The economics of utopia: A co-evolutionary model of ideas, citizenship and socio-political change

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Abstract. We propose a new history-friendly approach to evolutionary socio-economic dynamics based around competition between five 'utopias' as central ideas about which to order society: capitalism, socialism, civil liberty, nature, and nationalism. In our model, citizens contribute economic resources to support their preferred utopia, and societal dynamics are explained as a co-evolutionary process between these competing utopias. We apply the model to analyze certain aspects of socio-economic and political change in the US from the 1960s-present. We carry out a history-friendly analysis inspired by such episodes as the outbreak of civil movements in the 1970s, the rise of neo-liberalism in the 1980s, and the channels through which America has engendered an 'age of fracture'. Further applications for empirical and theoretical research are suggested.

Keywords: Utopia, citizen, subsystem, political economy, co-evolutionary modeling

JEL: B52, O57, P16, P51, Z10

Supplementary material: https://luis-r-izquierdo.github.io/utopia

The reader can replicate all simulation results presented in this paper by using the computer program provided in the supplementary material. This program can be run using NetLogo (Wilensky, 1999)[1], open source software available at http://ccl.northwestern.edu/netlogo for free.

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[1]Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/.
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1 Introduction

The standard way to develop a more history-friendly economic model is to embed economic actions within a broader context of institutions, politics, government, culture or the natural environment. This constructs a more realistic economic model by imposing institutional, political, cultural or environmental constraints on all economic agents (Denzau and North 1994, Beland and Cox 2011, Leighton and Lopez 2013, Acemoglu and Robinson 2013, Rodrik 2014). In this paper we propose an alternative approach in which these constraints do not appear independently or universally, but are first understood as competing *ideas*—e.g. the idea of the free market, the idea of state control, the idea of civil liberty or group rights, the idea of nature, and so forth. We assume that competing ideas on the good society—as alternative sets of guiding principles and values regarding the priority of the role of the state, the dominion of nature, the market economy, the management of common problems, or the expression of group identity, or what we call *utopias*—will appear to each individual as a dominated rank ordering. Each agent conceives a utopia as a society in which their preferred idea is indeed the dominant one. The extent to which the agent contributes economic resources to advance that utopia against competing utopias is the measure of their activity as a *citizen*.

We propose a new analytic approach to the evolution of socio-political and economic systems—an evolutionary political economy—by exploring the co-evolutionary dynamics of competing utopias. In this framework economic, social and political institutions are dynamic evolutionary consequences of competing utopias, or ideas about the rank ordering of the good society and the willingness of citizens to back these ideas with their own economic resources. In a market utopia, for example, the ideas of private property, free enterprise and profit as an objective indicator of success are the dominant ordering principles in society, and those of the state, civil liberty, culture and/or the environment are subordinated. In an environmental utopia, the idea of nature is the dominant ordering principle in society, with the state, civil liberty, culture and the market subordinated. In this context, we assume that individual economic agents make differential contributions of effort and economic resources in pursuit of their own conception of a utopia, defined as a world in which one of those ideas dominates the other ideas. To the extent that one idea can dominate another as a social ordering principle, then utopias compete. Each agent conceives their own utopia, but the extent to which they contribute to that utopia with effort, time, money and other resources, and thereby benefit others pursuing a similar utopia, may differ. By choosing a utopia, and then committing effort and resources to it, each citizen plays a role in the co-evolutionary process of utopia competition. Thus, preferences over *ideas* (which coevolve with socio-institutional change) as ordering principles define utopias, and citizens' uneven contributions to distinct utopias generate utopia competition. This approach thereby furnishes both a co-evolutionary theory of societal, political and institutional evolution as idea-competition, and an evolutionary theory of the economic agent as a citizen.

To formalize our approach, a co-evolutionary replicator dynamics model is developed in Section 3. In Section 4 we undertake a history-friendly computational analysis (Malerba et al. 1999, 2016) that draws upon historical facts from the US during 1960s-present. This analysis develops a recent idea-centered view of history by Montgomery and Chirot (2015) who identify four main ideas that have shaped the modern world, plus an anti-enlightenment movement; a total of five ideas. These are the utopias we use in our model. We implicitly assume that ideas and institutions co-evolve through feedback processes, but the line of causality in our model runs from the succession of ideas to corresponding changes in social structures. This is why we focus on utopia competition as a key driver of social change. Our history-friendly analysis uses historical analysis of the evolution of American socio-political and economic ideas during the last five decades to parameterize a robust representative setting from which we run the model and reproduce the rise of market-oriented ideas and the erosion of fundamentalist thinking in the US. Our model also indicates how these processes emerged and developed. In addition, the robustness analysis of the results, and the additional analysis in the Appendix, point out to certain factors that suggest future research lines. Section 5 summarizes some of these suggested lines of progress when we consider our present model as a benchmark step. Section 6 concludes by making the case for evolutionary political economy as a new analytic approach to historical analysis.

2 New concepts: ideas, citizens, utopias and subsystems

Using evolutionary economic theory and models (Metcalfe, 1998; Malerba et al. 2001), we present a wholly new approach to political economy built around the concept of *citizen* as an economic agent that may foster (to a higher or lower degree) the diffusion of specific ideas regarding *the good society*. These ideas define different *utopias* that compete through a co-evolutionary dynamic process. Our approach departs from standard models of political economy in several fundamental ways. First, we eschew Social Choice economics (Arrow 1951; Sen 1970, 1999; Taylor 2005) where collective outcomes derive from preference aggregation and axiomatic bargaining theory. Instead, our co-evolutionary model derives macro outcomes from group competition and population dynamics.

Second, we eschew Public Choice economics in which political institutions are conceptualized as markets (Downs 1957, Buchanan and Tollison 1984). Our approach is not based around voting mechanisms (cf. Buchanan and Tullock 1962, Caplan 2007), and the essential role of a citizen is not that they vote, but their propensity to contribute effort and resources to the ideas that govern and shape society, and furthermore to shape the ideas of others. Thus our approach is based around idea (or utopia) competition (Keynes 1936, Leighton and Lopez 2012).

Third, our approach is also not Institutional, in either the habits and routines sense (Veblen 1898, Commons 1936, Hodgson 2015), or the rules of the game sense (North 1990, Williamson 2000), or in the sense of historical exegesis or circumstance (North and Weingast 1989, Acemoglu and Robinson 2012). Instead, we conceive of the ordering principles of society as emerging from a complex systems conception of governing ideas, as in Boulding (1978) and Gowdy (1994). These co-evolving guiding ideas, or alternative utopias, ultimately would engender the resulting productive activities, organizations and institutions. In our model, citizens are economic agents that contribute resources to the development of their particularly chosen utopia. Our new approach to political economy develops a framework in which agents are both *economic actors* and *citizens*.

It is clear that our approach to political economy is not standard. There are two interrelated questions here: why do we seek a new non-standard approach, and how do we justify these new concepts? Both questions have the same answer: namely, we seek to develop a political economy centered on the evolution of competing ideas,[2] as the ordering principles of a society, which ultimately bring about the corresponding

[2] Ideas at this scale are constitutional meso-rules (Dopfer et al 2004, Potts 2007, Dopfer and Potts 2008).

institutional changes. An idea-centered view of history is not new to economic history and political economy (Keynes 1936, Hayek 1960, Rodgers 2011, Leighton and Lopez 2012). However the specific formulation we work with is from Montgomery and Chirot (2015), who characterize modernity in four big ideas that they associate with: Adam Smith (on free markets), Karl Marx (on collective property), Charles Darwin (on nature and evolution), and the debates between Thomas Jefferson and Alexander Hamilton (on democracy and civil liberty). They contrast this with the anti-enlightenment responses of nationalism, religion and other cultural group-based ideas.

For the purposes of this paper, as inspired by Montgomery and Chirot (2015), we consider five subsystems, each expressing a fundamental idea as an organizing principle of society: *viz.* a market subsystem (M); a state subsystem (S); a civil liberties subsystem (L); a group identity subsystem (G); and a nature subsystem (N).[3] Later we will refer to $\Pi = \{\mathrm{M}, \mathrm{S}, \mathrm{L}, \mathrm{G}, \mathrm{N}\}$ as the set of all five subsystems.

A group identity utopia—which we denote as subsystem G—is atavistic and based on in-group preferences, whether these derive from religion, ethnicity or nationalism (e.g. see Kohn 1944; Mosca 1939, for oligarchies). A free-market utopia—subsystem M—is the idea of order arising from individual pursuit of value through exchange. Montgomery and Chirot (2015) associate this with the ideas of Adam Smith as expressed with the values of economic liberalism. A civil liberties utopia—which we denote as subsystem L—is associated with civil society-led collective action. Montgomery and Chirot (2015) associate this with the debates at the founding of the US constitution between Thomas Jefferson and Alexander Hamilton. A state utopia—subsystem S—is the expression of centralist order and communal property, which Montgomery and Chirot (2015) associate with the ideas of Karl Marx. A nature utopia—subsystem N—is a conception of man as part of nature and therefore subject to natural forces, which Montgomery and Chirot (2015) associate with the ideas of Charles Darwin. These five are a broad set, covering: pecuniary coordination (M), communal property (S), civil liberties (L), human systems as part of nature (N), and human identity groups (G). As a first pass, these are the major ordering principles of society. Additionally, as Montgomery and Chirot point out, we consider that once an idea

[3] This particular set of five is somewhat arbitrary – there could be more or fewer. Our economic actor/citizen is (directly or indirectly) affected by the state of all of the subsystems but, as citizen, our agents seek to promote one of these subsystems in preference to others.

emerges, it can generate variations around the prior original conception (what we call the initial *core-ideas*). To be specific, we assume that the *core-ideas* in each subsystem are: the *Market* utopia moves around private property, individual self-interest, market efficient allocation of resources and price coordination mechanisms; the *State* utopia focuses on commitment to communal ownership and public property rights, centralized allocation and equality; the *Civil Liberty* utopia deals with the origins of the Social Contract, civil activism, the emergence of democratic Constitutions and the Institutions involved; the *Group Identity* utopia rests on identity similarities and the resistance to change, the status quo, traditions; and finally the *Nature* utopia deals with the relationships between humans and nature and the process of natural selection. In Section 4 we identify for each utopia two variations around the initial *core* ideas (a weaker and a stronger version surrounding the core). Therefore, we assume that citizens not only choose a specific utopia to contribute to, but also position themselves in one of the three possible branches of the utopia, modulating their contribution and commitment (between low, medium and high contribution levels). Specifically, we assume that low efforts corresponds to adherence to the weaker version of the utopia; medium efforts correspond to the citizen identification with the *core* ideas; and high efforts represent identification with the stronger version of the utopia.

Finally, we assume that citizens get changing payoffs from[4] (Fatas-Villafranca et al. 2011):

(i) Their own contribution to the favored subsystem/utopia (a good for the citizen)

(ii) The state of the favored subsystem (the perception of being effective in their supporting actions increases the agent's satisfaction)

(iii) An externality derived from other agent's contributions to their utopia. Includes positive and negative externalities, depending on perceptions of stronger or weaker commitment from peers. Heterogeneous boundedly-rational citizens assess whether they are contributing too much (bearing excessive opportunity costs), or too little (benefiting from more committed peers which defend common core-ideas, but also being at risk of their utopia losing social prominence).

[4] In Fatas-Villafranca et al. (2011; 2009) we revise the behavioral economics and psychology literature upon which we draw to pose our changing-payoff functions, and our formal updating proposal (below).

Competitive citizenship through differential contributions to ideas affects the internal and inter-systemic evolution of subsystems, thus shaping economic payoffs. In turn, citizens can revise their degrees of contribution, and even they can change their supported utopia as they observe the chosen utopias, contributions and pay-offs of other citizens. In this way, they influence the relative size, power and presence of different worldviews in the overall socio-economic system. We use this approach to propose a theory of socio-economic dynamics and change that can be traced through the differential citizen involvement in and contribution to competing subsystems.

An idea-centered view of history need not imply a philosophical or rational tournament to determine truth. Rather, it can be formulated as an evolutionary economic process if agents direct resources to support and develop their utopia, and seek to persuade others to abandon their utopias and join theirs. This is not simply to assume that preferences are endogenous and that institutions evolve. It is to seek to formulate a specific mechanism by which both evolutionary preference dynamics and evolutionary institutional dynamics are outcomes of a deeper process of idea dynamics, which we formulate as a co-evolutionary competition between ideas through the agency of citizens making contributions toward their utopia.

3 The model

3.1 Citizenship and subsystems

We develop a multi-population dynamics model driven by differential citizen contributions to one of five utopias, or subsystems. The agent is characterized in our model by their degree of citizenship when promoting their chosen utopia (with citizenship capturing lower-to-higher intensity of engagement with the pure-core ideas of the selected utopia; higher adherence leads the citizen to allocate more resources to utopia promotion). This degree of citizenship may be represented by the *proportion* of their total resources (including money, time, effort) devoted to fostering their desired utopia at time *t*.[5] To simplify, we suppose that citizens position themselves in one of three discrete settings: low (x_1), medium (x_2) or high (x_3) levels of contribution, such

[5] It is difficult to calibrate and measure the "level of effort" in effective terms, since it is composed of observable (time, financial and material resources) and non-observable (e.g. personal abilities, effort, skills, connections, knowledge) variables.

that $0 < x_1 < x_2 < x_3 < 1$. To further simplify, we assume that (x_1, x_2, x_3) are identical in all subsystems. The total population of citizens in a subsystem is distributed among these three alternative behavioral patterns at any time. For each subsystem $\pi \in \Pi$ at *t*, with $\Pi = \{\mathrm{M}, \mathrm{S}, \mathrm{L}, \mathrm{G}, \mathrm{N}\}$, let s_{it}^{π} be the share of citizens within subsystem π whose level of contribution is x_i. For example, among the citizens contributing to the market utopia, s_{1t}^{M} is the share of those whose level of contribution is x_1. Naturally, $0 \leq s_{it}^{\pi} \leq 1$, and $\sum_i s_{it}^{\pi} = 1$ for all $\pi \in \Pi$.

