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Fabrizio Li Vigni

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Futures. The Journal of policy, planning and futures studies
“Five anticipation communities in complex systems sciences”

Fabrizio Li Vigni

Postdoc fellow at Laboratoire Interdisciplinaire Sciences Innovation Sociétés,
Université Paris-Est Marne-la-Vallée, Cité Descartes, 5, boulevard Descartes,
Champs-sur-Marne, 77454, Marne-La-Vallée, Cedex 02

Abstract

Complexity science has always been ambivalent about the possibility to foretell the future. On one side, one of its leitmotifs has aimed at highlighting the intrinsic uncertainty and unpredictability of ‘multi-scale,’ ‘non-linear’ and ‘evolutionary’ systems, because of their sensitivity to initial conditions. On the other side, some complex systems specialists tackle the future almost daily but show different attitudes toward it. For example, some scholars find easier to foretell the long run evolution of a system, but only in a coarse-grained manner, while others propose to follow and predict the agents of a modeled system almost individually, thanks to their fine-grained computer simulations. In this article, five anticipation communities within complexity science are described by studying their research, their normative views, their extra-academic activities, and their anticipation activity. To expound these groups in a coherent fashion, I will use and readapt for my study the concept of ‘anticipation communities’ introduced by French sociologist Céline Granjou. The five groups described here are named as follows: the ‘high-frequency prediction,’ the ‘open-ended evolution,’ the ‘decentralized prediction,’ the ‘future co-construction,’ and the ‘centralized anticipation’ communities.

Keywords: Anticipation Communities, Science & Technology Studies, Complexity Science, Quantitative Geography, Computational Epidemiology, Artificial Life

1. Introduction

Complexity sciences have always been ambivalent about the possibility to foretell the future. The founders of this heterogeneous field of research have often hyped their nascent domain describing it as the ‘science of the XXI century’ [1, 2], capable of transforming the nations who will be able to master it into ‘the economic, cultural, and political superpowers of the next century’ [3]. In 1988, some of them even launched an interdisciplinary program of research and simulation in order to predict the geopolitical and environmental future of the planet in the Cold War context [4]. As Figure 1 shows, this group of scientists worked at a huge and complicated model which openly recalls the Club of Rome’s ‘World 3’ model [5]. But this kind of initiatives remain rare in the field. Indeed, one of the leitmotifs of complexity

specialists has rather aimed at highlighting the intrinsic uncertainty and unpredictability of ‘multi-scale,’ ‘non-linear’ and ‘evolutionary’ systems [6]. The specialists who consider impossible to anticipate the future of non-linear systems adduce the extreme sensitivity of the latter to their initial conditions: small events can lead to huge effects on the long run [7].

[Insert Figure 1]

If some complexity exponents do not even face the question of foresight in their research (for they are interested more in understanding than in predicting) [8], others tackle the issue almost daily but show different postures toward it. Some scholars find easier to foretell the long run evolution of a system, but only in a coarse-grained manner [9]. Others propose to follow and predict the agents of a modeled system almost individually, thanks to their fine-grained computer simulations [10]. In this article, I propose to explore five anticipation communities among the complexity scientists I have studied in my PhD doctoral research conducted between 2014 and 2018 [11]. The present text relies upon different materials: more than one hundred semi-directive interviews of two hours and a half average length, which I essentially conducted with European and American complexity scientists – most of whom have pioneered the field internationally –; some short ethnographies and laboratory visits in seven complexity institutes in Europe and the United States; as well as a bibliographic analysis of my interviewees’ scientific publications.

Let us start with a definition of our object. ‘Complex systems sciences’ are an interdisciplinary and transnational domain of research that emerged in the 1980s. While some French, Belgian, Italian, and American scholars used the term of complexity back in the 1970s, the label of ‘complexity science’ appeared in 1984 with the foundation of the American private research center ‘Santa Fe Institute.’ Since its inception, this field gathers a set of natural, social and engineering sciences under the study of ‘complex systems.’ These are canonically defined as systems ‘in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolution’ [12]. Some examples of them are genetic networks, ecosystems, cities, financial markets, and epidemics.

It is important to specify two things. Firstly, that complexity is – according to this community – a property of natural and social systems themselves (and not of models or of the relationship between models and the study objects). Secondly, that complexity science is but one of the complexity theories that exist out there: Andrei Kolmogorov’s complexity, computational complexity (NP problems), Edgar Morin’s complex thought, integrative complexity (in psychology), or Robert Rosen’s biological systems complexity are just some examples of alternative notions of complexity,

which are covered by groups of scientists other than the community that makes the object of this article [13].

It is also important to remind that considering complexity science as a discipline is not sociologically appropriate. Around sixty complexity institutes exist in the world [14], but scientific societies, journals, conferences, and pedagogical supports are rare; moreover, within the label of complexity many different subcommunities exist, who know each other but collaborate only occasionally for institutional reasons with the aim of building the field or keeping it alive [15]. Besides this, complexity specialists mainly stick to their particular discipline and never use the label of ‘complexity scientist’ as their unique professional qualification. Sometimes, this does not even appear in their official documents and research articles.

Within complexity science, a certain homogeneity is nevertheless observable, since the people claiming to belong to this field generally share the same tools of inquiry, as well as the same physics and informatics culture [16]. Its representatives offer indeed to study different kinds of complex systems through computer, physical and mathematical tools, such as network theory [17], agent-based modeling [18], cellular automata [19], genetic algorithms [20], statistical physics [21] and dynamical systems theory [22], among others.

Despite its fame both in academia and in the popular culture, complexity science is poorly understood under an historical, an epistemological and a sociological viewpoints. If both best-selling books [23, 24] and scholar works [25, 11] have shown that the most important actor in the field is the Santa Fe Institute, few social scientists have seriously studied complexity theory in a thorough manner and with an outside perspective [26]. On the other hand, many social scientists have used complexity science in their own work to renovate their approaches and theories [27, 28] – the field, as the readers of this journal know, is also well known in Futures Studies. The aim of this article is to describe five types of anticipation activity that seem to be operational within the vast international community of complex systems specialists. If this list is not exhaustive and can of course be amended by future papers, its vocation is not normative but descriptive. This is not an article about the evaluation of complexity science for an ‘application’ in future studies or in social sciences in general: others have tackled this issue in this journal before [29, 30, 31, 32].

