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ARTICLE

From the optimal planning theory to the theory of the firm and the market: a quest in Masahiko Aoki's early works

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Abstract This paper highlights Masahiko Aoki's theoretical quest in the 1970s. The subject he first chose was the design of processes to find the solution maximizing a given objective function of a large-scale economic organization. So long as the information on technologies is scattered among individual production units, the optimal solution must be approached through successive communication between the central planning board and these production units. In his first book (1971), the optimal planning theory is considered to be an analytical tool for the search of a more desirable social system than existing systems in terms of both efficiency and morality. However, in the second book (1978), this theory is applied to describe prototype models of adjustment mechanisms working in the actual capitalist system: one is "the quantity adjustment mechanism" in which parts of inputs are assigned to production units based on a comparison of their shadow prices and the other is "the dual adjustment mechanism" in which each production unit increases production in response to excess demand and raises price when it is lower than marginal cost. Aoki's theory of the capitalist firm starts from the perception that the firm organization is an institutionalized form of the quantity adjustment mechanism. It is also accompanied by a theory of the market being an institutionalized form of the dual adjustment mechanism. The latter contends that successive corrections of short-term disequilibrium in product markets due to inevitable errors of demand forecasts by individual firms involve underemployment of durable capital goods and labor. Although these developments of Aoki's view are less known than his game-theoretic comparative analysis of the firm organization in later works, they are worth receiving more attention as an ambitious challenge to construction of the general theory of the matured capitalist system.

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1 Introduction[1]

Masahiko Aoki (1938–2015) is widely acknowledged as an originator of the game-theoretic firm theory and the comparative institutional analysis. However, his first book as an economist[2] *The Economic Theory of the Organizations and the Planning* (Aoki 1971a, hereafter referred to as *Theory*) is not a study on firms. It tackles the problem of how the planner of an organization should set the procedure of information exchanges with its members to find the allocation of productive resources maximizing a given objective function of that organization. Such information exchanges are required, because knowledge on the technological possibility of production is dispersedly held by individual production units. In *Theory,* Aoki does not hesitate to express his normative criticism against the contemporary capitalist system dominated by giant corporations, as well as the Soviet socialist system suppressed by an all-embracing bureaucracy. He hopes that the analytical framework of optimal planning theory provides some clues for search of a more desirable society in terms of both efficiency and in morality.

A transition of Aoki's research subject from the optimal planning theory to the theory of the firm was accomplished in his second book *Model Analysis of the Firm and the Market* (Aoki 1978, hereafter referred to as *Analysis*). One of the key terms in this book is *quantity adjustment mechanism*. In *Analysis*, this term represents a mechanism in which parts of goods are assigned to users based on their shadow prices in individual production processes. The first three chapters of *Analysis* restate the essence of the analysis in *Theory* with the aim of confirming superiority of this mechanism to the price adjustment mechanism under a non-convex economic environment. Its fourth chapter characterizes the firm organization as an institutionalized form of the quantity adjustment mechanism.

Such a development of the argument in *Analysis* was accompanied with turnabouts of Aoki's viewpoint in several respects. It is evident that the center of his concern shifted from the search of a desirable system to exploration of the *existing* system. Each planning process is now considered as "a prototype model" of adjustment mechanism working in the capitalist system. As to the theoretical approach, in the preface of *Analysis,* Aoki expresses "reflection" that "the analytic-technocratic

[1] This article is one of a series of papers commemorating a great evolutionary economist Masahiko Aoki. See Volume 14, Issue 2 of this journal.

[2] More precisely, before this book Aoki had already published a book titled *Formation of the State Monopolistic Capitalism in Japan* in 1960 (under the pseudonym Reiji Himeoka).

method" of *Theory* was "not so fruitful". According to his renewed view, distribution of the collective benefit produced by efficiency of the mode of information exchanges inside an organization induces its members to take part in these exchanges. In this way, the collective purpose of an organization is formed through such "coordination and integration of each member's individual motivation" (Aoki 1978: ix). More concretely, Aoki presented a model in which the firm's goal is formed through a collective bargaining between employees and shareholders under mediation by the executive manager.

Naturally, the theory of the firm is inseparable from the theory of the market as a place, where firms interact each other. *Analysis* is also a treatise on the functions of the market. Taking a Keynesian position that the short-term adjustment of the markets lacks the mechanism to attain full employment of durable capital equipment and labor, Aoki further argues that the existence of unemployment and unused capacities is required so that the balance of production and demand is not hampered by unavoidable forecast errors. However, partly because Aoki himself did not further elaborate this point in later works, his market theory has not yet received the attention it deserves.

The purpose of this paper is to revisit these Aoki's theoretical quest from *Theory* to *Analysis*. Section 2 states that some historical and personal backgrounds under which Aoki chose the theory of optimal planning as his first research subject. Section 3 addresses characteristics of his theoretical approach in construction of the models of the optimal planning. Finally, Sect. 4 elucidates development of Aoki's theoretical standpoint in *Analysis* and reflect on its significance.

2 The optimal planning theory as Aoki's first subject

The optimal planning theory is a research field that formulates various alternative resource allocation mechanisms in the form of mathematical models and compares their features. Comparisons are made in terms of achievability to the (locally or globally) optimal solution(s), kinds, and quantities of information to be exchanged among members, and the consistency between the mode of information exchanges and the motivation of members. From the late 1950s to the early 1970s, Kenneth Arrow and Leonid Hurwicz led rapid development of this subject through their close collaboration as well as their respective contributions (Arrow and Hurwicz 1977). The name "the design of resource allocation mechanisms", given by Hurwicz (1973) to this subject, indicates that it does not accept existing social systems as given conditions. Rather, it tries to design new mechanisms which have more desirable features (at least in some respects), and thereby "enlarges our field of vision and helps economics avoid a narrow focus on the status quo, whether East or West" (Hurwicz 1973: 27).[3]

[3] According to Hurwicz, "in a sense" Utopian socialists were "the first systems designers" in the realm of society. He thinks it "unfortunate" that Marx, Engels and their followers neglected the problem of resource allocation in the socialist system on the ground that the transition to this system is "historically inevitable" (Hurwicz1973: 3).

