THE INNOVATIVE CHOICE AS AN OUT-OF-EQUILIBRIUM PROCESS: TOWARDS AN ADAPTIVE (OR SEQUENCE) APPROACH

Jean-Luc Gaffard

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ABOUT THE AUTHORS

Jean-Luc Gaffard, Emeritus Professor University Côte d'Azur, Institut Universitaire de France and OFCE-Sciences-Po.
Email Address: jeanluc.gaffard@sciencespo.fr

ABSTRACT

As Richard Day pointed out, an evolutionary approach focuses on the characterization of the way economies function when they work out of equilibrium and represents their capacity to change structure. Our paper aims at providing the basis of the analysis of qualitative change as learning process whose evolution is not predetermined but depends on what happens along the way, that is, on the recurrent distortions in the time structure of productive capacity due to co-ordination failures. Qualitative change is a change that implies a structural modification, which can only be brought about through a process in real, irreversible time. Physical, human, and financial capital are complementary in this process of reshaping and may constrain each other. Viability of the disequilibrium process depends then on the interaction between behaviors and policies.

The Innovative choice as an out-of-equilibrium process:

towards an adaptive (or sequence) approach[*]

Jean-Luc Gaffard
Emeritus Professor University Côte d'Azur,
Institut Universitaire de France and OFCE Sciences-Po

e mail jeanluc.gaffard@sciencespo.fr jl.gaffard48@gmail.com

Abstract

As Richard Day pointed out, an evolutionary approach focuses on the characterization of the way economies function when they work out of equilibrium and represents their capacity to change structure. Our paper aims at providing the basis of the analysis of qualitative change as learning process whose evolution is not predetermined but depends on what happens along the way, that is, on the recurrent distortions in the time structure of productive capacity due to co-ordination failures. Qualitative change is a change that implies a structural modification, which can only be brought about through a process in real, irreversible time. Physical, human, and financial capital are complementary in this process of reshaping and may constrain each other. Viability of the disequilibrium process depends then on the interaction between behaviors and policies.

Key words: Coordination, equilibrium, structural change, viability.

JEL codes: E14, E23, E24, E32, 043**.**

Résumé

Comme l'a souligné Richard Day, une approche évolutionniste se concentre sur la caractérisation du fonctionnement des économies lorsqu'elles ne sont pas en équilibre et représente leur capacité à changer de structure. Notre article vise à fournir les bases de l'analyse du changement qualitatif en tant que processus d'apprentissage dont l'évolution n'est pas prédéterminée mais dépend de ce qui se passe en cours de route, c'est-à-dire des distorsions récurrentes de la structure temporelle de la capacité de production dues aux défaillances de la coordination. Le changement qualitatif est un changement qui implique une modification structurelle, laquelle ne peut être provoquée que par un processus en temps réel et irréversible. Les capitaux physique, humain et financier sont complémentaires dans ce processus de remodelage et peuvent se contraindre mutuellement. La viabilité du processus de déséquilibre dépend alors de l'interaction entre les comportements et les politiques.

Mots clefs : Coordination, équilibre, changement structurel, viabilité.

Codes JEL : E14, E23, E24, E32, 043.

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1. Introduction

Behind growth, which is usually considered the expansion of a quantity index referred to output, productivity, or else, there are always qualitative changes – changes in technology, in consumers' preferences, in form of organization of economic activities, and the like. The source of growth, in other words, is a complex economic process: and this is what innovation comes down. Understanding this process requires reconsidering economic theory.

As Richard Day pointed out, "from the beginning of the discipline's 'modern' era, two complementary streams of thinking have flowed through the domain of economic theory – one characterizing and deriving properties of economic equilibrium, the other characterizing and deriving properties of disequilibrium. Both are found running through all the great classical and neo-classical founding fathers, and in the great economists of the twentieth century (including among many others) Wicksell, Keynes, Schumpeter, Hicks, and Hayek" (Day 2004 a p. 2).

In accordance with this divide in economic analysis, the definition of Dynamic Economics is a matter of controversy. Economic models are often considered to be dynamic when they employ dynamic methods. Steady growth has been reckoned a dynamic method; the introduction of non-linearities is said to lead to dynamic models; the use of dynamic optimization appears as a significant advance in the field of dynamic economics. We maintain instead that dynamic analysis, in economics, depends on dealing with issues which are in the nature of dynamic problems, rather than referring to supposedly dynamic methods.

What is a dynamic problem? As stressed by Hicks (1985 p.2) dynamics has to do with change: but change cannot be reduced to a steady state, that is, to a static equilibrium continuously blown up through multiplication by a scalar. Change implies a structural modification which can only be brought about through a process in real irreversible time. Innovation is the foremost example of change. Therefore, what matters is that, when change does take place, the existing productive structure is disturbed, and its way of functioning is affected. This puts the economy out of equilibrium, and as a result a problem of intertemporal complementarity of production arises which calls for co-ordination over time of economic activity to render the process of change that has been undertaken viable.

