INSTITUTIONS AND ECONOMIC DEVELOPMENT AFTER THE FINANCIAL CRISIS

Editors: Sebastiano Fadda and Pasquale Tridico

(Routledge publishers, forthcoming 2013)

Evolutionary Dynamics in Revolutionary Times

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Version 26-03-2013

Abstract

Evolutionary theory is held together by two distinct elements: On the one hand it is the object of investigation – the emerging forms of life – that defines the scope of this scientific discipline, on the other hand the topic studied feeds back on the toolbox of methods, which the researchers in evolutionary theory use: there emerges an evolutionary research approach. Though both elements historically are evolving simultaneously and with close interplay, they nevertheless can be described independently – at least in retrospect.

And these two perspectives are what this chapter aims to outline. First, from a diachronic consideration, the emergence of life forms as a sequence of alternations between relatively stable evolution and revolutionary changes in entities and relationships is discussed. Second, from a synchronic perspective, the methodological consequences of the historical observations are highlighted.

In the last and third part of the chapter the logic of the first two parts is inverted: Reviewing the given evolutionary toolbox of methods it is investigated if it can help to understand the current revolution-loaded state of the global economy. But understanding for evolutionary theory always implies changing, simply because understanding itself is part of the evolutionary process. This argument provides the third element of evolutionary theory: It has inevitably to be a driver of actual revolutionary changes in the real world. This necessary practical involvement of this scientific discipline is particularly visible in evolutionary political economy at the current stage of world history. It is out to redesign the consciousness and interactions of newly emerging (aggregated) global agents.

1 - Diachronic profile of biological evolution

In a highly influential text with the intriguing title 'What is Life?' the physicist Erwin Schrödinger in 1944 tried to provide a sketch of an answer to a question, which had puzzled him for quite some time: After the breath-taking progress in theoretical physics in the first decades of the 20th century the notion of time still was entering the theory only via the second law of thermodynamics, which described a continuous, though stochastic, global increase of entropy – while the evolution of all kinds of living systems is characterized by an decrease in entropy. The two countervailing forces – one towards more disorder the other one, embedded in it, towards build-up of order – clearly are coupled by the notion of a *stochastic* relationship. Indeed it was the genius of Ludwig Boltzmann, who several decades earlier had simultaneously developed (advanced) probability theory, and a theory of physical processes (the connection between randomly moving micro-particles and stochastic laws governing observed aggregates). Schrödinger's courageous turn was to look at what happens in the physical processes of living matter to decrypt the appearing contradiction in theoretical consideration. To do so it was necessary to step down to the smallest scales at which observation was possible – Schrödinger's text was a kick-off for microbiology. There, at the level of atoms and the even smaller units and processes they consist of, a completely new world had appeared: the world of quantum electrodynamics. It had been difficult to reconcile the different opposing concepts found there: continuity versus discreteness[1], particle versus wave, determinate causality versus stochastic openness, etc. Schrödinger considered the build-up of structure in non-living crystals[2] and concluded that an additional twist – some aperiodic element – had to be present to distinguish the too repetitive growth of crystalline structures from the growing life forms. Some kind of 'quantum jump', of endogenously induced deep restructuring seems to be present in living systems – a first hint on the necessity to model alternating different (*at least two*) dynamics to grasp the evolution of living forms.

But the focus on extremely small scales in the spatial dimension to discover the primate of discreteness as well as the stochastic nature of all macro-level laws implied as well that the capacity of life forms to use such laws to propagate their own structure was only possible for organisms consisting of an enormous amount of atoms in the spatial dimension. The conservation of living structure generally proceeds with an increase in size in space and an increase in consciousness. *Time* is the central concept that encompasses the emergence of consciousness in living systems[3]. And again the consideration of the extreme long-run evolution of living systems can help to discover an underlying diachronic profile. First it is only straightforward that the stochastically occurring episodes of decreasing entropy during the long-run increase in entropy of the universe, i.e. living entities, are

[1] In a quickly written tour de force trying to incorporate the new views into mathematics John von Neumann wrote: ".. what was fundamentally of greater significance, was that the general opinion in theoretical physics had accepted the idea that the principle of continuity ('natura non acit saltus'), prevailing in the perceived macroeconomic world, is merely simulated by an averaging processing a world which in truth is discontinuous by nature. This simulation is such that man generally perceives the sum of many billions of elementary processes simultaneously, so that the levelling law of large numbers completely obscures the real nature of the individual processes." (Neumann, 1983 (1932), p. 4).

[2] Twenty years ago I have called the theories on the evolution of crystals E.T.0, 'Evolutionary Theory 0', evolutionary theory of plants and animals E.T.1, and evolutionary theories concerning the human species E.T.2; see (Hanappi, 1992, p.111).

[3] In Schrödinger's answer to the question 'When is a piece of matter said to be alive?' time plays the same pivotal role: 'He (Schrödinger) answered as simply as possible: "When it goes on *doing something*, moving, exchanging material with its environment, and so forth, for a much longer period (!, H.H.) than we would expect an inanimate piece of matter to *keep going* under similar circumstances.' (Gleick, 2011, p.283)

characterized by birth and death. In the end each physical carrier system has to surrender to the 2nd law of thermodynamics, while birth of consciousness located at an extremely small new physical nucleus refers to the mysterious quantum jump that enables life as a species. It is the split-up of the species in independent physical entities, which allows a species to live longer than any individual member. The role of the concept of species therefore is central to an understanding of the evolution of life, despite the confusion that currently still obscures the theoretical discourse on this notion. A species is the mediating element, which on one side is more enduring and framing for the evolution of its members while on the other hand it assumes the role of an individual unit that is in turn conditioned by the evolution of other species as well as by the non-living environment. A grand theory of evolution[4] therefore would address the historic development of the sequence of species. Charles Darwin in the title of his famous book tried to highlight the blind spot in this story: The *origin* of species. Based on his empirical research he considers the framing environmental conditions to be the cause for the properties of a species. From Darwin's perspective the set of species properties during the lifetime of a species is *regulated*, even determined by its more or less constant environment[5]. While this was a radically progressive opinion in a time when catholic ideology dominated social life, it had to remain rather vague with respect to the 'quantum jumps' that must have led from one species to the next. This, of course, is another aspect of origin: A species not only originates in the stabilizing feedbacks that the environment produces in a population (basically a stable growth process, call it 'Fast Process' of a certain stabilizing 'regime'). At the beginning of a regime new species emerge as the result of a much shorter process, their origin (in this second meaning) thus is to be found in the 'revolutionary dynamics' following a far-reaching extinction of other species or natural catastrophes. An often cited example is the Cambrian revolution, which clearly has led to an enormous variety of species, which only in a later stabilizing phase was reduced by Darwinian selection processes to fewer species. These survivors had originated in both, their original emergence as well as their superior survival feedbacks.

