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MASTER'S THESIS

BEHAVIORAL PHENOTYPES IN EVOLUTIONARY GAMES ON NETWORKS

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Master's Degree in Physics of Complex Systems

Centre for Postgraduate Studies

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ABSTRACT

Evolutionary Game Theory simulates collective behaviors to explain the emergence of cooperation from self-interest decisions. Our aim in this thesis is to analyze if uniformity and moderation into the payoff matrices drives to the emergence of higher solidarity, as we have insistently been said by monotheisms, nationalisms and ideologies commissioners; or either diversity, multiculturalism, persistent discussions, even polarized, about the variability in "value scales", about the different point of views and perspectives, as in modern democratic societies, improves the emergence of altruism.

To do so, we will simulate collectives as networks of individuals playing evolutionary games, where they can choose to collaborate or defect, under different parametrizations of the payoff matrices, in addition, to see if diversity of criteria, drives to the emergence of higher collaboration rates in the systems, we include in our numerical model different behavioral phenotypes observed in experiments with human subjects. We conclude as a clear trend that single thought, homogeneity in values and point of views, border lines and closeness, brings normalized societies to lower altruism levels.

1. INTRODUCTION

1.1. THE ALTRUISM PARADOX

A.Smith in 1759 published his "*Theory of Moral Sentiments*", (*resentment, revenge, virtue, admiration, corruption and justice*), as a counter-argument to T.Hobbes' approach on the selfish Nature of the Human Being. From there on is the concept of empathy, although he called it sympathy. Later developing his own argumentation, he convinced himself to the contrary -"*Black Hand of the Market*"-, and 4 years later he wrote "*The Wealth of Nations*", which founded the *Classical Economy* -rational decisions in everyone self-interest-. This controversy has transcended until our time, in collaboration as a motivation opposed to competition: the good man in a society that perverts him vs. the bad man in a society that tames him.

Nor “nice man” or “nice collective” are good or bad. Nor collaboration or competition are good or bad. Nor egoism or altruism are good or bad. Good intentions may produce bad consequences -the opposite can be also true-, and theoretical approaches demonstrate that, with appropriate tunning parameters, from self-interest and imitation emerges collaboration. Individual behavior has not a linear relation with collective behavior. A religion based in unconditional love to all human beings has driven cruel wars, genocides, tortures or slavery. A self-interest economy has driven Humanity to the absolute lowest violence, famine and misery, of all our evolutionary history (S.Pinker). A fist is not always stronger than fingers; or a “fasces” is not intrinsically better than a quiver of arrows. A high level of agreement between most citizens into totalitarian regimes nightmares last century and at the same time, diversity and capitalism, based on egoism and envious, won the deal.

Social ideologies, sustains over a supposed *Natural Morality* understanding -we should be able to say they understood, but unfortunately this is not the case as science “thermalizes” in its transposition to the society-, as an essential linear hypothesis that selfishness generates competitiveness and altruism, produces solidarity. XIX Paradigm was that Natural Morality of Homo civilizes us and separates us from the beast that we would be without Morality ... The first response that we collectively accept, as the first neurotransmitter to occupy its neuroreceptor -even if it is nicotine-, or the first passenger in the plane seat -although with wrong seat number - spends less energy taking its place, than is needed by another passenger, by another more natural molecule, another bacterium more beneficial to the intestinal tract, or another more rational response. In his context, C.Darwin was not so despised "ad hominem" for the evolutionary mechanism that he proposed, as others had tried other alternatives without much success or controversy, but because it implied the eviction of the Natural Morality in vogue (¿ It is bad for a tiger to make its prey suffer?, why is man the only animal that kills without reason? and other mythological rhetoric of the same “sophistry” style). Knight Lamarck's proposal was better than divine response, but not enough to dislodge the professorship seat, by then occupied for priests. But the Darwinian Selection was forceful enough to lift the Natural Morality out of the seat and sit in its place,… so logically, the responses that resisted, insisted that Darwin's alternative response was not complete: competition did not explain collaboration. This was named as *Altruism Paradox*.

Although *Darwin's Theory* is very consistent, as it is deepened, deficiencies were appreciated for those who resist (and indeed that has been a trigger to enrich the theory), which to a greater or lesser extent have been solved: simplicity is more efficient than complexity; preservation is cheaper than innovation;

there is not enough stochastic time for complex life in a random exploration; the environment conditions are strangely restrictive, so that various processes obtain similar results; chirality; the pressure of increasing entropy; patterns manifestation in chaos; complex gaps with no middle steps (like the eye, the self-awareness),... To explain the "*Paradox of Altruism*", P.Koprotkin, both naturalist and theoretician of anarchism, proposed "*Mutual Support*" as a collaborative mechanism opposed to the self-interest of capitalist Darwinism. The *Synthetic Theory* of R.Fischer, J.B.Haldane and S.Wright, sought to negotiate and proposed as an evolutionary unit the "cluster" (which has given way over time, after a degenerate and radical phase, to *Social Darwinism*). Subsequent to the *Kin's Selection*, an attempt was made to justify the sacrifice of the oldest, of mothers, of relatives, ... as competition between lineages -subcolectives-, (the gene as evolutionary unit and the punctuated changes, J.B.Huxley, E.Mayr, R.Dawkins, L.Margulis, S.J.Gould,...). A.Damasio, tried to solve the paradox through the "somatic maker biasing", but Morality was not the final answer for the Altruism Paradox, which became from *Evolutionary Dynamic Complex Networks*.

Since 1957 *perceiver programs* -automatic pattern identifiers- were developed, simulation from Complex Systems has been used in Natural Selection, traffic, politics -*Formalist-Idealist Models*-, distribution logistics, oligopolies –*Cournot's Model*-, social behavior -*Axelrod Model*-, hydrodynamics, prices, ... In the 70s, M.Eigen applied it to biochemical evolution -*Hypercycles*-, J.H.Conway made fashionable his "*Game of Life*" -without players-, automata with three very simple, and unexpected patterns emerged: "gliders," "spaceships," "debris sinks," ... In the 1980s, S.Wolfram and others developed increasingly sophisticated life games, evolving without intervention. *Backpropagation, Adaptive Resonance, Hopfield, Boltzmann Machines, or Anderson Linear Associators*. In the 90s, T.Ray, with the *Network Earth Project*, tried unsuccessfully to explain the *Cambrian Explosion*, emerging without having been programmed symbiosis, parasites, demographic self-control by suicide or sex (29000 genotypes and 300 sizes). J.Holland, proposed the *Echo System*; S.Kauffman, the biochemistry evolution modeling. J.S.Tahakashi's *E-Cell*, accumulates 20 years of development of enzyme reaction simulations and is operated in 3D with the Remote Wii. Self-organizing properties, unstable equilibria and extinctions, ... patterns within the chaos emerge from the simulations. *Technosphere*, in which users could create their creature, had 90,000 bugs. The *Wilderness Downtown* combines artificial life technologies, with real-time animation superimposed on Google Street View images. *Second Life, Wiggle Planet, Grandroids*, ... Web 2.0 itself opens up new perspectives on simulations of complex adaptive systems, models in flow diagrams and networks, which end up proving to meet all the requirements of being alive. Evolutionary Network Games attract multibillion-dollar investments, due to their potential in stock market predictions or in natural language translators and "interfaces". In the *Openworm* project, since 2011, S.Larson and his team try to copy the 959 cells, where 302 of them are neurons, of C. Elegans, in a computer, trying to create a functional organism. The *Human Brain Project* to develop the *Connectome* is the budget-star of European scientific projects, with permission from ESA and ITER.

Social perception of the relationship between individual egoism and solidarity in the group is represented in the *Tragedy of the Commons* (G.Hardin, 1968), which describes a situation in which several individuals, motivated only by personal interest and acting independently but rationally, they end up destroying a limited shared resource (the common one) even if none of them, either as individuals or as a whole, it is convenient for such destruction to happen. Networks have no obligation for a single equilibrium solution, let alone an optimal dynamic to achieve it. Promoting fear or hope can be double-edged weapons, and depending on the rules of interaction and matrix values, it may be the

opposite of what is perceived as a plausible result. Depending on what it is simulated, the observer may be interested in collaboration or competition.

Perhaps the collective is interested in a competitive economy and a collaborative society, or a collaborative economy in a collaborative society, or a collaborative consumption with competitive suppliers,... there are no good or bad, and if there are, the good can do bad things for good reasons and bad guys can do good things for the wrong reasons. In simulations, *"Payoff" values and imitation rules*, drives the general tendency to cooperate or compete, but in reality there is diversity and certain individuals tend to hope and others to fear. Simulations in Evolutionary Dynamic Networks, prescribe that collaboration can emerge from egoism, or competition from altruism. The *Natural Morality* claimed by each political option, the Kinship or Mutual Support, the attitude, the conviction, the awareness, the education, the kindness, the tolerance, the propaganda, ... can influence the parameters of value and dynamics of the simulation models that predict the emergence of collaboration patterns , but self-ethical attitudes are not necessary to explain the *Paradox of Altruism*.

In a paper titled "*Is There a God?*", B.Russell in 1952 wrote: "*Many orthodox people speak as though it were the business of sceptics to disprove received dogmas rather than of dogmatists to prove them. This is, of course, a mistake. If I were to suggest that between the Earth and Mars there is a china teapot revolving about the sun in an elliptical orbit, nobody would be able to disprove my assertion provided I were careful to add that the teapot is too small to be revealed even by our most powerful telescopes. But if I were to go on to say that, since my assertion cannot be disproved, it is intolerable presumption on the part of human reason to doubt it, I should rightly be thought to be talking nonsense. If, however, the existence of such a teapot were affirmed in ancient books, taught as the sacred truth every Sunday, and instilled into the minds of children at school, hesitation to believe in its existence would become a mark of eccentricity and entitle the doubter to the attentions of the psychiatrist in an enlightened age or of the Inquisitor in an earlier time."*

The tea pot here is the linear assumption of uniformity in the right values of the citizens, to reach the right values of the whole society. We have been said that education has to uniformize the right values that defines each collective and polarization is seen as a threat for the good of all. So we design training in values, we claim for awareness about collective goals as happiness, wealth, environment quality, justice, and so on. The linear hypothesis that fills our "Zeigeist" is: the more uniform value set, aligned with the society goodness, will gain efficiency to reach the collective goal. But societies are not linear.

Both competition and collaboration can achieve collective efficiency -improvement- in the result of a sequence of decisions. From computer simulation models of *Multipersonal Network Game Theory*, they emerge in very diverse assumptions and environments, just by tuning the Payoffs and the imitation rules. Competition and collaboration are neither good nor bad, but adequate or inappropriate criteria for objectives that the subjects do not know, but that are guided by efficient causes at different scales. At least as a hypothesis based on simulation models, today we know that there is no opposition between individual and collective interest, that the second emerges from the first and that from the second the subdivision of the community into "clusters" by alliances. Collaboration can emerge from selfishness, as well as collective solidarity does not have to emerge from individual altruism. At least in the current scientific paradigm it is like this, after the phase of ideological opinions has already passed through morality.

We know how one strategy on one scale can imply the opposite on another (it seems that voters do not want to know, and we all continue to assume that solidarity attitudes generates collaboration, and competition inequality, at all scales). The political assumptions that are repeated with different rhetoric and labels, that a better average payoff, with less standard deviation, is obtained from the collective interest, are unfounded in the models, at least as a generic norm. It wasn't that !: There is no contradiction, but complementarity, scale, emergence, and feedback. Furthermore, we know how parameters affect dynamic processes, although they are described without the classical differential equations, since the equilibria solutions of the networks are not unique, but with computer codes.