An important prelude to this theory is the socialist calculation debate which began with Ludwig von Mises' celebrated paper contending the impossibility of rational economic calculation in the socialist economy (von Mises 1935). Just after Friedrich Hayek published a famous collection of papers on this subject by various writers including Mises and himself (Hayek 1935), Oskar Lange took part in this debate to defend socialism (Lange 1936, 1937). The point of Lange's argument is that by imitating the Walrasian *tâtonnement* (searching) process, the central planning board of the socialist state can attain the optimal resource allocation without directly solving a countless number of simultaneous equations defining equilibrium conditions.[4]

The rapid development since the 1930s of the general equilibrium analysis reached its zenith in the 1950s with the existence proof of the general equilibrium. The optimal planning theory was one of the attempts applying theoretical tools contrived by the general equilibrium analysis to resource allocation mechanisms other than the classical market mechanism. It is a "planning" theory, because the result of the resource allocation is evaluated by a single utility function.[5] However, it is distinguished from purely mathematical planning theories in that it presupposes the situation where the knowledge on the possibility of production is dispersedly held by individual production units and the planner cannot collect them in a direct (i.e., not coded) manner.[6] To find or approximate the optimal solution, the planner must give certain guidance to the production units and receive certain information from them. The way this information is exchanged distinguishes various planning processes.

The basis of the optimal planning theory was established by a celebrated paper of Arrow and Hurwicz "Decentralization and Computation in Resource Allocation" (1960). Agents in the model of this paper consist of three types: the *helmsman* (representative consumer) who chooses the final demand based on a single utility function, a large number of *process managers* who choose the combination of inputs and outputs under respective constraints on production, and the *custodian* who plays the role of the auctioneer. The task of planning is to determine the final demand and the combination of inputs and outputs of each process maximizing helmsman's utility under technological and supply constraints. Here, supply constraint means that the demand for each good cannot exceed the sum of its production and initial stock.

[4] The equilibrium conditions which should be satisfied in the socialist economy were examined in the 1900s by Pareto (1971) and Barone (1935). Pareto clearly pointed out huge practical difficulties in the collection of information required for setting equations as well as in the computation of these equations.

[5] Hurwicz justifies this assumption as "an introduction, at least, to the more complex problem raised by the presence of many individuals, each of whom judges the workings of the economic system in the light of his own utility function". He notes that "the difficulties of the simpler situations do not disappear when goal conflicts are introduced" (Hurwicz 1973: 4).

[6] Aoki criticizes the Turnpike growth model for the reason that it assumes that the planner can calculate the optimal path based on "centralized knowledge on the technological structure" (Aoki 1978: 244). Recent Ramsey-type models of optimal growth almost completely neglect the problem of *how the planner computes the optimal solution*. While planning processes analyzed by the optimal planning theory are imaginary processes that go on in logical time, the strong concern with the possibility to approach the optimal solution is undoubtedly one of the important merits of this theory.

As a way to compute the optimal solution through successive information exchanges between agents, Arrow and Hurwicz designed the following mechanism. (1) At each point of the process time, the custodian sets accounting prices (an evaluation index vector) of all kinds of good. (2) With these prices given, the helmsman chooses the final demand maximizing the difference between its utility and its expenditure evaluated by prices, and the process managers choose the combinations of inputs and outputs maximizing their profit evaluated by prices. Both of these agents report their choices to the custodian. (3) The custodian aggregates demand and supply of each good, and then, for each good, raises its price if the demand for it exceeds its production and lowers it in the opposite case.

These rules are based on Lange's idea, though the rule for the helmsman is somewhat modified to make the process stable. Arrow and Hurwicz (1960) indicated that the above process is equivalent to the procedure of calculating the saddle point (i.e., the optimal solution) of the Lagrangian function of a constrained maximization problem by the gradient method. They also proved that, under a strongly convex environment,[7] this process converges to the optimal solution through successive revisions of prices by custodians.[8] If the custodian is regarded as the central planning board of the socialist state, this result seems to allow an interpretation that a decentralized planning system can work at least under a particular environment. It should be noted, however, that Arrow and Hurwicz themselves carefully avoided endorsing such an interpretation.

Mathematical approaches to the planning were also developed in the Soviet Union from the end of the 1930s. Leonid Kantorovich applied linear programming to practical problems of resource allocation (Kantrovich 1965). However, political constraints hindered full-fledged development of his study. Adopting a similar method with Kantrovich, Tjalling Koopmans elucidated conditions for profit maximization under finite number of linear production processes (Koopmans 1951). As far as the existence of equilibrium is concerned, the general equilibrium analysis can be applied to the case of constant returns to scale. Thus, it successfully took in results of linear programming including those of Kantorovich and Koopmans and thereby provided rich tools for the optimal planning theory. A part of planning models in the 1960s, especially the model of János Kornai and Tamás Lipták (Kornai and Lipták 1965), which greatly influenced Aoki, assumes linear production technologies.

Let us turn our attention to the political and ideological situation in the 1960s. While disillusionment with Soviet (and Soviet-type) socialism was rapidly growing, the ideal of socialism had not yet lost its appeal to radical intellectuals including dissenters in Eastern Europe. Resolutely rejecting any kind of bureaucratic dictatorship, they still believed in the possibility of the decentralized and democratic socialist

[7] Roughly speaking, the strong convexity of economic environment means: (1) an 'average' of two different bundles of final goods gives higher utility than each of them (decreasing marginal rates of substitution), and (2) for any two different feasible combinations of inputs and outputs, there exists another feasible combination which is more efficient than their 'average' (decreasing returns to scale) (Aoki 1978: 29–30).

[8] Under assumptions which are more loyal to Lange's original formulation, stability of the process depends on the property of aggregate excess demand functions (Aoki 1971a: 69).

system ensuring individual freedom. In spite of its very high level of abstraction, the optimal planning theory was in concert with this spirit of the time. Since it looked at resource allocation mechanisms themselves as "a variable" of the social system, it was also immune to the conventional Marxist attack against "the bourgeois economics" for uncritically presupposing the capitalist system.

Taking these factors into consideration, it is not surprising that young Aoki was strongly attracted to the optimal planning theory. From his days as a distinguished student theorist of revolutionary Marxism (from the late 1950s to the early 1960s), he was free from the political authority of Soviet socialism and the international communist movement. After the defeat of the political movement against the US–Japan Security Treaty, Aoki entirely retired from politics and started to study modern economic theory.[9] It was in this period (around 1962–1963) that he knew about the above-mentioned paper of Arrow-Hurwicz. After more than 40 years, he recollected his original impression as follows: "The encounter with the paper by two professors felt like a revelation. A combination of the most fundamental concern on social organizations and precise logic—it was what I earnestly required after getting tired of illogical partisan controversies" (Aoki 2008: 98). As this recollection indicates, for Aoki the attraction of the optimal planning theory was not only its logical strictness, but also breadth of its theoretical scope beyond the market mechanism.[10] It gave him the possibility of tackling the task of exploring functions of actual and alternative socioeconomic systems by strictly analytical (and, therefore, non-partisan) methods.

