CONTRIBUTI DI RICERCA CRENOS

SOCIO-TECHNICAL DYNAMICS AND POLITICAL INSTITUTIONS: A MULTILEVEL DARWINIAN FRAMEWORK OF SUSTAINABILITY TRANSITIONS

Gerardo Marletto

WORKING PAPERS

2014/12

CUEC

CENTRO RICERCHE ECONOMICHE NORD SUD
(CRENOS)
UNIVERSITÀ DI CAGLIARI
UNIVERSITÀ DI SASSARI

CRENOS was set up in 1993 with the purpose of organising the joint research effort of economists from the two Sardinian universities (Cagliari and Sassari) investigating dualism at the international and regional level. CRENoS' primary aim is to improve knowledge on the economic gap between areas and to provide useful information for policy intervention. Particular attention is paid to the role of institutions, technological progress and diffusion of innovation in the process of convergence or divergence between economic areas. To carry out its research, CRENoS collaborates with research centres and universities at both national and international level. The centre is also active in the field of scientific dissemination, organizing conferences and workshops along with other activities such as seminars and summer schools.
CRENoS creates and manages several databases of various socio-economic variables on Italy and Sardinia. At the local level, CRENoS promotes and participates to projects impacting on the most relevant issues in the Sardinian economy, such as tourism, environment, transports and macroeconomic forecasts.

www.crenos.it
info@crenos.it

CRENoS – CAGLIARI
VIA SAN GIORGIO 12, I-09100 CAGLIARI, ITALIA
TEL. +39-070-6756406; FAX +39-070- 6756402

CRENoS - SASSARI
VIA TORRE TONDA 34, I-07100 SASSARI, ITALIA
TEL. +39-079-213536; FAX +39-079-213002

Title: SOCIO-TECHNICAL DYNAMICS AND POLITICAL INSTITUTIONS: A MULTILEVEL DARWINIAN FRAMEWORK OF SUSTAINABILITY TRANSITIONS

ISBN: 978 88 8467 904 8

First Edition: December 2014

Via Is Mirrionis, 1
09123 Cagliari
Tel./Fax 070 291201
www.cuec.it

Socio-technical dynamics and political institutions: A multilevel Darwinian framework of sustainability transitions

Gerardo Marletto[·]
University of Sassari and CRENoS

Abstract

The study of sustainability transitions (SUSTRANs) is an emerging research field that provides useful keys to understand how more sustainable ways to meet societal needs may emerge and develop. As stressed by some scholars, much more work is needed to make political institutions endogenous to SUSTRANs. This paper contributes to such a research endeavour by providing a simple conceptual framework based on multiple levels of Darwinian evolution. The evolutionary environment is defined by a societal function (e.g., urban mobility), which is fulfilled by socio-technical systems (STSs) (e.g., the car, public transport, the bicycle, etc.). Three levels of evolution are considered: a lower level, with firms; two higher levels, with innovation networks and socio-political communities, respectively. While competing within the same STS, firms cooperate within a socio-political community in order to back their STS, and compete with other – both existing and emerging – STSs that fulfil the same societal function. With this simple framework SUSTRANs can be represented as a multilevel evolutionary process that endogenously generate the needed favourable policies (FPs). A socio-political community supporting a new and more sustainable STS achieves the ability to induce FPs only if it is able to scale up – and reach a tipping point – in the cumulative causation process between the enlistment of new members and an increasing level of legitimation. The proposed framework can be applied not only to SUSTRANs, but to all socio-technical transitions, where power and competition can be considered as multilevel phenomena, and multi-industry dynamics are at centre stage.

Keywords: Sustainability transition; Political institutions; Evolutionary; Group selection
Jel classification: B52, O35, Q56

Acknowledgments

I thank Anna Bergek for providing useful comments and suggestions on a previous version of the paper. For the same reason I also thank Karolina Safarzynska and Simone Franceschini.

· Email address: marletto@uniss.it

1. Introduction

The study of sustainability transitions (SUSTRANs) is an emerging research field (van den Bergh et al., 2011; Markard et al., 2012). Even if the literature does not provide a crystal clear definition, a SUSTRAN is a process of radical change that generates more sustainable socio-technical systems (STSs), i.e. more sustainable ways to fulfil societal needs. For a SUSTRAN to deploy a twofold process must take place: 1) a new and more sustainable STS emerges from the alignment of multiple institutional, technological and economic changes; 2) the current dominant position of an unsustainable STS is destabilised and took over by the emergent STS. The literature stresses that both the above conditions depend on favourable policies (FPs): 1) tipping points in the emergence of a new STS are achieved when public authorities provide supporting regulations, infrastructures, subsidies, etc.; 2) specific public interventions help to destabilize the dominant STS. Understanding how such FPs emerge is therefore a crucial research topic.

It has been stressed that a gap in the literature on SUSTRANs is apparent as the emergence of FPs is usually considered exogenous (Frantzeskaki and de Haan, 2002; Smith et al., 2010; Kern, 2011; Meadowcroft, 2011). Actually this is not completely true: some scholars have explicitly considered the role of political networks when studying the emergence of new technologies (Bergek et al., 2008b; Hekkert et al., 2007; Smith and Raven, 2012); some others have tried to integrate a political dimension into the analysis of SUSTRANs (Rosenbloom and Meadowcroft, 2013; Geels, 2014; Hess, 2014). Notwithstanding all these efforts much more work is needed to understand how changes in political institutions endogenously emerge along a SUSTRAN.

Following the seminal hint provided by Safarzynska and van den Bergh (2010), this paper contributes to this endeavour providing a group selection framework of SUSTRANs. Multiple levels of Darwinian evolution are used to show that firms cooperate within social groups in order to improve their performance. In particular, firms (and other organizations) participate to socio-political communities to gain, increase and retain political influence. The proposed framework does not have the ambition to give a full representation of the political dimension of SUSTRANs, but only to point out how firms influence it. In particular, the framework clearly shows that a cumulative process between the empowerment of a socio-political community – supporting the establishment of a new STS – and the emergence of FPs is endogenous to SUSTRANs.

This paper explicitly share the idea of generalizing Darwinism (Aldrich et al., 2008). Following this idea, the core principles of variation, selection and replication can be applied to the social domain. In order to integrate humans' ability to learn and act intentionally, some specificities of social (Darwinian) evolution must be made explicit: 1) social agents are able to manipulate both the environment and their habit/routines (i.e., the social equivalent of genes); 2) imitation is a much more relevant source of replication (and variation) than inheritance via offspring; 3) the elimination of habit/routines as a result of selection can take place without the elimination of the hosting replicator (Hodgson and Knudsen, 2010). With these specifications a Darwinian framework is also able to represent the dynamics of entities and processes involved in a SUSTRAN. Moreover, thanks to the use of a Darwinian 'vocabulary', the framework presented here may interface with other evolutionary theories of socio-economic change.

The rest of the paper is structured as follows: in Section 2 the socio-technical background of

SUSTRANs is presented, with specific reference to their political dimension; Section 3 builds a group selection framework of SUSTRANs founded on a limited number of evolutionary concepts; Sections 4 and 5 discuss the framework against the relevant literature and conclude, respectively.

2. The socio-technical background of sustainability transitions

All approaches to SUSTRANs refers to some common theoretical roots: complex systems theories, neo-Schumpeterian theories of innovation, other sociological and institutional representations of innovation, etc.. This is why no taxonomy is able to provide clear-cut distinctions between them. For example, Markard and Truffer (2008) suggest to integrate the two most prolific approaches in terms of publications and citations: the multi-level perspective (MLP) (Kemp, 1994) and the technological innovation systems (TIS) (Edquist, 2004; Bergek et al., 2008a). Van den Bergh et al. (2011) and Markard et al. (2012) provide two different – but partially overlapping – taxonomies of the main approaches to SUSTRANs. Both includes the MLP and the TIS (even if the latter is considered with a different naming) and they add some other approaches, respectively: transition management (TM) (Rotmans et al., 2001) and strategic niche management (SNM) (Kemp et al., 1998); complex systems (which includes TM) and evolutionary systems (van den Bergh and Stagl, 2003; van den Bergh and Gowdy, 2009). A third taxonomy will be used in this paper covering the first two and considering only three approaches: a) Innovation systems (IS); b) Complex systems (CS; which includes MLP, TM and SNM); c) Evolutionary systems (ES) (see Table 1 for a synopsis of the three taxonomies).