On the 33rd night, Sherezade sang to the Sultan:" *In business, necessity forces you to do what is not right, because nobody does anything if what you do does not bring you benefits".* It is the holistic -network structure- that can generate more or less collaboration according to the distribution of payoffs in a uniform network. From the interest of the "nodes" -individuals- in improving the efficiency in their relationships with other nodes, the efficiency of some "clusters" -alliances- or of the entire network may emerge, which in turn improves the statistical efficiency in the system nodes, giving feedback. Whether due to their own statistical nature or due to the conditioning of mathematical tools, well-known phenomena in thermodynamics appear universally and are experimentally verified, such as phase changes, resilience, local equilibria,...

A.Damasio describes rationality as a methodology of slow decision making in situations of uncertainty. A luxury of the tranquility. We are the story of the individual decisions we make: hundreds or thousands each day. Irrelevant or transcendent, individual and collective, rational and instinctive, they have the same mechanism with a diversity of values. All decisions are economic, although most are not monetary (Marxist Dialectic when applied to classes, or today, to all kinds of collectives): they weigh expectations of efficiency, that do not have to coincide with the consequences. Expectation and result. "Verba et facta".

The distance between expectation and benefit is the risk, uncertainty, conditioned by the limitation of the rhythm of time and of the energy invested in harvesting, weighing and storing the information. The time and effort for a decision thus limit the availability of information. Sometimes we weigh with monetary values, others for convictions, customs, intuition, ... but whatever the unit of measure in which we group all the pros and cons of a decision: cents, "likes", concentration of oxytocin, adrenaline or testosterone , seconds, watts, years in prison, applause, kisses, hugs, ... we value options with monetary, ethical, emotional and risk criteria. A baby's laughter has value -that can be simulated in a payoff matrix-, and a price in "happiness cents": when making the decision to go to prepare dinner or play with the child, we assign payoffs to each option, perhaps not in paper money, but in some currency that is ultimately listed at the self-private currency exchange office. The price depends on the exchange rate to the "currency" that we take as a reference in a more or less personal-social scale.

The surviving remains of the "*Moral Sentiments"* and "*Wealth of Nations"*, of "*The Capital"*, merge in the same environment: Value and Rules. A.Machado summarized, *"It is not wise to confuse Value with Price"*, because only a small part of value, has a price agreed between all. That does not mean that the price of what has no price is null, but it has not been agreed according to the mechanisms of the Market Laws and remains on the private currency exchange priorities (moral, preferences, beliefs, opinions,... let's resume all them on "attitudes"). Individual currency exchange tables are not public, nor homogeneous! All currencies have value and have a consensus exchange rate, not the value of a poem

or a friendship. It is very foolish to confuse currency with price, and damn foolish, to confuse unknown exchange rate with null or infinite value (the value with no price, is a distribution in which an average has not been agreed). If individual currencies are not optimized by a market of moral values, they can never be homogeneous and shared by all citizens.

There are natural values -programmed in our genome-, such as love for children, that no one votes; and cultural values -programmed in our culture-, such as rights and duties, which some vote from time to time. Both are, to a greater or lesser degree, imposed values: they have been selected as what identifies us as a species, as a collective and as a tribe. Quick decisions, with no time to collect and weigh information, tend to be emotional, pre-programmed, intuitive. Slow decisions can afford the energetic luxury of gathering more information, being somewhat rational, and described by classical sociology and economics. However, "classic" comes to indicate deterministic developments - linear or multilinear, computable - from ideal assumptions. Dimensionless points, isolated systems, ... are necessary, but in themselves self-limiting by their own paradigm. If the decisions are not rational, the information is not complete, the market is not perfect, ... the falsifiability of classical economy collapses.

In 1979, the theory of decision-making gave another twist to the classic conception of equilibrium, of altruism that forces cooperation and rationalism to emerge, from the hand of D.Kahneman & A.Tversky, (*Prospect Theory*), according to which individuals make decisions in uncertain environments that deviate from probability -*heuristic shortcuts*-. An example is *loss aversion* or a tendency towards conservatism or conservationism -which we have already discussed-, depending on whether it is a right-wing or a left-wing aesthetic: an individual prefers not to lose 100 before gaining 100, which implies an asymmetry in decision making (seller and buyer).

Behavioral Economics certified its maturity with the Nobel Prize to R.Thaler, for whom traditional models -rational slow decisions- suppose our own interest, but that in reality we have no self-control, and our beliefs and opinions (attitudes) skew decisions about the price of values. From here, the uniform bias is incorporated into the decision-making theory by modifying the payoff in the models of social and economic simulation, but the diverse bias according to groups or individuals that are variously permeable to the environment, homologated as "clusters" with a collective interest, skews the same social or economic network (as in Relativity, the scenario is incorporated into the script). No-rational, *Behavioral Sociology* has not yet been developed and politics continues to be exercised assuming rational decisions, with complete information and analytical description (opinions), or appealing to grudges and fears (emotions), without a weighted approach. To dilute the individual personality of each node in a cluster community, is to make a person an example of the subspecies of which they assign an example: coarsening (change the scale assigning a grain size for uniformity of the cluster emerging the state variables, i.e. PVTS in gases, MCWS in black holes,…).

For a *Behavioral Sociology*, religions, ideologies, parties, homelands, identities, ... are not only rational opinions, but also cultural, moral, emotional and risk aversion attitudes. In their behavioral role, they permeate and biased diversity, all the more standard deviation in the distribution of biases, and radical attitudes: they take on the market in different ways of the types of currency exchange with which the value is quantified . "Educating in Values", it is just like intervening a bias in the exchange rates in the each one’s payoff matrix and imitation rules. Topic or phenotype, in this case it is an example of the uniform specimens for being from a group (substitution of the values of each agent in the system, by statistical values of the set, which do not have to be the mean).

To simulate the link network not uniformly, it is not enough from this behavioral point of view to skew the payoff, but rather the structure of the network and its communities change the decision strategy. The incorporation at the "node" or "cluster" level, of prestige -the specific weight of each node according to its relationships-, conservatism -the fear or value of risk-, envy -the probability of imitating more efficient behaviors- , contempt -the probability of eliminating and / or replacing the link-, ... provide more elaborate criteria in simulating a dynamic than mere "self-interest", making it depend on the position and weight of the "node" and the "link "… Of how people, animals, products,… the agents of a system are related; but the description is not complete if we do not introduce the Behavioral Bias of the ideologies, homelands, religions, identities, ... of the "cluster" or sub-collectives that are reinforced in the dynamics of a non-uniform network: the bias in values, that are not the same for all.

For some "clusters" murder is less valuable than blasphemy in their payoff matrices. The price is a democratic payoff, as buyers and sellers vote on each transaction and agree on the exchange currency value. The moral value, an imposition that may not be so democratic, when voting indirectly at best, conditioned by biases and from time to time (it is an intervened market). The clusters are standardized in the models due to the cultural value agreed by the individuals who share ideology (cultural bias). Emotion is dictatorship of the subconscious: predetermined decisions, almost reflex acts, which can also be conditioned: attack or flee, fear or confidence (heuristic bias). The exchange rate is established by each individual, who, if he belongs to a "cluster", tends to share an attitude as well. In deciding we had already made the decision because the pressure of being part of a collective. This subjectivity means that the payoff of each set of values to be considered in a decision can be as uniform as the values are agreed or depend on the ethics -scale of values- of each "cluster" or the emotional state of each individual, as long as it is for the value that each assigns to the variables that are taken into account in the decision. There is diversity in the expectation of efficiency, not only by structure, but also by scale and spirit (fear or hope, flee or attack).

Heating the coffee in the morning is a decision that includes concentration of neurotransmitters, expectation of less drowsiness, time spent, pleasure in taste, cost of energy and coffee, availability of the products used, inertia, routine, ... Is it worth it? worth getting up 10 minutes early? The decision to leave home for breakfast is an economic decision in a currency that can be translated into a payoff matrix sized in money or other currencies. Gold was not of the same value to the conquerors as the trinkets, but neither was it to the indigenous: both had expectations of efficiency in self payoff matrix. Each believed to improve with barter. Thus, payoff is the result of adding weightedly the expectations of improving valuations when making a decision, which is always economic in the broad sense of the term, among: Monetary, Risky, Ethical and Emotional Values.

All private decisions indirectly or directly affect the decisions of others and although having coffee in the morning can be described according to a decision-making chart disconnected from the network, in which we make an optimal between investment and profit; perhaps the decision to start when the traffic light turns green, should include within the values to be weighted, that we can run over a pedestrian who is running in amber. Decisions are made in a social network environment in which there are no clear optima, but pseudo-equilibriums of commitment (J.Nash), near to equilibria but out of it, enough and satisfactory, that do not have to be unique.

Every experimental or observational theorem, theory, or interpretation is true only within the limits of its Paradigm. Until just a couple of generations ago we lived in the deterministic paradigm. When

P.S.Laplace, the greatest exponent of Determinism, presented Napoleon his Celestial Mechanics, he asked him: "*What role does God have in all this?*" to which he replied *"I have not needed that hypothesis*". We could paraphrase the situation of Morality into the *Paradigm of Evolutionary Dynamic Networks Simulation Models as*: "**What role does attitude have in the Emergence of Solidarity and Collaboration?"** ... Maybe the Morality or the Attitude of each individual are not the answer to the *Paradox of Altruism*, but they are a factor to take into account in the payment matrix and the rules of interaction.

Governments, monotheisms, nationalisms or ideologies, propose linearity between individual and collective goals, so that they will improve collaboration or competition of the collective, modifying and normalizing the payoff matrices of the individuals for collaborate or compete through laws, norms, education, media -awareness- and prices. They can indeed do so intervening value matrices, while if there is no linearity they risk to obtain emergence of the opposite, and if uniformity on those values is taken as the way for granted, why diverse and democratic societies have reached historical unknown levels of collaboration and improvement in expectations for a fullness live? Why in markets, uniformity means strongest benefit reduction and specialization is taken as the way for efficiency?

Here I will try to answer through statistical simulation of a self-interested and imitative collective, if cultural uniformity and moderation on values are the proper path to improve collaboration, as proselytism claims. Following the success of Evolutionary Dynamic Networks to explain collective collaboration into a competitive Darwinian environment, I will apply the same methodology to improve the model with variability of “value scales” and measures if its uniformity of currencies between ethical, emotional, risks and prices, for the agents of a collective, improves the altruisms, as ideologies, religions, teachers or nations, claim to be.

1.2. SIMULATION AND DRIFTS

In the 13th century, R.Llull conceived in his *Ars Magna*, a reasoning system by logical rules (automata thinker), with which he tried to evangelize Muslims. He explained it in a “functional” graph (the first in history). In the first half of the s. XVIII, L.Euler properly started the *Graph Theory* with the "*The Königsberg Bridges Problem*". A century later, G.Kirchhoff applied it to electrical networks; F. Guthrie raised with her first theorem with "computerized" proof: the "*Four Color Problem*”. A century later, graphs were used in *Operational Research* to determine "optimal paths" (APSP, SSSP, GPSS, SIMSCRIPT, ...) and in distributed computing, for the first seeds of what will later become to be the Internet.

Also in the middle of the last century, in the context of the Cold War, O.Morgestern and J.vonNewmann, proposed *Game Theory* as a way to study strategic interactions between the two blocks and used as a demonstration of "*Mutual Guaranteed Destruction*". Concepts that will be later developed in several variants, -i.e. cooperative and non-cooperative games, zero sum vs non-zero sum,...-, mainly in the context of the Economy. Intimating the next revolution against the “classical” paradigm, I.Asimov, as early as the 1950s, cites H. Seldon's Lecture at Trantor University: *Can History be coded by a simpler simulation, than History itself?* Or, in another way, *is reality the Algorithm of God (the optimal factorization) or can it be fully described with less information?* o *Is the reality computable, ... contingent?* H. Poincaré and S.Lyapounov had already established that in general it is not, (except in those processes that Stuart Mill, announcer of *Emergentism*, called *holopathic* and that we now call *linear*).