3 The economic theory of the organizations and the planning[11]

3.1 Background motivation and setting of the problem

One of the notable features of *Theory* is that its takes an openly critical attitude toward the giant corporations in capitalist economies as well as the all-embracing bureaucracy in Soviet socialism. In the preface and the first section of this book, Aoki explains his motives behind subsequent abstract model analysis.

Neoclassical economics has clarified the conditions under which the market mechanism can accomplish effective resource allocation. Simply speaking, this mechanism works well if its economic environment satisfied strong convexity and markets universally exist for all kinds of resources. However, these conditions are "quite unrealistic" and attainment of the optimal market equilibrium is hindered by

[9] On Aoki's active participation in this movement, see his own recollection (Aoki 2008).

[10] In 1962–64 Aoki joined into the seminar of Yoshiro Tamanoi held at the University of Tokyo. While Tamanoi was originally a Marxian economist, in the 1960s he had already moved to a position searching an intersection of Marxian and modern economics. Especially, he was concerned with the socialist calculation debate and the linear economic theory (see Tamanoi 1966). It is highly probable that discussion in Tamanoi's seminar exerted some influence on Aoki's choice of subject.

[11] ***Theory*** was written in Japanese during Aoki's temporal return from the United State (Minnesota, Stanford, and Harvard University) to Japan (Kyoto University) during 1969–70.

factors such as externalities, economies of scale, and uncertainty. In this respect, the main contribution of neoclassical economics lies rather in "the negative aspect elucidating the limit of efficiency of the market economy". As a reaction to the limit of the market mechanism, various forms of collective action have been taken. In contemporary economies, they take forms of "interventions by the state into economic activities" or "hegemony of giant corporations". Yet, the experiment of economic planning in Soviet Russia has "secreted an arrogant group of planning bureaucrats" attempting to record and administrate all the production. Consequently, "a certain reform of its extremely centralized planning method is becoming an urgent task" (Aoki 1971a: iii and iv). Also in the capitalist economy, giant corporations tend to bring many people dissatisfaction and alienation, and deprive them of "creativity and initiative". In addition to huge political influences, giant corporations "come to exert monotonic, impersonal, and sometimes vulgar influences on social and even people's mental life through advertisements and other tools of demand control" (Aoki 1971a: 13).

From these observations, Aoki concludes that existing administrative mechanisms must be replaced by a new mechanism of "a community of more self-conscious individuals" accompanied with "their joint actions and participation to decisions". In light of this necessity, the traditional approach that regards existing economic systems as "a given condition" is no more satisfactory. What should be added to economics is "*the normative comparative economic theory* which treats administration-adjustment mechanisms of economy as a variable to be selected[12]" (Aoki 1971a: iv). The aim of *Theory* is to develop this theory. It challenges the problem "to find a way of resource allocation which can attain *the most desirable situation* from the social viewpoint". Because any normative judgement requires a certain clear criterion, this aim can be achieved by "developing a … framework to *design, compare, and select* processes which can realize a certain clearly defined purpose" (Aoki 1971a: 13, emphasis added).

In this way, Aoki sets a task to explore "various possible modes of information exchanges and decision makings inside a large-scale organization with a clearly defined purpose" (Aoki 1971a: 4). He admits that this task is limited in that it is not concerned with how people, each with different values, form a unified purpose. It simply treats the purpose of an organization as a given condition and pays attention to internal information exchanges required to attain this given purpose. The adjective "large-scale" entails the situation where knowledge on the economic environment (especially on technological conditions of production) is "held by individual units (of the organization) in a dispersive manner", and therefore, "concentration of the whole information into the central computation center is possible only with almost prohibitive costs or loss of precious information" (Aoki 1971a: 15–16). Under such a dispersive holding of knowledge on the environment, coordination of

[12] Another new field which Aoki thinks equally important is "*the public economics* which proposes collective actions intended to extend participatory democracy under existing economic systems" (Aoki 1971a: iv). The policy proposals made in the last section of *Theory* can be read as an attempt to taking a first step in this direction.

the decision on activities of each unit requires information exchanges in some coded form inside the organization.

Investigation of modes of information exchanges can be started from empirical observations of existing organizations. However, Aoki adopts a deductive, or what he calls "technocratic" approach and raises a problem "how a particular human group should design the process of information exchanges and decision makings to pursue a particular purpose under a given environment" (Aoki 1971a: 4). The framework of this approach is as follows. An organization consists of the *helmsman* who defines the purpose of the organization and a large number of *production units* each of which produces goods. Throughout *Theory,* the number and the inner structure of production units are all treated as given. The helmsman is assumed to play also the role of the *central planning board* (hereafter referred to as the CPB). This assumption implies that "the CPB knows the organization purpose and loyally carries out administrative functions to attain it" (Aoki 1971a: 76). Communication gives new information to the helmsman-CPB and the production units, but do not add any new information from the viewpoint of the whole organization.[13]

The optimal economic plan is a combination of each unit's activity maximizing the single utility function. A planning process is defined by the rules of successive information exchanges between the CPB and production units and the rules of the final decision making.[14] Each planning process is evaluated from such criteria as the possibility of approaching the optimal plan (stability), operation costs measured by the necessary amount of information exchanges (informational efficiency), and compatibility of the rules of process and motivation of individual units. The last criterion cannot be omitted, because "whether a process can work in a desired manner depends on the incentive for the production units to join information exchange process observing stipulated rules" (Aoki 1971a: 60). Motivations of individual members might depend on the distribution of benefit produced by the organization. Nevertheless, in *Theory,* the organization purpose is predetermined and not affected by the way of distribution among members.[15]

In his comparative examination of various planning processes, Aoki effectively uses "concepts and methods developed in mathematical planning and neoclassical (mathematical) economics". He stresses that full utilization of "analytical tools which modern economics has accumulated for long years" is "indispensable as a spring board for study and discussion of the comparative economics" (Aoki 1971a: v). Furthermore, for Aoki during that period, utilization of mathematical tools was

[13] In *Analysis* Aoki pays attention to formation of new knowledge through the diffusion process of existing knowledge, and states that "Hayek finds the merit of the market mechanism in the possibility of the change of knowledge which the mathematical comparative economic theory has excluded from its sight" (Aoki 1978: 258).

[14] In more detail, a planning process is defined by (1) the components of signals sent by the CPB to the production units, (2) the reaction rule to these signals imposed on production units, (3) the CPB's revision rule of signals to the production units, (4) the way to start communication, and (5) the way to make the final decision after the termination of communication (Aoki 1971a: 78).

[15] Admitting this independence in his model, Aoki points out that members of an organization might be paid by "mental satisfaction" or "a possibility of promotion" (Aoki 1971a: 105).

a weapon to resist politicization of the normative comparative economic theory. Undoubtedly based on his own experiences and observations, he puts it: "Lazy political and dogmatic speculations, which do not require intellectual creativity and analytical ability, will end with subordination of the theory of the choice of economic systems to inhuman political authority, not to moral authority pursuing humanistic relation of humans" (Aoki 1971a: v).