Table 1. Alternative taxonomies of main approaches to sustainability transitions:

Markard et al. (2012)	*Bergh et al. (2011)*	*This paper*
Technological innovation systems (TIS)	Innovation systems (IS)	Innovation systems (IS)
Multi-level perspective (MLP)	Multi-level perspective (MLP) (includes SNM)	Complex systems (CS) (includes MLP, TM, SNM)
Strategic niche management (SNM)	Complex systems (CS) (includes TM)	Evolutionary systems (ES)
Transition management (TM)	Evolutionary systems (ES)	

2.1. Socio-technical systems and their dynamics

All approaches to SUSTRANs share the idea that complex systems are at the heart of innovation processes. Such systems cover multiple and interacting dimensions of change (markets, technologies, institutions). In the rest of the paper I will refer to such systems as socio-technical systems (STSs). I am are aware that such a denomination is not shared by all approaches to SUSTRANs; also for this reason I will stress all relevant differences between approaches to SUSTRANs with reference to the characterisation of STSs.

Any societal function is fulfilled by one or more socio-technical systems (STSs). For example, the societal function of urban mobility is fulfilled by the following STSs: the car, public transport, the bicycle, sharing schemes. Each STS is related to one final product or

service, and usually includes many market segments, more than one technology, and several inter-industry links. E.g., several market segments (compact cars, sedans, SUVs, sport cars, etc.), two core technologies (internal combustion and electric propulsion), and both productive and organisational links between different industries (the automotive industry and the industries of car components, of course, but also the industries of oil, road building and management, advertising, etc.) are part of the car STS (Geels, 2005). Each STS can also be related to an overall discourse that affects the whole societal function. Referring again to the function of urban mobility, it is apparent how its dynamics has been influenced by the consideration of the car, not only as a mere transport mean, but also as a powerful driver of individual freedom, and as a striking representation of social advancement (Urry, 2008).

STSs are (more or less) stable configurations of a group of social agents (usually organizations such as: firms, research bodies, public authorities, NGO, etc.) and a structure made of material and immaterial constituents (plants, infrastructures, knowledge, preferences, rules, etc.). All social agents feature bounded rationality and – through action and learning – they replicate and change the structure of the STS. In more general terms, the functioning of STSs can be conceptualised as structured agency (Giddens, 1994)[1]. In the IS approach the performance of STSs depends on functions that link structural elements (actors, networks, institutions, knowledge and artefacts) to structural processes (entry of new firms; formation of networks; alignment of institutions; accumulation of knowledge and artefacts). In particular, the following are usually considered: knowledge development and diffusion; entrepreneurial experimentation; influence on the direction of search; resource mobilization; market formation; legitimation; development of positive externalities (Bergek et al., 2008a).[2]

Usually one STS holds a dominant position, that is, it is very stable and strongly influences the dynamics of other subaltern or residual STS. Social agents interested – and actively acting for – the reproduction of an existing STS are also called "core-actors" (Smith et al., 2005). The CS approach – and in particular the MLP perspective – helps to understand how dominant STSs are occasionally exposed to radical change. Stability – or, more exactly, incremental change – is explained by the core level of the "regime", i.e. the complex of rules which is shared by a wide community of actors (researchers, engineers, entrepreneurs, users, policy makers, societal groups, etc.) and influences the direction of innovation (Geels, 2002). Radical change is generated by top-down and bottom-up processes that are originated, respectively: a) in the "landscape", that represents overall socio-cultural exogenous changes; b) in "niches", that are protected spaces where innovations are experimented and new knowledge is generated. Also the migration of STSs – coming from other societal functions or from other geographical areas – may contribute to socio-technical transitions (Raven and Verbong, 2007). The IS approach stresses that both the formative and growth phases of a STS can be blocked, hampered or slowed by the malfunctioning and/or the inconsistency of

[1] Actually the notion of structured action – yet expressed in terms of a cumulative causation process involving the interdependent changes of both agents and their environment – date back to Veblen (1898).

[2] See Bergek et al (2008a, Appendix A) also for a comparison of other slightly different sets of functions.

one or more of its functions; the opposite happens when functions generate positive feedbacks – or "motors of change" (Hekkert et al., 2007) – between the structural elements of the STS, giving place to a self-sustained dynamics.
The dynamics of STS may be grouped into two large families: the adaptation of a dominant STS and the establishment of a new dominant position (Geels and Schot, 2007). Adaptation can be conceptualised as a homeorhetic process that is granted by the structure of the dominant STS – which gradually changes – and is supported by its core-actors. Things completely change when a STS tries to take over the dominant position: at the beginning of the process no structure is available to coordinate all the needed changes, because the structure itself must be created. This is why the establishment of a new dominant position is an exceptional event which is virtually impossible without the increasingly coordinated action of "enactors" who aim at transforming an innovation into a social practice (Suurs et al., 2010). The seminal typology provided by Geels and Schot (2007) and the subsequent studies of Haxeltine et al. (2008) and Papachristos et al. (2013) detail the analysis of the dynamics of STSs by explicitly considering the role of agents.
Following the ES approach, all the above dynamics may be expressed in terms of Darwinian evolutionary mechanisms, i.e.: variation, selection and replication (or inheritance). In particular, it is shown that: a) the dynamic interactions between the institutional, economic, technological dimensions of any STS are better described as co-evolutionary processes (Safarzynska, 2012); b) path-dependence and lock-in phenomena that hinder the emergence of new STSs can be expressed in terms of repeated selection (of the dominant STS).
As already stressed in the Introduction, a SUSTRAN is nothing but the establishment of a new and more sustainable STS in a dominant position.

2.2. Sustainability transitions and political institutions

All approaches to SUSTRANs explicitly consider political institutions, mostly as an exogenous factor. In particular, in the CS approach SUSTRANs are mostly considered as proactive and reflexive processes of innovation that need to be carefully managed by public policies. The strategic niche management approach (SNM) provides useful insights on how niches for sustainable innovations can be created and nurtured (Kemp et al., 1998). The transition management approach (TM) explains how a more sustainable regime can emerge from "transition arenas" where a new long-term vision is shared, and where a process of guided variation and selection is based on collective learning-and-doing (Rotmans et al., 2001).[3] The applied TM literature mostly focuses on the role of incumbents actors: Loorbach and Rotmans (2010: 244) claim that the involvement of both in and off-regime actors is needed not only "to build up a close relationship with (parts of) the regime and maintain the autonomy of the transition process", but also in order to avoid the risk that dominant actors see the transition arena as a threat and try to regain control of it; Schot et al. (1994) in their seminal comparison of the Dutch and Californian approaches to policies for electric vehicles, signal that the latter risks to fail because of the resistance of big automotive companies to changes in the institutional environment; in Kern and Smith (2008) and Smith and Kern (2009) it is stressed that the Dutch energy transition policy is hampered by the inclusion of incumbent actors, who reduce both bottom-up variations and top-down pressures and leave

[3] SNM and TM approaches can be integrated, as explained in Rotmans and Loorbach (2009).

room for incremental – rather than radical – changes; Genus (2012: 199) goes further and makes explicit the conflictual dimension of any SUSTRAN: "both incumbent and niche actors 'enact' the 'landscape'".

Also in the IS approach public policies are often considered an exogenous factor that can address "system failures" or "functional weaknesses" (Bergek et al., 2008a: 423) featured by STSs during their formation or growth. A relevant exception is the reference to political networks which are crucial for the legitimation of a STS and for the alignment of relevant institutions (Bergek et al., 2008b)[4]. Both processes are particularly relevant in the formation phase of a STS, when the "battle over institutions" between dominant and emerging STSs can be described as a competition between alternative supporting coalitions (Hekkert et al., 2007). This vision is shared by Foxon et al. (2010) who hybridize IS and CS concepts and show that cumulative causations between technological, institutional and market changes, are also driven by the lobbying activities of conflicting supporting coalitions. New supporting coalitions are created along the formation phase of an emerging STS: at the beginning disorganised actions are carried out by single and dispersed agents; afterwards supporting coalitions are created and actions become more and more coordinated. An increasing level of legitimation is the necessary condition for the structuring of coalitions to take place.