3.2 Citizen payoff

We include gains and (implicitly) costs in each citizen's payoff. This payoff depends on: (i) the level of individual citizenship; (ii) the relative size in society of the citizens' favored subsystem, a motivation akin to strongly-partisan citizen utility; (iii) a double-externality effect (through which citizens feel bad, or on the contrary, they benefit from other citizens being less committed, or more committed in support of the corresponding social utopia). As we will see, citizen payoff functions will capture lower to higher levels of permeability to said externalities. This relative sensitivity to partisan-motivations *vs* externalities turns out to be a key parameter in the model (see below and Appendix).

Regarding (i), we assume that the level of participation, engagement and commitment in pursuit of a utopia through political, civil and social discussions, participation and actions is an endogenous source of utility for each citizen, and is thus in effect a consumption good. This assumption is consistent with intrinsic motivation theory (Frey, 1997, 2001; Ryan and Deci, 2000) in which individuals have goals that motivate actions in the belief that they are intrinsically good. But the assumption is also consistent with an extrinsic motivation where citizens care about their social reputation among those who share a similar sense of identity (Akerlof and Kranton 2000).

With respect to factor (ii), it is clear that agents devote their resources and ideas to improve, reinforce, and extend the utopia associated with their favored subsystem – e.g. building up new organizations and institutions that support the utopia's ideals, appearing in the mass media, and in shaping other citizens' minds. Thus we propose that when the favored utopia increases its relative size and presence in society (gaining supporters), this represents a source of satisfaction for the agent (a perception of self-realization and efficiency in action). As we will see, this partisan motivation may be mild or strong.

Regarding (iii), we incorporate the opportunity cost of citizenship into the payoff. Less-committed peers erode a citizen's utility by their lower adherence to the core-utopian principles, while more-committed peers contribute to their utility. As explained in Fatas-Villafranca (2009, 2011), we assume local externalities since behavioral and cognitive *proximity* are crucial when agents' payoffs are shaped by the behavior of others. A simple way to capture these local effects is by adding a double-local externality component to the citizen payoff. Thus, more committed peers generate a positive externality on others, whereas less committed peers generate a feeling of opportunism or, somehow, a negative externality in more committed ones. We incorporate a parameter regulating the relative intensity of these local externalities (permeability to local intra-subsystem commitment). Formally, we can represent effects (i) to (iii) above in the following payoff functions u_{it}^{π} for citizens within subsystem π whose level of contribution is x_i:

$$\begin{aligned} u_{1t}^{\pi} &= (\gamma_t^{\pi}(1-\varphi) + \varphi s_{2t}^{\pi})x_1 \\ u_{2t}^{\pi} &= (\gamma_t^{\pi}(1-\varphi) + \varphi(s_{3t}^{\pi} - s_{1t}^{\pi}))x_2 \\ u_{3t}^{\pi} &= (\gamma_t^{\pi}(1-\varphi) + \varphi(-s_{2t}^{\pi}))x_3 \end{aligned} \qquad (1)$$

where γ_t^{π} is the share of subsystem $\pi \in \Pi$ (proportion of supporters) in society (so $0 \leq \gamma_t^{\pi} \leq 1$, and $\sum_{\pi\in\Pi} \gamma_t^{\pi} = 1$), and parameter $\varphi \in [0,1]$ captures the intensity of the externality effect (permeability to peers behavior and opinion). This parameter incorporates a certain bias in citizen payoff regarding strong-partisan motivations (low φ) *vs* high permeability to local externalities (high φ). We can see in (1) how citizens behaving in a specific way perceive (positive or negative) local externalities from more or less committed peers (see Fatas-Villafranca et al. 2009; 2011).

In addition, we can define the average level of citizenship within each subsystem as $x_t^{\pi} = \sum_i s_{it}^{\pi} x_i$. The average payoff within each subsystem at *t* is $u_t^{\pi} = \sum_i s_{it}^{\pi} u_{it}^{\pi}$.

Finally, it is clear that, the average level of citizenship in society at *t* will be $x_t = \sum_{\pi\in\Pi} \gamma_t^{\pi} x_t^{\pi}$.

3.3 Intra-subsystemic evolution

Citizens in our model can endogenously change their level of citizenship in pursuit of a utopia, and they can also choose a different utopia. Consider first a *change in the level of citizen contribution*. We have assumed that citizens within each subsystem are heterogeneous in behavior (commitment levels) and receive a specific payoff attached to their contribution level. In cases where citizens perceive that they may benefit from changing their levels of contribution, we expect agents to update their behavior. More precisely, f_{ij}^{π} denotes the rate at which citizens contributing x_j switch to behavior x_i (within subsystem π) in pursuit of more satisfactory behavioral patterns. The switching rate is:

$$f_{ij}^{\pi} = \theta max\left(u_{i}^{\pi} - u_{j}^{\pi}; 0\right), \ \theta > 0$$

where $\theta > 0$ captures the ease of this behavioral change. We assume that, given the valuation criteria in (1), when a citizen from behavioral group i meets another from j within subsystem π, she discovers the possibility of adopting behavior x_j. Then, by comparing her present satisfaction u_{i}^{π} with the level u_{j}^{π} enjoyable in case of contributing x_j, the citizen may decide changing behavior. We are considering boundedly-rational citizens that gradually move in the direction of an endogenously-changing, non-unique, higher-valuation. If we assume that $(\delta\, s_{i}^{\pi}\, s_{j}^{\pi})$, $\delta \in (0,1)$ gives the probability for a random and independent interaction between one citizen with contribution i (share in the population s_{i}^{π}) and other one with behavior j (share s_{j}^{π})in a small interval Δt, the flow of citizens from j to i would be given by (Hofbauer and Sigmund 1998):

$$\delta s_{i}^{\pi} s_{j}^{\pi} f_{ij}^{\pi} \Delta t$$

and the change in the proportion of citizens with behavior x_i would be:

$$\Delta s_{i}^{\pi} = \sum_{j} \delta s_{i}^{\pi} s_{j}^{\pi} \left(f_{ij}^{\pi} - f_{ji}^{\pi} \right) \Delta t$$

where

$$f_{ij}^{\pi} - f_{ji}^{\pi} = \theta \left(u_{i}^{\pi} - u_{j}^{\pi} \right)$$

Therefore, the continuous time-evolution of the proportion of citizens with contribution i may be described by the equation (Fatas-Villafranca et al. 2011):

$$\frac{ds_i^\pi}{dt} = \sum_j \delta s_i^\pi s_j^\pi \left(f_{ij}^\pi - f_{ji}^\pi \right) = \delta s_i^\pi \sum_j s_j^\pi \theta \left(u_i^\pi - u_j^\pi \right)$$
$$= \theta \delta s_i^\pi \left(u_i^\pi - \sum_j s_j^\pi u_j^\pi \right)$$

Thus, we can represent the evolving intra-subsystem distribution of citizen contributions by the replicator dynamics system:

$$\dot{s}_{it}^\pi = s_{it}^\pi (u_{it}^\pi - u_t^\pi) \quad \forall i, \forall \pi \in \Pi \quad (2)$$

This *intra-subsystemic dynamics* (from which changing distributions of behavioral patterns, and different trajectories for the average level of citizenship emerge) operate as a social learning mechanism for the five subsystems (utopias) that co-exist in (2).

3.4 Inter-subsystemic dynamics and co-evolution

We assume now that subsystems (utopias) with strong citizen support, and higher than average citizen commitment/pro-utopian action, will gain relative presence in society. More precisely, we close our co-evolution model by proposing a replicator system of five differential equations, coupled in a bi-directional way with systems (2) above[6], which can be written as follows:

$$\dot{\gamma}_t^\pi = \gamma_t^\pi (x_t^\pi - x_t) \quad \forall \pi \in \Pi \quad (3)$$

To explain the coupled dynamics, let us note that, from (2), different paths for the average level of citizenship *within each subsyst*em $x_t^\pi = \sum_i s_{it}^\pi x_i$ emerge. These paths determine the dynamics in (3) in such a way that subsystems with $x_t^\pi > x_t$, that is, *utopias with higher than average citizen support, tend to gain relative presence in society* ($\dot{\gamma}_t^\pi > 0$ in (3)). Thus, we are considering that citizens may change their utopia since they live in a society in which different levels of utopia support co-exist, and utopias with higher than average support ($x_t^\pi > x_t$) attract supporters ($\dot{\gamma}_t^\pi > 0$).

In turn, notice that increasing (or decreasing) relative social presence (γ_t^π) influences the intra-subsystem payoffs in (1) and, thus, condition the intra-utopian dynamics in (2); which, again, influences the inter-subsystem dynamics (3); and so on. These coupled dynamic systems generate an emergent pattern of transformation and

[6] See Hofbauer and Sigmund (1998) and Almudi et al. (2012) for analysis of coupled dynamic systems.

socio-political change. The Appendix to this paper provides further details on the mechanics of the model and it shows the type of emergent results that we may expect. As we will see (in Section 4 and the Appendix), as a result of this co-evolutionary process, the relative social presence of each utopia will endogenously change and we can obtain evolving trajectories with different profiles (smoothness towards conformity; fluctuating evolutions; permanence of different utopias; etc.). In the following section, we are going to carry out a history-friendly analysis of the model. We provide supporting results in the Appendix for many of the socio-economic interpretations and results presented in Section 4.

4 History-friendly simulations for the US

Given the nonlinear and complex nature of the model, we carry out a first approach to the study the model dynamics by performing a representative experiment modeled on US society through the second half of the 20th Century. We follow the *History-Friendly methodology* described in Malerba et al. (1999, 2001, 2008, 2016). In 4.1, we describe the core-ideas, origins and structure of the five subsystems (utopias) that compose our model as guidelines for our case study. In 4.2, we delineate initial settings departing from historical sources for the US. We run the simulations and present intervals of robustness for the results. The general trends that our model generates from the robust initial setting qualitatively fit with the corresponding historical facts. In 4.3, we show that, even though we depart from a specific (i.e. history-friendly) initial setting, there is a wide neighborhood of parameter values and initial conditions for which the same results apply. We also present counterfactual results and partial formal results (in Appendix) that suggest future research lines.

4.1 A brief history of utopia competition in the US

We define five specific utopias – as systems of concepts, beliefs and bodies of thought eventually materialized in real structures – that have shaped the modern world and, specifically, American society. These utopias will correspond to the five subsystems (populations of citizens supporting the same utopia) in our model. We argue that, within each utopia, we can specify three different interpretations of the core-ideas (from mild, to strong interpretations and adherence to the core), which can be assimilated to our model degrees of commitment (i.e. lower to higher degrees of citizen contribution and adherence to the core corresponding to mild efforts/adherence x_1, medium effort/adherence x_2, and high citizen adherence and utopian contribution x_3).

As Montgomery and Chirot (2015) explain, once an embryonic set of utopian ideas appears, we observe the dynamic configuration of interpretations of these ideas. Thus the *Market* utopia focuses on private property, individual self-interest, efficient allocation of resources and price coordination mechanisms (this is the core that can be defended and pursued with lower to higher intensity $x_1 < x_2 < x_3$); the *State* utopia focuses on commitment to communal ownership and public property rights, centralized allocation and equality; the *Civil Liberty* utopia deals with the origins of the Social Contract, civil activism, the emergence of democratic Constitutions and the Institutions involved; the *Group Identity* utopia focuses on identity similarities and the resistance to change, the status quo, traditions (with variants); and finally, the *Nature* utopia deals with the relationships between humans and nature and the process of natural selection.

In each utopia, we will start by delineating what we consider the embryonic original ideas leading to the utopian core, and, then, two different developments and interpretations of said ideas. The different interpretations correspond to citizen intensities of commitment and promotional efforts regarding the core utopian ideas ($0 < x_1 < x_2 < x_3 < 1$). In all the utopias we identify the highest level of commitment (x_3) with the strongest adherence and support (effort, resources etc) for the pure-core ideas; the medium level (x_2) for the mid-interpretations and support of core ideas; and low level (x_1) with mild interpretations of core ideas.

Market utopia

For the free-market utopia, we find the embryonic and mid-core ideas in Smith-like classical thinking according to which the self-interest of men can be trusted as a fair and productive way to allocate resources and organize society. Individual self-interest, entrepreneurship and spontaneous market order (the invisible hand) were deemed better than central governments or privileged (ancient-regime) social strata to manage the economy. We can identify Smithian ideas with our x_2 (medium embryonic/original degree) of commitment to the free-market utopia; in fact, although classical liberalism believed in markets as self-regulating and moral systems of social organization, they were not "laissez faire" doctrinaires. They detected an elastic range of activities where authorities and non-pecuniary motivations should operate.

