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THE FORMAL STRUCTURE OF INDUSTRIAL REVOLUTIONS

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Before starting the main discussion, several important points should be made regarding the concept of history. History as *Geschichte* means a set of hard facts with certain 'space-time coordinates' in which their uncertain future developments can be nullified. Economic history is also a succession of these historical facts which are observed in economic science. Therefore, it is a fundamental object of every economic research. In particular, theory of economic history aims to grasp at time paths of economic history from relatively long-term aspects, and to complete historical descriptions (economic history in a narrower sense) of images constructed in the space-time arena of economic activities. Economic theoreticians also objectify economic history as a starting point of their logical deduction process, but they seek an ideal image (structure) abstracted from many facts with space-time coordinates. Thus, the difference between economic history and theory will become very clear. However, history or historical description is not useless for economic theory. It is just the same in physical science in which, for example, the half-life (history) of an isotope can be expressed (described) by differential equations.

We need a similar methodological attitude in discussing industrial revolutions. Their history has been incompletely treated by many historians who have no more than an amateur's knowledge of the scientific background of industrial technology. As a result, they have come to a very insufficient image of industrial revolutions. We cannot describe any precise history of them without having considerable scientific knowledge, for example, that of thermodynamics, statistical mechanics, or other applied physics and chemistry. Moreover, we must have some knowledge of cybernetics, information and ergodic theory, the automaton, etc. to interpret the content of industrial revolutions in the twentieth century. Of course, we do not need to become accomplished experts in these sciences and technologies, but we have to understand their proper contents for our research works. From such a methodological standpoint will we try to construct a more rigid history of industrial revolutions.

I. *Introduction*

1

There are several reasons to make 'industrial revolution' a common noun of the subject of scientific research. The most popular reason is that it is an extremely influential topic in contemporary economic history. The general purpose of economic-historical research is to obtain an efficient viewpoint in order to analyze scientifically—not teleologically—present-day economic situations, whatever historical times and places it may be concerned with. For example, study of ancient economic history can be indirectly connected with our present economic concerns by means of elucidating its universal methodology and the meaning of the historical incidents that it tries to verify. On the other hand, research into modern economic history, which includes study of industrial revolutions, is to be appreciated only through the contemporary significance of its subject and methodology.

The second reason is that industrial revolutions may reflect the most typical event of modern and contemporary economic history as a process of the formation of a capitalist economic system. Any research on them can provide a proper viewpoint for describing several essential characteristics of capitalism. Thirdly, the phenomenon of industrial revolutions expresses various structural aspects of capitalist economy or economic structure, which has been able to successively create unprecedented powers of production. However, capitalism has not provided a self-sustaining structure that can control itself for its survival, but a parasitic one that may ingest diverse social organic bodies. In particular, the structures of scientific technology and a nation-state may be inseparably linked to capitalism, and each industrial revolution can therefore be regarded as a complex that is composed of these structures.

The fourth reason is that an industrial revolution may be a suitable subject for tracing the developmental path of a new type of mankind that remains unsocial and self-centered as in the case of a self-contained and self-sustaining machine. Such a 'human-machine', which may be easily controlled by the allurements of various chaotic information networks, has become a universal human type in the successive process of industrial revolutions. This is the most important issue of our research.

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First, we begin with examining the expression 'industrial revolution'. It generally means the Industrial Revolution in England of the eighteenth century. What position has it been given in world history? Since it indicated unparalleled industrial developments in world economic history, it has been used as an economic term that marks a new epoch of capitalist development or a point of take-off of a traditional society for economic growth and maturity. However, we can hold a more extended discussion of an industrial revolution by means of the term 'scientific revolution', which may afford several efficient points of view for the subject in hand.

The term 'scientific revolution' can be defined in two ways. Butterfield used the word to show the process of extraordinary extension of scientific knowledge in Western Europe from the sixteenth to seventeenth century.[1] It means the Scientific Revolution that expresses a specified historical fact as in the case of the Industrial Revolution. However, we do not refer to this terminology from now on, for it has no serious bearing upon our viewpoints. We are mainly interested in the term 'scientific revolution' not as a proper noun, but as a common one. This is the concept that Thomas Kuhn examined in detail in his famous work.[2] He attempted to find a general tendency of scientific history through specifying and isolating a certain structure of scientific revolutions. He called the fundamental structure of 'normal science' a 'paradigm', but did not thoroughly discuss the very problematic concept of 'structure' itself. In order to dispel obscurities in his discussion, we have to produce a clear-cut explanation of the

[1] See Butterfield (1957).

[2] See Kuhn (1962).

conceptual difficulties relating to 'structure'. Generally speaking, structure can be defined as a complex of elements and their relations to one another, or, more logically expressed, a pair of a model and formal language. Every structure is able to transform itself without change of a certain relationship embedded in it. It does not change itself gradually and continuously, but develops with sudden transformation and reconstruction. Such characteristics of structure play a decisive role in Kuhn's arguments on the revolutionary history of scientific doctrines.

He summarized the total process of 'revolution' as a three-stage development. The first stage is marked by the discovery of new facts or 'anomalies' that may violate 'the paradigm-induced expectations that govern normal science'.[3] Then, an 'extraordinary science' emerges for the purpose of theoretically explaining the 'new' situation of 'nature'. And in the final stage, that 'extraordinary science' becomes a new 'normal science'. This process may be called scientific revolution. Kuhn's point of view from which this revolutionary process can be formulated as a repetitive time path with succession and discontinuity may also be applicable to interpretation of the history of industrial revolutions.

Amongst many historical studies of industrial revolutions, there can be distinguished two representative approaches, that is, a descriptive history of them without theoretical consideration, and a stage-theoretic analysis of their history from the angle of so-called historicism.[4] Most historians have used the former approach and described various local and regional processes of industrialization as story tellers. On the other hand, the latter type of analysis has been conducted by many economic historians who have built up a hypothetical scheme for successive historical stages of industrial development, for example, the 'stages of economic growth' formulated by W. W. Rostow.[5]

However, our standpoint is different from these two approaches. We attempt a structural and universal analysis of industrial revolutions (abbreviated to IRs from now on) in a space-time frame of modern world economic history. First, we will make a provisional division of periods in the history of IRs from the eighteenth century to our time. Each period corresponds to one of the following three successive IRs:

First IR: the period from the second half of the eighteenth century to the first half of the nineteenth century,
Second IR: the period from the second half of the nineteenth century to the first half of the twentieth century, and
Third IR: the period from the second half of the twentieth century to the present day.

Each period should not be considered as a historical stage in successive phases of world economic history, but as an iterating process of a certain particular structure that characterizes a given IR. Then, how should we interpret the meaning of that particular structure? It indicates a complex of four substructures: technology, machinery, division of labor, and profit making. We may call it a normal structure of production (abbreviated to NSP). Expressed schematically, when some 'extraordinary' elements (structures) appear in the NSP established by the preceding IR, the next IR then begins to arise from them and constructs a new NSP. This scheme will be justified in the arguments of later chapters, and a decisive signification of

[3] *Ibid*., pp.52-53.
[4] See Popper (1957).
[5] Rostow (1960).

the term NSP for formal structural analysis is afforded in the last chapter. To start with, we analyze the structure of technology.

II. *Structure of Technology*

1

We will commence with taking up several fundamental concepts and explaining their meanings.

Of course, our primary concern is to define the term ‘technology’. It is a well-known fact that the theme of Aristotle’s *Physica* was to establish a universal proposition or law in order to recognize a general form (εἶδος) of nature. A potential form in nature, which can be obtained through theory (θεωρία), becomes an indispensable prerequisite of technique (τέχνη). The reason is that any form or structure of human behaviour must be embedded in technique, which includes no arbitrary and contingent external elements. The word ‘technology’ as an abstract and structural collection of techniques emerged early in the eighteenth century. According to the OED, ‘technology’ is ‘a description of arts, especially the mechanical’. It may be paraphrased in a more up-to-date form as the theoretical and experimental type of human activity that incorporates natural laws into a teleological structure. On the other hand, a special person called a technologist or an engineer creates technology in various concrete systems. In other words, technology is realized in the construction of a system by a prodigious technologist or an elite corps of engineers. Then, what is the meaning of ‘system’?

A system in general is a structure that uniquely matches the rational relationship between the end (final output) and the means (initial condition or input) to a certain theoretical proposition or relation, or, more formally expressed, an ‘input/output scheme’[6] that includes input, operator, and output as three essential elements. For example, the steam engine is material equipment that embodies a teleological structure corresponding to a certain physical law of transition from mechanical to thermodynamic energy. To give another example, the automaton is an outcome of correspondence between mathematical law (especially associative law) and input-output mechanism. These two examples may be called in order ‘production technique’, which means an applied system for a production process, and ‘production technology’, or particularly after the first half of the nineteenth century, ‘scientific technology’, which has created various types of production technique. Following the above three IRs, this production technique can be divided into three types, that is, a specialized physical technique (typically the steam engine), a generalized physical technique (a sort of physical input/output apparatus), and a universal and abstract technique (all kinds of input/output system reducible to information symbols). Now, we will examine the historical roles played by famous men of genius or technologists in the above terminology.

[6] Luhmann (1984), S.24.

2

First, we can pose the fundamental question to be solved here: What is the historical and technological significance of the invention—more precisely, the improvements—of the steam engine by James Watt, who is deemed to be the first technologist?

It is a well-known fact that he made two great inventions. First of all, in 1765, he manufactured a revised steam engine, which had removed several defects in Newcomen's engine constructed in 1712. In particular, the latter had a serious fault that the greater part of steam power was wasted on account of the cooling effect of a water jet upon the inner wall of a cylinder. In order to eliminate the defect, Watt set up a condenser on the outside of the cylinder. Secondly, he achieved great success in devising a mechanism for converting to-and-fro motion into rotational motion. This invention not only contributed to putting the steam engine to immediate practical use, but also linked it with the development of the internal combustion engine designed in the latter half of the nineteenth century and later, the gasoline engine for automobiles.

Such improvements of the steam engine by James Watt had universal significance in the history of technological developments. Of course, the steam engine may be regarded as a typical system. Now, we must analyze the structure of the steam engine itself. Two problems should be investigated. The first is its effect on the economy or economization. Economy means a sort of technical structure or teleological manifestation of technique. It may be constructed as a set of elements that are mutually combined through the end-and-means relation. Since technique is necessarily accompanied by human behaviour, it includes the human relationship between producer and consumer, plaintiff and defendant, employer and employee, etc., and at the same time, the relationship between human beings and physical objects (external nature) such as agriculture, paintings, ceramics, gardening, and so on. Then, how should the term 'economy' be defined? According to Lionel Robbins, economy is a technique for rational choice between various alternative scarce means.[7] Therefore, the economic structure of the steam engine can be represented as a teleological set of relations appropriate for maximum output that is produced by a combination of alternative means (*primum mobile*) such as labor power, force of wind and water, steam power, etc., and equipment to minimize costs and to make optimal use of mechanical energy as a steam generator.

The second problem is related to the system itself, that is, the specified structure of application (one-to-one correspondence) of natural law to some teleological structure. The first achievement of Watt as a system engineer is the invention of a condenser based on the results of improvement of the Newcomen engine. In this case, he utilized a couple of natural laws. First of all, a famous chemist Joseph Black suggested to him that 'latent heat'—that is, the condensation heat released in the case of phase transition from gas to liquid—causes mass consumption of cooling water for condensation, and then a fall in the temperature of the cylinder. Moreover, Watt hit upon the idea that steam as an 'elastic body' must expand in a vacuum, which was based upon scientific knowledge at that time. It was an analogical application of Hooke's well-known law that tensile force must operate in a certain part with lower pressure (vacuum area) in a uniformly pressured condition (the interior of a cylinder). Thus, natural laws were made to correspond with teleological structure, the construction of

[7] Robbins (1935), p.16.

which was motivated by the technological interest of James Watt. In fact, he succeeded in controlling the amount of cooling water by means of separated condensation to create a state of vacuum at the exterior of the cylinder, and reached the goal of economic use of steam power generated in a boiler while keeping the temperature of the cylinder constant. The second result achieved by him is, of course, the steam engine itself. For that purpose, he found an empirical tendency by his own efforts. He observed actual relations between the pressure and temperature of steam (gas), and at the same time, he believed in the 'law' that when temperature increases in arithmetic progression, pressure increases in geometric progression. According to this 'law' and analogy of Hooke's law, Watt constructed a teleological and therefore technological structure of the steam engine in which efficient pumping could be carried out by an external condenser and where the continued motion of the piston in the cylinder could consequently be set up using high-pressure steam generated by the boiler.

At the beginning of the nineteenth century, the technological inventions of James Watt were analyzed more deeply and connected with the creation of new systematic thinking. The steam engine was regarded as an empirical material of the so-called Carnot's cycle, that is, the virtual form of motion of the heat engine theoretically constructed by a French scientist N. L. S. Carnot. Watt verified as an empirical fact that heating gas could expand its volume or raise its pressure. This relationship may be expressed in different words that cooling of gas can bring about a decrease in its volume or a fall in its pressure. Such reasoning is nothing but a generalization of the real process confirmed by the Newcomen engine, in which water (fluid) and vacuum can be produced in the cylinder by cooling, and atmospheric pressure pushes down the piston.