The study of actual and potential SUSTRANs have provided several relevant insights into the interaction between supporting coalitions and changes in political institutions. The establishment of a powerful coalition is considered among the success factors of renewables in Germany, where a positive feedback between techno-economic and political changes took place (Jacobsson and Johnson, 2000; Johnson and Jacobsson, 2001; Bergek and Jacobsson, 2003; Jacobsson and Bergek, 2004; Jacobsson, Sandén and Bångens, 2004; Jacobsson and Lauber, 2006). Studies by Roald Suurs, Marko Hekkert and other scholars on alternative automotive fuels in the Netherlands confirm the relevance of such feedbacks (Suurs and Hekkert, 2009; Suurs et al., 2010). Inter alia, they show that successful lobbying induced a variety of actors to re-enter the market of natural gas and pushed three major Dutch companies to abandon their scepticism, thus creating the conditions for a tipping point in this specific SUSTRAN. The opposite happened in the domain of biofuels, where enactors were too weak and confronted by a coalitions of opponents. Mazur et al. (2014) focus directly on the political dimension of SUSTRANs and explain the differences between UK and German policies for electric mobility in terms of relations between political and local industrial actors. In Germany, such policies are slowed down in order to leave enough time to the (still strong) domestic automotive companies to internally generate the needed innovations. In the UK – where the dimension of the domestic automotive industry is negligible – national policies aims at stimulating the creation of a national system of electric mobility, which is based on the integration of small local producers and big foreign players (such as Nissan). Benjamin Sovacool supports the idea that SUSTRANs to both renewables and electric mobility are slowed down because of socio-cultural impediments; in particular he stresses that the potential of any innovation is strongly reduced when interpreted through dominant practices, values and interests (Sovacool, 2009; Sovacool and Hirsch, 2009). The

[4] In their seminal paper, Adrich and Fiol (1994) made a clear distinction between cognitive and sociopolitical legitimacy which is not always apparent in IS studies. On the relevance of this distinction in a multilevel evolutionary representation of entrepreneurship, see also Aldrich and Martinez (2003).

work of Philip Vergragt and Halina Brown may be considered as a response to Sovacool's warnings. In their studies of SUSTRANs in the mobility and housing sectors, they stress the role of higher order learning, i.e. a combination of multi-stakeholders visioning exercises and small-scale experiments that can integrate available innovations into radically new visions about how societal needs should be fulfilled (Vergragt and Brown, 2007; Brown and Vergragt, 2008; Brown and Vergragt, 2012). These are considered as effective policy tools, both to weaken actors aligned with the existing regime, and to allow the creation of a critical mass of grassroots (social) innovators (Seyfang et al., 2014). The recent work of Penna and Geels (2012) helps understand that the greening of the car industry have resulted from the ever changing dialectic between socio-political pressures and economic responses; in particular, it is stressed the importance of both firms' cognitive framing and alternative (when not conflicting) political discourses. In this study too, activist groups and social movements play a relevant role.

Smith et al. (2005) share the above vision by making explicit that STSs are produced and reproduced by networks of (core) actors and that their dynamics also depend on the institutional power of such networks. More recently Smith and Raven (2012) developed these insights with reference to the "stretch-and-transform" empowering of niches, i.e. to the ability of niche actors (enactors) to make the overall selective environment favourable to the innovation they support. They also show how actors' interests and political narratives are entrenched; an issue further developed by Kern (2011): the battle over institutions is also a "battle over discourses". This brings us back to the issue of political legitimacy: societal discourses change through a struggle between coalitions who use their power to influence public opinion, collective sense making, political debate and – eventually – to get support from specific political decisions (Geels and Verhees, 2011; Grin et al., 2011).

Safarzynska and van den Bergh (2010) use a group (multilevel) selection framework to analyse such a co-dynamics between agents and institutions, with specific reference to environmental policies. Power is a central concept in their analysis too. Through an upward agency mechanism, groups with different interests and visions use their power to influence environmental institutions, thus affecting both the direction and the speed of a SUSTRAN. Through a downward structuration mechanism – and as a result of the dynamics of environmental institutions – power is differentially bestowed to groups, and the further evolution of both individuals and groups is affected. As a consequence, the whole "demography" of groups is relevant to understand a SUSTRAN: the creation of a new group from scratch; an individual joining a group or migrating from a group to another; the merging, splitting and re-assortment of groups; etc.. Moreover, a cumulative causation process may take place: the more a group is able to influence environmental institutions and increase its resources, the more it attracts other groups and individuals (bringing along their resources), the more that group is able to influence environmental institutions and increase its resources, and so on.

The following – and more general – step is in some extent a natural consequence of the above considerations: both the instigation of a SUSTRAN and the resistance to it result from the strategic action of alternative politico-economic coalitions (Hess, 2014; Rosenbloom and Meadowcroft, 2014). Inter alia, this implies that along a SUSTRAN: a) both cooperation/synergy (within coalitions) and competition/antagonism (between coalitions) are relevant power relations, and b) both "deconstructive and constructive forms of power

are exercised in such a way that old resources are replaced with new resources and a new distribution of resources is established at a societal level" (Avelino and Rotmans, 2009: 562).

2.3. Summing up and going ahead

Most theoretical and applied studies of SUSTRANs acknowledge the relevance of political institutions. Political institutions are more often considered as an exogenous factor, but some attempts to make them endogenous can be found in the literature. In particular, some authors (e.g., Adrian Smith) explain that political changes are influenced by the "battle" between existing and new groups of actors that support different STSs. Some other authors (e.g., Staffan Jacobsson) go further and draw the attention to the positive cumulative causations between political changes and the political power of such groups. Others (e.g., Karolina Safarzynska) suggest that these feedbacks could be interpreted as results of a multilevel (group) selection mechanism. All this suggests that a two-ways relation between agency and political should be considered when studying SUSTRANs, and that such a relation could be better represented as a multilevel evolutionary dynamics. These are useful insights that should be further developed in order to reach the ambitious goal of making political institutions endogenous to the analysis of SUSTRANs. Before dealing with this task in the next section, there is a crucial point that deserves to be tackled here: the terminological (and sometimes conceptual) confusion featured by the literature on SUSTRANs when dealing with political institutions.

When considering political institutions, most authors use the shorter term "institutions". I think that such use of this term is confusing, because we have several institutions: technological institutions, market and firm institutions, socio-technical system institutions (i.e., regimes), and political institutions. Moreover, political institutions – as stressed by many scholars – include both formal norms and informal rules and should not be confused with public authorities.

As acknowledged above, groups of actors play a relevant role in SUSTRANs. It is sometime explicit – but more often implicit – that each STS is supported by a group of actors. In particular, a group of core-actors (or incumbents) supports the dominant STS, and more groups of enactors (or prime-movers, or new entrants) back niche STSs. As stressed by Staffan Jaccobsson and his colleagues, rival and non-rival firms as well non-firm actors, may take part to these groups. Some scholars call these groups "(political) networks", others "(advocacy) coalitions". I think that the term 'socio-political community' is more appropriate, both to avoid the confusion with networks built by firms with the specific aim of promoting technological innovation, and to stress the fact that in communities ties between members are weaker than in networks or coalitions.

Only recently, some authoritative scholars acknowledged that STS other than niches can co-exist with the dominant one; these are structured (i.e., they are not niche STSs) but subaltern systems (e.g., public transport is a well-structured STS of urban mobility, but it is dominated by the car STS). This implies that also the socio-political communities of subaltern systems should be considered into the analysis of SUSTRANs. It must also be stressed that almost always the dominant system is called the "regime"; I think that this is a wrong synecdoche: the "regime" is nothing but the rules (i.e., the institutions) shared by the actors supporting a system, but any system features a regime, not only the dominant one (even niche-systems feature a regime, even if less stable). This is why in the following I will use the term

'dominant STS', instead of regime.
Last – but not least –all terms referring to "evolution" should be used in their stricter meaning. First of all, the term "evolution" itself should not be trivialised as a synonymous of a generic "change", but it should be used only when the processes of variation, selection and replication of a population are at stake. Also the term "coevolution" should be used when the evolution of two (or more) sub-populations depends from one another; "coevolution" is not a generic term to be used to indicate – as often happens in studies on SUSTRAN – all interactions or co-dynamics between sub-populations or sub-systems. Moreover, even if in some way a multilevel evolutionary mechanism could be considered as a specific case of co-evolution (i.e., the co-evolution of the sub-populations of individuals, groups of individuals, groups of groups, etc.), to avoid any confusion I will not use the terms "multilevel" and "coevolutionary" as synonyms.