3.2 Traditional planning processes and their defects

After explanation of the analytical framework, Aoki picks up two "traditional" planning methods. One is "the material balance method", which is empirically the most well known, and the other is "the *tâtonnement* process", which is theoretically the most sophisticated (Aoki 1971a: 51).

In a simplified model, the material balance method proceeds as follows. (1) The CPB determines the tentative final demand of the helmsman and the tentative gross outputs to be produced by the production units. (2) Each production unit chooses inputs which can effectively produce designated gross outputs. (3) The CPB revises its plan of the gross outputs so that the net demand (the sum of the final demand and the intermediate demand minus the initial endowment) is satisfied. Since the CPB must give different directives to different production units, respectively, this planning process involves a tremendous amount of information exchanges. In spite of such a vast scale of communication, the process may not approach the optimal solution even under an infinite operation time. Furthermore, this method has "fatal difficulty in contriving a remuneration system necessary for smooth operation of the planning process" (Aoki 1971a: 60).

As already mentioned, the *tâtonnement* process imitating adjustment in the market was proposed by Lange and modeled (with some modifications) by Arrow and Hurwicz. Under a strongly convex economic environment, this process converges to the optimal solution. It is the most informationally efficient process in that the CPB sends only accounting prices of each good. Moreover, if the distribution of products to production units depends on their profits calculated by accounting prices, the rules of this process are consistent with the motivation of production units.[16] However, in Aoki's view, these properties of the *tâtonnement* process do not imply its absolute superiority for the following reasons.

First, its stability is crucially dependent on strong convexity of the environment. Under constant or increasing returns to scale, the optimal production of each production unit cannot be uniquely determined, and thus, the process loses stability. To avoid this difficulty, Arrow and Hurwicz (1960) contrived a modified process that has local stability under a weakly convex or non-convex environment. However, Aoki points out that the new rules imposed on production units are not compatible with their motivation. This indicates that "characteristics of a planning process are not independent from the environment it covers". He further infers that under a

[16] However, each production unit still has a motive to raise the prices of its outputs or lower the prices of its inputs by manipulating the report of its production plan (Aoki 1971a: 114).

non-convex environment, "there exists a kind of trade-off between various characteristics, and therefore, if you want to get a good characteristic in light of one criterion, you have to make sacrifice favorable characteristics in light of other criteria" (Aoki 1971a: 116).

Second, as Malinvaud (1967) noted, tentative final demands at a point of operation time do not fill the supply constraint unless equilibrium has already been attained at this point. Therefore, if the process is terminated before attainment of equilibrium, the tentative final demand at this point is *not feasible* and must be curtailed in accordance with the supply constraint. As long as it takes a long time for variables to approach the neighborhood of the equilibrium, this difficulty does not disappear even under a strongly convex environment (Aoki 1971a: 74).

Then, is it possible to design a planning process that has satisfactory properties under the linear or non-convex environment within finite operation time? As a pioneering work on this question, Aoki pays a great attention to a process presented by Kornai and Lipták (1965). Their model assumes that both the utility function and the production technologies are linear. The signals in which the CPB sends to each production unit are the assignments of inputs it can use for production. Under this constraint (and within technological possibility of production), each production unit chooses a production plan maximizing the amount of its sole product, and then reports shadow prices of inputs. While the revision rule of the assignments of inputs for each production unit is complicated, the point is that, for each input, the production unit giving the highest prices to this input receives more and the residual production units receive less. Although the Kornai-Lipták process converges to the optimal solution, it is not satisfactory from the informational and motivational point of view. Nevertheless, Aoki highly evaluates their basic idea that rational resource allocation is possible also by using quantity signals.

3.3 Two planning processes for an economy with increasing returns

With inspiration from the model of Kornai-Lipták, in *Theory* Aoki presents two original planning processes applicable to the non-convex environment. One is a process in which the CPB allocates investment funds, and the other is a process in which CPB designates the levels of supplies of commonly utilized goods (public goods). These models have a common feature in that the CPB controls activities which can be a source of economies of scale.

In the first model, production requires capital stocks as well as current inputs. Although the law of decreasing returns holds under given capital stocks, the possibility of economies of scale is not excluded with respect to the scale of capital stocks. The helmsman seeks to maximize the sum of utilities over a certain finite number of periods. The signals in which the CPB sends to each production unit consist of (accounting) prices of all goods in all periods and investment funds.[17] While prices are common to all units, investment funds are different among them.

[17] On this model, see also Aoki (1971b). For sake of simplicity, we omit evaluation of terminal stocks and foreign currency included in Aoki's original model.

Under the technological and financial constraints, each production unit determines its (tentative) production and investment plan maximizing the sum of profits over planning periods (payment for investment must be made exclusively from allocated funds). Having received these plans, the CPB calculates the amounts of goods available for final consumption and revises prices in each period by the equation $\dot{p}_i = u_i - p_i$, where p_i denotes the price of good i, u_i denotes marginal utility with respect to product i under the tentative final demand corresponding to tentative production plans at the point of operation time, and $\dot{p}_i$ denotes the rate of price change per time. Namely, the CPB judges that good i is in shortage if its marginal utility is higher than it price. As to allocation of investment funds, each production unit reports the CPB its marginal profit of investment calculated by "expected prices" equal to $p_i + \dot{p}_i$.[18] The CPB first compensates the effect of price changes, and then increases investment funds for each production unit if its reported marginal profit of investment is positive, and decreases it in the opposite case.[19] When the process of information exchanges is stopped, the helmsman's final demand and the production units' production and investment plans at this point of time are adopted as the final solution and carried out.

In the second model, the production units are divided into two groups: each production unit of the first group produces single public goods, whereas units of the second group produce private goods. Public goods are commonly used by all production units and the helmsman. Although the law of decreasing returns holds when supplies of public goods are fixed, the possibility of economies of scale is not excluded with respect to the scale of public goods. The CPB sends all the production units (accounting) prices of private goods. Furthermore, the CPB sends each unit of the second group the supply level of the public good to be produced. In light of these constraints, each production unit chooses its production plan maximizing its profit (no payment is required for utilization of public goods). On receipt of these plans, the CPB calculates the amounts of goods available for the final demand and revises prices of goods by the same rule as in the first model. As to the supply levels of public goods, each production unit reports the CPB its marginal revenues with respect to each of the public goods, and in addition, each public-good producing unit reports the CPB its marginal cost. Like the first process, these marginal revenues and marginal costs are calculated by "expected prices" (i.e., by marginal utilities). The CPB revises the supply level of each public good with the rate of change per time equal to the gap between the sum of marginal evaluation given to it by all of its users (including the helmsman) and its marginal cost. The final decision rule after the termination of the process is the same with the first model.

