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The influence of Economics on agricultural systems: an evolutionary and ecological perspective

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Putting agricultural systems on a more sustainable path is a crucial policy issue. Within that context, the objective of this paper is to show how the unsustainable character of current agricultural systems is strongly related to the prevailing rationale of mainstream economics and the Cartesian-Newtonian worldview on which it is founded. Using the example of the transformation of post-war agriculture in France, our analysis underlines the profound influence of the logic of mainstream economics on the modernisation of agricultural systems. The resulting transformation of agricultural systems based on the triptych specialisation-intensification-concentration is then further explored regarding its negative impacts in terms of sustainability. Particular attention is dedicated to environmental impacts, given their magnitude and the fact that mainstream economics, because of its "mechanistic reductionist" framework, has intrinsic difficulties in dealing with them. Since the fundamental assumptions of mainstream economics are being strongly challenged, it becomes legitimate to resort to an alternative economic framework for designing appropriate policies and measures. Given that many empirical studies demonstrates that agricultural systems may be locked-in to some extent, the choice an evolutionary line of thought in an ecological perspective is quite straightforward. This approach of economic change both underlines its historically-contingent nature and the role played by systemic interdependencies. Through underlining the path-dependence of agricultural systems, the use of the evolutionary framework in an ecological perspective allows us to shed a new light on their transformation by suggesting some strategies (i.e. niche accumulation and hybridisation) that have proven efficient in overcoming cases of lock-in in other fields.

Keywords: Agricultural systems; Mechanistic reductionism; Evolutionary economics; Path-dependence and lock-in; Environmental pressures

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The influence of Economics on agricultural systems: an evolutionary and ecological perspective

Full text

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ABSTRACT

Putting agricultural systems on a more sustainable path is a crucial policy issue. Within that context, the objective of this paper is to show how the unsustainable character of current agricultural systems is strongly related to the prevailing rationale of mainstream economics and the Cartesian-Newtonian worldview on which it is founded. Using the example of the transformation of post-war agriculture in France, our analysis underlines the profound influence of the logic of mainstream economics on the modernisation of agricultural systems. The resulting transformation of agricultural systems based on the triptych specialisation-intensification-concentration is then further explored regarding its negative impacts in terms of sustainability. Particular attention is dedicated to environmental impacts, given their magnitude and the fact that mainstream economics, because of its "mechanistic reductionist" framework, has intrinsic difficulties in dealing with them. Since the fundamental assumptions of mainstream economics are being strongly challenged, it becomes legitimate to resort to an alternative economic framework for designing appropriate policies and measures. Given that many empirical studies demonstrates that agricultural systems may be locked-in to some extent, the choice an evolutionary line of thought in an ecological perspective is quite straightforward. This approach of economic change both underlines its historically-contingent nature and the role played by systemic interdependencies. Through underlining the path-dependence of agricultural systems, the use of the evolutionary framework in an ecological perspective allows us to shed a new light on their transformation by suggesting some strategies (i.e. niche accumulation and hybridisation) that have proven efficient in overcoming cases of lock-in in other fields.

KEY WORDS

Agricultural systems; Mechanistic reductionism; Evolutionary economics; Path-dependence and lock-in; Environmental pressures.

1. Introduction

The need to make agricultural systems more sustainable is recognised as an urgent issue by most decision-makers. As claimed in Gafsi et al. (2006, p. 227), this widespread consensus is most likely due to "the manifest limitations of the conventional agriculture, in terms of negative impact on environmental quality and on resource availability, of deterioration in human health, of family farms difficulties and desertification of rural areas". On the other hand, as noted in Allanson et al. (1994, p. 3), the development of economics "has favoured a Cartesian-Newtonian world view of a mechanical system operating according to strictly defined laws" - in line with what prevailed in life and most social sciences (Lawn, 2001).

Building on the assumption that both trends are connected, this paper investigates how this Cartesian-Newtonian world view has shaped mainstream economics and how the resulting rationale of mainstream economics has, in turn, influenced the development path of agricultural systems. More precisely, the underlying driving forces of mainstream economics (i.e. directly connected to the Cartesian-Newtonian world view) made that the same logic that prevailed in industry was applied in order to modernise and rationalise agriculture (Smith et al., 2005, p. 1493). This led to the propagation of a productivist agricultural system (Lowe et al., 1993, p. 221) centred on the "modernisation triptych" suggested by the economic logic: specialisation, intensification and concentration. The spread of modern agricultural techniques (and the related increased use of energy input and chemicals) that resulted from this industrialisation of agricultural practice consequently created those environmental and social issues mentioned above.

Beyond this negative influence regarding the sustainability of agricultural systems, mainstream economics is also being strongly challenged by scholars from different fields with respect to its fundamental assumptions (for a brief overview of recent sources of criticism, see Gowdy and Erickson, 2005a). It is then straightforward that resorting to this theoretical framework for designing policies aimed at making agricultural systems more sustainable is highly questionable. More particularly, drawing on David and Arthur theory of "path-dependence and lock-in[1]" and in line with what has been shown to be the case of the current carbon-based socio-technical systems (Maréchal, 2007), many empirical studies tend to show that the current agricultural system may be locked-in to many extent (Cowan and Gunby, 1996; Grantham, 2000; Hogg, 2000; Wilson and Tisdell 2001; Tisdell, 2003; Ajayi and Waibel 2003; Allison and Hobbs, 2004; Van Loqueren and Baret, 2008).

Beyond the crucial insights from ecological economics, it thus follows that turning to the framework of evolutionary economics could also provide an insightful framework of analysis given that its perspective of economic change both underlines its historically-contingent nature and the role played by systemic interdependencies. Besides, as extensively shown in earlier papers (Maréchal, 2007; 2008), its shift of focus towards a better understanding of economic dynamics together with its departure from the perfect rationality hypothesis renders evolutionary economics an inevitable theoretical ground in setting up environmental policies.

This paper is structured as follows. The following section provides an overview of the historical development of mainstream economics with the aim of showing how it is strongly impregnated with a Cartesian-Newtonian worldview that led to a model relying on "mechanistic reductionism". Section 3 then briefly describes the intertwining of mainstream economics with policy-making through the widespread use of the decision framework of welfare economics. In section 4, a description of the transformation of French agriculture after World War II is used to illustrate how the mechanistic-reductionist paradigm and the related rationale of mainstream economics have impacted the agricultural systems. The economic and environmental consequences thereof are further analysed in section 5 while section 6 illustrates how the neglect of environmental issues can be directly connected to the intrinsic Cartesian-Newtonian foundations of mainstream economics. Section 7 then turns to the growing sources of criticism that challenge mainstream economics, focusing on those that directly question its "mechanistic reductionism". Drawing on the insights from the previous section, section 8 concludes by providing an alternative perspective resorting to the

[1] The concept of path-dependence stresses the historically contingent nature of economic change and refers to the fact that technological systems follow specific trajectories that it is difficult and costly to change (Arthur, 1983, 1989 ; David, 1985).

framework of evolutionary economics, focusing on the transition of agricultural systems away from the path-dependent unsustainable trajectory they are currently locked-in.

2. Descartes, Newton and Mainstream Economics

All along this paper, we will use the word "mainstream" ("modern", "traditional" or "orthodox" could also be used) to avoid the problems arising from the somewhat ambiguous use of the term "neoclassical", as shown in Colander, 2000[2]. By mainstream economics, we refer to the Walrasian model of welfare economics – which, as will be shown, can be defined as the theoretical synthesis of the Marshallian approach with marginal production theory and the rigorous precision of mechanical mathematics. It can be dated back to the second half of the 20th century with the work of economists like Alchian and Friedman.

Mainstream economics is today often considered to be the counterpart of neo-Darwinism in biology (i.e. the integration of Darwin's theory with the genetics of Mendel). This is mainly due to the obvious influence that Spencer's interpretation of Darwin's theory (i.e. Spencer coined the phrase "survival of the fittest") has had on many leading neoclassical economists (Hodgson, 1993a). For example Friedman (1953, p. 22) relies strongly on the natural selection analogy to elaborate his argument in favour of the neoclassical model and its predictive power.

However, following the analysis of Dopfer (2005), the works of Descartes and, later, Newton seem to have had a greater influence on the development of mainstream economics. Indeed, derived from Descartes' work, the concept of "dualism", which distinguishes between the physical and the spiritual world, has led to the idea that only physical phenomena are worthy of scientific enquiry and theoretical construction because, unlike the "soft" side of reality, there are visible, comprehensible and measurable. This concept of "dualism' has also led to the notion of perfect rationality. Moreover, Descartes' mechanical conception of the functioning of nature has paved the way for Newton to expand his mechanical view to the whole universe and to complete it with mathematical laws. As Lawn (2001, p. 143) states it, with this mechanistic-reductionist view, "Newton developed the methodology upon which the sciences, including the life and most social sciences, effectively have been based ever since."