3. A multilevel Darwinian framework of sustainability transitions

3.1. Basic concepts of social evolution

3.1.1. Darwinism and social evolution

Darwinism represents how populations change over time. Members of a population are non-identical entities who live in the same environment, and whose survival is conditioned by the access to some scarce resource. These entities are able to replicate, that is, "to pass on to others workable solutions to problems faced in the struggle for existence" (Hodgson and Knudsen, 2010: 33). Some entities are more successful than others in surviving and replicating; as a result, (successor) selection is generated and the composition of the population is modified over time. Variation is at the same time a result and a pre-requisite of Darwinian evolution: without variety there is no differential replication and selection. The difference between the replicator and the interactor must be stressed: the former is the information being replicated, the latter is the entity hosting such an information.
The core Darwinian principle and concepts can be used to represent the evolution of both natural and social entities (Aldrich et al., 2008). Without entering into the debate on generalised Darwinism (Pelikan, 2011; Schubert, 2014), it is worth to stress the specificities of Darwinian social evolution: 1) Interactors can manipulate their replicators (e.g., a political party changing its founding ideology); 2) Interactors can manipulate their environment (e.g., a firm successfully lobbying for a change in formal norms);[5] 3) Replication may take place also without offspring, and the selection of replicators does not necessarily implies the death of some interactors; 4) In particular, replicators may diffuse through imitation, without any migration of interactors (e.g., some norms of a State are repealed and replaced by norms copied from another State, but both States survive).[6] Inter alia, all these specificities help explain why social evolution is much faster than the natural one.

[5] A property of social evolution which is called "transmutability" by Brown (2013).
[6] Imitation (of replicators) is called "cultural diffusion" and migration (of interactors) is called "demic expansion" by Cavalli-Sforza et al. (1994).

3.1.2 The evolution of social groups and organizations

From the above examples it appears that many social agents are groups. Social groups of humans share some rules about: membership; internal relations, positions and responsibilities. These rules are an emergent property of a social group and can be considered its social structure. The more explicit and strict such rules are, the more cohesive the group is; this is the case of organizations (such as firms, NGOs, political parties, public authorities, etc.). Also second level organizations (i.e., organizations whose members are organizations) are present; e.g., industry, trade and professional associations. Organizations usually – but not always – feature an explicit hierarchy and shared goals.

Darwinian principles and concepts can be applied to social groups. The prosperity of an individual strongly depends on the prosperity of the social groups she belongs to; this is why cooperation (within a group) and competition (between groups) are both relevant evolutionary forces. Individuals not only cooperate within a group, but can also: compete within a group (e.g., for leadership), migrate from a group to another, create new groups from existing ones (as a result of merge, split, re-assortment, etc.) or from scratch. The evolution of social groups is a specific case of (cultural) multilevel selection (van den Bergh and Gowdy, 2009): both groups and individuals are interactors, and both host their specific replicators. As well as habits are social replicators hosted by humans, routines are replicators hosted by social groups: both are behavioural dispositions that are put into action when necessary, at the individual and organizational level, respectively. Routines are emergent properties of the social group: they are not reducible to the habits of its members alone, but also result from the social structure of the organization. (Breslin, 2011; Vromen, 2011; Aldrich and Yang, 2014).

It is worth to stress that in the case of groups, replication takes place not only via imitation or offspring (e.g., the split of a political party or the spin-off generated by a firm), but also via the enrolment of a new member in the group (e.g., a new researcher entering a research body). In all cases, replication may imply variation because of the imperfect copying of routines; the fact remains that the variation of routines is mostly generated by groups directly changing them (that is, via manipulation).

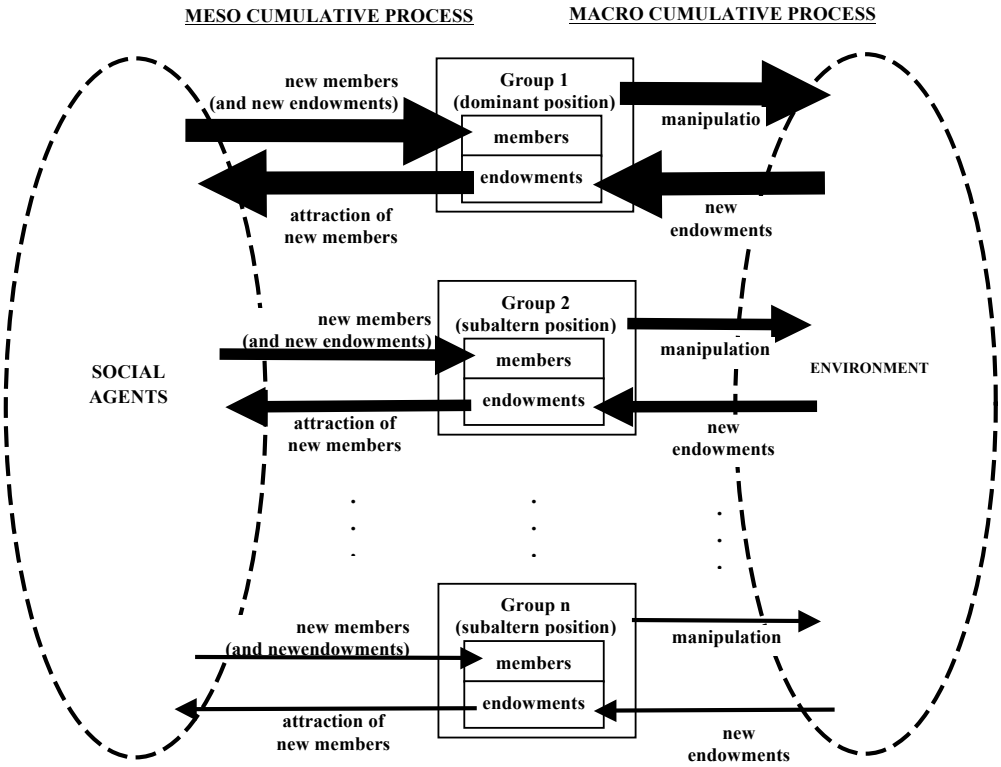
3.1.3. Collective endowments and cumulative processes

Social groups own (or have access to) material and immaterial endowments, e.g.: physical and financial resources; knowledge, competences and capabilities; social capital, reputation and legitimacy. Social groups use their endowments to prosper. In more general terms, social groups mobilise their endowments to achieve their goals, that is, they exercise some form of power (Avelino and Rotmans, 2009; Safarzynska and van den Bergh, 2010). Inter alia, endowments are used to manipulate the internal routines and the external environment. Group endowments can be either individual – that is, owned by a member – or collective, that is, generated through the interaction of members within the group itself (Musiolik et al., 2012). This implies that the endowments of a group are more than the mere sum of the individual endowments of its members (or, in other words, that endowments too are among the emergent properties of a group).

Group endowments are generated either by the enlistment of new members and the clustering with other groups, or gathered directly from the environment. In both cases a cumulative process may be generated (see Figure 1). The first one refers to the group and its

actual and potential members: a group increases its endowments → new members are attracted and enter the group → the group increases its endowments... The second cumulative process is centred on the interaction between the group and the environment: a group increases its endowments → the group increases its ability to gather new endowments from the environment → the group increases its endowments... It is apparent that these two cumulative processes: a) generate a third between the attraction of new members and the increasing ability to gather new endowments from the environment; b) may result in a group holding a (more or less stable) dominant position.

Figure 1. Cumulative processes between agents, groups and the environment



3.2. The framework

3.2.1. Firms, innovation networks and socio-political communities

Three kinds of social groups are considered: firms, innovation networks and socio-political communities. Firms feature higher level of internal cohesion and coordination than networks and communities. All these groups share a single evolutionary environment, defined by a specific societal function (e.g., urban mobility).

Firms are organizations providing a final product or a service fulfilling a specific societal function (e.g., cars, buses, bicycles). Firms, while competing to reach a higher number of consumers, cooperate with other social agents within second level social groups.

Innovation networks are second level social groups whose members are one firm and other organizations (in particular: suppliers of inputs; research bodies; finance operators) (e.g., Volkswagen and its industrial, commercial and technological partners). Innovation networks support the ability of the firm to innovate their products and services. Innovation networks compete with each other.[7]

Socio-political communities are second level social groups whose members are firms producing a specific kind of product or service (e.g., cars) and other social groups (in particular: lobbying professionals; political parties; other NGOs; grassroots movements; media). Firms participate to socio-political communities either directly or through their industry association (e.g., single national automotive associations or the International Organization of Motor Vehicle Manufacturers-OICA). Socio-political communities back the ability of the participating firms to increase their political influence.

