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**Title of paper:**

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and what are its policy implications?**

**Author's name:**

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**Keywords**

Complex adaptive economic systems; emergence; networks; institutions; self-organization mechanisms; economic policy.

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**What is complexity economics, why is it heterodox,  
and what are its new policy implications?<sup>1</sup>**

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**Keywords:** Complex adaptive systems (CAS); complexity; economic policy; emergence; evolution; institutions; networks; self-organization; group size; state structure and qualification.

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## 1 Simplistic and complex systems and policies

Mainstream policy conceptions and prescriptions appear to be normative postulations for a permanent “state planning for more market”, mainly organizing “de-regulation *cum* privatization”, rather than deliberate sets of conditional recommendations based on pondering alternative potentialities and paths. Such crude normativity has dominated the world for four decades. Furthermore, it usually is put forth tacitly, due to the attitude of *T-i-n-a* (“There-is-no-alternative!”).

The economic conception behind such *crypto-normativity* is the idea of some *unique* (and optimal) *equilibrium* benchmark (point or path) related to a “perfect market” that is derived from a rather *simplistic* model. The latter is custom-made to allow for analytically tractable solutions, with its “representative agents”, “optimal” information and decisions, suitable functional forms, and equilibrating mechanisms, allowing a predetermined equilibrium, and thus a *teleological* attitude, which already T.B. Veblen had criticized (Veblen 1898; Foster 2006; also Fontana 2010; van den Berg 2016).

Stochastic versions, such as dynamic stochastic general equilibrium (DSGE) models, presume *random stochastic* processes (the notorious “Brownian motion”). Related statistical distributions of values and event-sizes thus always are considered *normal distributions*. And *rational expectations* of clear-cut (and existing!) *mean* values (and comfortable variances as calculable “risk”) can then be justified (Kirman 2016).

This, however, is only warranted either in *simple* (as indicated) or in *non-organized complex systems* (Weaver 1948), the latter having great numbers of identical particles, whose properties and motions can be assumed to average each other out, as in early 19<sup>th</sup>-century physics for the prototypical gas in a container under static conditions. This presumption has also been used in stochastic neoclassical models, and related financial-sector models pre-2008 (the Nobel-laureated models of Black, Scholes, and Merton). Economies, including the financial sector, however, are not “non-organized” complex systems. Those models, thus, turned out to be a cornerstone of the *financial crisis 2008ff.*, as real systems, with their human agents systematically interacting, adapting, aspiring, and anticipating under fundamental uncertainty, are precisely systems with so-called *organized complexity* (Weaver),<sup>3</sup> which behave qualitatively different from random motions (Mandelbrot 1997; Lux, Marchesi 1999; Mandelbrot, Hudson 2006; Battiston, Stiglitz et al. 2015; Tang, Chen 2015),<sup>4</sup> based on diverse complex self-organization mechanisms.

But *self-organization* capacities of “organized complex” systems have justified, particularly along Hayekian lines, to redudantize proactive policies, as they are theorized, under the assumption of a favorable information distribution in the “market”, to generate some relatively “optimal” (“natural”) “spontaneous order” (for such a “non-policy” towards the financial crisis, Lewin 2014).

But such self-organization capacities are, in fact, just *any kind of systematic interactions of agents*, appropriate or not (Kirman 1998b; Rycroft, Kash 1999:90ff.). Self-organization

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<sup>3</sup> The older reference shows that current complexity economics is in the traditions of older *general systems theory* (L.v. Bertalanffy) and *cybernetics* (N. Wiener, W.R. Ashby). For complexity ideas in the history of economic thought, Elsner et al. 2015, Ch. 12.

<sup>4</sup> There are, of course, many definitions and measures of complexity, based on, e.g., how difficult a system is to be described or reproduced, in terms of computational time or information bits (Lloyd 2001). We will not confine ourselves to a particular definition but focus on briefly describing complexity properties.

mechanisms do exist in both natural and social complex systems, from sand-pile and snow avalanches to tectonic plates' moves, natural forest-patch and related forest-fire sizes, to frequencies of words in languages, human territorial settlements, firm populations, financial sector, to all human agents' interactions in general. And implications are severe.

As economies are also *open, metabolic systems*, self-organization may increase the systems' complexity, at the expense of their entire surrounding system (society, nature) – far *beyond optimality and predetermined equilibrium* –, which refers to so-called *dissipative structures* or systems (Prigogine, Nicolis 1967). Such *complex adaptive systems* (CAS) display *dynamics* with transitions between some temporarily increasing *order* and often abrupt and volatile *disorder*, stasis alternating with turbulence, moving between complete information conservation in simple systems and extreme diversity generation (and information loss) in chaotic systems, mostly lingering “at the edge of chaos” (Kauffman 1993; for economic CAS, e.g., Bloch, Metcalfe 2011; Durlauf 2012; Valentinov, Chatalova 2016). “Self-organized” order and increasing complexity, thus, has little to do with equilibrium, “optimality” or “natural” states:

“... seeing the social system as a complex evolutionary system is quite different from seeing it as a self-steering system requiring the government to play no role, as seems to be suggested by unsophisticated market advocates” (Colander, Kupers 2014:5).

So economic *policy*, in order to shape and influence economic CAS and their dynamics “for the better”, comes into play:

“... self-organization does not release us from ... public policy” (Room 2011).

And it will have a qualitatively greater, and completely different, role to play than in a simplistic world.

Particularly in decentralized and de-regulated spontaneous individualistic economic systems, called “*market economies*”, with their particular turbulences and incentive structures, mostly favoring a *myopic* maximizing (a “hyper-rational” behavior) (Aspara et al. 2014), “self-organization” mechanisms do dominate that generate *fallacies of aggregation* in intricate decision-making structures, such as ubiquitous *social dilemmas* (Valentinov, Chatalova 2016),<sup>5 6</sup> and a “pervasiveness of *negative unintended consequences*” (Wilson 2014:12; italics added). Often, *cumulative, positive feedbacks* tend to shift the system towards some *lock-in*, often in inferior states (David 1985; Arthur 1989). This mirrors – besides *cumulative* and disequilibrating technological processes, such as increasing returns in production or network externalities in use – manifold *information deficiencies*, fundamental *uncertainty* and bounded rationality, cumulative behaviors (herding), *power-related* structures, or *ceremonial* (power- and status-based) degenerations of institutions.

De-regulated and globalized “markets”, with increasing *volatility* and *opacity* for individual agents, tend to generate some (perceived) *over-complexity* (of the individual decision situation) and *over-turbulence*, with well-investigated *systemic costs* (Helbing 2013; Mirowski 2013; Battiston, Stiglitz et al. 2015), unsurprisingly *restricting creativity and innovation* capacities (and willingness) of individual agents (Vega-Redondo 2013).

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<sup>5</sup> We elaborated on the ubiquity and everyday relevance of social dilemma elsewhere (e.g., Elsner, Heinrich 2009).

<sup>6</sup> Valentinov and Chatalova develop a systems-theoretic explanation of the ubiquity of social dilemmas: Social systems inevitably are operationally somewhat closed towards their environment, but at the same time, metabolically dependent on it. Social dilemmas then originate from the conflict between these two systems identities, when systems disregard their environmental dependence. Economic incentives then are individual-level projections of systemic imperatives from their artificial closure, and social dilemmas then explained in terms of excessive myopic economic incentives, which make individual agents insensitive to their dependence on their environment.

*Complexity Economics* (CE)<sup>7</sup> suggests that, although self-organization mechanisms might shift a CAS into some stationary state (or so-called *attractor*), they usually will give rise to *multiple equilibria, superior and inferior ones, often unstable and transient*.