We believe that two (almost opposite) interpretations of this mid-core classical idea have emerged and diffused (to different rates and through different channels) during modern US history (Harvey 2005). The first is Keynesianism (which we associate with a weak level x_1 of commitment with free market ideas). Inspired by the Great Depression, a stream of thinking that starts with Keynes develops through economic theorists such as Tobin, Samuelson, Krugman and Stiglitz, who defend market societies but caution that markets can fail and aggregate demand can be weak, and so governments can re-equilibrate and stabilize economies by stimulating demand and fixing market failures. They also advance the idea that market economies require international political cooperation and financial regulation.

The second development of classical liberalism that we detect in the US is the emergence of strong supporters of the pure-core ideas of individual economic freedom, rationality, market optimality and perfect order. We refer to Friedman (1962), Hayek (1960), and other Chicago School economists of the free-market utopia. This level of attachment to the free-market vision claims that almost everything central authorities could do with respect to prices, allocations and economic life (except protecting the rule of law, private property and maintain a stable currency) is socially harmful. This can be assimilated to our level x_3 maximum-strong support of the free market utopia: a stream of thought which displayed very strong individual efforts and citizen commitment to promote free-markets, and which is often related to neo-liberalism.

State utopia

Another core body of modern thinking traces back to the ideas of Marx. This trend of thought argues that capitalism tends towards overproduction, unevenly distributed wealth and unavoidable unemployment. It is argued that the capitalist owners of the means of production seek to exploit the working class proletariat. The envisioned utopian solution for this unfair situation rests on abolishing private property through a communistic revolution. Then, communal property, the sharing of the means of production, and the industrial advances would allow everyone to develop their human potential. We assimilate this Marxist view of collective property with our medium level (see below) of support x_2 for the state utopia.

A mild version of these core ideas (that we represent by x_1) would be reformist socialist parties and (trade) unionism. For these organizations, capitalism does not inevitably impoverish the proletariat but can be gradually reformed (without revolution) towards an equalitarian centralized society. By 1914, the leading socialist parties and labor movements in Europe and in the US had moved Marxist ideas toward peaceful social action, in the US culminating in Roosevelt's New Deal programs established in the 1930s. On the other side, the most pure (extreme) version of the communitarian-statist utopia (x_3), can be found around the Lenin-Bolshevik-Stalinist orientation and its influences all over the world. A tightly controlled intelligentsia, and a perception of a way to the Marxist-best-world through repression, led to a path that combined the socialist-centralized-equalitarian future, with the use of strong efforts to erode enemies. Montgomery and Chirot (2015), and Lipset and Marks (2000) discuss why socialist ideas failed in the US.

Civil Liberties utopia

The idea underlying this utopia is that fundamental rights and individual freedoms in general are consubstantial to human beings. These human fundamentals should be limited only through unanimous constitutional agreements to facilitate common coexistence through collective choice mechanisms. The center-core issues around this utopia are related to the Institutional forms a society should adopt in order to guarantee the aforementioned fundamental freedoms. The Jefferson-Hamilton debates represent an embryonic core which we relate to an intermediate position with respect to the role that government should have in limiting individual liberties. This position may correspond in our model with a level of citizen commitment with a libertarian utopia x_2. The strongest version of this utopia (x_3) would be the anarchism ideals, since they strongly held the idea of self-governed societies with a very weak state, or even in the limit state-less societies, and voluntary institutions and civil organizations. Finally, the mild version of this utopia could be associated with the defense of a Central Democratic State which seeks to limit and control individual freedoms, as for example in France, in order to achieve an adequate coexistence in society, while seeking to defend human fundamentals. This mild level of commitment with civil-liberty is represented in our model by x_1.

Group Identity utopias

Citizens who pursue collective utopias consider that belonging to the same 'imagined communities' (Anderson, 1983) and preserving common beliefs and traditional values, particularly those associated with group identity (e.g. ethnic, religious, national, cultural), are the core of civilized human action (Mitchell 1996). Nevertheless, in-group/out-group distinctions, a deep aspect of human evolutionary heritage (Bowles and Gintis 2011), can be a matter of degree. Drawing on the typical definition of traditional-nationalism, people ruled by the same state are really part of a large family sharing a common culture, values, traditions and even (occasionally mythic) common ancestry (Kohn 1944). This nationalism can be identified (as we will justify) with a medium level of commitment and effort x_2. Extreme feelings of identity group, together with a large resistance to change can result in forms of Fundamentalism (x_3 in our model). Finally, smaller groups of reference with specific singularities, that normally try to defend their status quo in society, can be assimilated to forms of elitism (oligarchies, Mosca 1939). This would concentrate around a low level of group identity x_1.

Natural or Environmental Utopia

Darwin's *Origin of Species* definitively changed relations between humans and nature. His theory posed that all living organisms on Earth share a common ancestor, and all are all subject to natural selection. The core idea is that those better-adapted forms of life increase their probability of survival. Increasing adaptation to the environment implies further possibilities for kinship to continue. We can identify these core ideas with a moderate (mid) level of commitment with natural selection and the survival of the fittest (x_2). Coming from evolutionary theory two almost opposite strands emerge. The first argues that rational humans can invent sophisticated solutions for natural and social problems. Science and reason can overcome the natural selection process by literally shaping nature, with human societies being the most sophisticated product of evolution capable of controlling even nature itself (Montgomery and Chirot 2015). We call this strand Scientism with a very strong support of the primacy of the fittest (x_3). A second strand argues that humans are small in the universe and their imagined capacity to control nature is hubris. This is Environmentalism (x_1).[7] A map of the five main utopias in US society is in Table 1.

[7] On the key influence of Darwinian ideas in political and philosophical thought, see Dewey (1910) and Jones (1980).

Citizen level	Market	State	Civil Liberties	Group	Nature
x_1 (mild)	Keynesians	Socialism	Centralism	Elitism	Environmentalism
x_2 (mid)	Liberalism	Marxism	Jefferson	Nationalism	Darwinism
x_3 (strong)	Neoliberalism	Stalinism	Anarchism	Fundamentalism	Scientism

Table 1: Utopias/Level of contribution and commitment to the core ideas

4.2 The US case: From the Great Society to the Age of Fracture

In this section, we delineate a history-friendly initial setting (Malerba et al. 1999) that represents the co-existence of different utopias in the US during the 1960s in a stylized way. We justify and propose the setting and then, by running the model from this initial scenario, we obtain time paths that are qualitatively consistent with the evolution of American utopias during the past four decades. Analysis of these results within our co-evolution model allows us to reflect on possible driving forces of America's recent social change. The initial setting is not a unique representative "point"; on the contrary, we can define a wide neighborhood of values for parameters and initial conditions around the initial setting for which the simulated process holds. So our results are robust to significant changes in initial conditions and parameters that qualitatively fit the historical departure point (see robustness analysis in section 4.3 below).

The 1960s in the US saw burgeoning diversity, intense socio-political creativity, and mass collective action in many realms of American life (Rodgers 2011, Watson 2000). Table 2 illustrates what US President Lyndon Johnson called the 'Great Society' is composed of traits of freedom, equality, liberation, democracy and nature that are, when taken together, well balanced through a significant presence of different ideas.[8] Sociologists and political theorists widely report that US society has evolved during the last four to five decades towards a more fluid and atomistic contemporary society in which market models govern social and political discussions about a wide range of concerns (Abbot 2005; Fukuyama 1992, 2006; Huntington 1996; Lipset and Marks

[8] Although we seek to provide a stylized representation in Table 2, Page and Shapiro (1992; Ch. 3-5) present numerical info compatible with Table 2.

2000; Senett 1998). This is not to say that the US have evolved into a paradigm of free-market liberalism—clearly it has not—but rather that market ideas, whether promoted or opposed, are a dominant organizing principle for political and social discourse and analysis. Concepts of efficiency, rational choice and consumer society have widely colonized sociology and policy studies (Becker, 1993; Downs, 1957). The historian Daniel Rodgers (2011) argues that US society has over this period followed a path increasingly dissolved into its utility-maximizing atomistic parts, a process he calls the *age of fracture*. To synthesize the features of the 1960s (initial setting), we consider Table 2.

	S_{10}	S_{20}	S_{30}	γ_0
Market	0.55	0.10	0.35	0.25
Civil liberties	0.30	0.35	0.35	0.30
State	0.40	0.35	0.25	0.15
Group	0.35	0.35	0.30	0.20
Nature	0.35	0.30	0.35	0.10

x_1	x_2	x_3	φ
0.1	0.2	0.3	0.5

Table 2: The Great Society - Initial Setting

Note that in Table 2 the civil-liberties (L) utopia prevails ($\gamma_0^L = 0.3$), with the market (M) and the traditionalist group identity utopia (G) representing $\gamma_0^M = 0.25$ and $\gamma_0^G = 0.2$ of the total population respectively. Although at a lower scale, environmental (N) and even pro-statist (S) utopias were also significant at that time. We also consider that the levels of effort and commitment were such that everybody devoted from 10 to 30 percent of personal resources to a specific worldview (i.e. $x_1 = 0.1$; $x_2 = 0.2$; $x_3 = 0.3$). We do not bias the intensity of intra-subsystemic externalities in the payoff functions (i.e. $\varphi = 0.5$). Admittedly, the values for the parameters shown in Table 2 are somewhat arbitrary. We include a robustness analysis in the next section to show that the same qualitative results are obtained if many other values in the vicinity of those shown in Table 2 are employed. We now examine the intra-subsystem shares depicted in Table 2.

Market utopia

The models and policy prescriptions of the Keynesian-Neoclassical Synthesis were generally taught in most influential American Universities until the mid-1970s. Paul Samuelson's *Foundations* and his textbook *Economics* incorporated Keynesian fundamentals into a Neoclassical scientifically modern framework. At the same time, the Tinbergen Econometric project was fully developed to guide US macroeconomic policy (developed by Klein, Tobin and Modigliani). In Table 2, we assign a 0.65 [0.55+0.1] intra-subsystem share for American Keynesianism – with moderate liberalism traces during the 1960s. It is notable that during the 1960s, the neoliberal ideas that would dominate the last quarter of the 20th Century were already on the table (Harvey 2005). In fact, two highly influential books of the 1980s were written in the 1960s: *Constitution of Liberty* (1960) by Hayek and *Capitalism and Freedom* (1962) by Friedman. Initially, they did not gather many followers, although an active embryonic proto-neoliberal mass around the Mont-Pelerin Society, Frank Knight's Chicago, and so on existed. It therefore seems reasonable to instantiate a relatively small proportion of intra-subsystem support (0.35) to promoting pro-market neo-liberalism in the 1960s.

State Utopia:

The *counterculture movement* emerged during the 60s in the US panorama. This meant that a refreshed Unionism, Socialism, and diverse forms of American (pseudo) Marxism (*intelligentsia* in the University movements and so on) called to action and spread across the country (Abbot, 2005; Lipset and Marks, 2000). We represent the State utopia by considering 0.4 of (intra-subsystem) Socialism supporters, 0.35 of (pseudo) intellectual-Marxism defenders, and 0.25 radical pro-state supporters; not much within a subsystem that represents 15 percent global opinion (see Table 2).

Civil Liberties Utopia:

The Cold War dominated the American political thinking of the 60s until the end of the 80s. Freedom and the defense of the Democratic System and individual rights were both public and civic-social affairs (Fukuyama, 2006; Sennett, 1998). Democracy and civil society activism were at the forefront of US society at that time. We represent this situation in Table 2 by assuming a significant share of US society defending the Free-

Democratic system as an envisioned form of 'the good society' in any of its forms, Centralism or Federalism (intra-subsystem share 0.3+0.35). The 60s were also times of radical political disruptions and civil society open demonstrations: new citizen movements pro-civil rights, the anti-war and anti-nuclear movements, the gay liberation and anti-racial segregation groups, the free school movement, feminism, and a range of counter-cultural movements. These trends erupted from civil society in pursuit of new rights that defended unprecedented anti-status quo views in America. We represent those liberty movements by a share 0.35. Recall that we will show later that our simulation results are robust to significant changes in Table 2 initial setting.

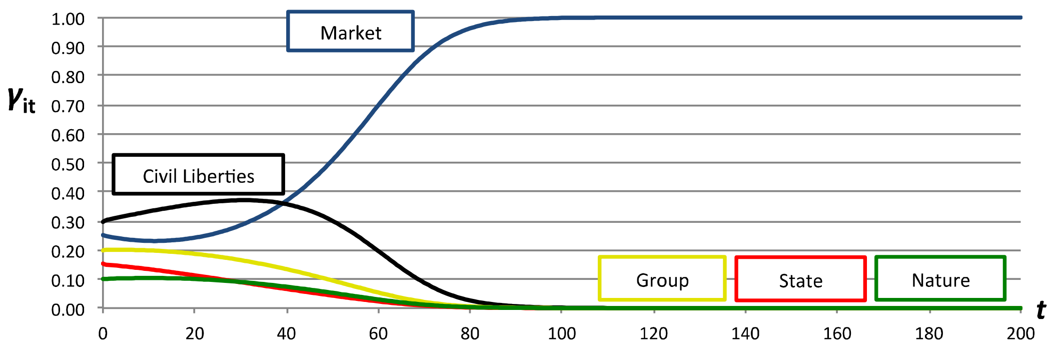
Group Identity utopia

The Cold War also inoculated a strong sense of American nationalism (Abbot, 2005). We represent this by assuming that the Group utopia (G) holds 20 percent of social support, with nationalist supporters being 0.35 (intra-subsystem share). At the same time, McCarthyism, which can be seen as a form of fundamentalism, was part of the American hidden politics of the 1960s and 70s - e.g. FBI's secret COINTELPRO, Watergate and Iran-Contra scandals. Thus, we represent fundamentalism (essentially political but also reactionary US ideologies) in Table 2 with an intra-subsystem share of 0.30. We consider also 0.35 of oligarchy defenders.