3.2.2. Levels of evolution

Three levels of evolution are considered:[8] a lower level, with firms; two higher levels, with innovation networks and socio-political communities. There is no hierarchical relation between the two higher levels, as they refer to two different dimension of the societal function, that is, technological innovations (T) and political institutions (P), respectively.

See Table 2 for a synopsis of the three evolutionary levels.

At the lower level firms are the interactors; productive and commercial routines (i.e., how goods and services are produced and marketed) are their replicators. Replication takes place mainly via an imitation process, i.e. a firm adopting the routines of another. Replication via off-springs (spin-offs, joint-ventures, etc.), merge of existing firms and enlistment (of individuals) takes place too, but it is less relevant. Variation depends on both manipulation (i.e., firms modifying their productive and commercial routines) and imperfect copying (in the case of imitation, off-spring and enlistment/merging). Also migration (of individuals between firms, and of firms between societal functions and geographical areas) generates the variation of routines. At this level, selection of routines is the result of (mainly short-term) market performance (measured by market shares and other market indicators). It must be stressed that the extinction of productive and commercial routines may take place either with or without the extinction of the firms hosting them. Firms manipulate the environment,

[7] Actually innovation networks may also cooperate, e.g., to develop and share standards (Aldrich and Martinez, 2003).

[8] The level of individuals is present but not explicitly considered.

mainly through advertising and other commercial practices.

Table 2. Levels of evolution and evolutionary mechanisms: a synopsis

Level	*Interactors*	*Replicators*	*Replication*	*Variation*	*Selection*
Lower	Firm	Commercial and productive routines	Imitation (Offspring) (Enlistment of individuals) (Migration*)	Manipulation (Imperfect copying)	Selection results from (short-term) market performance
Higher T	Innovation networks (Firms + other organizations)	Innovation routines	Enlistment of organizations Clustering of networks Imitation (Offspring) (Migration[a])	Manipulation (Imperfect copying)	Selection results from (mid-term) technology performance
Higher P	Socio-political communities (Firms + other organizations)	Political routines	Enlistment of organizations Clustering of communities Imitation (Migration[a]) (Offspring)	Manipulation (Imperfect copying)	Selection results from (mid- and long-term) political performance

[a] From other societal functions or geographical areas

At the higher level T, innovation networks are interactors; innovation routines (i.e., how innovation is pursued and generated) are their replicators. Replication takes place via the enlistment of new members, the clustering or re-assortment of existing innovation networks and an imitation process. The creation of off-springs is much less relevant. Variation depends on both manipulation (i.e., innovation networks modifying their innovation routines), imperfect copying (in the case of enlistment, imitation, off-spring) and recombination (in the case of clustering and re-assortment). Also migration (of members between innovation networks and of innovation networks between societal functions and geographical areas) generates the variation of routines. At this level, selection of routines is the result of (mainly mid-term) technological performance (measured by patents and other technological indicators). The extinction of innovation routines is usually associated to the extinction of the network hosting them; this is mostly due to the lower level of cohesion of networks (if compared to firms). Innovation networks manipulate the environment, mainly through R&D and other innovation practices.

At the higher level P, socio-political communities are interactors; political routines (i.e., how policies are selected and implemented) are their replicators[9]. Replication takes place via the

[9] The concept of political routines is very similar to what Rodrik (2014: 190) considers as "*ideas* that political agents have about: 1) what they are maximizing, 2) how the world works, and 3) the set of tools they have at their disposal to further their interests. Importantly, these ideas are subject to both

enlistment of new members, the clustering or re-assortment of existing socio-political communities and an imitation process. The creation of off-springs is much less relevant. Variation depends on both manipulation (i.e., socio-political communities modifying their political routines), imperfect copying (in the case of enlistment, imitation, off-spring) and recombination (in the case of clustering and re-assortment). Also migration (of organizations between socio-political communities and of socio-political communities between societal functions and geographical areas) generates the variation of routines. At this level, selection is the result of (mainly mid- and long-term) political performance (measured by ideological and political consensus). The extinction of political routines is usually associated to the extinction of the community hosting them; this is mostly due to the lower level of cohesion of communities (if compared to firms). Socio-political communities manipulate the environment, mainly through lobbying, influence on media and other advocacy activities).
Downstream and upstream causations between the lower and the two higher levels of evolution are both in force: the performance of firms is conditioned by the performance of their innovation networks and socio-political communities, and vice versa.

3.2.3. A multilevel Darwinian representation of socio-technical systems and sustainability transitions

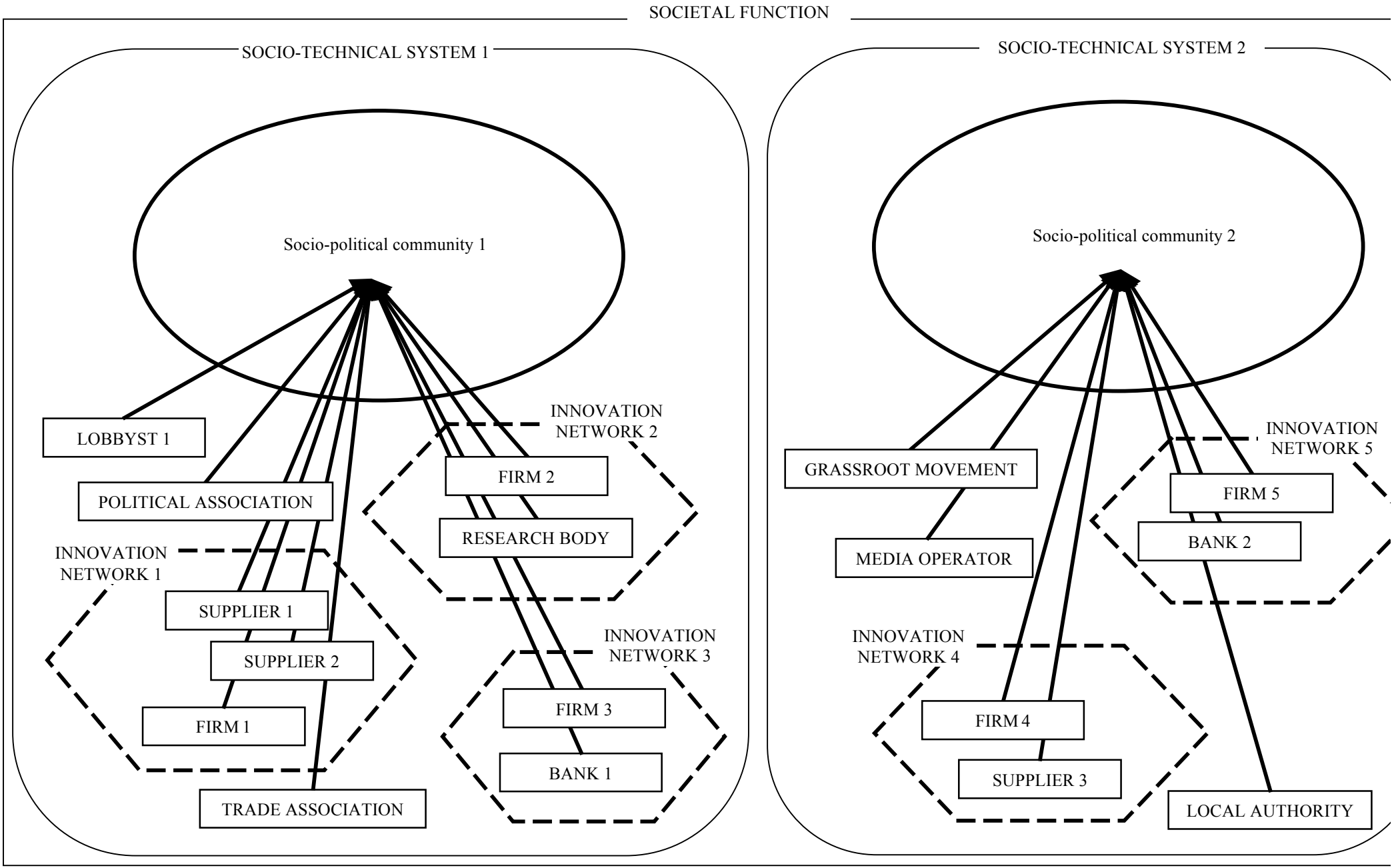
The above multiple levels of evolution can be used to represent the dynamics of STSs and, in particular, SUSTRANs. Firms compete against each other within the same STS (e.g., Volkswagen versus Toyota), but cooperate within a socio-political community in order to back that same STS (e.g., Volkswagen and Toyota are members of OICA which is part of the community that supports the car). Socio-political communities compete against each other (e.g., the community that support the car versus the community that support the bicycle). See Figure 2 for the graphical representation of an example. Though all levels of evolution are always involved in the dynamics of STS, in the case of the adaptation of a dominant STS the evolutionary levels of firms and innovation networks are more relevant. The manipulation of both routines and the environment, and the dynamics of groups taking place at these levels are the main drivers of change and innovation. The level of socio-political communities is less relevant, yet active.
Firms – and their associations – play a relevant role (if not actual leadership) in both dominant and subaltern communities in order to protect their business. Subaltern communities mostly implement defensive strategies; they play a more active role only when the dominant STS is put under pressures by external factors. In this case, they may also try to enlist new members as well as they may participate to the recombination of existing communities. Dominant communities invest their endowments to keep gaining support (or a weak pressure) from already existing FPs. If necessary, the dominant community counteracts opposing agents, whether they are dispersed individuals and movements, or more structured communities supporting alternative STSs. In some cases, dominant communities may absorb opposing agents in order to: benefit from their pressure for innovation; weaken their potential disruptive effects; and avoid the risk that they coalesce with others. When a