Now, we examine in detail the causal path from heating gas to its expansion or its state of high pressure. Heating operates to preserve the high temperature of gas, and consequently to increase its volume with relatively small drops in pressure. However, it also makes a transition from a state of low temperature to that of high temperature, of which Watt had already made empirical observations. Such dual processes of heating were analyzed theoretically by Carnot who established an ideal and abstract concept of the heat engine in which *calorique* can be changed into work without any loss. In Carnot's engine, four completely distinct processes make up its single cycle: in the process of isothermal change, expansion (contraction) of the volume of gas and a comparatively slow decrease (increase) in its pressure are caused, and in the adiabatic process, without any influence of external temperature, the expansion (contraction) of gas causes more rapid decrease (increase) in its pressure and then a fall (rise) in its temperature. Thus, the successively associated processes of isothermal expansion→adiabatic expansion→isothermal contraction→adiabatic contraction can be theoretically discriminated and they constitute the Carnot's cycle, which was designed in 1824.[8] It is a virtual system of an engine constructed by the abstraction of a piston's motion within the cylinder of a steam engine under the condition that the equation of the state of gas is satisfied completely. In this imaginary experiment, Carnot provided three presumptions, that is, a quasi-static process, conceptual dichotomy of processes (adiabatic and isothermal ones), and abstraction of working substance (air). He set up the heat engine in order to elucidate the mechanism of transition from the motion of *calorique*—in fact, entropy—to work. Since he aimed for universal truth and infinite scientific inquiry by means of theoretical ideas, the heat

[8] See Sadi Carnot (1824).

engine itself was not directly linked to technology or any technical invention. But the adiabatic process that could be interpreted as a condition for the positive work done by Carnot's engine and the thermal efficiency whose supremum can be fixed by it had the potential to create some teleological structures or technical systems.

Certainly, Carnot's prodigious idea anticipated an essential technological core of the second IR, but it was not directly connected with the creation of new technical systems. The same may be said of various inventions of James Watt. From the viewpoint of influence on later generations, his technological achievements can be divided into three parts. Firstly, his invention of the refined steam engine of practical use materialized the technological structure of system creation. His second accomplishment is the transition of the up-and-down motion of the piston into cyclical movement. It caused the steam engine to play a leading role in the first IR as well as to become deeply linked with the diffusion and practical implementation of the internal combustion engine in the second IR. The last and the most influential invention of Watt is that of the 'governor'. It was to have extremely great importance for later developments of the machinery system, though it appeared only as a part of the steam engine. In fact, it became a forerunner of automatic control in the third IR.

In the next section, we will clarify the historical significance of the internal combustion engine (abbreviated to ICE).

3

From the angle of technological history, which originated from the invention of the steam engine, the age of the second IR may be characterized as that of global diffusion of ICE. In effect, during the 1880s, there was a succession of inventions of steam turbines and various gas engines that blazed a trail for the popular use of the gasoline motor. Moreover, in the 1890s, the invention of the compression ignition engine by Rudolf Diesel became a most significant advance in ICE design. In the last phase of the second IR, there was remarkable development of the gas turbine.

The structure of technology in the second IR generally presented a striking feature from two institutional aspects. The first is the institutionalization of technology. We should pay particular attention to the historical role of four German technologists: Nikolaus August Otto, Gottlieb Daimler, Karl Friedrich Benz, and Rudolf Diesel. Three of them except Otto received the same type of technical education. They became technical experts after studying mechanical engineering in professional schools, and made use of a research institute for the development of their technological applications. For example, Daimler opened a new factory for an experimental car, and Benz conducted successive tests on new engines in the machine-manufacturing plant of Mannheim established in 1871.

The second aspect is the technologization of science. In the case of James Watt, the technical necessity of his invention was considered with top priority, and its scientific basis was then explained by means of experimented causality. By mere chance, he found natural law-like causality in his trial experiments. The inevitable relationship between natural law and experimental regularity was not consciously pursued until the second IR. Let us take an example from Diesel's career. After completing technical high school in Augsburg, he entered a college of engineering in Munich and studied there thermodynamics. In 1893, he published the results of his research, which opened up the possibility of putting the Carnot's cycle to practical use. In order to evaluate the theoretical meaning of Diesel's achievement, we must decompose four constituents of the Carnot's cycle into abstract operations or phases. Since the cycle (isothermal expansion→adiabatic expansion→isothermal contraction→adiabatic contraction) can be regarded as a reversible process, it is to be transmuted into more abstract process: isothermal(I)→adiabatic(A)→isothermal(I)→... This alternating process includes an inverse one, that is, A→I→... Thus, the cycle consists of two simple motions I→A and A→I, which will be denoted as κ and κ^{-1} below.

Now, we assume that to write down these symbols from left to right means a process of motion from right to left. If a state without motion is denoted as κ^0, the following rules can be obtained:

① $\kappa\kappa^0=\kappa^0\kappa=\kappa$,
② $\kappa\kappa=\kappa^0$,
③ $\kappa^{-1}\kappa=\kappa^0$, therefore $\kappa=\kappa^{-1}$.

It is a well-known fact that a mathematical (algebraic) structure satisfying these rules may be called a group, or more accurately, a cyclic group of 'order' 2. It is a simple and clear representation of the infinitely circulating motion of the Carnot's cycle. The substitution of λ^2 for κ^0 can make another sequence: λ, $\lambda^2(=\kappa^0)$, $\lambda^3(=\kappa)$, λ^2, λ^3, ... This is a cyclic semigroup of 'order' 2, which includes the above cyclic group as a 'cycle' (a part of the semigroup that constructs group structure). If λ is considered as a symbol expressing 'initial output', it may be regarded as a representation of machine structure. In fact, this way of thinking has brought about a technology with the external factor of 'ignition' for the introduction of cyclical motion to the machine (engine). The first type of this technology was the Otto cycle, and then replacement of ignition by adiabatic compression produced the Diesel cycle. It is common knowledge that the former was put to practical use as a four-cycle gasoline engine, and the latter resulted in the invention of the compression ignition engine (the Diesel engine).

In this historical process, we may clearly find the universal character of technologization of science that technology can clarify reification of cyclical and reversible motions by science. In the real world, the motion of every observable object is usually not cyclical, but irreversible. It looks like a cyclical structure, but actually, its irreversible motion expresses repetition with shearing strain. The role of technique in the technologization of science may consist of practical implementation of this repetitive character of scientifically modified realities.

Nevertheless, the structure of technology in the second IR still presented itself as concrete and substantial. But further development of technology in the latter half of the twentieth century has effected a drastic change in the form of technical inventions. And at the same time, many-sided diffusion of ICE has exerted a dreadful influence on the natural environment. The automobile in particular has created a 'negative natural law' that its emissions as input must cause the deterioration of the environment as output. This topic is referred to in later chapter.

4

Until the 1870s, no attention had been paid to the invention of the governor by James Watt. It was only in the latter half of the twentieth century that technology of automatic control as a generalized form of governor made dramatic progress. Our chief point in question here is to clarify certain characteristics of the structure of technology in the age of the third

IR from the viewpoint of automatic control. However, apart from consideration of the machinery system, we cannot give any historical significance to that technology in this period. Therefore, we have to be satisfied only with a preliminary survey that is limited to a fundamental notion of the sequential machine including automaton and the idea of cybernetics.

As is widely known, the sequential machine is a system with a built-in logical line, that is, a diagram: input→information processing (internal state)→output. In other words, it is a kind of system in which internal state and output can be determined uniquely through the operation of a function of variables consisting of a pair of internal state and input. Thus, feedback control as a fundamental operation of automatic control can be maintained in a sequential machine. The acceptor in it is called automaton. Then, what is the historical significance of the appearance of this system? Briefly, it has extended the possibility of reducing physical inventions of technology to a set of signals (a sequence of symbols) without any tangible form. In effect, the structure of technology in the third IR has been increasingly actualized by means of information exchange and its control. This has been symbolized in the advent of cybernetics as an interdisciplinary science. Its name originates from a Greek word κυβερνήτης, which means governor. Cybernetics is a universal theory of communication systems and their control. Norbert Wiener who coined this English word anticipated that technology in the twentieth century would assume the shape of systematic control of information. The notion of the machine as such an information system may be called an abstract machine. Arguments on its concept will be left until the next chapter. Here, we will treat only two points of issue, that is, the negative situation suggested by cybernetics or similar ideas that can separate knowledge from human beings, and the 'safety' of various feedback systems.

Cybernetics as a synthetic 'science' for developing various methods of information engineering has made us recognize that knowledge as information can be separated from the organism of human beings. What is the meaning of this situation? Science and technology are the result of human abilities in reasoning and image making based on well-ordered knowledge. Therefore, at first, separated knowledge has to operate reasoning power from outside, and consequently delivers most of technological functions to the machinery system, perhaps by means of cybernetics. It means the reification of technology or the appearance of a reified system. This situation will become a serious bottleneck that holds up accumulation of technological wisdom. On the other hand, separation of knowledge from human beings may destroy cultural activities. Since culture represents accumulation of human knowledge or wisdom of life, it will lose its *primum mobile* when the machine becomes the exclusive agent of knowledge engineering. Eventually, technology will continue to raise the level of machine-made knowledge, while the social and cultural ability of human beings may increasingly decline.

The next topic affects the safety net or safe mode of human society. Can the feedback function that forms one of the fundamentals of automatic control system guarantee safety for the existence of the real world? We will take an example as an explanation of this question and leave its general solution till later on. The so-called nuclear deterrent seems to be a suitable topic for clarifying the point at issue. Thirty years ago, a famous Japanese physicist Hideki Yukawa stated the following:

One of the most important factors that has been standing in the way of nuclear

> disarmament may be an attitude of 'nuclear deterrence'. There are various opinions about it, but it is clear that such an approach always results in 'positive feedback'. It means 'an infinite orientation' of nuclear armaments of superpowers. It is decisively opposed to nuclear disarmament, which points to 'zero'. We have no any other policies for nuclear disarmament than repetition of 'negative feedback'.[9]

Strictly speaking, the 'positive feedback' in this speech, which implies forecasted control of nuclear weapons, is just the same as control by feedforward. It assumes that a state of deployment of nuclear weapons in a great power can be compared with that of other strong states at a certain point of time. However, Shin-ichiro Tomonaga, an intimate colleague of Yukawa in the anti-nuclear movement, insisted that this assumption was ill grounded because of the real dynamics of continuous 'technological breakthroughs'. According to Yukawa and Tomonaga, mankind could not be freed from the nuclear threat without throwing away the idea of 'positive feedback' in the systematic control of nuclear weapons. They then proposed the view of 'negative feedback', which can nullify the output of that pro-nuclear system. This idea may have many potential applications. It will be useful for constructing certain compensating systems against various ill-behaved ones that can bring such inconveniences as destruction of the economic system or preservation of an ossified bureaucracy. But any social background of 'negative feedback' cannot continuously exist except through serious conscious efforts. Rather, there will be a stronger possibility of accumulated crisis through decision making made by the majority principle, because the majority of people in the world have been steadily controlled by convenient and profitable techniques and machinery systems.

III. *Structure of Machinery*

1

A machine may be a thing or material pillar of a system created by alienation and reification of differential physical operations of human beings. But not all tools, such as trowels, hoes, or ladles, though they are objects independent of the alienated operations of hands and arms, can be said to be machines. It is only the result of local alienation. In order to give motion to our body, we require a skeletal structure, a transmitting mechanism, and internal organs. When these factors construct a unique correspondence between teleology and natural laws, alienation can be realized as a system. In short, the systematic alienation of operations of the human body may create machines or a machinery system.

Then, what are the characteristics of a machine as such? First of all, a machine moves irreversibly. Although Carnot devised an infinitely cyclical structure as an ideal design, any applied form of his idea must presuppose some finite output. Consequently, ICE as the teleological structure of cyclical motion makes an irreversible natural law. Secondly, a machine can exist as a whole. A concrete machine often comprises partial machines, but each of them can also exist locally as a complete whole. Thirdly, a machine is automatically controllable. Sometimes, it must not only identify any acceptable input (such as automaton), but also regulate input in order to control output. The latter operation in particular has

[9] Address at the Meeting of Pugwash Conferences in Kyoto (August 1975).

developed the idea of a 'learning machine,' which can correct fallacies of output. Lastly, a machine is 'unsocial'. Since it has the nature of wholeness as a set of partial machines and also as an independent simple machine, it cannot relate to the other as it is. But such difficulty may be surmounted by means of input-output regulation or feedback.

Now, we examine more closely the above-mentioned systematic alienation. Let us suppose that there is a certain complex machine created by systematic alienation of human operations, and that its input and output can be denoted as I and Ω, respectively. Then, three partial machines may become its constituents:

① machine with output I (input machine),
② machine for supporting I (supporting machine),
③ machine with input I and output Ω (output machine).

It should be noted that each of them is to become a system by itself. If these partial machines are associated with one another in this order, the initial complex machine can be constructed completely. It may be called machinery system that forms the most elementary system of a set of machines. We will next take up Marx's opinion on machinery system, for he was the first to characterize theoretically its economic meanings.

