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The disciplinary influence of physics, biology, and chemistry on economic modelling

Overview and implications for understanding agricultural change

Martin Petrick

SiAg
DFG-Forschergruppe 986
Strukturwandel im Agrarsektor

Herausgeber:
DFG-Forschergruppe 986, Humboldt-Universität zu Berlin
Philippstr. 13, Haus 12A, D-10099 Berlin
http://www.agrar.hu-berlin.de/struktur/institute/wisola/fowisola/siag

Redaktion:
Tel.: +49 (30) 2093 6340, E-Mail: k.oertel@agrar.hu-berlin.de

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Einflüsse aus Physik, Biologie und Chemie auf die ökonomische Modellierung Überblick und Schlussfolgerungen für das Verständnis agrarstrukturellen Wandels

Martin Petrick*
Leibniz-Institute of Agricultural Development in Central and Eastern Europe (IAMO)

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Abstract

Economic research on structural change in agriculture has repeatedly induced controversies about basic theoretical concepts, such as rational behaviour and equilibrium, and their analytical and political implications. To contribute to the epistemological dimension of this debate, the article gives an overview of three paradigms to economic modelling whose proponents have been inspired by physics, biology, and chemistry. The key concepts of general equilibrium theory, evolutionary economics and the "social chemistry" of Jon Elster are presented and compared. While all keep the idea that intentional individual action can explain aggregate outcomes that are nevertheless unintended, they differ in assumptions concerning preferences and the characteristics of coordination mechanisms. There is no consensus on what counts as a good scientific explanation. Similarly, views differ to what extent a spontaneous order in the economy has desirable properties. The emerging theoretical heterogeneity, I conclude, provides new opportunities for understanding agrarian change in contemporary society, of which a few are outlined.

Keywords: economic modelling, natural sciences, agricultural change, philosophy of science.

Zusammenfassung

Die ökonomische Forschung zum Strukturwandel in der Landwirtschaft hat immer wieder Kontroversen über die Verwendung grundsätzlicher theoretischer Konzepte, wie etwa Rationalverhalten oder Gleichgewicht, und ihre politischen Implikationen ausgelöst. Dieser Artikel möchte einen wissenschaftstheoretischen Beitrag zu dieser Debatte leisten, indem er einen Überblick über drei Paradigmen

* Comments by Wilhelm Brandes and by workshop participants in Liebenberg are gratefully acknowledged. The usual disclaimer applies.

der ökonomischen Modellierung gibt, deren Vertreter von den naturwissenschaftlichen Disziplinen Physik, Biologie und Chemie beeinflusst wurden. Es werden die Schlüsselkonzepte von allgemeiner Gleichgewichtstheorie, evolutorischer Ökonomik sowie der „social chemistry" Jon Elster's vorgestellt und verglichen. Während alle drei Ansätze auf der Idee beruhen, dass absichtsvolles, individuelles Handeln aggregierte Ergebnisse erklären kann, die jedoch von den Einzelnen unbeabsichtigt eintreten, unterscheiden sie sich in ihren Annahmen über Präferenzen und den Eigenschaften von Koordinationsmechanismen. Es besteht keine Übereinstimmung in der Frage, was als gute wissenschaftliche Erklärung gelten kann. Ebenso unterscheidet sich die jeweilige Einschätzung, inwieweit die spontane Ordnung eines Wirtschaftssystems wünschenswerte Eigenschaften hat. Die sich entwickelnde theoretische Vielfalt, so meine Schlussfolgerung, bietet neue Möglichkeiten für das Verständnis von agrarstrukturellem Wandel in der Gegenwart, von denen einige skizziert werden.

Schlüsselwörter: Ökonomische Modellbildung, Naturwissenschaften, Strukturwandel im Agrarsektor, Wissenschaftstheorie.

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1. Introduction

Some thirty years ago, a group of agricultural economists originating from various Western countries founded what they called the "Trans-Atlantic Committee on Agricultural Change" (TACAC). A major driving force in the formation of this group was a prevalent dissatisfaction with the theories and models available at the time to study structural change in agriculture. Heidhues (1976, 152-3), in an introductory article to a symposium issue of the *European Review of Agricultural Economics* that presented the main results of TACAC, commented on the standard modelling approach of that time as follows: "An accepted way to analyze change is to set up an economic model, determine the equilibrium of the system, and investigate its properties. … However, as a certain level of familiarity and proficiency in economic analysis is reached, both in government and in general, not only the benefits, but also the limitations of thinking predominantly in terms of equilibria become apparent. These limitations are not new but they need to be stated nevertheless." He moved on to address the major shortcomings of this approach. According to Heidhues, in studies of agricultural change, the existence and stability of equilibria is often not of focal interest. Furthermore, he claimed that the partial approach of the dominating paradigm neglects the embeddedness of agrarian change in a larger social system and thus fails to provide an adequate understanding of the causes, directions, and rates of change. This diagnosis led him to a plea for an explicit disequilibrium approach to agricultural change, which should address such issues as the objectives and behaviour of individuals and the processes of goal formation as well as the study of the information and coordination systems available for individual and group decision making (Heidhues 1976, 153-8).

