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Intentionality and the emergence of complexity: an analytical approach

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Abstract Emergence is a generic property that makes economies become complex. The simultaneous carrying out of agents' intentional action plans within an economic system generates processes that are at the base of structural change and the emergence of adaptive complex systems. This paper argues that goals and intentionality are key elements of the structure of rational human action and are the origin of emergent properties such as innovation within economic complex systems. To deal with the locus and role of goals and intentionality in relation to the emergence of complexity we propose an analytical approach based on agents' action plans. Action plans are open representations of the action projected by agents (as individuals or organizations), where the means (actions) and objectives (or goals) are not necessarily given, but produced by agents themselves.

Keywords Intentionality · Action plans · Emergence of novelty · Complexity

JEL Classifications B41 · B52 · D89 · O10

> We may therefore feel justified in treating economic systems as a relatively new class of manifestations of a general evolutionary principle of building systems by making selective connections between elements of existing systems. We may also feel justified in seeking to analyse the structure of each system without investigating its elements in detail. However, when we encounter human-based systems an important modification of the neo-Darwinian version of this

> principle is required: neither random genetic mutation nor selection by differential genetic inheritance is appropriate. We must introduce intentionality.
>
> (Loasby 2012: 837)

1 Introduction

Economics focuses on the parts of action that are rational (even in contexts of true uncertainty) and involves the allocation of scarce means to goals. Thus economic actions, and actions in general, are configured and deployed on the basis of reasons for acting (Searle 2001; Bratman 1987 [1999]). Rational action is first planned and then carried out in interaction with other agents within a system and in accordance with the corresponding plans of action. Of course, not all human action is planned -feelings and emotions may play a very important real role in an individual's action- and planned actions may produce unintended consequences. However, as far as economists are concerned, the main focus is on the part of the action that is the result of deliberation and choice as Mises (1949) pointed out.

Economic agents interact in economic complex systems. In recent decades there has been an increasing amount of literature in which the economy is considered to be an evolving complex system (Anderson et al. 1988; Blume and Durlauf 2006). Amongst others, important examples include the Santa Fe Institute, a large part of evolutionary economics (Witt 2003) and literature on innovation systems (Antonelli 2011). There are many factors that lead to the emergence of complexity in human interaction systems.[1] Some of these factors depend on agents' heterogeneity -their basic characteristics differ in terms of original endowments such as learning capabilities, size, location, etc. This said, agents also differ in their goals and intentionality. In the area of social sciences, psychology and neuroscience, etc., the concept of "intentionality" (which dates back to Brentano (1874))[2] has also gained momentum: in the last ten years, the number of articles and other papers containing the term 'intentionality' in their *title*, *keywords* or *abstract* has grown immensely. For example, between 2002 and 2011, the number of papers referenced in the ISI-Thompson and Scopus databases totaled 1161 and 1704 respectively. However, it is rare to find the connection between both semantic fields, i.e. "intentionality" + "economics" and the topic seems to be marginal in economics in comparison with neuroscience, for example.

Some economists celebrate the fact that intentionality (and other "folk psychology" terms (Hands 2001)) tends to disappear in economics. However, in recent years the debate about the role of purposeful action, intentionality and the elements that encourage action and knowledge has been revived in this field, at least among evolutionary economists (see for example Hodgson and Knudsen 2007, 2011; Levit et al. 2011; Nelson 2007; Vanberg 2006; Witt 2006).[3] Some authors have used different

[1] Emergence is a key generic property that makes economies become complex (Harper and Endres 2012).

[2] A good classic precedent in philosophy is Ascombe (1957). An interesting approach quite complementary to ours is Bratman's (1987 [1999], 1999). (See also Bratman et al. (1988).) An interesting review is Zimmerman (1989).

[3] In a quite related field, Arthur (2007, 2009) has stressed the purposeful character of (actions that give rise to) invention and technical development.

analytical approaches to highlight the need to associate intentionality with economics and position it at the base of the explanation of economic processes as processes that generate complexity (Antonelli 2011; Muñoz et al. 2011; Rubio de Urquía 2003; Levit et al. 2011; Wagner 2012 among others).

This paper's main concern is to understand the sources and the process of economic change. More specifically, it investigates the role of agents' intentionality in the generation of economic processes that give rise to complex adaptive systems. As will be shown, agents' goals and intentionality play an essential role in explaining the emergence of complexity in economic systems. Thus, economic dynamics may be understood as the process for the generation, selection and attempted implementation in the interaction of agents' *intentional action* -and not only choices (Lane et al. 1996)- and their consequences.

Accordingly, we use an action plan approach (Encinar and Muñoz 2006). This approach allows us to establish micro-foundations (Felin and Foss 2009) that give rise to phenomena and processes such as the intentional orientation of projective action, the continuous appearance, dissemination and retention of novelty in economics, creative responses (Antonelli and Ferraris 2011; Kelly 1963: 8) and entrepreneurship, evolutionary capabilities (Cañibano et al. 2006), etc., that otherwise have no place in an eminently static approach (*a*-temporal, in the sense of Shackle (1972, 1977)). The fact that an unseen or unheard-of event arises from the interaction of these intentional dynamics is another matter. Nevertheless, this does not discount the fact that a key source of complexity lies in the agents' intentionality: intentionality has a systemic structure capable of producing unexpected events. The generation, dissemination and use of knowledge is fundamental for explaining the complexity of economic processes (Loasby 1999), however it is not sufficient to provide a full explanation of these phenomena. We claim that the intentionality-knowledge binomial lies at the base of complexity and evolution.