2

Certainly, Marx made up his own theoretical concept of machinery system that reflected the age of the first IR, but his idea was based upon the views of J. A. Borgnis who had been a machine engineer from Piémont and later became a professor of mechanics at the University of Paris. Borgnis classified machinery system into six components in the following order: *récepteur*, *communicateur*, *modificateur*, *support*, *régulateur*, and *opérateur*. Marx simplified Borgnis's classification and reduced these six elements into three factors in view of the analogical time path of economic activities (production, circulation, and distribution) and the above-stated functional breakdown of the human body as a system. He called three elements of machinery system a motor-machine, a transmission-machine, and a tool-machine, each of which corresponds to the cardiac, vascular, and muscular system of the body.

Among these three machine types, we must pay attention to the function of the tool-machine, for it can build up a self-contained machinery system within a factory by itself. When an organic relationship among tool-machines is to be established there, it may be called a tool-machine system. And, more widely, if a certain machinery system is closed in a community or a circuit of social reproduction, it can be called a social machinery system.

To begin with, we will indicate the general character of a tool-machine system. According to Marx, since any produced 'article either results from the mere mechanical fitting together of partial products made independently, or owes its completed shape to a series of connected processes and manipulation',[10] several working processes could be integrated temporally or spatially, in other words, serially or heterogeneously. Consequently, there might be a distinction between 'serial manufacture' and 'heterogeneous manufacture' in the case of manufacturing production, and particularly in the cotton industry, a distinction between a weaving factory, which reposes 'on the mere cooperation of similar machines', and a cotton mill, which

[10] Marx (1965), p.342.

reposes 'on a combination of different machines'.[11] Moreover, in later developments of capitalist production process, seriality and heterogeneity correspond to mass production and diversified small-quantity production, respectively.

Now, we should note some limitation of the tool-machine system in that it cannot produce a closed system by itself. In fact, the spinning mill of the so-called Arkwright type needed natural (water) power to operate working machines outside the factory. Of course, it was the steam engine that enabled the installation of a motor-machine in the workshop. Then, we discuss an automatic system of machines that is to establish a social machinery system. Since this system is to condition technically the existence of 'industrial capital', two presuppositions of 'continuity of production' and 'carrying out of the automatic principle' must be fulfilled. Marx specified a couple of requirements for the automatization of machinery system. The first of them is the emergence of 'a prime mover capable of exerting any amount of force, and yet under perfect control',[12] which was embodied by the invention and diffusion of the steam engine. This is seen in a plant where there is such a closed tool-machine system such as in a mule-operating factory. The second requirement is the possibility of producing 'the geometrically accurate straight lines, planes, circles, cylinders, cones, and spheres, required in the detailed parts of the machines',[13] which was met by the invention of constructive machines or machine tools. But their installment within an ordinary manufacturing factory could not have any realistic possibility and was not in need of 'industrial capital'. Rather, a socially closed machinery system could be completed with the establishment of a plant for machine tools as an independent tool-machine system, which may be illustrated as follows:

$$\mathrm{B} \cdot\cdot\cdot\!\to \mathrm{T} \cdot\cdot\cdot\!\to \mathrm{W}$$
$$\uparrow \qquad\quad \uparrow \qquad\quad \uparrow$$
$$\mathrm{K}$$
$$\uparrow$$
$$\mathrm{B} \cdot\cdot\cdot\!\to \mathrm{T} \cdot\cdot\cdot\!\to \mathrm{W}$$

B, T, W, and K indicate motor-machine, transmission-mechanism, tool-machine, and constructive machine, respectively. Each of them constitutes a part of a social machinery system. The diagram represents a single cycle of social production and suggests infinitely successive motions from the bottom to the top. If the upper part of the diagram consisting of B, T, W, and K at a certain point of time τ is to be denoted as $\{B, T, W, K\}_\tau$, it can be interpreted that W at τ produces $\{B, T, W, K\}_{\tau+1}$, which shows the same arrangement (order relation) as in τ.

The above cyclical diagram can be regarded as an 'elevation' of every social machinery system, though its 'ichnography' is to become increasingly complicated. The characteristic structure of machinery in the second IR may be depicted in this 'elevation' both theoretically and practically. And it is noteworthy that Marx suggested a conceptual, though naïve, framework that could make such recognition of machinery.

[11] *Ibid*., p.381.
[12] *Ibid*., p.385.
[13] *Ibid*., p.385.

3

During the second IR, the tangibility of individual machines was still maintained, but the social machinery system itself changed in quality and the number of machine types extended remarkably. Now, we will shed light on the characteristic social and economic structures of this period in relation to machinery system.

First of all, the relationship between mankind and machine evolved drastically enough. Generally speaking, the establishment of machinery system means that no one can be a dominator of machinery, but must become its attachment. As science had an inseparably close relationship to the development of industrial technology, such a situation might become more realistic in ordinary economic life. In the second half of the nineteenth century, machine-tool production had so advanced as to create a universal machine-tool, but it imposed restrictions on the smooth progress of production line. In effect, the specialization of machines, especially machine-tools, occurred in every sphere of industrial production. Whereas production velocity rapidly increased and the standardization of manufactured goods advanced with the introduction of various specialized machines, skilled labor tended to be eliminated in production process. In the later period of the second IR, this tendency became extremely conspicuous owing to the development of production control. Arts of production and factory management such as the Taylor system, the ‘principles of scientific management’, and the Ford system with the conveyor belt accelerated the subordination of human labor to machinery system, which reflected the rationalization of tool-machine system. Amongst others, through the Taylor system that aimed at the standardization of the unit working hour, each part of production process could be regarded as the time sequence of unit work. Taylor himself pointed out the following four principles for the achievement of a unit task[14]:

(1) a large daily task (the achievment of a daily task to a high standard),
(2) standard conditions (a daily unit of labor with means of working),
(3) high pay for success (the guarantee of high wage for the achievement of tasks), and
(4) loss in the case of failure (compensation by workers for loss inflicted by the unattainment of their tasks).

The Ford system was a developed form of the Taylor system. It extended the latter to a global system of production control, and created a production space in which the unit task might be drastically simplified and the temporal sequences of individual tasks could be synchronized with one another. In this case, any production line could be characterized by the moving assembly method that introduced the conveyor system as its most suitable device.

Then, what changes did these control systems bring about in the relationship between mankind and machine? Every worker was to be operated as a part of machinery. It meant the standardization of various tasks of individual production processes according to machinery system. Its most famous example is the conveyor system that was symbolically visualized in Chaplin’s *Modern Time*s. It forced laborers to work as partial machines and produced such effects as smoothing different ways of processing and economizing the time of conveyance. Moreover, as the control system was developing in many directions, management labor or the task of determining the contents, procedure, and implementation programme of actual

[14] Taylor (1911), pp.63-64.

operations became an independent occupation as professional work. It stimulated the double-tracking of control systems, which resulted in setting up lines and staff organization.

From here, new aspects of development grew conspicuously. The intensity of rationalization of machinery system became so strong as to exclude mankind from a wide range of production processes. At the beginning of the twentieth century, so-called automation developed extensively. In particular, mechanical automation could exploit the possibility of continuous production as a finite sequence of input and output, and consequently, it was installed in every factory for mass production, for which the continuity of operating process became a necessary prerequisite. The automation system widely progressed from the conveyor system to the transfer machine. And process automation (an input-output system with automatic control), which was first applied in the chemical industries, has come into wide use in the third IR. However, it should be noted that the limited production of a wide variety of goods (originally, automatic production by machine-tools) has also played a vital role in contrast to general diffusion of various automation systems. This type of production was to be systematized in the latter half of the twentieth century when the electronic computer constituted an indispensable part of production. Its control system has changed from a control board of analog type to digital control, which, as we shall see later, forms a peculiar aspect of the third IR.

We will next explore a few types of human relationship, especially those of dominance and subordination, during the second IR. Generally speaking, diversity of machine types may exert significant effects on the organization of mankind. First of all, a universal tendency to bureaucratization can be pointed out in the sphere of social organization. As machinery penetrates every corner of ordinary human life, analogy with machinery may take many forms. Its typical and familiar shape has been constructed as the organization of modern bureaucracy. A bureaucrat as its component may be an individual and partial machine (a human-machine), which can eliminate conflicts according to documented regulations. Bureaucracy is also a machinery system that can originally offer administrative service by the chain of command and obedience corresponding to the status hierarchy. However, every generalized service labor may be provided in the bureaucratic system, because all sorts of social labor can be logically bureaucratized. In such a situation, labor and the laborer (bureaucrat) are to be regarded as an operation and an operator in machinery system. Thus, bureaucracy has pierced administrative organs of state as well as industrial activities such as giant capitalistic enterprises and nationalized firms under a socialist regime. But, ironically enough, the process of industrial development has been accompanied by a wide range of independent and small-scale units of production—for example, those of iron foundry or pottery—where skilled labor still might play a decisive role with no conflicts between management and labor. Such 'small businesses' or traditional industries, which may be indispensable to the workings of a capitalist society, often makes scarcely any division of labor, but establishes a solid basis for the specified integration (specification) of production. It should be noted that specification means the single-handed integration of specified, mutually divisible, continuous processes of production, which may be exemplified by a work of ceramic art. Specification also has a certain quality peculiar to machinery system, but this point of issue will be discussed in the next section.

It is a well-known fact that Max Weber classified in detail the distinct types of dominance including bureaucracy.[15] However, here, I will examine them from a different angle. Whereas

[15] As for the following discussions, see Weber (1972), S.511f.

Weber based his theory concerning the formation of dominance on 'legitimacy' and then introduced the category of 'legitimate dominance', his analysis of the structure of 'legitimacy' itself, which may be ultimately reduced to an alienated structure, cannot be fully conducted even from a sociological viewpoint.

In the age of the second IR, the structure of dominance seems to have been principally constructed by its analogy with machinery system. We will first define a terminology for expressing theoretically our point of view, and then analyze the structure of dominance in this period.

The structure of dominance is a set of men or groups of men within a specified circle that has a determined relationship of dominance or a fixed command/obedience relation. It consists of a pair of mutually complementary relations, the order of which may be mathematically termed 'order isomorphism.' One of them is an input/output relation or command/obedience relation (from now on abridged to CO relation). It corresponds substantially to the functional mode of modern bureaucracy that Max Weber clarified, but it has much to do with dominance in a more general (not historical) sense. The other relation is that of the commander/subordinate relation (CS relation in abridged form), which is a personal expression of CO relation. It should be noted that CS relation denotes nothing of the concrete attributes peculiar to the diverse positions of bureaucrats that Weber listed in detail.

During the second IR, the thinking pattern of drawing, consciously or unconsciously, an analogy between human relations and machines appeared to become increasingly conventional. It might form a decisive situation that Weber called 'rationality'. When a certain structure of dominance embodies a rational society (*Gesellschaft*) that is based on the rational decision making of individual persons, we give it the name of 'analog structure of dominance (ASD)'. In relation to ASD, we shall also introduce the term *Genossenschaft*,which means the self-cooperating structure of dominance. It consists of a human group with similar interests, where every member (cooperator) is put in an equal social position. Such an equal relationship (hereafter called a γ relation) may be characterized by a mixture of *Gesellschaft* and *Gemeinschaft* (community). As examples of the latter case, we can mention several relationships among masters of a gild, believers of a religious sect, or members of a cooperate society.

According to the above-mentioned general characteristics of ASD, we may illustrate its frame as follows:

$$
\begin{array}{l}
\qquad\qquad \gamma_0 \cdot\cdot\cdot \gamma_1 \cdot\cdot\cdot \gamma_2 \cdot\cdot\cdot\cdot\cdot\cdot\cdot\cdot\cdot\cdot \gamma_i \leftarrow \text{feedback} \\
\qquad\qquad \downarrow \qquad \downarrow \qquad \downarrow \qquad\qquad\qquad \downarrow \\
\text{initial input}(C_0) \rightarrow O_0 = C_1 \rightarrow O_1 = C_2 \rightarrow \cdots\cdots \rightarrow O_{j-1} = C_j \ \text{(ultimate output)} \\
\qquad\qquad c_0 > s_0 = c_1 > s_1 = c_2 > \cdots\cdots > s_{j-1} = c_j \ \text{top-down order} \\
\qquad\qquad \downarrow \qquad \downarrow \qquad \downarrow \qquad\qquad\qquad \downarrow \\
\qquad\qquad Z_0 > Z_1 > Z_2 > \cdot\cdot\cdot\cdot\cdot\cdot > Z_j \ \text{descending order of levels of income}
\end{array}
$$

It should be observed in the diagram that the bureaucratic mechanism that is the order relation with no initial output ($C_1 > S_1 = C_2 > \ldots > S_j$) corresponds to Weber's 'modern bureaucracy'. In this case, the order of levels of income is almost fixed in the mechanism.