In order to study complexity scientists’ ways of dealing with future, I will take into account at the same time their epistemic, ontological, and axiological assumptions and practices [33]. To expound them in a coherent fashion, I will use – with some adaptations – the concept of ‘anticipation communities’ introduced by French sociologist Céline Granjou to analyze environmental experts’ field diversity [34]. I propose to name the five detected groups as follows: the ‘high-frequency prediction,’ the ‘open-ended evolution,’ the ‘decentralized prediction,’ the ‘future co-construction,’ and the ‘centralized anticipation’ communities.

2. The concept of ‘anticipation community’

All the specialties inscribed in complexity sciences develop and employ computational or numerical tools. Yet, these subcommunities are very heterogeneous, since they mobilize different bodies of knowledge and techniques, refer to different kinds of ontology, operate in different normative contexts, and have a different way of dealing with the future. How to wrap up the epistemic, the ontological, the axiological, and the anticipatory levels into a single concept?

In 2015, French sociologists Céline Granjou and Isabelle Arpin introduced the concept of ‘epistemic commitment’ in order to ‘address how relevant research, that is, research worth doing, is reflexively defined and made by researchers in context’ [35, p. 1023]. While referring to Karin Knorr-Cetina’s work on ‘epistemic cultures’ [36] which only focused on scientists’ epistemic practices and norms, Granjou and Arpin have addressed the diversity of commitments that scientists and other practitioners have in an interdisciplinary field such as biodiversity studies: ‘epistemic commitments are meant to describe the diversity of the making of knowledge in an interdisciplinary field in which issues of the knowledge of nature and issues of its governance are strongly intertwined’ [35, p. 1025]. The criteria that Granjou and Arpin took into account in order to distinguish between four different ideal-types within biodiversity studies are the following ones: a ‘type of environmental scenarios and issues,’ which describes the kind of problems concerning the ecosystems and the form of possible solutions for the future; a ‘type of disciplinary approaches and research devices,’ which describes the kind of ecological theories, tools and perspectives that practitioners use to make sense of ecosystems; and a ‘type of contributions to decision making and environmental management,’ which describes the kind of managerial, political and consulting activities that biodiversity specialists engage into. In their article, Granjou and Arpin highlighted the dynamical and contextual intertwining between knowledge and commitment: ‘Against Merton’s argument that scientists share a universal commitment to a certain type of ethics [...], we argue that the researchers’ various epistemic commitments are progressively shaped and stabilized (or abandoned) in context, as they refine their research agendas’ [35, p. 1025]. Also, the two sociologists make clear that their typology does not correspond to impermeable groups of specialists, but that they are ‘ideal-typical regimes that might be hybridized in practice’ [35, p. 1030].

One year later, Granjou published a book in which she extended the concept of epistemic commitment and inserted it within a broader one called ‘anticipation regime’ or ‘anticipation community’ [34]. The extension is due to the fact that, through this concept, Granjou wishes to seize the way different environmental experts commit in a specific anticipation activity. The main difference between the first and the second concept is that the latter includes a fourth element to the list of criteria to take into

account to establish the ideal-types – namely the ‘type of anticipation policy,’ which consists of assuming a certain disposition toward the future of ecosystems and a certain politics of tackling the challenges represented by ecosystem scenarios. Such anticipation activity can consist in alerting about species loss, in anticipating environment degradation, in pushing for specific practices for resilience etc. Granjou [34, p. 106] thus defines the concept of ‘anticipation regime’ in the following way:

‘A regime of anticipation is defined as a group of researchers, experts and managers sharing a specific scenario and representation of the future of biodiversity, to a certain kind of project of understanding the evolution of biodiversity (disciplinary approaches and research methods judged as relevant and important with regard to the scenarios), to a certain model of science/politics interface. Communities of anticipation thus also share a certain politic of anticipation (i.e. a prescriptive view of the kind of environmental governance that we need to implement). Communities of anticipation therefore not only share a vision of the future of biodiversity and a prescriptive ideology, but also a kind of practical investment into a project of knowledge and governance to face the future with.’

To resume, the ‘epistemic commitments’ concept focuses on the fact that actors develop their commitments and perspectives on the environment within the context of their practices. The ‘anticipation regime’ concept emphasizes instead the fact that epistemic commitments imply that biodiversity experts develop a certain agenda of knowledge production, which makes sense in relation to the grand environmental scenarios and issues on the ongoing and future evolution of the environment that they believe in.

Here I get inspiration from Granjou’s notion of anticipation regime and reshape it for my needs concerning complexity sciences.

First of all, I prefer to talk about ‘anticipation communities’ instead of ‘regimes’ for two reasons. On one side, I work less on ideal-types than on existing and self-conscious communities. Granjou and Arpin have detected different ways of understanding biodiversity research through their interviews with the researchers, who ‘were committed to substantially different views of the research that matters’ [35, p. 1030]. In the case of complexity sciences, the groups are easier to detect, because they belong to different disciplines and specialties. What I describe in this article are communities that are aware of their homogeneity and of their relative unity and coordination. The members of each community I will describe collaborate within national and international scientific projects and events linked to their specialty – more rarely, the members of the different communities also collaborate within the bigger frame of complexity institutes and societies in order to make the field exist as a meta-space for the different specialties in presence. Granjou (and Arpin) propose(s) in

contrast four ideal-types that have their internal coherence but that do not strictly correspond to given communities.

On the other side, here I introduce the notion of ‘future regimes’ to analyze complexity specialists’ time modelling and logic of action relatively to the future and to its anticipation. Consequently, the usage of ‘community’ allows me avoid a confusion between different notions and levels of analysis.

Secondly, I propose to slightly rearrange the list of the four elements chosen by Granjou to describe her ideal-types. To detect the five anticipation communities within complexity sciences, five foci seem to me pertinent for the analysis. While I exclude the ‘type of environmental scenarios and issues’ because of its lack of pertinence herein, I keep the ‘type of disciplinary approaches and research devices’ – synthesized as ‘approaches and devices’ – in order to take into account the kinds of knowledge, practices and ontologies of nature and society that complexity scientists mobilize or assume for their research activities and commitments.

To this, I add the term of ‘performativity of simulations’ – synthesized as ‘performativity’ – with which to consider the predictive power that scientists attribute to their digital models. According to practitioners, does the simulation anticipate, predict or simply suggest? This is important to take into account in order to understand the kind and degree of commitment that complexity specialists show in their extra-academic activities. Concretely, somebody who has got epistemological reluctance about her model predictive power will likely spend little energy to make her tool available to policy makers, NGOs and enterprises to offer anticipation expertise. Scottish sociologist Donald MacKenzie distinguished between ‘general performativity’ (any symbolic act has an effect on culture), ‘narrow performativity’ (self-fulfilling prophecies), and ‘counter-performativity,’ which indicates a self-fulfilling prophecy that ends up producing an effect which is contrary to the desired one [37]. The activity of circumvention of the worst scenarios can be seen as a fourth type of performativity that I propose to call ‘anti-performativity,’ since it consists in counteracting the events that it announces. French philosopher Jean-Pierre Dupuy names this approach ‘enlightened catastrophism’ [38].