The evolution of different species therefore needs much more refinement, and not just a simple variation-test mechanism[6]. A historically observed sequence of species that are only defined by the stabilizing mechanism of a sequence of environments only shifts the question of origin to the question for the reasons of shifts in the environment. For non-living environments this boils down to the assumption of a sequence of natural catastrophes - what in modern mainstream economics bluntly is called exogenous shocks. What Darwin actually wanted to reveal too is the even more important issue that newer species can be described as derived from earlier species. And this is exactly where the second meaning of 'origin' has its place: The border between two different species in a sequence of the same timeline – what makes them distinguishable – is not just an instantaneous mutation, a point where the old species vanishes and the new one starts. It rather is a short process, which transforms *essential* elements of the old species and changes the main direction of its overall

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[4] Several scientists, mostly biologists, have set out to sketch such a grand theory; compare e.g. (Laszlo, 1987), (Davies, 1988), (Kauffman, 1995), and (Bak, 1996). Many ideas presented in this chapter have been inspired by these authors. A careful evaluation of their respective view would be very important but goes beyond the scope of this text.

[5] The Galapagos Islands, which Darwin visited, were a wonderful substitute for such laboratory conditions.

[6] The clearest and most concise definition of the evolutionary mechanism came from Herbert Simon: ‚The simplest scheme of evolution is one that depends on two processes; a generator and a test. The task of the generator is to produce variety, new forms that have not existed previously, whereas the task of the test is to cull out the newly generated forms so that only those that are well fitted to the environment will survive. In modern biological Darwinism genetic mutation is the generator, natural selection is the test.' (Simon, 1985, p.52)

dynamics (compare figure 1). Partly the newly emerged species after this short period of revolutionary transformation still carries some marks of earlier species, but new combinations[7] of such older elements also enable a large set of qualitatively new features.

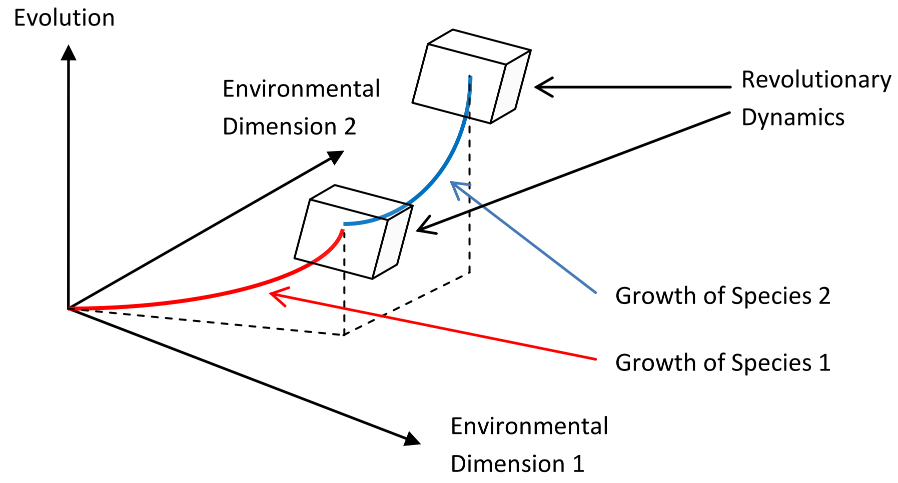

Figure 1: Evolution of Species

The new dimension along which the stabilized growth of the new species develops differs visibly from that of the older species – though some material indices like the size of population of species members might be common (measured on the vertical axis in figure 1). The two dice indicating the black box of revolutionary dynamics seems to have not really received appropriate attention in biology yet. The search for some common features of these black boxes encounters similar problems as the search for general rules in innovation economics. Since Darwin's time the path-breaking successes of microbiology have reallocated the properties characterizing a species (based now on the concept of genomes) to extremely small entities. And there, at the level of atoms, natural science has discovered two exciting facts[8]: (1) The fundamental role of randomness and (2) the unavoidable interdependence between the object of investigation and the scientific observer. So far these discoveries have not resulted in a convincing theory about the revolutionary dynamics generating a new species. To assume randomness only is a confession of (preliminary) non-knowledge of the intermitting revolutionary dynamics, which is needed to understand the evolution of species.

How these revolutionary dynamics could be understood had remained completely unexplained in Darwin's 'survival of the fittest' argument. Indeed Darwin had copied the latter expression from Malthus, an economist being famous for the formulation of dynamic forces in capitalism that stabilize the real wage of workers at the lowest possible level. Darwin was not very explicit on the human species and political economy in particular; he seems to have been rather afraid of the

[7] Though Schumpeter refused to be called an evolutionary economist his major theoretical innovations, e.g. the concept of 'new combination', point in the opposite direction; compare (Hanappi & Hanappi-Egger, 2004).

[8] A third observation at the micro-level concerned the difference between the growth of crystals, E.T.0, and life, E.T.1. Schrödinger had articulated it already in 1944: 'Solids in crystalline form; they can begin with a tiny germ and build up larger and larger structures; and quantum mechanics was beginning to give deep insight into the forces involved in their bonding. But Schrödinger felt something was missing. Crystals are *too* orderly – built up in "the comparatively dull way of repeating the same structure in three dimensions again and again." Elaborate though they seem, crystalline solids contain just a few types of atoms. Life must depend on a higher level of complexity, structure without predictable repetition, he argued. He invented the term: *aperiodic crystals*. This was his hypothesis: *We believe a gene – or perhaps the whole chromosome fiber – to be an aperiodic solid.*' (Gleick, 2011, p.285)

conservative forces of his time. But he had started to describe a pattern of the evolution of life forms, which in the mid of the 19th century actually had been in the air already (compare figure 2). For each line of development of a sequence of species the behavior during a stage was connected to set of exogenously fixed elements which limited and were safeguarded by fast adaption processes of the respective species. The border between species was drawn by mostly unexplained sudden changes (revolutions) in the set of these limiting exogenous variables. In each new stage (partly) different fast adaption processes were emerging. Looking at the sequence of changes in exogenously fixed variables, their movement can be described as a slow dynamics (blue vertical arrows). Any evolutionary theory thus has to comprise of at least two different speeds to be able to alternate between longer periods of relative stability and a perspective on long-run 'tectonic' shifts in the overall system.