Particularly in “market” economies, a required problem-solving self-organization, facilitating some stable superior attractor, namely some “instrumental” *institutional emergence* in intricate incentive structures, may be (1) very *time-consuming* to come into effect, and (2) *fragile* (prone to backslide), if not (3) *blocked at all*. Some system(at)ic *policy vis-à-vis economic CAS*, to push it into superior and stable areas or paths, thus is due.<sup>8</sup>

Properly elaborated *complexity policies*, then, particularly when focusing on *proper institutions and institutional change*, may improve incentive structures and other critical conditions of agents’ behaviors, thus supporting *problem-solving* (instrumental) emergent social *institutions*. These may promote collective problem-solving capacities, *stabilize* the system’s path, make it settle in a *superior attractor*, and generally improve its properties and dynamics (e.g., Colander, Kupers 2014; Gilles et al. 2015; Hu et al. 2015). This will not be any rampant interventionism, and no Hayekian “road to serfdom”. On the contrary, *strong and reliable, long-term and adaptive systemic policies* may avoid cumulatively increasing ad-hoc interventionism that has been the paradox consequence of the increasingly crisis-prone neoliberal era.

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<sup>7</sup> E.g., Waldrop 1992; Arthur et al. (Eds.) 1997; Foster 2005; Velupillai 2005; Garnsey, McGlade 2006; Holland 2006; Miller, Page 2007; Beinhocker 2007; Mitchell 2009; Kirman 2011; Colander et al. 2011; Aoki et al. (Eds.) 2012; Arthur 2013, 2015.

<sup>8</sup> Kirman (2016) assumes a more radical view against such policy optimism, arguing that “attractors” (below) always change with evolution, undermining meliorating policies. On top of that, we may argue, policy itself also changes such conditions. We will consider remaining policy options.

Since the financial crisis, it has become obvious to an increasing number of economists (and practitioners) that we need *different theories and models* than those related to perfect agents and mechanisms, to “smooth” process, and unique equilibrium. CE, in fact, is incompatible with the historical message of the mainstream that the “market” economy tends towards a general and relatively optimal equilibrium and thus is the only way, vanishing point, and end of human history.

Complex models consider *many and heterogeneous agents* in recurrent direct *interactions*, within many different and intricate *incentive structures*, with different *self-organization* mechanisms and ongoing differential *replications* in an *evolutionary* process, and on different social and spatial *topologies*. They can only be applied, in the final instance, as *agent-based models* (ABM) on *topologies*, using social network analysis (SNA). This then not only is no longer analytically solvable and can only be computed in complex simulations, but also demonstrates that we have to deal with completely different problems than predetermined optimal equilibrium – a true *paradigm shift* (Fontana 2010; Arthur 2015).

With its models and computation tools, its *systemic* and “*mechanismic*” character, and its implications of *mutual micro- and macro-foundations*, CE has developed into a promising cross-paradigm that has the potential to serve as a common denominator for heterodoxies (Thornton 2016).

*Policy* implications of CE have become a major theme recently, naturally occurring with some time lag vis-à-vis its underlying paradigm (CE), and particularly boosted around the financial

crisis.<sup>9</sup> The present chapter will exemplarily refer to a well-known group of CAS, with repeated social dilemmas in an evolutionary game-theoretic (EGT) and an evolutionary-institutional perspective – the *evolution-of-cooperation* approach (Axelrod 1984/2006; Lindgren 1997; Kendall, Chong (Eds.) 2007; Colander, Kupers 2014) – in order to derive some concrete policy orientations. We will, however, not have the space to develop particular policy cases, such as, e.g., financial sector reform.

Section 2 will briefly review CAS, addressing structures, mechanisms, critical factors, and dynamic properties. Section 3 will consider some policy orientations from the CE literature. Section 4 will refer to the “evolution-of-cooperation” and its policy implications. Section 5 will generalize and discuss policy implications derived from an evolutionary-institutional perspective on games on networks and populations with ever-changing fitness conditions. Section 6 will consider implied requirements for the state, with socio-political evaluations of system outcomes and related action, introducing the idea of “new meritocracies”, coinciding with long-standing pragmatist/instrumentalist policy conceptions, and the qualifications the state itself would need to develop.

## 2 Properties of economic CAS

### *Initially “given” structure*

In CAS, with a population of many heterogeneous interacting agents, some network topology, and games played on graphs, the model structure considered “given” includes:

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<sup>9</sup> E.g., Durlauf 1997; Hayden 2006; Salzano, Colander (Eds.) 2007; OECD 2009; Geyer, Rihani 2010; Room 2011; Durlauf 2012; Fontana 2012; Morçöl 2012; Dolphin, Nash (Eds.) 2012; Wilson, Gowdy 2013; Colander, Kupers 2014; Fontana, Terna 2015; Geyer, Cairney (Eds.) 2015; Price et al. 2015.

*Decision structures:* Agents are directly interdependent and *recurrently* interacting in different, more or less “intricate” (usually many two-by-two) decision problems (incentive structures). They are potentially heterogeneous as they have different behavioral/strategic options, some of which may be interactively learned in a process. The usual formal language here is game theory. We may think of different coordination, anti-coordination, non-(or dis-)coordination, and social-dilemma games. Different options then may generate (*initial*) *strategic uncertainty* in an ongoing process beyond hyper-rational behavior, opening space for social *learning* of different behavioral *rules and institutions* (Schotter 1981). These then may become habituated and emerge under reinforcement learning, when interactions are indefinitely repeated, and a learned and habitually acquired longer time horizon substitutes initial short-termism. Other conditions for *cognition*, *expectation* building, and learning of coordination and cooperation, such as the *fierceness* of the quantitative incentive structure, interaction-arena *size*, the initial *minimum critical mass* of cooperators in the population, or *agency capacities* such as partner selection, are also important for modeling.

*Network structure:* Those games also may be defined on different network topologies (Jackson, Zenou 2015),<sup>10</sup> defining a population with different social or geographical distances/proximities (neighborhoods), with related differential probabilities to interact, and implications for differential performance and behavior diffusion (a classic neighborhood model: Schelling 1971). Empirical network structures display different spatial centrality, clustering, and distance patterns.

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<sup>10</sup> Note that we call the given (and later perhaps endogenous) topology of a population (a system of interaction *arenas*) a *network*, and an emerged *platform* of multilateral institutionalized cooperation will be termed *emerged network* (Kirman 1998b), usually emerging in individual arenas and for parts of the population (a “group”, neighborhood, firm cluster, or a functionally defined field).

Neighborhoods may be *clusters* within a larger network. There also may be overlapping and staged systems of clusters, where one agent may interact in different arenas in different social roles, for different “goods” (with different overlapping and staged reaches for their part), in all so called multilayer or *multiplex* networks (Cozzo et al 2016). Further, agents may die, get born, learn and change strategies, imitate, or occupy behavioral niches, in response to their relative success, and when they are allowed to move in reaction to their relative performances, the network will become endogenous (Schelling 1971; Kirman 1998a).

*Institutional structure and ”rules of the game”*: Initial structures are generally assumptions in a modeling method. Initially given decision structures, strategies, and network structures are no preset “givens” in reality but always evolved results of preceding historical process. While even “rules of the game” (e.g., periodization of inter-actions, mutual rationality assumptions and other common knowledge, common time horizon, correct comprehensibility of actions, “trembling hands” etc.) may be part of what we want to explain, they also are methodologically mostly required as givens – which of course implies cautious modeling strategies.

***Process, emergent structure, and resulting system properties***

*Continuing interaction, nonlinear aggregation, and structural emergence*: Ongoing interactions, usually among intentional, learning, and adaptive agents (or, in EGT, among strategies and their carrier groups), generate, already under simple conditions, some cumulation and nonlinear aggregation, compared to linear summing up of supply or demand quantities of representative agents. Agents will adapt to each other, their neighborhoods, or to the global state of the system, they may imitate and herd, or cumulate in other ways. With non-linearities, resulting structures

cannot be traced back (re-duced) to the properties of individual agents – the well-known phenomenon of emergence.<sup>11</sup>

*Emergent “macro” and “meso” properties:* Emergent structure shows that boundaries between micro and macro blur. Empirical *stochastic* analyses of system behaviors (real-world or artificial) relate to both (“macro”) structure and the (“micro”) level (Jackson et al. 2015; Acemoglu et al. 2015), resulting *distributional statistics* are indicative of both micro and macro properties. And emergent macro structure feeds back to micro behavior and changes it (*reconstitutive downward causation*; Hodgson 2002). And when it comes to emergent structure and (cumulative) downward feedback (“macrofoundations of micro”), the limits of analytical tractability and determinacy are quickly touched. Often it is also appropriate to focus on some “*meso*” level (considered below the size of the entire “macro” economy or population, as a constituent component of them), since informal structural emergence often occurs prominently at “mid-sized” arenas, due to better cognitive and expectational conditions there (Elsner, Heinrich 2009; Dopfer 2011; Elsner, Schwardt 2014).