The structure of the paper is as follows: in Section 2, we present the conceptual base of the action plan and the analytical approach to develop our main argument, which links intentionality to agents' action plans. Section 3 proposes an analytical representation of agents' action that allows us to identify both the locus for intentionality and the necessary connections between the formation and the carrying out of plans in interdependent contexts. Section 4 examines the role of intentionality and its dynamic consequences in terms of production of new realities (novelties) and emergent properties. It is shown that intentionality is a sufficient (but not necessary) condition for the emergence of new properties within complex systems. The paper ends with some concluding remarks.

2 Intentionality and agents' action plans

Economic agents interact in economic systems that are of an evolving complex kind; economies are non-ergodic systems; economic processes are historical (North 2005) and agents plan and deploy their courses of action in a context of radical uncertainty (Knight 1921). In this context, the claim that an agent's action is rational means that it is configured and deployed on the basis of reasons. That is to say that an agent's action is, essentially, planned; i.e.: in accordance with action plans.

Action plans consist of the projected intentional sequence of actions that lead to goals (Rubio de Urquía 2011: 414; see also Miller et al. 1960) posed in a future (imagined in the sense of Loasby (1996)) time.[4] An agent's action plan may then be interpreted as an "analytical" template or guide for action that connects different kinds of elements projectively (that is, towards an imagined future) in accordance with the agent's intentionality: something that is to be reached (objectives or goals) is connected with actions that lead to it. These plans are drawn up by individuals, and they are inherent to them. There may also be plans that outline the action and coordinate the objectives of groups of people (all kinds of organizations).[5] Action plans are *open representations* of the action projected by the agents (as individuals or organizations), where the means (actions /resources) and objectives (goals) are not given as suggested by Robbins (1932), but rather are the results of the agents' own planning activity. The plans drawn up intentionally by the agents are those which, when carried out in interdependent contexts, configure social and economic dynamics (Muñoz and Encinar 2007): their consequences transform the agents themselves as well as the physical-natural, but above all human environment in which they interact.[6] When agents evaluate the consequences of their interactions they may perceive (or not) the inconsistencies of their plans and revise (fully, partially or not at all) their configurations, and, eventually, learn. The dynamics of interaction generates complexity because of this feedback mechanism. The consequence is a restless mechanism (Metcalfe et al. 2006) of economic change, which in this context means the (economic) dynamics of endogenous structural change are capable of inducing or generating novelties.

Not all human action is planned: the actual action of an individual comprises both *planned action* and *unplanned action*. Unplanned action is not something of residual or trivial importance that is inaccessible to scientific knowledge. In fact feelings and emotions play a very important and real role in an individual's action. However, as previously stated, our main interest lies with the part of the total action resulting from deliberation. Moreover, planned action brings in a number of fundamental dynamic elements that enable us to understand, for example, the dynamic role played by the intentionality of the action, a phenomenon which we can analyze in detail, as the following section shows.

2.1 Action plans

The concept of an action plan incorporates a number of important elements for explaining rational human action. Two of those elements are the objectives and projective nature of the action. The bonds between means and goals logically depend on what the agents know or think they know, i.e. on what we refer to as their cognitive dynamics (which we will refer to as *CD*). *CD* refers to the understanding agents have

[4] Fuster (2003, 2008) physiologically locates action plans in the prefrontal cortex of humans.

[5] For example a family's travel plans, the business or production plans of a company, etc.

[6] The concept of action plan has been used with different formalization by economists as diverse as Lachmann (1994 [1976]), Keynes (1936), Hicks (1939), Stackelberg (1946 [1943]), Barnard (1938), Debreu (1959), Penrose (1959), Malinvaud (1999), Boulding (1991), etc.

of reality, where this understanding is condensed into representation systems made by agents (according to scientific-technical representations). *CD* also refers to beliefs in terms of what this reality *is* like and to the evolution of this understanding.

However, plans are established intentionally according to the objectives and targets that agents wish to achieve. These objectives and targets guide the action and give it *meaning*. Therefore, we can distinguish analytically between agents' perception of what reality is like or could be like in the future - agents' *CD*- and their conception of what reality should be: their ethical dynamics, referred to as *ED*. Together with socio-cultural dynamics (*SD*),[7] in which the agents deploy their activity, both dynamics modify the content and form of the plans and, consequently, generate new realities. These realities stand as a contrast between what has previously been conjectured (in the sense of Popper (1972)) in the agents' action plans (*ex ante*) and what they (*ex post*) understand as what has actually happened. The compared *balances* between expectations and events (may) activate review mechanisms (learning) of the agents' plans and the way in which they are formulated.

As shown below, economic dynamics can be understood as the process for the generation, selection and (attempted) interactive implementation of agents' action plans and its consequences. The alteration of intentionality implies that agents' action plans are internally modified and that the interactive implementation of the new plans generates new realities. Indeed, the introduction of new objectives alters not only the spaces of objectives but also induces new types of knowledge, capabilities and actions.