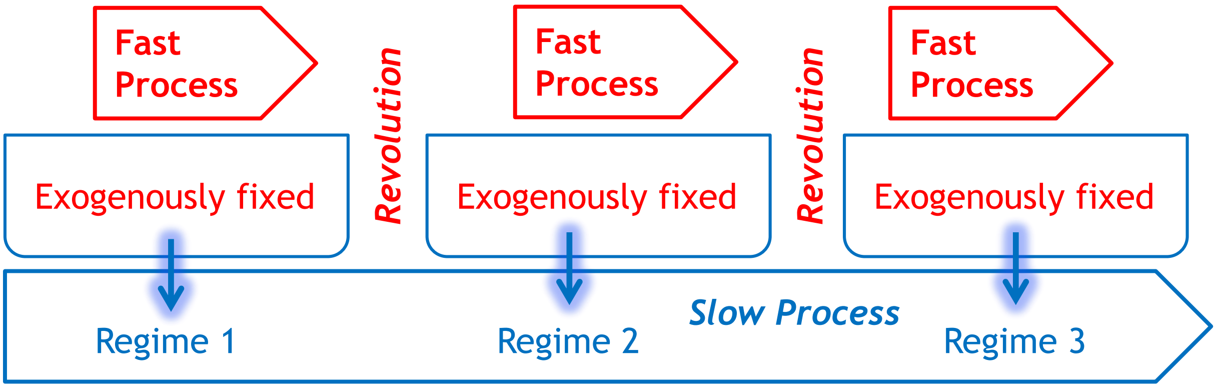

Figure 2: Typical profile of life dynamics

One of Darwin's contemporaries, Karl Marx, had presented an analogous scheme for the evolution of the human species only[9]. According to Marx the history of human societies can be understood as a sequence of modes of production. Each mode of production can be described as a relatively stable ensemble of forms of production techniques and their encompassing cultural (sometimes called 'institutional') and ideological frameworks. And Marx did lay emphasis on the revolutionary periods in the history of the species - he called them the 'fast trains of history'! Moreover Karl Marx had adopted and in a certain sense 'inverted' the dialectical logic of his early teacher Hegel, which implied that he interpreted an observed historical sequence as a chain of sequentially solved (revolutionary solved) contradictions. During each stage of relative stability a set of contradictions is slowly building up. Some of the less severe contradictions can be solved without a change of regime but a few of them get deeper and deeper[10] until the final break in a short revolutionary process.

The next revolutionary break from capitalism to communism in Marx view was already approaching. In fact, some 30 years after his death it needed the 1st World War to finally sweep away feudalism in the most advanced capitalist countries. The end of capitalism was postponed. A look back to the development of capitalism after World War 2 did suggest that capitalism should itself be divided into three different stages: merchant capitalism, industrial capitalism, and integrated capitalism (compare

[9] There existed personal and intellectual links between Darwin and Marx, see (Gould, 1999).

[10] It is tempting to rediscover in this process a '1st law of thermodynamics' for the social sciences: The sum total of contradictions in a closed system is constant. If some smaller ones are locally solved, they reappear in disguised form as parts of larger ones. Or, the system has to expand into new territories, has to become an open system.

(Hanappi, 1986, 1989) for a more detailed periodization of capitalism). In each of these stages some medium sized contradictions were building up, which then lead to a new type of capitalist sub-form which integrated them. It is not surprising that figure 2 in a Marxian interpretation looks a bit more specific, see figure 3.

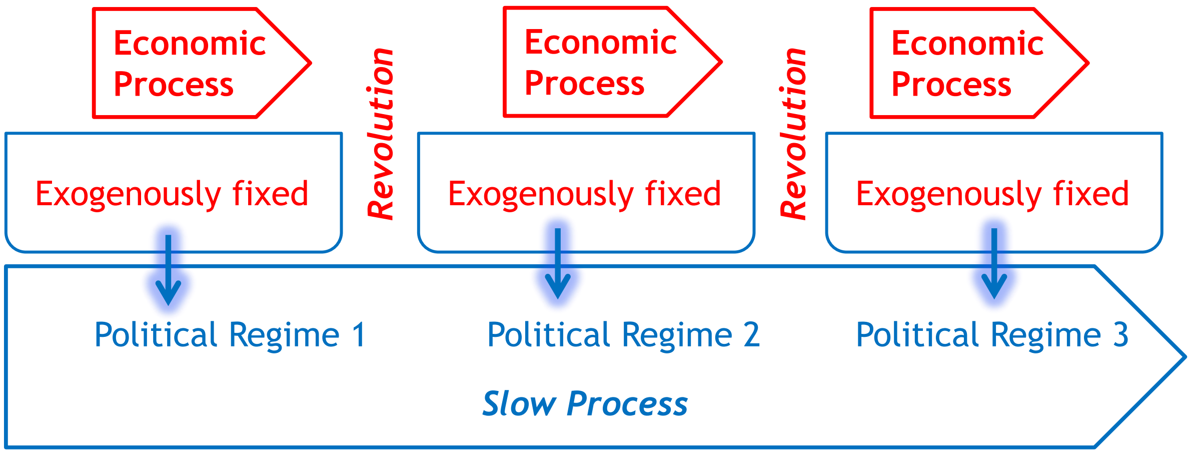

Figure 3: Profile of social dynamics of the human species

The fast processes in this scheme now are the typical economic processes that a certain political regime needs and regulates to maintain its own stability. As a necessary ingredient of these economic processes a variety of contradictions occur – some of them typically named 'externalities' in mainstream economics. The process of contradiction selection and production of additional variety of contradictions during a certain stage is itself an evolutionary process: It selects the ever growing avalanche, which in the end finishes the stage in a revolutionary dynamics. To do so this selection process has to choose processes that remain hidden from the ideological twisted eyes of the guardians of the prevailing regime. If they realize the danger to their regime due to their own specific blindness – they are themselves completely convinced of the ideology they spread - only in the last moment; then the quick changes will take them by surprise. This description perhaps can serve as a starting point for a future discussion of short-run revolutionary dynamics; it will be continued in the next section of this chapter.