One important thing to bear in mind about economics, when assessing the importance of the Cartesian/Newtonian legacy, is that its development is *epistemic*, in that it reflects "the cultural value of our civilization" (Alcouffe and Kuhn, 2004, p. 224). It is thus essential to look at how economics developed historically if one wants to get a comprehensive picture of what it is today and how it influences policy-making.

Typically, even though the very origin of modern economics is often attributed to the work of Thomas Hobbes, modern economics, as a discipline, arose in the 18th century, the European Age of Enlightment. Given that economics developed "along some paradigmatic lines determined by the cultural crucible in which the stuff of our mind is initially mixed" (Perlman and McCann, 1998, p.2), it was thus strongly influenced by the climate of Newtonian mechanistic science that was reigning at that time.

More precisely, the triumph of Newtonian economics first materialised with the "marginalist revolution" instigated by William Jevons in response to the critics made about the classical model only working with "objective" values. Later, Alfred Marshall showed that it was possible

[2] As noted in Young (2000), p. 417, this is a hotly debated issue among historians of economics but the dominant view is that neoclassical economics is significantly different from classical economics insofar as the emphasis has changed. Neoclassical could then rather be termed "anti-classical".

to reconcile the objective and subjective approaches of value by using biological analogies but subsequent economists (for instance, Marshall's influential follower Arthur Cecil Pigou) did not pursue his example and turned instead to physics for inspiration (Corning, 1995, p. 425). The framework used for mainstream economics consequently turned mechanical mathematics into the new Mecca of economists[3] - a choice obviously made to the detriment of biology, the other potential Mecca of economics (Hodgson, 1993b; Foster, 1997; Witt, 2004).

But Cartesian rationalism eventually gained the upper hand after the work of Léon Walras on “General equilibrium” which served for post-world war II economists to enthrone deductive methods and mathematics rules of analysis as the corner stones of economics. As mentioned above, mainstream economics is nothing else than the coupling of the “marginalist revolution” with Cartesian “logical rigor”. This Cartesian legacy thus allowed a shift of “analytical mode” which “moved from the concern with the empirically observable to developing formal rules of analysis” (Perlman 1996a, quoted in Alcouffe and Kuhn, 2004, p. 224).

Accordingly, the "maximisation" hypothesis - on which mainstream economics rests - can be considered as the Newtonian invariant law of economics[4]. Thus, only exogenous forces (i.e. external shocks) can trigger a structural change and push the system out of equilibrium – an equilibrium which is then re-established through competition and market forces (Foster, 1997). This model is said to be universally deterministic (Dopfer, 2005). It also reduces individuals to their mechanical properties which, as Prigogine (2005) shows, can be attributed to the well-anchored philosophical view of Descartes. In sum, in copying Newtonian physics economics became “progressively more reductionist and formalistic” (Hodgson, 1993a, p. 251).

All together, the Cartesian/Newtonian influence on economics was decisive. It has led to a model based what could be called “mechanistic reductionism”. Indeed, not only does this model explain whole economies on the basis of one sole agent/firm – through the assumption of the “representative agent” – but the characterisation of that agent/unit is reduced to its mechanical properties (it is viewed as an optimising machine).

Moreover, the rationale underlying mainstream economics relies on the “potential for human omniscience and omnipotence – the latter implying the potential for full human control over future states of the universe as well as an ability to make appropriate corrective responses” (Faber et al., 1992 in Lawn, 2001).

As it is claimed in Foster (1997 p. 432), the Cartesian/Newtonian legacy also makes that we are left with a linear and a-historical paradigm in economics insofar as it does not “depict a process unfolding in history”. In addition, since the view “that economic processes tend towards timeless equilibrium states remains the foundation upon which mainstream economic analysis is built” (Foster, 1997, p. 429), it leaves the room for analyses to be performed considering economic evolution as a reversible process.

3. Mainstream economics and policy-making

The problem is that mainstream economists - whatever outdated the philosophy on which their theory is based (Hodgson, 1997) - are not isolated in their citadel. In fact, mainstream

[3] Foster (1997, p. 432) also convincingly argues that both Spencer's neo-Darwinian synthesis and neo-classical economics (i.e. mainstream) are Newtonian in nature. This proximity may explain the strong reliance of Alchian and Friedman on “natural selection” to justify the maximisation hypothesis.
[4] Similarly, Smith's "invisible hand" is the invariant law of the Classical model.

economics has become an unavoidable discipline in the field of policy making. From a tool supporting decision-making processes, it is now often used as the unique science of decision-making. Its intertwining with policy-making and the prominence of its jargon (starring words like competition, efficiency, etc.) seem deeply anchored in modern societies. This is largely due to the fact that mainstream economics (through its mechanical reductionism) is able to offer a theoretical framework that allows for a policy assessment based on metric values, which is highly appreciated by decision-makers (Maréchal, 2007). This may explain why "policy recommendations of economists are still based on these outdated representations of human behaviour and commodity production" (Gowdy and Erickson, 2005b, p. 208) even though they are strongly challenged (including by scholars from within the mainstream profession) and that many theorists have abandoned them.

The application of mainstream economics to policy issues is known as welfare economics, an analytical model based on two fundamental theorems that enthrone competitive markets as the best way to ensure welfare efficiency (i.e. called Pareto optimality in the economic jargon) provided appropriate lump sum transfers are implemented. As claimed in Gowdy, (2005, p. 3) "these ideas turned economics away from questions of genuine well-being by shifting the policy focus from utility to consumption. They also justified the neglect of questions of distribution and the emphasis on economic growth as a general solution to basic economic problem such as poverty and environmental pollution". This last point may be used to illustrate the pervasive and profound influence of the Cartesian/Newtonian legacy. Indeed, in order for the mainstream model to display its properties (i.e. maximisation in a general equilibrium framework), consumers preferences must possess the required mathematical properties. Along with, among others, reflexivity, transitivity and continuity, preferences must also exhibit non-satiation and thus endless growth is intrinsically justified by theoretical requirements.

Thus, although traditional welfare economics (most notably its first theorem) has been said by Nobel-prize winner Joseph Stiglitz to be "of little relevance to modern industrial economies (Stiglitz 1994, p. 28)", it still lays the foundations of the economic guidance given to policy-makers on a variety of critical issues including environmental issues.

4. Post-war agriculture in France: a revolution under influence

The transformation of French agriculture after World War II provides an insightful example of how the mechanistic-reductionist paradigm and the related rationale of mainstream economics have impacted the agricultural systems. The following section is thus intended to portray how the transformation of post-war French agriculture unfolded in history with a particular attention to the underlying influence of the Cartesian-Newtonian legacy.

Indeed, until World War II, and despite the rural migration caused by the development of industry, French rural communities had maintained a conservatist status-quo in their social organisation (Muller, 1984). French peasants had also kept a diversified production, mostly directed at their own supply. This autarkical attitude offered them a relative autonomy towards the growing power of the cities: their production was primarily dictated by the fulfilling of their own basic needs, and only the surpluses were offered for sale.

After 1945, the whole social organisation of French agriculture was shaken by a new driving force which, as will be shown, can be related to the dominance of the Cartesian-Newtonian world view. Later and in retrospect, this new driving force has been called "productivism". (Lowe et al. 1993, p. 221), while French farmers who adhered to it were defined as "entrepreneurial farmers"[5] by Muller (1984, p. 63). Those entrepreneurial farmers, embodying

[5] Our own translation of the term " entrepreneurs paysans " that was coined by Muller (1984, p. 63)

the productivist ideology turned the old ways of French agriculture upside down: from conservatism it became a matter of anxiety to turn to progress, autarky was to be abandoned for integration in the economical process, and the previous focus on land and people management had to shift to output management.

Structural pressures like food shortage after WW II, mandatory schooling and the growing demands from the cities certainly played an important part in the profound transformation of French agriculture that took place at that time. The role of public policies should also not be underestimated. However, as it is convincingly argued in Prével (2006), those structural pressures might not have proved sufficient, had some entrepreneurial farmers not provided a new vision for the future of French agriculture.

Progress resting on science and technology was central to this new vision that exalted unlimited production growth. Such a concept of progress illustrates the profound influence of the Cartesian-Newtonian legacy. Indeed, it reflects the Cartesian aspiration for mankind to "master and possess nature"[6], as exposed by Descartes in his famous "Discourse on the Method" (Part 6). Besides, the heavy reliance on science reveals the importance that the mechanistic-reductionist paradigm would take in shaping agricultural systems, considering the fact that science is fully impregnated by this paradigm. In fact, as claimed in Bourdon (2003, p. 230) scientists have often preceded farmers in conceiving and applying new farming practice.[7] Moreover, the rationale of mainstream economics also shaped such a vision of progress, with the quest for unlimited production growth in agriculture echoing the concept of endless growth in mainstream economics.

Beyond their initial enthusiasm for what progress, science and new technologies could do to boost their production, integrating the economic progress was another starring concept for the emerging entrepreneurial layer of French farmers (as explained in Muller, 1984). Besides, entrepreneurial farmers pleaded in favour of conciliation with the ways of industrialisation. The influence of that new vision and of those who advocated it rapidly became "hegemonic" (Muller, 1984, p.84) and shaped the evolution of French agriculture for the next decades.