As representative types of ASD, we take up a republican form of government and a joint stock company. In a republic regime, the commanding power (C_0) of the president (c_0) can be constrained by the total power of a set of γ relations ($\Sigma\gamma_i$), especially by the term of office and the procedure of impeachment. On the other hand, the personal structure of bureaucratic mechanism may be changed by re-election of the president. In the case of a joint stock company, C_0 represents the general meeting where a γ relation between shareholders is formally established. Its practical function ($c_1 > s_1 = c_2 > ...$) can be carried out through the bureaucratic system. And various intermediate γ relations are often devised for tightening management control. To take some examples, the setting up of a staff system, the establishment of a divisional organization system, and the division of labor by a board of directors are well-known methods for introducing γ relations into higher stages of management. But trade unions may be also play a vital role as a γ relation. They can frequently take action beyond the limit of individual firms and function as social apparatus for system control. Increasing loss of the function of trade unions may cause incompetence of social system as a whole, and sometimes undermine the foundation of the business world itself.

Generally speaking, ASD is a universal signal of the mechanization of the dominance relationship in the second IR. Moreover, it is to suffer a significant change in the latter half of the twentieth century.

4

How can we characterize the machine type that has been structuralized in the third IR? In a word, it may be called an abstract machine that can be symbolized by the appearance of a sequential machine as a result of the technological control system originally developed by James Watt.

There are some early forerunners in the development of an abstract machine. First of all, a transfer machine is a device for increasing output through a fixed input chain, which results in the continuous control of specified input. Then, an automatic factory or factory as a machine is another type of concrete sequential machine. An early sign of it can be found in the eighteenth century, but only in the twentieth century was it constructed in practical form. Since the 1920s, an automatic factory has diffused mainly through the development of petrochemical industry. Its final form is an automated factory with unattended human operation.

At all events, in the twentieth century, mechanical automatization progressed unboundedly. Particularly in the third IR, various types of automation—mechanical automation, process automation, and business automation—have fully advanced, and the production of commodities and machines by machines, and the production of 'human-machines' by machinery system have moreover been encouraged and expanded everywhere. At the same time, another tendency of development has become conspicuous. The nature of the machine as a tangible and concrete object has been gradually lost, and reduced to a sort of abstract notion of the 'multiple-input, multiple-output transducer'[16] or the sequential machine or automaton. What is the historical meaning of this tendency? Several key points may be discriminated.

First of all, we have to examine the relationship between ideology and machinery. Ideology can be defined as a form of ideal or false social consciousness. Since the word

[16] Wiener (1964), p.32.

principally suggests the functional existence—finiteness and sociality—of human thoughts rather than their intrinsic value, it excludes an infinite process of rational and scientific thinking, and consequently cannot operate in the field of 'truth', which shall be separated from society. On the other hand, machinery system continues to destroy the ontological background of ideology by replacing man-to-man relations with machine-to-machine relations and diluting their sociality. Consequently, the idea of a system has taken the place of ideology and it has connected machinery with science. The system may lead human society into an unsocial, inorganic, and chaotic world of animal-like particles. In such a sense, it functions as another ideology that smashes any form of ideology. (This point at issue will be discussed later.) In the age of James Watt, any system that could not be separated from scientific activities was constructed by 'pure' scientists who sought scientific truth out of curiosity. However, this 'pure' attitude was gradually lost, and in the twentieth century, most scientists became a sort of mechanical operators of systems engineering.

Now, we will turn to discussing the second point, that is, the systematization of machinery and social structure. The notion of a structure corresponding uniquely to scientific laws with technology and techniques still remains in the concept of the machine after its tangibility and materiality has been left out of consideration. This notion may be properly called 'system'. An abstracted and idealized machine is a representative form of system that absorbs various types of technology, in other words, any visible and tangible machine can be produced by the construction of concrete and tangible materials that are arranged according to the notion of a fixed system. This aspect is a process of machine making that can be considered as the reification of a system. Not only machinery as such, but universal social structures—for example, the above-mentioned bureaucracy or ASD—can be also systematized everywhere. And from this point of view, economy may be regarded as machinery. In order to explain the situation in more detail, we need to decompose and reconstruct the famous economic models that were formulated without any analogy with machinery.

The fundamental nature that is common to general production models—for example, Marx's reproduction scheme, the Walrasian model of general equilibrium, the inter-industry relations table of Leontief, the Sraffa system, etc.—is that their formal structure can be reduced to a system of linear equations or linear mapping, which is represented by a structurally invariable transformation matrix. Since it is assumed to be non-singular, it makes an algebraic structure of group. This property of production models may be deeply connected with the structure of the machine, for they can be transformed into simple sequential machines with a set of states, the elements of which can preserve the invariability of a transformation matrix. We will take up Leontief's 'table', but the topic discussed here is confined to a simple system of equations that Leontief called 'fundamental equations'.[17]

Let the total output of ι industry ($\iota = 1, \ldots, \mu$) and its input of the product of κ industry ($\kappa = 1, \ldots, \mu$) be denoted as X_ι and $x_{\kappa\iota}$, respectively. And let the product of ι industry appropriated for the final consumption of households be denoted as $x_{\nu\iota}$. Then, the total balance held between each output and input of μ industry can be shown by the following equations:

[17] Leontief (1951), p.143.

$$X_1 - x_{21} - x_{31} - \cdots - x_{\mu 1} = x_{\nu 1}$$
$$-x_{12} + X_2 - x_{32} - \cdots - x_{\mu 2} = x_{\nu 2}$$
$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$
$$-x_{1\mu} - x_{2\mu} - x_{3\mu} - \cdots + X_\mu = x_{\nu\mu}.$$

If we define $X_\iota^* = X_\iota + x_{\iota\iota}$, these equations can be changed into the following:

$$X_1^* = x_{11} + x_{21} + \cdots + x_{\mu 1} + x_{\nu 1},$$
$$X_2^* = x_{12} + x_{22} + \cdots + x_{\mu 2} + x_{\nu 2},$$
$$X_3^* = x_{12} + x_{23} + \cdots + x_{\mu 3} + x_{\nu 3},$$
$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots,$$
$$X_\mu^* = x_{1\mu} + x_{2\mu} + \cdots + x_{\mu\mu} + x_{\nu\mu}.$$

Now, we will decompose these simultaneous equations into several sets. Firstly, a collection of all products can be represented by a set $\{S_1, \ldots, S_\mu\}$ or $\{S_\iota\}$ $(\iota = 1, \ldots, \mu)$, where $S_\iota = X_\iota^* - x_{\nu\mu}$. Secondly, let the set of total supply of labor provided by households be denoted as $\{\alpha\}$. Element α represents the labor power sufficient for obtaining the total quantity (υ) of final consumption of households where υ equals the sum $\Sigma x_{\nu\iota}$ $(\iota = 1, \ldots, \mu)$. Lastly, the set expressing the final state of consumption of households is to be denoted as $\{\upsilon\}$.

Then, under these notations, a set $\{S_\iota\}$, and two sets $\{\alpha\}$ and $\{\upsilon\}$, each of which comprises only one element, may be regarded as a set of state, input, and output, respectively. In this case, we can construct the function of a sequential machine as follows:

	α			
S_1	$S_1;\upsilon$	$S_2;\upsilon$	$\cdots$	$S_\mu;\upsilon$
S_2	$S_1;\upsilon$	$S_2;\upsilon$	$\cdots$	$S_\mu;\upsilon$
.	.	.	$\cdots$	.
.	.	.	$\cdots$	.
S_μ	$S_1;\upsilon$	$S_2;\upsilon$	$\cdots$	$S_\mu;\upsilon$

This sequential machine is a sort of machine that is 'embedded' in Leontief's 'table'. Such formal treatment based on the transformation of linear mathematical models into a sequential machine is always possible for other similar economic models. Then, what is the meaning of this fact? If any real economy is to be expressed as an economic model that elaborates upon the conceptual image of system, the sequential machine drawn from it must be an abstract manifestation of the actual structure of economy as machinery. On the other hand, it may be noted that we can obtain another concept of machine when we give a different reading of the above notations. If we assume α, $\{S_\iota\}$, and υ to be labor power, aggregate production and consumption, and waste, respectively, we can find a unique kind of 'machine' that receives labor power as input and provides waste as output. This may be called a 'free machine' that can emerge as a result of unintended input/output relations without any teleological structure. In fact, every machine is reduced to a 'free machine'. The cumulative process of its output is sometimes embodied in war, pollution, and local starvation. It necessitates feedback or feedforward, otherwise the original human-like function of machinery itself may be irrevocably lost. In this sense, a 'free machine' may be a signal for intended and programmatic system control.

Moreover, an abstract machine as a system penetrates several mental fields of human activities. It becomes a creator or pillar of the system and then bears a great resemblance to mankind as the *primum mobile* in systematic evolution. Norbert Wiener, who tried to show the possibility that machinery system might bear a close parallel to human beings, devised a system science called cybernetics. Taking his viewpoint into account, we will reconsider the concept of system that functions as ideology.

Ideology may be defined as a form of idea or consciousness that is limited by existence. Idea is a manifestation of existence, while ideology or a socially formed idea loses any chance of transcendence. Since ideology functions as a syntax of idea, the original materiality of an idea is often abandoned and some ideological critique is therefore justified. Many sorts of ideology as the object of such critique may be reified arbitrarily. Religious or theological ideologies sometimes transform themselves into various icons. Most social ideologies can be reified into physical institutions. Then, is machinery able to become ideology?

It is clear that machinery itself is not ideology, but creates a mechanism that plays the role of demolishing conventional ideologies. Cybernetics is a typical mechanism of this sort. It may not be a philosophical idea, but a technological ideology. Wiener, the preacher of cybernetics, showed the possibility of transforming any concrete machine into a set of signals, and constructed an ideal image of an abstract machine as the 'multiple input, multiple output transducer'. This is a systematic system or system-creating system. As it logically includes every tangible machine, it can be embodied at any time and place. This universal machinery with the possibility of reification emerged in the latter half of the twentieth century. Of course, cybernetics needed a background of fundamental sciences, especially mathematics (group theory and measure theory) and statistical mechanics. The synchronization of continuous and irreversible time based on the ergodic hypothesis, and the abstraction of concrete geometrical images by means of the measure theory of Lebesgue, must have had a decisive influence upon Wiener's idea.[18]

On the other hand, it is noticeable that cybernetics may not have any sense of social science. This is the reason that it can be regarded as an ideology or 'false social consciousnesses'. However, in spite of this, it should not be concluded that cybernetics is only a sort of vulgar 'bourgeois' ideology. Rather, Wiener emphasized the necessity of reconstructing the mechanized human world in a social context, because his ideal machinery might further the possibility of producing whatever concrete machines we like and, moreover, creating a submissive type of human being. And such an ideological situation formed a new social framework of mankind after the Second World War.

As remarked above, the structure of machinery in the third IR can be characterized by the complementary mixture of two factors, that is, systematization and humanization of machinery. Only when based on this viewpoint may the structure of technology in this period also be firmly grasped. But in some cases, another point of view is needed. It may be called the

[18] See Wiener (1961), Chapter 2, Chapter 3.

mechanization of human beings.

5

The German philosopher J. Habermas clearly described the situation of intelligence in the second half of the twentieth century as the ‘scientification of technique’.[19] But it may not be an accurate expression, and should rather be called the ‘scientification of technology’. We can give several reasons for this. Such teleological intelligence without an end—therefore, without any practical purpose—as in the case of pure science, is gradually disappearing owing to the dominance of profit making, while any arbitrary choice of research object based on monetary desire, affirmation of racial superiority, and individual hunger for fame has been justified in the wide sphere of technology. For example, this practice can be found in human experimentation conducted using nuclear weapons or surgical operations. Consequently, some scientism is to coexist with technology for its own sake where the dominance of technocrats or technocracy has grown rapidly. As Max Weber suggested,[20] various haphazard purposes set up by professional, but narrow-minded, technocrats such as bureaucrats, scientists, academics, and researchers have created a universal teleological structure that controls human society as a whole.

In general, technocracy may be a result of bureaucracy or ASD as mentioned above. During the second half of the twentieth century, ASD was further mechanized in combination with system concepts such as cybernetics, and it demonstrated a persistent tendency toward the digitalization of human intelligence and behaviour. It was exclusively reduced to a mass of digital signals, the sum of which became useful as a standard of evaluating the ability of human-machines. Since the result of their aggregation is not applicable to evaluation of the imaginative powers of mankind, it cannot provide any measures of human sensibility and reasoning ability, but can only introduce a formal and rigid standard for judging the degree of limited and specified mechanical abilities that can be digitally represented.

A serious problem has arisen from this situation, about which Joseph Schumpeter was apprehensive in his later work *Capitalism, Socialism and Democracy*. He argued that ‘the capitalist order not only rests on props made of extra-capitalist materials but also derives its energy from extra-capitalist patterns of behaviour, which at the same time, it is bound to destroy’.[21] The ‘extra-capitalist’ ‘protecting strata’[22] that include cultural, educational, and other social institutions are especially gradually disappearing in parallel with the rapid development of capitalism. What is the reason that they cannot perform any significant role in capitalist development? It may be that capitalism has been dominated exclusively by system concept and universalization of machinery. Consequently, every institution in both capitalist and socialist societies is to be absorbed into a certain ASD. In other words, technocracy continues to stimulate mass production of human-machines, while it is implicitly destroying powers of human imagination.