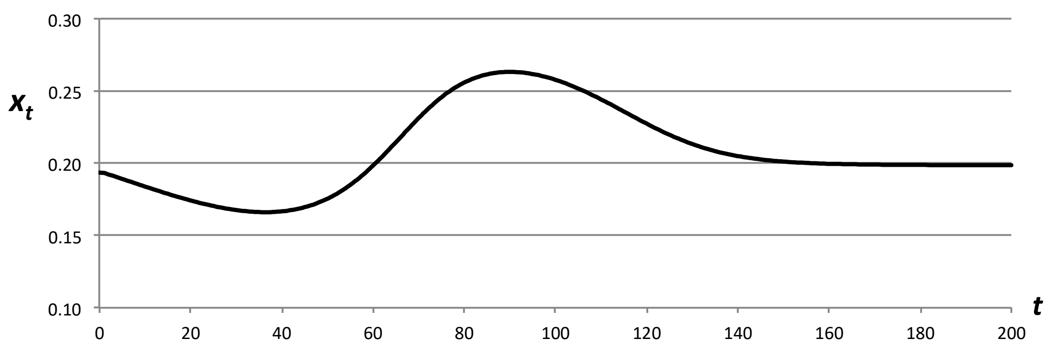
Nature utopia

The space race, with the *Apollo* project at the forefront, reached a milestone with the 1969 Moon landings. Several space missions and an increased interest in studying the outer space and, eventually, conquer it took place during the 1950s, 60s and 70s. These new realities even stimulated more the post-WWII pro-rational science spirit so that we can assume a significant 0.35 of Scientist/Rationalist-supporters within the Nature (N) strand. The conquest of space gave humanity for the first time a new planetary view, which coincided and amplified the emergence of the Environmental movement. Again, two books marked this period: *Silent Spring* (1962) by Rachel Carson and the *Limits to Growth* (1972) by the Club of Rome (Meadows et al. 1972). The World Wildlife Foundation was founded in 1961 and the Environmental Protection Agency began in 1970. Nature clearly moved into the socio-political arena at the 1960s. We have considered 0.35 of supporters for Environmentalism, and 0.3 intra-subsystem share for mid-utopians (see section 4.1, above).

If we consider Table 2 as a plausible representation of the 60s American distribution of utopias, what properties emerge in our model? Can we find explanations for the sub-processes underlying the historically-observed emergent trends? How plausible and sensitive are the properties that we obtain? By running the model from Table 2 we obtain the time evolutions shown in Graphs 1 and 2.



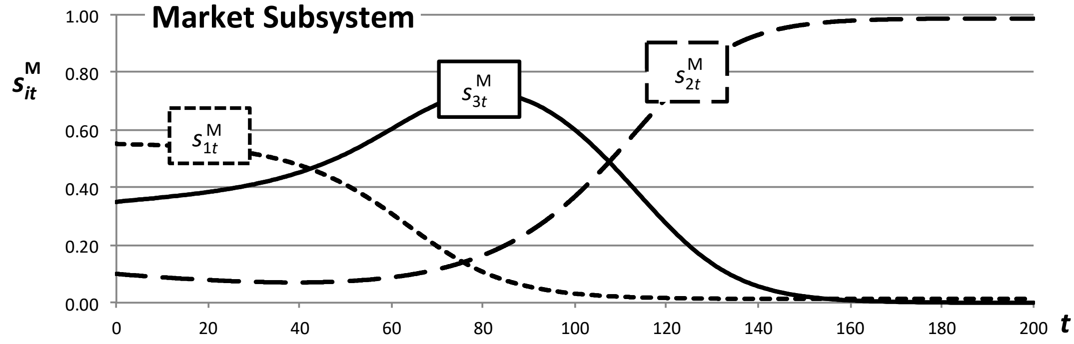
Graph 1: The Triumph of the Market



Graph 2: Average degree of citizenship and commitment in society (x_t)

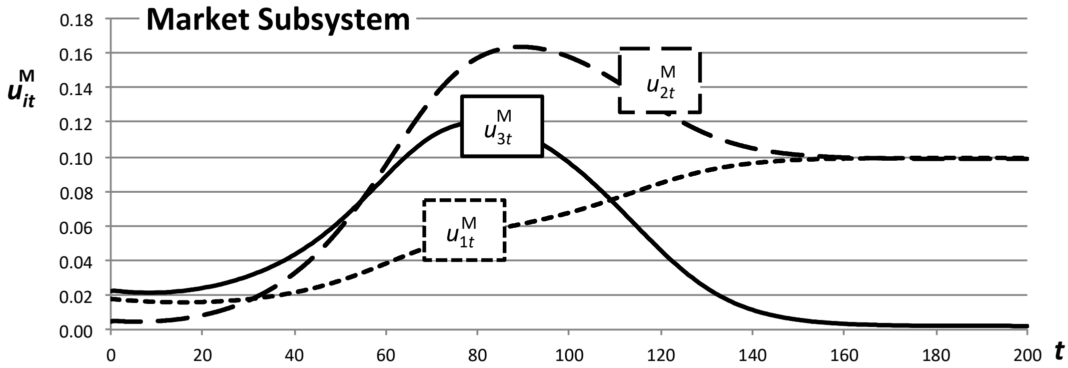
As can be seen in Table 2 and Graph 1, society departs from a reasonably balanced situation in utopias. Graph 1 shows that the State utopia declines since the beginning, whereas the market utopia starts declining, but only for a short time. The Nature utopia, Group identity and pro-civil liberties supporters begin gaining share in society, but this turns out to be just a transitory evolution. And this happens at a time in which free-market support seems to decline for a while. The rise of the Libertarian utopia accelerates during a significant lapse of time, but the declines of Nature and Group utopias open a space for the Market utopia. Then, a contest between Civil Liberties Utopia and Market Utopia is accompanied and driven by an intensified degree of commitment and debate in society (see Graph 2). Finally, the Market society eventually triumphs with a final decline in the social degree of citizenship.

To understand the sub-processes underlying the global trends in Graphs 1 and 2, we show in Graph 3 the (Market intra-subsystem) struggle between Keynesians and Neoliberals (e.g. the 1970s, the crisis of Keynesian thought and the intense influence of Neoliberals from the 1980s to the mid 90s, and the prevalence of Chicago School positions in theoretical and policy realms). In terms of the model, Graph 3 shows the defeat of old-Keynesians (s_{1t}^{M}) leading to the temporary victory of radical free-Market ideas (s_{3t}^{M}) (e.g. the rational expectations revolution and RBC models in the 1970s; Reaganism; Thatcherism; Supply-side economics and the cascade of Chicago Nobel Laureates through the mid-90s). Nevertheless, as we can observe in Graph 3, a new emerging synthesis led by intermediate intellectual positions from the mid 90s onwards (s_{2t}^{M}) (e.g. MIT scholars and doctrines, New-Keynesian models of mainstream inspiration, IMF and monetary policy in the 2000s) arise and ends up being the Market utopia consolidator in Graph 1. Notice in Graph 3 the decrease in the path s_{1t}^{M} – slowly first and inexorable thereafter, the increase of s_{3t}^{M} with a rapid phase of decline afterwards, and the slow rise in s_{2t}^{M}.



Graph 3: Intra-subsystem dynamics within the Market supporters

If we interpret now Graph 3 at the light of equations (1) and the dynamics (2), we find that, despite of the initial Keynesian pre-eminence, according to our model, the dominant position (in terms of higher initial pay-off) was not Keynesianism, but Neo-liberalism. As we show in Graph 4, Keynesianism and, even more so, moderate liberal positions, generated a low pay-off. Why?



Graph 4: Intra-subsystem pay-offs for Market supporters

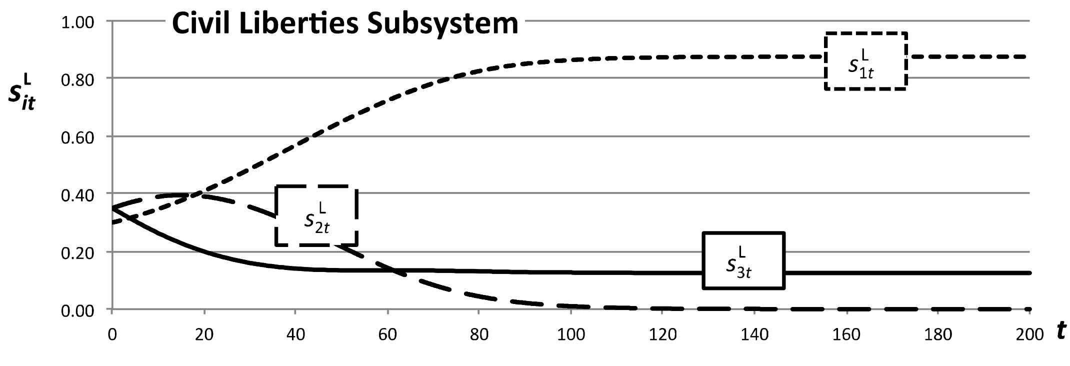
To understand Graph 4, we consider the expression of pay-off functions (1) for the market case u_{it}^{M}. Crucially, *the externality component* is highly favorable for neoliberals.[9] Also notice, on the one hand, that the global intra-market debate is very polarized. A high initial proportion of Keynesians are not very committed to the market – they have low x_{1}- and extract a low u_{10}^{M} from that source. Keynesians also get low positive externalities from moderate influences, i.e. low s_{20}^{M}. Keynesians generate no erosion on the neoliberals' pay-off, since both groups are too distant in the ideas arena; therefore, Keynesians do not affect directly u_{30}^{M}. On the other hand, neoliberals are not challenged strongly in the proximity of their ideas – low value for s_{20}^{M}; they are not eroded by debate with moderate pro-markets. In addition, they are committed to the free-market utopia and enjoy a high and almost ever-increasing pay-off $\gamma_t(1-\varphi)x_3$. This is consistent with the path u_{3t}^{M}. According to Graph 4, neoliberal success engenders, through a positive local externality $\varphi(s_{3t}^{M} - s_{1t}^{M})$ on moderate pro-markets, the rise of u_{2t}^{M} and the success of s_{2t}^{M} in Graph 3.

Does our simulation model fit reality? The late-1970s saw a crisis of ideas and the loss of intellectual authority and influence of the Keynesian thesis, defenders and

[9] See the initial intra-subsystem shares in Table 2 with a low value for s_{20}^{M} ; this implies that the neoliberal mass can develop in its niche with almost no direct challenge from close-moderate positions; they perceive a very low negative externality from s_{20}^{M}.

social prescriptions. Some supporters were perceived as being only loosely connected to market ideas and therefore receptive to socialist ideas.[10] Meanwhile, the success of Monetarism analysis and practice, and the debate on the Phillips curve led by Friedman and others created the conditions under which supply-side economics, individual rationality, atomistic utilitarian and for-profit competition, market self-coordination, and Pareto-optimality ideas appeared as the right way to reach social understanding and the "good society". Thus, during the 1980s, with almost no challenge from close positions, policy recommendations of fresh-water New Classical Macroeconomics and the Chicago school (inflation-targeted policies, constrained fiscal policies, deregulation and liberalization) were supposed to lead the economy back to its natural state. Nevertheless, the very strength of this new paradigm itself, together with crisis in parts of the world (Latin-America and Transition economies) swung the Neoclassical pro-market paradigm again into a rejuvenated moderate vision of imperfect markets, price stickiness and information problems; this led to the medium-road new-saltwater consensus of mainstream Neo-Keynesian/DSGE inspiration. Here we see a real story close to the simulation results from Table 2.

Now, how to explain the decline in civil liberty ideals and civil society activism in Graph 1? To understand this process, we present the intra-subsystem dynamics of the Libertarian utopia subsystem in Graph 5.

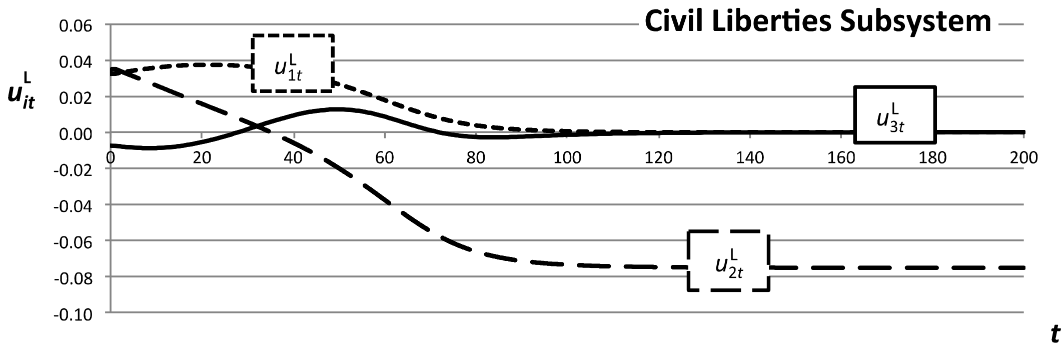


Graph 5: Intra-subsystem dynamics within the Civil Liberties (L) subsystem

In terms of equations (1) and (2), there is an initial debate within the (L)-subsystem between those supporting direct civil action, those in favor of medium Jeffersonian

[10] See the Mises-Keynesian debates on the viability of socialism, e.g. Paul Samuelson's failed predictions of the future of the Soviet Union in the first edition of *Economics*.