*Path dependence and non-ergodicity:* CAS are recursive not only among their components at one level but also among their micro, meso, and macro levels (Dopfer 2011). While agents act under complex conditions (many interactions with many heterogeneous and adapting agents,

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<sup>11</sup> Capacities of structural emergence are considered *the* distinctive property of CAS, to be analyzed in “generative sciences” (Epstein, Axtell 1996; Harper, Lewis 2012). See also the recent in-depth discussion of John Davis of the conception of emergence under the aspects of (1) relative non-predictability of emergent systemic properties (partial “surprise”), (2) relative non-explicability (particularly by simplistic, linear, mainstream conceptions), and (3) the epistemological understanding of economics as coevolving with the analysis and change of its object, the economy (Davis 2017). Here, it is suggested, in line with Davis, that our evolving theoretical capacity to identify and explain the self-organization mechanisms (see below) will further relativize “surprise” and increase the explicability of computational systemic results, and thus will contribute to that co-evolutionary epistemological conception for social science proper.

differential replication and thus *ever-changing socio-ecologies*), with relatively limited cognitive capacities (bounded rationality), mostly only local experience, and fundamental uncertainty, searching, experimenting, reacting and adapting, the system will typically behave non-regularly and *statistically non-stationary* over time, or: in “path-dependent” ways.<sup>12</sup> This may be consistent with the settling of the system (for some time) in some fixed point/attractor or its traversing of some (usually periodic) orbit. Path-dependent processes are sensitive to initial conditions, often vulnerable to small changes of initial conditions, and in this sense *history matters* (extremely so in so-called *chaotic* phases, where at some “tipping point”, or “phase transition”, we cannot even forecast in the short-run, whereto the system will go). Infinite recurrence, sequentiality of interactions, and infinite differential replication generate an “open-ended” process over real/historical time (indefinite in time and in phases unpredictable in the short-run). Such cumulative process is *irreversible*, and at instances becomes *idiosyncratic*, i.e., *unpredictable* as said, as there often are multiple potential equilibria and paths, and in the extreme it becomes what is called a “deterministic chaos”. Such systems are *non-ergodic* in the sense that the distribution of states that they do assume over time is not identical with the distribution of potential states they basically could assume (judged from their structure). Thus, no normal distributions of system motions with comfortable probabilities for forecasting exist, but a sensitive dependence on initial conditions rather.<sup>13 14</sup>

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<sup>12</sup> This requires that, in a nutshell, variables are time-dependent, in themselves [discretionary:  $x_{t+1}=f(x_t)$ ] and among each other [ $x_{t+1}=f(x_t, y_t)$  and  $y_{t+1}=g(y_t, x_t)$ ].

<sup>13</sup> (*Non-)*Ergodicity was adapted from statistical physics and stochastic processes of physical systems. Post-Keynesians, for instance, have discussed the issue in connection with Keynes’ conception of *fundamental uncertainty* and in distinction from the *rational-expectations* justification of non-intervention into the “market” (Sargent/Lucas, see Davidson 1982-83). Keynes, in his critique of early econometrics, with his argument of “*non-homogeneity*” and “*non-stationarity*” of stochastic process and time series, seemed to have an understanding of non-ergodicity (O’Donnell 2014; Rosser 2015-16).

<sup>14</sup> In this context there is a recent interdisciplinary discussion of *novelty*, *surprise*, and fundamental *innovation* (see already Shackle 1949). We cannot delve into this, but point out the nexus of rare events/surprise, fundamental uncertainty, sudden innovation, and non-ergodicity (Markose 2016; Heinrich 2016).

*Self-organization and persistent fat-tail distributions:* Self-organization capacities are reflected by surprisingly persistent empirical distributional structures of certain properties (centralities of agents, critical system motions). Certain stable centrality distributions may emerge, and some meta-attractor even may cause repeated system motions (such as financial crises) of a certain size distribution always back to it. We are talking about *right-skewed statistical distributions*, also called *long-tail* or *fat-tail* distributions. In “market” economies, particularly the financial speculation sector, there usually are many agents with only few relations, and very few with very many relations (or high centrality). The *mechanisms* at work have been considered as *the rich get richer* or *preferential attachment* (Barabási, Albert 1999). Individual problems of the most central and powerful may then cause *large system crises*, occurring with a considerably higher probability than suggested by a normal distribution. Of particular interest have been self-organization mechanisms that are so strict throughout the system that they display the same functional property at all levels. The functional form of the statistics, detected for the first time by V. Pareto for income distributions persistent across countries and centuries, are known as *power-law* or *scale-free distributions*, which have the same functional properties at all scales, indicating a self-organization mechanism working identically at different scaling – the phenomenon of *self-similarity* (as known from “fractals”). Mapped as log-log, they become a linear curve. In many spontaneous decentralized systems – usually historically emerged, deep-rooted *individualist cultures* of market economies –, human agents and firms *differentiate* in specific ways in terms of *power and status*. SNA and network statistics then reveal such long-tail or power-law distributions of degrees of centrality. They occur, as indicated, in diverse real-world areas, such as income and wealth, *firm size* (“Gibrat’s law”) or spatial settlement (city sizes; “Zipf’s law”), word frequencies in languages, internet-sites size distribution, the size distribution of natural forest patches (and of related forest fires), the size distributions of sand-pile or snow avalanches,

or of earthquakes. Some critical events (sudden movements, phase transitions) repeatedly make the system approach a certain state (a dominant or meta-attractor), as said, where the very continuous change of the system states after some major motion (crisis, avalanche etc.) contributes to the repeated system movement towards that attractor, the so-called *self-organized criticality* (Bak et al. 1987). Note that this also applies to capitalist cycles and financial sector crises in particular: If let alone, crises will reconstitute conditions (firm concentration, over-accumulation of capital, accumulation of cascades of securitized papers etc.), under which the system again builds up towards its next crisis. *Large financial crises* do in fact appear considerably more often than expected in mainstream models of random process (Mandelbrot, Hudson 2006; Taleb 2007). In contrast to normal distributions, fat-tail distributions often have no (finite) mean, around which “rational” expectations (of prices, events etc.) of “rational” agents might center. Note that this has been exactly a long-standing issue of *original evolutionary-institutional economics*. The mechanism of *emulation* of higher social castes and of *invidious distinction* among those of the same social class, if operating at all social strata of predatory (capitalist) societies, was central from the very beginning of institutionalism (Veblen 1899). Such *ceremonial* self-organization would then *trickle-down* the entire society, and somehow homogenize society, reducing its resilience and sustainability.

*Emergent small-world networks*: Topologies that display power-law distributions of nodes (“scale-free networks”; Barabási, Albert 1999) usually display hierarchical structures of sub-graphs, and often hub-and-spoke type sub-networks. More effective networks make a different use of central positions, combining *local clusters* and *long-distance relations*, so that central positions may play some role *within* local clusters, but mainly *among* clusters, at “gates”, where long-range relations to other clusters begin. So-called small-world networks (Watts, Strogatz

1998) facilitate, by their clustering, some local problem-solving through *dense interaction* and quick institutionalization, and at the same time display, through their long-distance relations, a relatively low mean path-length between any two agents in the entire network, ensuring relatively quick diffusion of information. Again, this all has little to do with optimality, as large nodes, such as *persistent hubs*, may still cause the problems mentioned for system stability and resilience. Central power positions, if not avoidable as such (*gatekeepers*), will need to be carefully controlled.