Overshadowed by a more spectacular Quantum Revolution, based on Indeterminacy, the Non-linear Statistics Revolution based on Uncertainty was discreet. Also parallel to Informatics, it began to develop in the same quantum environment, due to the need to solve non-linear systems of differential equations, with stochastic methods such as *Monte Carlo* (S.Ulam & J.vonNewmann) in the *Manhattan Project*. During the Cold War, the use of numerical simulations was intensified to solve problems of military interest; trajectories and dynamics of artificial satellites, guide missiles, pilot and astronaut training, weather forecasting, air traffic control, communications, computing, logistics, etc. In the 70s, trying simple atmospheric simulations E.N.Lorenz and the *Chaos Theory* development, collapsed the linear deterministic paradigm also at the macroscale; M.Feigenbaum discovered *Universality*; B. Mandelbrot the *fractals*; I. Prigogyne did the same with the thermodynamics out of equilibrium; R. Myerson combined networks, games and complexity; Harsany and Selten studied games with *incomplete information* and *imperfect markets*, as well as "*trembling hand equilibria*"; computer scientists created networks such as ARPAnet; and new practical applications followed in multiple fields such as chemistry, biology, ecology (R.Margalef), linguistics, sociology, ... with approximations of biased, asymmetric, stochastic situations, .. imperfect and not ideal. In 1984 the *Santa Fe Institute* was founded.

Graph Theory, Game Theory, No-Linear Statistics, Systems Theory and Chaos and Computing, joined to develop simulations of collectives to describe strategic interactions in decision making. Since those seminal works, the *Cooperative Game Theory* or the *Multipersonal Decision Theory*, have been announced, but until the availability of supercomputers to simulate large networks, in the late 20th century, the applications of Game Theory on Complex Networks was limited. Systems Dynamics in general and the Economy in particular, traveled at the turn of the century, with computer tools, from ideal conditions to *Complex Dissipative Systems, asymmetric, incomplete, diffuse, scalable, ...*; mathematically describing situations that were intended to overcome the self-limitations of classical rationalistic idealization. Inside that context, we can answer the Queen of England, who on her visit to the London School of Economics, asked in 2011, "*Why nobody had predicted the credit crunch?*": Classical Economics starts from ideal conditions (*rationality, balance, symmetry , complete, transparent information, isolated and perfect market, unlimited availability of time, capacity of process and memory, computability and absence of risks -linearity-*). Deterministic economics can explain and predict those *homopathic* or, with computers, even *hemipathic* processes (multilinear, complicated but computable), but not *heteropathic* (complex).

Altruism emerges for a set of parameters, from a rational and uniform evolutionary dynamics, in which agents decides in terms of self-efficiency, if cooperate or defect, and evolve imitating the success of their neighbors. However in reality cooperators are diverse and do not share the payment matrix in time, nor in their interaction priorities and imitation, neither in its evaluation, nor in expectations, nor in information, nor in scale, nor in distance, nor in density, on the others, and biases are manifested when comparing those simplistic modeling with reality. In reality, decision maker agents may be diverse in:

- *Resilience*: adaptability by changing strategy if the other players with better results
- *Risk aversion*: the conservative bias is all the more pronounced the closer is to equilibrium
- *Prestige*: the weight of each node depends on the relationships with the others (“scale free”)
- *Punishment*: the probability of imitating can promote the change of players (“rewiring”)
- *Term*: structuring parallel networks with different payoff’s according to short-medium-long terms (“layering”)
- *Noise*: adding randomness according to a pseudolinear structure (Langevin) in payoff

- *Asymmetry*: decision boxes in which the “row player” and the “column player” are weighted differently
- *Memory*: probability of strategy changes according to statistical values that depend on the improvements obtained in previous games (Bayesian’s probability).
- *Visibility*: the probability of change in the pay offs if the player thinks he is being watched (adding the "distance" in the memory algorithm)
- *Volatility*: unpredictable changes and randomness
- *Decoherence*: influence from outside of not-isolated systems from the observer, propaganda, morals, legislation, ...
- *Attitude*: fear or hope, mistrust or joy, morality, beliefs, ...

In *Multipersonal Decisions Simulations* with ideal information environments and strategies, collaboration can emerge from the competition for the interest of each player by adjusting the payoffs based on the imitation of better performers between neighbors, standardized by sub-collectives - "clusters" and coalitions - with their own interest, in a dynamic which can tend to a local equilibrium. The biases could be modeled, as a whole changing the overall matrix -as governments, religions, education or media, uses to try intervening the normalized and uniform payoff matrix-; or agent by agent, if it is assumed that payoff matrices and imitation and rewiring probabilities are diverse. More than this, they can be modeled with the asymmetry of the matrix, the rules of interaction, rewiring and imitation, the time scale, the memory and the noise dynamic, the distance for neighbors, evolving not homogeneously for every decision maker. However biases can also be diverse according to the structure of the network and its “clusters”, within a non-uniform set.

Weighting its diversity, which not only achieves different payoffs depending on the structure of the network, but different evolutionary strategy rules according to biases, not only behavioral. Each individual makes different decisions in analogous situations:

- the values of each variable are not always agreed (value and price)
- different groups - “clusters” - agree different values for the same variables
- time for decision making skews the assessment (rational-slow, instinctive-fast)
- monitored decisions (feeling observed by others), or distance of transparency to which neighbors are influenced (the success of a reference influences more than that of a stranger)
- collecting the information requires exponential effort (the same decision of the amount of effort to invest to collect information for a decision is a decision itself)
- the information is not uniform for all agents in the system, nor complete
- the same groups and individuals propose different expectations at different terms
- there can be the seller-buyer asymmetry, the one that proposes and the one that decides, ... the value of punishing is not the inverse of benefiting
- the diverse influence of individuals and groups on other individuals and groups
- changing is more expensive than resisting (occupying the seat first)
- the history of triumphs and disappointments in previous similar decisions, as well as inertia and habit (memory)
- a system is never perfectly isolated, (the observer or the stage are part of the script)
- the attitude, the humor, the fear, the hope, the morality,… both of the culture, of the clan or of the individual, propose different values in different situations.

Because all those considerations, I have chosen an game theoretical approach to simulate a society with variability in the "value scale" of each agent, leaving apart the other biases for the sake of measuring the effect.

1.3. EVOLUTIONARY GAMES ON NETWORKS

To describe the real relationship structure of a community, there is not a continuous and void-free *Network Structure Palette* as a candidate to represent a society, an ecosystem or a market, so I will consider here in several standards, each one representative of real social interactions. The overlapping will be qualitatively defined, and there are several families of networks to consider, while here I have taken the most commonly used as representative.

Network models can incorporate several ingredients to mimick features observed in real societies, such as: *asymmetry in interactions, non-normal distributions, incompleteness, memory effects, clustering,…* but to isolate individual variability, in this thesis I will focus on:

- *Erdös-Renyi random graphs (ER).* A graph is constructed by connecting pair of nodes randomly. Each possible edge is included in the graph with probability p, independently from every other edge. In this work we set the p=0.3 as representative value. However, ER graphs do not have two important properties observed in real-world: they do not generate local clustering; and they do not account for the formation of hubs, because its degree distribution converges to a Poisson function, rather than a heavy tailed power law.
- *Watts-Strogatz Small World networks.* Those networks are created starting from a regular ring, where each node is connected to its 4 closest neighbors and then rewiring links at random with probability p. In this way the high clustering coefficient of the ring is almost preserved but the typical distance between two randomly chosen nodes grows proportionally to the logarithm of the number of nodes N in the network. Its construction is to solve the low clustering issue said up for random. In this job I have chosen as representative a rewiring probability of 0.2 and an initial degree of 4.
- *Barabási-Albert Scale-Free networks.* This model incorporates two important general concepts: growth (number of nodes in the network increases over time); and preferential attachment, (the more connected a node is, the more likely it is to receive new links). Its construction solves the power law degree distribution issue. Nodes with a higher degree, have stronger probability to grab links added. As representative I have used a degree coefficient of 4, limited by the small size of the 50 nodes used as standard for this work (while in specific cases I have used 150 or 500 for comparison).

Taking as a condition the rest of biases as fixed, in this work we try to analyze the tendency to altruism through mathematical simulation of a society represented by individual decision makers -each network node represent a player and each one plays with his neighbor-, structured in different but overlapped social networks according to rules and procedures of Evolutionary Game Theory.

J.Maynard Smith, 1982, realized that an evolutionary version of game theory does not require players to act rationally—only that they have a strategy. The results of a game shows how good that strategy was, just as evolution tests alternative strategies for the ability to survive and reproduce. The success of a strategy is determined by how good the strategy is in the presence of competing strategies (including itself), and of the frequency with which those strategies are used. Participants aim to produce as many

replicas of themselves as they can, and the payoff is in units of fitness (relative worth in being able to reproduce). To mimicry the evolution effect in game theoretical models, several evolutionary rules have been proposed. In this work I will focus in the so-called Replicator Dynamics, where the reproduction probability of a strategy is proportional to the fitness it can generate with respect to the other strategies. In other words how the fitter players will spawn more replicas of themselves into the population and how the less fit will be culled, in a replicator equation. Games are run repetitively with no terminating conditions. Results include the dynamics of changes in the population, the success of strategies, and any equilibrium states reached.

Specifically, we will focus on a palette of 2-players games that combines, without overlapping or empty values, according to the values of the payoff. In each game, player has only two possible strategies: cooperate (C) or defect (D). Payoffs from each strategy are defined according to the payoff matrix defined below and can be summarized as the following: if both players cooperate, a Reward R=1, is received. If both players decide to defect both receive a Punishment (P=0). In the case of one player cooperates and the other defects, the defector gets a Temptation payoff (T) and the cooperator a sucker payoff (S). Finally, varying the values of both T and S it is possible to simulate four different games characterized by different equilibria.

	C	D
C	**R**	**S**
D	**T**	**P**

With appropriate choose of values, several standard games can be played as a single one:

- Mutual benefit -*Harmony Game*-, HG. $R \geq T$ & $S \geq P$.
  This game is structured in such a way that individual and collective interest coincide. Therefore the best strategy for all players is to cooperate and there is not dilemma.
- Mutual prejudice -*Hen or Chicken Game*- $T \geq R \geq S \geq P$.
  Also named *Hawk-Dove* or *Snow Drift Dilemma*, SG. It is an anti-coordinator games, used in the cited mutual assured destruction of nuclear warfare. The underlying concept is that players use a shared resource that creates benefits for all. The resource is non-rivalrous, and the shared usage creates positive externalities. Because the loss of swerving is so trivial, compared to the crash that occurs if nobody swerves, the reasonable strategy would seem to be to swerve. If one believes one's opponent to be reasonable, one may well decide not to swerve at all. In the belief that they will be reasonable and decide to swerve, leaving the other player the winner.
- Collective resources -*Stag Hunt*- SH. $R \geq T \geq P \geq S$.
  Also known as *Assurance or Trust Dilemma*. It is a coordination game where players can cooperate for a common goal (hunt a stag) or decide to act alone (defect e.g. hunt a hare). Each player must choose an action without knowing the choice of the other. The coordination of the two players is needed to hunt a stag, otherwise they would not be able to do this. If an individual hunts a stag, they must have the cooperation of their partner in order to succeed. Instead, an individual can get a hare by himself, but a hare is worth less than a stag.
- Trust and mistrust -*Prisoner's Dilemma*- PD. $T \geq R \geq P \geq S$.
  Two members of a criminal gang are arrested and imprisoned. Each prisoner is in solitary confinement with no means of communicating with the other. The prosecutors lack sufficient

evidence to convict the pair on the principal charge, but they have enough to convict both on a lesser charge. Simultaneously, the prosecutors offer each prisoner a bargain. Each prisoner is given the opportunity either to betray the other by testifying that the other committed crime or to cooperate remaining silent.

In a well-mixed population, the symmetric Nash equilibria for each game are as follows: PD and HG have one equilibrium, given by the pure strategies D and C, respectively. SG has a stable mixed equilibrium containing both cooperators and defectors, in a proportion that depends on the specific payoffs considered. SH is a coordination game displaying two pure-strategy stable equilibria, whose bases of attraction are separated by an unstable one, again depending on the particular payoffs of the game.