Fifteen years later, Schmitt (1992) rephrased the issue in the following question: Do agricultural economists have a theory of structural change in agriculture at their disposal? His trajectory, however, was different from that of Heidhues: Based on a neoclassical household labour allocation model, Schmitt's article employed strong notions of rationality and equilibrium to analyse the efficiency of part-time farming.[1]

While I do not want to take issue with specific claims of both authors here, it seems clear that their articles touched on a number of fundamental problems that any (economic) theory of agricultural change has to tackle: Which assumptions are appropriate to model the behaviour of decision makers? What are the major drivers of change or the reasons for inertia? How can we explain the substantial organisational heterogeneity in agricultural production? Is there a

[1] Schmitt's article is primarily a polemic against alternative views on structural change expressed by some of his professional colleagues, who are accused of using a theory of structural change that is inconsistent or of using no theory at all. His main hypothesis is that farmers, in times of rising off-farm wages, make a choice between on-farm and off-farm employment, so that the observed importance of part-time farming in many European countries can be interpreted as a rational response to changing constraints that leads to an efficient equilibrium of the farm household. The neoclassical theory of the firm as employed by other authors is accused of being unable to account for the empirical diversity of growing, shrinking, and stagnating farms. A central argument Schmitt puts forward in favour of a "rational part-time farmer" is that the actual opportunity costs of off-farm employment for farmers are allegedly overstated by most authors. See also Schmitt (1991).

role for politics? Even more fundamental questions could be as follows: Are concepts such as "rationality" or "equilibrium" useful for understanding agrarian change? What is the relation between theory and reality in the social sciences?

That these question are still unresolved is reflected in the recent establishment of a Research Unit (Forschergruppe) on "Structural Change in Agriculture" funded by Deutsche Forschungsgemeinschaft (DFG), which aims at the further theoretical and methodological understanding of agricultural change under conditions of contemporary society.[2] It unites researchers that represent theories and methods which traditionally have been important in agricultural economics, such as neoclassical investment as well as partial and general equilibrium models, institutional economics, econometrics, but also (for agricultural economics) more recent approaches such as experimental economics and multi-agent modelling. I take the kick-off of this group as an occasion to review some of the fundamental strands of thinking about modelling the economy in general and agricultural change in particular.

As a starting point for this comparative overview I have chosen the analogy between economics and the natural science disciplines of physics, biology, and chemistry. While this structuring is to some extent arbitrary, there can be no doubt that social scientists have always been inspired by the theories, methods, and perhaps successes of their colleagues from the natural sciences. My major aim is to demonstrate that recent years have seen a revived debate on these analogies, which may also provide new insights for the domain of agricultural economics. I attempt to make this analogy fruitful for shedding new light on the fundamental problems outlined above.

2. The natural sciences in the eyes of economists

In a first step, I present an overview of the fundamental approaches to science that are represented by the disciplines of physics, biology and chemistry. Of course, this overview is in no way able to do justice to the respective domains of these disciplines. It is highly selective and primarily represents the idealised ways in which social scientists have been inspired by the three natural sciences mentioned. Table 1 summarises the main ideas.

[2] DFG Forschergruppe 986 „Strukturwandel im Agrarsektor – eine unternehmens- und politikbezogene Analyse" (SiAg). The programme includes nine coordinated research projects located in Berlin, Braunschweig and Halle. See http://www.agrar.hu-berlin.de/struktur/institute/wisola/fowisola/siag for further details.

Table 1. Natural science inspirations in economics

	Physics	Biology	Chemistry
Characteristic approach to science	Universal order and harmony guided by fundamental, invisible laws of movement; axiomatic parsimony	Organic approach guided by self-organisation, path-dependencies, mutation by chance, survival of the fittest	No simple predictive principles, strong reliance on empirically observable causal patterns that trigger potentially indeterminate consequences
Founding reference	Isaac Newton's mechanics (*Principia Mathematica*, 1687)	Charles Darwin's evolutionary theory (*On the Origin of Species*, 1859)	Robert Boyle's analytical chemistry (*The Sceptical Chymist*, 1661)
Conceptual counterpart in economics	Neoclassical economics, general equilibrium theory	Evolutionary economics	Social chemistry
Selected representatives in economics	Walras (1874), Arrow and Debreu (1954)	**"Conservatives"**: Alchian (1950), Becker (1962); **"Revisionsists"**: Hirshleifer (1977), Bowles (2004); **"Revolutionaries"**: Veblen (1898), Nelson and Winter (1982), Bromley (2006)	Elster (1989; 2007)

Source: author.

2.1 Physics

There is a wide agreement that the development of economics as a scientific discipline was highly influenced by the then prevailing research programme of the natural sciences, notably Newtonian physics. The characteristic approach of physics that made it so attractive in the eyes of social scientists is neatly summarised by Redman (1997, 111, quoted in Cardoso 2004, 20):

> *"After Newton had founded order and harmony in the physical universe by discovering the laws that govern its movements, philosophers reasoned that disorder must be man-made and could be averted by studying human nature and ascertaining the natural laws or connecting principles that govern society. The existence of guiding social principles was taken for granted; the search for them then became the primary goal. The scholars of this age were convinced that immutable laws such as those reigning in the physical universe existed in society and in mental states of human beings."*