*Lock-in, ceremonial dominance, and collective-action capacities:* Intricate problem structures, such as social dilemmas, display mixed interests (partially consistent, partially conflicting), and under recurrence entail lasting tensions among agents. But even in relatively simple *coordination games* with Pareto-different solutions, a collective incapacity to ensure longer-run optimal solutions exists. As systems may run into technical and institutional *lock-in* (Arthur 1989; David 1985), this may be at an *inferior* technological and institutional coordination, which is indicative of differences between individualistic and collective rationalities. As rivaling technologies, innovation efforts, and *standard wars* (under scale economies and network-externalities) may be both coordination and dilemma games, *institutional lock-in* will be a reflection of dominant *ceremonial* warrant, dominant aspirations of differential status and power. This may be considered some degeneration of originally *instrumental* institutions (emerged in repeated dilemmas), for instance through an increasingly unequal distribution of cooperative gains (Elsner 2012). In contrast, as long as strategies can be interactively learned and adapted as “*instrumental*” solutions of coordination or dilemma problems, emergent structure assumes the form of problem-

solving rules or institutions.<sup>15</sup> But in either case social institutions are *complexity-reducing* devices. Whether instrumentally or ceremonially warranted, they generate some stability (“homeostasis”) and ensure some continuity. In the ceremonial case, this may be some “hysteresis”, in the instrumental case, they will generate some progressive adaptability (Bush 1987).

*Individual agent capacities, intentionality, and institutionalization:* EGT-based evolution-of-cooperation approaches assume many sequential two-person games in a population, calling for making implicit agency capacities (beyond hyper-rational maximization) explicit. In order to solve Prisoners’ Dilemma supergames (PD-SG), agents must culturally acquire longer-run perspectives (below). As behavioral innovators and initial cooperators in a defective social environment, they must be *risk-taking* (in the sense of being vulnerable to exploitation) and *not too envious*, should have some capacities of *memory*, *monitoring*, and *reputation*-building and -using, capacities of *preferential mixing* (partner selection) or establishing and terminating relations, and, in the spatial case, of moving into and out of neighborhoods. Further, in multi-agent and multi-strategy environments, where transparency and cognitive capacities may quickly be too small, and perceived complexity and volatility too high to behave globally rational (Durlauf 2012), agents must be both searching (experimenting, adapting) and endowed with some *intentionality* to improve their outcomes, to solve intricate common or collective problems,<sup>16</sup> and

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<sup>15</sup> On terminology: *Coordination problems* (coordination games) are solved by common, *coordinated behavior* through the device of learned *social rules*, while *social dilemma games* (requiring the sacrifice of the short-run maximum for solution) are solved by collective *cooperation* through the device of learned *social institutions* (learned in indefinitely repeated interactions). An institution then is a social rule plus an *endogenous sanction*, the credible threat of a *punishment* (with costs for the punisher), as exerted by a memorizing and provokable *trigger strategy*, such as, in the simplest case, *tit-for-tat* (Schotter 1981; Axelrod 1984/2006).

<sup>16</sup> Coordination games are solved in the immediate interest of individualistic agents, through coordination by a social rule, which is just *common*, parallel behavior. In contrast, the more intricate social dilemma, with its dominant incentive to defect and exploit, requires cooperation, through a long-run rational behavior, habituated and semi-consciously applied as an institution, a social rule plus threat of sanctioning and falling back to the Nash equilibrium, and in that sense is a *collective* phenomenon.

to *reduce perceived complexity*. This is where the rules and institutions come in, and Veblen's *instinct of workmanship* or *idle curiosity* would seem to apply as motivations to search, experiment, and learn cooperation after repeated frustration from the results of the one-shot logic.

***Performance and replication: Cumulation and endogenous networks***

*Differential performance and replication, fixed points, attractors, orbits*: Agents (or strategies) in a population with repeated encounters will have performed differently after many interactions within a “round” (a SG), and after many rounds played with many different agents, at the end of an (artificial) “generation”. A replicator mechanism generating differential “offspring” according to performance, also considered learning or imitation vis-à-vis some reference (average or maximum in the population, some peer group or neighborhood), will provide a next “generation” with a *different social ecology*, a changed *strategy composition* of the population. And with continuing replication, we may generate a full-fledged evolutionary process (early simulations: Axelrod 1984/2006; Lindgren 1997). Replication processes may, under certain constellations, converge to one out of multiple possible fixed points (how instable and transitory ever; analysis of dynamical systems will show whether such equilibrium is stable or not). If instable, the system may perform cyclical (periodic) or even non-periodic orbits, but usually it will perform recognizable behavioral patterns.

*Dynamic populations and size-dependent fitness*: Evolutionary “optimality”, in the sense of a survival of the fittest, across changing social ecologies, will typically not occur. A related “efficient” selection for such a result would require structural stability, so that a selection mechanism would have enough time to meliorate the system. However, this is typically not the condition of complex dynamic populations (an older *Veblenian* insight was that there are no

automatic “meliorative” tendencies). In particular, when “fitness” and population shares of the different strategies are subject to cumulative *first-mover* advantages or cumulative power acquisition, or, on the other hand, to some *limits of growth* (marginal returns decreasing with increasing population shares, the *s*-shaped logistic function), and thus are dependent on population shares achieved before, situations of a survival of the first, survival of the “fittest”, or a survival of all (with possibly different shares of each strategy) may occur (Nowak 2006).

*Circular upward and downward causation:* The evolution of CAS is, as said, not just bottom-up emergence but also downward causation (re-shaping incentive structures and behavioral patterns). Circular cumulative feedbacks have been mechanisms known in evolutionary institutionalism from *Veblen* through *Myrdal*, as well as in other heterodox orientations (Berger, Elsner 2007; Thornton 2016).

*Endogenous network structure:* As mentioned, if, in an agent-based model on a topology, agents, after some “generation” ended, may accordingly establish or terminate links or move into some other neighborhood, the network structure will become “endogenous” (Schelling 1971; Jun, Sethi 2007; Berninghaus et al. 2013).

With such basics of a complex evolutionary process we are

“... maturing to a point at which policy implications are emerging ... Moving forward, it is our hope and expectation that .. (this-WE) will greatly aid in the understanding of policies ...” (Jackson et al. 2015:41).

### **3 Policy orientations from some complexity literature**

Manifold non-optimality and shortcomings of structures, mechanisms, processes, and other system properties, thus, result in some perceived *over-complexity* and *(over-)turbulence*, inferior system states, and insufficient dynamics, not properly reflected by the mainstream theory of “market failure” (Fontana 2012). They require a proactive, systemic, often massive and persistent, but also adaptive and learning policy intervention. Much has been developed already for such “complex adaptive policies” in recent years.

### ***“Revising the concept of regulation”***

The analysis of CAS, as indicated, suggests a very different conception of “regulation” than the economic mainstream established. As socio-biologist D.S. Wilson argues, for a neoclassical and neoliberal economist,

“regulation is something imposed by governments, and self-organizing processes such as the market are regarded as an absence of regulation”,

while for complexity sciences,

“all of the metabolic processes that keep organisms alive and all of the social processes that coordinate ... [social animals–WE] are regulated ... The concept of regulation in economics and public policy needs to be brought closer to the biological concept of [self- – WE] regulation. The idea of no regulation should be regarded as patently absurd but determining the right kind of regulation and the role of formal government in regulatory processes are still central topics of inquiry. ... [It is] clear that unmanaged cultural evolutionary processes are not going to solve the problems ... at the scale and in the time that is required, which means that we must become ‘wise managers of evolutionary processes’ ...” (Wilson 2014:11).

Then, “the selection of self-organizing regulatory processes” (Wilson 2014:12) and their improvement become the major task. If appropriate policies would not be developed and engaged

for the regulation of a CAS, the system would be exclusively self-regulated by some deficient mechanism.