A model in evolutionary game theory is made complete by postulating the game dynamics, i.e., the rules that describe the update of strategies in the population. Depending on the problem, different kinds of dynamics can be appropriate. The game dynamics can be continuous or discrete, deterministic or stochastic, and within these major categories a large number of different rules can be formulated depending on the situation under investigation. On the macroscopic level, by far the most studied continuous evolutionary dynamics is the replicator dynamics. In biology, unlike in classical game theory, players do not choose their strategy and cannot change it: they are born with a strategy and their offspring inherit that same strategy; but in human societies, individuals may change its strategy if each one compare his efficiency vs the efficiency of their neighbors strategy, and with some probability humans are able to change their minds by imitation of success.

In this work, the code to run through the virtual experiments is built on *Wolfram Mathematica* 12, simulating several networks (All-to-All*, Random, Small-World, Scale-Free*), each of them representing an individual, interacting with other through decision games, each of them representing a decision for its self-interest: cooperate or defect; driven by a Payoff Matrix.

For this, tanking R = 1, P = 0, and varying T & S in the range $0, 2 \geq T \geq 0$ & $1 \geq S \geq -1$, will allow me to cover all the four games described above and test them on networks, built with different parameters (ER graphs, with probability p = 0.3) , (WS Small World, with rewiring probability 0.2 initial degree 4) and (BA Scale Free, with M = 4 & 8). As criteria for evolution, I assume a “Markovian” memory of a single previous experience.

As *Initial Condition* for each experiment, each node choose to collaborate or defect with probability 0.5. After each time-step the evolutionary dynamics takes place based on the finite population equivalent of the replicator dynamics: each node compares the payoff earned during the last iteration with one of neighbors, chosen at random. If its payoff is worse than the partner’s, the node changes its strategy with a probability proportional to the difference between the payoffs; otherwise, it remains with the same strategy. This process is iterated a hundred times to simulate evolution, and the last 10% time-steps, are stored for statistical purposes. Each experiment is done 20 times, and then the average fraction of cooperators in the system and its standard deviation over the different runs is calculated.

To verify the code, I tested it in an all-to-all network of 50 nodes, compared with theoretical predictions:

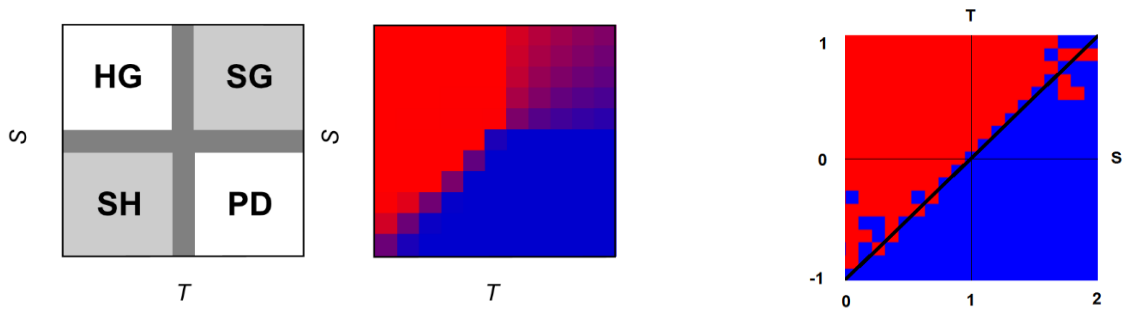

Figure 1. Comparative between TS Space codification, with R=1, P=0, for the Game Palette. Al the left hand side, what it is expected; and in the right hand side, my numerical result.

As it can be seen from the results in figure 1, the present code successfully replicates the theoretical predictions, and collaboration emerges from game iteration between players with selfishness and imitation criteria into certain parameters, generating coalitions that tend to become uniform. For comparison purposes, I evaluate it not only for a *Renyi-Erdös Network* -; but also for a *Watts-Strogatz Network*; or a *Barabàsi-Albert Network*. Results not showed as they are redundant with next results.

1.4. BEHAVIORAL PHENOTYPES

We will not describe reality without consolidated verification, but neither we will understand it without reduction and understanding of its parts. The least bad between too simplified methods. Simulations require reductionism of complex holistic relationships to reconstruct them in an environment of simplification and disregard of variables and irrelevant relationships, to compare results with reality (thus, simplification is consolidated in its limits or paradigmatic assumptions). To analyze experiments we must walk step by step, changing one parameter at a time and leaving a control basic environment. By not incorporating diversity through asymmetry, expectation, rewiring, memory and noise; we intend to place ourselves in a known starting situation, from which to include Attitude as a variable bias.

Related and subject to biases of **Attitude**, of which morality, such as psychological heuristics, emotional instincts, external propaganda, social pressure, cultural values, ... are modes. Restrepo (2009) cites some styles and strategies of extreme decision-makers:

- *Selfish*: systematically disappoints.
- *Altruistic*: always collaborate.
- *Crazy*: collaborate or defraud randomly.

Government and Management uses to design payoff matrices -or try to-: incentives and punishment expectative for citizens behavior. So, attitude can be generically modified by the expectations of efficiency improvement that are driven by media or political pressure, marketing and branding (uniform payoff matrices evolution); but also individually perceived and expected differently by different citizens or sub-groups (individual payoff matrices evolution). Generic attitude is for everybody, set by laws, economics, policies, media hart-cleaning,… The starting hypothesis to verify is that a society in which there is a structure of hopeful sub-collectives and fearful sub-collectives will behave differently than a uniform society with single thought and common shared values.

In J.Poncela et al. (2016), the authors measured the behavior of a set of 541 human subjects in a controlled experiment playing the mentioned Game Palette 8633 times. They found that some of them (n = 110 or 20% of the population), plays a sustainable biased strategy wherever T < R (that is, they cooperate in the HG and in the SH and defect otherwise). By using this strategy, these subjects aim to obtain the maximum payoff without taking into account the likelihood that their counterpart will allow them to get it, in agreement with a maximax behavior. Accordingly, they call this phenotype "optimists." Conversely, they label subjects in the second phenotype "pessimists"(n = 113 or 21% of the population) because they use a maximin principle to choose their actions, cooperating only when S > P (that is, in HG and SG) to ensure a best worst-case scenario. The behaviors of these two phenotypes, which can hardly be considered rational, are also associated with different degrees of risk aversion. As was the case with optimists and pessimists, third behavior phenotype (n = 161 or 30% of the population), is far from being rational in a self-centered sense, in so far as players forsake the possibility of achieving the maximum payoff by playing the only Nash equilibrium in HG and exclusively cooperate in the upper triangle of HG, that is, wherever (S − T) ≥ 0. In turn, these subjects seem to behave as driven by envy, status-seeking consideration, or lack of trust. By choosing D when S > P and R > T, these players prevent their counterparts from receiving more payoff than themselves even when, by doing so, they diminish their own potential payoff. The fact that competitiveness overcomes rationality as players basically attempt to ensure they receive more payoff than their opponents suggests an interpretation of the game as an assurance game and accordingly, they dubbed as "envious." The fourth phenotype includes those players who cooperate in almost every round and in almost every site of the (T, S) plane (n = 90 or 17% of the population). In this case, and opposite to the previous one, these players' behavior can be associated with trust in partners behaving in a cooperative manner. Another way of looking at trust in this context is in terms of expectations, because it has been shown that expectation of cooperation enhances cooperation in the PD. Lacking an unambiguous motivation of the observed actions of the subjects in this group, they named "trustful" to refer to this phenotype. Last, the unsupervised algorithm found a small fifth group of players (n = 66 or 12% of the population) who cooperate in an approximately random manner, with a probability of 0.5, in any situation. For lack of better insight into their behavior, they refer to this minority as "undefined."

The objective is to evaluate quantitatively the incidence of individuals' biased attitude towards ethics, inequality, cultural diversity and misinformation or the atmosphere of fear or hope that drains different personalities differently. We have been insistently said as obvious by education, by media, by institutions, that apprehension or trust that a society generates in the decisions, it makes to adapt to changes. This could maybe be true in a linearly related collective: trust generates wealth and wealth, trust, from which emerges in a network of defectors, collaboration. A society in which its citizens trust: each other, in institutions, in contracts, in justice, in laws; it is supposed to be a progressive society because it changes with hope, obedience and ordered, and it has mechanisms of adaptation to unintended objectives. We have been insistently said that a distrustful society is a fear society in which some become defensive -*phase of ignorance*- against changes, or they counter-offensive -*phase of knowledge*- against changes (the two most commonly used approaches dispute the vote). Both will continue the phase of haggling, even fury, with reality, either from the previous internalization or from a theoretical hypothesis about what should have been. But what we have been insistently said is just a reasonable hypothesis,… is it true?

To test this hypothesis, we will simulate an evolutionary game on different games, including the behavioral phenotypes just described and calculates how cooperation varies withs different parameters and structures.

2. EXPERIMENTAL DESIGN

2.1. NETWORK SIZE

Running experiments for full TS-Space shows an overall insight with low precision. In this section, in order to have a more detailed understanding of the effect of the inclusion of behavioral phenotypes on the game dynamics, in the next experiments we will focus in the region S=0 and 1<T<2, which means a border line between the Classical *Prisoner Dilemma*, PD, and the *Snowdrift Game*, SG.

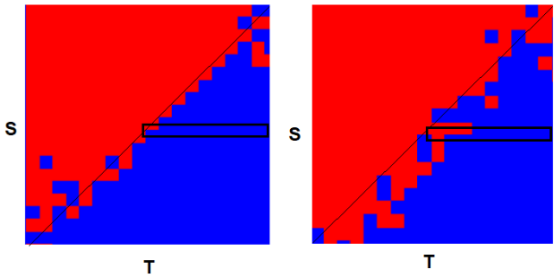

Figure 2. TS-Space for a 50 nodes Full Connected Network uniform, compared with the same with 30% variability. The area to be zoomed -squared in black border- will allow to better quantify the consequences of variability. That variability increase collaboration as there is more red bellow the diagonal.

In terms of network structure, along with the all-to-all configurations, I will also focus on the three different network models previously described (ER random graphs, WS & BA scale-free networks), with three different sizes: 50/150/500 nodes. The characteristics of the generated networks are described in figure 3.

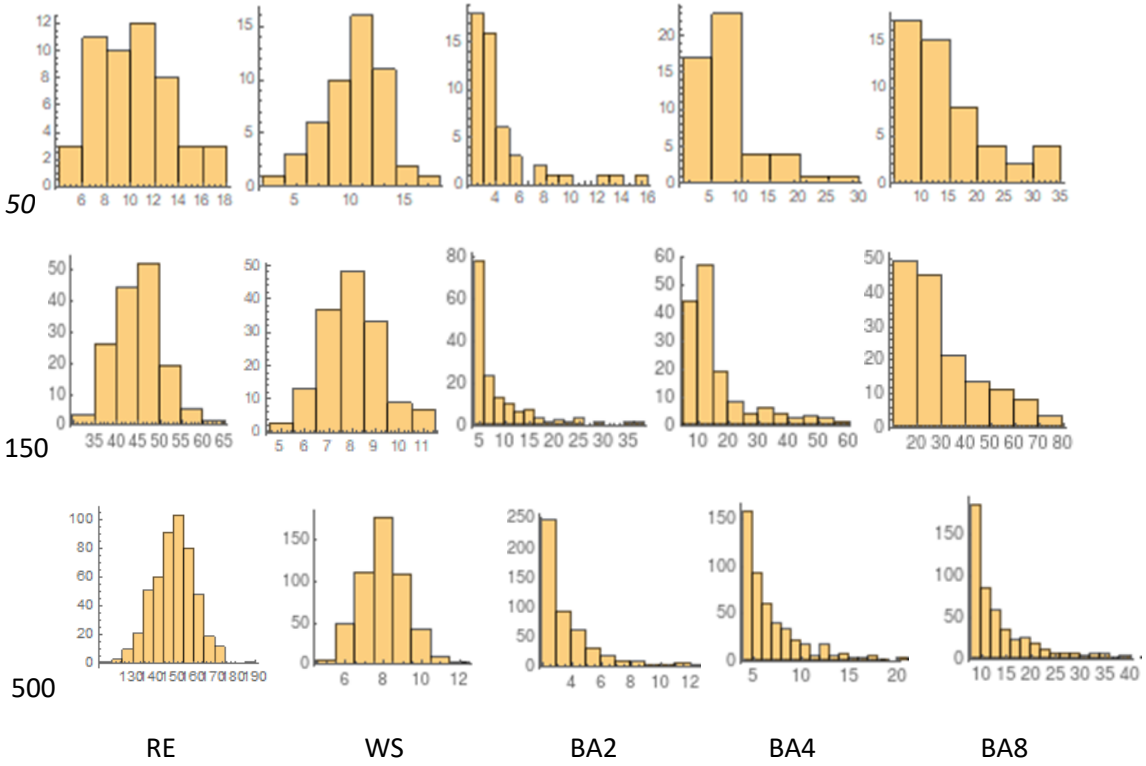

Figure 3. Degree distribution for several 50, 150 to 500 nodes networks.

