the software must be loaded and running in the physical medium of the computer, and there are definite physical limits to computation. Nevertheless, it is in the nature of computers and software to separate clearly the knowledge of how to accomplish a certain function from the physical embodiment of that knowledge. (More accurately, the software is a symbolic representation of the knowledge; in this way it embodies the knowledge. When loaded in a computer, the computer then embodies the software that embodies the knowledge.)

Because the knowledge aspect of software tools is so clearly distinguishable from their physical embodiment, in investigating software capital we may distinguish clearly the knowledge aspects of capital in general. While software may seem very different from other capital goods in this respect, we find no fundamental difference between software tools and conventional tools. What is true of software is true of capital goods in general. What a person actually uses is not software alone, but software loaded into a physical system—a computer with a monitor, or printer, or plotter, or space shuttle, or whatever. The computer is the multi-purpose, tangible complement to the special purpose, intangible knowledge that is software. When the word processor or computer-assisted design package is loaded in, the whole system becomes a dedicated writing or drawing tool. But there is no important difference in this respect between a word processor and, say, a hammer. The oaken dowel and molten steel are the multi-purpose, tangible complements to the special purpose, intangible knowledge of what a hammer is. When that knowledge is imprinted on the oak in the shape of a smooth, well-proportioned handle, and on the steel in the shape, weight, and hardness of a hammerhead; and when the two are joined together properly, then the whole system—raw oak, raw steel, and knowledge—becomes a dedicated nail-driving tool. All tools are thus a combination of knowledge and matter. They are knowledge imprinted on or embodied in matter.

The value of our tools is not in their weight of substances, however finely alloyed or refined. It is in the quality and quantity of knowledge imprinted on them. Menger notes:

Increasing understanding of the causal connections between things and human welfare, and increasing control of the less proximate conditions responsible for human welfare, have led mankind, therefore, from a state of barbarism and the deepest misery to its present stage of civilization and well-being. Nothing is more certain than that the degree of economic progress of mankind will still, in future epochs, be commensurate with the degree of progress of human knowledge (1871: 74).

In sum: a significant proportion of the knowledge we use in production is not in any person or even group, but in the tools we use. We who use a hammer know nothing of ergonomics, and have not the slightest idea what the “correct” ratio of head weight to handle length is. Nevertheless, when we drive a nail, we can tell if the hammer feels right. Thus we use that knowledge. The knowledge is “built into” the hammer. Capital goods, then, are embodied knowledge of how to accomplish productive purposes.

The social character of the valuable knowledge in capital

The knowledge of many people is combined in capital goods; product development is a process of social interaction, not a matter of individuals working autonomously. Most individual capital goods are manifestations of a far-flung division of knowledge, an incomprehensibly extensive sharing of the knowledge and talents of thousands of people across time and space. The ever-changing pattern of relationships among these capital goods—the capital structure as a whole—is an essential aspect of what Hayek called “the extended order of human cooperation” (Hayek 1973). Capital goods and the capital structure at any time result from a tremendously rich social interaction through which the knowledge of many has been combined. One type of social interaction occurs in the social construct that we refer to as the firm (and the teams within and between firms that work on particular projects).

The division of labor is best understood as the whole pattern of cooperation in production, direct and indirect. The indirect contributions—in the form of tools and processes developed elsewhere—are, in an advanced economy, the most significant. The crucial “labor” is the creative effort of learning how to do things, and the embodying of that learning in the design of a tool that can be used by others, who themselves lack the knowledge in any other form. Through the embodiment of knowledge into an extending capital structure, each of us is able to take advantage of the specialized knowledge of untold others who have contributed to that structure. Thus, this structure becomes increasingly more complex over time, as the pattern of complementary relationships extends.

In modern, capital-intensive production processes, the division of knowledge, capital and labor is to be found not in the large number of people at work in a particular production process, but in the tools (including scripted techniques and instructions) used by a relatively few people who carry out that process. The knowledge contribution of multitudes is embodied in those tools, which give remarkable productive powers to the individual workers on the spot, though, as explained above, these productive powers have to be organized by the discerning judgment of the entrepreneur. In a fundamental sense, all economies are “knowledge economies” and all firms are “knowledge-based” and this is because they are “capital-based.”