Another property that leads directly to questions of methodology is the finite fractal structure of evolutionary theory. As briefly mentioned above, commodity producing societies consist of a sequence of modes of production, each mode of production is further structured into a sequence of stages (e.g. capitalism consists of merchant capitalism, industrial capitalism, and integrated capitalism) of which each one can be further taken apart. At each level of this structure self-similarity with higher levels as well as with lower levels can be detected, e.g. the sequence of the building-up of contradictions which leads to revolutionary dynamics, or the self-stabilizing mechanisms (institutions), which guarantee an increase in times of a dominant species. The immediate theoretical consequences are the production of taxonomy of species, a family tree, and for historians of the human society the need to define progress in contrast to a background of endless repetition of self-similar templates. This, of course, reminds of Schrödinger's problem of 'aperiodic crystals': Somehow structure is preserved, but not in a too regular way. Hegel – influencing Marx – had a similar idea some hundred years earlier and expressed it using the double meaning of the German word 'aufheben': It means saving something from the past but also getting rid of the past stage. The really difficult question, which cannot solved by only assigning names to it, is what actually happens in the short revolutionary periods when this ‘inversion’ takes place. Historians so far only seem to be able to point at case studies – a necessary but not a sufficient starting point to open the black box.

A last lesson that can be learned from the history of economic contemplation of human evolution in the last 300 years is the long-run swing in focus. It led from a dominance of national dynamics (to be found already in Quesnay’s work) to a dominance of arguments concerning human individuals (the high times of the classical marginalist school starting in 1874, and their rather anachronistic contemporary trailers in microeconomics), and more recently back to a possible hegemony of a macroeconomics, which appears to be predominantly mirrored in most internally used models of micro- and meso-economic entities. Note that this long swing is *not* a swing in economic activity itself (e.g. a Kondratieff Cycle), it is a swing in the history of economic thought. A possible explanation for the observed evolution is the following argument: First, during late feudalism, ordinary households and production units had so little to decide that the grand aggregates of a national economy, mainly based on agricultural dynamics, appeared as a natural macro-process. With industrial capitalism during the first half of the 19th century it became more and more difficult for social scientists to accept naturalistic point of view. Class dynamics became all to visible; Malthus tried to see a taming ‘natural law’ by formulating his ‘eternal law of wages’, Ricardo favored the productivity enhancing capitalist class over feudal landlords, Marx even saw a final victory of the working class. Instead of an amorphous gray mass lying below a ruling feudal nobility the new generation of classical political scientists distinguished interdependent classes within a population. Moreover this new setting induced the scientists to declare their own position; they became more or less consciously part of the dynamics they were describing. More generally, there emerged the confusing situation that the observer of social dynamics could not escape from realizing that he was part of the object of observation. When the surge of the French enlightenment that resulted in the bourgeois revolutionary events finally broke down in 1848 classical political economy with a lag of 26 years followed its downturn: In 1874 the theories of Walras, Jevons and Menger seemingly freed economics from its just acquired political component. Like mechanics it was conceptualized as a politically neutral formal description of the interaction of smallest, ‘natural’ elements: human individuals. As a matter of fact such a perspective fitted well to the new coalition between a bourgeois class that was allowed to run its capitalist business for the price of financing a feudal class, which remained political ruler of last resort. This stabilized compromise prevailed till World War 1. The ideology it implied was a combination of moderate decrease of the influence of the church on the one hand, and a politically tranquilizing introduction of metaphors taken from the natural sciences (mechanics of human individuals) that substituted class analysis on the other hand. An important lesson to be drawn from the period 1848 to 1918 is that ideology production can be efficient precisely because it provides *inadequate* mirror images of social dynamics thereby helping to freeze the current status and thus helping the currently powerful classes. In the previous period social consciousness of certain classes had been enhanced by *their* social theorists who were catalyzers of consciousness because they tried to provide an adequate picture of what is going on. Towards the end of the 19th century an inverted situation emerged: Producing more inadequate models - preferably by using formal tools making it more difficult to detect inadequacy – proved to be a more convenient way to absorb critical scholars and prevent them to stir up class dynamics. This was the starting point for a new elite of social scientists who were safe in their ivory tower; safe in a double sense: They would do no harm to the prevailing power relations and they themselves could feel safe because they were financed by the classes in power, substituting in that respect the fading role of the church.

With World War 1 the forces of the material world driven by capitalism outside the ivory tower ended the old constellation. But again it took some time, from 1918 to 1936, till John Maynard Keynes gave mainstream economics a new twist by pointing at an alternative framework to save capitalism from being swept away by its own dynamics. The way Keynes chose to shift the focus of economic theory from microeconomics to macroeconomics is more interesting than most of the content of his texts. Keynes did never produce a mathematical model of his 'general theory'; he preferred to use everyday language, brilliant in style but necessarily riddled with ambiguities[11]. In the face unbelievably high disequilibrium in all markets and exploding unemployment during the Great Depression the mathematical apparatus on which mainstream economics was based had lost its charm, since it still used as a fundamental principle that it only considers equilibrium positions. In other words it declared itself by assumption as impotent concerning economic policy in times of crisis; it only covered economic policy issues when they were not needed (in general institution-free and frictionless equilibrium) and therefore concluded – what a surprise – that public policy intervention is not appreciated. Keynes, the politician, saw that the hegemony of the capitalist class was in danger and that in this situation studying the interactions of optimal rational decision making of single human individuals using an abstract mathematical framework was just cheap talk. Parallel to the fraction of mainstream economists in the microeconomic ivory tower, the ruling class needed a second fraction of economists, which was able to restore a sufficiently stable exploitation regime with the help of more or less crude state power: the macroeconomists. Macroeconomics had to provide a recipe to fight crisis without calling into question class relationships, and to start with it had to collect aggregated data in the newly installed state-owned statistical offices. The down-to-earth job of Keynes generation of macroeconomists in the sequel was to invent and to estimate the simplest possible systems, usually static linear systems, which at least were able to express the idea that the collection of relevant variables is interdependent and should be considered as a system. Keynes left this task to Hicks and Kalecki and remained in the background with his vague qualitative statements. Keynes' return to a theory, which should inform a new fraction of the elite of mainstream economists, a fraction which would be able handle class domination by direct intervention of the capitalist state institutions (and not just by disorienting critical minds), this return to a pragmatic macroeconomic perspective triumphed[12] when global capitalism had to reinvent itself at the end of World War 2.