It can be shown that these ideas were of direct importance for several of the economists that shaped the fundamental concepts of the discipline. Albert (1979, 52) argues that the

foundation of economics in Adam Smith's "Wealth of Nations" (1776) can be interpreted as the analysis of social order by using the methods of the natural sciences.[3] Another important figure is Léon Walras, whose influence on modern textbook economics and notably partial and general equilibrium modelling is evident. Bowles (2004, 478) goes so far to denote the standard curriculum taught to undergraduate students of economics today as the "Walrasian paradigm". It is the neoclassical general equilibrium model of the economy with its normative counterpart, welfare economics. I will describe this paradigm later on in a little more detail. Here it suffices to note with Blaug (1997, 550) that "the true origins of Walras's formulation of general equilibrium theory was Louis Poinsot's once famous textbook in pure mechanics, *Eléments de Statique* (1803), a book which Walras kept by his bedside throughout his life. No wonder then that Walras's *Elements* [*of Pure Economics* (1874)] bristles with complimentary passages about Newton, drawing analogies between Newtonian physics and the 'new' economics typified by his own work." Walras's central idea of the existence of a multiple market-clearing general equilibrium was later generalised and formally refined by Arrow and Debreu (1954).

2.2 Biology

Despite the lasting influence of Newtonian physics, economists were not unaffected by other approaches to science. Probably the most important, second to physics, is the influence of biology, and notably evolutionary theory. From today's perspective, an early reference to the analogy between economic and evolutionary processes is Veblen (1898). Schumpeter (1954, 788) notes that the idea of society as an 'organic', not a 'mechanical' system played an important role already for 19th century economists. More recently, Nelson and Winter (1982, 10) characterised the evolutionary approach as follows:

> *"The broader connotations of 'evolutionary' include a concern with processes of long-term and progressive change. The regularities observable in present reality are interpreted not as a solution to a static problem, but as the result that understandable dynamic processes have produced from known or plausibly conjectured conditions in the past – and also as features of the stage from which a quite different future will emerge by those same dynamic processes. In this sense, all of the natural sciences are today evolutionary in fundamental respects. ... Science has come to see the continents as shifting with sporadic violence beneath our feet, the changing behavior of the Sun as a possible factor in human history, and the world's climate as threatened with major and perhaps irreversible change as a consequence of industrialization. Against this intellectual background, much of contemporary economic theory appears faintly anachronistic, its harmonious equilibria a reminder of an age that was at least more optimistic, if not actually more tranquil. It is as if economics has never really transcended the experiences of its*

[3] Cardoso (2004, 16) demonstrates how Smith was directly influenced by Newton.

childhood, when Newtonian physics was the only science worth imitating and celestial mechanisms its most notable achievement."

However, the continuing influence of evolutionary theory on economics, in particular the ideas of natural selection, self-organisation, and the role of chance in dynamic processes, was not uniform, but led to various strands of thought within what could be labelled the field of evolutionary economics. Vromen (2004) usefully distinguishes three major groups of "evolutionary" economists: the conservatives, the revisionists, and the revolutionaries.

- For the *conservatives*, such as Alchian (1950) or Becker (1962), evolutionary ideas are used to "rescue" standard economic theories (Vromen 2004, 104). Whereas the details of the evolutionary processes at work remain vague, the basic idea is that profit maximising behaviour is induced by competitive markets in a process similar to natural selection, which thus provides an instrumental reason for keeping the orthodox model.
- The *revisionists* aim at a "friendly amendment" of conventional theory (Vromen 2004, 110). In particular, they introduce more complex (e.g. altruistic) preference structures of individuals and argue that these are the product of evolutionary processes of the past (Hirshleifer 1977). As such, evolutionary theories are used to provide a better understanding of observed behaviour, not (as in the conservative group) to justify certain a-priori assumptions in the orthodox neoclassical model. A recent textbook treatment of the revisionist camp is Bowles (2004), whose approach will be outlined below.
- The *revolutionaries* consist of a number of more or less heterodox subgroups of economists who argue that the neoclassical standard model should be completely discarded. One of these subgroups is American institutionalism, of which Veblen (1898) is a classical and Bromley (2006) a recent representative. Nelson and Winter (1982) have been influential with a Neo-Schumpeterian, organisation-based analysis of growth and competition.[4]

2.3 Chemistry

To my knowledge, Jon Elster was the first to introduce the idea of a "social chemistry", which he explains as follows (Elster1989, 1): "At the present time, the social sciences cannot aspire to be more than social chemistry: inductive generalizations that stick closely to the phenomena. The time for social physics is not yet here, and may never come." In a footnote, he quotes Rigden (1987, 36-7) to make the difference clearer: "Physics is parsimonious. A few basic ideas have a validity that extends across nature from the smallness of the atom to

[4] Views differ where the appropriate place for evolutionary game theory should be (Young 1998, Binmore 2005). Sugden (2001) argues that this is nothing more than a "recovery programme" of formal behaviourism which recovers Nash equilibria as a result of boundedly rational choice and strong normative a-priori assumptions. However, as Vromen (2004, 117) points out, it might also be regarded as revolutionary because it substitutes the equilibrium selection concepts of classic game theory and its "refinement programme" (hyperrationality, common knowledge) by evolutionary arguments. It models the spontaneous emergence of stable, self-sustaining social patterns of behaviour, without design by an authority and without being the result of concerted action, thus formalising ideas of Austrian economists.