Accordingly, this new vision resulted in a greater exposure of French farmers to the rationale underlying mainstream economics. Furthermore, the opening up of agriculture to the logic of industrialisation offered a well explored avenue to modernise agriculture. It is important to note that applying the logic of industrialisation to agricultural practice required denying the necessity of a different treatment for natural ecosystems and their living resources compared to traditional industrial resources. This can be seen as reflecting the mainstream economics conception of "natural capital solely as a productive asset (considering it and 'human-made' capital as substitutes) from which to maximise consumption, subject to limiting constraints" (Midmore and Whittaker, 2000, p. 174).

In order to achieve profitability within that context, farmers were urged to "modernise" their farming exploitations, a move that was strongly backed by productivist policies (Prével, 2006), both at national, and European levels. The shift to productivism implied, using the definition stated by Lowe et al. (1993, p. 221) "a commitment to an intensive, industrially driven and expansionist agriculture with state support based primarily on output and increased productivity". Regarding agricultural systems, productivism is generally associated with three main dimensions: specialisation, intensification and concentration (Walford, 2003, p. 493). Accordingly, it seems necessary to further investigate those three elements from the paradigmatic point of view highlighted in this paper.

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[6] Our own translation of "*nous rendre comme maîtres et possesseurs de la nature*"

[7] The example provided in Bourdon (2003) is more specifically centered on the industrialisation of livestock farming.

It can be argued that the trend to specialisation reflects the atomistic side of the mechanist-reductionist paradigm, and its efforts to fragment complex interactions in order to isolate replicable processes. As the logic of specialisation was further extended, processes became indeed more systematically organised, leading to norms, standardisation and replicable farming practice. Exploring the "extend of the disconnection between farming practice and locality", Jenkins (2000, p. 306) concludes that it "has varied between regions (…) but in general terms the weakness of locality is reflected in the fact that external technological and market circumstances come to represent the conceptual standard against which the utility of local resources is judged". It also reveals the profound influence of Descartes' mechanical conception of the functioning of nature. The quest for replicable farming practice that would only need little adaptation to local conditions can indeed be linked to the fact that the Cartesian/Newtonian legacy created an aspiration for invariant laws.

Intensification was another basic aspect of the modernisation of French agriculture. As it had previously happened in industry, increased mechanisation became a substitute for animal power and human labour[8]. Meanwhile, scientific research provided new insights that materialised in a massive use of fertilisers and pesticides provided by the agrochemical industry. Changes also took the form of new production techniques, such as artificial insemination for example. Intensification of agricultural practice thus mostly took place through capital intensive technological innovations. It is very likely that the mainstream economics concept of the *Homo oeconomicus*[9] has played a role in maintaining farmers on the capital-intensive technological path. The concept of man seen as a rationalising machine with profitability as a unique bottom line might indeed have induced farmers to accept some technological innovations or new agricultural practice despite the fact that they were either threatening to their health (such as the use of pesticides for instance) or in total departure from their previous conception of their relation with their animals. It is worth noticing that farmers had, in earlier times, resisted similar innovations proposed by scientific experts. Indeed Bourdon (2003, p. 230) provides an example of how farmers opposed new livestock practice in 1848, mostly for animal well-being considerations resting on the fact that they did not accept the vision of the animal purely as a "machine".

Besides, applying the typically industrial logic of economies of scale to agriculture also led to the third aspect of productivism. Concentration can indeed be seen as a necessary corollary of specialisation and capital intensification, in order to increase profitability. Under this light, the fact that many farmers had to quit their job and sell their land was seen, at that time, as ineluctable and even beneficial for the modernisation and rationalisation of French agriculture (Muller, 1984).

As it follows from this analysis, the influence of the Cartesian-Newtonian legacy and the related rationale of mainstream economics were at work behind the radical transformation of French agriculture that took place after WW II. The objective of the transformation was clear: modernisation and rationalisation of French agriculture in order to increase production. The means to achieve it basically rested on specialisation and capital intensification, with concentration as their necessary corollary.

Other Western European countries had already or were still experiencing similar shifts to productivism. As underlined in the case of French agriculture, the role of public policies

[8] Allanson et al. (1994, p. 31), also acknowledge that modernisation of agriculture in the UK involved mechanisation. Smith et al. (2005, p. 1493) suggest that, along with intensification, mechanisation is a common characteristic of modern agriculture in a quest for an "increased factor productivity (…) measured in terms similar to industrial productivity".

[9] This refers to the theoretical representation of the economic agent on which the traditional economic model is founded. It sees economic agent as self-interested and perfectly rational individuals that maximise their utility based on perfect information and through using their capacity to ordinate their preferences.

should not be underestimated in this transformation of Western European agricultural systems. At both national and European levels, tools and mechanisms of public intervention have been deliberately designed in order to promote a development based on specialisation and capital intensification. They included infrastructure building, land tenure reforms, increased access to bank credit, development of research and extension services, land allocation schemes, market regulation and support to agricultural prices. As stated in Lowe et al. (2002, p.14) : "It *(the European Common Agricultural Policy, especially before its 1992 reform)* has undoubtedly brought national agricultural development strategies under a single all-embracing dynamic, that of increased productivity and intensification, farm holding restructuring and market intervention".

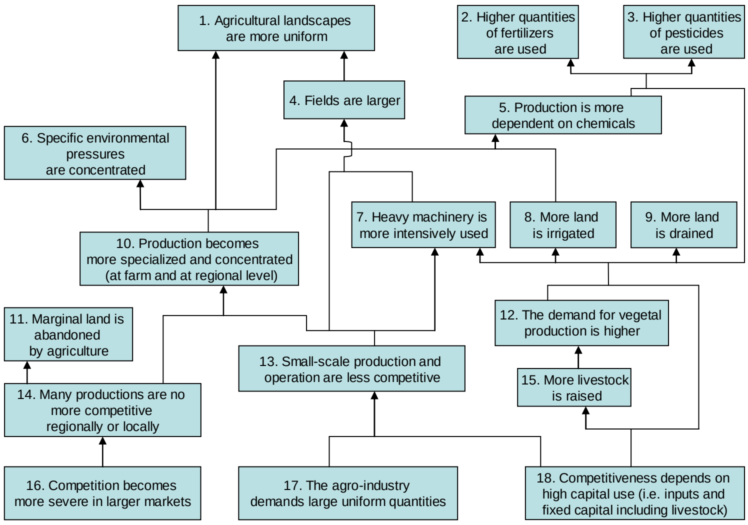
The shift of Western European agricultural systems to productivism centred on specialisation, capital intensification and concentration obviously had many consequences which are explored in the following section.

5. Consequences of specialisation and capital intensification of the rural systems in Western Europe

Capital intensification consists of an increasing use of both circulating capital (inputs: pesticides, fertilizers, water, animal feed) and fixed capital (equipment, machinery, livestock) which reflects a move from the primary sector to the secondary (transforming) one. Along with the demand of the industry for large homogeneous quantities of single products it encourages mass production and therefore specialisation through economies of scale. The intensive use of chemical fertilizers and pesticides also leads to the loss of the sanitary and fertility benefits provided by mixed farming (i.e. crop rotations and exchanges of manure and feed between livestock and crops) and therefore supports specialisation. In turn specialisation provides higher incomes that can be invested into physical capital and leads to a higher need for those chemical inputs. Both trends are thus correlated and mutually supportive, through economical and technical mechanisms. This very idea of circular reinforcement is crucial as it is a feature that can not be easily depicted through the framework of mainstream economics given its linear and deterministic nature.

In a context of modernised agricultural systems, figure 1 serves to illustrate the causal links between the existing forces towards specialisation and intensification on the one hand and sources of environmental pressures on the other hand. Resulting environmental changes are further explored in inset 1.

Fig 1. Some of the causal links between intensification-specialisation issues and sources of environmental pressures.



Inset 1. Resulting environmental changes can be explained as follows for the EU (see also Stoate et al*.* (2001) and Kenneth and Wood (2005)).

Soil degradation. The use of heavy machinery (Box 7 in Fig. 1) on soil with low organic matter content (a consequence of mineral fertilising, Box 2) leads to soil compaction, higher run-off and consequently erosion, increased sediment load, floods, reduced aquifer recharge, higher eutrophication and pollution of surface water (polluted by pesticides and phosphates: Boxes 3 and 2). Landscape uniformity (Box 1) and large fields (Box 4) contribute as well to high soil vulnerability to erosion and (with urbanisation) to more severe floods. Erosion is particularly severe in the Mediterranean basin, where it contributes to desertification in the driest areas and where fires denude periodically the soil on abandoned land. 13,5 millions hectares were considered at moderate or high erosion risk in the EU in 2003 (EEA, 2000).