Let p^i_{th} represent the action plan h of an individual i at the time t. The plan p^i_{th} consists of executing in t actions a^i_{th1} and a^i_{th2}, to reach in $t+1$ the goal $G^i_{(t+1)h1}$ and, also in $t+1$, executing actions $a^i_{(t+1)h3}$, $a^i_{(t+1)h4}$ and $a^i_{(t+1)h5}$, to finally achieve the objective $G^i_{(t+2)h2}$ in $t+2$. The hierarchy of goals is as follows: $G^{i*}_{(t+2)h3}$ is the main goal and $G^i_{(t+2)h2}$ and $G^i_{(t+1)h1}$ are both lower level goals.

From a theoretical point of view, an action plan p^i_{th} can have, in general, any projective linkage structure. These linkages are represented in Fig. 1 by arrows indicating the direction -intention- of the action to an objective. The linkages can include estimates of probability (both 'objective' and subjective probability) or conjecture, all kinds of conditionalities (also including strategic plans); feedbacks; etc. Of course, the plan p^i_{th} may be defined incompletely by the agent. In that case, the plan p^i_{th} may include connections or actions that are not fully specified, pending future specifications.

Many outstanding features and properties of personal action plans can be known in relation to internal, logical or material consistency and ex ante and ex post feasibility (see Bhattacharyya et al. 2011; Sen 1993). Moreover, plans may involve a hierarchical structure of goals that can include a wide variety of contents: from low-level hierarchical determination (no goal is worth much more than another) to high-level hierarchical determination. Thus, the structure of a plan's goals can be inconsistent

[7] Culture, defined as in North (2005), plays a fundamental role in economic change.

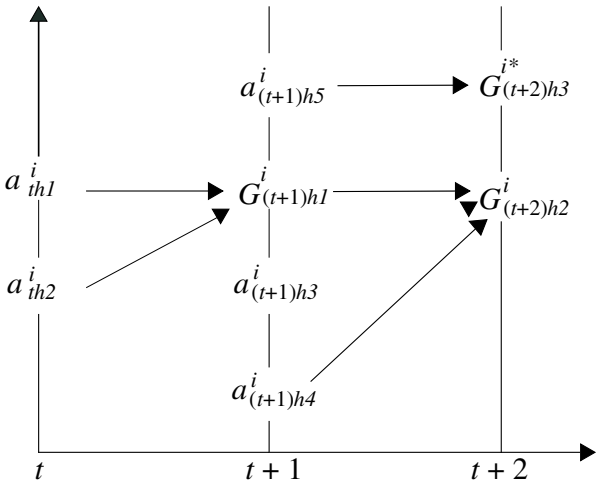

Fig. 1 Example of an action plan

insofar as one or more of the goals contained in the plan may be incompatible with other goals within the same plan.[8]

The hierarchical structure of goals allows for a simple representation: Fig. 1 shows both a sequence and a hierarchy of goals. For example, in $t + 2$, the goal $G^{i*}_{(t+2)h3}$ occupies a higher hierarchical position than $G^{i}_{(t+2)h2}$, this being represented by drawing the former above the latter.

2.2 Bundles of action plans

In general, agents try to deploy several action plans; we will refer to this set of action plans as a bundle of action plans, B^i_t. Figure 2 illustrates a bundle of action plans B^i_t.

The bundle represented in Fig. 2 comprises three action plans and four periods of time: t to $t + 3$. At time t, the projected action relative to the individual i is based on these three plans. The chart has some intersections that are not empty between plans because they have elements (both means and goals) in common. Accordingly, for example, action a_{t13}, located in terms of time at time $t + 1$, inherent to plan 1, is also necessary for achieving target G_{t22} inherent to plan 2. In addition, the bundle B^i_t has a projective horizon of three periods, but not all the plans have the same duration in terms of reference time and not all the plans start and end at the same times in this reference time.[9]

[8] Investigation cannot pre-exclude plans that contain systems of goals that are internally inconsistent. In fact, these kinds of plans may form part of the reality under study and constitute an interesting field of study in themselves. See for example Encinar (2002).

[9] As far as plans are components of a bundle, and are intrinsically linked together forming a whole course of action, each pattern of bundling may be understood as an attempt at tentative modularization of action by the agent. The plans that form the bundle (three plans in Fig. 2) would be themselves quasi-decomposable modules of a higher level "system" of actions-goals –the bundle- that would direct the future course of action of the agent. For the meaning of quasi-decomposability and modularization see, respectively, Simon (1962) and Langlois (2002).