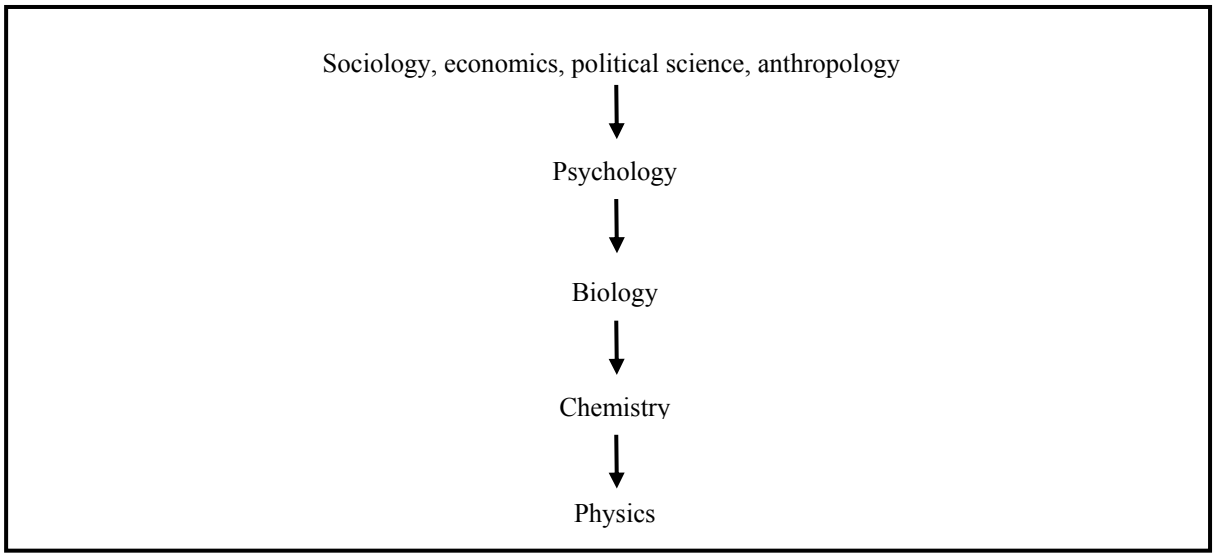
the vastness of the galaxy. Furthermore, these basic ideas capture a variety of factual information in the network of logical connections between them. The person who sees charm and beauty in the ideas of physics may see no enchantment whatsoever in chemistry. Lacking the simple predictive principles that are the stock in trade of physics, chemists are marvelous in their ability to hold in their heads at all times a vast array of information. Physicists, on the other hand, work from a base formed by a few remembered ideas." Although not mentioned by Elster, the early chemist Robert Boyle may be an appropriate reference for this approach: Boyle's work marks the transition from alchemy to chemistry. While he was highly insistent on the importance of empirical and experimental work to find out the principles of chemistry, he had few of them available at his time.

Elsters research programme is influenced by two important themes, which makes his contribution particularly interesting in this survey. On the one hand, primarily his early works are motivated by a firm background conviction that humans have a type of rationality at their disposal that is *superior* to that of all other species (Elster 1979, 1-35; Petrick 2008). On the other hand, Elster is highly insistent that social science must be strongly empirically driven and must not reduce its efforts to find out the *real* processes that determine human behaviour. The first point leads Elster to reject the usefulness of the idea of natural selection to understand human societies.[5] According to Elster (1979; 2007, 271-286), man has the distinct ability to find and approach global maxima. In contrast, all other living beings are only capable of reaching local maxima. For the second reason, Elster is highly critical with the type of functionalist explanations prevalent in mainstream economics, which he claims do only purport to be general laws but lack sufficient empirical foundation (Elster 1979, 28-34; 2007, 9-31; see Pies 2008 for an overview). The biologists' task is to discover the reasons for this difference. In contrast, the agenda of the social scientists is to find out why humans *fail* to reach global maxima, despite their extraordinary rationality potential. Therefore, Elster's research programme can be regarded as a study of the nature of human's *imperfect rationality* and its implications for the individual and its social environment (Petrick 2008).

Because there are no lawlike generalisations in the social sciences, the researcher has to search for what Elster calls *mechanisms*, a form of generalisation intermediate between laws and description. Elster (1999, 1) defines mechanisms as "frequently occurring and easily recognisable causal patterns that are triggered under generally unknown conditions or with indeterminate consequences". Mechanisms allow true explanation but no prediction, and enable the scientist to explain when generalisations break down (Elster 1999, 6). They are often described by proverbs, such as "out of sight, out of mind", "like attracts like", "like father, like son". Elster reconstructs these patterns by using rational choice arguments in a non-formalised, qualitative way.

[5] Elster (1979, 31) concedes that the behaviour of the profit maximising firm in a competitive market is one of few exemptions to the rule that natural selection can be used as a non functionalist explanation in the social sciences.

Figure 1. Reductionism in science according to Jon Elster



Source: Elster (2007, 257).