Contribution to climate change. The direct contribution of the agricultural sector to climate change consists mainly of methane (CH_4) emissions from enteric fermentation (linked with the development of cattle breeding, Box 15) and nitrous oxide (N_2O) emissions (resulting from the heavy use of fertilizers, Box 2) (Bellarby et al*.*, 2008). Nitrous dioxide is also emitted by the production of N fertilizer (Box 2) Wood, S. and Cowie, A., 2004) and by nitrate-contaminated waters (another consequence of Box 2). The importance of non- CO_2 GHG is reflected by the share of the agricultural sector in the total European GHG emissions, which is almost three times the share in energy use (EEA, 2008). However agricultural changes have also directly contributed to higher emissions of carbon dioxide, notably through the use of machinery (Box 7), reduced carbon sequestration in biomass and in soil (Freibauer et al., 2004) and heavy indirect emissions generated by the agro-industrial sector (especially N fertilizer production) and transportation (linked with intensification and specialisation).

Air pollution. Heavy (Box 2) and concentrated (Box 6) use of fertilizers leads to locally high ammoniac (NH_3) and nitrogen oxides (NO_x) emissions which contribute to ozone (O_3) concentrations (detrimental to human health and to other species, notably mosses and lichens). The agro-industrial sector (UNEP and UNIDO, 1998) and transportation also pollute air with nitrogen oxides, organic volatile compounds and particles.

Pressures on water resources. Irrigation together with water eutrophication and pollution (Boxes 2 and 3) reduces the availability of high quality water. Specialisation tends to concentrate pressures (Box 6) on water resources, including water extraction (mainly in Mediterranean areas) and nitrate emission (especially in areas specialized in intensive livestock raising, for example Brittany and the North Sea plains, a combined result from boxes 6 and 15). Furthermore, the high production of protein rich food, linked with the development of stock breeding (Box 15), is also reflected in the high nitrate content (and therefore in the eutrophication impact) of domestic and urban waste waters.

Biodiversity at ecosystem level: habitat change. Land abandonment (Box 11, especially on marginal land, in mountains and in Mediterranean dry areas) and capital intensification result in an overall decline of low-input practice, which has swept off extensive agrosystems (notably grassland, moorland, steppic cultivation with fallows) in most regions, including endemic habitat types (Beaufoy et al. 1994; Baldock et al*.,* 1996; Stoate et al., 2001). Wet grasslands have also dramatically suffered from drainage (Box 9). Agricultural abandonment and decline of grazing in marginal land (Box 11) of the Mediterranean region also contributes to forest and scrubland fires (Duché, 2003). Other impacts are exported outside of the agricultural land by air (effects of acid rains, O_3, nitrogen deposition on forests and other ecosystems, resulting from boxes 2 and 15) or through changes in water regime (through dam building, water extraction, Box 8) or water quality (eutrophication and pollution resulting from boxes 2, 15 and 3, sediment content resulting from soil erosion), reaching sea waters where many coastal areas around Europe lack of oxygen (Ærtebjerg et al., 2001; UNEP, 2003).

Biodiversity at species level: population declines. Habitat reduction, fragmentation or alteration (see ecosystem level) cause population decline of many species, especially those depending on traditional extensive agrosystems (Beaufoy et al., 1994; Baldock et al*.,* 1996). Regional specialisation affects species depending on the conjunction between particular farming practice and soil or climate conditions (an effect of specialisation). Poisoning, reduction of food supply (Box 3) and shelters (Box 1), earlier and mechanized hay harvest (Box 7), decline in plant diversity due to herbicides and fertilizers (Boxes 3 and 2), decline in high stem orchards in most regions (Box 14) are also reducing wildlife (plants and animals) in agricultural land, notably birds (Donald et al., 2001). The less known soil biodiversity is also deeply affected.

Biodiversity at genetic level: loss of varieties. Many crop varieties and animal breeds have been lost because of standardisation, mass production (economies of scale), regional concentration (specialisation, Box 10), “decoupling of breeds” from local conditions (Tisdell, 2003, p. 373) as an impact of capital intensification. 55 percent of mammalian and 69 percent of avian livestock breeds are estimated to be extinct in Europe (Steinfeld et al., 2006).

Pressures on fossil and mineral resources. In EU the share of final energy use by the agricultural sector is quite modest (3,3% in EU-27, EEA, 2008) because of the huge energy consumption of other sectors but agricultural intensification, notably through mechanisation (Box 7), has relied directly on fossil fuel consumption with a decreasing energy efficiency (Mercier, 1978). This trend added to the energy demand of the agro-industry (in particular the production of nitrate fertilizers, Box 2) and transport (which is both a driver and a result of specialisation) contributes logically to the overall pressures on oil resources and to the impacts of the oil industry. The use of phosphate and potash fertilizers (Box 2) leads similarly to pressures on non renewable resources and to the impacts of mining activities (UNEP and IFA, 2001), for example contamination by heavy metals from phosphate mines in Morocco (Kaimoussi et al., 2001) and the formerly famous high pollution of the Rhine by potash mines.

As shown in inset 1 agricultural intensification and specialisation in Europe appear to have greatly contributed to all major environmental damages caused by agriculture or associated sectors and to major environmental problems in general. Environmental externalities are the logical result of the individualistic rationality assumed and promoted by mainstream economics. However we may consider that individualistic rationality is more a consequence than a cause of modern changes, since farmers were originally more engaged in collective practice and linked to their social community (Bourg, 1993), as well as more in step with in their physical environment. Specialisation and the correlatively increasing exchange flows have loosen those bounds with the social and physical environment and have increased the dependency upon the market, the industry and the institutions. Noticeable is the fact that environmental pressures are not only externalities but they also damage farmer's land, even when privately owned. In fact modern farmers accept soil erosion just as they accept the depreciation of their fixed capital and accept the replacement of natural resources by artificial capital (technological or financial).

Modern farmers had also to accept a greater dependence in their decision-making processes. Indeed, state supports policies and agro-businesses interests started interfering with farmers' usual concerns for land, and production. Besides, as it is convincingly explained in Jenkins (2000), the choice for modernity often implied a dramatic devaluation of traditional insights to the point that modern farmers became increasingly dependent on science, technology and the advice of agronomists for the management of their farms. These factors were aggravated by a deterioration of terms of trade for the agricultural sector (Midmore, 2000, p. 175). In this light, income decline caused by such a deterioration of terms of trade could only be counteracted by productivity gains offered by new technologies. In order to finance those new technologies, farmers had often to resort to more credit, being thereby trapped in a technology-investment-credit spiral (i.e. intensification). On the other hand, farmers who did not follow this trend endured income decline and often had to cease their activity. This led to massive loss of employment and increased concentration in the agricultural sector, the latter allowing greater economies of scale and thereby reinforcing the trend. Since the increasing labour productivity also led to dramatic loss of agricultural employment, the growing use of capital seems to have sacrificed both the other primary sources of production which are land (nature) and human labour (man). Food security has been the positive side of those changes but production and consumption largely exceeded human needs in Western Europe.

6. The neglect of environmental issues

The description of mainstream economics performed in the first sections (i.e. as relying strongly on the Cartesian/Newtonian legacy) makes it obvious that this theoretical framework would experience difficulties in dealing with environment-related issues (among which the aforementioned impacts of conventional agriculture on the biosphere). Indeed, it is with an inherently reductionist, linear and deterministic model favouring short-term efficiency that mainstream economics tries to approach long-term environmental phenomena that display systemic and emergent properties while also being better explained through circular causation.

Another factor that may also explain the drawbacks of mainstream economic analysis of environmental issues lies in the above-mentioned reversible nature of the model which is in contradiction with the potential irreversibility of many environmental damages (such as biodiversity losses, for instance). In addition, it has to be noted that the difficulty of the task was reinforced by the fact that economics is disconnected from environmental constraints (partly because the latter – being a non-market good - fall off the focus of analysis that is to ensure market efficiency in allocating scare resources).

Furthermore, we may even consider that the neglect of environmental matters inherent to mainstream economics has, by occulting one of its weakest sides, greatly contributed to its success. Subsequent application of its principles to agriculture might not have taken the upper hand the way it did in Western countries, had environmental matters been taken into consideration from the beginning.

7. Contestability of the dominant paradigm

In addition to the specific concerns relating to agriculture and to the intrinsic difficulty of dealing with environmental issue using mainstream economics, there are more general concerns regarding the dominant rationalist – reductionist paradigm.

The first problem with this Cartesian/Newtonian legacy of economics is that Descartes' notion of "dualism" (or separable entities) - which lays the ground for the perfect rationality axiom characterising the *Homo oeconomicus* - is now rendered somewhat obsolete by the development of modern neuroscience. As Damasio (1995, 2000) shows, the presence of cortical interconnectivity in the human brain (in a "communication" zone) means not only that we are able to exert a control over our automatic functions and instincts (located in the archecortex), but also that emotions, moods and other feelings can influence our conscious behaviour (governed by the neocortex).This implies that economic decisions are partly guided by feelings, and thus emotionally coloured. As Dopfer (2005, p. 25) nicely puts it, this brain configuration provides the human being with "intelligent emotions and emotional intelligence".