manipulation and innovation, making them part of the political game". Interestingly Rodrik (2014: 203-205) considers "policy mutation" (i.e., variation) and "emulation" (i.e., imitation) among the sources of new political ideas.

dominant STS is put under pressure, it may happen that individual supporters start exploring some alternative, either with or without exiting the community.
The level of socio-political communities becomes more relevant than the others two when the dominant position is taken over by a new STS. In this case, social and economic 'pioneers' realize that there actions and goals are consistent and may be coordinated. Afterwards a socio-political community is gradually created that is able to scale up the cumulative causation process between the enlistment of an increasing number of members and the growing influence on political institutions. At the beginning of this process political legitimation is the main target, then explicit advocacy and direct lobbying become more and more important, also with the purpose to destabilize the existing dominant position.
Before achieving durable credibility and a stable influence on agendas, formal norms and policies, the emerging socio-political community must be able to affect shared cultures, political discourses and ideas, and informal rules. When successful, this process reaches a tipping point and ends up with the whole societal function locked in a new STS, whose dominant position is supported by favourable policies (FPs) (Unruh, 2000 and 2002; Walker, 2000).
The emergence of a new – and potentially dominant community – result from a cumulative process that may be triggered by one or more of the following factors: the migration of a stable STS from another societal function; the coalescing of many subaltern and niche STSs; the increasing coordination of several agents supporting a niche STS. In the latter case, firms may not have a leading role since the beginning: only when business opportunities become apparent they start playing a more active role. In all cases grassroots agents and movements may play a relevant role, especially in the starting steps of the process[10].
As stated above, a SUSTRAN is nothing but the establishment of a new and more sustainable STS in a dominant position. Then: a) A SUSTRAN can be represented as an evolutionary process taking place at three levels: market(s), technology(ies) and political institution(s); and b) Political institutions are endogenous to SUSTRANs.

[10] It may also happen that grassroot agents later turn into (or are incorporated by) firms; see for example the case of carsharing schemes in Switzerland (Truffer, 2010).

Figure 2. Social groups and socio-technical systems: a graphical example



4. Discussion

The existence of multiple levels of competition is one of the main outcomes of the framework presented here. Firms (with the support of their innovation networks) compete in one or more markets which are relevant to fulfil a given societal function. At the same time they cooperate into socio-political communities (each backing a STS) which compete against each other for political influence, which in turn is crucial to achieve – and then maintain – a dominant position in the whole societal function. The latter level of competition is always relevant in SUSTRANs, not only in the formative stage of new STS. Even when a STS is well established in the dominant position, its socio-political community keeps acting in the political dimension of the societal function to prevent and counteract pressures from both existing and potential competing STS. This implies that policy changes during SUSTRANs result from both intra and inter-industry dynamics; this is why – when considering a specific SUSTRAN – the analysis of single industries will not result in an exhaustive comprehension of current and future changes. E.g., the analysis of the car industry is not sufficient to understand what is happening (and what will happen) in the car industry; to obtain a full comprehension of the relevant dynamics, one should look to: a) other existing and potential STSs, which compete with the car to fulfil the societal function of urban mobility; b) the migration of STSs between societal functions and geographical areas, and of agents between STSs. In more general terms, the framework helps to overcome the monistic bias of most analyses of SUSTRANs based on both the IS and CS approaches – that is, the focus on the transition occurring in one industry only – and provides a conceptual tool to open the way to a more pluralistic view, that is, to consider more potential – and possibly competing – transition pathways. Such a bias is featured also by a recent work by Penna and Geels (2012): the proposed "Dialectic Issue Life Cycle" proves valid to analyse the dynamic interaction between economic and socio-political changes in the greening of an industry, but it is not able to understand if (and how) inter-industry evolutionary forces are relevant too.

The framework considers power as a basic constituent of SUSTRANs. First – and as a corollary of the existence of multiple levels of competition – it is now acknowledged that power is exercised at different levels: not only the market power of firms is relevant for the analysis of SUSTRAN – and the technological power of their innovation networks – but also the political power of socio-political communities. Second – and more important to understand the dynamics of SUSTRANs – two power mechanisms are simultaneously considered: an upward power mechanism (agency) generated by agents that try to manipulate their selective environment, and a downward power mechanism (structuration) generated by the distribution of resources from the environment to agents (Safarzynska and van den Bergh, 2010). When both in force, agency and structuration form multiple processes of cumulative causation at the market, technology and political level of a societal function. The latter is especially important for both the positive and normative analysis of SUSTRANs, in order to understand – and overcome – any lock-in into unsustainable STSs. It must be stressed again that such cumulative causations are always analytically relevant, not only in the formative stage of a new STS. Third, the framework helps to understand at which level (the market, the technology, the political institutions) the empowerment of agents is needed to increase the viability of a SUSTRAN. As repeatedly stated, one could expect that – as the political level is particularly relevant for SUSTRANs – the empowerment of one or more

socio-political communities will be the main target of specific policies aimed at helping them to increase their endowments, to enlist new members, to implement their strategies, etc. Then, most of the political corollaries of the CS approach to SUSTRANs can be re-interpreted as actions for the empowerment of (new) socio-political communities. As apparent in most practical applications of TM and SNM tools, also the 'de-powerment' of (dominant) socio-political communities may be the goal of policies for SUSTRANs. This is also consistent with a recent work of Turnheim and Geels (2012) where the "destabilisation" of existing regimes and industries is considered the result of both economic and political pressures and a constituent of transitions. The framework proposed here helps to understand that action for destabilization should also be addressed to the socio-political community that is currently dominating a societal function, e.g., by removing explicit or hidden subsidies to (or by introducing tighter standards on) unsustainable products/services.

The framework presented here also considers socio-political communities as central constituents of SUSTRANs, therefore indicating the need to understand their role and strategy when studying any specific SUSTRAN. Two approaches to accomplish this task can be found in the relevant literature: the advocacy coalition framework (Weible et al., 2011) and the political network analysis (Marsh and Smith, 2000). The former is mainly centred on the existence of core beliefs shared by the members of alternative coalitions (and how these influence their actual actions), while the latter mostly looks at the internal articulation of power within a coalition (and how this affects the generation and exchange of resources). As stressed by Adrian Smith (2000), better results can be achieved by using the two approaches in combination, thus limiting their respective bias for agency and structure. Such a suggestion is consistent with the framework, where political changes result from the competition of socio-political communities, with cumulative processes between structuration and agency mechanisms, and between discourses and resources, both playing a crucial role. Whatever approach followed, a conceptual question remains crucial: the internal cohesion of socio-political communities. Indeed – following Hodgson and Knudsen (2010) – no social group can be an interactor without featuring high level of internal cohesion.

The framework can be used not only with reference to SUSTRANs, but also to understand how evolutionary levels and drivers are differentially involved in all transition pathways. As shown in Table 3, the seminal typology introduced by Geels and Schot (2007) can be re-interpreted through the conceptual lenses of group selection.