As a third focus, I keep from Granjou’s list the ‘type of contributions to decision making and environmental management,’ which describes the kind of managerial, political and consulting activities that biodiversity specialists engage into their professional or para-professional activities. I propose to call this item ‘extra-academic activities,’ which is more compact and more general, for it includes all sorts of commitment in which scientists employ their research for the sake of policy and/or entrepreneurial objectives. What view of the expertise do researchers have? Which interpretation of the science-society interface do they follow and perform? Do they think that science is neutral or socially engaged?

As a fourth focus, I propose to introduce the concept of ‘future regimes’ as it has been described by French sociologists Francis Chateauraynaud and Josquin Debaz [39]: urgency, expectation, anticipation, prediction, prospective, promise, prophecy, and science-fiction. The Table 1 synthetizes their main characteristics under three axes: time modelling, logic of action, and prototypes.¹ How do actors conceive time? Is it linear or non-linear, open or closed, slow or accelerated? Which logic of action do these regimes imply: the intervention on an ongoing process relying upon background knowledge in order to anticipate what is next, or the calculation of a linearized time in order to plan the future, or rather the production of scenarios because of future openness and uncertainty? Do actors work to build a desirable forthcoming or to thwart an undesirable one? Last but not least, toward which direction does the time arrow run according to the actors? Does it go from the present to the future, or the other way round?

Table 1.

	Time modelling	Logic of action	Prototypes
Urgency	Time is short	Race against time to save a situation	Backup plan after an alert
Expectation	Suspended time	Continual displace of expectation time	Blackout: waiting for the return to normality
Anticipation	Accelerated time	Action over an ongoing process; preparedness	Climate change; pandemics
Prediction	Calculated and linearized time	Calculation space; planning	Demographic models; GDP evolutions
Prospective	Time is non-linear and open	Scenarios production	Energetic scenarios
Promise	Delay logic	Engaging in a promise; proving one’s credibility	Biotechnologies; transhumanism
Prophecy	Eschatological time	Announcing an inevitable future	Collapse of complex societies

A parenthesis needs to be done at this point in order to clarify a certain number of concepts that will be used in the course of this article. In the first place, the reader will remark the doubling of a word – anticipation – at two different levels of analysis. The meaning of ‘anticipation’ at the general level contained in Granjou’s notion of ‘anticipation community’ differs from the more restricted meaning of ‘anticipation’ as stated by Chateauraynaud and Debaz. We can indeed talk about anticipation in general to refer about any kind of activity which is turned toward the future. Italian philosopher Roberto Poli [40 , p. 1] has written that ‘As a lay term [anticipation] refers to all forward-looking attitudes and activities,’ and that as such it

‘is a widespread phenomenon present in and characterizing *most* types of real systems. Life in all its varieties is anticipatory; the brain works in an anticipatory way; the mind is obviously anticipatory; society and some of its structures are

anticipatory; even non-living or non-biological systems can be anticipatory.’ [40, p. 3]

On the other hand, according to Chateauraynaud and Debaz anticipation refers to the often frenetic activity that human beings do in given situations – mostly negative or threatening – where the need to prepare themselves becomes desirable or imperious. In a way, anticipation is in most cases a more distended version of urgency. As anthropologists Rebecca Bryant and Daniel Knight [41, p. 28] wrote, ‘Anticipation [...] is more than simply expecting something to happen; it is the act of looking forward that also pulls me in the direction of the future and prepares the groundwork for that future to occur.’ Also, they pertinently write that ‘at the collective level we find that anticipation is linked to particular moments of uncertain or threatening futures’ [41, p. 48]. It is no by coincidence if, within complexity scientists, anticipation is the dominant mode of computational epidemiologists: ‘Anticipation, in these instances, is a collective way of addressing the anxiety of uncertainty, and of forestalling or altering something that threatens a radical revision of the present’ [41, p. 48].

Secondly, since the terms of prediction and prospective are going to be used to characterize some of the complexity communities in what follows, here are some useful definitions. As Chateauraynaud and Lehtonen [42, p. 8] wrote,

‘the metrologies and spaces of calculation shared by the actors give modelling a central place in the construction of understandings of the future [...]. The advocates of the regime of *prediction* generally justify their claims by a “sound use” of mathematics. Prediction requires a relatively stable computational space with commensurable and computable parameters.’

By contrast, the prospective or foresight activity implies ‘the production of different scenarios, allowing for the opening and exploring the space of the possible’ [42, p. 9]. More in detail:

‘Foresight does not act in advance or change the order in which phenomena occur, but rather, operating at a distance, it visualises a plurality of futures to constrain reasoning and deliberation, and to make visible the expected cognitive and normative frames that make some future directions more plausible and more desirable than others.’ [42, p. 9].

The conceptual originality of this article is to propose two new future regimes to Chateauraynaud and Debaz’ list – the ‘high-frequency’ and the ‘optimization’ regimes. The ‘high-frequency’ has indeed a particular logic of action and relationship to time,

which distinguishes it from the ‘urgency’ regime. To explain such distinction, let me first introduce the concept of ‘orientation,’ which is defined by Bryant and Knight [41, p. 2] as follows: ‘[orientations] represent differing depths of time and different, though often related, ways in which the future may orient our present.’ With this concept, the two anthropologists intend ‘to help us gain an ethnographic hold on the relationship between the future and action, including the act of imagining the future’ [41, p. 16]. Moreover, while they do not conceive time as linear, Bryant and Knight [41, p. 17] reintroduce the concept of finality into the debate: ‘By “orientation” we intend to break from the notion of linear time while still retaining an aspect of teleology that we find to be important for thinking about everyday lives.’ ‘Urgency’ and ‘high-frequency’ regimes may seem synonyms, but they have different depth and teleology. While urgency faces short time, it generally implies the effort of reacting to a dangerous situation, in order to limit damage – which in urgent situations is at least partly fatally inevitable. On the other side, while high-frequency faces even shorter a time than urgency, it generally implies the anticipation on a competition for a gain. In order to do this, the work of those who live in a high-frequency regime consists in a visual navigation over a continuous flow, where time is divisible in ever tinier pieces. The ‘optimization regime’ is the second I propose to introduce here, in order to describe an orientation to future which implies invention and evolution for survival and gain. Its relation to time summons a constant and self-organized adaptation to an open future. The logic of action consists of an automatization of the learning process, thanks to which an actor can renovate itself depending on the evolution of its environment. The optimization regime implies to delegate to a device – human, technological or hybrid – the task of finding new solutions to solve problems. The Table 2 resumes the two new regimes proposed in this article.