During the following decades the two fractions of mainstream economic theory - abstract microeconomics considering mathematical dream worlds[13] and pragmatic macroeconomics consulting piece-meal engineering of capitalist governments – marched in parallel. The repeated attempt of the former to build a mathematical bridge allowing to *derive* macroeconomics from axioms stated in microeconomics, the so-called microeconomic foundation of macroeconomics, gloriously failed[14]. The trajectories of the political economy of capitalist states evolved practically

[11] This choice must have been consciously made, since Keynes was always fond of mathematics as his early written texts on probability theory proves (Keynes, 1921).

[12] Keynes had proposed his new approach already after World War 1 with his arguments to reconsider the impact of Germany's reparation payments on European macroeconomic stability – but at that time failed to convince the relevant policy-makers, see (Keynes, 1920).

[13] Microeconomic theory therefore rather resembles a religion, and as a consequence I have dubbed it micro-theology (Hanappi, 1994, pp. 9-11).

[14] The best try remained Paul Samuelson's PhD thesis from 1947, which proclaimed a 'neo-classical synthesis' (Samuelson, 1947). It is the theoretical core of what more recently has been misnamed as 'neo-liberalism'. The latter term lumps together an unsound mixture of a critique of Samuelson's 'neo-classical synthesis' and a diversity of conservative ad-hoc policies missing any theoretical underpinning. It produces only confusion.

unaffected from both fractions of economic theory till 1971, when the system of fixed exchange rates, the Bretton Woods Agreement, was given up. During these years, from 1946 to 1971, only Keynes rather unspecified advice to enable a kind of integrated capitalism with the help of national credit systems aiming at ironing out business cycles had some influence. With respect to the micro-macro- relationship the integrated capitalism of the first decades after WW2 nevertheless had profound consequences: The possibility of stable reproduction, even at slowly rising living standards and profits, became deeply implanted in the internal models of households and small and medium sized enterprises (SMEs). In many countries of the developed world Keynes' vision of a 'social market economy', of a capitalism with a flexible public credit system invaded the minds and hearts of the population. And as long as the productivity gains, brought about by global trade integration and a pacified labor movement in the West, were able to provide a real economic basis for the self-fulfilling prophecies of monetary policy, as long as this tandem worked, the micro-, meso-, and macro-framework of internal models could remain largely consistent – as long as the cake to be distributed did grow sufficiently.

But when the sudden fall in the US Dollar[15] reduced the revenues of the world's large energy producers – in particular the cartel of the Seven Sisters, the main petroleum products producing multinationals – the first large oil crisis struck. This crisis synchronized, and therefore amplified the business cycles in all capitalist countries leading to a crisis of the institutions of governments, of integrated capitalism. From 1980 onwards the global roll-back to conservative economic policy, deconstructing the institutions of integrated capitalism takes place. It has been accompanied, even enabled, by an offensive directed at the internal model building process in the minds of human individuals. Mass media and new ICT technologies were increasingly successful in occupying central places in the mental models used by people in households, as employees, or as firm owners to take their decisions. Centrally produced role models stemming from a flourishing communication industry more and more destroyed all other traditional patterns used for social identity formation[16]. Though again a new emphasis on the pragmatics of macroeconomic intervention was launched, this time it concentrated on turning public institutions, which in principle were co-determined by organizations of the labor movement to guarantee a smooth working of integrated capitalism, into private enterprises, which usually were at the disposal of members of the ruling class. Production, including the production of appropriate ideology, was streamlined to serve sustained accumulation and redirection of income flows towards the ruling class. An enormous new wave of enhanced exploitation in OECD countries started. Though it did not went unnoticed by large parts of the population it was only with the beginning of the deep crisis in 2007 that the unavoidable divergence of economic forces in this type of capitalism brought the existence of theories of political economy back to the minds of ordinary people. What had happened to economics?

Taking 1982 as a somewhat arbitrary starting year of modern evolutionary economics[17], the thirty years of development of evolutionary economic theory can be interpreted as a struggle to overcome the interdependence between micro-, meso-, and macro-levels of the processes of political economy. In this sense the history of this discipline started by pointing at the many shortcomings and

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[15] It is interesting to note that the trigger for the breakdown of Bretton Woods was that the slow build-up of doubts of monetary authorities in the USA concerning the feasibility of the fixed exchange rate system had surpassed a certain threshold, and thus quickly lead to a switch in policy. The repercussions of such a policy switch of a major player at the time were not really anticipated.

[16] The surge of religious fundamentalism, e.g. in many US churches and the Arab world, just proves the strength and the broad range of applicability of the new techniques.

[17] The famous book by Nelson and Winter (Nelson and Winter, 1982) can be used as first breakthrough.

inadequate concepts of mainstream economic theory. If it would have stayed at that level, and if that would have been its only agenda, then the adjective heterodox economic theory would have been good enough, but evolutionary economic theory had to offer more. In particular with respect to the just mentioned problem of different levels of investigation it could draw on insights from general theories of evolution, in particular on the notion of self-similarity and fractal structure in biology. Several other methodological instruments from neighboring sciences could be added to its toolbox and will be discussed in the next section[18]. Furthermore, due to its embedding in evolutionary theory it tends to include both, long-run consideration and its short-run complements. With the aspiration to acquire this capacity evolutionary economic theory implicitly has to enable to describe the temporal aspect of short-run entities, i.e. the emergence of new essential elements as well as their eventual disappearance. It is not surprising that these high-flying goals of a research program cannot be said to have been reached yet. They still serve as a vision.