As the processor requirement is proportional to the square of the number of links ($GL^2/2$, being G average degree and L, number of edges), and each experiment takes about 10-30 min each experiment, on a personal computer for 50 nodes with a single variable T on the *Payoff Matrix* (3-9 hours for 20

trials); 150 links will expend per more than 10 times the resources. To run over the 75 experiments that will follow it should be necessary more than a year-processor-time in a personal computer, and some shortcut has to be taken (or a much more powerful computer).

So, as this is to analyze increasing or decreasing collaboration trends, comparing uniform and diverse payoff matrices by each player, to adapt availability of time to resources, I have run a subset of experiments comparing 50/150/500 nodes networks, for a uniform and a 30% in variability. (We will understand variability as the different reward value perception from different individuals). At this point we have not considered any asymmetry, limitation of memory, time or processor, volatility, noise, heuristics, bias,… just to have controlled conditions to compare.

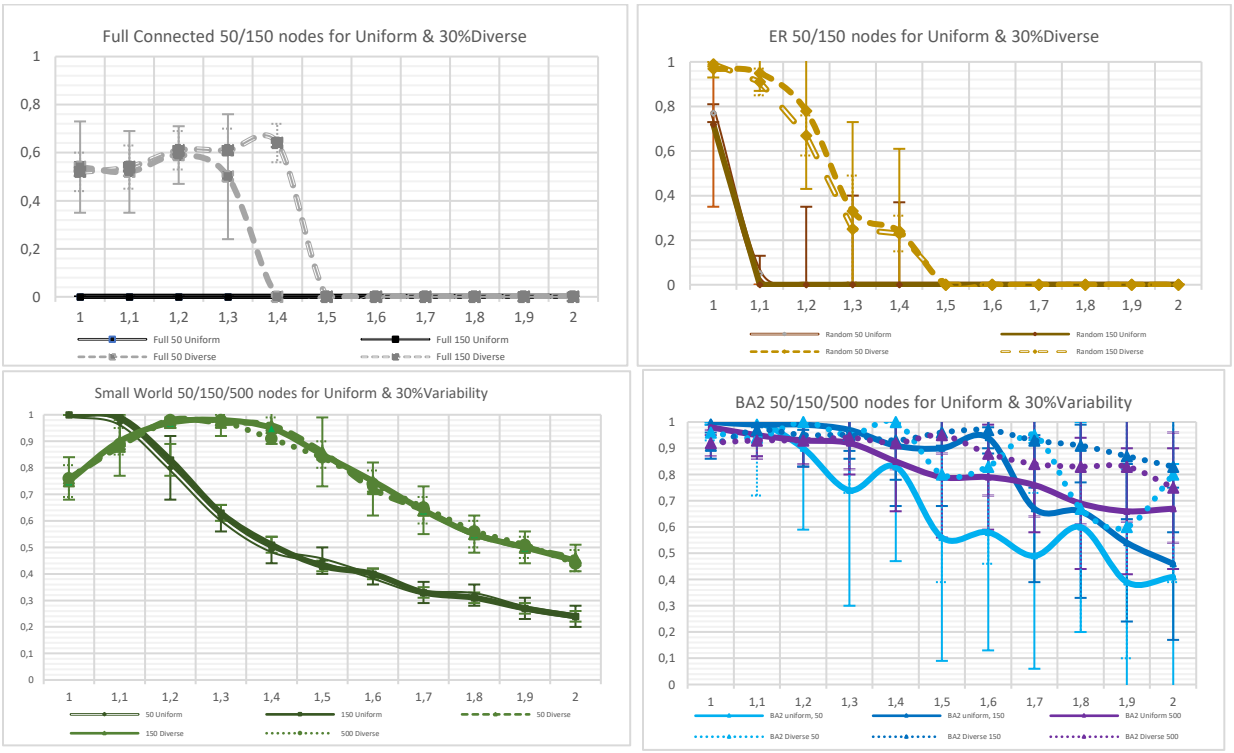

Figure 4. Comparative of results for different network sizes. Random and Small World Networks show the same behavior for 50, than for 150 and 500 nodes, with low deviation: there is no need to simulate bigger networks. Scale Free Network show to be more collaborative with size, with higher deviation: they preserve the trends from 50 to 150 and 500 nodes, but to compare with other networks, they need to simulate around 150 edges (500 nodes networks, see fig. 3).

Sizes sometimes matters. More nodes would increase the effect, as we can see in fig. 4 for all-to-all and scale-free networks, but in any case, N=50 would give enough information about trends. Beside this, as we do not know exactly what a % in "value scales" has to be translated to reality (when including not only money, but also moral values, happiness, quality, heuristic biases,… to be set as parameters of the payoff matrices), the key are the trends, not that much to quantify exactly the collaboration ratio per polarization level, and size is thought not critical at this point.

2.2. VARIABILITY

To the tested evolutionary game altruistic model, now we apply a variable value scale for each node, considering that values of T can be appreciated by each individual heterogeneously, and so we will simulate societies with individuals that do not appreciate the same value for the same incentive or punishment. I have run this code assuming random and phenotype (from real experiments) variability, for a *Full Connected Network* as control experiment, a *Random, Small-World* and a *Scale-Free Network* with 4 degree, all with N=50:

- Random variability: each node holds a white noise of +/- 5%, +/- 15%, +/- 25%, +/-35% and +/- 45% in value scale for incentives and punishments into representative games $S=0$ & $1 < T < 2$
- Phenotype variability: each node holds a variability of 10%, 20%, 30%, 40%, 50%, 70% and 90% values of X, for the same range of games as the real sample referenced by J.Poncela-Casasnovas et al. 2016, analyzing categorization of attitudes to play standard games. They states clear and well defined "phenotypes" or sustainable strategies, that can be used as a diversity parameter for currency between values and prices: I have translated that to the code.
  - "optimistic" perceives a lower incentive for defection -T = T (1-x)-, and they are assigned to 20% of nodes which holds same strategy in all steps for each round
  - "pessimistic", 21% of nodes, steadily perceives higher -T = T (1+x)-, but as the other they can only change her attitude randomly in each round
  - "envious" and also perceives higher incentive for defection, but assumes that the other player may have lower incentive for his defection -T = T (1+x/2) & S = S (1-x/2)-
  - "trustful" profile represent 17% of the players and always cooperate under any circumstance
  - "undefined" decides randomly cooperate or defect

2.2.1. RANDOM VARIABILITY

To compare with the biasing shown with real players, I have run the code with random assigned noise levels, representing the value per money of incentives and punishments disagreements between agents, i.e. a random uniform noise is applied of the values of T of the payoff matrix of each individual, so that the average value of T on the network will remain the same, but each individual will experience a variability of 10% (+/- 5%), 20% (+/- 10%), 30% (+/- 15%), 50% (+/- 25%), 70% (+/- 35%) and 90% (+/- 45%):

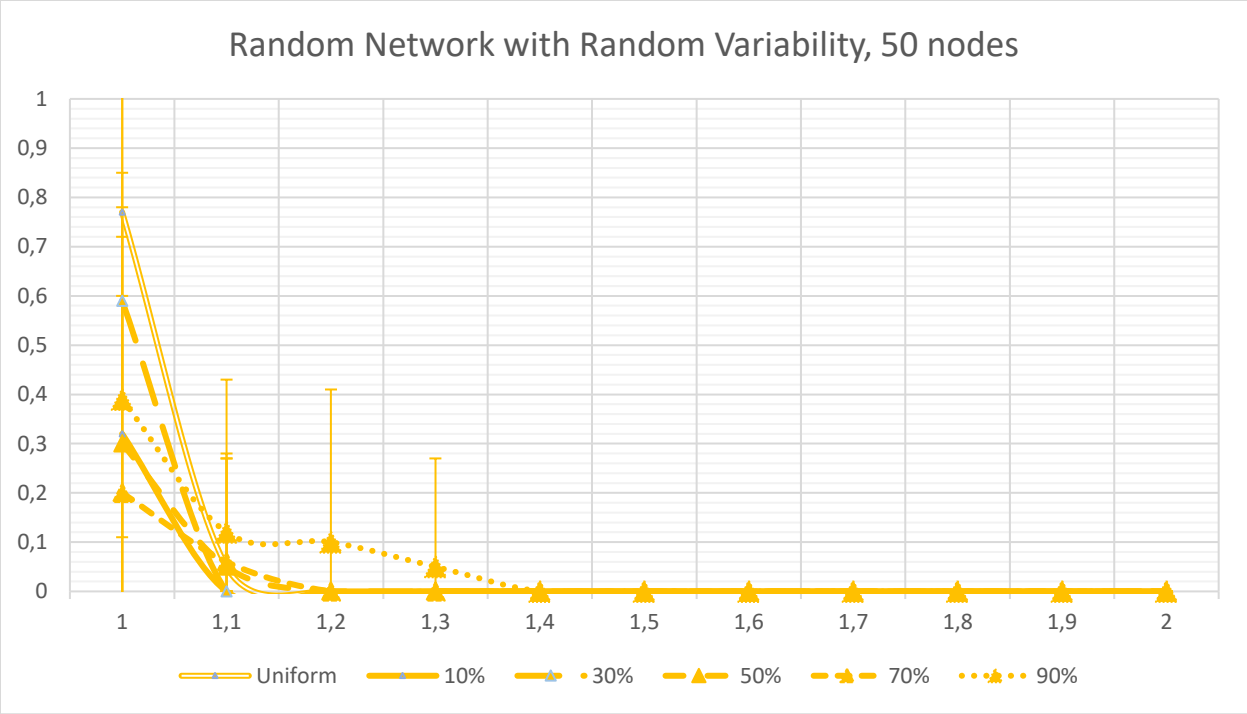

Figure 5. Random Network (0.3). Without a relationship structure between nodes, random variability do not show any trend to improve or worsen collaboration ratio.