Generally, an ‘entrepreneur’ can be defined as a man of profound vision or imagination. Only this type of man may be able to fulfill the function of specification that controls any

[19] Habermas (1969), S.79.
[20] See Weber (1930), p.181f.
[21] Schumpeter (1950), p.162.
[22] *Ibid*., p.134.

division of labor in human society. According to Schumpeter, the ability to yield entrepreneurship may not be installed in capitalist system, and yet neither has it been developed in any socialist nations. Furthermore, there will be the least possibility of cultivating entrepreneurship wherever system concept exclusively dominates the bulk of social relations.

Of course, ASD is transforming itself in the third IR. If all commands in an ASD have been changed into digital signals, most of its members will not understand their total, consistent meaning. For example, we assume the following functional hierarchy $\alpha \rightarrow \beta \rightarrow \gamma \rightarrow \delta \rightarrow \varepsilon$:

α: a command expressed by English, French, mathematical language, etc.,
β: position of members (acceptors) who transform the command into a digital signal such as a finite denumerable set of binary digits,
γ: transmission of the signal,
δ: translation of the accepted signal (compiler),
ε: execution of the command.

When such a chain of commands is given, the necessary condition for operating the system may be that only two members at α and ε can understand the contents of a command and the other members merely process the data of signals on a fixed manual.

Let each temporally ordered sequence ($1<2<\ldots$) of meaningful signals at the starting and final points (α and ε) be denoted as α_ι ($\iota=1, 2, \ldots$) and ε_κ ($\kappa=1, 2, \ldots$), respectively. On this occasion, not all patterns of correspondence $\alpha_\iota \rightarrow \varepsilon_\kappa$ can be recognized simultaneously and uniformly, and consistency in the bulk of signals may therefore not be confirmed by anyone. Consequently, nobody knows what the true content of the command is. This 'totalization-free' situation can create an odd world where there are many null sets dotted in disorder and many denumerable sets of blinking signals that iterate infinite motions of self-induction. In this world, the possibility of judging the efficiency of a specified and unified (economic, diplomatic, social, and other) policy determined by a certain group increasingly diminishes. The situation may further deteriorate owing to diversification of the contents of a command (corresponding to that of public agencies, private firms, and markets) and their verbal symbols. Now, it has come to this: any chance of mutual and direct understanding between fellow men has gone, while the whole picture of the social complex of machinery system will disappear from everyone's sight. Since mechanization of human beings infers the negation of human genus through the medium of humanity, only a few men who have the privilege of controlling their own structure of self-domination will be able to take the minimum necessary action for free choice.

6

Now, we are going to discuss the last topic of this chapter: systematization and mechanization of human intelligence, which must be brought about by the appearance of human-machines. Scientific investigation may also transform itself into a machinery process, which is symbolic of the tendency toward degeneration of intelligence into a mechanical operation. As an example, we will take the case of economic science.

Jean Piaget, a famous psychologist, argued that there must be a 'subject' (*sujet*) that can recognize a certain external object as a structuralizing structure by means of making up any controllable structural notion.[23] This notion may be called a 'constructive structure'. We will employ the term to interpret the history of economic thoughts where several representative economists have created various constructive structures of contemporary economic affairs.

Around the middle of the eighteenth century, François Quesnay devised the *Tableau Économique* by making use of his ability in compiling anatomical charts and his knowledge of the system of blood circulation. Adam Smith, who had enjoyed an excellent education in philosophy, literature, and other fields, gained profound insight into economic life and then arrived at a better understanding of the structure of political economy, which was described in his famous work *The Wealth of Nations*. In the nineteenth century, David Ricardo constructed an abstract economic model with his ability in the fundamental critique of past economic doctrines, his business sense as a stockbroker, and his marvelous logical imagination. He was the first economic scientist who consciously established a method of abstraction in the sense of elimination of space-time coordinates from economic historical facts. Then, J. S. Mill mobilized all the resources of philosophy, logic, literature, and other abundant knowledge to compile his assorted thoughts on economic theory and history into a voluminous book named *Principles of Political Economy*.

In the same period, Karl Marx contrived the 'value equations' and 'reproduction scheme' and then structuralized the economic framework of modern society as a 'capitalist mode of production' by making the best use of his gifted critical power and philosophical imagination, though he had little knowledge of mathematics and physics. Several years later, L. Walras, who had good skill in mathematical thinking, formulated a certain set of equations that could represent the so-called general equilibrium. But his image of economic structure was very different from that of Marx, for in the Walrasian model, the 'capitalist mode of production' was supposed to have the highest economic efficiency. Furthermore, Alfred Marshall, as well as Walras, has been regarded as one of the founders of the 'neoclassical school'. He had a wide background in scientific learning such as mathematics, physics, psychology of associationism, classical and German political economy, etc., and adapted it to construct his own economic model of 'partial equilibrium'. In the twentieth century, J. M. Keynes, a disciple of Marshall, who had extensive knowledge of mathematical analysis, probability theory, social psychology, empiricist philosophy (ethics), and others, restructured and remodeled the 'neoclassical' economics represented by Marshall and Pigou. Joseph Schumpeter, who was a contemporary of Keynes, but not sympathetic to his doctrine, made remarkable achievements in every branch of economic science owing to his profound scientific intelligence, which could be favourably compared with Keynes'.

However, economic science or economics has conspicuously transformed itself after the center of economic studies moved to USA in the latter half of the twentieth century. The most advanced economic research must have been undertaken by a homogeneous group of economists or 'economic engineers' who acquired a high level of mathematical apparatus—for example, linear mathematics including non-negative matrices and linear inequalities, topological analysis, game theory, and so on—but had least knowledge of the humanities such as philosophy, literature, psychology, etc. Consequently, only a shriveled constructive structure produced by them could be utilized for economic analysis and modeling, while historical and concrete economic thinking has faded away from the academic world. In fact, the practical,

[23] See Piaget (1968), Chapter IV and VI.

often superficial, analysis of economic realities has been left to professional public officials or amateur economists.

As shown in the above rough sketch of the history of economic thoughts, various types of constructive structure imagined and created by several economists as ‘subjects’ have always produced different forms of objective cognition through abstraction from historical facts. In particular, an image of structure constructed by a ‘subject’ who emphasizes some structural balance or self-regulation is best exemplified in the Walrasian ‘general equilibrium’ model. It may be a well-known fact that his theoretical model had not the least influence upon the cognition of equilibrium in developmental psychology and Saussure’s linguistics. On the other hand, Marx as a ‘subject’ who played up the possibility of structural transformation of economic societies offered an anti-equilibrium model of capitalist system. At all events, economics can be created by economists as ‘subjects’, and real economic phenomena may be regarded as the objects of their constructive operation. But an economic model, when it has been embodied in the real world, will probably become a real event, and in this respect, any operation or repercussion of its ‘producer’ upon real objects can be readily achievable. This external reaction to an economist’s thinking may be reinforced with his own ideology such as *laissez-faire*ism, liberalism, individualism, socialism, interventionism, nationalism, opportunism, and so on.

Now, we will review some characteristics of ‘economics’ in the second half of the twentieth century. It is possible to raise two questions. What is, first of all, the meaning of the ‘application’ of economics, especially that of economic theory to policy making? Since the word ‘application’ in French means ‘mapping’ in a mathematical sense, the application of an economic theoretical model may be equal to fixing a certain ‘mapping’. More precisely, it is to specify a ‘mapping’ from a set of elements that build up a theoretical model into that of real (selected) economic events that should be controlled or modified. This ‘mapping’ may be called ‘representation’ in mathematical terminology. If application is equal to finding function Φ as a ‘representation’, it can be efficiently executed by a computer. In other words, such operations as increasing or decreasing the number of variables to specify or generalize a certain theoretical model may be reduced to a mechanical computing process. From this point of issue arises the second question. Can any computer of high quality perform the construction of economic theory and its application to real economic policies? Of course, these works have hitherto been carried out mainly by stereotyped economists with the least sensibility and imagination (‘the scientific masses’). However, they also seem to have become computer-like machines in a workshop for the production of economic models, where a group of economists of homogeneous quality always pursue an arbitrary goal (output) that has been defined by some external (political or social) influence, and then theoretically justify the application of their model to it.

Since the age of Keynes and Schumpeter, individualism and individuality in the academic world of economics has gradually declined and the social function of economists has been increasingly determined by a ruling social system of dominance that can be controlled mechanically by technocracy or a system of human-machines. As a result, any personal intention or idea of an economist has been wholly neglected and perhaps he himself must be thrown upon his own resources.

Although the above arguments concerning mechanization of economics and ‘ochlocracy’ in economic science may also be applicable to other fields of science, we will not discuss this topic in any more detail and change the subject to investigation of the third element of NSP.

IV. *Structure of Division of Labor*

1

In this section, we will establish the basic terminology concerning division of labor (abbreviated to DL below). In particular, we will define the following terms: microscopic and macroscopic, specification and specialization, and industry.

The term 'microscopic' corresponds to a theoretical viewpoint of molecular structure in thermodynamics. We will make use of this adjective when emphasis should be placed on the parts or constituents of objects of our research. Meanwhile, the term 'macroscopic' indicates a viewpoint of the physicist when he inquires into something to do with mutual relationship between global thermal motions. We will use the word to grasp a certain relative 'whole' when we can guarantee the existence of its constituents. A factory or office as a microscopic structure of DL and an industry or national economy or the world market as a macroscopic structure of DL may be particularly important for our later discussion. Incidentally, it should be noted that localization plays a decisive role in the structure of a national economy, while standardization characterizes that of the world market or economy.

For our purposes, it is important to draw a distinction between specification (*Leistungs-spezifizierung*) and specialization (*Leistungsspezialisierung*), as Max Weber put it.[24] It must be done both individually and regionally or locally. From an individual point of view, specification means the aggregation of individual tasks, each of which can be clearly graded and become an essential part of a whole (a certain product). If an individual laborer and his whole work may be regarded as a one-element set and a set of individual tasks, respectively, it means a one-and-many correspondence in a mathematical term. Typical pillars of specification are craftsmen, ceramic artists, and other jacks-of-all-trades.

On the other hand, specialization from the angle of individuality means professionalization of an individual worker to a specified task and at the same time, the successive diversification of a certain entire production process. It may be represented by one-to-one correspondence between laborer and task, and become a prerequisite for both social DL and industrial production. Then, from a regional or local viewpoint, specification means regional DL that is oriented toward the self-contained satisfaction of local economic needs, while specialization means inter-regional DL that is discussed later concerning 'localization'.

Lastly, according to Max Weber, we will expound the conceptual meaning of industry.[25] He defined industry in general (*Gewerbe*) as the transformation of raw materials (*Stoffs-umwandlung*). Naturally, he excluded transportation, commerce, and agriculture from industry, but included mining. In fact, there is an important reason for this classification. Since Weber was particularly interested in the formation process of 'industry with profit motive and factory organization' (*Industrie*), he focused on the mining industry as a well-suited model of *Industrie*, which accelerated the mechanization of workshop production and then the com-

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24 See Weber (1972), S.65.

25 Weber (1924), S.110, and Weber (1961), p.97.

pletely rationalized production process. And he also emphasized the fact that a capitalist relationship had started earlier in the mining industry. Therefore, its modern history based on his descriptive explanation must be summarized next.[26]

He asserted that ownership (*Herrschaft*) or landownership (*Grundherrschaft*) had been dominant in agriculture, while fellowship (*Genossenschaft*) had diffused in the mining industry where its business was managed by a corporation (*Gewerkschaft*) of miners. Under these conditions, the development of various mines such as tin, coal, iron ore, etc. was hastened in quality and quantity. Accordingly, three distinct tendencies emerged in the process. First, as the demand for labor increased, the number of outside fellows (*Ungenossen*) grew rapidly. Then, a homogeneous group of miners became stratified under the necessity of DL. And lastly, a sort of capitalist miner came on the scene as a result of increasing demand for capital goods or equipment (pits, upcasts, carriers, and others). Owing to these trends of development, fellowship in the mining industry collapsed and moreover, capitalist ownership was established there. In effect, the stratification of miners developed the relationship between capitalist (*Herr*) and wage laborer, and at the same time, a corporation of the mining industry transformed itself into a capitalist enterprise.

The historical process that Weber described with regard to the mining industry suggested a universal logic of the formation of industrial capitalism. Perhaps it best fitted in with the economic affairs in England of the eighteenth century. Of course, the key object of our analysis below is not *Gewerbe*, but *Industrie*.

2

Now, we will examine the structure of DL in the first IR from a microscopic as well as a macroscopic viewpoint.

In the previous chapter, machinery system was assumed to consist of three fundamental parts. It should be noted that each of them is also a machinery system. They can be discriminated from one another and signified respectively from the angle of DL. First of all, an input machine is the *primum mobile* of DL, through which the activity of mankind is originally alienated. Secondly, a supporting machine defines the DL relation within a specified machinery system. Lastly, an output machine constructs a machinery system as representing the DL relation between several machinery systems. The structure of a superordinate machinery system consisting of these systems can be determined by the state of alienation of human activity and the organic relationship between alienated physical objects.