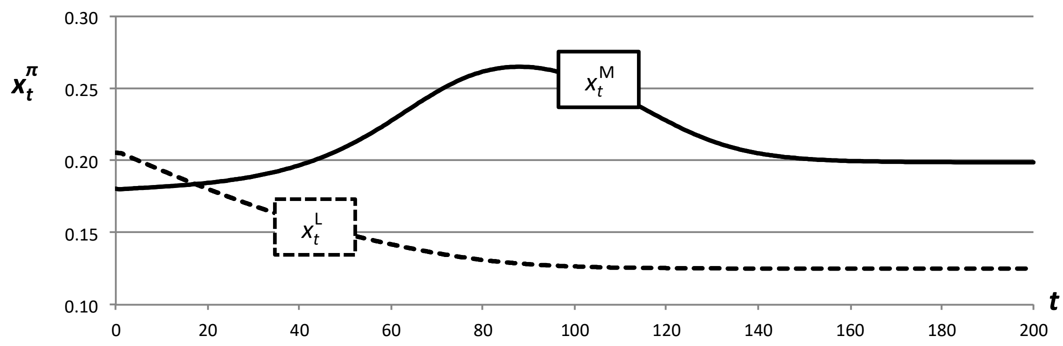
ideals, and supporters of Democratic Centralism (Table 2). Centralists (i=1) are the sub-group that ends up leading the way towards a (failed) Civil Liberty utopia (Graph 5). This seems to have been so in the US and in most Western nations. During several decades, democracy has become a corporatist-bureaucratic version of itself increasingly less committed to direct action and increasingly centralized. More precisely, as apparent in Graphs 5 and 6, note both: (i) the rise of centralism that erodes through the negative externality the attractiveness of Jeffersonism; and (ii) the decline of direct action (s_{3t}^{L} decreases so that highly committed citizens lose size; thus, the positive-externality they projected on mid-level Jeffersonians vanishes). Then, libertarians and Jeffersonians decline, leaving the Centralist group as a weakly committed (L)-supporter.



Graph 6: Intra-subsystem pay-offs for Civil Liberties-supporters

Note that the triumph of the Market subsystem (Graph 1) emerges from an almost opposite process, as described in Graphs 3 and 4. Within the market utopia, extreme neoliberal supporters beat weak pro-market Keynesians, injecting a net positive externality (high citizenship pro-market momentum) on renewed market moderates (group 2-supporters). This is enough to engender an average degree of effort for pro-market to defeat pro-civil liberties supporters (L-supporters that, since almost the very beginning, were the Centralists, see Graph 6).

Finally, observe that the underlying dynamics corresponding to the decline of Nature, State and Group identity are qualitatively similar to Graphs 5 and 6. Under these conditions, it is natural that people looking for freedom, individual self-realization, and socio-energizing forces found a new expression in support of pro-market ideas. Market supporters in the model show a much higher degree of commitment and promotion dynamism than L-supporters. We depict this in Graph 7 below, which reveals the stronger activism of pro-markets as compared with Demo-civil liberties supporters. As Graphs 2 and 7 show, the latest phase of the simulation shows a marked decline in citizen activism; it seems as if the market utopia (one specific worldview) had consolidated its position (Graph 1) generating a fluid 'age of fracture', characterized by the atomistic decomposition of a US market-driven society in which individual rationality, economic calculus and pecuniary motivations prevail over deeper social fundamentals.



Graph 7: Market versus Civil Liberties degree of commitment

4.3 Robustness analysis.

In this Section we carry out a robustness analysis for the Great Society Scenario (Table 2). Our objective is to show that our simulation results are not exclusive for the specific parameter setting shown in Table 2; on the contrary, the same qualitative results are obtained within a sizable set of parametric values. Naturally, to demonstrate such a statement rigorously, first we must formally define what constitutes the "same qualitative results" for us. We consider that the essence of the dynamics observed in the "Great Society Scenario" can be summarized in the following two results:

- Result 1: The market subsystem prevails. Formally, we impose what we call condition 1: $\exists t_1$ such that $\gamma_{t_1}^M > 0.999$; i.e. at some point the Market subsystem gains a support greater than 99.9%.
- Result 2: In the battle for dominance, the main competitor of the Market utopia is the Civil Liberties utopia. Formally, we impose what we call condition 2: $\exists t_2 < t_1$ such that $\gamma_{t_2}^S, \gamma_{t_2}^G, \gamma_{t_2}^N < 0.05$ and $\gamma_{t_2}^M, \gamma_{t_2}^L > 0.05$; i.e. at some point before the market utopia triumphs, the support for the State, the Group and the

Nature utopias all fall below 5% and, at the same time, the Market and the Civil Liberties utopias both enjoy a support greater than 5%.

The goal of the robustness analysis is to identify a wide range of parameter values for which conditions 1 and 2 are satisfied. To do this, we conduct a one-factor-at-a-time analysis first, and a multiple-factors-at-a-time subsequently.

4.3.1 One-factor-at-a-time robustness analysis

The one-factor-at-a-time experiment departs from the default values set in the Great Society Scenario (Table 2) and consists in changing the value of each of the parameters of the model, one at a time (i.e. whilst keeping all the others at their default value), in order to compute the range of values for which the two conditions above remain valid. Table 3 shows the results for parameters s_{i0}^{π} and γ_0^{π}.

	S10		S20		S30		γ0	
	[ ]	%	[ ]	%	[ ]	%	[ ]	%
Market	[0, 0.75]	100%	[0, 0.26]	37%	[0.21, 0.55]	62%	[0.09, 0.65]	86%
Civil liberties	[0.01, 0.62]	61%	[0.10, 0.94]	88%	[0.23, 0.75]	55%	[0.19, 0.70]	73%
State	[0.09, 0.90]	90%	[0.16, 0.85]	81%	[0, 0.46]	48%	[0, 0.35]	64%
Group	[0.13, 0.95]	86%	[0.24, 0.92]	72%	[0, 0.42]	42%	[0, 0.31]	52%
Nature	[0.07, 0.95]	93%	[0.15, 0.93]	78%	[0, 0.55]	58%	[0, 0.23]	33%

Table 3: One-factor-at-a-time Robustness Analysis

Table 3 shows, for each one of the 15 parameters s_{i0}^{π} and 5 parameters γ_0^{π}, the range of values within which conditions 1 and 2 prevail in the one-at-a-time experiment, and the length of this range as a % of the maximum admissible range for that parameter[11]. It is noteworthy how high these percentages are for most parameters.

[11] Note that there are a few constraints that must be taken into account when changing the values of the parameters in Table 3, namely: $\sum_i s_{i0}^{\pi} = 1$ for all $\pi \in \Pi$, and $\sum_{\pi \in \Pi} \gamma_0^{\pi} = 1$. To ensure that the restriction $\sum_i s_{i0}^{k} = 1$ is maintained when adding a certain (positive or negative) value δ to the default value $\left(s_{j0}^{k}\right)^{DV}$ of any parameter s_{j0}^{k}, we subtract $\delta/2$ from the default value $\left(s_{i \neq j0}^{k}\right)^{DV}$ of the other two parameters $s_{i \neq j0}^{k}$. Similarly, when adding a certain (positive or negative) value δ to the default value $\left(\gamma_0^{k}\right)^{DV}$ of any γ_0^{k}, we subtract $\delta/4$ from the default value $\left(\gamma_0^{\pi \neq k}\right)^{DV}$ of the other four parameters $\gamma_0^{\pi \neq k}$ so that the restriction $\sum_{\pi \in \Pi} \gamma_0^{\pi} = 1$ is maintained. This procedure implies that the range of admissible values that can be

We also conducted a one-at-a-time experiment for the other parameters $\{x_1, x_2, x_3\}$ and φ. In order to explore a wide range of combinations of levels of contribution $\{x_1, x_2, x_3\}$, we define parameters α and β and use the formula: $\{x_1, x_2, x_3\} = \alpha\{1, (1+\beta), (1+2\beta)\}$ to generate different combinations. Thus, parameter α regulates the proportion of resources that society devotes to their ideals in general, whilst parameter β regulates the differences in contributions between the different levels of commitment in each Utopia. As an example, the contributions in the Great Society Scenario $\{x_1, x_2, x_3\} = \{0.1, 0.2, 0.3\}$ correspond to values $\alpha = 0.1,\ \beta = 1$.

The robustness of our simulation results to parameters α and β is complete, i.e. they can take any value within the admissible range[12] (one at a time) and the simulation results are qualitatively the same as in the Great Society Scenario.[13] The robustness of the simulation results to parameter φ is also very high, i.e. any value of φ in the range [0.19, 1] will lead to the same qualitative results as in the Great Society Scenario (see Table 3-Cont.). Let us notice that all the results stated up to know can be clarified and extended for the more-formally oriented reader in the Appendix to the paper. We will also refer to the Appendix to complete the interpretation on some counter-factual findings below.

α		β	
[ ]	%	[ ]	%
(0, 1/3]	100%	(0, 4.5]	100%

φ	
[ ]	%
[0.19, 1]	81%

Table 3-Cont. Linear Robustness Analysis: α, β, φ.

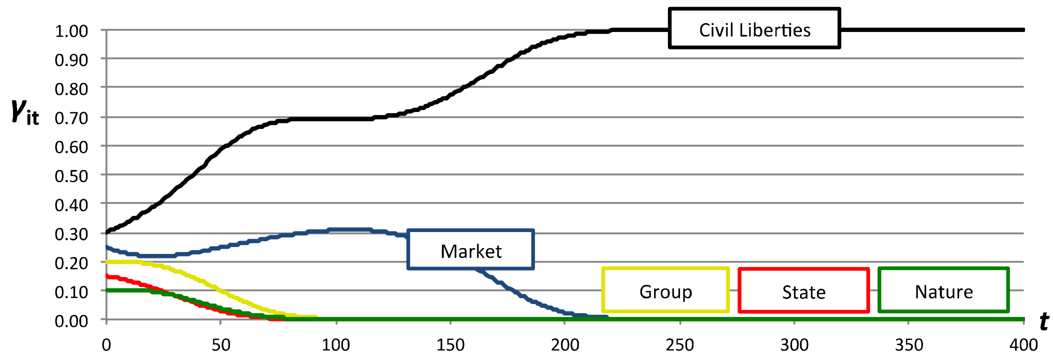
As an example of a counter-factual finding, we show as an example a parameter setting that does not generate the same qualitative results as the Great Society Scenario. To do this, we change the value of φ from 0.5 to 0.18 (see Graphs 8 and 9). This parameter

explored for a particular s_{j0}^k is often smaller than [0,1], since we must also honor the conditions $s_{i\neq j0}^k \geq 0$. To be precise, the admissible range when changing a particular s_{j0}^k is $\left[0,\ \left(s_{j0}^k\right)^{DV} + 2 \cdot \min_i\left(s_{i\neq j0}^k\right)^{DV}\right]$. The same argument applies for γ_0^k and the conditions $\gamma_0^{\pi\neq k} \geq 0$. The admissible range when changing a particular γ_0^k is $[0,\ (\gamma_0^k)^{DV} + 4 \cdot \min_i(\gamma_0^{\pi\neq k})^{DV}]$.

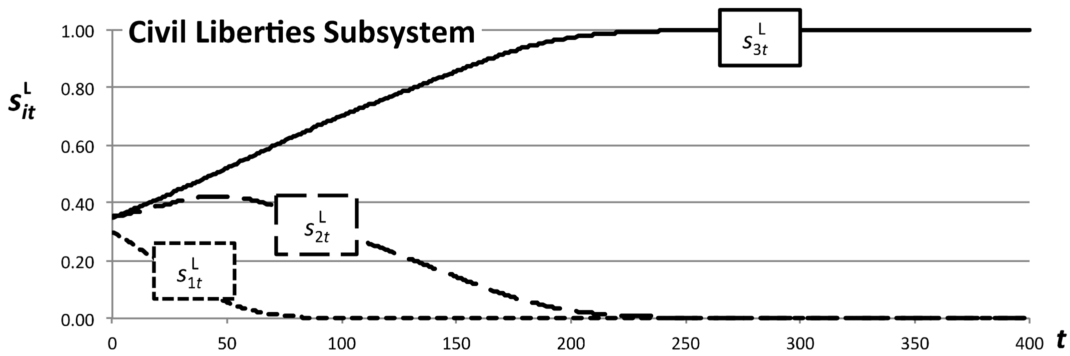
[12] Only values of α and β that make $0 \leq x_i \leq 1$ are admissible.

[13] The effect of changing the value of α is merely a change in the time scale. This can be easily proved analytically conducting a change of variable $t^* = \alpha \cdot t$. The lowest value of β that we have checked is 10^{-5}.

suggests interesting counter-factual insights for our case (more on this in Appendix): for any value of $\varphi \leq 0.18$ the Civil Liberties utopia dominates (keeping the rest parameters at their default value).