### ***Policy system partly endogenous***

Public policy is itself a complex system with its own relative structural, procedural, and performative strengths and weaknesses, but when interacting with its target economic CAS, it will have to develop a certain *minimum degree of complexity*. And it is to be considered (partly) endogenous to the CAS under its scrutiny and control, as it needs to be adapted according to the evolutionary dynamics of the target CAS. Such endogenous control may cover a bandwidth of impacts from a temporary *non-reaction* of the system through some *policy evasion* of its agents, preventing the system from properly reacting, to a *hyper-reaction* in a way that policy not only directly shapes it in intended ways but also may *change its very conditions*, mechanisms, and dynamics, under which the policy initially was made. This twofold impact may still entail the intended effects, but the second type of impact also might counteract the intentions.<sup>17</sup> The policy agent needs to take the double impact into account and consider that the *foundations* of its decision making may be *altered through its very action*. This is typically the case when *mechanisms* and *structures*, e.g., *distributional*, *institutional*, and *network* structures, will be affected. With proper consideration, policy intervention could be made even more effective.<sup>18 19</sup>

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<sup>17</sup> As a methodological reflection of such endogeneity in an evolutionary-institutional framework, Hayden (2006) developed the *Social-Fabric-Matrix* approach to investigate network structures among agents, institutions, value systems, and the policy system. The approach has often been applied to policy issues and helped pursuing policy impacts throughout the socio-economic system, with results often counterintuitive from a simplistic perspective.

<sup>18</sup> While Kirman (2016) suggests that such policy is impossible, as (superior) attractors always change with the system, policy intervention may make the case even worse. But we will stick to the more optimistic argument (shared by Colander, Kupers 2014) that proper and careful self-reflection of policy and its primary and secondary impacts may keep options towards improvement open. It is supported by cutting-edge methods of forecasting for CAS (Markey-Towler 2016).

<sup>19</sup> To be sure: While “imaginative” crucial decisions (Shackle), taken by private agents under fundamental uncertainty (but certainly institutionally shaped; e.g., Keynes’s “animal spirits”), may contribute to the system’s non-ergodicity, this may also apply to *measures of the policy agent*, which may destroy the very conditions in place when the decision was made. While this double impact involves the political control system further into the target system,

But the policy system must keep itself sufficiently *exogenous* to, and *independent* of, the target system, and can do so if it deliberately develops its different independent constitutional mechanism: uniform, transparent, and (de-)centralized public participative discourse and decision-making, informed of the complexity and properties of the target system (and of its own complexity). With this, some *superior collective rationality* may become effective (Elsner 2001), then

“moving the economy from an undesirable basin of attraction to a more desirable one” (Colander, Kupers 2014:53).

### ***A higher complexity for the control system***

An early insight from information and control theory was that the complexity of a control system needs to be at least as high as the complexity of the target system (“Ashby’s Law”; Ashby 1956), where only variety of the control system can “absorb” variety of the target system. In order to shift a controlled system into an aimed-at area of outcome, while dealing with sometimes unpredictable adaptations of that system, the control system must be able to assume at least as many possible states or, equivalently, have at least as many degrees of freedom, as the controlled one.

But cause and effect between target and control systems can no longer be considered simple, unidirectional, or structurally constant. For instance, a reversal of earlier policy will usually not generate proportionate reverse effects. For instance, *institutional collapse* will not take place at

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making it *more intensely “endogenous”*, policy might become more effective, when its instrumentation can make use of both channels of influence. This will usually be the case, when it systematically *implements structural/institutional change*, changing the *conditions of individual human agency* (the second channel).

the same parameter constellation where *institutional emergence* did occur, due to, e.g., hysteresis effects. Nor will the strengths of effects of identical measures be the same over time. Thus, the “complexity-policy” system not only needs to be more complex, but also process-oriented, with a long-run learning and adaptation perspective – “policy as a collective learning process” (Witt 2003). It needs to be prepared to assume different states for the pursuit of its objectives.

### ***“Reducing complexity”***

Proper complexity reduction is a major complexity-policy issue. We have to distinguish between the complexity of the system and that of the decision situation of individual agents (compared to their limited cognitive capacity). The system may remain highly complex, while individual decision situations become less complex, e.g., through institutionalization.

With respect to *system complexity*, many have warned recently against increasing instability and uncontrollability under increasing (over-)complexity and (over-)volatility of globalized and financialized networks (see Helbing, Mirowski above) and argued that, to make that system manageable, a *fundamental redesign* (Helbing) is needed. One of the standard devices is already provided by some *modularization* into subsystems, considering that some *decomposability* of CAS usually exists, through their very historical emergence from simpler and smaller systems (Simon 1962).

According to Loasby (2012), appropriate deliberate (*re-*)*modularization* of today’s real-world economic and financial CAS is to be based on a more *selective connectivity* (neighborhoods, clustering, localization, smaller arenas, and layered arena systems; also see partner selection), rather than further pursuing the ideal of a globalized “total” connectivity into anonymous and

obscure giant arenas. But modularization, or *delinkage* (Mirowski), particularly urgent for the oversized, leveraging, and “herding” financial sector (Mirowski 2013), must go together with proper *module or arena coupling*, i.e., proper *small-world* structures, which may include some *overlap and hierarchization among modules*, according to the reaches and hierarchies of relevant functions (“goods”). The issue applies to many current trends and discussions, such as the usual *firm clusters and networks, shrinking and “balkanizing” the internet, peer-to-peer money and credit systems, local sharing economies* etc. Maintaining the system’s *resilience* requires such modularization into cognitively appropriate *arena sizes* and maintaining their *diversity* [Biggs et al. (Eds.) 2015]. But a simple system is certainly not a vanishing point of proper complexity reduction.

Thus, the issue stretches not only along the dimension of complexity reduction or increase, but also along the dimension of volatility and crisis vulnerability, so it is about proper selective connectivity and (de-)linkage. Current *regressive political reactions* and votes of people *against globalization* gone astray and against a system with ever more *uneven distribution* of income, wealth, power and centralities, reflect such structural aberrations of CAS that have become over-complex, over-turbulent, and over-obscure.

Given CAS’s often discontinuous behaviors, reducing the system’s (over-)complexity and (over-)volatility, preventing it from entering chaotic phases, may be more or less successful in *different system phases*, as CAS may be more or less policy robust or sensitive at different times. If the system is in an inferior “basin of attraction”, interventions may have to be very massive and enduring to have even only little effect. In other phases and areas of the system, “nudges” may serve the purpose.

With respect to the *decision situation of individual agents*, emerged collectivities (emerged networks or platforms) of cooperative agents reflect emerged social institutions, thus some complexity reduction (Bloch, Metcalfe, 2011:85f.). Policy support for instrumental institutional emergence then will help reducing perceived (over-)complexity and turbulence, better reconciling complexity levels with agents' cognitive capacities. This may also help reducing myopia/short-termism and support a culture of farsightedness and, thus, an easier willingness towards (behavioral, technological) innovation.

As indicated, under enforced volatility, the reaction of agents, paradoxically, may be switching to higher *rigidity*, as agents can no longer properly organize search and learning – and the entire system will likely *slowdown* (Vega-Redondo 2013). This appears to be consistent with some Polanyian *protective countermovement* against the deterioration of conditions of individual decision-making through increasing “marketization” and de-regulation. This may also explain many current *petrifactions* (including institutional lock-ins and ceremonial degenerations of institutions) in response to de-regulation and “flexibility”.<sup>20</sup>

Policy then, through complexity reduction by some selective connectivity, delinkage, and modularization may *de-block*, *accelerate*, and *stabilize* processes of emergence of new institutions, thus enabling and empowering agents.

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<sup>20</sup> We have argued elsewhere that in large anonymous and/or highly mobile/turbulent populations with frequent random partner change, agents may tend to stick to a PD-SG with the same partner as long as possible, or to “meet again” (the same) more often, as far as such *preferential mixing* is feasible to them (Elsner 2005; Elsner, Heinrich 2009).