After the unfolding of the microfoundation-of-macroeconomics project the two fractions of mainstream economic theory fell apart even more drastically. The mathematically inclined microeconomic branch did find a hideaway from all empirically oriented disturbances by extreme assumptions on knowledge and information processing capacity of micro-units. In this quiet place of esoteric research a lot of progress, i.e. additional insight into a tautological kind of truth has been made. The pragmatic branch of mainstream theory focused on the immediate difficulties, which occurred as discrepancies between the need to sustain profit rates and the possibilities to use credit frameworks became pressing again. This usually was expressed as the problems of reducing cost, stimulating demand and elaborating finance, and no common theoretic framework was envisaged any more. Most of this branch degenerated and became managerial economics: accounting, marketing, finance, in the end marketing of finance. Mainstream economic theory indeed collapsed many years before the Lehmann Brothers disaster occurred in 2007.

Evolutionary economic theory promises to fill the vacuum left by mainstream economists.

2 – Synchronic profile of evolutionary methods

As the previous section showed a specific method of a specific branch of evolutionary theory, namely evolutionary political economy, only was emerging slowly during the last few hundred years since the revolution of the natural sciences in the 17th century. The theory by and large followed the ups and downs of general social evolution, eventually being involved and fighting battles on both sides of the ideological battlefield: On the progressive side (e.g. Hegel, Marx), as well as on the conservative side (e.g. Malthus, Schumpeter). Moreover it is noteworthy that ideological attacks and counterattacks usually occurred only decades *after* the battle in material life had been decided. Hegel followed the French Revolution, the theory of marginalist economists (Walras, Jevons, and Menger) followed the 1848 events, Keynes' theories followed the WW1 disaster, etc. But turn now to the question of *methods* used by evolutionary political economy.

A synchronic profile of these methods, that is a structured collection of the currently available methods, evidently has to start with the tools of the old masters of the trade: ***writings of texts*** in a language close enough to everyday language though with a touch of what in their time would have

[18] Among the most exciting research fields to be integrated are network theory, see (Barabási, 2002a), and the Neumann-Morgenstern project of a new formal language for the social sciences, better known as 'Game Theory', compare (Hanappi, 2013a).

been called 'philosophical aspiration'. Writing prose has been the style for almost every scholar till the Fifties of the last century – including John Maynard Keynes. Insofar it is fully justified to consider a scholarly written text as the first example of formalization, which is still a valid contemporary tool. Nevertheless not every prose text qualifies as scholarly work in evolutionary political economy. As the historical sketch provided previous section should have shown, economic history (and the included history of economic thought) is only an indispensable instrument, indeed a method, if it is interpreted history. Only if the power of abstraction enables a scholar to provide a more systematic picture of historic events, e.g. by postulating certain periodic reoccurrence or general features of different historic eras, only then simple description of historic events becomes a theory of political economy[19]. While the reference to economic history thus is a necessary condition for evolutionary political economy, it is not a sufficient condition.

What is particularly interesting with respect to this first form of formalization is that it is usually a precursor to what later is developed in other types of formal languages. Since *evolutionary* political economy has identified evolution as a process of pulsation (compare figure 3) it is straightforward to identify its authors as those scholars who describe dynamics as a process involving countervailing forces. Only with forces pointing in opposite directions with different strength at different points in time, only with such a setting the workings of disequilibrium and emergence can be encapsulated. When Richard Day produced his mathematical model of the ideas of Malthus he explicitly cited the passage of Malthus' text referring to the 'irregular movement' of social dynamics, which he, Day, presented as a chaotic dynamic system (Day, 2000). Another more recent example is Laszlo Barabási's book 'Bursts' (Barabási, 2011). In this book a representative historical drama is interwoven with reports of cutting edge contemporary network research. The intention is to help the reader to get a feeling that sudden, unexpected burst of traditional behavior occurs and in the sequel can have consequences, which go far beyond their first singular appearance. When and how such breaks happen and how they depend on the network types within which a process in a singular node suddenly passes an invisible threshold, all these details are not readily available and cannot be neatly packed in a formalized framework yet. But the stories told are seductive enough to inspire readers to let their creative potential float. Instead of a hierarchy of languages introduced by the philosopher Hegel, which sees mathematics on top and everyday language on bottom, evolutionary theory rather considers a pulsation process (of language styles) again: While during the more stable era a hegemony of certain more abstract styles prevails, towards the end of such an era the overshooting rigidity of abstract dogmas becomes inadequate and progress again depends on styles closer to empirically observed phenomena and everyday language. During the period of revolutionary dynamics some new combinations of more daring abstractions are mingled with the needs stemming from the deep crisis of political economy. Language pulsation turns out to be just another tool of the human species, which has emerged more recently in history.

The first type of mathematical abstraction extensively used by political economists in the after war period are ***dynamic equation systems***. The early ones were even static and only allowed for a comparative static comparison of different states of exogenous and endogenous variables. Endogenous variables simply were those variables were the assumption of their actual value was substituted by an assumption about a static relationship between at least two variables. As soon as

[19] One of the early debates in the discipline, the 'Methodenstreit' between the German Historic School (Gustav Schmoller) and the marginalist school (Walras, Menger), can be seen as the attempt to define what has to be added to simple story telling to arrive at a respectable theory. From today's perspective, both sides were wrong and exaggerated their case tremendously to win the argument.

different points in time for the involved variables in such an equation were assumed, the system turned into a dynamic equation system, and the presentation of results became comparative dynamics, i.e. a comparison of the set of trajectories of variables for different start (or end) values of endogenous variables and different assumptions on the trajectories of exogenous variables. Taking time as an element into the model immediately raised the question if it has to be considered as a continuous process or if it proceeds digital. From a formal point of view that takes into account of how economic processes work[20] it is straight forward to allow for both possibilities, which means that difference-differential equation systems have to be considered. A further complication arises with respect to the type of functional relationships postulated: As long as the links introduced between variables are assumed to be linear there exists a well-developed mathematical apparatus to study system behavior. For non-linear links such a treatment only exists for a few special cases. Yet linear relationships are extremely rare in the natural sciences, even Newton's gravitational forces decrease with the square of the distance of two masses, not to speak of the forces present in the human species. The usual excuses for using linearity include treatability and the restriction to consider only very small time periods, which are assumed to be sufficiently approximated by linearity. The first of these excuses has to be encountered by the argument that it is the insufficient formal apparatus that has to be changed, physical reality dictates its path of evolution since it is itself part of that evolution. The second excuse for linearity is even more interesting since it coincides with the economic approach of (neoclassical) marginalism: Marginal changes (for economics read: 'of prices reflecting social value') are adjusting to marginal changes (for economics read: 'of each individual subjective utility') by law-like eternal rules (for economics read: 'of unconstrained market forces'). If the time scale is pushed to its limit – that is either processes are assumed to be infinitely fast or infinitely slow – then very strange relationships between stock and flow variables emerge. The central issues of such theories usually discharge in a parallelism between a set of eternally valid laws and a protective belt of theory fragments, which has to explain why the paradigm represented by this set fails to explain what is observed empirically[21]. As a consequence of this dilemma several textbooks in mainstream economics rather concentrate on explaining methods of calculus and algebra with only an elusive link to problems of political economy[22]. Even if important lessons with respect to the advantages of a rigid argument can be learned from this literature (compare in particular (Chiang, 2005)) it nevertheless remains rather unsatisfactory for the tenets of evolutionary modeling. This became visible when some dynamic equation systems with very specific parameter constellations were found to exhibit a surprisingly unconventional behavior: Models of deterministic chaos did shake the self-confidence of the knights that were on a quest for the true economic dynamic equation system.