Graph 8: Counterfactual run with $\varphi = 0.18$ *in Table 2.*



Graph 9: Counterfactual run $\varphi = 0.18$; *intra-subsystem evolution of Civil Liberties Subsystem.*

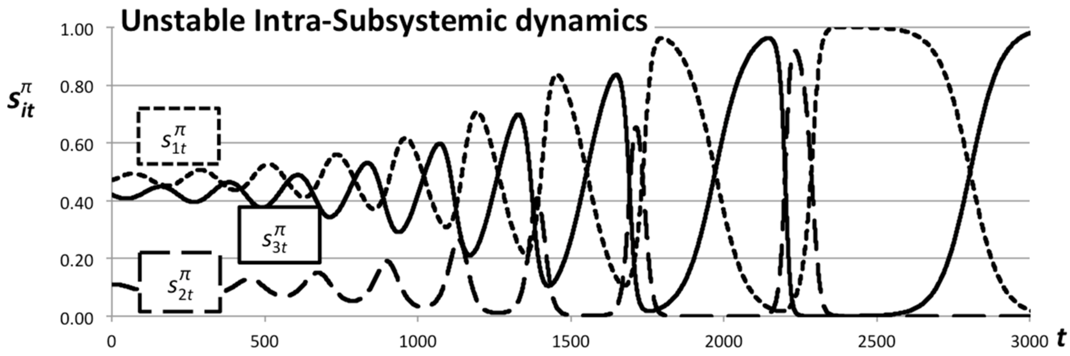
Graphs 8 and 9 show how, according to eqs. (1), (2) and (3) in the model, for low values of φ, the intense momentum reached by libertarian activities in the US 1960s-70s would have persisted and intensified, leading to a lower role for the market utopia in society and a larger role for the L-subsystem. This is a counterfactual exercise that exceeds the scope of this paper but suggests lines for future empirical research. On the other side, the discussion in the Appendix may allow us to better understand the role of parameter φ. It seems to be determinant in conditioning the prevalence of certain utopias, and even the co-existence of diverse worldviews in the societal system (see Appendix). Here, and to maintain the history-friendly tone of the paper, let us just show that the dynamics of the model do not necessarily end up with one single utopia dominating the others. Trivial cases where all utopias would coexist include those where they are parameterized in the same way (their intra-subsystemic dynamics are the same, and $\gamma_t^\pi = 0.2, \forall t, \forall \pi \in \Pi$). But it is also possible to identify non-trivial scenarios where various utopias would coexist with different degrees of support. Thus, Table 3 shows a setting where the number of utopias that coexist with stable (and different) degrees of support in the long run is five (i.e. all) if $\varphi = 0.02$, four if $\varphi = 0.03$, three if $\varphi = 0.04$, two if $\varphi = 0.05$, only one (i.e. the Nature utopia) if $\varphi = 0.07$, and again only one, but a different one (i.e. the Market utopia) if $\varphi = 0.1$.

	s_{10}	s_{20}	s_{30}	γ_0
Market	0.30	0.30	0.40	0.20
Civil liberties	0.29	0.31	0.40	0.20
State	0.28	0.32	0.40	0.20
Group	0.27	0.33	0.40	0.20
Nature	0.26	0.34	0.40	0.20

x_1	x_2	x_3
0.1	0.2	0.3

Table 3: Initial setting for different scenarios where various utopias can coexist with different degrees of support, depending on the value of φ.

There are other scenarios where the dynamics never stabilize. As an example, Graph 10 shows the intra-subsystemic dynamics of any of the five utopias when they all start with $\{s_{10}^\pi, s_{20}^\pi, s_{30}^\pi\} = \{0.47, 0.11, 0.42\}$ and $\gamma_0^\pi = 0.2$, and the levels of contribution are $\{x_1, x_2, x_3\} = \{0.1, 0.2, 0.3\}$.



Graph 10: Example of unstable intra-subsystemic dynamics.

4.3.2 Multiple-factors-at-a-time robustness analysis

Now consider a sizable neighborhood of parameter values around the Great Society Scenario for which the same qualitative results (Conditions 1 and 2) are obtained. To define this neighborhood, we have grouped all the model parameters into 5 sets: s_{i0}^{π}, γ_0^{π}, α, β and φ. In contrast with the one-at-a-time-factor, here we vary several parameter values at the same time; we alter any one parameter value within each of the five groups at the same time[14]. Table 4 shows parametric ranges within which Conditions 1 and 2 hold when (at most) one change within each of the 5 parameter groups is induced.

	s_{10}	s_{20}	s_{30}	γ_0
Market	0.55 ± 0.05	0.10 ± 0.05	0.35 ± 0.05	0.25 ± 0.05
Civil liberties	0.30 ± 0.05	0.35 ± 0.05	0.35 ± 0.05	0.30 ± 0.05
State	0.40 ± 0.05	0.35 ± 0.05	0.25 ± 0.05	0.15 ± 0.05
Group	0.35 ± 0.05	0.35 ± 0.05	0.30 ± 0.05	0.20 ± 0.05
Nature	0.35 ± 0.05	0.30 ± 0.05	0.35 ± 0.05	0.10 ± 0.05

α	β	φ
(0, 1/3]	[1, 2]	0.5 ± 0.05

Table 4: General Robustness Analysis

[14] As explained before, any change in a parameter s_{i0}^{π} or γ_0^{π} forces us to alter the value of other parameters to ensure that the constraints $\sum_i s_{i0}^{\pi} = 1$ for all $\pi \in \Pi$, and $\sum_{\pi \in \Pi} \gamma_0^{\pi} = 1$ are preserved.

As an example, the following parameter setting would lead to results qualitatively identical to the Great Society Scenario:

- $s_{10}^{M} = 0.55 - 0.05 = 0.5$
  (and consequently $s_{20}^{M} = 0.10 + \frac{0.05}{2} = 0.125;\ s_{30}^{M} = 0.35 + \frac{0.05}{2} = 0.375$)
- $\gamma_0^L = 0.30 + 0.05 = 0.35$
  (and consequently $\gamma_0^M = 0.25 - \frac{0.05}{4} = 0.2375;\ \gamma_0^S = 0.15 - \frac{0.05}{4} = 0.1375;$
  $\gamma_0^G = 0.20 - \frac{0.05}{4} = 0.1875;\ \gamma_0^N = 0.10 - \frac{0.05}{4} = 0.0875$)
- $\alpha = 0.2$ and $\beta = 2$
  (and consequently $\{x_1, x_2, x_3\} = \{0.2, 0.6, 1\}$)
- and $\varphi = 0.5 - 0.05 = 0.45$.

Note that the variety of possible settings for which the qualitative results of the Great Society Scenario hold is remarkably large. Focusing only on (e.g.) possible levels of contributions, results are qualitatively the same for values: $\{x_1, x_2, x_3\} = \{0.001, 0.002, 0.003\}$ (obtained with $\alpha = 0.001$ and $\beta = 1$), $\{x_1, x_2, x_3\} = \left\{\frac{1}{3}, \frac{2}{3}, 1\right\}$ (obtained with $\alpha = 1/3$ and $\beta = 1$), or $\{x_1, x_2, x_3\} = \{0.05, 0.15, 0.25\}$ (obtained with $\alpha = 0.05$ and $\beta = 2$). Thus, the results obtained for the Great Society Scenario are robust within a truly sizable neighborhood of parameter settings.

4.4 *Some general interpretations.*

Before we move to the next section, here we provide an overall interpretation of the model dynamics inspired by what we have obtained above, and the results in the Appendix. This reflection does not seek to be exhaustive; we just intend to clarify interpretations and suggest future theoretical research. Thus, considering what we said in Sections 3 and 4, and in the Appendix, it is clear that parameter φ, which fixes within the citizen payoff (1) the bias between strong-utopian partisanism *vs* permeability to externalities, plays a key role in the model. In the standard setting (Table 2) we chose the intermediate value $\varphi = 0.5$. However, as we have seen, with high degrees of strong utopian-partisan bias (low φ), more than one subsystem may engender a high average degree of citizenship (especially those subsystems with high initial share, and a significant initial proportion of highly committed citizens), and they may end up co-existing in society after a transition process (with equal levels of average commitment in the stationary state; see Appendix). More complex behaviors emerge in the case of high permeability to local externalities and relatively low partisan motivations (high φ).

In these cases, complex dynamics may emerge, since citizens are highly sensitive to peers behavior and they revise (accordingly) their commitment level. Notice that, as in this model intra-population revisions of behavior co-evolve with inter-population changes, the overall dynamics are highly connected to the existence of convergence to similar average levels of commitment among subsystems, see expression (3) –Section 3. For two or more utopias to co-exist, they must engender identical levels of average citizenship.

5 Future developments

Having reached this point, we believe that our co-evolutionary approach to political economy is congruent with previous works in evolutionary economics, and it may inspire future research connecting this line of thought with evolutionary game theory, agent-based stochastic models, and network theory. Let us devote this section to suggest possible future developments of our model along these lines.

Firstly, let us anticipate that the complete mathematical exploration (even in this simple version) of the model is a highly challenging (although extremely interesting) task. As we have seen in the Appendix*, population dynamics methods and evolutionary games* machinery for large-multiple populations in co-evolving settings might be combined to extract results. But it is not simple at all. In fact, notice that although our present model is simple (almost intuitive) in its representation of reality, it displays multiple equilibria and qualitatively different (often complex) dynamics, because of the multiple (positive/negative and local/global) feedbacks that it includes. As we have proved in previous works (Fatas-Villafranca et al. 2007, 2009, 2011), even analyzing the (much simpler cases) of fully isolated intra-subsystem dynamics, the mathematics were highly challenging, and the results surprising and complex. Regarding our present co-evolution model, it is remarkable how the simple combination of intra-subsystem deterministic dynamics, just by linking them through a simple (but *in the center of co-evolution*) replicator process, generates intriguing, complex and non-trivial dynamic outcomes. We believe that our model is an exemplar of simple (non-complicated) but intrinsically complex model. Complexity arises from co-evolution and positive/negative feedbacks at local/global levels. Thus, a suggested path for future research (not only in political economy, but also in traditional evolutionary approaches to innovation and industrial dynamics) may consist of coming up with stylized and simple evolutionary representations of different phenomena (Metcalfe, 1998; Vega-Redondo, 1996), and then, including pertinent local positive/negative feedbacks and co-evolutionary mechanisms, so that the resulting structure may be addressable from the most innovative machinery in population dynamics theory (Sandholm, 2010). New results to deal with deterministic and stochastic evolutionary models of this type have appeared during the last decade (Almudi et al., 2013).

Secondly, as in recent parallel efforts in evolutionary economics to deal with macroeconomic issues through *agent-based models* (e.g. Dosi, Fagiolo and Roventini, 2010), the history-friendly spirit of our model could be preserved (*á* la Malerba et al. (2016)) and even moved forward (following Di Guilmi, Landini and Gallegati (2017)) by applying the *Master Equation* (ME) methodology to obtain results in so-called *granular models* -with heterogeneous agents, interactions among meso-subsystems, stochasticity and aggregate emergent properties. The ME methodology draws basically on a differential equation for the probability distribution of the underlying process (which represents the development of a domain-specific granular system, as stated above); then, two methodological approaches exist: it is possible to either approximate solutions as computed by (e.g.) Aoki (1996), or, alternatively, the ME can be used to identify the moments of the corresponding stochastic process. In both cases, political economy issues inspired by our current model could be addressed, and emergent macro-dynamics (average levels of contributions, persistence of diversity in the socio-political realm, etc.) would be obtained from granular micro-foundations involving uncertainty, heterogeneity and scattered interactions. This line of progress is clearly comparable with our model assumptions and results.

Finally, it seems possible to develop our modeling proposal along the lines of the theory of *complex social networks* (Vega-Redondo, 2008). Our current model incorporates incentives and pay-offs, gradual and ongoing interactions among heterogeneous agents that may update their positions as time goes by, and local/global interactions driving the emergent dynamics. As Jackson (2008) suggests, these are good wickers on which we can start building up random networks with economic meaning, small world-structures, scale-free networks and even multilayer networks, where distinct layers could correspond to alternative utopian views, and diffusion/search along and across layers would engender dynamics comparable to the ones we obtained. We believe that the combined use of these suggested lines of progress could promote the theoretical development of *evolutionary political economy* by establishing bidirectional links with *complexity theory*, *networks*, *statistical physics* and *evolutionary games*. In any case, for the time being, we just suggest these fascinating alternatives as possible avenues of advance which follow from our stylized history-friendly co-evolution model as a benchmark for future studies.

6 Conclusions

We have introduced a new history-friendly modeling approach to the study of long run societal transformations as the outcome of high-level competition between ideas that furnish the overarching ordering principles of a society (Montgomery and Chirot 2015). We have called these utopias, and characterize our approach as that of co-evolutionary utopia competition, which is an emergent outcome of differential citizen support and economic contribution. We have set out the underlying analytical model, and illustrated this with a stylized case study of the rise of free-market liberalism in the US, and the relative defeat of socialist and other utopias. In Almudi et al (2017), we use the same approach to examine the rise of environmentalism in the context of climate change.

By specifying a socio-economic order as made of subsystems, a utopia as a preference for the dominance of a particular subsystem, and citizenship as the agents' private contribution to a subsystem, we have developed a replicator-dynamics model to study historical patterns of idea-competition. Our co-evolutionary subsystems-based model of long-run historical economic change differs from the broad suite of institutional approaches since our approach is built around an agent of change – the economic actor as a citizen engaged in idea competition, drawing upon their own economic resources. We can thus characterize indices of historical change in support of ideas, as we have illustrated with our vignettes on US societal transformations. This approach models ideas as engaged in evolutionary competition, and maps this to not only agents choosing to support different utopias, but also to choose their level of contribution, which we represent in three discrete levels (low, medium and high). This enables us to (qualitatively) check the plausibility of our model with respect to certain historical facts of the US society.