Table 3. Typology of sociotechnical transition pathways (Geels and Schot, 2007): A group selection re-interpretation

Overall dynamics	*Transition pathway*	*More relevant level of evolution*	*Main evolutionary drivers*
Adaptation of the dominant STS	Transformation (Core-actors react to pressures coming from other agents or from the environment)	Lower level: Firms	- Manipulation of commercial and productive routines - Manipulation of the environment (market dimension)
	Reconfiguration (New agents become core-actors)	Higher level T: Innovation networks	- Enlistment of new members into existing innovation networks (possibly from niches) - Clustering of existing innovation networks (possibly from niches) - Manipulation of the environment (technology dimension)
Creation of a new dominant position	Substitution (New core-actors take over and change the dominant STS)	Higher level P: Socio-political communities	- Migration of agents and/or imitation of routines through societal functions and geographical areas (and possible re-assortment of existing innovation networks and socio-political communities) - Manipulation of routines and the environment (political dimension)

In the case of "transformation" core-firms react to external pressure mainly by manipulating their internal routines; the demography of innovation networks (and the involvement of niches) is more relevant when a "reconfiguration" of the dominant STS is at stake; immigrating powerful agents (mostly from other societal functions) trigger the re-assortment of the dominant socio-political community and eventually takeover previous core-actors in the case of "substitution"; the diffusion via imitation of political routines – which were developed in niches by emerging socio-political communities – generates the "de-alignment and re-alignment" of the constituents of existing STS in the whole societal function, and eventually leads to the establishment of a new STS in the dominant position. As apparent, with a group selection approach, the typology of transition pathways can be extended from the original market and technology dimensions, to the political one. As already stated, the latter is particularly relevant for the creation of a new dominant position in a societal

function. All that has two important policy implications: 1) no SUSTRAN is viable without significant changes taking place in the political dimension of the relevant societal function (that is, new socio-political communities, new political routines, new policies, etc.); 2) not only firms, but also all other members of emerging socio-political communities should be the target of policies that aim at empowering agents that can lead a SUSTRAN.

5. Conclusions

The simple multilevel Darwinian framework presented here has proven valid: a) to make the dynamics of political institutions endogenous; b) to show that both power and competition can be described as multilevel phenomena; c) to represent multi-industry interactions. These are original results that can be applied not only to SUSTRANs, but to all socio-technical transitions. It is worth noting that the framework is able to integrate many of the basic concepts of all the relevant approaches to the study of socio-technical transitions. In particular: the consideration of innovation as the result of multidimensional changes in complex STS; the relevance of niches as protected spaces for both technological and socio-political experimentation; the existence of cumulative causation processes between agency and structuration at the core of the dynamics of STS; the crucial role of dominant agents as a determinant of path-dependence and lock-in phenomena. This is why this framework may be also considered as a contribution to a much more ambitious project: the building of an overarching multilevel Darwinian model of social change. In particular, the explicit reference to a Darwinian 'vocabulary' may be used to build solid conceptual bridges with evolutionary economics and its representation of firms, markets and technological innovations, and with evolutionary political science and its representation of political institutions, agents and behaviour.

References

Aldrich, H.E., Fiol M.C., 1994. Fools Rush in? The Institutional Context of Industry Creation. The Academy of Management Review 19, 645-670.

Aldrich, H.E., Martinez M.A., 2003. "Entrepreneurship as Social Construction: An Evolutionary Approach." In: Zoltan Acs and David Audretsch (Eds.), Handbook of Entrepreneurship Research: An Interdisciplinary Survey and Introduction. Boston: Kluwer Publishers.

Aldrich, H.E., Hodgson, G.M., Hull, D.L., Knudsen, T., Mokyr, J., Vanberg, V.V., 2008. In defence of generalized Darwinism. Journal of Evolutionary Economics 18, 577-596.

Aldrich, H.E., Yang, 2014. How do entrepreneurs know what to do? Learning and organizing in new ventures. Journal of Evolutionary Economics 24, 59-82.

Avelino F., Rotmans J., 2009. Power in Transition. An Interdisciplinary Framework to Study Power in Relation to Structural Change. European Journal of Social Theory 12, 543-569.

Bergek A., Jacobsson S., 2003. The emergence of a growth industry: a comparative analysis of the German, Dutch and Swedish wind turbine industries. In: Metcalfe S., Cantner U. (Eds.). Change, Transformation and Development. Physica-Verlag, Heidelberg and Berlin.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008a. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. Research Policy 37, 407-429.

Bergek A., Jacobsson S., Sandén B., 2008b. 'Legitimation' and 'development of positive externalities': Two key processes in the formation phase of technological innovation systems. Technology Analysis & Strategic Management 20, 575-592.

Breslin, D., 2011. Interpreting futures through the multi-level co-evolution of organizational practices. Futures 43, 1020–1028.

Brown, C., 2013. Transmutability, generalised Darwinism and the limits to conceptual integration. Cambridge Journal of Economics 2013 37, 209–225.

Brown H., Vergragt P.J., 2008. Bounded socio-technical experiments as agents of systemic change: The case of a zero-energy residential building. Technological Forecasting and Social Change 75, 107-130.

Brown H., Vergragt P.J., 2012. Grassroots innovations and socio-technical system change–Energy retrofitting of the residential housing stock. In: Marletto G. (Ed.), Creating a sustainable economy. Abingdon, Routledge.

Cavalli-Sforza, L.L., Menozzi, P., Piazza, A., 1994. The History and Geography of Human Genes. Princeton: Princeton University Press.

Edquist, C., 2004. Systems of innovation: perspectives and challenges. In: Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), The Oxford Handbook of Innovation. Oxford University Press, Oxford.

Frantzeskaki N., de Haan H., 2009. Transitions: Two steps from theory to policy. Futures 41, 593-606.

Foxon T.J., Hammond P.G., Pearson, P.J., 2010. Developing transition pathways for a low carbon electricity system in the UK. Technological Forecasting and Social Change 77, 1203-1213.

Geels, F.W., 2002. Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case Study. Research Policy 31, 1257-1274.

Geels, F.W., 2005. Technological Transitions and System Innovations: A Co-evolutionary and Socio-Technical Analysis. Edward Elgar, Cheltenham.

Geels, F.W., 2014. Reconceptualising the co-evolution of firms-in-industries and their environments: Developing an inter-disciplinary Triple Embeddedness Framework. Research Policy 43, 261-277.

Geels, W.F., Schot J., 2007. Typology of sociotechnical transition pathways. Research Policy 36, 399-417.

Geels, W.F., Verhees B., 2011. Cultural legitimacy and framing struggles in innovation journeys: A cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986). Technological Forecasting & Social Change 78, 910-930.

Genus, A., 2012. The governance of technological transitions–The case of renewable energy. In: Marletto G. (Ed.), Creating a sustainable economy. Abingdon, Routledge.

Giddens, A., 1984. The Constitution of Society. Cambridge: Polity Press.

Grin, J., Rotmans, J., Schot J., 2011. On patterns and agency in transition dynamics: some key insights from the KSI programme. Environmental Innovation and Societal Transitions 1, 76-81.

Haxeltine A., Whitmarsh L., Bergman N., Rotmans J., Schilperoord M., Köhler J., 2008. A conceptual framework for transition modeling. International Journal of Innovation and Sustainable Development 3, 93-114.

Hekkert, M., Suurs, R.A.A., Negro, S., Kuhlmann, S., Smits, R., 2007. Functions of innovation systems: a new approach for analysing technological change. Technological Forecasting and Social Change 74, 413-432.

Hess, D.J., 2014. Sustainability transitions: A political coalition perspective. Research Policy 43, 278-283.

Hodgson, G.M., Knudsen, T., 2010. The Search for General Principles of Social and Economic Evolution. Chicago and London: University of Chicago Press.

Jacobsson, S., Johnson, A., 2000. The diffusion of renewable energy technology: an analytical framework and key issues for research. Energy Policy 28, 625-640.

Jacobsson, S., Bergek, A., 2004. Transforming the energy sector: the evolution of technological systems in renewable energy technology. Industrial and Corporate Change 13, 815-849.

Jacobsson, S., Lauber, V., 2006. The Politics and Policy of Energy System Transformation–Explaining the German Diffusion of Renewable Energy Technology. Energy Policy 34, 256-276.

Jacobsson, S., Sandén, B., Bångens, L., 2004. Transforming the energy system: the evolution of the German technological system for solar cells. Technology Analysis and Strategic Management 16, 3-30.