Thus, Richard Day discerns "two fundamentally distinct characterization of economic dynamics, both descendant of classical and neo-classical economics: one of adapt*ed* equilibrium dynamics and one of adapt*ive* evolutionary dynamics" (1993 p. 21). The property of adaptive, evolutionary approach is to focus "on the characterization of the way economies work out of equilibrium", and to explicitly represent "their capacity to change structure, i.e., to evolve or self-organize" (ibid.). Many difficulties and problems are inherent to such an approach. Dynamic Economics, which is based upon a clear characterization of production and decision processes, provides a solution to "the problem of generating out-of-equilibrium dynamics and characterizing economic evolution itself using disequilibrium theory" (ibid.).

In short, dynamic analysis essentially comes down to the analysis of structure changing processes. Of course, "chaos is generic in any model of a dynamic process that retains inherent non-linearities", but there are two distinct lines of work. "One that assumes intertemporal equilibrium, and one involving mechanism that work out of equilibrium. To the former belong the optimal growth, real business cycle, and overlapping generations model. To the latter belong the market adjustment, disequilibrium business cycles, adaptive optimizing, and system dynamics model" (ibid. p. 23-24). As a matter of fact, the adaptive or innovative

behaviors that characterize out-of-equilibrium processes may bring the economy beyond limits which imply its collapse. These limits represent barriers within which the economy itself must be kept to remain viable. A construction process that builds-up along the way must be explored, and its viability ascertained, by working out the evolution of the economy through the sequence of periods through which the inter-temporal complementarities and the interactions that characterize the functioning of the economy trace out the effects of the initial structural change.

Focusing on structural change brings back to the surface coordination issues. Equilibrium in macroeconomics assumes away expectations' errors and market disequilibria. It makes heterogeneity difficult to model. It hides possible instabilities. It makes money look unimportant. At the opposite, disequilibrium in macroeconomics focuses on a process build-up step by step, that is on adjustments and reaction to disequilibria, which, step by step, determine the evolution of the economy. This "requires far more structure than does the equilibrium approach. Mechanisms that describe how agents make decisions, how prices are determined, and how exchanges can take place out of equilibrium must be specifies" (Day ibid. p. 21). Viability is the main problem associated with these processes, and interaction, complementarity, and coordination overtime, which determine how the processes themselves are actually shaped, are the relevant issues for viability. Pushing on along the line that Hicks (1973) indicated makes it possible to develop this new and original view of how the economy works out of equilibrium.

In section 2 we will discuss how Hicks addresses complex dynamics by introducing a representation of production that makes it possible to analyze its time structure. In section 3, we will show how to go further, giving-up the notion of traverse as an asymptotic stable path from the old to the new equilibrium and adopting that of out of equilibrium process. In section 4, we will discuss which use to do for a model that captures the qualitative features of an out of equilibrium process. In section 5, we will analyze the nature of fluctuations that characterize the out-of-equilibrium process that are not so much due to changes in technology or preferences *per se* but reflect the co-ordination issues arising in a process of structural change. We will conclude in section 6 underlying the relevance of an out of equilibrium approach in the perspective of understanding what happens along the way in presence of irreversibility and radical uncertainty.

2. Methods of dynamic economics

Modern models of economic dynamics remained until recently trapped in a dichotomy: some of them attempted to incorporate and so preserve the notion of equilibrium and developed it further into growth dynamics; and others maintained a disequilibrium interpretation of observed fluctuations in the levels of economic activity. This dichotomy corresponds to a distinction between growth dynamics as extension of General Equilibrium theories, and theories of fluctuations or of off-equilibrium. However, fluctuations are referred to equilibrium paths, the growth paths. When the notion of equilibrium is used, its preeminence tends to dwarf all disequilibrium dynamics.

This classification is in line with the conception of dynamics as developed by Samuelson (1947) who separate dynamic optimization models featuring the maximizing behavior of representative agents, from the study of macroeconomic fluctuations focusing on the interaction between economic units. In this argument, aggregation over heterogenous agents was implicitly considered (Boianovsky 2020 p. 607-611).

Bringing back to the surface aggregation issues explains the rejection of optimizing behavior of a representative agent. Coordination issues arise as consequence of this heterogeneity. Those are long-run coordination issues. As a matter of fact, "technological change raises the same sort of coordination problems as do changes in aggregate demand, and adjustment to technological change is not a question of making a self-limiting transition to a new steady state but is a permanent condition of economic life in a progressive society" (Howitt 1994 p. 765).

The Neo-Austrian approach (Hicks 1973), which cannot readily be classified within either one of the side of the above divide and rules-out any optimization behavior, opens the way to an out of equilibrium analysis of fluctuations that focuses on coordination issues. Adopting this approach requires reconsidering the notion of equilibrium.