[18] Since "expected price" $p_i + \dot{p}_i$ is equal to marginal utility u_i, it implies that the CPB receives each firm's marginal profitability calculated by marginal utilities. In other words, it is equivalent to an assumption that the CPB informs each production unit the marginal utilities and orders it to calculate its marginal profitability by them. Aoki admits that to regard marginal utilities as expected prices is "a mere possible institutional interpretation" (Aoki 1971a: 155).

[19] Namely, "the CPB transfers the funds from projects with negative marginal profitabilities to those with positive marginal profitabilities" (Aoki 1971b: 277).

Aoki proved that, in both processes, the value of the objective function monotonically increases until equilibrium is attained, provided that each production unit calculates its marginal profitability or marginal revenue by marginal utilities of the helmsman (which are communicated as "expected prices"). Under increasing returns to scale, there can be multiple equilibria including ones that are not the global optimum. However, considering successive increases of the utility on the path to any equilibrium, it is highly probable that the process converges to at least one of the locally optimal solutions. Importantly, in these processes, a tentative solution at any point of time is feasible provided that the initial tentative solution is feasible. In addition to these properties, they have also relative informational efficiency. Indeed, the first process is informationally more efficient than the process in which the CPB sets rental prices of all capital goods in all periods they operate.[20]Likewise, the second process is informationally more efficient than the process in which the CPB sets and controls prices of all external effects exerted by public goods.[21] Furthermore, since production units are required to maximize their profits calculated by accounting prices (of private goods), both processes can be satisfactory from the motivational point of view.[22]

3.4 Policy proposals on production of public goods

The final section of *Theory* is devoted to some policy proposals on information goods and environmental pollution. These topics are directly related to the second model in the above subsection. Applying the result obtained from the analysis of this model, Aoki maintains that the allocation of (positive or negative external effects of) public goods should be separated from the payment of compensation for them. To reinforce this argument, he adds that establishing markets for public goods is practically difficult for many reasons. Because information is a kind of public good and inventions can be regarded as new information, he opposes the patent system assuring inventors monopolistic profit and advocates a scheme in which any inventions are freely used after registration and the inventors receives tentative payment (the possibility of future additional payment is not excluded).

The model of public goods production is applicable to the problem of environmental pollution if the production units producing private goods are interpreted as individual consumers. In this interpretation, consumers "produce" utilities from private goods and (positive and negative) public goods, and the helmsman's objective function takes these utilities as its variables (namely, it is a kind of social welfare

[20] This point is described more explicitly in Aoki (1978: 37).

[21] It is informationally the most efficient since the number of necessary signals is equal to the number of goods (prices of private goods and quantities of public goods). If the CPB sets prices of all external effects, it must distinguish them by (1) the production unit that causes a particular externality, (2) the public good through which this production unit affects other production units, and (3) the production unit that is affected by this externality.

[22] As long as public goods are freely supplied, the problem of "free riders" does not occur. Inversely, production units may attempt to obtain more supplies of public goods by inflating their evaluation (Aoki 1971a: 206).

function). On the possibility of solving the pollution problem through internalization of external diseconomies, Aoki remarks that "it is almost impossible to determine the admissible limit of pollution through spontaneous markets (negotiations)" (Aoki 1971a: 227). Thus, the public authority must either set the admissible limit of pollution or play the role of the market in a form of taxation on polluters or payment of subsidy to polluters. In the latter policy, reduction of pollution to the admissible level is intended to be attained through economic calculation of the agents involved.

The choice between taxation and subsidy depends on the value judgment on resultant income distribution. As to this choice Aoki supports taxation on the ground of "my empirical recognition that polluters gain relatively high portion of national income" and "my subjective standards of value preferring more equal income distribution" (Aoki 1971a: 227–228). At the same time, he notes that taxation does not necessarily induce polluter firms to curtail the level of pollution (since what firms are concerned about is reduction of *total* cost). Therefore, eventually, Aoki proposes direct regulation of the admissible limit and other relating policies including compensation to people affected by pollution. However, he strongly objects to carry out these policies in a form of unitary control by the central government. In his opinion, they must be entrusted to local governments, for no matter how excellent bureaucrats are, "they cannot decide everything from the height of chimneys to the compensation to asthmatics considering the interests of residents of local communities as well as geographic and technological variations" (Aoki 1971a: 230).[23]

Deep interest in a desirable social system and critical stance towards existing systems are characteristic of his works in the early 1970s. In one of them, Aoki sketched a comprehensive vision of "a multidimensional and decentralized system" which satisfies Rawls' two principles of justice and ensures "unique development of individual personalities". It is worth noting that there he states that capital investment should be placed under "broader collective management" (Aoki 1973: 42).

4 Theoretical development to the theory of the firm and the market[24]

4.1 Comparative economic mechanisms

Analysis consists of three parts: the first part is a restatement of problems dealt in *Theory* from new perspectives. Its introduction starts from an argument about "large gaps" between the "stylized Japanese economy" (J model) and the Walras model which is standard in modern economics (W model). The task of *Analysis* is to explain "collectivistic actions" embodied in firm organizations not by "frictional factors" but by "methods of traditional economic analysis" in harmony with "selfish

[23] Aoki remarks that functions of the central government in this field are to be limited to mediation of conflicts among communities and intervention to communities adopting too egoistic policies (Aoki 1971a: 231).

[24] Like the first book, this book was written in Japanese when Aoki was at Kyoto University, and has not yet been translated into English.

profit-seeking motivations peculiar to the capitalist system". While in later works, "the J model" comes to represent a model formulating peculiarities of the Japanese economy; in *Analysis,* Aoki says that "features of the J model are not characteristics peculiar to the stylized Japanese economy, but rather more or less observable features in any matured capitalist market systems" (Aoki 1978: vi, 4–5). Here, Aoki pursues elucidation of the general features of contemporary capitalism.

In *Analysis,* Aoki refers to the optimal planning theory as "the comparative economic mechanisms theory". Now, this theory is used to extract "prototypes" of mechanisms institutionalized in various forms in actual capitalist economies and to specify the environmental conditions under which they work adequately. More in detail, the prototype model of the Walrasian price adjustment mechanism is compared with the prototype models of two non-Walrasian mechanisms: the quantity adjustment mechanism and the dual adjustment mechanism. This comparison clarifies unique reasons for the existence of these alternative adjustment mechanisms in the actual capitalist economy. Looking from "the form by which typical agents of the mechanism are connected", the quantity adjustment mechanism is "institutionalized inside the firm organizations" (Aoki 1978: 6). Accordingly, consideration of the quantity adjustment mechanism constitutes an indispensable part of the theory of the firm.