Chaotic systems differ from non-chaotic systems mainly by introducing randomness without the need to add (artificial and unexplained) stochastic terms to the equations. In other words it is

[20] While e.g. decisions on government budgets are not taken continuously, some growth processes in agricultural economics might be formalized that way. Interestingly enough theoretical physics after an early emphasis on continuous time (Newton and Leibniz) since Einstein favors a view that gives (digital) quantum considerations a certain primacy.

[21] In the natural sciences this interplay usually is emphatically celebrated as the experimental method, which allows improving the set of 'eternal laws'. There is at least a certain in-built modesty, admitting that the current theory might be preliminary, only a special case of a more general theory. Neoclassical economists often are far less modest since due to their object of investigation they assume that they can avoid laboratory experiments.

[22] In the didactically very clear textbook of Giancarlo Gandolfo (Gandolfo, 1998) at least many standard mainstream models are clearly discussed under the perspective of this mainstream formalism.

possible to produce a time series, which is identical to white noise by setting up a rather simple specific deterministic equation system. Such a system then is called a chaotic system. This exciting finding would be of minor importance for economic theory if the specification of chaotic systems would need strange and singular properties, but quite the opposite is the case: It has been proved that with increasing numbers of variables and equations the probability of chaotic behavior increases. For systems mimicking the interactions in human societies, where each individual entity maintains an internal model (a projection of its environment including communication), for these highly interconnected networks chaotic motions are almost inevitable. Turning the argument around, this implies that two candidates for evolutionary modeling emerge: On the one hand straight forward complexity modeling (largely based on chaotic systems) might help[23], while on the other hand the question how such chaotic motions can be coordinated at all has called into life diverse schools of 'regulation theory' (Boyer and Saillard, 2002). For the latter the focus is on the understanding and design of (man-made) regulation systems, rule systems, which allow for temporary coordination of the social entities actions. Such a focus brings politics (i.e. the discourse on power) and history with force back into the picture of economic theory[24].

More recently ***complexity research*** has joined forces with ***network analyses*** (see e.g. (Barabási, 2002b)), ***input-out analysis*** (see e.g. (Newman, 2010)), and new approaches in ***game theory*** (see e.g. (Coolen, 2005), ((Hanappi, 2013b)). The story behind this new mix is very plausible: Social entities act as a tightly woven network in a way that makes it unreasonable to predetermine which direction of causality in a certain period dominates – from the nodes to the overall network or from the overall network regulation to the restrictions of action sets of single nodes[25]. As a consequence, the choice made by an entity sitting at a certain node is made with the help of an internal model, the goal variables of which are additionally influenced by choices made by other entities at other nodes. This is the typical starting point for game theoretic analysis. An extremely complex analysis since it has to be taken into account that entities are embedded in a communication system: They are perceiving and interpreting only signals within a certain range of their communication network, and are themselves also are producing signals only within a limited range. This is the essence of what Herbert Simon a long time ago had dubbed 'bounded rationality' (Simon, 1982); but now it is not just a theoretical attack on the assumption of hyper-rationality. It takes a positivist turn and tries to make explicit what instead of hyper-rationality has to be formalized. The sheer amount of links to consider justifies calling such a system highly complicated, to characterize it as 'complex' leads to an important discussion of the concept of complexity itself. It started in the Fifties in information science when Andrei Kolmogorov and Gregory Chaitlin defined it in a very specific way: A bit string was defined to be more complex than a second bit stream if it took a larger program to produce it. For the most complicated bit strings, the most complex ones, it turned out that they cannot be computed by any program at all – they are their own shortest description. And here is the surprising

[23] The scientific communities summarized under the label of ‚Complex Adaptive Systems' (CAS) have recently attracted many young scholars worldwide.

[24] The French school of regulation theory is just one early example of several scientific communities trying to accomplish such an approach. Though starting with fewer formal aspirations these attempts more recently are reaching out for methods explored by econophysics. An early inspiration evidently has been (chemistry) Nobel-prize winner Hermann Haken's ideas of adiabatic approximation and the slavery principle. Compare (Haken, 1977, 2010) and (Zhang, 1991, pp. 193 - 212).

[25] In mainstream economic jargon this would be expressed as discarding any primacy of microeconomics with respect to macroeconomics, or vice versa. In the same vein the arguments of top-down versus bottom-up modeling lose their meaning.

link to deterministic chaos (as described above): The stochastic looking trajectories produced by a chaotic system can elegantly (though with demanding techniques) be reduced to their generating algorithm; they are much less complex than a look at the produced trajectories would suggest. Generalizing this idea[26] leads to the view that knowledge accumulation can be defined as the capacity to compress unintelligibly looking streams of signals to shorter generating programs, a task very similar to what in contemporary information science is called ***pattern recognition***[27]. As a side issue of deep philosophical significance Gregory Chaitlin emphasized the fact that most (infinitely many) bit strings (or numbers) cannot be compressed and they therefore show that there are sign structures outside our knowledge accumulation process, which never will be understood[28]. Evolutionary economics therefore swims in a pool of limited time and space, trying to compress incoming data streams to sets of generating systems. There is no hope for overarching 'first principles'. This is a disaster for all social theories aiming to model a convergence towards a final and global equilibrium state – the much appraised general equilibrium theory in mainstream economics, or other more explicitly religious believe systems are excellent examples. For an evolutionary theory of the type sketched in the previous section - with pulsation and the need to include two well-specified but different time scales and models – Chaitlin's result is rather supportive. It restricts possible generality to a manageable size and at the same time stresses the need to get as close to the object of investigation as possible, even to accept the theorist as part of the object he or she studies. Self-reference is certainly not just a logical playground but rather a deeply rooted property of living systems. This leads directly to another fashionable technique to be included in the evolutionary toolbox: Fractal analysis.