Then, we can define the concept of factory. It is a mechanical structure that is regulated by the social DL established through machinery system and the hierarchical order accompanied by the chain of command and obedience (*Herrschaft*). In other words, it is a complex of workplaces comprising flesh and blood, whatever names—servants, wage earners, workers of a nationalized enterprise, etc.—they may be given. In order to make clearer the concept of factory, we will compare it with a 'workshop' according to Weber's classification. He pointed out that a workshop (*Werkstatt*) is a place where the production of specified goods is undertaken (it is noticeable that not all places of production can be fixed, for example, in fishery and transportation), where a group of men and women who work for it operate

[26] As for the following explanations and discussions of Max Weber, see *Ibid*. S.110ff, and p.97ff.

together, and where the objects of labor and the means of production available for this human labor are concentrated. The ἐργαστήριον in the ancient Mediterranean world may be one of the oldest types of workshop. Its modern type can be represented by a 'manufacture' where the internal DL has been rationalized to the extreme.

Meanwhile, a factory (*Fabrik*) is also a workshop in a more limited sense. Then, several characteristics must be added to the concept of workshop; that is, appropriation of the means of production by a 'ruler' (*Herr*), the establishment of an internal DL, and the installment of machinery system. The 'ruler' may be called a capitalist under the structure of capitalism, and in a socialist factory, a technocrat or 'leader' at the top of the intramural bureaucracy.

Particularly in connection with capitalism, some more characteristics must be added to the concept of factory. First, a factory has an inseparable relationship with the management, which is based on capital accounting (accounting of fixed capital, or industrial bookkeeping) concerning equipment (*Anlage*) as a complex of working place and apparatus. Secondly, a capitalist factory must be operated by means of 'free labor' with lawful labor contracts and fixed capital originating from manorial equipment or communal facilities. As Weber properly pointed out, 'factories developed as little out of craftwork as they did out of the domestic system; rather they grew up alongside the latter.'[27] However, these explanations should be complemented by Marx's concept of 'industrial capital', because it allows us to change Weber's historical and genetic viewpoint into a theoretical and structural one, and consequently grasp the structure of an abstract capitalist factory. As is commonly known in economics, the cyclical movements of 'industrial capital' reproduce class discrimination between capitalist (*Herr* or ruler) and laborer (*Untertan* or subordinate), and moreover, may give rise to iterated and extended disorder in industrial relations and fluctuations under capitalist system.

On the whole, it should be known that the DL between mankind and machine can be constructed on the basis of both man-to-man and machine-to-machine DL (specialization). Such DL within a factory may be called horizontal DL, which characterized the microscopic structure of DL during the first IR.

Next, we have to analyze the structure of DL in the same period from a macroscopic point of view. If we consider a national economy or a so-called 'local market area'[28] as the reproduction area or region within which the circular movements of a specified DL can be completed, we can regard it as an input-output structure of goods and services that can be produced and consumed there.

Let us assume that there are only two such regions denoted as 1 and 2. If there exists ι-region's input ($\iota=1, 2$) needed for the output of staple products of λ-region ($\lambda=1, 2$), we shall write $\alpha_{\iota\lambda}=1$, otherwise $\alpha_{\iota\lambda}=0$. Then, we can define 2×2 square matrix $A=[\alpha_{\iota\lambda}]$ and demonstrate five distinct types of its numerical representation as follows:

$$\text{(a)} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad \text{(b)} \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}, \quad \text{(c)} \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$$

$$\text{(d)} \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}, \quad \text{(e)} \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}.$$

Amongst them, (a), which shows $\alpha_{12}=\alpha_{21}=0$, corresponds to the situation where there is

[27] *Ibid*., p.136.

[28] Gras, N. S. B. (1915), p.35.

no input-output relationship between two regions. In this case, matrix A is often called 'decomposable' according to the terminology of linear algebra. On the other hand, in the case of (d), A is called 'indecomposable'. Thus, (a), (b), and (c) are 'decomposable', but (d) and (e) are 'indecomposable'. However, in order to give consideration to the economic meaning of these five cases, it is appropriate to arrange the following classification, which is to distinguish three groups or sets:

① ・ ・ ・{(a)},

② ・ ・ ・{(b), (c), (d)},

③ ・ ・ ・{(e)}.

Now, we will discuss the issue in terms of two distinct cases, both of which include this classification in a different sense. The first case is that there exists an input-output relationship within a national economy where both regions 1 and 2 are located. Type ① indicates the situation where an isolated 'local market area' is identified within a region. In type ②, a region consists of a group of 'local market areas' that are related to one another. Type ③ shows that a regional specialization (a domestic DL) has developed into a national economy.

The second case is where there is an input-output relationship between national economies and where regions 1 and 2 indicate 'our country' and 'another country', respectively. Then, type ① shows that a single reproduction area comprises individual (or blocks of) countries without any mutual economic contact. As typical examples of this, Fichte's 'closed commercial state (*der geschlossne Handelsstaat*)'[29] or Thünen's 'isolated state (*der isolierte Staat*)'[30] should be remembered. However, in this case, type ②, which is a mixture of domestic and international DL, is the most universal, whereas type ③ indicates a pure international DL, which scene is almost exactly assumed in the Ricardian doctrine of 'comparative costs'. Although a model of international DL lacking in domestic DL may be unrealistic, it is undeniable that the world of Pax Britannica in the nineteenth century exhibited a tendency toward a similar situation.

In connection with a national economy, we must pay attention to the phenomenon of 'localization'. According to the classical definition of Alfred Marshall, economies 'dependent on the general development of the industry' among those 'arising from an increase in the scale of production of any kind of goods' may be called 'external economies'. Then, he attached great importance to a specified type of them that 'can often be secured by the concentration of many small businesses of a similar character in particular localities, or, as is commonly said, by the localization of industry'.[31] Such 'localization' was typically represented by the Lancashire cotton industry and the potteries in Staffordshire during and after the first IR. At that time, there was also a rather moderate 'localization' in the iron industry of the Midlands and the West of Scotland. On the whole, it may be said to have developed in key industries that led the first IR.

From the angle of the world economy, this type of 'localization' was reduced to a biased specialization of each individual national economy in certain domestic products. Accordingly,

[29] See Fichte (1800).
[30] See Thünen (1826-).
[31] Marshall (1920), p.221.

the actual international DL between national economies extended the sphere of commodities and exchange and then promoted the 'standardization' of economic transactions. It may be common knowledge that development of the world market based on the 'Atlantic economies'[32] in the eighteenth century was accompanied by expansion of the market for mass-consumption goods and consequently created the beginning of an integrated world-wide price system and 'standardization'. The word 'standardization' was originally employed by Marshall as an economic term indicating the quality standard of manufactured goods, but here, it shall mean the unification of various economic calculations with different weights and measures that are needed for the universal development of commodity markets.

In conclusion, it seems that the macroscopic structure of DL during the first IR takes the shape of international DL composed of specialized national economies and other economic regions, and firmly stands in the setting of appearance and growth of the capitalist world market.

3

Since the second half of the nineteenth century, the development of an 'organization' in the microscopic structure of DL had been noticeable to a great extent. Therefore, we will mainly discuss this phase of DL and only make an additional remark about its macroscopic structure.

During the second IR in every industrialized region, the whole process of commodity production and distribution was divided into several partial processes and again integrated into another whole process. In the first IR, the division and specialization of productive processes had already progressed considerably, but in the second IR, it extended widely enough to create a higher importance of distributive process. It allows us to make an abstract and symbolic formulation of the history of DL.

Let a whole process of production and distribution be denoted as Ψ (linear operator). If we assume that the process is composed of n-partial processes $\Psi(X_\iota)$ (X_ι: a factor of production, $\iota=1, ..., n$), which are disjointed from one another, we can obtain the following equation:

$$\Psi(\Sigma X_\iota)=\Psi(X_1)+\Psi(X_2)+\cdot\cdot\cdot+\Psi(X_n)=\Sigma\Psi(X_\iota).$$

In the case of underdevelopment of DL, all factors of production are addable ($\Sigma X_\iota=X$) and the whole production process can then be represented by $f(X)$. If the total volume of factors of production decreases or increases ($\mp\delta$), $f(X)$ becomes $f(X\mp\delta)$. As DL gradually progresses, every part of a whole process may become independent or disjointed from each other, and consequently, the total sum of production and distribution with decrease or increase of individual factors of production ($\mp\delta_\iota$, $\iota=1, ..., n$) is expressed by the following formula:

$$\Psi(X_1\mp\delta_1)+\Psi(X_2\mp\delta_2)+\cdot\cdot\cdot+\Psi(X_n\mp\delta_n)$$

Owing to such a rigid DL, the 'organization' or formation of an independent organ is needed in every corner of industrial and commercial development. Pasdermadjian, a Swiss economist, appropriately defined 'organization' as a complex of 'previous research, provision

[32] This is part of Davis' title (1973).

for pre-condition, normalization, and systematization',[33] which should be effectuated according to the characteristics of the above function Ψ. To put it concretely, Ψ could determine a sequence of specialized machines, an arrangement of interchangeable labor power, the fixed proportion of indirect producers (laborers for spade work, recorders, assistants, etc.) to the whole process of production and distribution, and several types of specified managed labor. Especially in distributive process during the second IR, various types of commercial activity such as department stores or chain stores emerged as the result of rationalization, while increasingly rationalized distribution processes steadily disrupted direct communication between fellow human beings, which also might be a natural consequence of the 'organization' of the production process. Thus, the division of the total economic process by means of 'organization' developed a new system of management accounting and in its turn, the latter further advanced the growth of 'organization' itself.

As mentioned above, during the second IR, the horizontal DL between machines remarkably advanced and then the Ψ type of production and distribution process emerged everywhere in advanced industrialized countries. But at the same time, human relations took various shapes of 'organization' outside direct production. In other words, there appeared a multi-copying process (*la mecanographie* or MG in abbreviated form) based on the development of the modern accounting system.

The advancement of DL in the nineteenth century reflected the transition of the accounting system from the English type comprising many distinct special journals to the French type based on a centralizing journal (*journal centralisateur*). MG evolved rapidly corresponding to this division and integration of accounting procedures. Since MG means the mechanization of office work, an office became a chief place at which it worked. In fact, it took place not only in the office of an individual firm, but in that of a shop or banking company engaged in a distributive or circulative business.

It is clear that the emergence of MG reflected an increasing volume of accounting management. As MG itself means nothing but 'waste', many devices for its reduction raised the 'productivity' of accounting operations and in its turn, created further different types of MG. The first machine for executing MG might be a typewriter, which made its appearance in 1872 and became widespread since 1896. It was succeeded by a calculator, which was to reach the stage of practical application in the 1890s. Although these machines were not originally intended for the management of accounting, they gradually played a decisive role in the conspicuous development of MG since 1900. Particularly in about 1908, the 'accounting by copying' and the invention of an adding machine resulted in the remarkable progress of MG. Moreover, cash registers and rectilinear adding machines were successively invented and consequently, automatization in MG advanced rapidly. It reached a new phase of development in the 1920s when the management of accounting became totally reorganized through the punch-card system, which was originally devised by Herman Hollerith in 1880. It institutionalized data (information) processing by a punch-card, and at the same time, constructed a sort of machinery system composed of a card punch, sorter, calculator, tabulator, etc. Thus, in the sphere of MG, room for human labor also became less and less, while the costs of fixed capital equipment added up accordingly. This situation was to necessitate a further spiralling sequence of inventions in MG.

[33] Pasdermadjian (1959), p.127.

In parallel with the progress of MG, a new type of DL came into being in major parts of the apparatus of the state, industrial enterprises, and commercial (and banking) companies. It may be called vertical DL, which appeared as a pattern of purely human relations and as such, joined the existing horizontal DL. Pasdermadjian explained as follows:

> Recent vertical DL, which is one of the characteristics of the second IR, has had a structural effect on the appearance of new specified functions, which could make a separation between the abstract part of 'planning' or organization on the one hand, and the more concrete part of direct management and simple watchful supervision on the other...[34]

However, since personality or personal elements in 'the abstract part' may become inconspicuous through mechanization as a basic process of 'organization', the hierarchy of managerial posts must be increasingly fractionalized, and then the original aim of any 'organization' becomes obscure for most of its members. In this sense, vertical DL is necessarily accompanied by such 'abstraction'. Thus, the machinery system in vertical DL has boosted the mass production of machine-like human beings, while it has constructed a generalized system of bureaucracy. As the function of vertical DL became relatively independent from that of original DL between machines, the waste part of personal economic activities might continue to grow by degrees.

Finally, we must examine the characteristics of DL during the second IR from a macroscopic viewpoint. The significant role of a national economy as a pillar of specification is particularly worthy of note in this period. Various branches of production and distribution, market systems, exploitation programmes of natural resources, and the state apparatus to support these activities became the constituent parts of a group of national economies and economic regions. Sometimes, a ruling national economy assumed leadership of the group and then constructed a global economic and political sphere of influence that might be called an imperial economy or an economic empire. A characteristic feature of the structure of macroscopic DL in the age of the second IR was so constituted that such a few global and powerful national economies continued to repeatedly divide the world market, which had originally been established as an economic framework of the Pax Britannica, and consequently competed and fought againt each other. Therefore, the latter half of the nineteenth century and the turn of the century have often been called 'the age of empire'.[35]

4

The structure of DL must be ultimately decided by specification, which means the totalization of production processes based on synthetic judgments and technological reasoning of human beings. This proposition may become extremely significant for the present age of the third IR. So, we will sum up the problematic situation of specification in this period.