To be perfectly clear, when we say that a capital good “knows” how to accomplish a certain set of activities, what we mean is that, when used by someone who knows what he is doing, these activities can be successfully accomplished because at some earlier time someone else knew how to design this capital good to perform the way it does when used properly. The latter knowledge is obviously more comprehensive in that the designer of the equipment, in addition to possessing the knowledge of how to use it, also has an understanding, at a more fundamental level, of the workings of the designed equipment. This deeper knowledge has to be retained by someone if such expertise in design is to be retained in the economy at all, and if progress in design is to occur, but it can be dramatically economized on to the extent that it is unnecessary for the routine operation of the capital good. Most of the users do not have and do not need to have that knowledge. Furthermore, and importantly, the design process itself is subject to knowledge and time-saving design, in that the various design components, or modules, are highly specialized (Baldwin and Clark 2000). This obviates the need for very costly and time-consuming iteration when setting design parameters of different components of the capital good. In fact, in modern production processes in the current information age, the line between production and design is often blurred. Products evolve rapidly through various versions as specialized producers implement incremental improvements. The rapidly growing literature on the science of product design (see Baldwin and Clark (2000) for an extensive treatment) unconsciously echoes in a very concrete way the more abstract Austrian Capital Theory with its examination of, what Austrians would call, the inseparable connections between capital accumulation and technological change (Lachmann 1978; Lewin 2011), as well as the phenomenon of the enhanced productivity of

wisely chosen roundabout methods of production (Böhm-Bawerk 1959) or, more recently, the increasing complexity of the capital structure (Lachmann 1978). These enhancements and complementarities offer opportunities for further research along these lines.

In summary, we have established that underlying the physical form of machine and human, there lies an intricate structure of knowledge embodied in capital goods and complemented by the knowledge of how to use such goods in the minds of workers. The development of capital goods brings to bear increasing amounts of knowledge to the productive process over time. Economic growth and development entails the increasing complexity of knowledge, one aspect of which is the increasing ratio of knowledge to “stuff” embodied in capital structures. We may refer to this as the *complexification* of production. It is this complexification that has given rise to the challenges of managing in the capital-using economy, including the familiar firm-boundary, agency and hold-up problems (Lewin and Baetjer, 2011).

The organization of production

The ingredients of any production project are the (human and physical) capital assets in capital combinations, characterized by their economic heterogeneity and complementarity and also by their substitutability/specificity/adaptability in the face of change. The capital goods of an economy compose a structure within which exist a multitude of substructures. At each level, these structures are the result of planning and exogenous change. At the level of the economy, the capital structure is a result of the spontaneous workings of the market and inter-firm contracts. Firm-level structures have to be carefully planned and maintained, though their adaptive mutations are governed by unpredictable, emergent knowledge phenomena. As discussed earlier, recapping briefly, heterogeneity of capital resources is a reflection of the division of labor and knowledge—of the specialization of knowledge and function. As emphasized, different capital goods “know” how to do different and complementary things. Thus, the greater the degree of specialization the more heterogeneous the capital structure. Furthermore, heterogeneous capital implies heterogeneous knowledge. And since the extent of the market and of economic growth is crucially related to the degree of specialization, heterogeneity will increase with economic growth and development—as will complexity. The greater the heterogeneity of resources the greater the complexity of the organizational task.

Organization of heterogeneous knowledge assets into productive combinations requires organizing ability and an organizational structure. The organizational structure of the firm can be thought of as an aspect of the firm’s general capital structure. The firm has “social capital” in the useful (knowledge economizing) rules, customs, norms, etc. that it develops. The value of its leadership lies in the ability of the leaders to organize complementary activities “through the creation of belief conditions that (at least) approximate common [homogeneous] knowledge” (Foss 2001: 357). So, homogenization of the knowledge of both the “rules of the game” and “the aim of the game,” is necessary for the efficient coordination of heterogeneous production knowledge. This homogenization provides the “constitution” within which the complex activities of the firm are carried out (Vanberg 1994). The organizational efficiency of the firm thus depends crucially on the functionality of this constitution, and the value of its leadership depends on the extent to which such a constitution can be successfully developed and accepted.