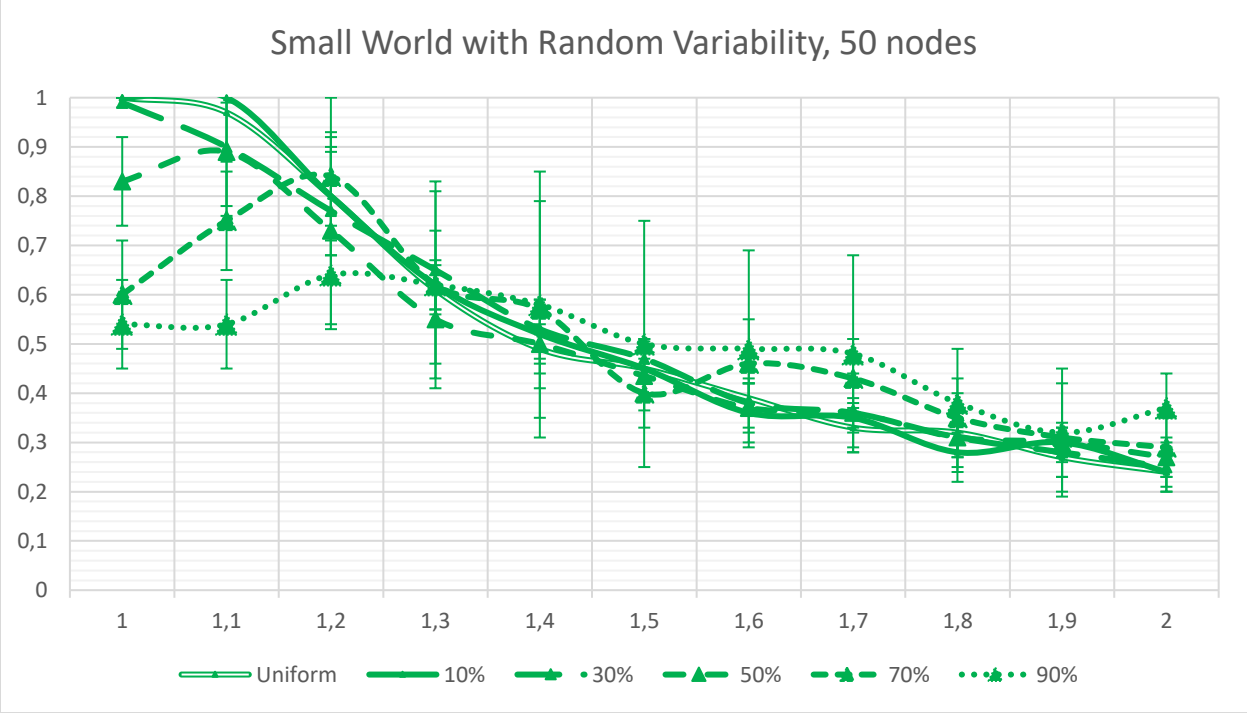

Figure 6. Small World Network (0.2 & 4). Random variability do not show any trend to improve or worsen collaboration ratio.

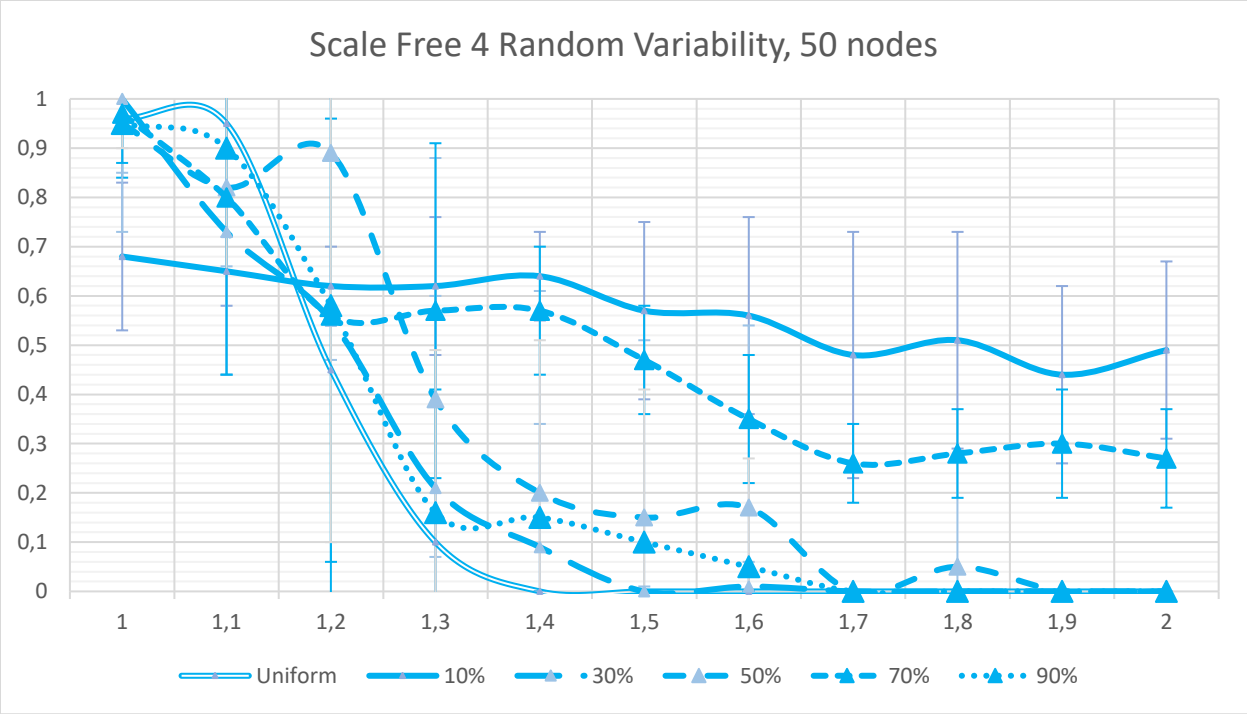

Figure 7. Scale Free Network (4). While there is not seem to be correlation between variability level and collaboration rates, all variability improves the collaboration over a homogeneous society where equality in the value scale would be the norm.

Heterogeneous perspective of life values at worse do not worse altruism, and even with any criteria sometimes, like in Barabàsi-Albert social structure even, improve it on irregular basis.

2.2.2. PHENOTYPE VARIABILITY

But if we consider the phenotype, as a real diversity of point of views to take decisions with different scale values represented by payoff matrices, taken from a sample of human subjects, the variability can be approached as they are. Social pressure through media, education, laws, prices, fear, hope,… can modify the phenotype distribution, but we can launch the simulation without considering this at this moment.

At this stage, we can see that in all cases diversity of criteria valuing the incentives for defection, improves collaboration and the more polarized is diversity, the more improvement in collaboration ratio. Always!

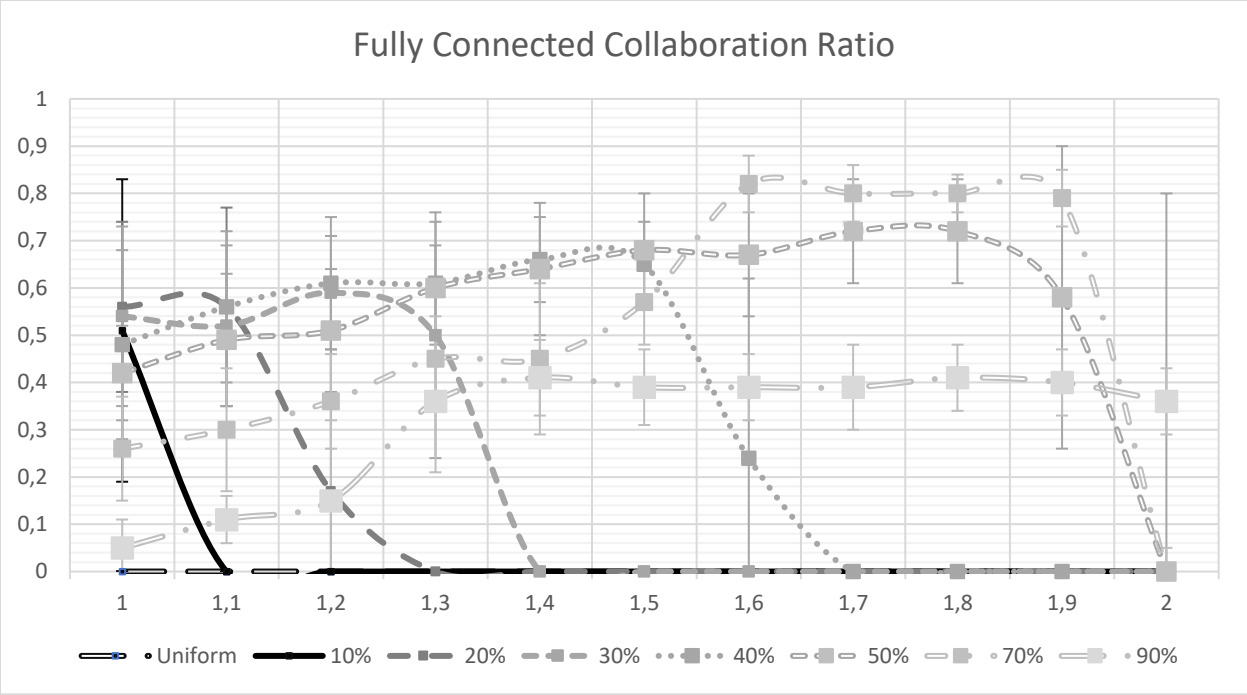

Figure 8. Full Connected Network as a control experiment. Polarization increases from 0 to 90%, and the more diversity on values increase collaboration up to a point, around 50-70%, that system becomes "tired", and worse competition again, but in a generic way. The more diversity affects more in the higher defection incentives, but reduces collaboration at the lower. No phase change is observed.

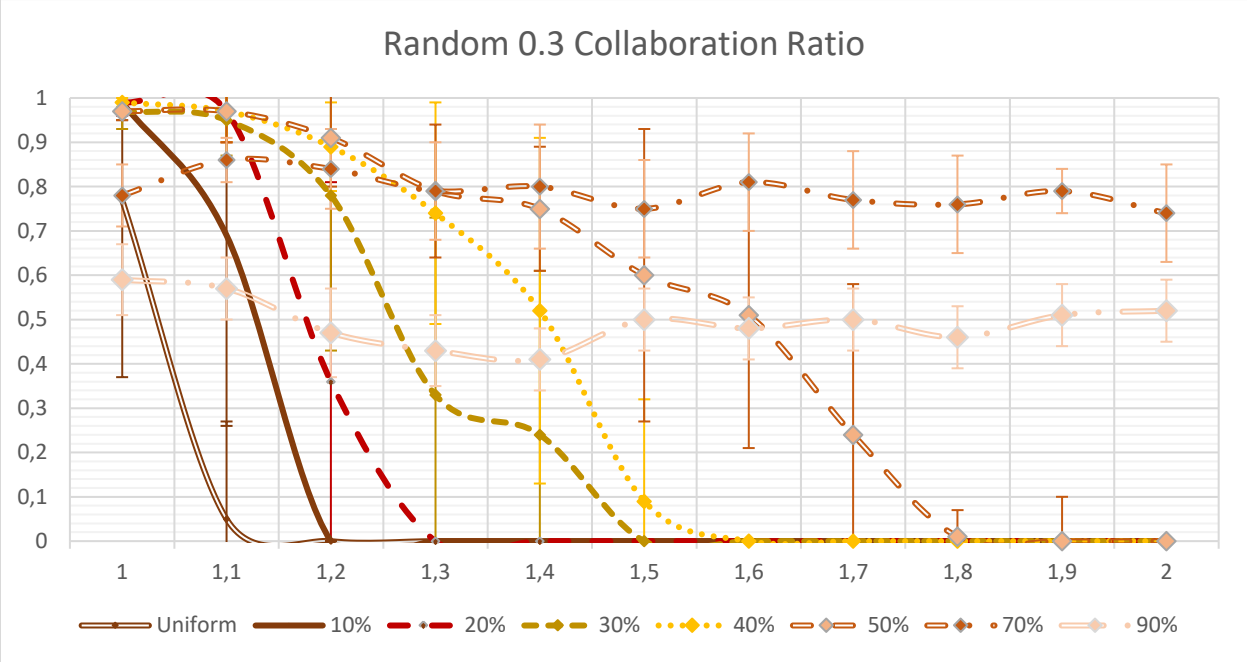

Figure 9. Random Network with 0.3 coefficient. Same trends as in full connected network, but because its lower degree -lower relationships for each node-, fatigue happens with a higher polarization.