### ***“Non-algorithmic” policy measures***

While analytical intractability and often unpredictability of CAS quickly occur with increasing complexity (mirrored in model building from simple components, say, a 2x2 game, to a full-fledged evolutionary model), *computation* and *simulation* requirements obviously are much higher for CAS than for simple systems. But although formal methods are more demanding (dynamical-system analysis, SNA, ABM simulations), forecasting “to the point” and related technocratic hopes of quick and easy “manageability” (point interventions for to-the-point outcomes) will be infeasible (but see Markey-Towler 2016). Policy interventions, therefore, have been said to remain “nonalgorithmic” in some critical instances (Velupillai 2005, 2007). Policy then will have to be more *inductive* and experience-based, and required continuous adaptations suggest a “change in the worldview that is currently dominant in policy circles” (Velupillai 2007:275). We sometimes only can say that a massive (institutional) change is required to push the system out of an inferior attractor but will be unable to forecast the system’s exact reaction (considering, e.g., policy evasion or deeper “secondary” structural impacts, as mentioned). But such difficulties do not absolve politics from the requirement of adopting and maintaining a strong *proactive role* (Velupillai 2007; Durlauf 2012:62ff.). Drafting such “complexity policy” justifies Colander’s and Kupers’s (2014) dictum of a complexity-based “art of public policy”.

### ***Further “Complexity Hints for Economic Policy”***

Salzano and Colander (Eds., 2007) pioneered on policy implications of CE. One group of authors in their volume, Gallegati et al. (2007) focused on *power-law distributions of firm sizes* and argued that system stabilization under power-law structures has to control the “*idiosyncratic volatility*” caused by certain motions of the largest firms (the “tail risks”). They concluded to pursue a *reduction of high firm centralities and concentration*, particularly by reducing certain

legal protections of size and power (namely “intellectual property rights”), which appears to be a quite traditional policy reform orientation similar to the pragmatist policy tradition (below).

There still seems to be room for a closer look at a specific set of CAS, when striving to advance exemplarily specified policy orientations, measures, and tools. While these then still appear little operational (partly because never practiced), they can verifiably be related to some model base and may open up further policy perspectives.

#### **4 A simple example for a frame-setting policy for institutional emergence and change**

##### ***The “evolution of cooperation” approach***

We refer to Axelrod’s (1984/2006) approach to the evolution-of-cooperation in PD-SGs, a simple formal reflection of his early complex multi-strategy simulations. This has triggered a surge in the use of PD-SGs and simulations ever since (for an overview: Kendall et al. 2007). It bears some exemplary policy relevance. But only an evolutionary-institutional interpretation, considering network structures and games on graphs, will provide some more far-reaching policy implications (see section 5).

The well-known starting point is the PD normal form:

$$a, a \quad d, b$$

$$b, d \quad c, c$$

$$\text{with } b > a > c > d \text{ and } a > (d + b)/2.$$

The approach to the superiority of cooperation, in the sense of an evolutionarily stable strategy (ESS), in a population with randomly matched agents playing 2x2-PD-SGs, applies one of the

usual ESS-conditions of EGT, comparing defectors' (*ALL-D*) yields against tit-for-tat-cooperators (*TFT*) with what cooperators attain playing against their kind.<sup>21</sup> The approach of a SG is the current capital values of related payoff streams compared ("single-shot"):

$$P_{TFT/TFT} = a + \delta a + \delta^2 a + \dots$$

$$= \frac{a}{1-\delta};$$

$$P_{ALL-D/TFT} = b + \delta c + \delta^2 c + \dots$$

$$= \frac{c}{1-\delta} + b - c .$$

The ESS criterion used here is, whether an existing population of cooperators can (or cannot) be invaded by defectors and thus be an ESS. In order not to be invaded, incumbents must fare better with each other than invaders against incumbents:

$$P_{TFT/TFT} > P_{ALL-D/TFT},$$

$$\text{thus } a/(1-\delta) > c/(1-\delta) + b - c$$

$$\delta > (b-a)/(b-c).$$

The result is a logical condition for the institution of cooperation to prevail in a population, which however is to be embedded in an interpreting narrative.<sup>22</sup>

The critical condition here is the combination of EGT with SGs, i.e., *recurrence* and culturally acquired *time horizons*. Such cooperation not only is infeasible under one-shot hyper-rationality

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<sup>21</sup> *TFT*, as known, is the simplest cooperative strategy in a PD-SG that does reflect the sequence of interactions (with one period memory), thus is responsive and therefore not always strictly dominated (as *ALL-C* would be).

<sup>22</sup> The related question for a population of defectors to be invaded by *TFT* cooperators is: What would the *minimum critical mass* of *TFT* cooperators be that can invade, survive, and expand in a defector population and take it over (Axelrod 1984/2006; Elsner, Heinrich 2009).

(myopia), and would not be an ESS in regular EGT. But it may attain ESS status in SGs with emergent proper cognitive conditions and expectations, indicated by the *discount factor*  $\delta$ . The latter is equivalent with the expectation of meeting the same agent again next interaction, i.e., recurrence. In a population, it is also equivalent with meeting any “knowing” third agent, who may be informed about my earlier behavior (through *monitoring*, *memory* or a *reputation chain*), or, even more generally, with the experienced *general expectation (general trust) of meeting a cooperator*. In a sequential (evolutionary) interaction process, this would require *social learning* and cultural acquisition of a related *longer-run perspective* (a higher  $\delta$ ). A question for more complex modeling, then, is the actual emergence of such longer-run rationality. The higher  $\delta$  then indicates a high (perceived) probability, in any particular interaction, that the interaction will continue with the same partner (or a “knowing”, or a generally cooperative one).

*Habituation* of cooperation as an *institution* may (and must) emerge, as agents must “irrationally” *sacrifice* their short-run maximum,  $b$ , then receiving  $a$  (their sacrifice being  $b-a$ ). The institution then solves the PD-SG through establishing habituated cooperation, being a social rule plus an *endogenous sanction* mechanism for not sacrificing (exerted through the *credible threat* of a trigger strategy, such as *TFT*, to defect upon defection and in this way *punish* the defector, even with cost for herself). This then may prevent agents from chasing after their myopic maximum, which is achievable only through free-riding and exploiting others (but not achievable among equally clever agents, who then run into the dilemma, the one-shot Nash equilibrium). As persistently hyper-rational agents would play series of one shots, it must become habituated and pursued *semi-consciously*, by “rational fools” (Sen), i.e., pursued as a rule as long as there is no reason to expect that in the next interaction the partner will intend to exploit.

In the evolution-of-cooperation approach, there have emerged a great number of elaborated models and approaches that have analyzed further conditions of evolving cooperation. Just to mention two: With a potentially *infinite number of strategies* that can be ever further elaborated by agents, ever more sophisticated cooperative strategies may emerge (and will more or less dominate; e.g., Lindgren 1997 and follow-up simulations). Second, *clustered topologies* will overall be advantageous for institutional emergence (e.g., Watts 1999).

### ***Some immediate policy implications***

A solution will transform the PD into a *coordination* game with two Pareto-different equilibria, and a policy perspective for the solution of a social coordination problem was already presented by Sen (1967). In a context of an endogenous national development strategy and a related collective saving effort of a population to build a national capital stock, he introduced into a stag-hunt game (which will not be solved under general distrust) the idea of a *public assurance* that all agents will contribute to the capital fund, forego current consumption and increase saving, to build that fund, in order to make the next generation (and not only own offspring), benefit (known as “assurance game”). A credible public assurance of even loads for all would be equivalent with an informal *contrât social* (J.J. Rousseau, who had introduced the example of stag hunt in 1762), or a *general-trust* building that in fact *all* will contribute *evenly* in order to yield the Pareto-superior coordination.

But as long as agents remain uncertain, hyper-rational and myopic, the superior, instrumental solution may remain *completely blocked* and the system caught in the one-shot Nash logic. Also, its emergence may be very *time-consuming*. Finally, an actually emerged instrumental solution may be *fragile* and prone to backslide and later breakdown, depending on the parameter settings

and paths of evolutionary processes. Thus, there are more requirements for policy support for *improved self-organization* and faster and more stable institutional emergence.