Furthermore, Elster is sceptical with establishing *analogies* between the natural and the social sciences (despite his plea for "social chemistry"). The theory of natural selection in biology is his prime example to demonstrate the dubious value of such analogies. Instead, he strongly advocates a *reductionist* connection between them (Figure 1). He believes that insights of the social sciences can be reduced to principles of psychology, which in turn builds on biology. The further steps of this ladder down to a more general science are chemistry and physics, which according to Elster is the most fundamental of all sciences (Elster 2007, 257-260). My reading of these statements is that Elster recommends to use the *methods* of the natural sciences (such as all types of induction based on empirical observations or experiments, including psychological ones, but also based on studying poetry or the arts in general), but warns to import their *theories* in an insufficiently reflected manner.

3. A closer comparison of model ingredients

In a further step, I now want to subject the specific concepts used in the three stylised strands of modelling to further scrutiny. Table 2 summarises the characteristics of each of the paradigms, which I now distinguish as "Walrasian economics", "evolutionary economics", and "social chemistry". It allows to see commonalities as well as differences.

Table 2. Key concepts in economic paradigms influenced by physics, biology, and chemistry

	Physics	Biology	Chemistry
Paradigm	**Walrasian economics**	**Evolutionary economics**	**Social chemistry**
Behavioural principle	Intentional individual action		
Generation of aggregate outcomes	Generally unintended		
Drivers of results	Constraint through competition		Imperfect rationality
Basic analytical model	Solution of a constrained optimisation problem; comparative static comparison of unique, stable equilibria	Adaptive agents carrying behavioural rules; explicit out-of-equilibrium dynamics, role of chance	Qualitative commonsense rationality interacting with empirically observed "mechanisms"
Individual preferences	Self-regarding, exogenous	Self- and other-regarding, possibly endogenous	Variety and plasticity of preferences & motivations as complex representations of human rationality
Coordination mechanism	Market-clearing prices, no institutions (other than the market)	Genetic & cultural selection; coevolution of institutions, noncontractual relations in noncompetitive settings are common	No natural selection, man = global maximiser; variety & interdependency of institutions
Technology	Convex	Increasing returns, positive feedbacks, learning	No a-priori assumptions
Open questions	Illuminating about real (historical) processes? Desirability of outcomes?		

Source: author, inspired by Bowles (2004, 479).

3.1 Common roots

All three paradigms are united by a methodological individualism that seeks to explain human behaviour as a result of *intentional* individual action, which is directly related to their commitment to rational choice explanation. A further common idea is that aggregate outcomes are generated and should be explained as *unintended* results of individual action. Both tenets have traditionally been fundamental to economics and could even be regarded as its constitutional elements (Stigler and Becker 1977; Satz and Ferejohn 1994; Elster 2007, 13, 300).

Competitive pressure on markets has always been a major object of study in economics, and it is here where many evolutionary economists see the analogy to natural selection processes.

This is thus the third of the "familiar triplet of ideas" that unite Walrasian and evolutionary economists (Bowles 2004, 8). Elster's emphasis is more on studying the consequences of imperfect rationality in a variety of settings. Instead of focusing primarily on competitive environments, he is interested in opening the "black box" of individual (Elster 1999) and social (Elster 1989) decision making.

3.2 Divergent research programmes

For all of the four following characteristics one could say that they commonly imply strong theoretical assumptions in the Walrasian paradigm. The plausibility of the equally strong principles or laws within this paradigm (for example, the Fundamental Theorems of Welfare Economics or the Coase Theorem) rests on the validity of the assumptions. However, discontent with the validity and usefulness of these assumptions has been among the major driving forces behind the import of ideas from biology and chemistry. For this reason, the rigidity of concepts is more and more relaxed when one moves to the right of the table.

The basic analytical model of the Walrasian paradigm is the constrained optimisation of utility or profit by participants of a perfect and complete market system. To achieve the desirable results of this coordination mechanism, namely the existence of a market-clearing price that produces a Pareto-optimal outcome, assumptions of exogenous preferences and convex technologies are commonly invoked. These are the preconditions that make the comparative static comparison of unique, stable equilibria a useful procedure.

As noted above, almost all of the fundamental assumptions of this paradigm have been called into question by proponents of a more evolutionary, explicitly dynamic economics. The major point I wish to make here is that recent years have seen such an intensive development of this field that it has now left the stage of being merely one of many heterodox variants of economics. In my view, the publication of the textbook treatment by Bowles (2004) shows that there is now a closed, unified evolutionary approach to economics that claims to provide a more relevant and better empirically founded understanding of society than the orthodox Walrasian paradigm. While Vromen (2004) (in my view correctly) regards Bowles as a representative of the revisionist and not the revolutionary camp in evolutionary economics, the major departures from the traditional model are as follows:

- Social interactions are commonly regarded as non-contractual rather than complete and readily enforced.
- Individual behaviour are understood as being of an adaptive and other-regarding nature.
- Generalised increasing returns, positive feedback effects and learning processes are the norm rather than the exception (Bowles 2004, 9-13).

Along with relaxing the standard assumptions, new analytical techniques have been developed, among which experimental studies, game theory, bargaining models, heterogeneous-populations and multi-agent models are prominent (see for example parts I and III of Bowles

2004). These in turn allow the analysis of explicit out-of-equilibrium dynamics as well as complex institutional settings and their evolution.