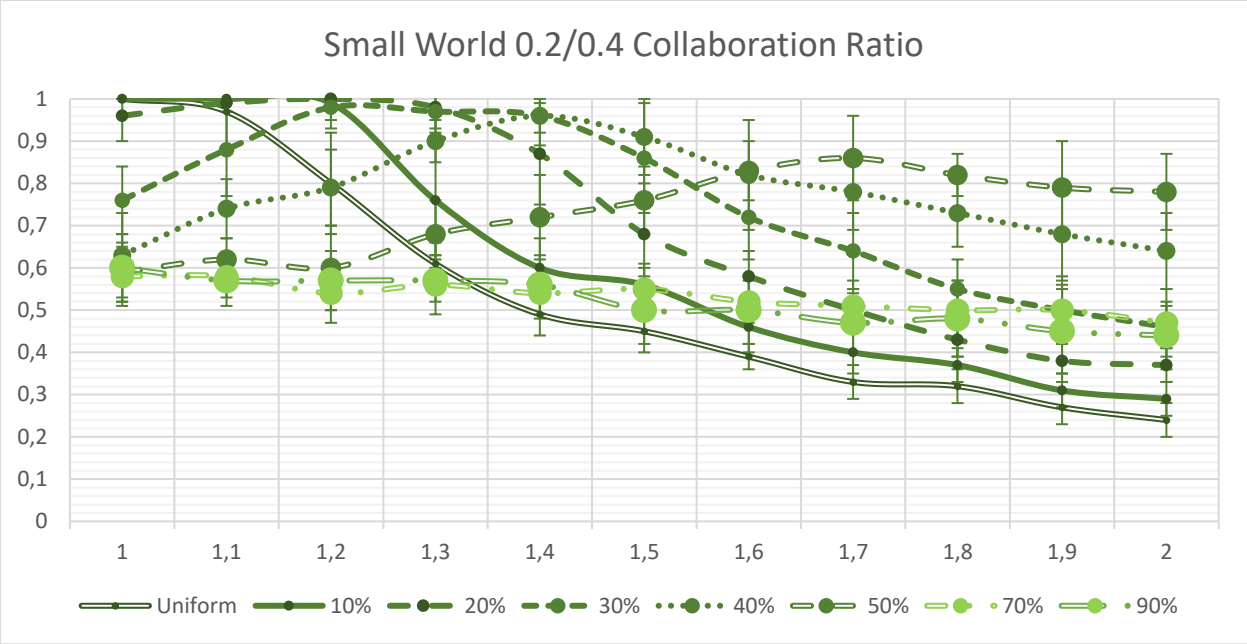

Figure 10. Small World Network with 0.2 coefficient and 4 connectivity. By structure itself, those networks are more collaborative than Random, even in uniformity and moderation, while also improves col ratios with diversity and polarization, to a point, where the system becomes tired and reduce collaboration. There is not any phase change.

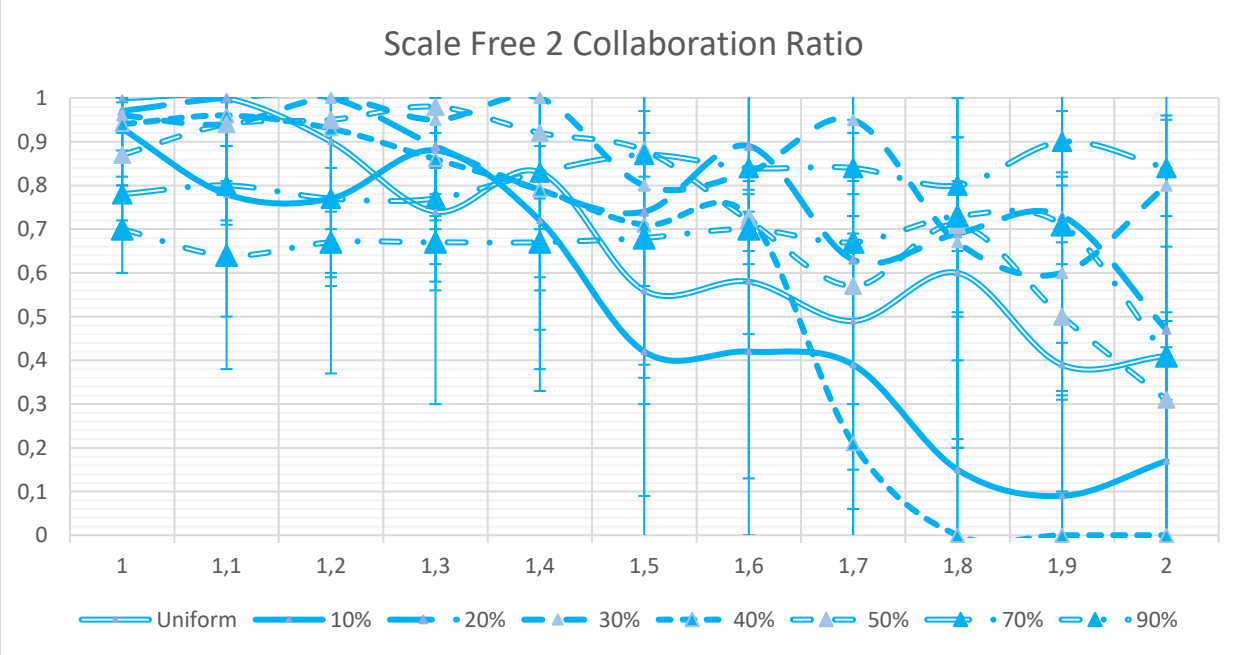

Fig 11. Scale Free Network with 2 connectivity parameter. Collaboration ratio even improves the Small World structure, but with higher deviations. Fatigue appears at the same level of polarization.

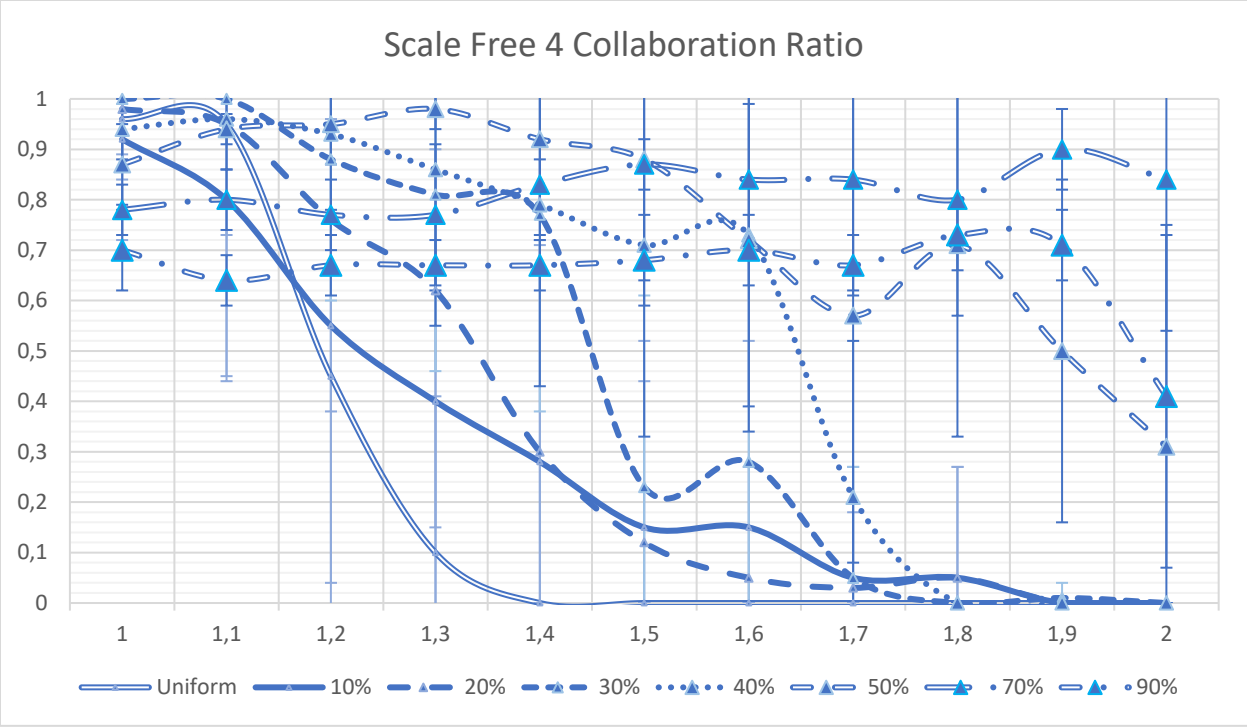

Figure 12. Scale Free Network with 4 connectivity parameter. Trends are the same towards more collaboration with diversity up to a fatigue phase, but with higher deviation and some irregularities as local maxima.

To measure how makes the difference to be positive or negative in decisions I have run the code only for positive biassing -optimistic+trustful- and negative biassing -pessimistic+envious-, and surprisingly, even if decision makers are mostly sad and unhappy in a system, this untrusted and fear diversity increase collaboration percentages and fatigue at high polarization:

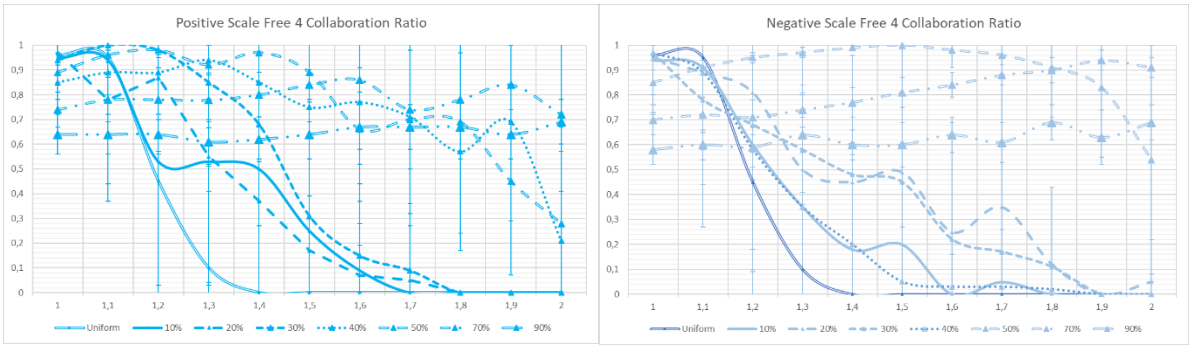

Figure 13. Positive & Negative 30% Diverse Scale Free (4)

So, at this point, with this simulation criteria and in those parameters, we can say that Uniformity and Moderation in values decrease cooperation in a society,… just the contrary of what we have been always said by governments, political organizations, education structures, monotheisms, nationalisms and ideologies; but as we expect on mature markets (uniform in quality and benefits, but high competitive in price).

2.3. NETWORK STRUCTURE

Network structures matters while we can see more cooperative strategists in Small World and Scale Free structures than if Random or Full Connected (all to all relationship and same probability to edge). *Small World Networks* are size-free, and as for high numbers of nodes, in Scale Free collaboration generically increases, occasionally it happens with more susceptibility.