Table 2.

	Time modelling	Logic of action	Prototypes
High-frequency	Continuous flow	Visual navigation; uncertain anticipation on a very short-time	High-frequency trading; military missions
Optimization	Adaptation to an open future	Automatization of a learning process; creative randomness	Machine learning; adaptive management

The fifth and last element to take into account for describing anticipation communities draws from Granjou’s list and it concerns the ‘type of anticipation policy.’ With this term, the sociologist refers to the kind of politics that actors choose to adopt in order to tackle the challenges represented by the specific ecosystem scenarios they believe in. Under the focus of ‘anticipation policy’ I propose to have a look at the normative assumptions and objectives that complexity scientists inscribe in their models and in their extra-academic activities. In the field of Science & Technology Studies, several works have questioned the alleged neutrality of technoscientific models, equations and theories, by showing that scientists’ worldviews are always inscribed in their work and

results [43, 44, 45, 46, 47, 48]. Simulations not only aim at embodying a cognitive function to account for reality, but are also used as management tools to perform a certain reality to the detriment of others [49, 50, 51]. This article inscribes and contributes to the body of works that analyze the hidden, often unconscious normativity of computer simulations. Computer scientists' adage 'garbage in, garbage out' refers to the fact that, while simulating, nonsense input can produce nonsense output. But with this proverb, modelers often limit their concern to the epistemological validity of their simulations results. STS scholars show that normative lenses are intrinsically integrated into epistemological stakes, which implies that certain ideological premises bring to certain conclusions. If we had to synthesize this idea in one sentence, that would be: 'values in, values out.' So, to analyze complexity scientists' anticipation policy, a certain number of questions have to be asked: What kind of knowledge and tools are mobilized by researchers for what stated objective? What implicit and explicit values feed scientists' simulations and extra-academic commitments? And finally, what social order do they engage with?

3. The high-frequency prediction community

Approaches and devices. The name of this community refers to the physicists, economists and computer scientists that gave rise to 'complexity economics' [52], to 'econophysics' [53], to 'phynance' [54], and to 'computational economics' [55]. The numerical tools used by this group of researchers include chaos theory and dynamical systems mathematics, time series, neural networks, genetic algorithms, statistical physics, agent-based modeling, and network theory. Some of these algorithms are used to evolve according to real tick data flow in order to test different hypotheses and to locate structure and patterns in markets dynamics. The idea is that, as time passes, the algorithm gets smarter and becomes more efficient in predicting the curves describing stock options trades. At the bottom lies the fundamental idea that, despite the chaotic behavior of markets, an underlying structure exists which, thanks to the right inquiry tools, can allow scientists to predict future economic developments. In its turn, this promise relies upon a deterministic chaos ontology of human affairs and an epistemological refusal of neoclassical economics: in complexity economics perspective, markets are not in equilibrium; they are inefficient, but regularities do exist because humans are described as irrational, trend-following, and herd-driven. In such a frame geopolitical happenings are reduced to psychological dynamics, so that the valuable bodies of knowledge are not hegemonic economics and social sciences, but physics and behavioral economics. As an econophysicist put it, 'Randomness is in the eye of the beholder,' so the challenge is to turn randomness into something structured and thus predictable. Twenty years in advance on Chris Anderson's 'end of theory' [56], this group of scientists adopted a (big) data driven approach where models were black-boxed software supposed to automatically spot order into disorder.

An analogy is here performed between fluid turbulence and climate evolution, on one side, and market oscillations, on the other. According to this community, being exposed to the same mass media and sharing the same kinds of emotions make humans analogous to water flows and to the weather. The stake for this community is to find the chaotic attractors into market fluctuations.

Performativity. As an econophysicist put it, ‘The future, in some sense, will be like the past.’ In this perspective, as long as theories and software permit to find patterns, simulations can actually predict the future. If markets seem random, even the slightest anticipation ability can produce a breakthrough. With the passing of time, the prediction promises of this community have been downgraded in view of algorithms failure to anticipate market fluctuations.

Extra-academic activities. If econophysics can detect the actual underlying structure of economic and financial markets, then it is possible to beat the market and make money out of chaos and complexity sciences. That is the thought that some SFI scholars had in 1991, when they founded the ‘Prediction Company’ based in Santa Fe [57]. A year later, the fathers of the company managed to be funded by a Chicago based derivatives trading house, the O’Connor & Associates, which was bought by the Swiss Bank Corporation later that same year. The partnership with SBC – which in its turn merged into Union Bank of Switzerland in 1998 – lasted until 2005, year in which UBS fully purchased the company. In 2013 the Prediction Company was acquired by Millennium Management hedge fund and was finally dissolved in 2018. However, going into business or stock options speculation concerned few econophysics scholars, the vast majority of whom were and stayed academic professors and researchers.

Future regimes. According to this community, sensitivity to initial conditions impedes to foretell long-term events. Markets change constantly, as if they started to play a new game every day. Forecasting has to be done on a very short-term basis. Consequently, one can think of a mix of urgency, anticipation, and prediction regimes. But as it has been stated in the conceptual section, I rather propose to add a novel category to appreciate the specificity of this community interpretation of time – the ‘high frequency regime.’ Its time modelling is over a continuous flow and cannot ever be stopped. Its logic of action is a visual navigation, because future is so uncertain that it is very difficult even to predict from one minute to another. Indeed, with the passing of time the initial promises of Prediction Company founders were little by little abandoned in favor of more modest, but still effective methods to beat the market: the law of large numbers and the coin flip technique. By betting over the highest number of stock options, they used statistical arbitrage in order to gain a little more than once every two. Furthermore, before exceptional events (wars, change in central banks’ interest rates, etc.), Prediction Company team backed upon human judgement instead of trusting model forecasts, which turned it into more classical an investment fund.