As Hicks pointed out, "the equilibrium assumption looks distinctly different according as it is used in one or another of the … branches of economic theory… In Welfare Economics there is no problem: the equilibrium assumption is included in the way the theory is set up' (Hicks 1965 p. 17). This is because the social optimum is defined by a social welfare function, so that the economy is treated as if it consisted of a single individual and hence "it is the equilibrium choice of that single chooser which is the optimum choice… A welfare optimum has to be an equilibrium" (ibid.). Within a normative context, then, equilibrium dynamics is perfectly at ease, not in the sense of determining the actual path which the economy will follow, but in the sense of sketching out the optimum path, that is, the path that will best satisfy a given social objective. In this perspective, the focus on optimizing individual behavior points to intertemporal resource allocation mechanisms as the main determinants of dynamic paths. Various such paths are thus sketched out, including fluctuations, as is typically the case with real business cycles, which are the outcome of optimizing behavior as an answer to exogenous real shocks.

It is true that some sort of structural change can be contemplated whenever we consider a change in technique, or a productivity shock as in real business cycles, or an enlargement in the list of production goods or consumption goods. But these is no attempt to bring to light the economic problem that these changes imply: namely, problems of the intertemporal complementarity of production and decision processes and the associated co-ordination problems. As a matter of fact, co-ordination of economic activity is always *assumed* in normative models. Optimal models always imply an equilibrium over time, and over time co-ordination is assured because the equilibrium assumption implies that expectations are always fulfilled.

Briefly, equilibrium growth models do not allow a thorough dynamic analysis. This is so because qualitative change is involved whenever a dynamic problem is dealt with, and qualitative change implies structural change, which is an out of equilibrium process.

As Richard Day pointed out, "equilibrium theory underplays the complexity of technology, overplays the rationality and knowledge of households and firms, and exaggerates the efficiency of markets… It is essentially a theory of economic processes in a state of adaptiveness. Adaptive economics, on the other hand, begins not with structures of rationality and equilibrium but with an assumption that change evolves from current conditions. It focuses on the economizing of partially informed agents whose transactions are imperfectly coordinated; whose use adaptive procedures such as servomechanisms, behavioral learning rules, suboptimization with feedback, and the like; and whose numbers, activities, rules of

behavior, and organization evolve. Adaptive economics is primarily the study of economy adapt when individuals and institutions are not perfectly coordinated" (Day 2004 a p. 39-40).

As the equilibrium assumption is no longer included in the very definition of the path followed by the economy, "it is to be justified". In other words, the existence of the equilibrium must be proved, and even "if the equilibrium exists, it has still to be shown that there is tendency towards it … and even if the tendency to equilibrium exists, we must still have sufficient ground to justify the equilibrium assumption if the convergence to equilibrium is very slow" (Hicks 1965 pp 18-19).

Harrod growth model (1948) addressed the problem of the tendency to a long-term equilibrium and questioned the existence of such a tendency. In this model, the coordination of economic activity is not assured. This is because the short period is explicitly considered as well as the long period, and the interaction between the two comes to the fore. Investment – unless along the knife edge, where the economy can only be by chance – brings about a productive capacity which is not harmonized with final demand. The original imbalance which results from an attempt to increase (decrease) the rate of accumulation, thus making the effective growth rate diverge from the warranted (expected) one. The long period profile of the economy is nothing else than a sequence of short-term disequilibria.

The limit of Harrod's analysis is that the out of equilibrium process considered cannot be exhibited as a sequence and followed suit step by step. We remain halfway between a stability analysis, aimed at bringing into light stability (or instability) conditions, and the analysis of a thorough process taking sequentially place over time. The reason is that Harrod has no theory of production as a time structured process to deal explicitly with the intertemporal complementarity of the production process that makes up the effective backbone of an out of equilibrium process. While due to irreversibility of investment decisions, an instantaneous adjustment is impossible: errors made are fossilized in the capital stock and in human resources. What happens along the way depends on how adjustments take place.

Articulation over time of the production process is the distinctive feature of the Neo-Austrian model (Hicks 1970, 1973). In this model, production appears as a scheme for transforming a sequence of primary labor inputs into a sequence of homogeneous final output. The production process is fully vertically integrated: which makes it possible both to exhibit explicitly the phase of construction of productive capacity by bringing it inside the production process and to stress that it must necessarily come before the phase of utilization of the same capacity. In other words, any productive capacity incorporating a given technology must be built before being used, and old machines cannot be transferred to new processes. Such a method "is at the extreme from the Von Neumann method. The von Neumann method is the extreme of disintegration; there is a complete reference back to the market in every period, a period which can be made as short as we like. Ours, on the other hand, is the extreme of (vertical) integration. There is no 'intermediate' reference back to the market. The production process, over time, is taken as a whole" (Hicks 1973 p. 6).