Among changes in Aoki's theoretical standpoint from *Theory* to *Analysis*, the following two points are particularly important. First, while *Theory* starts from a normative task to design the most desirable mechanism, *Analysis* pushes to the front a thoroughly positive attitude seeking to understand and explain mechanisms which actually work in existing capitalist economies. Giant corporations are no more criticized as the source of alienation. According to Aoki in *Analysis*, the comparative mechanism theory by the early 1970s does not succeed in specifying the most desirable system. Rather, its values lie in that it showed that "any adjustment mechanism cannot have absolute superiority in its system-specific and economically rational utilization of instrumental knowledge". Thus, the actual economic process must be understood as "a complex process made of various mechanisms each of which has different scope of application regarding its bearers and time horizon" (Aoki 1978: 7). Construction of a prototype model of each mechanism corresponds to "logical manipulation extracting basic types from the complex of modes of information exchanges in the (capitalist) system" (Aoki 1978: 19).

Second, *Analysis* seriously reflects upon the previous assumption that the objective function of an organization is exogenously given. Aoki now takes the position that the purpose of an organization must be endogenously explained. People who have entrusted their resources to an organization have mutually different economic motives. The question to be answered is "how and to what organization purpose" are these different motives integrated. Aoki thinks that this integration is attained, especially in firm organizations, through "mediation of mutually contending claims by the controllers of resources toward organization's final product". Analysis of the way of information exchanges among economic agents assuming a certain preset organization purpose can be justified only under the situation in which "the system works as if maximizing a single objective function as a result of habituation and institutionalization of this mediation" (Aoki 1978: 24). In this sense, in any organizations

(including firms), the mode of information exchanges and the mode of income distribution are inseparably interrelated.

4.2 Prototype of the quantity adjustment mechanism

In *Analysis,* Aoki emphasizes limitations of the price adjustment mechanism more strongly than in *Theory*. Since the convexity condition is "too restrictive" and not satisfied in a wide range of cases, "the role of the decentralized price adjustment mechanism is far more limited than the one usually supposed in textbooks of economics". While Lange imagined realization of ideal perfect competition in the socialist planning system, his vision cannot but be "*a utopia in the true sense of the word* in that nowhere exists the perfectly competitive and decentralized price mechanism" (Aoki 1978: 38, emphasis added). The significance of the Arrow-Hurwicz *tâtonnement* model lies in that "it exposed limitations of the decentralized price adjustment mechanism through indication of restricted conditions for its working (and though illustration of the fact that any violation of these conditions leads instability)." By this negative finding, their model "stimulated theoretical search for alternative or complementary mechanisms which can overcome these limitations", one of which is the quantity adjustment mechanism (Aoki 1978: 30).

Aoki constructs two prototype models of the quantity adjustment mechanism[25] which can work in a non-convex environment. A key feature common to both models is that the *controller* (corresponding to the CPB-helmsman in *Theory*)[26] assigns inputs or supplies of resources which can be a source of the economies of scale to the *process managers* (corresponding to the production units in *Theory*). In spite of its name, assignment does not necessarily cover all goods. As will be shown below, both processes use price signals as well as quantity signals.[27]

In the first model, the possibility of economies of scale is allowed for inputs of the sole primary factor. The controller sends each process manager accounting prices of all producible goods (common to all the managers) and the assignment of the primary factor (specific to individual managers). In light of the prices of producible goods and the assignment of the primary factor, each process manager chooses the production plan maximizing its profit calculated by prices, and then reports the controller the chosen plan and the shadow price of the primary factor. Receiving this information, the controller calculates the amount of physical goods available for final demand and revises prices by the equation $\dot{p}_i = u_i - p_i$. As to the assignment of the primary factor, the controller transfers it from the managers who reported shadow prices lower than the average to the managers who reported shadow prices

[25] In literature on the mechanism design this term denotes a mechanism in which some (not necessarily all) of goods are controlled by quantity signals. Note the difference from its usual meaning.

[26] Aoki made this change of naming from the CPB to the controller in order that his argument might not be interpreted as a description of a planning system. He asks readers of *Analysis* to read *Theory* as "a study of mechanisms in the system of a single helmsman" (Aoki 1978: 257).

[27] Here quantity adjustment means that the CPB uses quantity signals, or more concretely, makes assignments on inputs or outputs. Note that it does not exclude the possibility that a part of goods is controlled by the price adjustment mechanism.

higher than the average. In the calculation of this transfer, the controller converts the reported shadow prices into the evaluation by marginal utilities.[28]

Aoki proved that this mechanism has the same favorable properties as two processes in Sect. 3.4 if the scale effect of the primary factor is "neutral" in the sense that it does not affect the relative ratio of inputs of producible goods.[29] He argues that this mechanism reflects "basic characteristics which are working inside organizations" in its centralized allocation of capital as well as its specificity of information channel and its content. The change of shadow prices corresponding to the revision of the assignments does not always lead to an increase in each manager's net profit in consideration of the payment for primary factors. Therefore, institutionalization of this mechanism by an imaginary market (payment of shadow prices of primary factors by the managers) does not work properly. It must be institutionalized by a form that induces the process managers to take part in this mechanism through distribution of the values of the final products produced by its *whole* working. The utility function of the helmsman is formed as a result of this institutionalization (Aoki 1978: 44–45).

The second mechanism is the same with the model of public goods production. As already described, the mechanism setting the supply level of public goods is far more informationally efficient than the mechanism which sets prices of all externalities distinguished by public goods, its users, and affected goods. Institutionalization of this mechanism by a market will be faced with a difficulty in preventing the possibility that "a process manager who imputes high evaluation prices to public goods falsifies its demand prices lower than the true evaluation." To avoid this difficulty, it is necessary to cut off the connection between "the payment of production cost of public goods in the realm of transaction" and "the computation and the report of imputation prices in the realm of information exchanges". Besides institutionalization by a grant system, institutionalization by an organization realizes such a separation (Aoki 1978: 50).

This mechanism is applicable to the adjustment process of capital investment if durable capital goods are regarded as a kind of public goods "commonly used over different times". As in the case of public goods, it is impracticable to establish markets for capital goods that can be used only in a particular production processes. Aoki notes that these circumstances promote internalization of capital investment into firm organizations (Aoki 1978: 51).

[28] The weights used in the calculation of the average are the quotas to each production unit. The conversion into evaluation by utility prices is done by multiplying each shadow price with the ratio of the profit of the corresponding production unit calculated by marginal utilities to the one calculated by prices (Aoki 1978, mathematical note: 34–36).