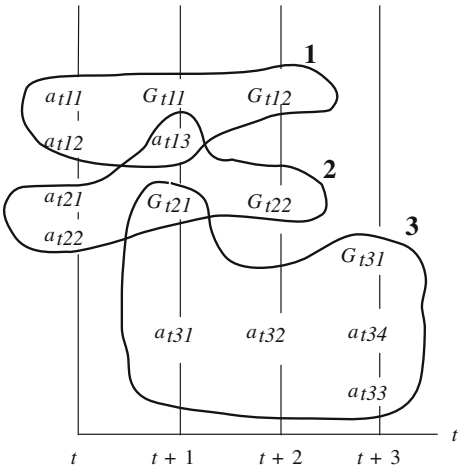

Fig. 2 Bundle of action plans B_t^i

3 An analytic representation of agents' action

Despite the fact that goals can be treated analytically as static elements, intentionality is inherently dynamic. Intentionality is understood as the tendency towards a goal that first appears in the individual's mind as a purpose. This definition of intentionality is closely linked to the concept of plan. Intention is the determination of will in accordance with a purpose. Additionally, intention is what makes it possible to differentiate between the purposes of individuals (or groups of individuals) and their mere desires. The latter do not necessarily activate subjects' actions or, therefore, their intentions. However, the conception of purpose activates behavior and actions that focus on their achievement through intention and will.[10] Agents can be distinguished on the basis of their knowledge and skills, but also by the purposes they pursue. All this leads to agents being able to introduce a wide variety of changes in the environment through their actions, altering other agents' space of action.

This section proposes a model of agent action in order to identify the necessary connections between the formation (constitution) and interactive implementation of intentional plans and the production of new realities and emergent properties that change the landscape of the system. The model has the advantage of offering a summarized representation of the elements that configured the projected action by agents, its interactive implementation and its transformation into real (external/observed) action. The model has three building blocks -agents, actions/means, and goals- that are connected in action plans, and four analytical stages (see Fig. 3) –formation;

[10]The new goal psychology represents a step forward in the integration of motives for action with psychological theories, generally cognitive, on human action. The links are the very goals or objectives of the action. See various chapters in the *Oxford Handbook of Human Action* (Morsella et al. 2009), especially those included in part 2 (dedicated to the activation, selection and expression of action) and in Moskowitz and Grant (2009). On motivation in Economics see Frey and Jegen (2001) and Gerschlager (2012).

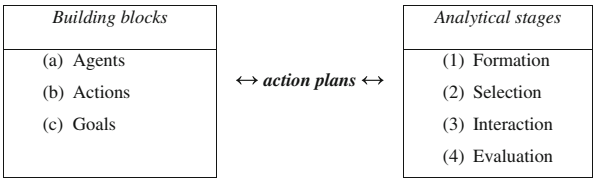

Fig. 3 Constitutive elements of the model

selection; interactive implementation and evaluation of the consequences of action plans.

3.1 The (evolutionary) stages of agent action[11]

1. *Formation*: The first stage in the model of agent action is the process by which individuals form their *bundles* of individual action plans, in each instant of time t, B_t^i. From these bundles of plans B_t^i, agents establish a hierarchy, determine some of them as possible, $\tilde{B}_t^i$, and choose the bundle, $\hat{B}_t^i$, that best satisfies their objectives.[12] Logically, the relation between these bundles of plans is: $\tilde{B}_t^i \subset B_t^i$, $\hat{B}_t^i = \max\left\{\tilde{B}_t^i\right\}$, where $\left\{B_t^i, \tilde{B}_t^i, \hat{B}_t^i\right\} \neq \emptyset$.

   In each instant of time t, the specific content of B_t^i is shaped by means of the current agent's set of beliefs, values, attitudes, representations of reality that the individual i holds at that time t. We will refer to this set as the agents *ensemble* of beliefs, etc. -or simply the ensemble- E_t^i.[13] Both the elements and the relationships between them contained in the ensemble are the result of the previously mentioned ethical, cognitive and socio-cultural dynamics (ED_t^i, CD_t^i and SD_t respectively) of the agents. In particular, SD_t, which includes the general environment (including institutional settings, technologies, habits and rules, etc.) within which agents are inserted and deploy their actions. The ensemble E_t^i supports the subjective domain of planning, i.e., how the world is made; what is possible and what is not;

[11] Subsections 3.1 and 3.2 are grounded and develop the approach by Rubio de Urquía (2005) introducing *intentionality* within the analytical framework.

[12] This bundle in a neoclassical account would roughly correspond to the bundle that maximises some objective function (utility, profits, etc.). However, in a more general (and realistic, that is, where true uncertainty prevails) framework the agent chooses bundles that "meet targets of adequacy rather than pinnacles of attainment" (Earl 1983: 78–81). It is very interesting to compare our analytical stages with those proposed respectively by Earl and Potts. The former (Earl 1983: 149-150) presents a multistage process in which the agent proceeds sequentially as follows: (1) problem recognition (a failure to match up to aspirations), (2) search of (not given) courses of action, (3) evaluation of possible sequels of particular choices, (4) choice itself, (5) implementation (often difficult and partially accomplished), and (6) assessment (the agent examines to which extent what was decided was achieved). Potts (2000: 120–123) addresses the problem of acting in a non-integral space. Agents must form conjectures as a solution by means of searching among adjacent possibilities which relationships may solve (are more promising ways of solving) their particular problems. The 'decision cycle' that makes these operations possible consists of four separate components: {LIST, CONSTRUCT, RANK, SELECT}. The main point in Potts' proposal is that, for him, these conjectures are the agents' preferences (note the conjectural character of action plans).