Although Elster as a major proponent of "social chemistry" is sceptical about the analogies employed by evolutionary economists, his own approach is nevertheless widely consistent with the evolutionaries, if not in modelling style, at least with respect to the major theoretical implications. In some respects, Elster goes even further than the "friendly revisionists" of evolutionary economics, in that his analysis of basic motivations for behaviour is of a much finer grain than common in the economics literature and can hardly be captured by a formal utility function. Introducing his most recent treatment of the subject, Elster (2007, 75) writes:

> *"In the following, I focus on two specific issues, selfishness versus altruism and temporal shortsightedness versus farsightedness. These two issues complement each other, the latter being as it were the intertemporal version of the former, interpersonal contrast. ... The set of human motivations is a pie that can be sliced any number of ways. Although none of them can claim canonical status, there are four approaches that I have found useful. The first proposes a continuum of motivations, the second and the third offer both a trichotomy, and the forth a simple dichotomy. The classifications are both somewhat similar and interestingly different, allowing us to illuminate the same behaviour from different angles."*[6]

In a sense, however, Elster's intellectual journey arrives at similar conclusions about the characteristics of human behaviour as that of many evolutionary economists, but from a different starting point. Evolutionaries have started with very simple (animal-like) behavioural assumptions and introduced more complex patterns such as other-regarding preferences by arguing that these were "added" in the course of human evolution (Binmore 2005). Elster begins with a praise of superior human rationality only to find out later that "real" everyday circumstances and mindsets often dilute these distinctive abilities.

4. Which approach provides better explanations of real processes?

Inspired by Bowles (2004, 87), two fundamental questions shall be picked out for further commentary. First, do the representatives of biological and chemical metaphors in economics live up to their promise to provide better explanations of reality, or of real historical processes? Second, if the alternative (or enriched and modified) theories are true, what do they have to say about the social desirability of the processes and outcomes they postulate?

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6 Well in line with the labelling as "social chemistry" is the title of another book by Elster that examines the relationship between rationality and the emotions: "Alchemies of the mind" (1999).

Elster (2007, 21-28) sets out a very strict definition of what counts as a good explanation by enumerating what, in his view, is not an explanation:[7]

1. A statement does not count as an explanation if it does not provide an actual causal mechanism,
2. explanation is not simply correlation or coincidence,
3. to say that there was a necessity for something to happen (for example the death of a person that is ill to death) is insufficient as an explanation if other causes are possible (the person could have been killed),
4. explanation is not storytelling, or stating what *might* have caused something to happen, which includes a rejection of "as-if" explanations,
5. to cite statistical significant findings as true explanations may be a fallacy if the general tendency in a dataset is not valid in each single case,
6. to explain nonevents by nonevents is absurd (example: "the scientist did not cite my article in his book because he was not aware of it"), and
7. prediction is not causal explanation, because the relevant causal mechanisms can often only be identified after an event had taken place, not before, in particularly in cases where several triggering mechanisms are possible.

According to Elster, what *does* count as a true causal explanation is what he defines as a "mechanism", as cited above. What he has in mind is a qualitative social science that "combine[s] utter authority in factual matters with an eye both for potential generalizations and for potential counterexamples to generalizations." Such researchers "can pick out the 'telling detail' as well as the 'robust anomaly,' thus providing both stimulus and reality check for would-be generalists" (Elster 2007, 447). Elster explicitly mentions historical analysis and case studies as being examplary for such an approach. His own studies have not been left uncriticised, however: Pies (2008) argues that an explanation by mechanisms results in a possibilistic approach to science, one that states how events *might* have been caused. This would imply that Elster himself commits the fallacy of storytelling, as (4) above.

It is beyond the scope of this overview to conduct a comprehensive comparative analysis of the explanatory power of the three paradigms, which would require to look at specific subjects studied by the three. As a general comment, I have argued elsewhere that economists frequently purport to provide "hard" explanations, backed by statistical evidence, although they actually employ variants of storytelling (Petrick 2004). I have also suggested that this is simply a reflection of the fact that science is a communicative arena in which the most plausible arguments win – whereby the jury consists of the group of other scientists who criticise and probe the arguments put forward. The growing interest in evolutionary economics seems to indicate that more and more researchers do find this approach plausible – because it employs more valid assumptions, corresponds better with reality, uses more

[7] See Elster (1979, 28) for a related list on what may count as a true functional explanation.

striking metaphors, or, after all, allows to tell more interesting stories. In a parallel to Elster, Bowles (2004, 88) sees a major function of evolutionary models in providing useful starting points for more detailed historical studies that may unveil the "true" processes. He illustrates this point in a discussion of an evolutionary game theory model of the spontaneous formation of property rights (Bowles 2004, 69-87). The question at hand is whether such institutions evolved spontaneously "by accident" or as a result of planned collective action. Bowles (2004, 88) writes:

> *"Of course nobody supposes that a single model as simple as [this] ... provides an adequate framework for understanding something as complex and historically contingent as the process by which property rights have been modified over the years. Models do not explain history, but they may tell us where to look. ... Evolutionary modelling will have done the study of institutional change a great service if it can provide a framework for integrating the aggregate effects of large numbers of individuals each acting singly and seeking their own ends while occasionally acting jointly with others for whom institutional change is a project, not an accident."*

Do economists have more to offer than "adequate frameworks" that "may tell us where to look"? What counts as a good explanation is, in relation to its importance for the progress of science, rarely discussed openly. My personal view is that the economic profession would gain significantly from a more honest debate of this matter, which includes the consideration of epistemology in the standard curriculum of the subject.