As discussed in the previous chapter, at the beginning of the third IR, the concept of system suggested by cybernetics became a ruling social ideology that prevailed everywhere in the world. And then, the abstract and therefore constantly reificatory machinery system has

[34] *Ibid*., p.75

[35] 'The age' has been colourfully and ably described in Hobsbawm (1987).

taken on a key role in specification. In more detail, specialization or DL between concrete and tangible machines is regulated and controlled by abstract machinery (or an electronic computer as its representative form), which can also determine the relationship between machine and mankind or between human beings. As a result, the computer has occupied the leading position of abstract machinery, for it can carry out any operation such as recollection, judgment, and logical choice, and then execute every sort of application programme for human activities with self-control of its working speed and storage capacity.

On the other hand, a decisive role in the global development of DL during the latter half of the twentieth century has been fulfilled not by individual national economies, but by groups of 'transnational' profit-makers or 'capital'. The so-called conglomerates and the mass of international 'capital' have continued to break into various national economies and economic regions and moreover subordinate the power systems of these areas to their own private interests.

However, the progress of specification in this period has raised a couple of serious problems. First of all, is it possible for human beings to perform specification based on higher development of specialization or DL? Generally speaking, any specification ability is indispensable for artistic activity as well as business enterprise, but it may decline under certain circumstances. Extremely advanced bureaucratization can particularly hamper the growth of entrepreneurial imagination as a sort of specification ability. This point of issue may result in the question of whether human beings can continuously keep up with their own imaginary power or not. Then, we face the second problem. Can specification in science continue to exist? David Hilbert, the leading mathematician of his day, once talked about *harmonie préétablie* between Einstein's theory of relativity and Riemannian manifold, though he could not give any adequate reason for using this term of Leibniz.[36] Perhaps it should be interpreted as a representative type of scientific specification, where physics and mathematics were skillfully composed by means of tensor calculation. The same reasoning may hold good for the 'harmony' between Hilbert space theory and quantum mechanics. However, scientific specification must increasingly accelerate specialization owing to the technologization of science, which was mentioned in the previous chapter, until at last, the mechanization of science arises from the situation of excessive and discrete specialization. In this sense, it seems that the prospects for specification in science are fading away.

Now, we will turn to the problem of social DL in the twentieth century, and look at its relationship with socialism and bureaucracy from a macroscopic viewpoint. As can be inferred from the above distinction between horizontal and vertical DL, rapid growth of DL brings about both a vertical rank structure or social equality in human relations and a relationship between man and machine or between machines. The rank structure with command/obedience relations may be reduced to a system of bureaucracy in which the concept of equality is almost repudiated and only a rigid ordered relationship can be emphasized. Presumably, exchange of the vertical order for the horizontal relation in this system might have produced an image of socialism based on social equality. But in fact, the reverse process took place in most socialist states of the twentieth century.

In order to make clear the point of issue, we will sort out three types of mixed structure composed of capitalism, socialism, and bureaucracy. The first type may be called bureaucratic

[36] See Hilbert (1935).

capitalism in which capitalist economic structure becomes dominant while bureaucracy remains subordinate. It can be typically found in England of the nineteenth century where the ideology of a night watchman state (*Nachwächterstaat*) structurally checked the swelling of government officials and institutions, though this might be only the case with England or France.

The second type is rather unrealistic or idealistic, and might be equivalent to what Dickinson called 'liberal socialism'.[37] Oskar Lange once tried to theoretically construct such 'socialism' on a model of economic experiment in Socialist Poland.[38] However, his idea was not entirely feasible under the real regime of socialist economy. The third and the most realistic type of mixture can be represented by two kinds of bureaucracy—capitalist and socialist. In this case, a heading such as 'capitalism versus socialism' may be meaningless, for bureaucracy occupies the dominant position in this mixture, while capitalism or socialism can only play a subordinate role. Indeed, bureaucracy as an independent structure historically discharged several important functions in ancient societies long before the emergence of capitalist or socialist regimes. Thus, it is advisable to assume the predominance of bureaucracy over capitalism and socialism within any national framework. In particular, socialism has almost sacrificed its ideals to the self-preservation of a bureaucratic system.

As examined in the previous chapter, the organization of bureaucracy as the structure of machinery has increased in malleability since the second IR. But at the same time, its circularity has increased to such an extent that its 'initial input' has been lost sight of. Then, bureaucracy may have a tendency to become an ossified circular system, which has been illustrated from historical experience in Eastern countries such as Russia, China, and Japan. On the other hand, the 'initial input' of bureaucracy has often been provided by an arbitrary decision of a commanding power, which can promote various political and economic interests. Amongst others, the profit-making interests of capitalist enterprises have had a great and growing influence on the historical movements of bureaucracy. However, the structure of profit making or 'capital' itself is to be analyzed in the next chapter.

V. *Structure of Profit Making*

1

Marx called every alienated form of profit making 'capital'. It may be regarded as a sort of system or machine—a 'specification machine'—with moneyed input and output that can be connected by the profit-making operator. To start with, we will analyze the structural characteristics of 'capital' in the first IR.

In this period, 'capital', especially 'industrial capital', expressed the typical structure of profit making. The structural analysis of profit making in industrial activities was just the main theme of Marx's classical work *Capital*. However, the concept of 'capital' must not be limited to that arena, for the historical pursuit of profit or monetary advantage has long been undertaken by 'abstract capital' such as usury and commerce. Moreover, the survival condi-

[37] Dickinson (1939), p.26.
[38] See Lange (1938).

tion of 'industrial capital' that non-negative profits can always be guaranteed was not actually and continuously fulfilled in the age of the first IR. Thus, the category of 'industrial capital' cannot be used as a major tool for the analysis of the profit-making structure in this period. For that purpose, we must introduce another theoretical category.

Now, we will consider a finite game played by capitalists or entrepreneurs who are completely divided into two groups: 'comrade' (I) and 'foe' (II). Let a space where competition among them is carried on be denoted as Γ. It is a set of several elements that are also sets. We assume that these sets comprise the elements of land (L), workers or laborers (W), capital goods (K), available monetary resources (M), realizable prices (P), and exogenous (outer-economic) constraints (E). Then, Γ can be described as {L, W, K, M, P, E}.

Let the arbitrary elements of L, W, K, M, P, and E be denoted as ε_ι ($\iota = 1, 2, ..., m$), and I and II reciprocally choose only one element ε_ι from Γ. Then, we can obtain two series of chosen elements:

$$\text{I} \quad \varepsilon_1, \varepsilon_3, ...$$

$$\text{II} \quad \varepsilon_2, \varepsilon_4, ...$$

The number of indices shows the order of choice. When one of these series represented by a direct product $<>$ belongs to the subset of Γ, that is,

$$<\varepsilon_1, \varepsilon_2, \varepsilon_3, ..., \varepsilon_m> \in \Gamma_1 \ [\Gamma_2],$$

we say that I[II] has 'won'. If the 'function' of I[II]'s choice in consideration of II[I]'s choice is denoted as $\Phi_{2\iota+1}[\Phi_{2\iota}]$, we have

$$\varepsilon_{2\iota+1} = \Phi_{2\iota+1}(\varepsilon_2, ..., \varepsilon_{2\iota}), \text{ and } \varepsilon_{2\iota} = \Phi_{2\iota}(\varepsilon_1, ..., \varepsilon_{2\iota-1}).$$

Thus, the sequence of $\Phi_{2\iota+1}$ or $\Phi_{2\iota}$ represents the 'strategy' of I or II. If I chooses elements by its own 'strategy' independent of II's choice, and can 'win', that is,

$$<\varepsilon_1, \varepsilon_2, \Phi_3(\varepsilon_2), \varepsilon_4, ...> \in \Gamma_{\text{I}},$$

or, parallel to this, II can secure 'victory', that is,

$$<\varepsilon_1, \Phi_2(\varepsilon_1), \varepsilon_3, ...> \notin \Gamma_{\text{I}} \Leftrightarrow <\varepsilon_1, \Phi_2(\varepsilon_1), \varepsilon_3, ...> \in \Gamma_{\text{II}},$$

And it can be assumed that a 'sure way to win' always exists. In other words, the law of the excluded middle

$$(<> \in \Gamma) \vee (<> \notin \Gamma)$$

can be found at all times. Then, we can assume the sequence of Γ_κ(κ: index of time), which shows the existence of a realized 'sure way to win':

$$<\Gamma_1, \Gamma_2, ..., \Gamma_g> \in \Gamma$$

It may be called the 'historical sequence of profits' where the index of Γ_g indicates a certain time of the historical present. Since no 'capital' can exist when this (continuous) game is lost, $\Gamma_{\text{I}} \cap \Gamma_{\text{II}} = \phi$ holds constantly. Moreover, as the historical sequence of profits cannot be uniquely determined, most famous economists have not been able to provide any sufficiently explanatory tools or theories. There only exist diverse economic explanations of profit through such factors as 'alienation', 'surplus labor', 'new combination', full cost, or mark-up. Especially in the transition period from the first IR to the second IR, Marx advocated the exploitation theory of profits, but it was only a tool for describing a certain behavioural pattern of early 'industrial capital'.

Generally speaking, the historical sequence of profits may suggest that it has an irreversible character and cannot converge to a fixed point or level of 'equilibrium'. In that sense, 'capital' or a group of 'capital' builds up a unified global open structure or more briefly, a capitalist structure. Oliver Cox, an American sociologist, called it 'capitalism as a system'.[39] In the analogy of a topological structure with open sets, it may be called an open structure that comprises 'inner' elements with no 'boundaries', but 'peripheries' where various economic communications take place. Any capitalist structure tends to find a foothold for profit making on such 'peripheries'. On the other hand, there can be a closed economic structure such as household economy or planned economy inside and outside the sphere of a capitalist structure. It includes its 'boundary', which often performs the role of barrier against the penetration of capitalism. In fact, every capitalist structure has continued to break through such 'boundaries' or barriers, and further extended the 'peripheries' so as to spread a net of capitalist communication all over the world. Any closed states, nations, and peoples included in the network must be destroyed, and any forms of resistance against capitalism are destined to be overpowered by a capitalist structure. It has created a peculiar hierarchy to maintain its own structural stability. Cox assumed such a descending order of dominance as follows:

Leaders > Subsidiaries > Progressives > Dependents > Passives.[40]

Since the structural instability of this order may be induced by the existence of plural 'leaders', there can be a strong tendency toward the establishment of such a one-leader 'peaceful' rule as the Pax Britannica or the Pax Americana. Although replacement of members with 'subsidiaries' or below cannot cause any grave disorder, any external or independent economic structure like that of socialism may become a serious menace to a capitalist structure.

Incidentally, we should make some comments on the difference between the notion of capitalist structure and that of static and equilibrating capitalism. The latter does not include any time path of capitalist evolution, while the former may be a diachronic concept that can trace the route of the historical sequence of profits. Since the time-space coordinates of the sequence can be determined *ex post* within the above 'boundary', they cannot be reached from anywhere in a capitalist structure. On the other hand, individual 'capital' as an element of such a structure always tries to create its own exclusive sphere—the 'neighborhood'—of profit making and come closer to the 'boundary'. Therefore, any capitalist structure is able to keep its 'purity' by means of swallowing any outside 'impure' factors. The age of the first IR was the gestation period of such a capitalist structure when Great Britain developed a universal system of dominance that is often called the Pax Britannica. And the historical sequence of profits accompanied by the growing capitalist structure in the same period was to be mingled with another sequence of national economies in the coming age.

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[39] See Cox (1964).
[40] *Ibid*., pp.4-7.

2

In the age of the second IR, most 'capital' as a vehicle for making profits assumed its peculiar forms of organization, that is, those of joint stock company. Then, interests communities of 'capital' and nation-states were created in several fields of the world. As a result, the interests of profit making and those of national economies were often intensively combined.

In this period, a great amount of large or small 'capital' appeared as a set of joint stock companies with limited liability. Such undertakings as railway or banking with a high grade of 'publicity' had already introduced the legal form of joint stock organization, but during the second IR, many giant enterprises as well as small family firms took advantage of this form of corporation. In accordance with this tendency, company law in advanced capitalist states was progressively revised and amended to promote the spread of joint stock companies. However, at the same time, several private partnership companies also played a significant part in the capitalist structure of the nineteenth century. For example, a group of merchant bankers in the City of London continued to be an economic and financial pillar of the Pax Britannica.

In the same period, the collusion between 'capital' and state became remarkable, for the former made use of state power in many phases of economic activity and the latter exploited the abundant economic resources of a capitalist group from the viewpoint of national economy. Especially between the Wars, the positive and interventionist economic policy advocated by such government economists as Keynes, Schacht, and the like was designed to provide investment opportunities for 'capital' and to alleviate the economic depression. The penetration of state power into various economic spheres rapidly developed as a result of the growth of military production in the Second World War.

The root of such collusion may be found in the sequence of national economies, which can often intersect the historical sequence of profits. Since each national economy is supposed to be a player of the same game as in the previous case, a similar metaeconomic investigation into the present situation can be conducted.