It is worth noting that a lot of experimental studies in the realm of "neuroeconomics" support this view (Camerer and Lowenstein, 2004). It also fits the information gathered by an abundant empirical literature dealing with the actual behaviour of economic agents (see, for instance, Fehr and Gächter, 2000; Henrich et al., 2001). More specifically, those studies contradicts the *Homo oeconomicus* construct by revealing the existence of some degree of altruism (under the form of "strong reciprocity", as proposed in Gintis, 2000) and group–level influences most particularly through culture[10].

The importance of group-level influences brings us back to the second fundamental assumption that constitutes the Cartesian/Newtonian legacy of mainstream economics: its inherent reductionism. In a search for solid microfoundations, "the reductionist idea of explaining whole in terms of individual parts became the sine qua non of economic science" as shown in Hodgson (1997, p. 402). But this view has been strongly challenged notably by Alan Kirman for not taking into account the basic idea that economic agents do interact. Since the "independence of individuals plays an important role in the construction" of aggregation functions in mainstream economics, "if we are to progress further we may well be forced to theorise in terms of groups" (Kirman, 1989, p. 138). Based on his demonstration, he then concludes that "there is no more misleading description in modern economics that the so-called microfoundations of macroeconomics …" (Kirman, 1989, p. 138).

It is important to note that the two fundamental assumptions of mainstream economics are in fact two sides of the same coin. Indeed, the Cartesian idea that the left hemisphere of the neo-cortex (specialised in analytical abilities and computational operations) is dominant

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[10] For a good introduction to the debate on the importance of culture see Henrich (2004).

explains why efficiency is "at the centre stage of neoclassical economics" to the detriment of efficacy[11], a "fundamental economic problem – one that cannot be found at all in the neoclassical research agenda" (Dopfer, 2005, p. 25). In other words, if agents are all optimising machines, nothing but an optimum could come out of their interaction. In such a framework, it clearly follows that the process of interaction is thus not an object worth analysing.

The empirical evidence concerning the behaviour of economic agents (as well as other theoretical inconsistencies as, for example, the intransitivity of preferences shown in Tversky, 1969) together with the many problems raised by the microfoundations approach[12] not only put into question the relevance of mainstream economics but also questions the current policy-making approach that is based on that framework. As claimed in Ball (2006), "if mainstream economic theory is fundamentally flawed, we are no better than doctors diagnosing with astrology". This is confirmed by the analysis performed in Maréchal (2007) and that shows how the theoretical framework of mainstream economics has been misleading in the field of climate policy.

In such a context and if we want to provide policy-makers with more relevant guidance with respect to agricultural and environmental issues, we must break out of the mainstream vision of economics in which we are currently locked-in. In search for an alternative line of thought on which to base policy advice, we thus have to turn to an economic framework that would both depart from the perfect rationality hypothesis (i.e. the Homo oeconomicus paradigm) and provide an alternative to simple aggregation (i.e. the "representative agent" hypothesis).

8. Towards a paradigm shift: an evolutionary and ecological perspective

In previous sections, we have shown how mainstream economics is imprinted with mechanistic reductionism and how this contributed to render agricultural systems unsustainable in various respect. In addition, it has been shown how inherently difficult it was for mainstream economics to deal with environmental issues due to conflicting logics/rationale. Having acknowledged this and bearing in mind the fact that the core assumptions of mainstream economics about the behaviour of economic agents are at odds empirical evidence (Dopfer 2004, p. 186), it seems obvious that turning to an alternative economic framework could prove insightful in searching for solutions.

To that respect, the approach followed in this section/paper can be viewed as building on the insights from the framework of evolutionary economics but in an ecological perspective. Such a coupled approach is not new as illustrated by the pioneer work of Kenneth Boulding who linked both concepts of evolution and ecology (Boulding, 1978, 1981). Besides, as claimed in van den Bergh (2007, p. 522), ecological economics and evolutionary economics are "indeed very close in spirit" which renders the coupling approach both legitimate and promising.

Ecological economics obviously is a theoretical guiding post for the purpose of this paper. This is mainly because it offers crucial insights for shifting the focus from a technological and input-based endless production growth scenario to an "analysis based on the concept of carrying capacity (that) emphasizes environmental limits to system growth" (Harris, 1996, p.95). Besides, ecological economics also raises the question of the need for ethical choices in defining and prioritising societal goals in order to use resources accordingly (Lawn, 2001). In doing so, ecological economics departs from the mainstream economics view relying

[11] Efficacy is to be understood as relational complementarity and thus refers to the "interaction of agents" also raised in Kirman (1989).
[12] See van den Bergh and Gowdy (2003), p. 66 for a brief overview of the major objections to the microfoundations approach.

mostly on market-based mechanisms to deal with such matters. This ethical concern is particularly relevant for issues concerning food, and therefore agriculture, since it directly involves the fulfilling of one of human beings' most basic need.

Beyond the closeness of spirit mentioned above, the choice of an evolutionary-inspired line of thought is rather straightforward, for at least two reasons.

On the one hand, this is due to the fact that evolutionary economics can be said to have developed partly with the aim of correcting the “scientific failure” of traditional theory in explaining why economic agents do not always act as optimising machines. This can be illustrated by the seminal book of Richard Nelson and Sidney Winter[13] where profit-maximising behaviour of firms is replaced by a view largely inspired by Herbert Simon’s “bounded rationality”. On the other hand, it is also important to note that the other cornerstone of the evolutionary framework in economics obviously lies in its different interpretation of economic change. In fact, as claimed in Dopfer (2004, p. 178), what is exogenous in traditional economics “*comprises the endogenous core of evolutionary economics*”. Given that it focuses on economic dynamics resulting from innovation, selection and accumulation, evolutionary economics may offer new insights in the framing of environmental policies (van den Bergh et al. 2006).

Those two reasons render evolutionary economics an inevitable theoretical ground in setting up environmental policies, as illustrated in Maréchal (2007, 2008). The added value of evolutionary economics in providing support for designing environment-related policies lies in its reliance on Thorstein Veblen’s concept of “cumulative causation” as one of its theoretical hypothesis. Thus, contrarily to the rather deterministic and linear view that prevails in mainstream economics, economic change is better pictured as a process of cumulative, double (downward and upward) and interactive causation (van den Bergh and Gowdy 2003; Corning 1997, Hodgson, 1997).

As it has extensively been shown to be the case of some socially-acquired characteristics of human beings (Henrich 2004), group-level analysis (as opposed to analysis focusing on individual units) is very insightful in that it allows for circular and self-reinforcing interactions between economic agents - which are clearly at play in agriculture as shown in section 5 - to be taken into account. In other words, through such framework, economic dynamics involve processes that see individuals interacting with an emergent population in a self-reinforcing manner[14].

In this context, what makes the evolutionary perspective of economic change well-suited for analysing the above-mentioned issues in agriculture is that it stresses their historically-contingent nature (because causation is cumulative) and highlights the role played by systemic interdependencies (because causation is double and interactive). Allanson et al. (1994, p. 35) go further into the appropriateness of the evolutionary framework for analysing agricultural systems by claiming that “it focuses on the need for a holistic understanding of the complex of interrelated processes which constitute the rural economy in order to inform and manage a range of possible policy directions”.

As illustrated in Veblen (1915) through the example of British small wagons, systemic interdependencies imply that technologies can no longer be seen as isolated but rather as belonging to technological systems. Those systems can be defined as "interrelated components connected in a network or infrastructure that includes physical, social and

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[13] Even though there has always been economists interested in the evolutionary tradition (such as Thorstein Veblen or Joseph Schumpeter), the book titled “An evolutionary theory of economic change” is often considered as having founded “modern” evolutionary economics (Arena and Lazaric, 2003).

[14] It thus provides an alternative to simple aggregation by building “on the notion of circularity between individual and population” Dopfer (2006, p. 18).

informational elements" Unruh (2000, p. 819). Adding the fact that technologies are also dependent upon and connected with the wider range of cultural, organisational and institutional aspects of their environment that enable them to work together, we end up with what Geels and Kemp (2007) call *Socio-Technical Systems* (STS)[15].

This intertwining of different elements that characterises STS sheds light on the potential inertia of such systems as once historical conditions have lead to the emergence of a STS their multiple components contribute to stabilise the system in a self-reinforcing manner. The nature and type of a STS is thus dependent upon the path followed[16] and is further perpetuated through the interactions of its multiple elements. Positive feedbacks act as a sort of snowball which results in the "locking-in" of the incumbent STS following a "path-dependent" co-evolutionary process[17].

This perspective is very useful for analysing agricultural systems which are also better pictured as STS - the development of which is marked with path-dependence as suggested by many empirical studies that tend to show how current agricultural systems in Western Europe may be locked-in to many extent (Cowan and Gunby, 1996; Wilson and Tisdell, 2001; Tisdell, 2003; Ajayi and Waibel 2003; Allison and Hobbs, 2004; Van Loqueren and Baret, 2008). As convincingly argued in Hogg (2000), there has been a path-dependent lock-in to genetic uniformity in agriculture through a process that he calls the "breeding-chemical-mechanization (BMC) treadmill". In the same vein, Ajayi and Waibel (2003) present an empirical case study where they show how the interplay of institutional arrangements and wider agroeconomic influences led to the adoption of a chemical based pesticide technology and thus to the locking-out of the "integrated pest management" alternative irrespective of its more ecologically-friendly character.