5. "Blind watchmaker" vs. "global maximiser": how desirable are the aggregate outcomes?

The previous quote brings me to the second question, namely the social desirability of outcomes. Bowles (2004, 57-8) distinguishes two traditions of how the "right" institutions and policies are established: a constitutional and an evolutionary approach. The first, also called "institutions by design"-approach, posits that social rules and institutions are created in the human imagination, evaluated with respect to their problem-solving capacity and implemented if they are regarded as useful. This may involve the presence of actors who have benevolent preferences for social outcomes, as traditionally assumed in welfare economics. However, this need not be the case: Petrick and Pies (2007) present a contractarian approach to rule setting that does not require this assumption. The second, evolutionary approach implies that society organises itself by spontaneous order. Referring to a book title by Dawkins (1989), Bowles calls this the "blind watchmaker"-process. This may be phrased as a variant of the "invisible hand"-metaphor that is at the heart of the Walrasian paradigm: in the long run, the most efficient institutions will predominate, even if the outcomes they produce are unintended. However, evolutionary models as used by Bowles and others do not commonly reproduce this result. Bowles (2004, 90-1) lists a number of reasons why this is the case:

- Depending on institutional spill-over and complementarity effects, there may emerge multiple stable configurations of institutions, of which some may be very inefficient,
- even if there are selection processes at work that produce more efficient institutions at the community level, the community may lack the mechanisms necessary to implement the better institutions,
- similar to the emergence of new species, the creation of innovative designs in evolutionary models is highly improbable and still poorly understood,
- evolutionary change is so slow that the effects of external shocks may by much more important for the result.

According to Bowles, "survival of the fittest" is therefore unlikely to produce optimal results. This contrasts with the standard notion in Walrasian economics, where competitive market forces produce the results desired by consumers, but also with the arguments by the conservatives' camp in evolutionary economics, which are based on a strict analogy between market competition and natural selection.

In Elster's view, humans as global maximisers rather than gradient climbers should be able to produce desirable results. However, the argument runs opposite to the conservatives' natural selection argument: globally optimal results should be expected not because natural selection works so efficiently, but because humans are capable of overcoming the simple selection procedures used by evolution. By virtue of their intentionality, humans may use indirect strategies to achieve their goals, may recognise the value of waiting, and may aim ahead to reach a moving target (Elster 2007, 279). To the contrary, natural selection works opportunistically, myopically, individualistically, and cannot anticipate changes in the environment (p. 282). To a certain extent, however, Elster qualifies this statement himself by pointing out the various, empirically observable imperfections of human rationality (1989, 250):

> *"Most writers try to make do with rational self-interest as a sole motivational assumption, while I have invoked a broader range of motives. Though I share their preference for a parsimonious explanation and their hesitation to get into a morass of ad hoc assumptions, I have concluded, with some reluctance, that there is no way in which the programme can be brought forward on this narrow basis. Ultimately, parsimony must take second place to realism. In physics, truth may be simple. In chemistry, it is likely to be messy."*

In summary, the further we move away from assumptions that guarantee the functioning of a first-best world coordinated by the "invisible hand", the less likely is it that outcomes exhibit any desirable properties. Compared to the harmonious world order of the Walrasian paradigm, a society understood in biological or chemical metaphors will leave much to be improved by purposeful collective action.

6. Implications for understanding agricultural change

The traditional view of structural change in the farming sectors of Western societies is one of external technological progress in agriculture and, according to Engel's law, a decreasing food share in consumers' expenditures, which together lead to a fall in food prices and income decline in agriculture (Gardner 1992). As a result, farmers continuously have to adjust their production scale without being able to fully reap the benefits. For the same reason did most Western economies see a persistent reduction of the share of agriculture in gross domestic product (see Tracy 1993 for an overview and statistics). But this is not the complete picture. Under conditions of contemporary society, additional issues need to be explained, before agricultural economists can claim to have a complete theory of agricultural change at their disposal. I list a few examples:[8]

1. Which are the main drivers of farmers' behaviour? Do they display systematic patterns of behaviour that differ from other decision makers?
2. Why do apparently inefficient farm structures persist for a long time? Why is the reaction of farmers to income pressure so sluggish?
3. Why are farmers increasingly willing to integrate into vertical food chains?
4. How do changes in the external environment, for example trade negotiations or the rising demand for biofuel or the public goods agriculture produces, affect the structure and hence the economic and social situation of farming?
5. How quickly do such changes in external conditions lead to changes in structures?
6. To what extent is public policy able and legitimated to intervene in the agricultural sector, or under which conditions can we expect that desirable outcomes emerge spontaneously?
7. How do various types of policies, notably decoupled transfer policies of the current Common Agricultural Policy, affect structural change?
8. Why are farmers sometimes able to organise collective action (e.g., in terms of political representation), but sometimes not (e.g., with respect to forming producer or marketing cooperatives)?

The previous review of natural science paradigms in economics suggests that theories and methods are available to study these questions:

a) Agricultural economists have only recently taken notice of the insights of behavioural and experimental approaches to better explain structural change in agriculture. However, what were at best guesses about an alternative view to standard rational choice studies some twenty or thirty years ago can now rely on a systematically enriched view of human behaviour, notably in terms of rule-following, adaptive preferences, risk aversion, reciprocity, as well as other types of context-dependent behaviour (Bowles 2004, 93-

[8] In setting up this list I borrowed heavily from the proposal document of the Forschergruppe.