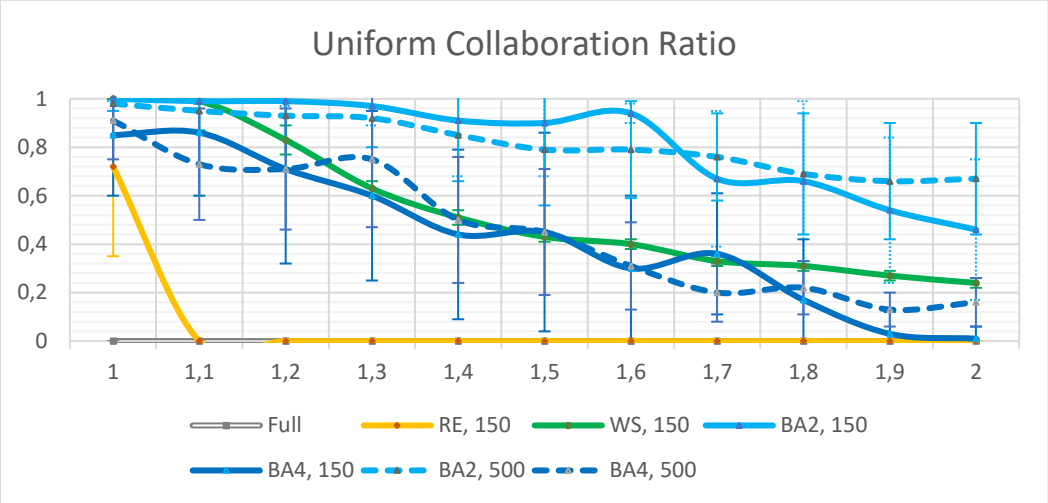

Figure 14. Uniform networks comparative (with no phenotype variability). Scale Free 4 approach with size 150 nodes to Small World collaboration, and Scale Free 2, even improve both. Simulation over 150&500 nodes are similar. The higher irregularity is sustained even increasing nodes, so it seems to be intrinsic to the BA structure.

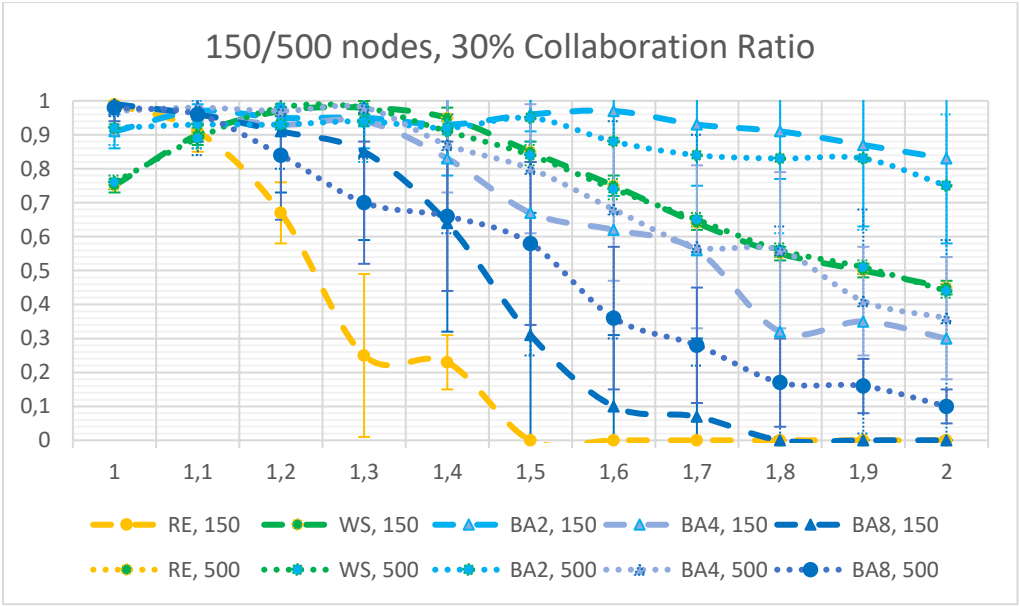

Figure 15. 30% diverse networks comparative. When including phenotype classes, the trends are sustained, and Scale-Free with low coefficient are more collaborative than Small-World, but that changes with high coefficient.

3. DISCUSION

3.1. INTERPRETATION

It may seem counterintuitive, but it is not, while this collective behavior happens in other “TS spaces” interpretations. In Economy is well known that markets evolve to maturity when an innovative successful product or service becomes generic and uniform. Many companies can produce and the competence over moderate differentiation, is gradually surpassed by competence over prices. Then productors relay to quantity and scale because the cost efficiency. Many logos sell similar products because uniformity and that increases competition. For the contrary, specialized and innovative products or services are diverse, prices are higher and companies needs synergies with other dealers of the market. In Economy Uniformity promotes competition and low benefits per unit, but in Sociology, the assumption is just the contrary.

Uniform political perspectives, a history telling, a religion, morals,… are claimed from all pulpits with proselytizing. Christians or Muslims, but also nationalists or communists, televisions or newspapers, say that if we all share same values, -same payoff matrix-, community will collaborate and if not, we all will lose solidarity and commonwealth. Collaborate or compete are not good or bad, but if the scale of values, which are the definitors of a society, are diverse, that will benefit the community… the more diversity in scale of values, the more solidarity. A fist is not always better than fingers and indeed, we all use fingers for the better and fists for the worse. But a diverse and polarized social environment can make people collaborate for the wrong as had happened in many examples from the last centuries. The educational system insists in homologate value scale to welcome youth to community, and maybe it would has to be the opposite. Standardization of languages, appeal to unity, awareness programs, brain washing, homologation of values and stories, neutrality,… is not the way. Heterogeneity, multiculturalism, diversification and radicalization, democracy and tolerance over the others value scale, trends to develop solidarity societies… up to a point, when, if too much, the system becomes tired. And to say this we have not need to assume morality, normalization or awareness programing, just self-interest and imitation rules for the individual success.

Romanticism remember only the better of worse ages. Equality, represented by a flat degree distribution and homogeneous payoff matrices, is less collaborative than structured societies with heterogeneous degree distribution. If we are all equal, our relation selection between neighbors will be more random; and if all we share the same scale value, our decisions will be predictable by others, so we will not need to collaborate to improve our expectations for the better. In the last two centuries, we have been said about the equality for solidarity, and that statement is not falsable.

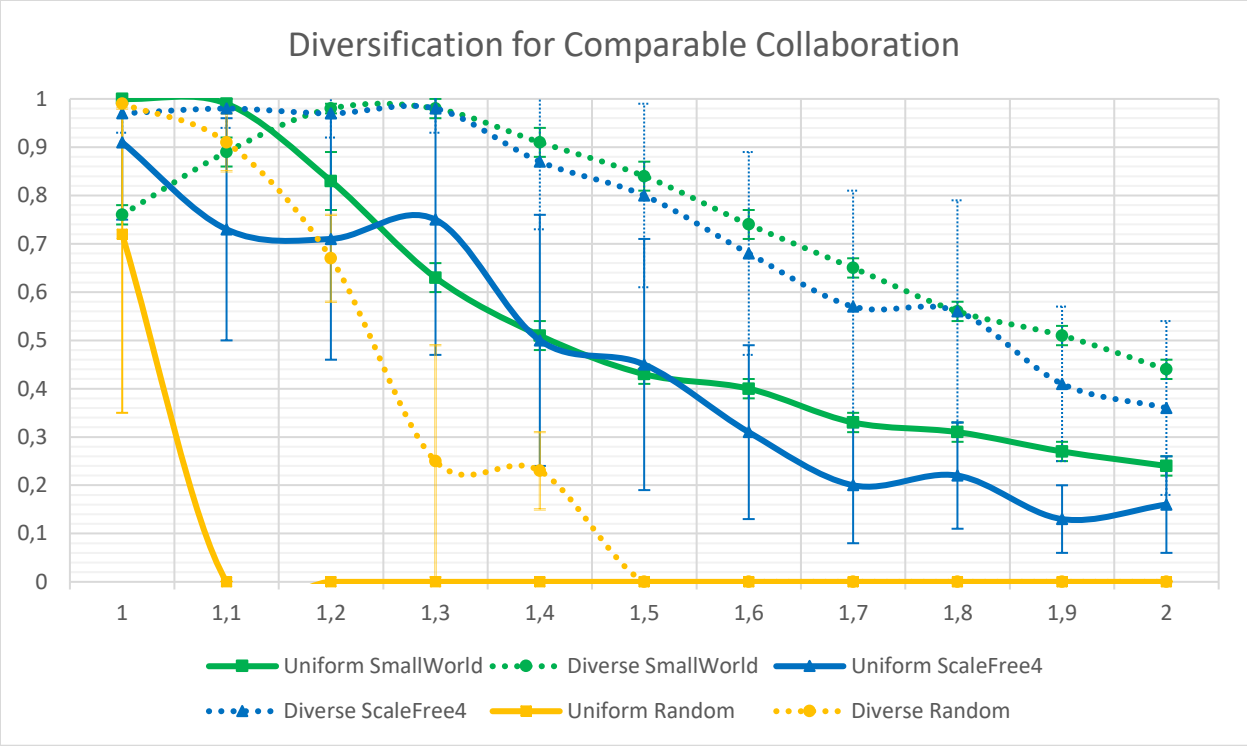

Fig 16. Comparison between networks for the sake of maintaining the collaboration ratio (area beyond the curves). Small World and Scale Free with appropriate parameters may produce similar solidarity and its diversification in values may produce similar improvement; much higher than Random Structure, but even then with double variability than others, a ER Network can achieve a high collaboration rate, as we can see in fig. 9 with 50-70% variability, similar to the 30% for WS&BA Networks.

Ideologies claim to redesign communities structure with some recipe -new or romantic-, and they justify to invest resources also in normalizing relationship and value scales in a certain way, but technologies and logistics by themselves also makes structures to evolve. i.e. nationalisms say we have to be more small-world-like and have a controlled isolation and clustering, but world trade, communication, logistics costs,… interact with recipes and investments in resources in structure design, results of lower incidence than expected, more expensive efforts to waste and uncertain results. Results shows that polarized value scale diversification is more efficient to join societies to work together for a purpose, than equality in wiring and values.

3.3. CONCLUSION

Collaboration emerges naturally from self-interest and evolves trough imitation, or at least that has explained better the *Altruism Paradox* than “kin selection”, “mutual support“ or “natural morality”. Anthropologically, any culture is defined by its value scale -the order from good to evil-, so it can be roughly quantified through a payoff matrix -it is more than a metaphor, but simplifies a lot, maybe too much, such a complex distribution of values-. So, while it is a very rude approximation, Evolutionary Game Simulations is much more an accurate method, than a mere opinion as “if we all have the same value scale, we all share the same values, we all believe in same gods, in same causes, in same sins,... if we all are educated in common values and agree a common opinion, if we are all equal, we will increase solidarity”. Here, inside the parameters described, this apriorism seem not to be true at all.

Wise management for governments, companies, markets,… will use money, laws, policy, training, education, media,… to modify incentives and punishments to place the game in an adequate site on the TS Space, not the maximum, but the optimal, near the “diagonal”. If the target is collaboration, move to the “red” in fig 3; or if it is for competition, move to the “blue”, (approximate knowledge about the network structure overlap, may optimize “where” the change from red-to-blue may be to do not spend resources if not necessary). This is what management use to do, but also trying to modify the structure as ideologies propose, and this generically will not be an efficient way, because the resources to invest in, produces small or even unpredictable changes (as it can be referred in last century history, plenty of failures as examples). But at the same time, and this is not what has been said to now by political commissioners, they invest resources in normalization, unification, homogenization, moderation and thought, control for solidarity. It is the commissioner’s fake. Education for tie the kids all the same, with same contents, with same pressure and effort, may produce less solidarity than radical and differentiate education each one for his and her capacities and wishes. Hey, teachers, do not leave the kids alone, but accompany the kids to be what they can be. No more commissioners for a single thought and equality. Political diversity may create more collaborative communities, -either for the better or for the worse-, than calls for unity and “clean” clustering inside border lines with homogeneity of races, cultures, incoming rents, languages or other “value scales” normalizations. It is better for the utility of a hand to have diverse fingers to be used each one differently, even as a fist.

As it happen in Science, disagreement in the payoff matrix, that quantify value scale, makes all of us stronger, not weaker. Bad news for totalitarianisms, nationalisms, standardizators in values, single language or history territories and monotheisms. Good news for radical diversity and democracy, not to tie in mediocrity to “normal distribution”, but to share between divergents for the better of collective.

Here there is more than a mere speculation about emergence of altruism in diversity of phenotypes, if we account all social resources from education, awareness, training,… in schools, media or political efforts, for the sake of unity, sharing values, homologating, moderate, standardize,… invested during ages for nothing. Calls for unity for the better are worse than worthless: they promote lack of solidarity.

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