[29] Under this assumption, the values derived through the conversion mentioned in the previous note are equal to the marginal revenues calculated by marginal utilities (Aoki 1978: 37–38).

4.3 Reasons for existence of firms in the capitalist market system

A crucial link of the transition from comparative analysis of mechanisms to the firm theory is the consideration of time factor. Setting a focus on "the operation time of a mechanism" ranging from the start of communication to the final decision, Aoki makes an important remark that informational properties of a mechanism must be evaluated not only by kinds and quantities of signals exchanged, but also by "*what the mechanism can do within finite time*?" (Aoki 1978: 53, emphasis added). In the decentralized price adjustment mechanism formulated in the form of *tâtonnement* process, "it is impossible to implement tentative decisions by the helmsman and the managers before equilibrium is attained, since prices are adjusted reacting to the gap between demand and supply". On the other hand, in the quantity adjustment mechanism, "the controller quantitatively administrates goods which play a critical role in adjustment of demand and supply". Thus, implementation of the tentative decisions is not hindered by disequilibrium of demand and supply of a part of goods. From this point, it can be interpreted as a process in which "information exchanges and transactions simultaneously go on" (Aoki 1978: 53).

A series of production processes which are in close technological interdependences or processes about which controllers have little knowledge are vulnerable to the risk of disequilibrium which inevitably occurs in the price adjustment mechanism of finite time. Therefore, inputs to processes which have these properties can be subjects of the quantity adjustment mechanism. However, the quantity adjustment applied to current inputs is informationally less efficient than the price adjustment. Expansion of the range of goods subject to some form of rationing has a risk of generating "a huge bureaucratic organization" through accumulative increases of burden of information processing (Aoki 1978: 56). Thus, it is necessary to establish *a certain balance between the efficiency in utilization of resources and the efficiency in information exchanges*. However, this does not imply that resource allocation outside firms must be exclusively coordinated by the price adjustment mechanism. As we will see later, Aoki thinks that the role of prices is restricted even in market transactions.

In the fourth chapter of *Analysis,* Aoki declares that he "moves away from a viewpoint purely considering informational properties of mechanisms, and gradually goes on to a position arguing it in a relation with specific ways of institutionalization" (Aoki 1978: 73). More concretely, he aims to explore the foundation of "the firm organizations as a specific form of institutionalization" in the capitalist system. He defines a firm as "an organization which makes production activities with resources consisting of labor powers continuously entrusted through the employment contracts and funds (and assets as their transformed forms) continuously entrusted through the shareholding system. Both labor powers and funds are "adjusted through an administrative managing mechanism". According to Aoki, the fundamental reason for firm organizations to exist is that "through participation in the firm organizations the employees and the shareholders can obtain economic benefit which is not obtainable if they use markets in an isolated manner" (Aoki 1978: 76). Ronald Coase explained formation of firms as authoritative relations by the difference of attitudes toward risk among its potential members and the difficulty

in making detailed contracts beforehand considering all possible situations. While Aoki admits the relevance of these factors, he considers that it is still insufficient as an explanation of "authoritative allocation of funds and labor entrusted on a long-term basis", for they do not hinder the use of spot markets in response to the situation that has actually happened or to apply a fictional market mechanism to allocation of funds and labor within the organization (Aoki 1978: 79).

Based on results of the comparative analysis of prototype models, Aoki unfolds his own argument as follows. Indivisible large capital equipment fills the conditions under which the quantity adjustment mechanism shows a better performance than the price adjustment mechanism such as economies of scale, common usability (over different periods), and strictness of technological requirements. It is difficult to apply capital goods a system imposing proper rental fees based on their shadow prices, because most of capital goods are specialized in particular processes and their users are in a monopolistic position. Consequently, "it is rather normal that administrative control of capital investment and utilization constitutes an important function of the administrative organ of a firm organization" (Aoki 1978: 80). In addition, skills of workers are not suitable for institutionalization by the market mechanism (whether actual or fictional), because, in addition to their dependence on accumulation of experiences in individual workers, their productivities are exerted collectively in relation with particular workshops. For this reason, usually, allocation of jobs of workers who have once entered into employment relation is unitarily administrated by an organization, which in many cases takes "a hierarchical form" concentrating the authority over personnel affairs into executive managers (Aoki 1978: 82). Thus, "the superiority of the quantity adjustment mechanism in firm organizations is embodied as combined efficiency caused by organizational combination in formation and utilization of durable capital goods and by worker's permanent connection" (Aoki 1978: 124).

In this way, Aoki grasps the firm organizations as an institutionalized form of the quantity adjustment mechanism. It is true that control by quantity signals (imposition of quantity constraints on its members) is a typical way of firm's internal resource allocation. However, the quantity adjustment mechanism formulated by Aoki is not a simple quota system. As we have seen, it includes a step in which process managers calculate and report shadow prices of goods subject to assignment. Quantity constraints should be revised based on these evaluations. Nevertheless, he does not explain how this process of evaluation and revision is institutionalized inside firm organizations. This might be a weak point in his explanation on the question as to why firms exist.

4.4 The dual adjustment mechanism and the Keynesian short-term process

If typical producers in the capitalist economy are not individuals but the firm organizations which have quasi-permanency, the market must be seen as "a field of interactions of firm organizations each of which has accumulated a certain amount of resources (funds and human resources)" (Aoki 1978: 83). In markets, the firm organizations "have active ability to form certain expectations and behave based on

it". In Keynes' expression, they engage in "higgling" to find out the market equilibrium by trial and error. As a prototype model of this process, Aoki formulates the dual adjustment process,[30] which goes on as follows.[31]

The controller sends each process manager who produces a particular product the amount it should produce, prices of all products, and prices of labor (the sole primary factor[32]). In light of this information, each process manager chooses its input plan minimizing costs calculated by prices, and then reports to the controller this plan and the shadow price of its product (marginal cost). The helmsman is double-layered. "The exogenous helmsman" decides the tentative investment plan maximizing its objective function within the constraint of fixed investment funds. "The endogenous helmsman" decides tentative consumption demands maximizing its utility within the income constraint equal to a certain percentage of income corresponding to the demanded amount of labor notified by controllers (Aoki 1978: 84). As to revision of the quantities firms should produce, for each product, the controller increases its production if the demand for it (the sum of investment, intermediate, and consumption demand) exceeds its supply, and decreases it in the opposite case. With regard to the revision of prices, for each product, the controller raises its price if its marginal cost exceeds its price and lowers it in the opposite case (the price of labor is fixed). Thus, in this process, quantities are adjusted by quantity information and prices are adjusted by price information.