Following the example of F. List, we may call any collection of language (λ), ethnos (ε), system of law (σ), people or nation (ν), religion of a people (ρ), and political system (π) the 'set of nationality', which is designated as

$$\Sigma=\{\lambda, \varepsilon, \sigma, \nu, \rho, \pi\}.$$

Let all national economies be divided into 'comrade' (I) and 'foe' (II), and the result of choice of these elements be denoted as $N_\iota \in \Sigma$(ι: the order of choice). Then, the following sequences of choice can be obtained:

$$\text{I} \quad N_1, N_3, \ldots,$$

$$\text{II} \quad N_2, N_4, \ldots.$$

If the 'function' of choice is designated as ψ, the existence of I's 'sure way to win' at time τ can be shown by the direct sum

$$< N_1, N_2, \psi(N_2), N_4, \ldots > \in \Sigma_\tau^{\text{I}}.$$

What is the meaning of this condition? It means that the 'strategy' of a 'comrade' can be realized by any military or political apparatus and the 'comrade' can therefore freely choose any elements from its set of nationality in order to construct so strong a national economy or a group of national economies that it is able to build up the freest social DL of all national economies in the world. On the other hand, what is the meaning of 'loser' in this game? National economies other than 'winners' or members of 'comrade' belong to a group of 'losers' or 'foe'. They certainly do not become extinct, but must subordinate to the 'comrade'. Consequently, they cannot make free choice from elements of a set of nationality and have to accept any distorted or unbalancing structure of their own economic systems. Thus, a certain time path (a direct sum) with a temporal order can be traced among such a constellation of national economies, which must continue a never-ending struggle in world history as if playing a game. It may be called the sequence of national economies, which is formally represented as follows:

$$< \Sigma_1^{\mathrm{I}}, \Sigma_2^{\mathrm{I}}, \ldots, \Sigma_\tau^{\mathrm{I}} > \in \Sigma^{\mathrm{I}}.$$

In the same period, another situation became remarkable. The nature of the game among 'capital' and national economies greatly changed owing to the emergence of the ASD mentioned in Chapter III. The following comment by Michel Lagache is extremely noteworthy:

> The homeostatic mechanism of real society and politics may easily break down the monopoly of information by a ruling social class. In other words, a game of marked cards can be played there.[41]

As newly arranged capitalist and nationalist games were appearing successively and another game that might deny the existing game was to come on the same stage, the capitalist structure became increasingly complex and sometimes extremely stiffened. In fact, Lagache properly pointed out that a mass society may not be more homeostatic than a small community.[42]

Clearly, in the age of the second IR, the mutual involvement of two kinds of 'sequence' created a multiplicity of realities in the world. Since the 1880s, several powers of the world continued to struggle for dominance of the capitalist structure and constructed an unstable oligarchy of leading national economies. Such a situation at the turn of the century was often called 'imperialism'. And it may be widely known that many types of socialism and nationalism appeared as anti-imperialistic movements. However, between the Wars, the sequence of national economies utterly faded away in consequence of intricate nationalistic movements. Not until postwar—particularly after the Cold War—did this sequence revive with the economic and political supremacy of USA, which also became a ruling power of the capitalist structure. As a result, the system of capitalism again demonstrated a tendency toward globalization and concentration under American hegemony all over the world.

3

After the Second World War, the control of state powers by 'capital' advanced increasingly and globally. It penetrated even the sphere of socialist countries in the so-called communist bloc. As Galbraith suggested, it reflected a tendency of various social organizations

[41] Lagache (1950), p.418.
[42] *Ibid*., p.418.

to converge into a single bureaucratic system.[43] In this trend, a new 'human-machine' called a technocrat emerged as a leading player among a homogeneous group of human beings who had lost their humanity and operated as a machine. And then it was to control and regulate public powers for the purpose of profit making.

As far as any state can provide economic opportunities for investment and control the aggregate demand of a given national economy, this capitalist system of technocracy may be on safe ground. But Schumpeter had the serious misgivings that it is not always able to create innovative ways and means of economic development, still less offer any promising opportunities for profit making.[44] Rather, every 'normal' form of technocracy, which mostly grants the license of a capitalist structure, must contribute to the profitable exploitation and destruction of physical nature, artificial nature, and human nature. Conversely, in the future, these kinds of nature that have suffered irreversible changes under the iterating process of metabolism will create an extremely hostile environment for the survival of mankind and its companion animals.

There is another factor that may control the course of capitalism of the third IR. It is the manifestation of a tendency that may be called 'the principle of social uncertainty'. It can be defined as the tendency that any forecast of future social trends has repercussions on the present state of a society and then introduces uncertain and stochastic elements into it. This 'principle' was suggested by Karl Popper as follows:

> We are faced, in the social sciences, with a full and complicated interaction between observer and observed, between subject and object. The awareness of the existence of tendencies which might produce a future event, and, furthermore, the awareness that the prediction might itself exert an influence on events predicted is likely to have repercussions on the content of the prediction; and the repercussions might be of such a kind as to impair gravely the objectivity of the predictions and of other results of research in the social sciences.'[45]

Although Popper himself discussed such 'repercussions' in relation to the 'objectivity' of scientific research and forecast in society, his proposition may surmount the constraints placed by the ambiguous concept of 'objectivity', and become linked to a far-reaching problem. A universally important result of 'the principle of social uncertainty' is that any significant action of predicting and telling the future of existing societies could have various repercussions on the present social orders, and therefore, as the discrepancy between this action and the present atmosphere of society becomes greater, the *status quo* can hardly be preserved. To express it more schematically, it is the hypothesis that the more the act of prediction becomes deterministic, the more the present situation becomes uncertain.

Now, we will take up a topic concerning the trend of capitalist society in order to clarify the meaning of this 'principle'. Marx expected the advent of the socialist system through cooperation or in a cooperative society and then 'predicted' the realization of an 'ideal' communist society that cannot coexist with any capitalist society. His idea did not suggest a structural change of capitalism, but the radical breakdown and transformation of capitalist

[43] See Galbraith (1978).
[44] See Schumpeter (1950).
[45] Popper (1957), pp.14-15.

society. If it had not had significant influence on many peoples of the world, the real capitalist society of which he himself became a member would have had enjoyed higher 'stability' and more 'conservativeness'. But his 'prediction' gave too strong an impulse to existing capitalist and other communities to cause not the least deviation of real capitalist society from its 'ideal type' and its permissible margin of distortion. Essential elements of a capitalist society such as free competition, trade union, and the idea of freedom were sometimes regarded as those that can intensify social uncertainty because of their 'repercussions' on the existing social order. Consequently, the encouragement of 'moderate' competition, 'non-radical' trade unions, the education of 'obedient' workers, and the disguised restriction of free speech and action under the pretext of 'publicity' are enforced and carried out by various assorted instruments of the state power, which can be set in motion with the strong urging of the existing capitalist community. In opposition to this succession of policies that might destroy the ideal and indispensable background of capitalism, some economists have constructed an economic model on the assumption of a 'cheap government' or the superiority of endogenous law, but could not provide any counterbalance to the trend of the real economic world. Rather, the 'repercussions' of Marx's 'prediction' seem to have given decisive assistance to the self-destructive policy making of capitalists and their fellow politicians. Schumpeter, though from a different angle, expressed a profound vision on the paradoxical nature of capitalism. According to him, a pure capitalist society lacks the ability to establish innovation that is indispensable to capitalism, for the ability can be created only through the personality of the pre-capitalist or trans-capitalist character.[46] In other words, as capitalist society so developed as to transform the state power to its own protective apparatus, it has produced an 'obedient' and mediocre mass through the school and social education, and consequently deprived men of creative and imaginative character who also might have a noble and liberal personality. After all, capitalist development itself may have continuous and serious 'repercussions' on the existence of capitalist society.

Again, towards the end of the twentieth century, the capitalist structure regained its strong vital power. As a matter of fact, by the 1990s, almost all anti-capitalist movements had disappeared, while the global capitalist structure resumed under the despotic control of USA (the Pax Americana). Major national economies of the world began to reconstruct a hierarchical order appropriate to that structure and at last, 'capitalism as a system' revived so remarkably that the historical sequence of profits might become extremely competitive, uncertain, and risky. The capitalist structure may continue to perform an irreversible movement that cannot be controlled by anyone, and to create only a human-machine type suitable for it. The movement often mercilessly drives out such disturbances and negative factors as socialism, religious movements of minorities, ecoactivities, and protection of human rights, and yet incessantly regenerates the capitalist structure as a 'clopen' set or an 'autopoiesis' system.[47] Perhaps this iterating, but irreversible movement will last until the total destruction of mankind.

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[46] See Schumpeter (1950).

[47] See Luhmann (1984), SS.61-62.

VI. *Algebraic Structure of Industrial Revolutions*

1

Hitherto, we have divided world economic history from the latter half of the eighteenth century to the present day into the three distinct periods of IR and then described several characteristics of each period. As a result, we could find the universal structure of IR composed of four elementary structures, that is, those of technology (T), machinery (M), division of labor (D) and profit making or capitalism (C). We may call it 'the structure of tetrad connation' or, more briefly, the 'tetrad'. We will make use of this concept in order to put together all the arguments that have been brought forward in the previous chapters.

In the same manner as Thomas Kuhn constructed his arguments about scientific revolutions through the word 'paradigm', we can describe the history of industrial revolutions as a transformation process of NSP (normal structure of production). From the viewpoint of the 'constructive structure' mentioned at the end of Chapter III, NSP can be constructed of the above-mentioned tetrad. To give a more detailed account, we will try to discriminate formally between four structures above on the basis of two complementary terms, that is, powers of production (abbreviated below to PP) and productive social relations (abbreviated below to PSR); then

T can be considered as the PP of PP,
M can be considered as the PP of PSR,
D can be considered as the PSR that produces PP,
C can be considered as the PSR that produces PSR.

Now, let us establish a correspondence between the set of two elements {PP, PSR} and the set of four elements {T, M, D, C}. For two elements $\alpha, \beta \in$ {PP, PSR}, we shall use α (PP or PSR)$\rightarrow\beta$ (PP or PSR), which stands for 'α produces β', and use the notation '$\Rightarrow$' for expressing the occurrence of T or M or D or C. Then, the above definitions can be represented as follows:

$$(1)\ \mathrm{PP}\rightarrow\mathrm{PP}\Rightarrow\mathrm{T},$$

$$(2)\ \mathrm{PP}\rightarrow\mathrm{PSR}\Rightarrow\mathrm{M},$$

$$(3)\ \mathrm{PSR}\rightarrow\mathrm{PP}\Rightarrow\mathrm{D},$$

$$(4)\ \mathrm{PSR}\rightarrow\mathrm{PSR}\Rightarrow\mathrm{C}.$$

Since the notation '$\rightarrow$' can be regarded as a sort of the 'law of composition', the following chart of four operations is drawn:

	PP	PSR
PP	T	M
PSR	D	C

Any two elements of the set {T, M, D, C} can be associated with each other to bring about significant results that will be examined in the next section. Here, we will briefly formulate the successive process of IRs or the transformation process of NSP.

When some 'abnormal elements' mix with a certain NSP, they are usually removed by social, especially economic and political, forces that are external to the sphere of production. But if the process does not operate properly, several 'abnormal' elements will survive and form the core of an 'abnormal' structure of production. For example, some monopolistic elements played such a role in the capitalist structure of the second IR. When the 'abnormal' structure eventually succeeds in the exploitation of protective social forces, it will become a formidable 'rival' to the existing NSP, and transform itself into so powerful a social structure as to deny at a stroke the existence of the latter.

2

Next, we have to think about possible binary relations that are formed out of any two elements of the tetrad.

First of all, we can find the following three elementary relations with the symbol of 'association' $\cdot$ and the arrow $\Rightarrow$ indicating the result of 'association':

(1) $T \cdot M \Rightarrow M$: The association between T and M produces M, that is, technology is so mechanized as to create technocracy;
(2) $D \cdot M \Rightarrow M$: The association between D and M produces M, that is, the division of labor is so mechanized as to create bureaucracy or a general structure of dominance and then cause the diffusion of MG (*la mecanographie*);
(3) $C \cdot M \Rightarrow M$: The association between C and M produces M, that is, capitalism cannot exist without machinery, and its progress is dominated by the development of machines, which is necessarily accompanied by several types of monopolistic competition for market and information.

Then, the following three secondary relations can be added to these elementary relations:

(4) $C \cdot D \Rightarrow C$: Capitalism promotes the division of labor, but the reverse is not necessarily true;
(5) $C \cdot T \Rightarrow C$: Technology is indispensable to the existence of capitalism, but the latter does not have the innate power to create the former;
(6) $D \cdot T \Rightarrow D$: Technology has stimulated and constructed the division of labor, but the latter has had nothing to do with the former either in logic or in reality.

If we assume commutativity of the associative law and the idempotent character of self-association, the sixteen pairs of association may be possible. They construct the following association (multiplication) table:

	M	C	D	T
M	M	M	M	M
C	M	C	C	C
D	M	C	D	D
T	M	C	D	T

As the table shows, the associative relationship of the tetrad can be represented by a semi-lattice of order 4. This algebraic structure may reflect the universal dominance of machinery in the real and ideal world. So, there has been *terminus ad quem*, whence we must start further metaeconomic thinking.

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