This should be fully acknowledged by decision-makers if they wish to design appropriate policies aiming at making agricultural STS more sustainable. Indeed, from the 1980's on, policies have been intended to bend the productivist trajectory followed by Western agriculture, given that "it became politically and economically untenable to continue subsiding an industry whose output was simply adding to existing stockpiles of surplus production." (Walford, 2003, p. 492). Still, despite the reforms that followed, it seems very difficult for policies to unlock agricultural systems out of the productivist era as suggested by a recent empirical analysis that shows it is "premature to conclude that large-scale commercial farmers can be regarded as having altered their agricultural systems to the extent that they be considered as wholly 'post-productivist' or 'multifunctional'" (Walford, 2003, p. 501). This should be somewhat qualified since, bearing in mind the problem related to the lack of a clear definition of the term, some authors consider the empirical evidence as sufficient to assert that post-productivism is occurring to some extent (Mather et al., 2006). Nevertheless, if changes towards a "de-emphasing of material production relative to other objectives" (Mather et al., 2006, p. 454) certainly are happening, it is still a long way forward before achieving a sustainable agricultural system. This echoes the work of Pierson (2000) where political processes are themselves viewed as highly path-dependent. A recent study confirms this view concerning multifunctional agriculture in the UK by underlying the fact that "policy development is still 'locked in' to placating agri-industrial interests, on the one hand, and the

[15] It should be noted that a "system" is a network of *elements* whereas a "regime" is a network of *peoples*. Socio-technical regimes serve to maintain and stabilise socio-technical systems (see Geels and Kemp 2007).

[16] In line with the concept of "path-dependence" which refers to the fact that technological systems follow specific trajectories that it is difficult and costly to change (Arthur 1983 ; David, 1985). As shown in Arthur (1989), these trajectories depend on historical circumstances, timing and strategy as much as optimality (i.e. the main focus of mainstream economics).

[17] Following the definition given in Puffert (2002), p 282, a path-dependent process is "one in which specific contingent events – and not just fundamental determinative factors like technology preferences, factor endowments and institutions – have a persistent effect on the subsequent course of allocation".

continued vibrancy of post-productivist (environmental and amenity) interests on the other" (Marsden and Sonnino 2008, p.8).

Accordingly, there thus needs to have policies that specifically target those factors[18] that contribute to maintaining the incumbent agricultural STS (i.e. relying on the triptych *specialisation-intensification-concentration)*. Needless to say, these policies would likely be more appropriate if they were designed using a theoretical framework that is able to accommodate for the inherent inertia of incumbent agricultural practice. In trying to surmount a case of lock-in, "it is important to focus policy interventions in order to concentrate resources in such a way that they are sufficient to overcome inertia at least in that part of the system", as claimed in Cowan and Gunby (1996, p. 539).

What is needed is thus what Windrum and Birchenhall (2005) called a "technological succession" or, to put it differently, a *transition* from the incumbent agricultural STS to a more sustainable configuration. However, as shown above, it is essential to recall that looking at systemic change through an evolutionary-inspired framework implies that transitions will typically involve a multi-level dynamic of complex interactions and feedbacks in a path-dependent manner. This clearly means that the outcome will be of an emergent (i.e. rather than planned and structured) uncertain and complex nature (Raven 2007). Acknowledging this, decision-makers should avoid simply promoting one identified solution and rather creating conditions under which the evolutionary process would lead to the desired outcome (i.e. a more sustainable agricultural system in our case).

There are two broad strategies that are commonly identified in the literature as capable of triggering transitions: niche[19] accumulation and hybridisation (Raven 2007, p. 2392), with the former starting from a radically distinct field while the latter building on the existing regime[20]. On a general level, both strategies obviously will display advantages and pitfalls that are related to their respective closeness to the incumbent system. This may explain why, in practice, it seems that successful transitions often involve a mix of both strategies, as in the case of the "lock-out" story of the gas turbine described in Islas (1997). Even though the literature on transition focuses more on technological change than on system change, it is nonetheless very insightful for the purpose of this paper. Indeed, with respect to agricultural practice, organic farming could be considered as the niche whereas multifunctional agriculture could be seen as a form of hybridisation.

Considering that agricultural systems clearly are "distributed systems where multiple components act together", a recent field study of the Dutch sector of Horticulture (Berkers and Geels, 2007, p. 22) suggests that transition in this sector will not only come from discontinuous breakthrough innovations but also from what is called a "stepwise reconfiguration" (i.e. a form of hybridization where multiple innovations are incorporated into the existing system and where incumbent actors carry the transition).

However, the role of organic farming as a niche capable of favouring the transition to more sustainable agricultural STS should not be underestimated. Indeed, the benefits to be expected from organic agriculture have been attested regarding several environmental problems previously raised in section 5. Besides its confirmed beneficial role regarding biodiversity (Hole et al., 2005), other positive effects of organic agriculture compared to

[18] Such a contributing factor is, for instance, the cost (economic as well as cognitive) of switching to a new system (see Wilson and Tisdell, 2001).

[19] A niche is a limited space where new technologies can mature. When there is a protection (whether public or not) a niche is said to be technological. If not, it is called a market niche (Mulder et al. 1999, p. 11). For instance, internet was developed within a technological niche whereas railways grew within a market niche (Windrum and Birchenhall 2005, p. 125).

[20] For example, as far as car fuel is concerned, agro-fuel is a form of hybridisation whereas the development of fuel cells is a niche.

conventional agriculture were recently underlined at the FAO conference on organic agriculture and food security held in Italy[21]. Those benefits include, among others, a reduced pollution of drinking water and of the environment due to the absence of pesticide leaching and the reduction of N and P leaching (Brandt, 2007, p. 16-19); higher soil stability and fertility; a lower and more efficient use of water; and a lower energy consumption (Niggli et al. 2007, p. 2, 4 and 8, respectively).

Despite its multiple potential benefits, organic agriculture has to face various obstacles to its development. A first set of obstacles concerns farmer's attitude towards conversion to organic production systems. In a study conducted in England, Midmore et al. (2001, p. ix) identified the main following obstacles: "less confidence in being able to cope with pests and diseases without use of agrochemical, (...) worries about the practicality of organic standards, (...) the financial viability of the system, (...) the quality , rather than the accessibility, of information and advice, (...) difficulties relating to standards, including their consistency and stability, (...) and access to market". On the consumers' side, the expectations of different categories of consumers towards organic food reveal contradictory trends. Indeed, core organic consumers are mostly concerned by quality, safety, and environmental protection; while newcomers are more "price- and convenience-sensitive", which could lead to conflicting objectives in the future development of organic food markets (Midmore et al., 2005, p.41).

Those obstacles suggest that, in order for its potentials in terms of agricultural sustainability to be fully revealed, and in line with evolutionary economics, a 'strategic niche management' could be advantageously applied to the development of organic farming. Indeed, 'strategic niche management' involves acknowledging that social and institutional factors contribute to "reinforce the locking-in of the incumbent technological system" (Maréchal, 2007, p. 5191). Although, in the case of agriculture, the locking-in is not only of a technological nature, an adaptation of this principle of 'strategic niche management' to systems could prove insightful for agriculture. Doing so could provide an answer to the demand expressed in Marsden and Sonnino (2008, p.9) regarding the fact that "the profound critical political economy that emerged in the 1980s and the 1990s concerning the analysis of the agricultural modernization process of the late 20th century has not been matched by a parallel project on how alternative rural development model could establish itself in a more harmonious way with both the rural and urban realm".

Besides, as mentioned in an analysis of distributed generation of electricity where it is noted that "some elements of the old regime were vigorously rejected, while others were carried along into the new regime" (van der Vleuten and Raven, 2006, p. 3747), putting agricultural systems on a more sustainable path will inevitably require bringing along not only incumbent actors of the field (although, probably with a changed role) but also new actors. In fact, as noted in Geels and Kemp (2007), the ability of regime actors to respond adequately to pressures and/or shocks from the external landscape and the degree of change in social networks appear to be major factors for the success of transitions (i.e. with respect to mere transformations). In addition, it should also be noted that such a transition will involve a structural change. In other words, there will need to be interactions between dynamics at landscape (i.e. wider external forces such as globalization, urbanisation, demographic pressures, etc.), regime and niche level (Geels and Kemp 2007). Bearing in mind the interplay of demand, technology and society (Maréchal, 2007), a "long-term technology policy should take account of the socio-cultural contexts in which technologies fit" as claimed in Wilhite (2007, p. 29).

As this analysis built on the framework of evolutionary economics in an ecological perspective suggests, further research would be necessary to ascertain how the concepts of

[21] FAO's International Conference on Organic Agriculture and Food Security held 3-5 May 2007 in Italy.

path-dependence, lock-in and transition (including strategic niche management and hybridisation) can successfully be applied to the development of sustainable agricultural systems.