We believe this offers a useful extension of the history-friendly approach into the domain of big-history and of the recent turn toward idea-centered history. We further suggest this approach may be useful in seeking to integrate evolutionary political economy with both a richer conception of the economic agent as a citizen, and also an endogenous approach to institutional dynamics. We have also suggested possible formal developments from our current work. In fact, we believe that our proposed model may be considered as a first prototype in *formal evolutionary political economy* against which future developments, with more complex idea-topologies, could be added.

Appendix

In this appendix, we present further insights on the intra-subsystemic dynamics of the model, and on the way these dynamics co-evolve giving rise to the overall dynamics of utopia competition. The exhaustive mathematical exploration of the model goes beyond the scope of this paper. Nevertheless, we want to highlight here some possible lines of progress in the formal exploration; likewise, we present certain results which clarify the mechanisms supporting our socio-economic insights in Section 4. We do not incorporate these results in Section 4 because, perhaps, they might interrupt the history-friendly style of discussion of the paper.

As we show in this Appendix, it is interesting to note that, although we have presented the model as a co-evolution framework that contributes to evolutionary political economy in line with population dynamics thinking, we can use machinery from evolutionary game theory to better understand the dynamics and the results. This is a typical way to proceed in population models (see Weibull, 1995; Hofbauer and Sigmund, 1998; Sandholm, 2010). Thus, in this appendix, we show, firstly, how the intra-subsystem dynamics can be decomposed for future analysis in two extreme subgames and infinite mixes of these subgames. This procedure allows us to better understand the role of parameter φ in the model and in our results (persistence of various co-existing utopias, etc). Afterwards, we consider these insights to reflect on the overall replicator process (expression (3) in Section 3) which is interlinked (in a bidirectional way) in the model with the distinct intra-subsystem replicators (expressions (1) and (2) in Section 3, and the bidirectional links with expression (3)). We present new simulations as supporting material for the socio-economic interpretations in Section 4. The appendix also helps us to pose possible future developments (departing from the current model as a benchmark) as we explain in Section 5.

Insights on the dynamics of the model

Decomposition of the intra-subsystemic dynamics

Note that the payoff for each level of contribution (eq. (1)) can be written as follows:

$$\begin{bmatrix} u_{1t}^{\pi} \\ u_{2t}^{\pi} \\ u_{3t}^{\pi} \end{bmatrix} = \left(\gamma_t^{\pi}(1-\varphi) \begin{bmatrix} x_1 & x_1 & x_1 \\ x_2 & x_2 & x_2 \\ x_3 & x_3 & x_3 \end{bmatrix} + \varphi \begin{bmatrix} 0 & x_1 & 0 \\ -x_2 & 0 & x_2 \\ 0 & -x_3 & 0 \end{bmatrix} \right) \begin{bmatrix} s_{1t}^{\pi} \\ s_{2t}^{\pi} \\ s_{3t}^{\pi} \end{bmatrix}$$

Thus, at the intra-subsystem level, eq. (2) can be seen as the replicator dynamics of a population game where players are randomly paired to play a 2-player 3-strategy game where the payoff matrix is:

$$\left(\gamma_t^{\pi}(1-\varphi) \begin{bmatrix} x_1 & x_1 & x_1 \\ x_2 & x_2 & x_2 \\ x_3 & x_3 & x_3 \end{bmatrix} + \varphi \begin{bmatrix} 0 & x_1 & 0 \\ -x_2 & 0 & x_2 \\ 0 & -x_3 & 0 \end{bmatrix} \right)$$

Let us consider the extreme values of φ. For $\varphi = 0$, we have the following game (henceforth SG1, for subgame 1):

$$\gamma_t^{\pi} \begin{bmatrix} x_1 & x_1 & x_1 \\ x_2 & x_2 & x_2 \\ x_3 & x_3 & x_3 \end{bmatrix}$$

Given that $x_1 < x_2 < x_3$, strategy 3 is dominant, and evolutionarily stable. Thus, the point $s_3 = 1$ is asymptotically stable and the system converges to it from any initial condition with $s_3 > 0$.[15] The speed of convergence will be faster the greater the value of γ_t^{π}. Figure A1 below shows the phase portrait of the dynamics of this game in the 2-dimensional simplex.

[15] The population profile induced by an Evolutionary Stable Strategy is asymptotically stable in terms of the Replicator Dynamics (Hofbauer and Sigmund, 1998, Weibull, 1995).

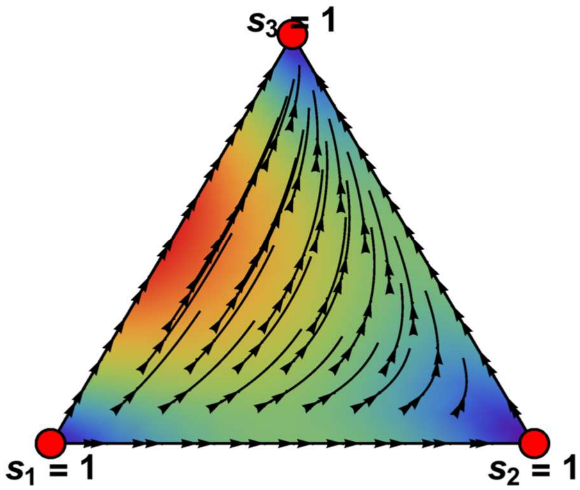


Figure A1. Phase portrait of the game SG1, with $x_1 = 0.1$, $x_2 = 0.2$, $x_3 = 0.3$, and $\gamma_t^\pi = 0.5$. Rest points are shown as red circles.

For the other extreme value $\varphi = 1$, we have the following game (henceforth SG2, for subgame 2):

$$\begin{bmatrix} 0 & x_1 & 0 \\ -x_2 & 0 & x_2 \\ 0 & -x_3 & 0 \end{bmatrix}$$

In SG2, strategy 3 is weakly dominated by strategy 1.[16] It is not difficult to prove that the rest points of the replicator dynamics for SG2 are:

1. All points in the line $s_2 = 0$ (and $s_3 = 1 - s_1$).
2. Point: $s_2 = 1$. This point is unstable, as it is invadable by strategy 1.

Figure A2 shows the phase portrait of the dynamics of this game in the 2-dimensional simplex.

[16] Note, however, that this does not imply that strategy 3 will be wiped out in the Replicator Dynamics. Weakly dominated strategies in the Replicator Dynamics may remain present forever. In this particular case, strategy 3 obtains a strictly lower payoff than strategy 1 at any point in the interior of the simplex, but the dynamics may lead the process "quickly" towards the boundary $s_3 = 1 - s_1$, where the selection pressure over strategy 3 disappears.

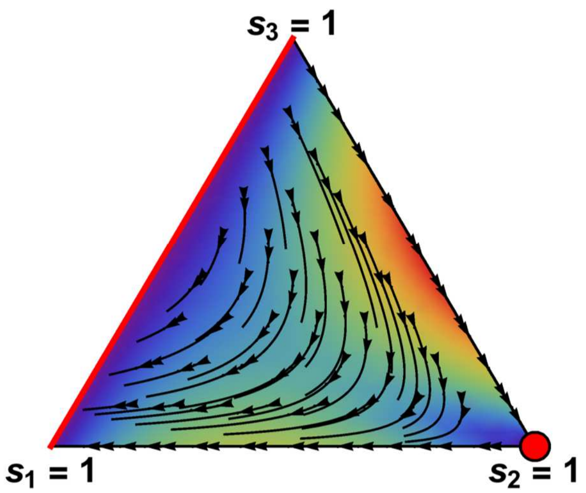


Figure A2. Phase portrait of the game SG2, with $x_1 = 0.1$, $x_2 = 0.2$, $x_3 = 0.3$. Rest points are shown in red.

Therefore, in terms of our model, when $\varphi = 0$, and citizens (within their subsystems) are purely partisans (in the sense that they just care about the rise to prevalence of their utopia, without paying attention to possible opportunistic behaviors by their peers in (1)) then, said subsystem tends (in isolated conditions) to a maximum average degree of citizen contribution. On the contrary, when permeability is absolute (as given by $\varphi = 1$ in (1)), then citizens perceive (or take advantage of) possible opportunistic behaviors and the subsystem tends to stabilize (in isolated conditions) in the lowest degree of citizen contribution. Of course, we have a continuum of possibilities between subgames 1 and 2, but we can infer that the lower the value of φ in a subsystem, we should tend to obtain higher average levels of commitment in said subsystem. Likewise, when φ is high, then low levels of commitment in the subsystem, or fluctuating paths driven by the ongoing revision of strategies, are expected. In any case, notice that when we couple the subsystems (considering (1), (2) and (3) together in Section 3), then the shares of the subsystems in society also evolve, and the effect of φ in the payoffs gets mediated by endogenously changing subsystem shares, and intra-subsystem behaviors. This much more complex situation is the one we see below.

Insights on the overall dynamics

Taking into consideration the decomposition shown in the previous section, and assuming $\varphi > 0$, note that the dynamics of subsystems with very low share γ_t^{π} are driven by SG2, so in such vanishing subsystems eventually strategy 1 becomes dominant, strategy 3 may hold some minor share, and strategy 2 effectively disappears. In the general case, the dynamics of subsystems with a non-negligible share γ_t^π will depend on the value of φ.

Low values of $\boldsymbol{\varphi}$

As pointed out above, in subsystems with low share γ_t^π, SG2 drives the dynamics, so eventually strategy 1 becomes prevalent, strategy 3 may hold some minor share, and strategy 2 effectively disappears.
In subsystems with high share γ_t^π, SG1 drives the dynamics, so strategy 3 is clearly favored, and the greater the value of γ_t^π, the faster the convergence to strategy 3. A greater share s_3 induces an increase in γ_t^π, thus creating a self-reinforcing dynamic. Which particular subsystem(s) will end up with a significant share γ_t^π will depend on initial conditions. A high value of $\gamma_{t=0}^\pi$ and, particularly, a high value of $s_{3,t=0}^\pi$ will be key. As a representative example, consider Figure A3, where φ = 0.03.

High values of $\boldsymbol{\varphi}$

As in the previous case, in subsystems with low share γ_t^π, SG2 drives the dynamics. The analysis of the subsystem(s) with significant share γ_t^π is more complicated, as both SG1 and SG2 influence the dynamics. As an example, consider the case where φ = 0.8 and there is a subsystem with $\gamma_t^\pi \approx 1$. This game shows cyclic dynamics, as can be seen in Figure A4 (where $x_1 = 0.3$, $x_2 = 0.45$, $x_3 = 0.6$). Figure A5 shows the overall dynamics of a simulation run where the Market subsystem prevails, and its intra-subsystemic dynamics are cyclic.

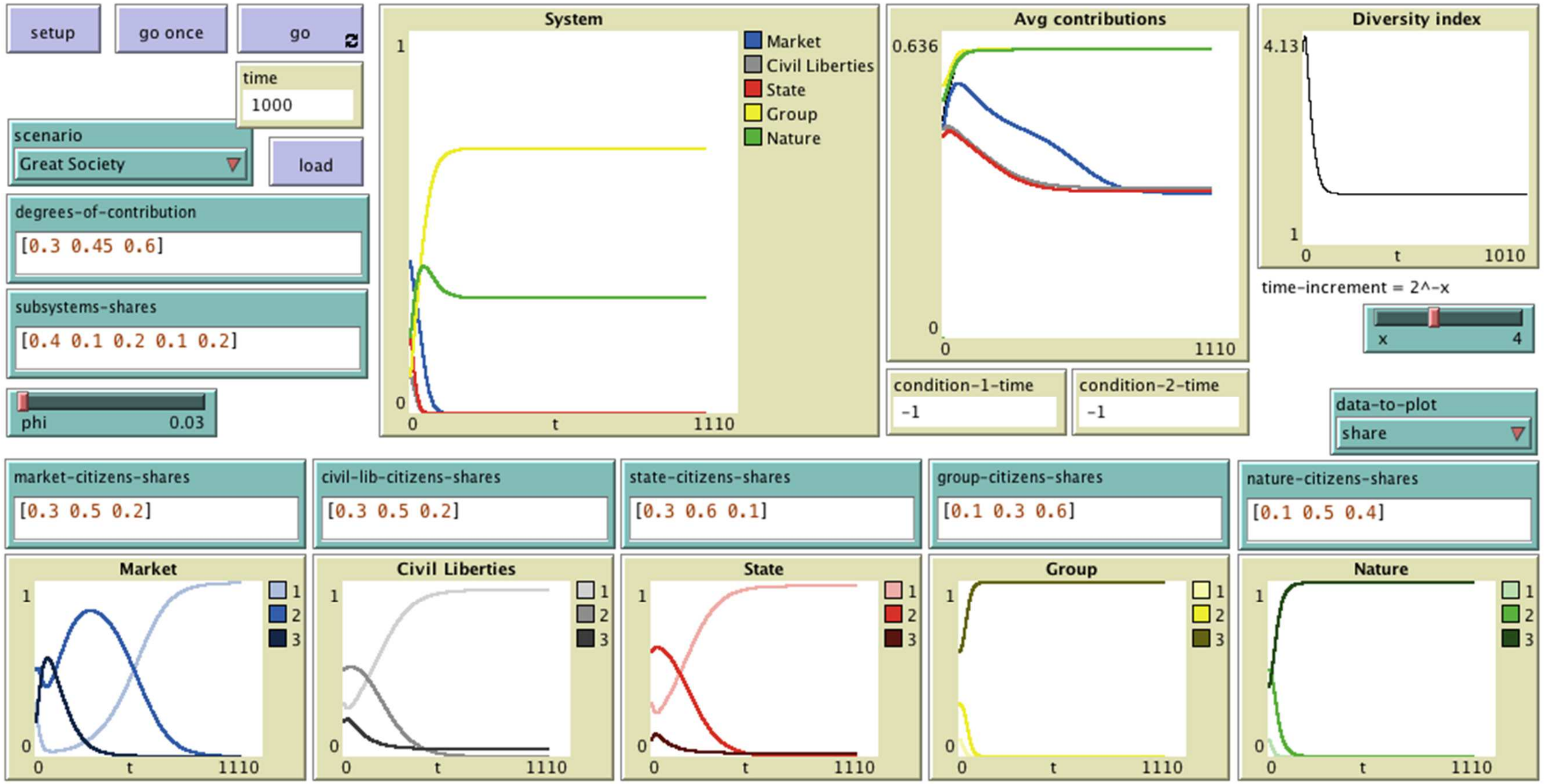


Figure A3. Representative example of a situation where two subsystems (Group and Nature) coexist. In these two subsystems $s_3 \approx 1$, whilst in the subsystems that vanish $s_2 \approx 0$ and s_1 is high.