Modularity as structure

As knowledge becomes more complex (heterogeneous), advanced knowledge management strategies can be expected to develop. Successful business ventures, involving more complex knowledge, can only occur if the complexities can be successfully handled. So, the observation of such successes is a clear indication of the development of practical, advanced knowledge-management strategies. One of the most ubiquitous development strategies is increased *modularization* (Garud et al. 2003; Langlois 2002).

Resource management requires structure. A structure can be described by a list of items that stand in a certain orientation to one another. Complex structures are composed of many items with many orientations and

interactions. A structure, as opposed to a simple list of the structure's elements, is distinguished by the fact that one can infer properties about the whole list from a description or observation of just a few component (or typical) parts together with an articulation of the principles of interaction, in other words by abstraction (Tulloch and Miller 2006). Abstraction is an important strategy for economizing on knowledge about knowledge. Modules are self-contained substructures, whose inner workings are hidden from the high-level observer (manager). Organizations (and their design and production activities) must be organized by deciding what managers need to know and need not know. They do need some knowledge of the knowledge of others. But what do we really know when we have knowledge about knowledge? We move to successive levels of abstraction (modularization) in order to economize on what we need to know. Yet the nature of knowledge as a phenomenon makes this very difficult. Knowledge of what we need to know about the knowledge of others is most complete when we share their knowledge, but this is precisely what we wish to avoid having to do. Successful management thus depends on finding the right level of abstraction—that is, knowing enough to make correct judgments about the deployment of assets (human and physical) that know more (about their specialized activities) than the managers do; but not seeking to know so much as to tie up managers' time and energies in the process of learning and understanding. The managers' "big picture" must be accurate yet not too detailed. Easier said than done, yet this is a key element of successful organizational design.

Modularity and out-sourcing

Another aspect of modularity is out-sourcing – the delegation of a group of tasks culminating in a particular input product or service to a separate firm, thus adding an element to the supply-network. This simplifies management and adaptation by raising it to a higher level (abstracting), managing by the emergent result and obviating the need to know about and deal with multiple production details and interactions. It also facilitates adaptation to change, by allowing a manager to plug firms in and out of the supply-network – within the constraints of existing contracts - instead of having to reconfigure complex, often durable production processes. (Using "core-suppliers" is perhaps an example of this.) This tendency to outsource, thereby creating additional supply firms, militates against the common tendency to simplify the supply-network by reducing the number of suppliers that need to be managed directly or indirectly (reference Choi, et. al. 2001). It seems both tendencies exist. The heterogeneity of supply-firms may provide an explanation. Outsourcing may be particularly profitable in relation to complementary inputs, whereas supplier-reduction may apply more to substitute supply-firms. Information-age supply-chain management technology allows for less redundancy in supply-network relationships.

As the production process becomes more complex, more complementary components are involved. Modularization by out-sourcing is a natural way to reduce the complexity of management. But it is not always possible. As Richard Langlois has argued, when markets are thin and market-supporting institutions weak, technological change, especially systemic change, leads to increased vertical *integration*, since in such an environment centralized ownership and control may be necessary to ensure the integrity of the supply chain (Henry Ford); but when markets are thick (technology is diffused) and market-supporting institutions well developed, technological change leads to vertical *disintegration*, since in that environment the benefits of specialization and the division of labor outweigh the (now relatively smaller) transaction costs of contracting (Langlois 2012). This attention to market context explains the increasing trend toward vertical disintegration – an increasing complexity of the production structure and the institutional structure to handle it.