Focus on the time structure of the production process, and on its intertemporal complementarity, makes it possible in turn to posit the transition between two different techniques (a ´Traverse´) as a thorough process through which the transition itself takes place, and to analyze this process by following it in its sequential development (Hicks 1973).

Then, the productive capacity of an economy can be represented as a population of production processes. Each process has a life cycle. Each given behavior of the economy is

sustained by a productive capacity characterized by a given age structure of the production processes. An equilibrium state or path is sustained by a particular age structure, that is, by a constant age distribution of production processes. This means that the 'horizontal dimension' of productive capacity – namely, the array of production processes at different moments of their lifetime, coexisting at a given moment – must be consistent with its 'vertical dimension' – that is, the time pattern of production associated with this age structure. When this is so, that is, when the phases of construction and utilization of productive capacity are harmonized at each given moment of time and over time, no market disequilibria arise. Investment and consumption, and supply and demand of final output are also harmonized.

A qualitative change - as opposed to a mere quantitative growth – implies a change in the way of functioning of the economy, that is, a structural modification which, according to the above definition, is characterized in the first place by a change in the age structure of productive capacity with respect to its previous equilibrium configuration. As we have just seen, investment and consumption are then no longer harmonized over time.

In the Neo-Austrian approach, the very distinction between the two forms of dynamics, adjustment dynamics and structural change becomes blurred and operationally unimportant, and structural change becomes the focus as a result of this. The role assigned to shocks is twofold: first to trigger a dynamics leading off a postulated initial equilibrium. This is a purely notional role and has the same function as an initial disturbance in a controlled experiment. The other, and more important, function is 'to keep alive' the dynamics off the original unique equilibrium behavior. Indeed, once we recognize that the time over which change takes place in a continuing and irreversible process which shapes the change itself, "it is impossible to assume the constancy of anything *over time* … The only truly exogenous factor is whatever exists at a given moment of time, as a heritage from the past (Kaldor 1985 p. 61). One of the main aspects of this path dependency is the change in the time structure of productive capacity.

3. From the traverse to full out-of-equilibrium dynamics

The appearance of problems of intertemporal complementarity is in fact the main consequence of the shock represented by the adoption of different technique; and the intertemporal complementary of the production process is the main link of the sequence of periods along which the barter economy described by Hicks – an economy in which a homogeneous commodity appears both as input and output – is made to move from the previous technique to the new one by the means of the mechanism provided by the assumption of Full Performance. This assumption implies that the output not absorbed by consumption out of wages paid to workers engaged on existing production processes (whether still in construction or already in the utilization phase) or by consumption of other kinds, is in fact used to start new production processes. The rate of starts, thus made endogenous, sketches out the path followed by the economy – a fully predetermined path leading to a new equilibrium state univocally defined by the characteristics of the new technique – once the value of the parameters of the model are given. Full Performance, on the other hand, also implies flow equilibrium in each period, both in the sense that final output is totally absorbed by existing demand and in the sense that investment is equal to *ex ante* saving. Thus, the existing productive structure is smoothly transmuted into the one adapted to the new technique as resources are gradually freed and invested into the building of the latter. In this context, there is no decision process and there are no disequilibrium co-ordination problems. Full performance allows to dispense with them and with the imbalances

which could otherwise arise from the strictly *ad hoc*, arbitrary saving function corresponding to the hypothesis of a constant, exogenously determined 'take out' (consumption out of profits). However, Full Performance only concerns final output; there is nothing of the sort on the labor market. This makes it possible to make the bold step forward that is represented by the analysis of the Traverse to bring to light "what happens along the way" (in particular to employment) as the result of taking explicitly into account the time structure of production in an out-of-equilibrium context (Hicks 1973 p. 10). The simple consideration of the distinction "between investment at cost and investment of output capacity" (Hicks 1973 p. 98), which can be appreciated when there is a breaking of the intertemporal complementarity of production as a result of an innovative choice, allows important analytical insights: of paramount importance is the demonstration of the Ricardo's 'machinery effect' – the appearance of a transitory unemployment associated with change in technology – a highly controversial issue in the history of economic thought.

Hicks describes a Traverse as an asymptotic stable path from the old to the new equilibrium. By contrast the long run dynamics that the economy follows is an irregular path which makes the very concept of 'new equilibrium' flurry. To be able to deal with such dynamics requires dropping the extreme hypothesis of Full Performance, which make it possible to sketch out the traverse itself as a predetermined trajectory to a given point of arrival.

The removal of this assumption allows one to realize that problems of intertemporal complementarity of production and problems of co-ordination of economic activity are the necessary result of the attempts to undertake qualitative changes which set the economy out of equilibrium. These problems lead to fluctuations which may render the economy not viable.