126). Elster (2007, 217-220) provides a list of eighteen common "anomalies" to canonical rational choice theory, which are comparatively discussed and set in relation to each other. The list includes concepts such as loss aversion, hyperbolic discounting, or wishful thinking, which may help to solve some of the "paradoxes" of structural change.

b) Based on work by Ostrom (1990) and others, Elster analyses "mechanisms" of decision making in groups that may stimulate further research on issues of collective action in agriculture. For example, some related "molecular mechanisms" quoted by Elster (2007, 43) are "there is a black sheep in every flock" and "it takes only one black sheep to spoil a flock". According to this "social chemistry", any larger group contains at least one contrary person, which makes collective decision making difficult and may explain the move to smaller governance forms. Building on three modes of collective decision making, arguing, voting, and bargaining, Elster (2007, 401-424) develops an insightful analysis of incentives for the misrepresentation of preferences.

c) The analysis of alternative forms of governance beyond the standard market model can now build on an elaborated and formally tractable typology that distinguishes three approaches to the regulation of coordination problems: privatisation, hierarchical regulation, or regulation through local interaction (Bowles 2004, 140). This typology has the potential to shed new light on the governance of public goods in rural areas (see Petrick 2007 for further discussion).

d) The trade-off between efficiency and equality that can be considered a "folk-wisdom" in economics is clearly violated in circumstances of imperfect capital markets (Bowles 2004, 299-330). In other words, wealth redistribution may lead to more efficient production structures because it allows those with initially few assets a better access to technology, and to avoid costly incentive problems because residual claimancy rests with the owner. Lacking access to capital in turn may cement structures and inefficiencies. These insights may enrich the understanding of vertical integration and provide an explanation for the intergenerational inheritance of economic status in agriculture. After all, they may even provide arguments to resolve the apparent trade-off between continuing government payments and the move to more efficient farm structures in European agriculture.

e) The evolutionary economics literature reports substantial advances in modelling institutional change. Institutional competition is but one of the relevant mechanisms, while the emergence within a society of a large number of individuals who violate existing norms or institutions and eventually displace them is another (Bowles 2004, 369). Recently developed methodological devices such as stochastic evolutionary game theory and multi-level selection models allow to set into relation the various parts played by conflicts of interest, chance, and collective action, and the highly irregular change processes called "punctuated equilibria" (p. 468). The application of such models to the understanding of various paths of agricultural transition is but one of many that could be imagined.

f) As argued in the previous chapter, there are various reasons why institutional evolution may not lead to desirable outcomes. Recent modelling advances go far beyond the "induced institutional innovation" hypothesis of Hayami and Ruttan (1985), which basically endorses the "invisible hand" analogy noted above. The insights of these evolutionary models may provide new justifications for government beyond the simple "no policy is the best policy" prescriptions, and may reinforce the need for critical policy evaluation by agricultural economists – but now with less certainty that "the market" will do it right.

This list is not complete, but may suggest a number of starting points for further research that has the potential to shift out the theoretical frontier of agricultural economics in general and our understanding of structural change in particular. While the Walrasian paradigm will continue to provide the benchmark for these research efforts, it seems clear that evolution and chemistry have something to offer that is worthwhile to be considered.

7. Concluding remarks

In the 1980s, Wilhelm Brandes conjectured that a future economic science will abandon the two concepts of utility maximising and equilibrium (Brandes 1989, 339). He added:

> *"It remains to be seen whether or not a markedly modified edifice of economic theory with a different mathematical structure will evolve. Such modifications would probably take away some of the subject's elegance and beauty, but could possibly increase its potential and usefulness to some extent".*

My personal conclusion from this survey is that today we have a coexistence of approaches to economics that differ in their a-priories and that are partly incompatible with each other. Perhaps not all of them can be grouped under the headings of physics, biology, or chemistry. However, the process so far has not been a revolution that ousted neoclassic orthodoxy altogether. The research landscape has become more heterodox, perhaps less well-ordered in terms of formal methods, but definitely has not suffered in beauty. I would argue that, *because* of this heterogeneity, the potential for insightful economic analysis is likely to be higher than some twenty years ago.

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About the author

PD Dr. Martin Petrick is deputy head of the department External Environment for Agriculture and Policy Analysis at the Leibniz-Institute of Agricultural Development in Central and Eastern Europe (IAMO). His major research areas are agricultural policy and rural development in Europe.

Address:
Leibniz-Institute of Agricultural Development in Central and Eastern Europe (IAMO)
Theodor-Lieser-Straße 2
06120 Halle (Saale), Germany
E-mail: petrick@iamo.de

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Editorial office

Dr. Astrid Häger *(Managing editor)*
e-mail: astrid.haeger@agrar.hu-berlin.de
phone: +49-30-2093.6062

Kerstin Oertel *(Layout)*
e-mail: k.oertel@agrar.hu-berlin.de
phone: +49-30-2093.6340

Humboldt-Universität zu Berlin
Landwirtschaftlich-Gärtnerische Fakultät
Institut für WISOLA
FG Agrarpolitik
Philippstr. 13, Haus 12A
10099 Berlin (Germany)