Macroeconomic Policy

With the resurgence of Keynesian economic policy as a response to recent financial crises, echoes of past debates are being heard - in particular, the debate from the 1930's between John Maynard Keynes and Friederich Hayek. Keynes talked about the "capital stock" of the economy. He argued that by stimulating spending on outputs (consumption goods and services) one can increase productive investment (adding to the capital stock) to meet that spending, thus adding to the capital stock and increasing employment. Hayek accused Keynes of insufficient attention to the nature of capital in production. Hayek pointed out that capital investment does not simply add to production in a general way, but, rather, is embodied in concrete capital items. The productive capital of the economy is not simply an amorphous "stock" of generalized production power; rather it is a very intricate

production structure of interrelated complementary specific production items as explained above. Stimulating spending and investment amounts to stimulating specific sections and components of this intricate structure. The “shape” of production gets changed by stimulatory activist spending. And, given that productive resources are not free, this change comes at the expense of productive effort elsewhere. The pattern of production gets out of sync with the pattern of consumption and eventually this discoordination must lead to a collapse. Productive sectors, like telecom start-ups or residential housing, become “overbought” (while other sectors develop less) and eventually a “correction” must occur. Add this “distortionary” effect to the fact that the original stimulus must somehow eventually be paid for and we have a predictable bust.

The Austrian vision of capital, as described above, enters crucially into this story. The complex and intricate capital-structure of the economy is partially organized, partially spontaneous (organic). Every production process is the result of some multi-period production plan. Entrepreneurs envision the possibility of providing (new, improved, cheaper) products to consumers whose expenditure on them will be more than sufficient to cover the cost of producing them. In pursuit of this vision the entrepreneur plans to assemble the necessary capital items in a synergistic combination. These capital-combinations are structurally composed modules that are the ingredients of the industry- or economy-wide capital-structure. The latter is the result then of the dynamic interaction of multiple entrepreneurial plans in the marketplace – it is what constitutes the market process. Some plans will prove more successful than others, some will have to be modified to some degree, some will fail. What emerges is a structure that is not planned by anyone in its totality, but is the result of many individual actions in the pursuit of profit – it is an unplanned structure that has a logic, a coherence, to it. It was not designed, and it could not have been designed, by any human mind or committee of minds. Thinking that it is possible to design such a structure or even to micro-manage it with macro-economic policy is a fatal conceit.

As we have seen, the division of labor reflected by the capital-structure is based on a division of knowledge. Within and across firms specialized tasks are accomplished by those who know best how to accomplish them. Such localized, often unconscious, knowledge could not be communicated to or collected by centralized decision-makers. The market process is responsible not only for discovering who should do what and how, but also how to organize it so that those best able to make decisions are motivated to do so. In other words, incentives and knowledge considerations tend to get balanced spontaneously in a way that could not be planned on a grand scale. The boundaries of firms expand and contract and new forms of organization evolve. This too is part of the capital-structure broadly understood.

For Austrians there is no “capital stock.” Any attempt to aggregate the multitude of diverse capital items involved in production into a single aggregate number is bound to result in a meaningless outcome – a number devoid of significance. Similarly the total of investment spending does not reflect in any accurate way the addition to value that can be produced by this “capital stock.” The value of capital goods and of capital combinations or of the businesses in which they are employed, are determined only as the market process unfolds over time. They are based on the expectations of the entrepreneurs who hire them, and these expectations are diverse and often inconsistent. Not all of them will prove correct – indeed most will be, at least to some degree, proven false. Basing macro-economic policy on an aggregate of values for assembled capital items as recorded or estimated at one point of time, is a fool’s errand. What do the policy-makers know that the entrepreneurs involved in the micro aspects of production do not?

The folly is compounded by connecting capital and investment aggregates to total employment, under the assumption that stimulating the former will stimulate the latter. Such an assumption ignores the heterogeneity and structural nature of both capital and labor (human-capital). Simply boosting expenditure on any kind of production will not guarantee adding to the employment of people without jobs. Our current economy is characterized by both sizeable unemployment numbers and job-vacancies. Their coexistence is a result, in part, of a structural mismatch – the structure, the pattern of skills, of the unemployed does not match those required to be able to work with the specific capital items that are currently unemployed.