An analytical framework based upon this representation of production (Hicks 1973) and a sequential articulation of the decision process (Amendola and Gaffard 1988, 1998), provides a solution to the problem of generating out-of-equilibrium dynamics and of characterizing economic evolution itself using disequilibrium theory. It is a theory of the economic process that brings into light both the intertemporal complementarity of production processes and the intertemporal coordination of the decision processes directly or indirectly related to production. As such, it makes it possible to show "all the phenomena and problems that hinge upon the incessant creation of new and novel capital equipment" (Schumpeter 1954, p. 280n). The interaction between short and long period is at the heart of this creation, and it can be captured by sketching out both an intra and an inter period sequence, where the one depends on, and at the same time determines, the other (Amendola and Gaffard 1998, pp.126-8).

The effective link between short and long period in such a sequential model are the economic magnitudes that at each given moment represent the existing constraints but are themselves the result of what has been happening along the sequence of periods that has led to the present state of the economy. Within this sequential context, output, prices, and wages determination mechanisms carry over and most likely amplify the imbalances in the structure of productive capacity (first the one between construction and utilization), which result from the original breaking up of the functioning of the economy due to the attempt to carry out a qualitative change. This stirs an out-of-equilibrium process that causes fluctuations in output and prices, and hence in available financial resources and in investment, which make productive activity less and less consistent over time and hence undermines the viability of the path followed by the economy; so that the viability of this path becomes the crucial analytical problem. Along the path, involuntary accumulated stocks – both real and financial - are the main channels of propagation of disequilibria

As a matter of fact, what happens along the way, step by step, affects the growth rate of the economy. Mainly, the amount and the direction of capital formation are bound to be affected by the business cycle, whether through investment in new productive capacity or through the scrapping of old productive capacity. Once an economy strays from a steady state for any reason (i.e., a change in technology, a change in the distribution of income, or a change in market conditions that generate unexpected consequences), it most likely does not find its way back to any equilibrium growth path. Irreversibility of investment decisions and imperfect knowledge about market conditions explain why this is so. Therefore, it is no longer relevant to separate growth and fluctuations.

Summing up, an out-of-equilibrium process, as it implies the disruption of a given productive structure, and of the established way in which it operates, and the construction of a new and different one, takes necessarily the form of fluctuations, which reflect the appearance of problems of co-ordination, and hence of market disequilibria, as the result of the original shock. In fact, the reactions to these disequilibria stimulate a process of adjustment sketched out by sequentially interacting disequilibria, which likely amplify the original deformation of the structure of productive capacity, and hence the width of the fluctuations, that often result in a threat to the viability of the economy. The success, or the failure, of the qualitative change undertaken depends on the possibility of re-establishing the disrupted coordination of economic activity, thus smoothing the fluctuations that affect the process through which changes in technology are transformed into increases in productivity.

This casts doubts on the relevance of the concept of potential growth rate, defined as the rate at which an economy can grow without inflationary pressures, and reckoned to depend on the potential productivity growth. Out of equilibrium, the dynamics of productivity is driven not only by long run, exogenous forces of technological progress and invention. It also reflects the process of transformation of the productive structure and the ability of agents and institutions to organize and to carry out this process within the prevailing constraints.

4. Which use for the models

An economy travelling on an equilibrium path (be it a steady state or not) is fully adjusted. Rational expectations prevent the agents of this economy from making systematic errors that would be 'fossilized' in the capital equipment or in human capital. This is the reason why given properties of 'technical' functions (production and utility function) and given initial conditions, including the information structure, are sufficient for determining the trajectories followed by this economy. On the contrary, an economy which is not fully adjusted travels an out-of-equilibrium path. Its evolution depends not only on 'fundamentals', but also and mainly on behavior mechanisms which reveal how the market information is treated step by step. The essence of Hicksian (Neo-Austrian) models is to consider such an economy. They cannot describe complete trajectories. They only allow to explore medium run sequences which derive from certain impulses and certain behaviors adopted in reaction to market disequilibria.

The Hicksian model captures the qualitative features of the out-of-equilibrium process, which is not a transition path, but a process which builds up step by step. This is because, once the very specific assumptions of the analysis of the Traverse have been relaxed, there is no attractor. In relation to this process, we do not derive anything similar to the invariant laws implicitly governing long run dynamics that are sought by the equilibrium approach. As a matter of fact, Hicksian models with complex structures generate complex dynamics.

The complexity of economic phenomena is explained in a large part by the intrinsic working of economic forces. The models here considered belong to the class of adaptive models. "Indeed, the pictures of economic activity these models give is of sequence of more or less distinct periods of development characterized by discrete set of resource scarcities and productive activities and distinct qualitative characteristics of change (growth, cycles, stationariness, etc.). Such discrete periods do not come in some fixed or immutable order as proposed by the stage-making theories of economic history. Rather they come in a great variety of orders and types that depend on the initial technological and behavioral conditions of the economy in question. They also depend on the economy's peculiar parameters of geography, technology, and culture" (Day 2004 p. 53).