Anticipation policy. The first objective of Prediction Company has been to create a sort of poker-like ‘royal flush’ in markets speculation: ‘No matter what happens, you win.’ Becoming rich, stop working, founding one’s own research center to quit the bureaucratic obstacles of universities and governmental laboratories, and other individualistic aims were motivating the company members into this enterprise. The secondary objective that was stated by the company founders was located at a philosophical, political, and macro-economic level. Facing some ethical internal critics about the zero-sum game characteristics of beating the markets, which would capture money from others turning them into losers, the company leaders defended their project by arguing that the presence of an actor like Prediction Company in the field would make stock exchange more stable and thus the market more just. The idea behind such an argument was that contributing to stabilizing markets would be good for real economy companies willing to borrow money to invest and to put people at work. As one of the company founders put it: ‘Such trades reduce the overall volatility of the markets, and thus the risk to participants is reduced. The profits that go to the successful predictor are like a fee that the markets pay for the service of making them more efficient and less risky’ [57, p. 238]. Prediction Company managed to earn every year but one during its two decades activity. Nevertheless, it never managed to breakthrough nor to stabilize markets.

4. The open-ended evolution community

Approaches and devices. The ‘open-ended evolution’ type refers to the Artificial Life community, one of the first ones to be active in the context of SFI complexity science [58]. Computer scientists, physicists, and bioinformaticians are the main figures that avail of such community. The digital tools mostly in use here are agent-based modeling, genetic algorithms, and cellular automata. Modeling actual living beings is, for this community, a secondary aim. What its members aim to do is to imitate and discover the principles of life generation and dynamics in general [59]. Computer models are seen as a way to openly explore biological evolution. Insects became an archetypical example of such models, while optimization became one of the core concepts. Insects optimize their resources by means of labor division and cooperation, resulting both flexible and robust. Psychology (herding and panic studies) and life sciences (entomology, ecology, etc.) constitute a source of inspiration for this anticipation community [60]. Physics provided some numerical tools (dynamical systems equations, network theory, etc.), while social sciences, robotics, economics, finance, business management, and even art are fields of technical implementation. Artificial Life was launched at the end of 1980s along the lines of Artificial Intelligence, with which it shares its two fundamental ontological beliefs. Firstly, hardware (matter) and software (form) are separated and independent from one another, both on an epistemological and a metaphysical level; secondly, software is

hierarchically higher than hardware, meaning that what makes the identity of life and intelligence is their structural organization more than the matter which they are made of. Consequently, a form can be implemented in any kind of matter without losing its original identity. Besides this computational view of nature, there is a physically inspired conviction according to which complex behavior arises from simple rules: ‘Theories of self-organization, originally developed in the context of physics and chemistry to describe the emergence of macroscopic patterns out of processes and interactions defined at the microscopic level, can be extended to social insects to show that complex collective behavior may emerge from interactions among individuals that exhibit simple behavior’ [61, p. 6]. Within the specialists of ‘swarm intelligence,’ at the core of Artificial Life field, another perspective is at work – an engineering one. Mimicking insects in robotics and industry reveals for them very useful, for ‘a social insect colony is undoubtedly a decentralized problem-solving system’ [61, p. 6]. In this community perspective, future is open and randomness is a resource. Whereas ‘high-frequency prediction’ community struggles to find the concealed structure under chaotic randomness, ‘open-ended evolution’ community claims that randomness is creative and productive. Algorithms are built with little constraints in order to explore a wider range of possibilities: ‘many solutions are generated, and only the most adapted ones are recruited’ [62, p. 321].

Performativity. According to this community, simulation and the target-system share the same structure or form. This not only implies that what can be said on simulation will concern the real living systems themselves, but also and most importantly that simulation can be considered alive or life-like. Paralleling the cognitivists according to whom strong Artificial Intelligence is already among us, some Artificial Life exponents think that an evolving digital model is as alive as a cell or an animal.

Extra-academic activities. The members of this community advocate a plethora of possible or actual implementations of their models and principles. They promise that robots based on swarm intelligence will be able to exert a range of tasks: satellite repair, pest eradication, waste disposal, home micro-aspirators, and marine debris cleaners. Some video games sprung out of the field and some contemporary artists took over Artificial Life techniques to produce digital artworks. But the most advanced and spread implementations are to be found in machine learning algorithms, employed for problem solving and decision making. If several representatives of this field patented some algorithms of this kind, few have founded a company to develop personalized consulting services for other companies with the aim of optimizing industrial production and business management. ‘Icosystem’ – founded in 2000 by French physicist Eric Bonabeau in Cambridge (MA) – is one of these. Its domains of application are corporate diversity, product design, marketing, operational strategy, and network analysis. The company has worked for corporations from different sectors (telecommunication, pharmacy) and for governmental agencies (defense, healthcare).

Future regimes. Artificial Life community is less concerned than the others by future prediction whilst being fully directed toward the forthcoming. Silicon agents are charged of producing unanticipated behaviors that could increase industrial efficiency. Robustness, which is given by the high number of cooperative agents, and flexibility, which is given by open-ended evolution, offer a bed for reinforcing capitalistic enterprises robustness and flexibility. As in the precedent community, here simulations work as black boxes. Consequently, future is assumingly opaque. The logic of action implies the automatization of a learning process in which artificial randomness becomes creative. The machine is here charged of the variation process that permits to create future possibilities of adaptation. It is a ‘competence without comprehension’ approach: one can be able to comprehend what the machine does, but she is not required to. As for the time modelling, here future is not preempted; it rather constitutes the riverbed of an adapting flow: ‘The difference between adaptation and prediction is that the latter tries to act before a perturbation affects the expected behavior of a system. [...] An adaptive system will be able to respond to the unexpected, to a certain degree, without the need of human intervention’ [63].

Anticipation policy. Seeking to imitate living being efficiency parallels the pursuit of economic efficiency in enterprises. Moreover, Artificial Life scholars are impressed by the productive creativity of evolution, which for them can be imitated to increase human productivity [64]. Hence, the ‘open-ended evolution’ community’s horizon is that of competitive, adaptive, and productivist capitalism. In their narrative, global competition creates a rapidly changing environment. In such a context, businesses must find ways to adapt at a faster pace, since solutions may become quickly obsolete. According to one of the members of this community, in a firm humans are constrained in similar ways as insects are in a colony. By adopting Artificial Life methods, an entrepreneur can perform the ultimate enterprise, which is capable of adapting quickly to fast-changing markets [65]. Besides optimization, adaptation of the fittest is also sought through robustness, which is supposed to turn enterprises more resistant to internal or external perturbations: when one or more individuals fail, the group can still perform its tasks. The third principle of Artificial Life is self-organization, namely the absence of a central planner or supervisor. This point recalls Adam Smith and Friedrich von Hayek’s invisible hand theory: in other words, silicon ants and termites enact the (neo)-liberal paradigm. To give some examples, Artificial Life principles and tools have been used to minimize overall costs and emissions of fossil-fuel power-stations in the context of electrical power dispatch problem [66]. They have also served to better plan hiring strategies and employee turnover, as well as helped to develop new drug molecules ‘at almost twice the speed and less than a third of the cost of the standard process’ [67].