References

Ærtebjerg, G., Carstensen, J., D., Dahl, K., Hansen, J., Nygaard, K., Rygg, B., Sørensen, K., Severinsen, G., Casartelli, S., Schrimpf, W., Schiller, Ch., Druon, J.N. and Künitzer, A., 2001. Eutrophication in Europe's coastal waters. EEA, 86 pp.

Ajayi, O. C., Waibel, H., 2003. Path dependence and adoption of sustainable agricultural technologies – Case of cotton-producing region of West Africa. Proceedings of the Deutscher Tropentag on "Technological and institutional innovations for sustainable rural development", Göttingen, October 8-10, 2003.

Allanson, P., Murdoch, J., Lowe, Ph., Garrod, G., 1994. The rural economy: an evolutionary perspective. Working Paper 1. University of Newcastle upon Tyne, Department of Agricultural Economics and Food Marketing.

Alcouffe, A., Kuhn, T., 2004. Schumpeterian endogenous growth theory and evolutionary economics. Journal of Evolutionary Economics, 14: 223-236.

Allison, H. E. and R. J. Hobbs. 2004. Resilience, adaptive capacity, and the "Lock-in Trap" of the Western Australian agricultural region. Ecology and Society 9(1): article 3. http://www.ecologyandsociety.org/vol9/iss1/art3/

Arthur, W.B., 1983. On competing technologies and historical small events: the dynamics of choice under increasing returns. International Institute for Applied Analysis. Working paper, 83-90, Laxenburg, Austria.

Arthur, W.B., 1989. Competing technologies, increasing returns and lock-in by historic events. The Economic Journal, 99: 116–131.

Baldock, D, Beaufoy, G, Brouwer, F., and Godeschalk, F., 1996. Farming at the Margins: Abandonment or Redeployment of Agricultural Land in Europe. Institute for European Environmental Policy, Agricultural Economics Research Institute, London and The Hague.

Ball, P., 2006. Baroque fantasies of a peculiar science. Financial Times, October 29, 2006.

Beaufoy, G., Baldock, D. and Clark, J., 1994. The Nature of Farming: Low Intensity Farming Systems in Nine European Countries. Institute for European Environmental Policy, London, 66 pp.

Bellarby, J., Foereid, B., Hastings, A., and Smith, P., 2008. Cool Farming: Climate impacts of agriculture and mitigation potential" Greenpeace International. Amsterdam, The Netherlands, 43 pp.

Berkers, E., Geels, F., 2007. Transitions and system innovation through stepwise reconfiguration: A techno-economic analysis of the transformation of Dutch greenhouse horticulture (1930-1980). Submitted to Technovation.

Boulding, K.E., 1978. Ecodynamics: a new theory of societal evolution. Sage Publications, Beverly Hills, California, 361 pp.

Boulding, K.E., 1981. Evolutionary economics. Sage Publications, Beverly Hills, California, 195 pp.

Bourdon, J.-P., 2003. Recherche agronomique et bien-être des animaux d'élevage. Histoire d'une demande sociale. Histoire et Sociétés Rurales, 19:221-239.

Bourg, D., 1993. Les agriculteurs : figures de la modernité, pp. 187-203. In Courtet, C., Berlan-Darqué, M. and Y. Demarne (ed.). Agricultures et société. INRA, Paris, 307 pp.

Brandt, K., 2007. Organic agriculture and food utilization. Issues Paper for the International Conference on Organic Agriculture and Food Security, FAO, Italy, 3-5 May 2007, 40 pp.

Camerer, C., Loewenstein, G., 2004. Behavioral economics: past, present, future. In: Camerer, C., Loewenstein, G., Rabin, M. (Eds.). Advances in behavioral economics. Princeton University Press, Princeton, New Jersey, 776 pp.

Colander, D., 2000. The death of Neoclassical Economics. Journal of the History of Economic Thought, 22/2: 127-143.

Corning, P., 1997. Holistic Darwinism: "Synergistic Selection" and the Evolutionary Process. Journal of Social and Evolutionary Systems, 20/4: 636-400.

Cowan, R., Gunby, Ph., 1996. Sprayed to death: path dependence, lock-in and pest control strategies. The economic journal, 106:521-542.

Damasio, A., 1995. Descartes' Error: Emotion, Reason and the Human Brain. Hayrer Collins, New York.

Damasio, A., 2000. The Feeling of What Happens: Body and Emotion in the Making of Consciousness. Harcourt Brace, New York, 2000.

David, P., 1985. Clio and the economics of QWERTY. American Economic Review, 75/2: 332–337.

Descartes, R., 1637. Discours de la méthode. Garnier Flammarion / Philosophie, réédition (2000), 189 pp.

Donald, P. et al., 2001. Agricultural intensification and the collapse of Europe’s farmland bird populations. Proceedings of the Royal Society London, 268: 25-29.

Dopfer, K., 2004. The economic agent as rule maker and rule user: Homo Sapiens Oeconomicus. Journal of Evolutionary Economics, 14: 177-195.

Dopfer, K., 2005. Evolutionary Economics: a theoretical framework. In: Dopfer, K. (Ed.), The evolutionary foundations of economics. Cambridge University Press, 592 pp.

Dopfer, K., 2006. The origin of meso economics – Schumpeter’s legacy’, Papers on Economics & Evolution #0610, Max Planck Institute for Research into Economic Systems.

Duché, Y. 2003. La forêt méditerranéenne, source de vie… tarie par le feu. XII World Forestry Congress, Québec, unpublished paper available on: http://www.fao.org/DOCREP/ARTICLE/WFC/XII/0021-B3.HTM.

EEA 2000. Down to earth: Soil degradation and sustainable development in Europe. A challenge for the 21st century. EEA, Copenhagen, 31 pp.

EEA 2004. High nature value farmland. Characteristics, trends and policy challenges. Report No 1/2004, EEA, Copenhagen, 26 pp.

EEA 2008. Final energy consumption by sector in the EU-27, 1990-2005 and Shares by sector in EU-15 greenhouse gas emissions in 2005. Data on http://themes.eea.europa.eu/ (visited on 24/06/2008).

Fehr, E., Gächter, S., 2000. Cooperation and punishment in public goods experiments. American Economic Review, 90/4: 980–995.

Foster, J., 1997. The analytical foundations of evolutionary economics: from biological analogy to economic self-organisation. Structural Change and Economic Dynamics, 8/4: 427-452.

Freibauer, A., Rounseevell, M.D.A., Smith, P. and J. Verhagen. 2004. Carbon sequestration in the agricultural soils of Europe. Geoderma, 122: 1-23.

Friedman, M., 1953. Essays in Positive Economics, Chicago, University of Chicago Press, 328 pp.

Gafsi, M., Legagneux, B., Nguyen, G. Robin, P., 2006. Towards sustainable farming systems : effectiveness and deficiency of the French procedure of sustainable agriculture. Agricultural Systems, 90:226-242.

Geels, F., Kemp, R., 2007. Dynamics in socio-technical systems: typology of change processes and contrasting case studies. Technology in Society, 29/4: 441-455.

Gintis, H., 2000. Strong reciprocity and human sociality. Journal of Theoretical Biology, 206: 169–179.

Gobin, A, Govers, G., Jones, R., Kirkby, M. and Kosmas, C., 2003. Assessment and reporting on soil erosion. Background and workshop report. EEA, Copenhagen.

Gowdy, J., 2005. Evolutionary theory and economic policy with reference to sustainability, Working Paper 05-05, Renselaer Polytechnic Institute.

Gowdy, J., Erickson, J., 2005a. Ecological economics at a crossroads. Ecological Economics, 53: 17-20.

Gowdy, J., Erickson, J., 2005b. The approach of ecological economics. Cambridge Journal of Economics, 29: 207-222.

Grantham, G., 2000. The sickle and the scythe: an instance of path-dependence. Études rurales - Autres temps, autres lieux, 151-152 (http://etudesrurales.revues.org/document1359.html).

Harris, J.M., 1996. World agricultural futures: regional sustainability and ecological limits. Ecological Economics, 17: 95-115.

Henrich, J., Boyd, R., Bowles, S., Gintis, H., Camerer, C., Fehr, E., McElreath, R., 2001. In search of Homo economicus: experiments in 15 small-scale societies. American Economic Review, 91: 73–78

Henrich, J., 2004. Cultural group selection, coevolutionary processes and large-scale cooperation. Journal of Economic Behaviour & Organisation 53(1). Special issue on "Evolution and altruism", 3-35.

Hodgson, G., 1993a. Economics and evolution: Bringing life back to economics. Ann Arbor, University of Michigan Press.

Hodgson, G., 1993b. The Mecca of Alfred Marshall. The Economic Journal, 103: p 406-415.

Hodgson, G., 1997. Economics and the return to Mecca: the recognition of novelty and emergence. Structural Change and Economic Dynamics, 8/4: 399-412.