[13] The ensemble refers to the "reality" such as it is conceived by the agents in order to produce their action.

what is known and what is not, in relation to the past, present and future; what the individuals acting can do; what is best and what is worst for these individuals; what they want and what they do not.[14] In short, E_t^i defines the subjective possible courses of action and provides elements of valuation for organizing them in relation to what should be, what is desired and what is preferred by the agent at each time t. This concept of ensemble is quite similar to Bratman's (see Bratman et al. 1988) conception of belief/desire/intention (BDI) architecture. For Bratman the (BDI)-architecture includes fair representations of agent's beliefs, desires, and intentions. However, the ensemble also includes the set of representations of reality that the individual i holds at a specific time t: it defines the subjective projective space of action of the individual i at each time t. Whereas in Bratman's approach agents' intentions are structured into larger plans, in our approach, intentionality is the source that *structurally* and *temporally* orders the contents of those plans; that is, intentionality generates the "library" of notional actions required to reach the goals pursued by the agents, giving sense and rationality, to their actions. Thus our approach allows us to deal with intentionality as the last source of rationality of actions.

2. *Selection*: Each ensemble E_t^i contains a structure of alternative planned action possibilities that *denotes intentionality*. After considering different planned possibilities, the individual selects one bundle $\hat{B}_t^i$ at each instant t, and begins to execute the actions (and reach the goals) corresponding to that instant t. In other words, at time t, the individual (organization) adopts one of the possible courses of action, the bundle $\hat{B}_t^i$ by means of an active decision which, among other elements, implies closing the hierarchical structure of all the alternatives of action with regard to the agent's ensemble, E_t^i. The ensemble *generates* the selected bundle:[15]

$$E_t^i \rightarrow \left\{ \hat{B}_t^i \right\}$$

This process of selection is internal to the agent's subjective domain of action.

3. *Interaction*: From individual planned action to individual observable action. It is by means of the simultaneous carrying out of plans in interdependent contexts

[14] The term "beliefs" refers to the set of conceptions, representations and knowledge to which the individual is faithful. In general, beliefs imply evaluation criteria that organize the projective action and the action of decision among alternatives and value judgments. "Values" is understood as the set of valuation criteria effectively used by the individual to projectively organize the action and issue value judgments. The possible difference between the valuation criteria implied by the beliefs and those effectively used in practice must be acknowledged. Values include tastes and preferences. "Attitudes" refers to stable features that introduce determination in certain aspects.

[15] In our approach, the symbol $\rightarrow$ neither represents a logical relationship (for example a material conditional if-then relationship) nor a mathematical function that relates two (or more) variables (as is the case of a production function, for instance). It designates a *mode* -that is, a conventional sign- of representing a necessary causal relationship among theoretical structures. Quite a different issue is that in some very specific circumstances it is possible to characterize parts of a theory of human action by means of proper (not imposed) mathematical structures as is the case of neoclassical economics under highly restrictive theoretical assumptions.

that planning connects to observable action. It is at this stage when, on one hand, *intentionality emerges* and produces external reality and, on the other, it is possible to show the analytical link between the micro- (individual) and meso-level. This is the crucial stage in which action is deployed interactively, producing instants of reality and the historical consequences of action –those that are captured in ordinary statistical measures, etc.

4. *Evaluation*: Moreover, interaction reveals which parts of the plans of interacting agents within a system are or are not compatible, and it retains ex post which parts of goals and courses of action considered ex ante as possible have been successful. In other words: agents examine whether or not their conjecture (the bundle of plans) was correct and thereby whether their goals have been attained. If evidence is in some sense unsatisfactory agents would revise how they form their plans in order to try and do so otherwise.[16] Thus, as long as plans are being developed they are evaluated and processes of learning are triggered. Interaction generates a process of selection external to the agent.

In order to develop these ideas, we need to open up the internal production of action "the black box" via a sequence of two intermediate steps:

Step 1: Let s_t^i be the state of the individual i at instant t, which comprises the state of the individual in biological and mental terms; his/her individual dynamics ED_t^i and CD_t^i, as well as everything that is external to the individual and may play a role in his/her actions.[17] Let be δ^i a kind of *operator* that binds together ED_t^i, CD_t^i and SD_t; with both the agent's state s_t^i and the state of the non-human environment at t, u_t; that is, with $\left(s_t^i, u_t\right)$. Thus, the formation of δ^i includes the dynamics ED_t^i, CD_t^i and SD_t, the sequence of personal ensembles of i before the time t and "what it is", including "what it has been". By means of δ^i the ensembles E_t^i and the bundles of plans $\hat{B}_t^i$ are continuously being formed by the individual i at time t. Thus:

$$\delta^i\left(s_t^i, u_t\right) \rightarrow \left\{E_t^i\right\} \rightarrow \left\{\hat{B}_t^i\right\}$$

Step 2: Let A_t^i denote the action really deployed by the individual i at instant t and α^i denote the system of relations that binds together the final action exercised A_t^i and the action planned in bundle $\hat{B}_t^i$ for the individual i at time t; in other words:

$$\alpha^i\left(\hat{B}_t^i\right) \rightarrow A_t^i$$

The dynamic α^i is based on the personal principles related to the relationship between planned action and unplanned action. Thus, the unplanned

[16] This stage is rather similar to the one that Earl (1983: 150) has called "assessment" in his multistage process model of choice.