As already shown by Axelrod, some policy support is immediately warranted even on the basis of such simple exercise:

- (1) According to the inequality above, one had to gradually *improve the quantitative incentive (payoff) structure* in favor of cooperation, reducing the fierceness of the PD, e.g., rewarding common cooperation ( $a$ ), punishing defection ( $b, c$ ), reducing the costs of common cooperation ( $b-a$ ),<sup>23</sup> increasing the frustration ( $b-c$ ) (which implies  $c$  to decrease stronger than  $b, c$ ), in all, *weakening the dilemma*. This would make the structure less intricate and difficult to be solved in a process, without necessarily dissolving the PD structure as such (which would be static and theoretically trivial). Formally, it is about reducing the right-hand side of the above inequality, so that the probability of realization of the superior, instrumental solution in an evolutionary process increases. Practically, this may be addressed through non-pecuniary payoffs from the public agent (such as, e.g., selective early provision of exclusive critical information to cooperating private agents), while, on the other hand, providing pecuniary subsidies to generate a sufficient level of cooperation in sufficiently short time periods might be fiscally very costly.
- (2) Promoting the *recognition of interdependence* (“recognized interdependence”; e.g., Bush 1999) and, particularly, the awareness of the *common future*, enlarging the time horizon

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<sup>23</sup> Which, however, is highly uncertain among equally “clever” agents, who will get  $(c, c)$ . Thus, costs in fact often are  $(c-a)$ , which in fact is a gain for all.

through social learning („enlarging the shadow of the future“–Axelrod). Technically, this renders the inequality above more likely to hold from its left-hand side. A *culturally acquired* longer-run perspective (formally, a longer-run calculation), to emerge as some enlightened self-interest, would then support institutionalized cooperation. This policy complex has also been an older *institutionalist* recognition, extensively dealt with as *futurity* by Commons (1934) (also Jennings 2005 on a “horizontal approach”). Axelrod already gave *policy examples* for this, such as involving agents in series of common projects that overlap over time, so that agents always have a perspective to “meet again” (also Elsner 2001, 2005, confirming that *regional networking* on identifiable collective issues through overlapping projects, as well as the *public assurance* that all relevant agents evenly contribute, may serve here).

This can, in general, be considered a *cheaper and leaner policy*, particularly as compared to a full public production of the public good (“on behalf” of the “failing market”), or a full subsidization of cooperative behavior to make cooperation the individualistically dominant behavior. Private agents not only need to be held liable for their *individual interests in the collective solution* (as indicated by the payoffs *a*) rather, and should correspondingly *contribute*. And their voluntary contribution should be “*intrinsically*” *learned* and emerge in a process among themselves – rather than being imposed on them (or provided in lieu of them) by the public agent. Then, any *gradual* improvement of conditions will increase the probability of attaining a social solution in a process.

The *public-policy agent* then needs to care that emergent private solutions will indeed be *in consistence with defined public concerns*, i.e., by supporting the instrumental solution through the

private agents, these would be enabled to provide a *collective good with a public-good dimension*, rather than colluding at the expense of third parties or of the general public (like a cartel).

The single-shot solution may be elaborated for some *maximum size of population* and some *minimum cooperators' share*, providing cognitive conditions with proper expectations “to meet (again)” (Elsner, Heinrich 2009). *Arena and platform sizes*, thus, are another strategic factor for policy.

## 5 More policy implications from the “deep size structure”

### *An interactive “framework” approach*

The examples above reflect a more general principle of *complexity policy*: While the “market”, as a complex system in the real world, is subject to system(at)ic failure and self-degeneration, if not properly regulated, the public agent may be able to implement conditions for longer-run individual and collective rationality, for a better collective-action capacity, controlling the private interaction system in order to mitigate systemic failure and improve the system’s path. However, there is no reason to assume the public agent, even a sophisticated and qualified one, “to know everything” or always “to know better”. Rather, the complex behavior of CAS suggests that the policy agent should *make use also of the knowledge and adaptations of the private agents* to steer, improve, and stabilize the system. This we may qualify as *specific frame-setting policy*, letting the interaction systems of the private agents do their adaptations.<sup>24</sup>

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<sup>24</sup> This seems to resemble simplistic mainstream perspectives. However, it has little to do with just pushing the “market” into a one-size-fits-all legal framework and then just let go.

Such specified framework approach, based on an interactive relation between diverse bodies and levels of knowledge and action, has, somewhat misleadingly, been called “activist laissez-faire policy” (Colander, Kupers 2014:214ff.) or “political stewardship” (Beinhocker 2012; Hallsworth 2012; Colander, Kupers 2014:240ff.). More appropriately, it is a

“norm influencing role for government (...) designed to influence the rules [...] of the social game”, and then government may indeed become

“a means through which individuals solve collective problems” (p.186).

### ***Policy orientations inferable***

This approach includes identifying mechanisms and critical factors that generate the visible complex system motions, and complexes of policy tools addressing them. Based on the discussion so far, these will include:

- (1) *recognized interdependence*: fostering the awareness, on the part of agents, of a recurrent, and often intricate, interdependence structure among them;
- (2) *incentive structures*: identifying their kind and quantitative strength (type and degree of “intricacy” of games): gradually improving them from “fierce” to less “fierce”, “intricate” to “less intricate”, leaving agents to adapt accordingly;
- (3) *futurity*: supporting private agents’ cultural acquisition of longer time horizons;
- (4) *interaction arenas*: designing their *sizes* and *structures*, supporting emerging *platforms* of cooperation with their carrier groups, and their particular network structures;

- (5) *collective goods*, incl. natural and social commons, to be “produced” (or reproduced) in those arenas and emerging platforms by way of cooperation: identifying their *reaches, overlaps, and layers*, identifying their *multiplex* structure;
- (6) *deficiencies of the spontaneous decentralized private social provision processes*: identifying them in terms of potential complete *blockage*, excessive *time requirement* of emergence, and *fragility* (danger of backslide);
- (7) *public social and political objectives*: identifying the *public-interest dimension* in those collective goods, to be clarified in a proper legitimate public process;
- (8) *private interests in those solutions* (goods): identifying payoffs private agents may get from cooperation, in order for the public agent to call the privates in to contribute accordingly.

### ***Further policy orientations, considering games on networks***

By elaborating on these policy components, in a “games on graphs” perspective, further orientations may be derived. We will give a brief overview of some literature conclusions here. There are obvious overlaps among the following orientations, which indicates that effective results might be expected from a more systemic context to be generated for them:

*Improving incentive structures, assuring, and supporting social focal points*: Both public assurance and making incentive structures less fierce may help agents to converge on superior coordination. For instance, applying the single-shot solution, it will be obvious that in *financial-sector PDs*, the short-term payoffs from one-sided defection usually are so large in relation to potential cooperative payoffs that an evolutionary, learned cooperative solution in the public interest can never be expected considering mere size orders of

numbers. The public agent thus would have no other choice than drastically *reduce the leverages* attainable through financial speculation and one-sided exploitation, in order to stabilize the system. In solved PD-SGs, transformed then into coordination structures, public activities, incl. assurance, may work to create a Schellingian “focal point” for some superior coordination (Calvert 1995; Arthur 1989; McCain 2009).

*Network structure I – Caring for appropriate arena sizes and network structures* to facilitate local clustering and global diffusion of knowledge: Both arena sizes and network structures need to become issues of public policy, with a focus on local *clusters*, selective *long-range* interconnections, *multiplex* structures, and resulting “macro” properties of the entire network of a population (Kirman 1997). *Small-world* structures need to be optimized, and *central positions* controlled and regularly exchanged among agents, since:

“[T]he more knowledge we have of how people are connected on the relevant network [...] the more chance a policy has of succeeding” (Ormerod 2012, 37).

For instance, supporting small-world properties, while avoiding too much centrality and power for only a few, may render distributions more even and less volatile (their graphs steeper). Put reversely: When *regulating connectivity structures*, the small-world property may not be suspended. Reducing high-level power positions should help stabilizing systems and increasing their resilience (Gallegati et al. 2007; Acemoglu et al. 2012, 2015; Biggs et al. (Eds.) 2015).