Hogg, D. (Editor), 2000. Technological change in agriculture: locking in to Genetic Uniformity. St. Martin's Press, New York, 296 pp.

Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, P.V., Evans, A.D., 2005. Does organic farming benefit biodiversity? Biological Conservation, 122: 113-130.

Huesemann, M. H., 2001. Can pollution problems be effectively solved by environmental science and technology? An analysis of critical limitations. Ecological Economics, 37: 271-287.

Islas, J., 1997. Getting round the lock-in in electricity generating systems: the example of the gas turbine. Research Policy, 26: 49-66.

Jenkins, T.N., 2000. Putting postmodernity into practice: endogenous development and the role of traditional cultures in the rural development of marginal regions. Ecological Economics, 34: 301-314.

Kaimoussi, A., Chafik, A., Mouzhadir, A. and S. Bakkas. 2001. The impact of industrial pollution on the Jorf Lasfar coastal zone (Morocco, Atlantic Ocean): the mussel as an indicator of metal contamination. Comptes rendus de l'Académie des sciences, Série 2, Sciences de la terre et des planètes, 333 (6) : 337-341.

Kenneth G. C. and Wood, S. (eds). 2005. Cultivated systems. Ch. 26 of Millenium Ecosystem Assessment. Ecosystems and Human Well-being: Current State and Trends Assessment, pp. 45-793.

Kirman, A., 1989. The intrinsic limits of modern economic theory: the emperor has no clothes. The Economic Journal, 99/395 (Conference Paper): 126-139.

Lawn, Ph. A., 2001. Toward sustainable development. An ecological economics approach. CRC Press LLC, Boca Raton, Florida, 462 pp.

Lowe, Ph., Buller, H., Ward, N., 2002. Setting the next agenda. British and French approaches to the second pillar of the Common Agricultural Policy. Journal of Rural Studies, 18: 1-17.

Lowe, Ph., Murdoch, J., Marsden, T., Munton, R., Flynn, A., 1993. Regulating the new rural spaces: the uneven development of land. Journal of Rural Studies, 9/3:205-222.

Maréchal, K., 2007. The Economics of climate change and the change of climate in economics, Energy Policy, 35/10: 5181-5194.

Maréchal K., 2008. An evolutionary perspective on the economics of energy consumption: the crucial role of habits, Submitted manuscript (http://www.solvay.edu/EN/Research/Bernheim/documents/wp08012.pdf).

Marsden, T., Sonnino, R., 2008, Rural development and the regional state: Denying multifunctional agriculture in the UK. Journal of Rural Studies, article in press, doi:10.1016/j.jrurstud.2008.04.001, 1-10.

Mather, A. S., Hill, G., Nijnik, M., 2006, Post-productivism and rural land use: cul de sac or challenge for theorization? Journal of Rural Studies, 22: 441-455.

Mercier, J.R. 1978. Energie et agriculture. Le choix écologique. Debard, Paris, 187 pp.

Midmore, P., Whittaker, J., 2000. Economics for sustainable rural systems. Ecological Economics, 35:173-189.

Midmore, P., Padel, S., McCalman, H., Isherwood, J., Fowler, S., Lampkin, N., 2001. Attitudes towards conversion to organic production systems: a study or farmers in England. Institute of Rural Studies, University of Wales, Aberystwyth, 71 pp.

Midmore, P., Naspetti, S., Sherwood, A.M., Vairo, D., Wier, M., Zanoli, R., 2005. Consumer attitude to quality and safety of organic and low input foods: a review. Subproject 11 : Determining consumer expectations and attitudes towards organic/low input food quality and safety, Integrated Project No 506358, Improving quality and safety and reduction of cost in the European organic and “low input” food supply chains, QLIF.
http://www.unctad.org/trade_env/itf-organic/meetings/misc/QLIF_Review_Reanalysis200509.pdf

Mulder, P., Reschke, C., Kemp, R., 1999. Evolutionary theorizing on technological change and sustainable development, Paper presented at the 1st European Meeting on Applied Evolutionary Economics, Grenoble, France, 7-9 June.

Muller, P., 1984. Le technocrate et le Paysan. Essai sur la politique française de modernisation de l’agriculture, de 1945 à nos jours. Editions économie et humanisme, Les Editions ouvrières, Paris, 173 pp.

Niggli, U., Earley, J., Ogorzalek, K., 2007. Organic agriculture and environmental stability of the food supply. Issues Paper for the International Conference on Organic Agriculture and Food Security, FAO, Italy, 3-5 May 2007, 32 pp.

Perlman, M., McCann, C., 1998. The Pillar of Economic understanding: ideas and traditions. Ann Arbor. University of Michigan Press.

Pierson, P., 2000. Increasing Returns, Path Dependence, and the Study of Politics. The American Political Science Review, 94/2: 251-267.

Prével, M., online on 28 august 2007. L’usine à la campagne. Socio-anthropologie du productivisme agricole, Ruralia, 2006-18/19,
URL: http://ruralia.revues.org/document1481.html.

Prigogine, I., 2005. The rediscovery of value and the opening of economics. In: Dopfer, K. (Ed.), The evolutionary foundations of economics. Cambridge University Press.

Puffert, D., 2002. Path Dependence in Spatial Networks: The Standardization of Railway Track Gauge. Explorations in Economic History, 39/3: 282–314.

Raven, R., 2007. Niche accumulation and hybridisation strategies in transition processes towards a sustainable energy system: an assessment of differences and pitfalls. Energy Policy, 35: 2390-2400.

Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. Research policy, 34:1491-1510.

Steinfeld, H., Gerber, P., Wassenaar, T., Gassel, V., Rosales, M. and de Haan, C., 2006. Livestock's long shadow. Environmental issues and options. FAO, Rome, 390 pp.

Stiglitz, J., 1994. Whither socialism ?. MIT Press, Cambridge, MA.

Stoate, C., Boatman, N.D., Borralho, R.J., Carvalho, C.R., Snoo, G.R.D. and Eden, P., 2001. Ecological impacts of arable intensification in Europe. Journal of Environmental Management, 63 (4) : 337-365.

Tisdell, C., 2003. Socioeconomic causes of loss of animal genetic diversity: analysis and assessment. Ecological Economics, 45:365-376.

Tversky, A., 1969. Intransitivity of preferences. Psychological Review, 76/1: 31–48.

UNEP, 2003. Geo Year Book 2003. UNEP, Nairobi, 75 pp.

UNEP and UNIDO, 1998. Mineral Fertilizer Production and the Environment. UNEP Division of Technology and Industry, Paris, 74 pp.

UNEP and IFA, 2001. Environmental Aspects of Phosphate and Potash Mining. UNEP, Division of Technology and Industry, Paris, 110 pp.

Unruh, G., 2000. Understanding carbon lock-in, Energy Policy, 28: 817-830.

van den Bergh, J.C.J.M., 2007. Evolutionary thinking in environmental economics. Journal of Evolutionary Economics, 17/5: 521-549.

van den Bergh, J., Gowdy, J., 2003. The microfoundations of macroeconomics: an evolutionary perspective. Cambridge Journal of Economics, 27: 65-84.

van den Bergh, J., Faber, A., Idenburg, A., Oosterhuis, F. 2006. Survival of the Greenest: Evolutionary economics and policies for energy innovation. Environmental Sciences, 3/1: 57-71.

van der Vleuten, E., Raven, R., 2006. Lock-in and change: distributed generation in Denmark in a long-term perspective. Energy policy, 34/18: 3789-3748.

Vanloqueren, G., Baret, Ph., 2008. Why are ecological, low-input, multi-resistant wheat cultivars slow to develop commercially? A Belgian agricultural 'lock-in' case study. Ecological Economics, 66: 436-446.

Veblen, T., 1915. Imperial Germany and the industrial revolution: the case of England, MacMillan, Londres.

Walford, N., 2003. Productivism is allegedly dead, long live productivism. Evidence of continued productivist attitudes and decision-making in South-East England. Journal of Rural Studies, 19: 491-502.

Wilhite, H., 2007. Will efficient technologies save the world ? A call for new thinking on the ways that end-use technologies affect energy using practices, Proceeding from the ECEEE 2007 Summer Study: Saving Energy – Just do it. European Council for an Energy-Efficient Economy.

Wilson, C., Tisdell, C., 2001. Why farmers continue to use pesticides despite environmental, health and sustainability costs. Ecological Economics, 39:449-462.

Windrum, P., Birchenhall, C., 2005. Structural change in the presence of network externalities: a co-evolutionary model of technological successions. Journal of Evolutionary Economics, 15/2: 123-148.

Witt, U., 2004. On the proper interpretation of 'evolution' in economics and its implications for production theory, Journal of Economic Methodology, 11: 125-146.

Wood, S. and Cowie, A., 2004. A review of greenhouse gas emission factors for fertiliser production. IEA Bioenergy Task 38.

Young, J., 2000. Book review of “The Pillar of Economic understanding: ideas and traditions” by Perlman, M., McCann, C., 1998. Journal of Economic Literature, 38/2: 415-416.