Fractal analysis formalizes the idea that structures often are characterized by self-similarity of the parts from which they are constituted. In a self-similar entity of a given size its components are smaller mirror images of itself, a kind of recursive call of a program. Each program in such structure is smaller than the program within which it is embedded and usually one bigger program contains several self-similar smaller ones. Self-references of the whole and its parts evidently work in both directions: from big to small and from small to big. To discover such a structure in nature typically implies a drastic reduction of complexity since all self-similar features only have to be described once; the rest is done by a repeated reduce and copy command. Fractal analysis therefore provides an excellent tool for knowledge accumulation. Fractal objects can be ascribed a fractal dimension, a well-defined number which characterizes the process with which they are generated. In the simplest case[29] this process is determined by the number of smaller mirror images, N, and the scaling factor used for reducing these images; call it S. The fractal dimension, D, then can be computed by inverting the formula

$$N = \frac{1}{S^D} \ .$$

The striking feature that objects can have a well-defined dimension in between the usual integers only due to their internal self-similar structure gives a new flavor to the evolutionary scheme

[26] Other interesting extensions of Chaitlin's approach were developed by Charles Bennett (Bennett, 1985, 2006).

[27] See (Hoyle, 2006) for an interesting introduction to the field.

[28] Chaitlin thus generalizes Kurt Gödel's famous proof on the limits of mathematics (Gödel, 1931) by extending it to (general) algorithmic information science (Chaitlin, 2001).

[29] An interesting introduction to fractal analysis is (Brown and Liebovitch, 2010). The stringent mathematical treatment of this area, of course, owes much to Benoit Mandelbrot. See (Mandelbrot, 2012) for his memoir.

displayed in figure 2. Since there is no explicit absolute time scale needed (just two scales different relative to each other) this scheme lends itself to fractal replication! Fractal analysis can help to reduce complexity even in a quantitative way[30]. How this can be accomplished and how it links to the other elements of the evolutionary toolbox is currently intensively investigated[31]. The focus of most of the research is on the question how coordination and cooperation of the seemingly disparate copies of different sizes can come about at all. The emergence of novelty clearly has to be understood as a feature of the communication sphere, of non-knowledge mirrored as a process of emergence. Simulation techniques are not included in this brief list of tools in the evolutionary toolbox because simulation is omnipresent in all areas. It would resemble to add the knowledge of the alphabet to the skills necessary for impressive poetry.

The final question now is if the use of these tools can influence the evolution of political economy. And as the reader might easily guess, the answer given in the concluding section of this chapter is affirmative.

3 – The feedback of methods on the evolution of political economy

In times of revolutionary dynamics, e.g. in current times, the global political economy is experienced as being in a state of widespread confusion. This concerns the dynamics of material flows as well as the organization of the world of ideas. For evolutionary theory this signals that a time of rather fast creative rearrangement, of a push towards a new level of social form of the human species has arrived. As in any transition phase of a living form (a species) the current potential jump to higher organization[32] is at the same time doomed by an increased possibility of extinction too. The dramatically increased global potential of destructive arms is an index showing how easy this possibility could be realized.

How can revolutionary dynamics be mastered and even used to advance the species? For evolutionary theory – and evolutionary political economy is only one branch in this broader perspective – the answer is straight forward: Still in accordance with the tenets of French Enlightenment what is needed are some action guiding grand theories helping to keep improvements and avoidance of bottlenecks on a global welfare increasing track. Where do these grand theories come from? Evolutionary theory – referring to Schumpeter's ideas – would point at the surprisingly quickly emergence of ***new combinations*** of existing (sometimes old or even almost forgotten) theory elements. Note that today theory production in the social sciences to a high degree takes place by the extensive use of formal tools, of new languages, which have been developed along the needs of a diversity of specialized research. The previous section of this chapter tried to collect some of these languages, while still keeping in mind that they cannot be arranged in a linear order. They rather proceed along a spiral working up to higher grounds by a repeated return (in some dimensions) to earlier forms[33]. Building such new combinations therefore is the most urgent task for evolutionary theory – across all existing disciplines and eventually founding new disciplines.

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[30] In (Barábasi, 2002b) the link to the modeling of hierarchical structures in networks is made explicit.

[31] For the link between input-output analysis and network modeling the tool of adjacency matrices is the immediate bridge (see (Newman, 2010, pp. 110-164)).

[32] In the larger perspective mentioned above these quantum jumps are just possible – though transitory - escapes from the law of increasing entropy, the 2nd law of thermodynamics.

[33] This scheme, of course, reminds on the methodological approach of dialectics that already intrigued researchers in ancient Greece.

A big problem then is how to ***implement*** changes in global governance, which can enforce an improved organizational setting. As history shows, such political changes can only be brought about by the support of larger parts of the population. As a consequence any forceful new 'ideology' needs a didactical component, to refer to something as difficult to understand as 'quantum electrodynamics' is not enough. The current theoretical goal therefore is not only to work on a synthesis (a new combination), but also to make it understandable to non-specialized people. Organizing the implementation is itself to be supported by evolutionary political theory – a an extremely urgent task since time is getting short rapidly.

Luckily there are not only obstacles but also some ***advantages*** at this newest transition phase. One concerns the electronic ***availability of incredibly large amounts of data***. A scientist could do research in many directions without being restricted too much by restricted access to empirical observations. The problem rather consists in identifying redundant lines of scientific activity. A second advantage, concerning mainly the problem of implementation, is the quickly emerging general ***ability of the population to use state-of-the-art computer technology*** – not just in OECD countries but also in more and more parts of the developing world[34]. In that respect the possibilities to distribute 'enlightenment content' are impressively increasing.

Thus there is no reason to despair for scientists working on evolutionary theory - but every reason to engage fast and with additional energy in this theoretical research. As another example of self-reference this chapter has been written as a modest attempt in this direction.

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[34] Today the use of mobile phones and TV hast o be included as a part of ICT.

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