Within the sequential context sketched out by the intertemporal complementarities of the production and of the decision processes, output, prices and wages determination mechanisms carry over and most likely amplify the imbalances (first of all that between construction and utilization) resulting from the original breaking up of the functioning of the economy due to the attempt to carry out a qualitative change. This stirs an out of equilibrium process that causes fluctuations in output and prices, and hence in available financial resources and in investment, which make productive activity less and less consistent over time and hence undermine the viability of the path followed by the economy. The viability of this path becomes then the crucial analytical problem. The main point to be stressed, here, is that different kinds of interventions - aimed at regulating the working of the existing dynamic mechanisms (prices, wages and output determination systems as affected by the control variables of the economy) or, as we shall see, at providing other compensating mechanisms - are required to interact dynamically in order to correct both the bias in construction and that in utilization, thus re-establishing the consistency over time of productive activity and making the evolution of the economy viable.

This mix of interventions, on the other hand, cannot be made once and for all but must be continuously modified as it has to deal with a process affected by perturbations which take on different shape and intensity in time. "Such *viability creating mechanisms* are the analog of equilibrium 'existence' proofs, but in the out-of-equilibrium setting. They are required to guarantee the existence of a continuing 'solution' to the system in terms of feasible actions for all its constituent model components" (Day 1993, p.39). This is the different way in which the concept of 'solution' must be intended when referred to an out of equilibrium process. It calls for a monitoring of the process itself to bring into light its salient moments: which can only be obtained by means of numerical experiments, that is, by simulations that, under certain conditions (chosen so as to stress aspects relevant to the analysis) allow to unveil what happens 'along the way'. As Day put it, model simulation, "can never yield general inferences from a given system of assumptions but can yield specific inferences of great variety and interest" (Day 1975, p. 29).}.

The relevance of this analytical set up for policy interventions is evident. As a matter of fact, these interventions are most often devised "in response to economic pressures caused by unemployment, bankruptcy, poverty and other problems of unviability experienced by individuals and organizations. Models that can generate similar phenomena could provide a realistic environment for experiments with alternative policy strategies. They might provide better 'engines for discovering the truth' and they might help formulate more effective mechanisms for steering the economy away from precipitous hazards and along less bumpy paths"(ibid.).

The intertemporal complementarities and the interactions that characterize a process of qualitative change trace out complex dynamic paths which call for an adaptive approach: although one of a particular kind. "Obviously, however, the adaptive approach will, when pursued very far, lead to models of great complexity and variety" (Day 1975, p. 30). When confronted with this problem we can take two different stands. We can use simple models to try to reproduce complex evolution paths of the economy, as it is the case with chaos theory. Or we can build models that take into account the complexity of economic phenomena and of their interactions over time and try to derive simple and clear evolutions from them. The reason of this choice is in the way in which we interpret a model: namely, as a heuristic tool for exploring economic phenomena so as to have a better understanding of their essence - in our case, the phenomenon of change which is in the nature of an out of equilibrium process, that is, of a process that has in its developing its analytical relevance - rather than as a device for reproducing particular aspects of economic reality, in a descriptive, *ex post* perspective.

Contrary to equilibrium relationships, for which reduced forms are of straightforward derivation, an out of equilibrium approach needs to first go through a complex calibration exercise. This needs to be aimed first and foremost at ensuring that the numerical simulations are robust to parameter changes. Secondly, at defining scenarios of co-evolution of the relevant variables that can be "brought to the data" to test the explanatory power of the framework.

Thus, the out-of-equilibrium model appears as a heuristic device to throw light on the crucial links which characterize the sequential (or adaptive) development of a process of structural change, so as to help to single out the intervention that, moment after moment, make it possible to render this process viable.

In this analysis, the results of numerical simulations are sensitive to small changes in parameter values, model structure and initial conditions. This attribute may appear to indicate that the analysis is incapable of providing reliable and general conclusions. However, as Baumol (1991) pointed out, examples derived from numerical simulations may reveal that widely held beliefs that have been derived rigorously from oversimplified models are just not valid as general propositions. The policy or behavior adopted on the basic of the general belief can turn out to be highly damaging.

5. Coordination issues

The fluctuations that characterize the out-of-equilibrium evolution of the economy are not so much due to changes in technology or preferences *per se*; but reflect the co-ordination problems arising in a process of structural change. To reduce the amplitude of these fluctuations, which might represent a threat to the viability of the change undertaken, policy interventions must therefore deal essentially with these problems.

Viability conditions must be distinguished from optimality conditions, that is, the conditions required for an optimal choice in an equilibrium context. The viability of the process that allows capturing the productivity gains potentially contained in new technologies (or in new markets) depends on re-establishing a co-ordination over time of supply and demand factors: over time because a thorough process is made up of steps that sequentially sketch out its evolution. It depends therefore on conditions that will take meaning and shape in the course of the process itself, while optimality conditions only refer to intrinsic properties of supply and demand, that is, of given costs and preferences.