5. The decentralized prediction community

Approaches and devices. The ‘decentralized prediction’ label refers to the community of quantitative geographers.² Such a group of scientists, some of which have a training in physics, consider the latter discipline as an epistemic model and as a source of operational methods [69]. They mainly use power laws, gravity laws, statistics, network theory and agent-based modeling to measure or simulate geo-socio-technical systems that are considered to be subject to a certain number of territorial and social ‘laws’ or ‘regularities’ [70, 71]. From an ontological viewpoint, these researchers naturalize more or less human societies and their history. Cultural relativity, freedom of will and politics are openly neglected in the name of an intrinsic predictability of human behaviors. As an interviewee from this community has told me, the policy maker job is ‘like catching a wave, the wave is already there but you can go faster if you know how to catch it. If you are against it it’s not going to work.’ For the vast majority of the people inscribed in this category, simulations can reproduce real system conduct. Their proof for that is the formal and quantitative homology they can often observe between the statistical patterns describing actual systems data and their simulations outputs. Overall, their view of complex systems is flat, self-regulated, highly constrained, and competitive. A finite number of parameters (demography, GDP, innovation rate, etc.) allow to describe and anticipate the evolution of these systems, which are seen as a set of nodes between which fluxes of matter, money, people and ideas circulate.

Performativity. Generally, this community thinks of science as a neutral knowledge, which is supposed to inform policy makers, NGOs, or enterprises about ‘what it is.’ Science is seen as exterior and autonomous respect to other social institutions. As a quantitative geographer from SFI put it: ‘science is not policy in the following sense, just like science is not engineering. Science is supposed to tell me how things work, whereas policy – or engineering even – is about making a specific thing that does something specific in a given context.’

Extra-academic activities. Their philosophy of the science/society interface brings them to oscillate between consulting activity, informal collaboration, companion decision making, and decision support vis-à-vis decision makers and “civil society.” Consulting is generally done occasionally in the context of a financed, finite, and goal-directed project with an NGO, an enterprise, a Foundation or an administration. Informal collaboration is normally based on an exchange without any official frame and funding – non-academic actors, be they private or public, can provide scientists with data, while scientists provide their partners with the (exclusive or not) results of their models. Companion decision making applies when the other “stakeholders” can have access to at least one of the model construction steps, and are taught by researchers to be (partially) autonomous with the models. Decision support is when scientists develop, provide, and apply their tools on behalf of, and for extra-academic actors, in order to help them take an efficient and reliable decision.

Future regimes. This community articulates some aspects of prediction, anticipation and prospective regimes. Its members work to model a linearized and calculated time and space aimed at future planning (prediction). This stays open on a plurality of possibilities (prospective). They rely upon the knowledge of the past of the system, because their action logic aims at acting on the upstream of an ongoing process (anticipation). For this reason, this community relationship to time can be metaphorized as an action upon an arrow going from the present toward the future, with the objective of curbing its course by building something novel and desirable.

Anticipation policy. Despite the political opinions variety I observed within this community (going from neoliberal to social democratic), researchers therein share the fact of considering social, technoscientific, and economic innovations as the motor of history. SFI researchers, for example, contemplate the possibility that cities grow indefinitely, as long as innovation or immigration rate follows the hectic rhythm of social phenomena unfolding in metropolis and megalopolis: ‘To grow indefinitely, a city has to periodically reset its growth rate. Such “resetting” can come from innovations that revitalize the economy, or from outside factors, such as shifts in immigration’ [72]. According to these researchers – who study clusters of cities through power laws –, ‘in principle’ there are no limits to the growth of an urban center: what threatens cities is too slow an innovation rate – if innovation is guaranteed, all the other problems can be solved or kept under control. On the other side of the Atlantic, I studied a community of quantitative geographers based at French National Research Center (CNRS) and Sorbonne (Paris 1) in Paris, who essentially differ from SFI affiliates for they use another kind of tools. They mainly employ agent-based modeling to simulate large systems of cities, which interchange goods of all kinds: resources, people, ideas. Yet their central focus stays on innovation – as a geographer from Géographie-Cités lab at CNRS/Sorbonne wrote in 1997: ‘the essential phenomenon of innovation [...] assumes greater significance in the genesis of the system structure, through diversification and complexification of its elements’ [73, p. 126]. In the simulations performed by the researchers of this laboratory, innovations become a good (under the form of a ciphered number or variable) that cities can trade. As Figure 2 shows, innovations are then filtered by a sort of “natural selection” that brings the software to erase those which are too old.

[Insert Figure 2]

6. The future co-construction community

Approaches and devices. This community is an interdisciplinary group composed by geographers, computer scientists, ecologists, agronomists, and social scientists, who cooperate within an action-research association called ComMod – contraction of ‘companion modeling’ [74, 75]. Founded in 2003 by a group of researchers from

French CIRAD (Centre International pour la Recherche Agronomique et le Développement), this collective reunites around forty members from France and some Global South countries, where the majority of the projects have been implemented with local “stakeholders.” The group employs a variety of tools, such as non-scientific verbal diagnosis, scientific formal representations, maps, serious games, audits, legal expertise, as well as agent-based models. Within this community, human beings are seen as free agents capable of handling their collective destiny. In their framework, cooperation prevails (or should prevail) over competition. Here, complex systems are not flat, but they tend toward symmetry. ComMod members refuse the idea that socio-ecological systems self-organize in a way that naturally move toward a beneficial order for all their components. According to these researchers, there is not an ontological homology between the target-system and the digital modeling. The latter is a deliberately simplified and metaphorical representation of reality.

Performativity. For ‘commodians’ (as they call themselves), simulation is not charged of proving a scientific theory, but rather to give rise to role-playing games that are supposed to show “stakeholders” the causal links at work within the systems they are embedded in. According to ComMod, such an awareness can allow participants to modify their behavior in the real world for the greater good. Even if commodians aim at being ‘neutral’ as for the concrete decisional issues of their workshops, they have a deliberately engaged view of science. As a CNRS geographer put it, ‘it is an ideological question, because to know whether a system must produce equality or inequality is a matter of choice.’