This mismatch is often seen by Austrian economists to be the result of a credit-induced cycle – the Austrian Business Cycle. The solution, from this perspective, is to remove the distortions – to allow the market process to “re-structure” production. This would mean a sustained period of consolidation in the distorted markets, not a

policy that attempts to revive them. But then, policy-makers seldom have the beneficial guidance of knowing Austrian Capital Theory.

Conclusion

Capitalist economies use capital in a fundamental way. But this is more than the simple mechanization of physical tasks. The accumulation of (physical and human) capital involves the generation and encapsulation of ever-more specialized and complex production knowledge. Knowledge is the glue that holds the capital structure together. This has implications for an understanding of economic growth and development, economic organization, and macroeconomic policy.

Appendix – the average period of production

The average period of production may be succinctly express as follows:

$$T = \sum_{t=1}^n (n-t)l_t / \sum_{t=1}^n l_t = n - (\sum_{t=1}^n tl_t / N)$$

where T is the average period of production for a production process lasting n calendar periods, t , going from 1 to n , is an index of each sub period, l_t is the amount of labor expended in sub-period t and

$N = \sum_{t=1}^n l_t$ is the un-weighted labor sum (the total amount of labor-time expended). Thus T is a weighted average

that measures the time on average that a unit of labor l is “locked up” in the production process. The weights $(n-t)$ are the distances from final output. T depends positively on n , the calendar length of the project, and on the relation of the time pattern of labor applied (the points in time t at which labor inputs occur) to the total amount of labor invested N . Since this formula is in units of time it may be added across various process to yield an overall measure of roundaboutness. In this way Böhm-Bawerk hoped to have solved the problem of measuring roundaboutness.

It should be clear that this formula does not allow for a unique or monotonic expression of “roundaboutness.” In other words, (a) this measure may yield a number that is consistent with an infinite number of input patterns, different amounts of labor time occurring sooner or later in the process, and (b) when considerations involving interest are included, this measure may not rise or fall uniformly in any ranking of roundaboutness as we add labor-time units at various points; it may change direction (in its ranking) at some points under certain conditions if we change the inputs at various points in the production process. These types of considerations played an important role in later criticisms of any attempt to measure capital in physical terms in the Cambridge-Cambridge debate mentioned above.

In the special case where there is an even flow on inputs so that the same amount of labor-time, l_0 is applied in each period, $\sum_{t=1}^n (n-t)l_t = 1/2 n(n+1)l_0$ and $\sum_{t=1}^n l_t = nl_0$, and therefore $T = n/2 + 1/2$ or simply $n/2$ (when n is large enough so that the $1/2$ can be ignored, or when T is expressed in continuous time where it is absent). So, when inputs occur at the same rate over time, each unit is “locked up” on average for half the length of the production period.

The effect of compound interest can be seen as follows. If l units of productive inputs are applied in the first and the second periods and if only simple interest is considered, then we may use the equation $2l(1+Tr)=l(1+2r)+l(1+r)$ where r is the rate of interest to solve for the unknown average period of production T . This gives 1.5 units, which is the same value as yielded by Böhm-Bawerk’s formula, $(l+2l)/2l$. Using compound interest, however, the equation changes to $2l(1+r)^T=l(1+r)^2+l(1+r)$. If we solve this for T we get $T=(\ln(2+3r+r^2)-$

$\ln 2 / \ln(1+r)$ which contains the rate of interest, r , implying that no purely physical measure can be obtained (Lutz 1967:20–21).

Besides this problem, numerous others exist. For example, the problem of measuring different qualities of labor inputs and the problem of accounting for the input of land (Lewin 2011: chapter 3). All in all, the notion of a viable quantitative time-based measure of the capital-stock turned is a chimera, one that diverted attention away from an appreciation of the richness of Böhm-Bawerk's many valuable insights.

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