*Network structure II – Shaping the system of interaction arenas*: Interaction arenas and cooperation platforms of proper *sizes*, *overlaps*, and *hierarchy levels* need to be considered, since they further shape cognitive and expectational conditions. Such structures will have to

mirror the overlapping and layered *reaches of the basic collective goods* and functions, and the *state structures* need to coevolve appropriately (Faggini, Parziale 2016, on coevolutionary *state structures*). This implies supporting local, regional, national, and global collective goods production through “*structural*” (*industrial, regional, environmental, developmental ...*) *policies* (Chertow, Ehrenfeld 2012). Generating proper *meso* arenas would help to better meet cognitive capacities and increase private problem-solving capacities (Loasby 2012; Charness, Yang 2014). Many analytical, empirical, simulation, and lab approaches have shown that *smaller* arenas within larger topologies promote recognized interdependence and futurity, and with this the quality of private decision-making (Richards 2012; Mirowski 2013; Vega-Redondo 2013; Elsner, Schwardt 2014; Kao, Couzin 2014). This also applies when agents can make voluntary location choices, i.e., spatial partner selection (Berninghaus et al. 2013).<sup>25</sup>

*Reducing turbulence by reducing dis-embedding mobility*: Reducing perceived over-complexity and over-turbulence also is related to providing proper *time frames* and some *deceleration*, required to learn, adapt, habituate, and stabilize expectations and relations (Houser et al. 2014; Acemoglu et al. 2015). One particular implication – most obviously running counter established neoclassical and neoliberal convictions, but making much sense within an evolutionary-institutional interaction perspective – is that such social-capital building may require the reduction of current levels of (*enforced dis-embedding and uprooting*) *mobility* that was so crucial for “flexibility” in the neoliberal narratives, but

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<sup>25</sup> This is of course difficult to police. We made some more operational consideration of shaping arena sizes for the case of rural-to-urban migrant workers in China elsewhere (Dai, Elsner 2015).

usually contributes to high social costs (Glaeser et al. 2002; Room 2011; Solari, Gambarotto 2014).

*Strengthening agent capacities:* Strengthening agents' capacity to deal with intricate problem-structures requires to provide them with improved *information* on their *interaction histories* (memorizing; Houser et al. 2014). Providing sufficient *time* for social learning (general deceleration) also should support capacities to *memorize*, *monitor*, build *reputation*, use reputation chains, and with such information to *select partners*. Policy should also support agents' risk taking, for trying to escape social dilemmas, and non-enviousness, should first cooperators be exploited once (which they can never make up, even if cooperation begins thereafter), further, *searching* and *experimenting*, in order to generate cooperative *minimum critical masses* required to make cooperation superior over all and spread.

*Informational openness and multiple-path creation:* Originally instrumental institutions may, due to their very *habitual* character, degrade into *abstract norms* and *ceremonial* devices, removing themselves from problem-solving when the original problem situation has changed. For instance, with cooperation gains unevenly distributed, a new social dilemma may emerge with the same institutionalized, but now "petrifying" behavior. Proper institutional renewal may be less rewarding in the beginning than the old institution, while superior in the longer-run (Elsner 2012; Heinrich, Schwardt 2013). Restoring agents' problem-solving capacities and promoting *progressive institutional change*, then will require some *break-out* from institutional lock-in. This, in turn, may require some *information openness*. A *multi-standard* or *technological-diversity* policy, breaking up

behavioral (as well as technological) standards, may be required. However, this may not always be feasible under returns to scale and network externalities. So there are critical conditions for new institutional solutions and standards to be learned and for *openness and transition* policies to become feasible, and they may exist in critical time windows only (Heinrich 2013, 2016; Houser et al. 2014; Papachristos 2017).

*Favoring equality*: It has been widely analyzed in interaction models that favoring equality among agents is a policy orientation warranted (Hargreaves Heap 1989; Binmore 2011:165ff.; Kirman 2016:563ff.). Asymmetric payoffs usually increase intricacy and volatility, through continuing income-distribution battles, distracting agents' resources from problem-solving and common wealth creation. It appears also from experimental analyses that more even payoff structures are easier to solve for agents, thus more stable in the longer-run, and *facilitating voluntary collective-good contributions* (Kesternich et al. 2014; Krockow et al. 2015; López-Pérez et al. 2015; Nishi et al. 2015), in this way also increasing macroeconomic performance and perceived welfare (Acemoglu et al. 2015).<sup>26</sup>

## 6 “New meritocracies”, pragmatist policy, and the qualification of the state

The *framework* approach, as laid out, is about shaping constellations for CAS that entail particular adaptive processes among interacting agents with dynamics and emerging structures in favor of superior outcomes, consistent with broad socio-political goals. It is *double interactive* in the sense that it interacts with a CAS and targets the interactions system and self-organizing

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<sup>26</sup> As we have not dealt with evolutionary macro-models with their aggregate agents/components, we will not delve into *macro-policies* here. But this is another area of applied CE and complexity-policy (e.g., Garbellini 2016, on *complexity reductions in fiscal policy* vs. neoliberally generated over-complexity).

mechanisms among the private agents. As it is targeted towards institutional structures, we may also call it *institutional policy*. It provides a clearer definition of the *relative private and public interests* and a more appropriate assignment of the relative private and public responsibilities and contributions, as compared to conventional collective-good theory. In current policy practice, the latter often leads just to bailouts of the big tail risks, to opaque “private-public-partnerships”, and to thriving, but obscure interventionism.

In this framework conception, the policy agent needs to *evaluate the outcomes* of the private interaction processes: What are the *dynamic deficiencies of the system*, their reflections in deficient self-organization mechanisms, and their outcomes? Evaluation criteria will be, as said, the probability of complete blockage of aspired institutional emergence and change, the time required for emergence or change, and the degree of its fragility. Policy then is to unlock/de-block, accelerate, and stabilize emergence. The traditional *merit-good* criteria of “wrong” price and quantity (R. Musgrave) will be extended in view of CAS by the above criteria. Thus, we may speak of a “new meritotics” (Elsner 2001; Ver Eecke 2008).

This, in turn, requires a “*strong*” state, capable of determining the public goods, persistent public objectives, and target levels, independently *evaluating* the private system processes and outcomes, and shaping the critical factors of the processes in a permanent *learning* and *adaptation* attitude, always prepared to quickly and massively intervene in structural and institutional terms. Obviously, this will be infeasible after four decades of neoliberal dismantling of a proactive state. The state would have to considerably qualify and adapt its structures for appropriately complex and effective action.<sup>27</sup>

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<sup>27</sup> For example, see Faggini, Parziale 2016, on coevolutionary federal state structures.

It is hardly surprising that policy implications of CE reveal the relevance of an independent *socio-economic political evaluation* of system dynamics and results. With this, it resonates a conception of policy that was developed in the 1920s by American *pragmatism* and *instrumentalism* (Dewey 1927), further developed theoretically and implemented practically by institutionalism in the 1920s and 1930s as a *negotiated economy* (Commons 1934). As such, it needs to be accompanied, qualified, and developed by a broad process of social *inquiry*, as such socio-economic valuations do not fall from the sky, nor are a “natural” result of a value-free “market” mechanism; they need to be made societally (incl. distributionally) transparent, reasonable, and problem-solving (Ramstad 1991). This conception was rudimentarily applied during the *New Deal* in the USA in the 1930s, and later operationalized by institutionalists into the *instrumental value principle* (Tool 1979/2001). Complexity policy converges with the pragmatist approach of a better problem-solving through continuing inquiry, learning, experimentation, adaptation, and a broad *democratic participation*.<sup>28</sup> It thus not only provides massive new causal knowledge, but also makes obvious the inevitable social evaluations required for institutional reform – with a clear view that intervention, learning, adaptation, and experimentation in policy may never end.

(10,518 words)

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<sup>28</sup> The institutionalist theory of participatory democracy has been further developed in Scholz-Waeckerle 2016.

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