Extra-academic activities. ComMod seeks to provide individual agents with knowledge about the system they form part of. The awareness of their role in it is supposed to give them the possibility to act. “Stakeholders” can be socio-professional players, associations, NGOs, technicians, experts, natural and social scientists, as well as local administrators. ComMod aims at a peaceful, democratic, and durable management of common goods defined as ‘complex socio-ecological systems,’ such as forests, lakes, rivers, and marine environments, in boundary and conflictual contexts. Projects are funded by French National Research Institute and other French national institutes. Participatory modeling is now a well spread methodology and similarities can be found between this community and other groups of scientists around the world using computer modeling for the same stakes.

Future regimes. “Stakeholders” are put around a table in order to acquire consciousness of an undesirable state of affairs and to impulse a change. Simulations are expected to reproduce and show the interrelations linking participants between them. ComMod workshops intend to perform a mirror function on a micro-society supposed to gain self-awareness to better self-organize. ComMod agent-based models have not a predictive, but a pedagogical scope – even if the simulation is turned toward the future. Commodians’ future regime is prospective, because time is non-linear and

future is open. The logic of action implies the production of a series of scenarios, which serve to address possible futures and their consequences. One of these futures is the continuation of business as usual, which in most cases risks to bring the community toward environmental resources collapse or toward conflict and war. Similarly to the ‘decentralized prediction’ community, ComMod conception of time implies an arrow that goes from the present toward the future – commodians’ objective is to curb its course by building something novel and more functional for the greater number of “stakeholders.”

Anticipation policy. ComMod community does not wish to take decisions in place of “stakeholders,” but makes of placing participants on an equal footing its number one priority. As a French agronomist based in Brazil testimonies, commodians’ sources of inspiration are, among others, emancipatory pedagogies, social learning theories and participatory durable development. In this perspective, modelers are conceived of as mediators among different cultures, bodies of knowledge, and diverging interests. ComMod chart urges researchers to make their working hypotheses and procedures transparent to participants, to share their knowledge with “stakeholders” instead of imposing it to them, and to give them the possibility to reconsider and change any part of the process. Such an approach conveys a democratic, egalitarian, and ecologist ideology. Indeed, ComMod members explicitly seek to implement ways to limit the power of the strongest (men, administrators, higher social classes) and to empower the weakest (women, farmers, poor classes) [76]. The inscription into the models of such a normative perspective is visible in Figure 3, where one can see that agent-based models are here conceived in such a way that participants can play their role into the simulation. For this reason, ComMod talks about Hybrid Agent-based Models (HAM).

[Insert Figure 3]

7. The centralized anticipation community

Approaches and devices. The ‘centralized anticipation’ label refers to the relatively homogeneous and international group of computational epidemiologists that in the last ten years has rapidly increased its legitimacy in policy makers’ eyes. Most of these researchers are trained physicists with remarkable experience and skills in computer modeling. The few teams around the world inscribed in this recent specialty know each other and often collaborate for scientific, technical, and institutional reasons. Computational epidemiology begot in the second half of 2000s from the most important achievements of complex networks study [77]. This community of researchers is now increasingly collaborating with national and international governments in order to perform epidemic surveillance and anticipation. It has been claimed that this specialty tends to understand the social sphere through biological lenses [78]. I rather argue that the biological metaphor is not preponderant. The spread

of a pathogen in a sociotechnical network relies on the contagion idea, but the infection circulates like an electron in an electric circuit – the working metaphor is thus informational. In numerical models of pandemics, the pathogen travels fluidly from one point to another of the globe, neglecting geographical, political, cultural, and material obstacles and frontiers. Infection is thus modeled and understood by means of statistical physics and other numerical tools. Knowledge coming from the field of public health serves as a terminological reservoir to name simulation variables and parameters. Nevertheless, this anticipation community does not share a flat view of complex systems with the ‘decentralized prediction’ one. Here, systems have got hubs like the State that can intervene and change the course of events [79].

Performativity. For their physical, mathematical and computational training, the members of this community see the world as a computational network that follows physical statistical rules. In their perspective, the simulation and the simulated system are homologous – they share the same structure. It is not surprising if, in their view, simulation can guess the concretization of certain yet-to-come events and allow authorities to circumvent the most dreadful of them. Indeed, computational epidemiologists manifest pride for the high reliability of their predictions – up to 83% of success in the case of 2009 H1N1 influenza [80]. The activity of circumvention of the worst epidemiologic scenarios can be qualified as ‘anti-performative,’ since their prediction aims at counteracting what it announces.

Extra-academic activities. Computational epidemiologists have a clear vertical relationship to power. Thanks to their confidence in their simulations, these researchers constantly seek for public powers approval. The present group shares a ‘neutral’ view of science with the ‘decentralized prediction’ community. As an interviewee from the Northeastern University in Boston put it: ‘we need to communicate our message in an appropriate manner, which should be at the same time understandable and rigorous, and we need to avoid making a choice. It is up to the policy makers to make a choice.’ The European and the American computational epidemiologists I have encountered look at meteorology as an epistemic and institutional model for their specialty. Their objective is to come up with a worldly infrastructure dedicated to health global surveillance, in order to provide policy makers and populations with an epidemic forecasting [81]. In particular, American actors from the Los Alamos National Laboratory and from other research centers in the country carry a lobbying activity vis-à-vis the White House, with the objective of constituting a new federal agency for epidemic surveillance on the model of the National Oceanic and Atmospheric Agency (NOAA).

Future regimes. This community’s regime overlaps urgency, anticipation and prospective – time is accelerated but foresight remains attentive to and open over a plurality of outcomes. The logic of action mainly involves preparedness, even if it implies scenarios production in a race against time. When an epidemics is in course,

modelers have to face with a sort of planned obsolescence of their own simulations, since scientists' anticipations and governmental prescriptions influence the course of the epidemics itself. A researcher from Los Alamos calls this phenomenon 'self-feedback,' while another from the Northeastern University suggestively says that 'the model is in the model.' Computational epidemiologists work to foretell the consequences of certain choices, but such choices are a reaction to an event that dangerously comes from the future toward the present. The aim here is to deflect the arrow of time in order to avoid the worst to occur.