[17] The agent's state may include explicitly the agent's "biography"; the set of all the states of all the individuals other than i prior to time t that may influence the agent.

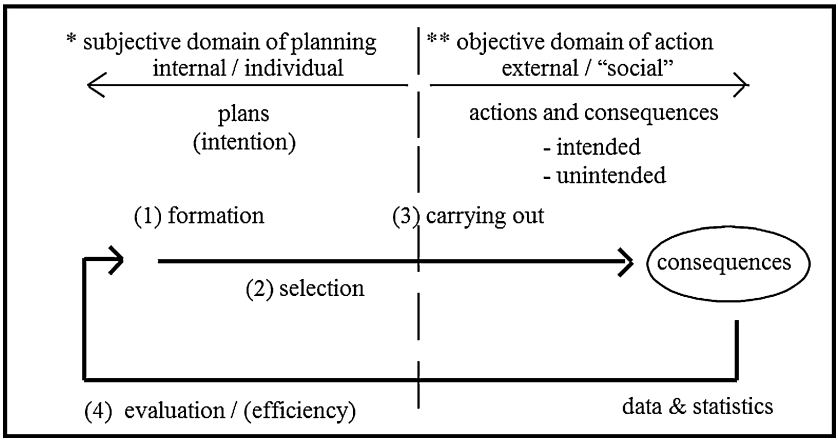

Fig. 4 The subjective and objective domains of action

action forms part of what is indicated in α^i.[18] It is when the agent deploys A_t^i that *intentionality emerges*, when we shift from the individual planned action to the individual observed action.

The process of interactive implementation of plans partly configures the economic dynamics –transforming the external (objective) reality as well as the internal (subjective) realities of agents. This process depends not only on how plans are internally formed, and on their structure and content, but also on the results of interaction. Figures 4 and 5 summarize these ideas.

3.2 Interaction with n-agents

At each instant of time t, there are n_t agents in the economy.[19] According to their previous states and what they understood as their own current state, economic agents generate their own instantaneous personal ensemble, E_t^i. Therefore, at each instant t there is a set of personal ensembles $E_t^i : \left\{E_t^1, E_t^2 \ldots E_t^{n_t}\right\}$. Depending on their own E_t^i, and by means of δ^i, each agent produces a set of bundles of potential courses of action $E_i^t \rightarrow B_i^t$, and selects a bundle of action plans -which corresponds to the planned courses of action that each individual tries to deploy, $\hat{B}_t^i : \left\{\hat{B}_t^1, \hat{B}_t^2 \ldots \hat{B}_t^{n_t}\right\}$. Both the set of all projected bundles of action plans (imagined and deemed as possible by agents) B_t^i and its subset of selected bundles of action plans $\hat{B}_t^i$ imply intentionality.

However, for the selected action plans that give rise to action, the operator α^i, mediates, producing the actual action of each agent i at each instant of time t : $\left\{A_t^1, A_t^2 \ldots A_t^{n_t}\right\}$. Finally, the action deployed by each agent in the economy together

[18] They could be unplanned actions due to, for example, the use of routines, rules, procedures and behavioural habits, which also generate consequences, expected or otherwise, in action.

[19] At t it may be that $n_t \geq n_{t-1}$ or that $n_t < n_{t-1}$.

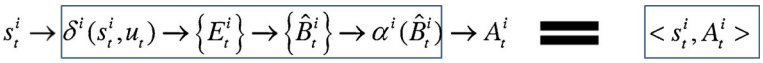

Fig. 5 Extended and resumed representations of agent action "*black box*"

with each agent's own state at t, $s_t^i : \{s_t^1, s_t^2 \ldots s_t^{n_t}\}$, interact. As a consequence of that interaction, the dynamics of generation of new individual states (including new knowledge, beliefs, attitudes, etc.) is produced, transforming both human and non-human environments, (new artefacts, institutions, u_t, etc.). In turn, the dynamic for the generation of agents' states 'returns' new states for the individuals and non-human environments that re-nourish the formation and interactive implementation of the action in the next instant $t + 1$.

Figure 6 shows the interactive implementation of action, represented by ΔS_t. It is at this stage when agents interact and produce new instants of reality.

Finally, the form adopted by ΔS_t depends on the decision of the modeller. Thus, ΔS_t may include networks of agents, functional relationships without structural change, etc.

3.3 Action and economic theory

Obviously, planning is not economic action -as shown by the difference between $\hat{B}_t^i$ and A_t^i. Planning is a part of action (an activity itself), but not the kind of action that is truly relevant for economics.[20] Economic theory has usually focused on the analysis and development of models based on a special version of the dynamic δ understood as an optimization principle. This version of δ operates over a hierarchized set B_t^i and a subsequent subset (hierarchized and deemed possible) $\tilde{B}_t^i$ of the latter, and selects $\hat{B}_t^i$.