The Neo-Austrian view of production makes it possible to see how a shock of whatever nature brings about in the first place a distortion of the existing productive capacity due to a breaking of the intertemporal complementarity of the production process. This implies the appearance of disequilibria, and hence of problems of co-ordination that, although originating on the production side, extend to all the aspects of the economic activity (resulting, e.g., in inflation, unemployment, and so on). Reactions to these disequilibria stimulate an out-of-equilibrium process of adjustment. This is sketched out by sequentially interacting disequilibria, which will amplify or dampen the original deformation of the structure of productive capacity - and hence create or eliminate viability problems - according to the working of the co-ordination mechanisms that prevails along the way. If co-ordination is not re-established, this will result in particular in increasing levels of unemployment and decreasing levels of productivity and real wages (Amendola, Gaffard 1998).

Let us consider the case of the introduction of a new technology characterized by higher construction costs, as it is typically the case of the new information and communication technologies. The costs come earlier, and hence cannot be financed out of current production. This causes a distortion of productive capacity and the dissociation in time of inputs from output, and of costs from receipts, which puts a financial constraint on investment in capacity. The availability of financial resources *at the right time* is then essential to build a bridge over time between costs and revenues, so as to render the required restructuring of productive capacity viable while it is still on the way and it does not yet deliver output and revenues. If these resources are not available the necessary investment cannot be realized, which will further reduce final output and postpone (or even cast doubts on the effective obtainment of) the expected increases in productivity. What we shall have in the meantime is less production and less labor demand. Unemployment, lower revenues, and the subsequent fall in final demand will further reduce receipts and financial resources. Insufficient investments will paradoxically result in excess supply, excessive productive capacity and in the scrapping of production processes. And so on, in a process that is a threat to the viability of the change undertaken.

This process also occurs if the new technology requires a different gamut of skills. We shall have immediately the appearance of a human resource constraint, taking the form of a labor mismatch, which implies the co-existence of unemployment and unfilled vacancies (for lower and higher skills respectively). Once again this will result in lower investment and hence in a subsequent fall in revenues and final demand. Unemployment thus reveals the existence of co-ordination problems at the economy level. It cannot be reduced to a matching problem, to be solved thanks to appropriate changes in the regulations of the labor market or appropriate actions that would allow workers to learn new competencies.

These scenarii just drawn illustrate the productivity paradox, that is, a fall in productivity notwithstanding the introduction of a superior technique in terms of production coefficients. There is a divorce between the productivity of the technique, which can only be verified in an economy already in the equilibrium state associated with the technique itself, and the effective productivity of the economy resulting from how the out-of-equilibrium process of transition takes place. This divorce has nothing to do with the specific character of the technique concerned; it depends on the co-ordination problems that arise in a transition process from an old technique to a new one (Amendola, Gaffard, Saraceno 2005).

Coordination over time concerns in the first place re-establishing a balanced structure of productive capacity, which will allow in turn to eliminate the resulting market imbalances, thus containing inflation and re-absorbing unemployment.

The availability of productive resources (the financial and the human resource) and the constraint that these may impose on production processes, together with the equilibrating (or disequilibrating) role performed by price and wage regimes are both essential elements of the required co-ordination mechanism.

To re-establish the co-ordination of economic activity we need an accommodating monetary policy, that is, a policy that provides the financial resources required for the investment necessary to take care of the distortion of productive capacity to be carried out. Of course, the opposite problem can occur. An excessive availability of financial resources may result in excessive investment with respect to that required to keep a balanced age structure of production processes, and hence in this case as well in an excessive productive capacity.

Of course, with a fully rational behavior making available the financial resources aimed at covering balanced investment expenses, equilibrium will be maintained or mechanically re-established. But this simply means wiping out by assumption the co-ordination problems that arise along a process of qualitative change and the implied requirement of a macroeconomic management of the process itself.

Unemployment and inflation are the unavoidable immediate outcome of a structural shock affecting the way of functioning of the economy. Unemployment, we have just seen, is the result of the temporary fall in final output and, in many cases, of the mismatch between the demand and the supply of skills due to the introduction of new and different techniques. Inflation occurs if and "because the goods in which the wages (...) will be spent (...) cannot be provided out of the product of the labour which is newly employed, for that is not yet ready" (Hicks 1990, p. 535). In dealing with inflation the central bank has a choice. It can try to curb inflation as soon as possible by resorting to a restrictive monetary policy. In this case, the investment necessary to carry out the innovation process cannot be realized. We shall have less production and less labor demand. Unemployment, lower revenues and the subsequent fall in final demand will further reduce receipts and financial resources. The initial negative impact of the shock on output and employment will thus be exacerbated. The central bank can, alternatively, decide an accommodating monetary policy characterized by the acceptance of a transitory inflation in the aim of ensuring the long-term viability, and hence higher growth, in the future. In this case, the expansionary monetary policy is the expression of the intent to pursue the objective of growth and employment rather than that of price stability. It is aimed at reducing the current disequilibrium between saving and investment (an investment reckoned insufficient) so as to also reduce the gap between supply and demand of final goods. The observed inflation then does not reflect a time inconsistency of economic policy that private agents should take into account. It is, on the contrary, a temporally coherent choice, since to accept a certain amount of inflation today makes it possible to fully re-absorb it tomorrow while also reducing unemployment. The availability of the required financial resources will in fact make it possible to keep a balanced structure of productive capacity thus re-establishing the co-ordination of economic activity.