Anticipation policy. The normative view of this community lays upon five pillars. Firstly the Hippocratic Oath, because, like all the others disciplines related to public health, the priority of this group is to save lives. Secondly, researchers are concerned by the optimization of the economic and governmental order in force: 'Think about how many work days get lost from illness from companies and businesses [...] [Thanks to computational epidemiology predictions,] as a company you'll decide [to] offer free flu shots for [y]our employees;' 'Same thing with hospitals – hospitals have issues with bed shortages and staffing. [Epidemic forecast] can better predict hospitalizations for certain conditions, you can better allocate resources efficiently to that.' The members of this community also works on cattle modeling, in order to limit animal and economic loss in the agro-industrial sector [82]. The third pillar rests on what American New Media scholar Richard Grusin calls 'premediation' [83] in order to inscribe media psychological 'preparedness' to terrorism in a larger media and ideological context: 'Premediation works to prevent citizens of the global mediasphere from experiencing again the kind of systemic or traumatic shock produced by the events of 9/11 by perpetuating an almost constant, low level of fear or anxiety about another terrorist attack.' By generalizing the concept, premediation serves to mentally prepare citizens to catastrophic events, so that they can be ready as soon as these occur. The stake is not to precisely predict the future, but to make possible scenarios proliferate so to anticipate surprise [84]. By taking a look at computational models of epidemics, one can see that the proliferation of possible futures is enabled by the presence of a considerable number of variables that the software user can modify at her will. Silicon agents can be made more or less mobile, infected, contagious, etc. The user can also establish the depart site of the infection, the disease seasonality and infectivity rate, and the value of many more parameters. Scenario production results from the complex articulation of all these factors. As for the fourth pillar, the 'centralized anticipation' community has a specific perspective on the social order: central State is strong in its capacity to collect data and to implement national measures to govern its population. This aspect is coupled with the fifth pillar, regarding the interpretation of expertise and the role of citizens. In computational epidemiologists' view, a strict labor division is in force, since experts inform, the State chooses and executes, while citizens implement the information and the decisions of

the formers. In computational epidemiologists’ models, the State is not an explicitly visible hub. The centralization of health measures is translated into a template in which, among the many variables that can be parameterized, four concern the administration of the viral treatment to infected agents. If three out of these four variables indicate the different health statuses that agents can go through, the fourth represents the window for governmental intervention. This variable designates the percentage of individuals that are vaccinated or treated by public health services.

8. Discussion and conclusion

Since its inception, complexity science has had a variety of discourses about the possibility to handle the future. In this paper, I have described five different future regimes as they are embedded into as many different anticipation communities within complexity science. The ‘high-frequency prediction’ community proposes methods of visual navigation to perform short-term predictions on a continual flow of time in order to increase speculative gains. The ‘open-ended evolution’ community conceives time as an open field where living-like machines can be implemented in order to creatively adapt to a fast-changing environment and, by that, increase capitalistic productivity. In these two cases, future is tamed more than gazed into crystal ball. The ‘decentralized prediction’ community proposes calculated scenarios in order to provide the impact assessment of urban or enterprise modifications, or in order to anticipate short- and long-run urban developments. Similarly, the ‘centralized anticipation’ community produces scenarios of epidemic peaks to accompany governmental preparedness to reduce casualties. The ‘future co-construction’ community employs simulation to produce scenarios that have more a pedagogical than a predictive aim, in order to empower “stakeholders” in view of change.

While for the ‘high-frequency’ and ‘optimization’ communities future is indecipherable and stratagems have to be set up to try to unravel it, for the other three communities the ye-to-come appears more accessible – even if with different degrees and time depths. In all cases but one – that of ‘centralized anticipation’ –, the arrow of time goes from the present toward the future and the models are there to help building a better forthcoming by predicting it or by creating the conditions to adapt to it. For epidemiologists, it is a matter of anticipating the threat coming from the future toward the present, in view of avoiding humanitarian catastrophes – an attitude I have qualified as ‘anti-performative.’ The ‘centralized anticipation’ community is unique under another perspective – the view of complex systems. While for the other communities, systems appear more or less decentralized and flat, for epidemiologists networks present big hubs corresponding to governmental intervention. They are indeed the only ones who have a vertical relationship to power.

	High-frequency	Open-ended evolution	Decentralized prediction	Future co-construction	Centralized anticipation
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	prediction				
Approaches and devices	Chaos theory, economics, psychology, times series, genetic algorithms, neuronal networks, statistical arbitrage	Evolution, Artificial Life, Artificial Intelligence, economics, entomology, agent-based modeling, genetic algorithms	Geography, physics, statistics, agent-based modeling, power laws, network theory	Geography, computer science, ecology, social sciences, agent-based modeling	Public health, network theory, physics, computer science, meteorology, agent-based modeling
Performativity	Detecting order within chaos permits short-term predictions	Artificial life simulations are alive and can evolve to solve problems	Homology between target and simulated systems allows prediction	Simulation can only provide simplified insights for pedagogy	Homology between target and simulated systems allows anticipation
Extra-academic activities	Speculating in the stock markets	Robotics, drugs, software for industrial optimization	Consulting for administrations and enterprises	Participatory forums with different stakeholders	Consulting for governments and agencies
Future regimes	High-frequency prediction	Optimization	Prediction (but also prospective and anticipation)	Prospective	Anticipation (but also prospective and urgency)
Anticipation policy	Making money, make the market more efficient, compete, bet	Make industry and management more efficient, increase gains, adapt	Help policy and enterprise in planning, innovation and competition are the motors of history	Democratize, pacify, and make more sustainable the management of environmental commons	Limit human and animal casualties, maintain political and economic status quo

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Figures legend

Figure 1: Please write under the image: Interactive elements of a global security system, Santa Fe Institute archives, Santa Fe, New Mexico.

Figure 2: Please write under the image: In this agent-based modeling of cities, the researcher treats innovation as an object which can be removed depending on its oldness. Source: Rey-Coyrehourcq, S., *Une plateforme intégrée pour la construction et l'évaluation de modèles de simulation en géographie*, PhD thesis in Geography, Université Panthéon-Sorbonne, 2015, Annexe, p. 80.

Figure 3: Please write under the image: A schema of a Hybrid Agent-based Model by ComMod. Source: Étienne, M. (dir.), *La modélisation d'accompagnement. Une démarche participative en appui au développement durable*, Versailles, Éditions Quæ, 2010, p. 75.

¹ In the original table by Chateauraynaud and Debaz, there is a fourth axe – the ‘type of critique that regimes can be subject to’ – which I have left out for its lack of pertinence herein.

² Other communities may be included, for example that of traffic jams modelers [68], but since I have not directly conducted research on these complex systems specialists, I will not dare to advance more than a simple suggestion.