As all bundles of action plans depend –in our approach- on the pre-existence of E_t^i, -because E_t^i projects the space of action of agents- it may be concluded that usual economic theorizing takes (at least implicitly) the agents' ensembles as given or for granted. (For example, in the case of usual consumption theory, the preferences over the consumption bundles are fixed a priori). The 'closure' of the economic models is indeed necessary for the analysis of open systems, as Loasby (2003) has shown so masterfully. If we are interested in assigning any role for intentionality, the closure has to be placed at the level of E_t^i, where the *choosable* (in the words of Shackle 1977) is produced.

When the action projected by the agent is being deployed, planned action is "transformed" into actual action. As we have pointed out, this transformation is the base of the production of 'actual' human action; in other words, the production of instants of reality. This transformation requires the analytical concurrence of the dynamic α. The production of the specific (and complete) reality of the agent is not completed

[20] How individuals set goals, etc., is very important for other disciplines such as psychology. (See for instance, Ajzen 1991; Miller et al. 1960; Moskowitz and Grant 2009).

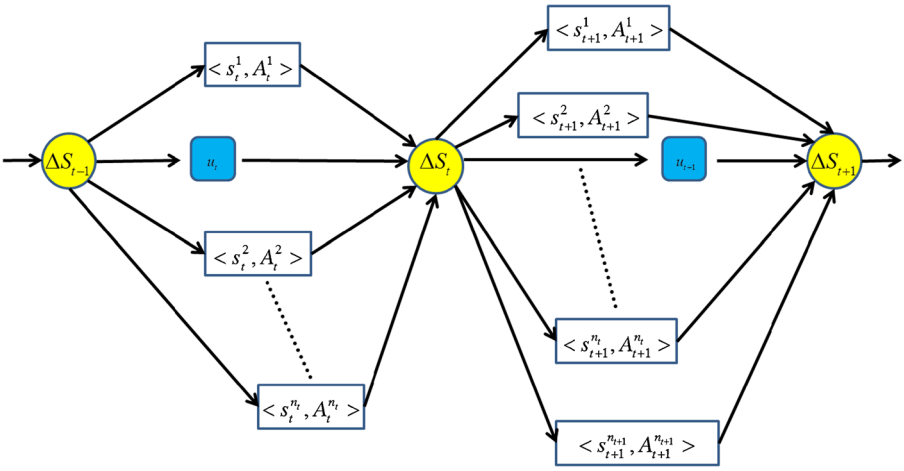

Fig. 6 A representation of the structure of agent interaction

until the operation of α, which triggers the interactive implementation of the action that is at the base of complex phenomena.

4 Intentionality and the emergence of complexity

Emergence is a generic property that makes economies become complex. The emergence of complexity within an economic system is not (necessarily) intentional; but depends on the agents' intentions, even though what happens is not necessarily what is being sought by agents. Observed actions can differ from what was intentionally sought -when they were projected actions- although this is compatible with the fact that intentionality is present in the analytical structure of action. The question about where and when new properties emerge may be addressed as follows. New properties emerge because agents: (a) discover or invent *new* actions; and/or (b) discover or "invent" *new* objectives; and/or (c) rearrange previously existing actions and goals in a *new* way. Agents implement all these new or revised actions and/or goals into *new* plans[21] and try to deploy such action plans in interaction with other agents and the external environment. Thus, revised actions consist of introducing entirely new actions linked to existing objectives (a radical understanding of novelty (Witt 1996)) or changing (or cancelling) the links between actions and objectives; revised objectives consist of introducing entirely new ones or of changing the hierarchy of already existing objectives. However, it is as a consequence of the simultaneous carrying out of actions in interdependent contexts (ΔS) that novelties emerge.

[21] New in the sense of "unheard-of".

Thus, the emergence of novelties can be both (1) the result of an agent's internal dynamics $\left(\text{that reproduce new } E_t^i, \hat{B}_t^i \text{ and } A_t^i\right)$, and/or (2) the result of interaction processes between agents. The former refers to conscious and *intentional* acts undertaken by agents; the latter refers mainly to unexpected products of interactions among action plans.[22]

Once new properties emerge, they fuel the processes of structural change as a necessary consequence as agents incorporate them into their space of action –via E_t^i and $\left\{\hat{B}_t^i\right\}$. Regardless of where novelties emerge, if they have any effect it is because, by necessity, novelties are incorporated into agents' action plans, producing specific actions, A_t^i, and novelties are disseminated through the interaction of agents' action plans.[23] When agents evaluate the results of interactions and learn, they perceive (or perhaps not) the inconsistencies of their plans and revise (fully, partially or not at all) their configurations, as feedback for their ensembles $\delta^i(\cdots) \rightarrow E_t^i \rightarrow \left\{\hat{B}_t^i\right\}$. The consequence of this interaction is a restless mechanism that generates continuous structural change.

Once the structural components of the model have been specified and extended to *nt*-agents -$\left(E_t^1 \cdots E_t^{nt}, \delta^1 \cdots \delta^{nt}, \alpha^1 \cdots \alpha^{nt}\right)$-, the process of economic change acquires full meaning, generating the states $\left(s_t^i, u_t\right), \forall i$: when any structural element changes, novelties emerge and then at least a new bundle of action plans (B_t^i) is configured. In the model, intentionality is located in the ensemble (E_t^i) and deploys its logic through the interaction of the revised agents' plans. Revised action plans, in which novelty has already emerged, induce economic change giving rise to processes of novelty-dissemination. Revised action plans are a source of complexity as far as they feed the generation of the renewed variety characteristic of evolutionary processes. Intentionality is a sufficient –but not necessary- condition for the emergence of new properties within complex systems.