Aoki interprets information exchanges in this process between controllers and process managers as "modeling of the process in which firms revise their forecasted demands with trial and error by interactions through markets and successively adjust their selling prices in relation with these revisions" (Aoki 1978: 87). In this interpretation, the assignment of production by the controller reflects *perception of demand constraint by individual firms*. The firm produces good i revises its expected demand by $\dot{d}_i^e = d_i - d_i^e$, where d_i and d_i^e denote actual and expected demand for good i, respectively. Thus, each firm follows the adaptive expectation (with a coefficient equal to unity) and decides its production amount, so that it becomes equal to the expected demand. This is a kind of the quantity adjustment in its usual sense.

Equilibrium is attained when production of each product coincides with demand for it and price of each product coincides with its marginal price.[33] Aoki indicated that this mechanism has local stability if the technologies satisfy the (weak or strong) convexity condition and the spending coefficient (propensity to consume)

[30] The term 'dual adjustment' is used in Morishima (1977) to denote the mechanism in which prices of goods are adjusted in response to its excess demand, and supplies of goods are adjusted reacting to the excesses of their prices to production costs. Aoki's dual adjustment mechanism corresponds to what Morishima calls "the Keynesian adjustment rule".

[31] The following explanation includes some simplification of Aoki's original model.

[32] It is easy to extend this model to the case of multiple primary factors. As far as short-term adjustment is concerned, capital goods can be also regarded as primary factors (Aoki 1978: 264).

[33] If the technologies are assumed to be linear, equilibrium prices of each product are equal to their respective production costs (including labor costs). It is easy to extend this model to the case that a certain mark-up is added to production costs. In the third part of *Analysis*, Aoki examines mark-up pricing by the firm in connection with its policies of investment, employment, and inner-firm distribution.

of the endogenous helmsman is less than unity.[34] Clearly, this process "lacks a mechanism equating the utilization of the primary resource with its endowed quantity" (Aoki 1978: 86). To what extent the primary resource is employed depends on the exogenous demands and the spending coefficient. On this point, Aoki makes an insightful statement that this property of the dual adjustment process "suggests that the adjustment of demand and supply of primary resources belongs to a time horizon different from formation of the Keynesian short-term equilibrium." To put it more concretely, this process belongs to "a more long-term mechanism relating adjustment of the absolute level of investment and real wages" (Aoki 1978: 87). In this sense, Keynes' theory is "a so-called 'short-term' theory concerning the level of total employment decided by factors formed in the time flow from the past to the future and the forecasts on the future" (Aoki 1978: 129).[35]

If the dual adjustment process cannot attain full employment due to insufficiency of exogenous demands, what is its merit? Aoki answers this natural question as follows. The dynamic path with full employment of labor and capital generated by the price adjustment mechanism is unstable and highly vulnerable to small errors of forecast. The capitalist system has a tendency to adjust its inner disequilibrium *not at once* but "*gradually by underemployment of durable capital goods (and labor power)*" (emphasis added). In other words, "the Keynesian short-term equilibrium carries out the function necessary to successively correct forecast errors by its very imperfect function of equilibration involving underemployment of primary resources" (Aoki 1978: 88–89). In this way, Aoki accepts the Keynesian view that underemployment of capital equipment and labor is the normal state of the capitalist system.[36] Besides, he indicates a unique recognition that underemployment of capital equipment and labor is an essential condition for the real (quantitative) process to go on while approximating the balance of production and demand "in the actual world, where the perfect forecast is impossible" (Aoki 1978: 111).[37] Evidently, here Aoki is approaching *a direction to reconstruct Keynes' theory into a true process analysis*.

The dual adjustment mechanism shares one weakness with the price adjustment mechanism in that the supply constraint is not satisfied until equilibrium is attained. In order that information exchanges and actual transactions go on in parallel, there must be inventory stocks as a buffer absorbing the gap between demand

[34] It should be noted, however, that the condition for (local) stability becomes more restrictive if time is assumed to be discrete. In that case, stability will depend also on the coefficient of adaptive expectation.

[35] As to the long-term growth path of the capitalist economy, Aoki argues that it can be stable only when long-term predictions of individual firms are roughly made common among them through a certain process (Aoki 1978: 249). Coordination of expectations among individual agents continued to be one of central points in Aoki's theory until his later years. See Aoki (2001).

[36] Interestingly, in late 1970s also Morishima turned from a Walrasian to a radical Keynesian and made an attempt to reconstruct Walras' model into a model in which quantities are adjusted by quantity signals and investment is determined independently from saving. See Morhishima (1977).

[37] This understanding on the role of unused capacities and unemployment is close to Kornai's view (Kornai 1971).

and production.[38] While introduction of inventories into the model causes a complication, it is by no means an unnecessary extension. On the contrary, explicit consideration of the role of inventories would make the dual adjustment mechanism a more adequate description of the short-term Keynesian process.

After publication of *Analysis* (and after he again moved to the United States), Aoki's interest was turned to the inner economic (and legal) structure of the firms (Aoki 1984), and then to the characterization of the Japanese firms (Aoki 1988). In spite of the great value of these works, it is regrettable that he did not further elaborate the above theory on market processes.

5 Conclusions

Aoki started his investigation of economics from the optimal planning theory during the half of the 1960s and shifted his subject to the theory of the firm and the market in the late 1970s. This shift of subject was accompanied with a change of his interest from design of a more desirable social system than existing ones to understanding and explanation of mechanisms compositely institutionalized in the actual capitalist system. Clarification of economic environment under which a particular adjustment mechanism has relative superiority led him to recognize limitations of the price adjustment mechanism. He indicated that the quantity adjustment mechanism (assignment based on evaluations by users) works well in allocation of durable capital goods and labor which could be sources of economies of scale. Based on this insight, he grasped the firm organizations as an institutionalized form of the quantity adjustment mechanism and argued that the purpose of the firm is formed in connection with the working of this mechanism and the distribution of the collective benefit produced by the organization. Together with a game-theoretic model of firms which is now widely known, Aoki presented a unique view on the market that its short-term adjustment process can successively correct inevitable errors of short-term forecasts of demands for products but lacks the functionality to eliminate underemployment of durable capital goods and labor.

It would be inappropriate to see Aoki's early theoretical quest described above as a mere preparatory stage for his later full-fledged firm theory and comparative institutional analysis. It has its own significance as a stimulating attempt to build the general theory of the matured capitalist system. We should also pay more attention to this part of Aoki's intellectual heritance.

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Compliance with ethical standards

Conflict of interest The author declares that he/she has no conflict of interest.

[38] Aoki admits this point and makes a provision that his model is "constructed as a subjective model used by firms in formation of their expectations, or a kind of *tâtonnement* process obtained by reflecting the adjustment process in historical time onto the one in abstract logical time" (Aoki 1978: 264).

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

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