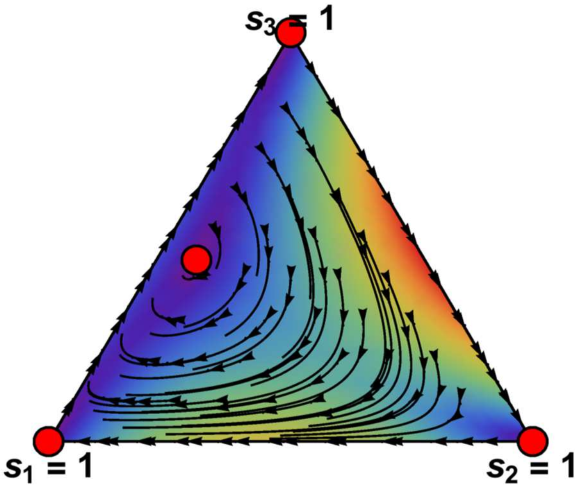


Figure A4. Phase portrait of a game with (x_1, x_2, x_3) = (0.3, 0.45, 0.6), φ = 0.8 and γ_t^{π} = 1. Rest points are shown as red circles. Rest point (1, 0, 0) has associated eigenvalues -0.33 and 0.06; rest point (0, 1, 0) has associated eigenvalues -0.45 and 0.21; rest point (0, 0, 1) has associated eigenvalues -0.06 and 0.33; and finally, interior rest point (0.472, 0.0833, 0.444) has associated eigenvalues $4.58 \cdot 10^{-3} \pm 0.095i$.

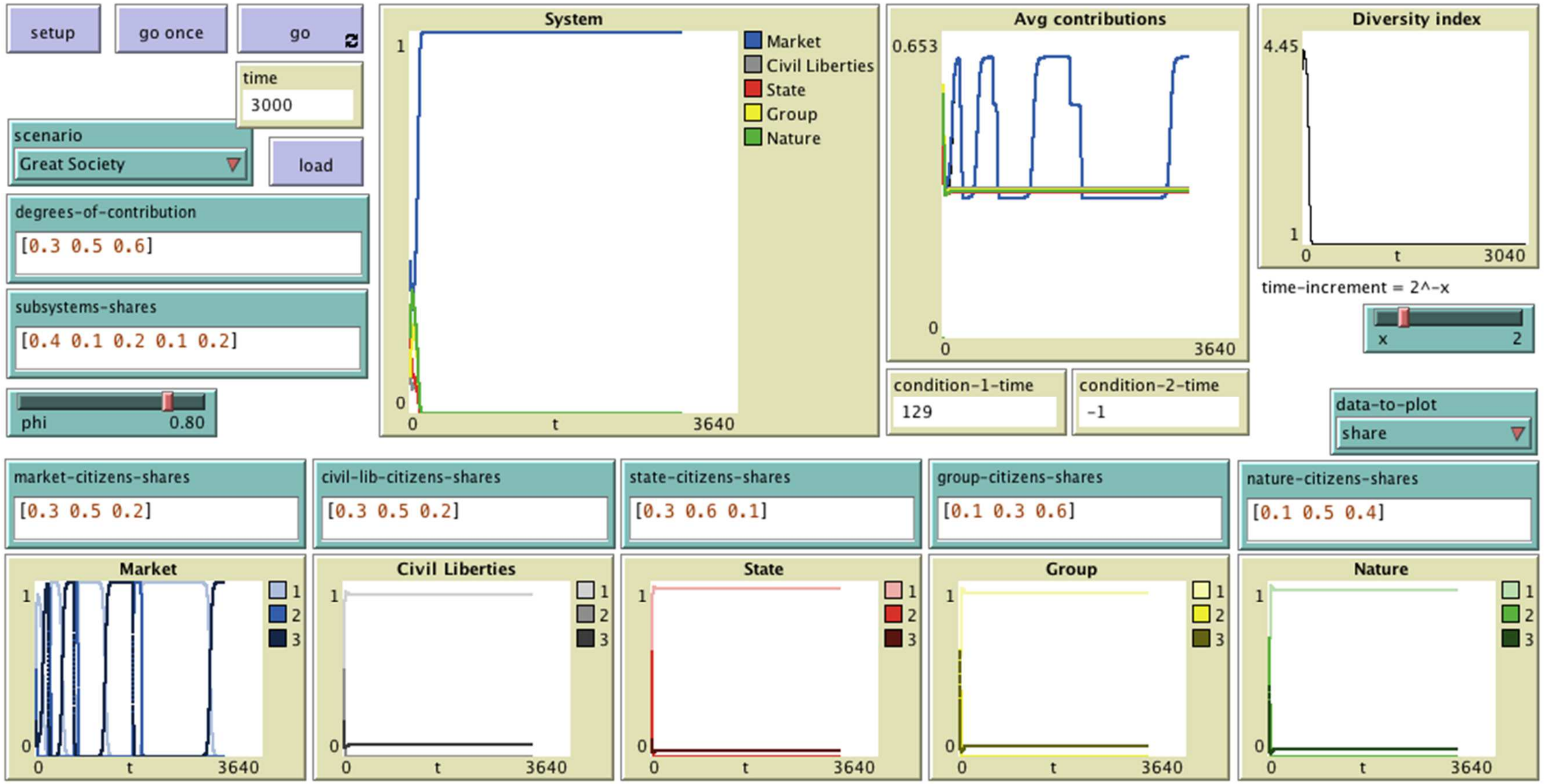


Figure A5. Representative example of a situation where only one subsystem survives (Market). The intra-subsystemic dynamics of this subsystem are cyclic.

A final example

In intermediate situations where both SG1 and SG2 play a role in the intra-subsystemic dynamics of some subsystems, the overall dynamics can be very different from the extreme cases outlined above. As a final example, consider a model with $x_1 = 0.3$, $x_2 = 0.45$, $x_3 = 0.6$, $\varphi = 0.16$, and two subsystems with $\gamma_t^{\pi} = 0.5$. In this setting, strategy 2 is dominant, and the associated intra-subsystemic dynamics can be seen in Figure A6.

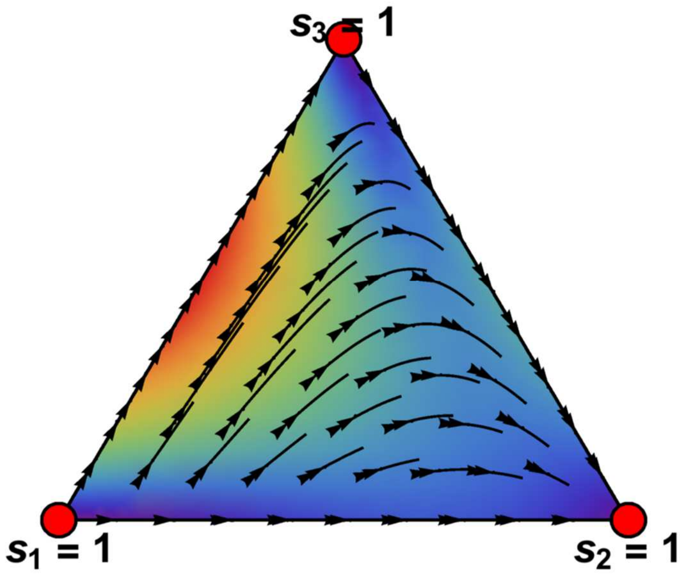


Figure A6. Phase portrait of a game with $(x_1, x_2, x_3) = (0.3, 0.45, 0.6)$, $\varphi = 0.16$ and $\gamma_t^{\pi} = 0.5$. Rest points are shown as red circles. Rest point (1, 0, 0) has associated eigenvalues 0.126 and 0.004; rest point (0, 1, 0), which is almost globally stable, has associated eigenvalues -0.054 and -0.036; and finally, rest point (0, 0, 1) has associated eigenvalues -0.126 and 0.038.

Figure A7 shows the overall dynamics of a simulation run where the conditions outlined above are approximately met.

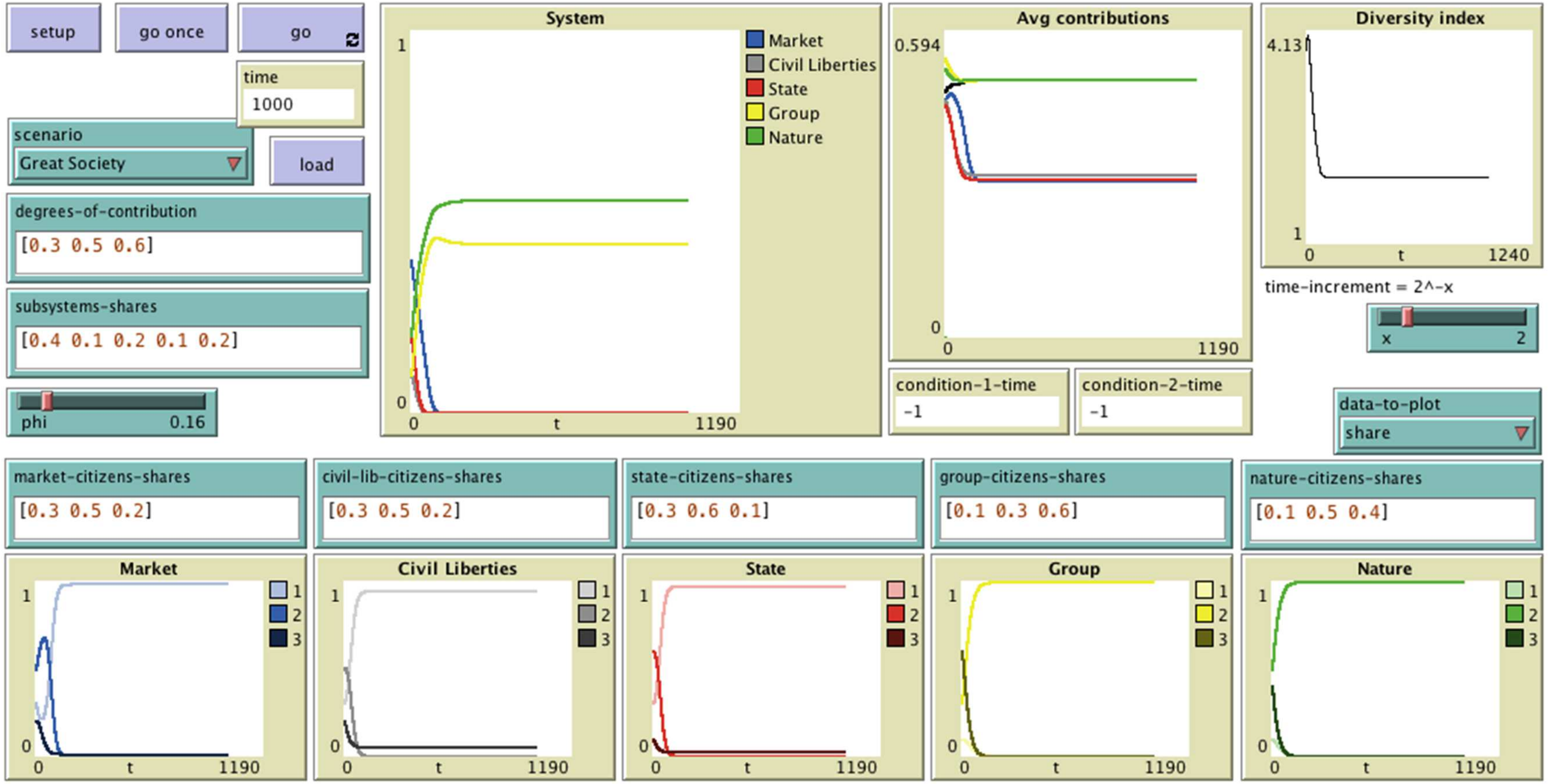


Figure A7. Representative example of a situation where two subsystems (Group and Nature) coexist. In these two subsystems $s_2 \approx 1$, whilst in the subsystems that vanish $s_2 \approx 0$ and s_1 is high.

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