Finally, interaction leads to the general dynamic of production of social and economic reality and (due to the appearance of all kinds of novelties -creative responses, unexpected consequences of actions, rationed action, positive or negative externalities, path-dependency, etc.) breaks down the sequences of the effective implementation of action plans, and triggers a dynamic of constant disequilibrium. These disequilibria do not lead to chaos, but rather generate complexity in the system of agents in interaction and in the non-social medium. According to the responses (positive or negative feedback (Miller and Page 2007)), systems stabilize

[22] Owing to this, novelties cannot be uncaused causes as Hodgson (2004, chap. 3) suggests: the ultimate cause is the intentionality of agents. In an example provided by Schumpeter's (2005 [1932]) Mantegna's innovations could be interpreted as a conscious and individual act undertaken by the painter; the 'Renaissance style' produced unexpected innovations in painting as a result of painters interactions.

[23] As has been said above, in economics the simplest example of ΔS is a perfect-competition market; in this structure of interaction –in which agents, agents' goals, and structure of interaction do not change- the consequences ΔS are expressed in terms of the complex of produced and consumed quantities and the equilibrium price. Of course ΔS may be more complex: we may think that there is rationing equilibria (Benassy 1986; Malinvaud 1977); non-market interactions (Schelling 1978); network effects (Katz and Shapiro 1994); etc.

or increase/decrease their degree of complexity. The logic of this entire mesh of interaction is more evident in specific case studies. Moreover, this logic appears more clearly when the level of analysis chosen by the theory is between the micro-meso and meso-macro levels (Dopfer 2011; Dopfer et al. 2004).[24]

5 Concluding remarks

This paper argues that intentionality is a key element of the structure of rational action and that it is at the origin of emergent properties within economic complex systems. The argument is consistent with the role that the categories of intentionality -such as belief, goal, intention, collective intentionality, etc.- have in cognitive sciences, artificial intelligence and social philosophy, as well as in the explanation of individual and collective behavior and the emergence of institutions (Baldwin and Baird 2001; Grosz and Hunsberger 2006; Malle et al. 2001; Metzinger and Gallese 2003).[25] Intentionality -an agents' feature of representations by which they are about something or directed at something (Searle 1995)- is linked to goals and in order to deal with the locus and role of goals and intentionality in relation to the emergence of complexity we have developed a model based on agents' action plans.[26]

There are many factors that lead to the emergence of complex properties in human interaction systems. Some of these factors depend on the fact that agents are intrinsically heterogeneous -their basic characteristics differ in terms of original endowments such as learning capabilities, size, location, etc. Even so, intentionality is a key factor for understanding the dynamics of human complex adaptive systems; although this factor tends to blur or even disappear in Economics. In many models, agents are portrayed as automata that are unable to implement the intentional pursuit of their interests (Rosser 2004). As a result, the main source of novelties usually remains obscured and, as Antonelli (2011) claims, the theory of complexity does not yet provide an analysis of the endogenous determining factors of the system's features.

The action plan framework presented in the foregoing sections allows for alternative uses. Our purpose in this paper has been to shed light on the endogenous link between intentionality and the emergence of complexity in Economics. Thus, the main use of this approach here is to locate and understand the role of intentionality in explaining dynamic processes such as the emergence of novelty and structural change

[24] Examples include the analysis of the origin and evolution of techno-economic innovation systems, the emergence of technological clusters, the evolution of institutions, etc.

[25] The role of beliefs, etc. has been recognised in economic theory. Recently, Acemoglu has pointed out that the fundamental causes of economic growth are luck, geographical differences, institutional differences and "cultural differences that determine individuals' values, preferences and beliefs" (Acemoglu 2009: 20).

[26] It must be stressed that the aim of this paper is not to offer a technical solution to a particular problem. It is an analytical proposal intended to make tractable North's (2005) and Loasby's (2012) challenges, i.e.: to erect scaffoldings (analytical frameworks) that allow us to deal with human interaction and the sources of complexity (and structural change) -scaffoldings being able to accommodate, at the same time intentionality and different "ecologies of plans" (Wagner 2012).

that are typical of complex systems. This approach also provides another important analytical use: it constitutes a natural place for intrinsically dynamic topics, such as Schumpeter's (2005 [1932]) "creator personality" (entrepreneur) and his role for explaining economic development. The Schumpeterian entrepreneur is the analytical subject who is *especially* capable of introducing new objectives, new actions or new relationships between actions and objectives, into his action plans; in other words, he offers creative responses to new situations (Schumpeter 1947a, b). The creator personality is especially capable of generating novelty and, therefore, of stimulating development. In all, novelty depends on the intentionality of agents. The fact that an unexpected event arises from the interaction of intentional dynamics is another matter. However, this does not eliminate the fact that its origin is intentional. Of course the creative reaction of each agent is not actually a one-off event that takes place in isolation in time and space, but rather a historic process in which the sequence of feedback plays a key role (Arthur 1990, 2007).

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