The potential gains of innovation may only be appropriated if agents succeed in reshaping the productive capacity (whose distinguishing feature is to be temporally articulated), and in recovering the intertemporal coordination disrupted by the introduction of the new

technique. Physical, human, and financial capital are complementary in this process of reshaping and may constrain each other. The outcome of the disequilibrium process depends then on the interaction of accumulation choices, learning, and finance behavior.

Keeping in mind that the success of a process of restructuring of productive capacity depends mainly on being able to smooth the fluctuations and the strong and extreme changes associated with this restructuring, flexibility interpreted as quick prices and wages adjustment, by affecting the levels of demand and employment, will bring about over-reactions in one direction or the other that result in a stronger alternation of excesses of supply and demand, thus amplifying the distortion of productive capacity. Wage stickiness, on the contrary, prevents the fluctuations from becoming too strong so as to represent a threat to the viability of the economy. Thus, e.g., labor institutions that promote bargaining between workers and employers and hence produce slow adjustments in wages make it possible to maintain the purchasing power of the workers and simultaneously to favor the viability of innovation processes (Amendola, Gaffard and Saraceno 2004, Amendola and Gaffard 2006).

In intertemporal equilibrium models, price and wage rigidities are neither represented as a reduced speed in adjustment toward equilibrium nor as an absence of co-ordination, but rather as co-ordination on an equilibrium alternative to the perfectly competitive one. In out-of-equilibrium models, the speed of their adjustment to current disequilibria becomes a means of co-ordination. The study of out-of-equilibrium processes allows switching the focus from the analysis of price systems corresponding to alternative equilibrium states of the economy to the sequence of constrained decisions that describes an economic process taking place in time. This analysis makes it possible to extend to real wages Keynes' conclusions as regards money wages, thus challenging the classical inverse relation between real wages and unemployment. More generally**,** real as well as nominal rigidities, instead of being an obstacle to the attainments of full employment, may appear as a useful device for preventing an aggravation of unemployment, and hence market imperfections condemned as the cause of rigidities may be a factor of stability of the system rather than an obstacle on the way to optimal equilibria. In any case, the focus of the problem of employment is shifted from the determination of the price of labor to the evolution of the structure of productive capacity.

6. Conclusion

The out-of-equilibrium analysis puts the emphasis on interdependence as do general equilibrium model. However, in general equilibrium models, interdependence is instantaneously obtained as the result of establishing an equilibrium system of prices reflecting the fundamentals of the economy after the shock which represent the only interdependence link. In this perspective, by definition, the temporal order of decisions does not matter.

The interdependence that out-of-equilibrium models do consider, instead, is interdependence along the out-of-equilibrium path. This takes the form of feedback mechanisms over time linked to the misalignment of plans and outcomes and the subsequent appearance of rationing. Different types of disequilibria can follow from this and interact which each other sequentially. Now, in principle, different evolution path of the economy may be associated with any kind of original shock (impulse). Hicksian (Neo-Austrian) or sequential models are heuristic tools that make it possible to explore them. What Hicksian (Neo-Austrian) analysis is after is attempting to unveil sequential causality relations which represent the backbone of processes of economic change. Unlike in the equilibrium approach, these processes are not

already totally sketched out by the 'fundamentals' of the economy but rather the outcome of what happens on the way, and this may change according to the decisions taken and the policies followed sequentially, that is, according to the institutional regime and to the policy choices.

In this perspective, institutional arrangements are not (cannot be) immutable. Institutional innovations appear as responses to the recurrent necessity of solving conflicts between agents and between policy objectives. "The mechanism of modern democracy makes such innovations possible within an evolving system of institutions and laws that can be created or redirected without overthrowing the entire system of government – and so it has worked for more than two centuries" (Day 2004 b p. 12). The role of institutions is even more important than that. It is not only to take care of the conflicts and social costs associated with rapid changes, but also to promote and make viable these changes, that is, to coordinate the decisions and behaviors of the economic agents involved.

This kind of analysis is particularly relevant in the current period marked by a structural change induced by the ecological crisis and the digital revolution. The structure of productive capacities will be heavily altered. The uncertainty about future technologies and preferences makes it impossible to know *a priori* which path will be taken. The reaction to imbalances in the various markets will lead to tensions on prices and employment. Hence it would be important to understand how the economy works out of equilibrium, step by step, and identify the institutional and organizational means best appropriated to coordinate the economy along the way.

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