Johnson A., Jacobsson S., 2001. Inducement and blocking mechanisms in the development of a new industry: the case of renewable energy technology in Sweden. In: Coombs R., Green K., Richards A., Walsh V. (Eds.). Technology and the Market: Demand, Users and Innovation. Edward Elgar, Cheltenham (UK) and Northampton (MA)

Kemp, R., 1994. Technology and the transition to environmental sustainability. The problem of technological regime shifts. Futures 26, 1023-1046.

Kemp, R., Schot, J., Hoogma, R., 1998. Regime Shifts to Sustainability through Processes of Niche Formation: The Approach of Strategic Niche Management. Technology Analysis and Strategic Management 10, 175-194.

Kern, F., 2011. Ideas, institutions, and interests: explaining policy divergence in fostering `system innovations' towards sustainability. Environment and Planning C: Government and Policy 29, 1116-1134

Kern, F., Smith, A., 2008. Restructuring energy systems for sustainability? Energy transition policy in the Netherlands. Energy Policy 36, 4093-4103.

Kohler J., Whitmarsh L., Nykvist B., Schilperoord M., Bergman N., Haxeltine A., 2009. A transitions model for sustainable mobility. Ecological Economics 68, 2985-2995.

Loorbach, D., Rotmans, J., 2010. The practice of transition management: Examples and lessons from four distinct cases. Futures 42, 237-246.

Markard, J., Truffer, B., 2008. Technological innovation systems and the multi-level perspective: towards an integrated framework. Research Policy 37, 596-615.

Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: An emerging field of research and its prospects. Research Policy 41, 955-967.

Marsh, D., Smith, M., 2000. Understanding Policy Networks: towards a Dialectical Approach. Political Studies 48, 4-21.

Mazur, C., Contestabile, M., Offer, G.J., Brandon, N.P., 2014. Assessing and comparing German and UK transition policies for electric mobility. Environmental Innovation and Societal Transitions, In Press, DOI: 10.1016/j.eist.2014.04.005

Meadowcroft, J., 2011. Engaging with the Politics of Sustainability Transitions. Environmental Innovation and Societal Transitions 1, 70-75.

Musiolik, J., Markard, J., Hekkert, M., 2012. Networks and network resources in technological innovation systems: Towards a conceptual framework for system building. Technological Forecasting and Social Change 79, 1032-1048.

Papachristos, G., Sofianos, A., Adamides, E., 2013. System interactions in socio-technical transitions: Extending the multi-level perspective. Environmental Innovation and Societal Transitions 7, 53–-69.

Pelikan, P., 2011. Evolutionary developmental economics: how to generalize Darwinism fruitfully to help comprehend economic change. Journal of Evolutionary Economics 21, 341-366.

Penna C.C.R., Geels F.W., 2012. Multi-dimensional struggles in the greening of industry: A dialectic issue lifecycle model and case study. Technological Forecasting & Social Change 79, 999-1020.

Raven, R.P.J.M., Verbong, G.P.J., 2007. Multi-regime interactions in the Dutch energy sector: the case of combined heat and power technologies in the Netherlands (1970-2000). Technology Analysis and Strategic Management 19, 491-507.

Rodrik D., 2014. When Ideas Trump Interests: Preferences, Worldviews, and Policy Innovations. Journal of Economic Perspectives 28, 189-208.

Rosenbloom, D., Meadowcroft, J., 2013. The journey towards decarbonization: Exploring socio-technical transitions in the electricity sector in the province of Ontario (1885–2013) and potential low-carbon pathways. Energy Policy 65, 670-679.
Rotmans, J., Kemp, R., van Asselt, M., 2001. More evolution than revolution: transition management in public policy. Foresight 3, 15-31.

Rotmans, J., Loorbach, D., 2009. Complexity and Transition Management. Foresight 13, 184-196

Safarzynska K., 2012. Agency and economic change. In: Marletto G. (Ed.), Creating a sustainable economy. Abingdon, Routledge.

Safarzynska K., van den Bergh J.C.J.M, 2010. Evolving Power and Environmental Policy: Explaining Institutional Change with Group Selection. Ecological Economics 69, 743-752.

Schubert. C., 2014. "Generalized Darwinism" and the quest for an evolutionary theory of policy-making. Journal of Evolutionary Economics 24, 479-513

Seyfang, G., Hielscher, S., Hargreaves, T., Martiskainen, M., Smith, A., 2014. A grassroots sustainable energy niche? Reflections on community energy in the UK. Environmental Innovation and Societal Transitions, In Press, DOI: 10.1016/j.eist.2014.04.004

Schot J., Hoogma R., Elzen B., 1994. Strategies for shifting technological systems. The case of the automobile system. Futures 26, 1060-1076.

Smith, A., 2000. Policy networks and supporting coalitions: explaining policy change and stability in UK industrial pollution policy? Environment and Planning C: Government and Policy 18, 95-114

Smith A., Stirling A., Berkhout B., 2005. The governance of sustainable socio-technical transitions. Research Policy 34, 1491-1510.

Smith, A., Kern, F., 2009. The transitions storyline in Dutch environmental policy. Environmental Politics 18, 78-98

Smith, A.,Voß, JP., Grin, J., 2010. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. Research Policy 39, 435-448

Smith A., Raven R., 2012. What is protective space? Reconsidering niches in transition to sustainability. Research Policy 41, 1025-1036

Sovacool, B.K., 2009. Rejecting renewables: The socio-technical impediments to renewable electricity in the United States. Energy Policy 37, 4500-4513

Sovacool, B.K., Hirsh, R.F., 2009. Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition. Energy Policy 37, 1095-1103

Suurs, R.A.A., Hekkert, M.P., 2009. Cumulative causation in the formation of a technological innovation system: the case of biofuels in the Netherlands. Technological Forecasting and Social Change 76, 1003-1020.

Suurs, R., Hekkert, M., Kieboom, S., Smits, R., 2010. Understanding the formative stage of technological innovation system development: the case of natural gas as an automotive fuel. Energy Policy 38, 419–431.

Turnheim, B., Geels, F.W., 2012. Regime destabilization as the flipside of energy transitions: Lessons from the history of the British coal industry (1913–1997). Energy Policy 50, 35-49.

Truffer, B., 2010. User-led Innovation Processes: The Development of Professional Car Sharing by Environmentally Concerned Citizens. Innovation: The European Journal of Social Science Research 16, 139-154.

Unruh, G.C., 2000. Understanding Carbon Lock-in. Energy Policy 28, 817–830

Unruh, G.C., 2002. Escaping Carbon Lock-in. Energy Policy 30, 317–325

Urry, J., 2008. Governance, flows, and the end of the car system? Global Environmental Change 18, 343-349.

van den Bergh, J.C.J.M., Stagl, S., 2003. Coevolution of economic behaviour and institutions: towards a positive theory of institutional change. Journal of Evolutionary Economics 13, 289–317.

van den Bergh, J.C.J.M., Gowdy, J., 2009. A Group Selection Perspective on Economic Behavior, Institutions and Organizations. Journal of Economic Behavior and Organization 72, 1–20

van den Bergh, J.C.J.M., Truffer, B., Kallis, G., 2011. Environmental innovation and societal transitions: Introduction and overview. Environmental Innovation and Societal Transitions 1, 1-23.

Veblen, T., 1898. Why is economics not an evolutionary science? Quarterly Journal of Economics 12, 373-397.

Vergragt P.J., Brown H., 2007. Sustainable mobility: from technological innovation to societal learning. Journal of Cleaner Production 15, 1104-1115.

Vromen, J.J., 2011. Routines as multilevel mechanisms. Journal of Institutional Economics 7, 175-196

Walker, W., 2000. Entrapment in Large Technology Systems: Institutional Commitment and Power Relations. Research Policy 29, 833–846

Weible, C.M., Sabatier, P.A., Jenkins-Smith, H.C., Nohrstedt, D., Henry, A.D., de Leon, P., 2011. A Quarter Century of the supporting Coalition Framework: An Introduction to the Special Issue. The Policy Studies Journal 39, 349-360.

Ultimi Contributi di Ricerca CRENoS

I Paper sono disponibili in: http://www.crenos.it

14/11 *Andrea Pinna,* Shall We Keep Early Diers Alive?"

14/10 *Gianpiero Meloni, Dimintri Paolini, Juan de Dios Tena,* "American Beauty: an analysis of U.S. movies revenues in the global market"

14/09 *Silvia Balia, Rinaldo Brau, Emanuela Marrocu* "Free patient mobility is not a free lunch. Lessons from a decentralised NHS"

14/08 *Gerardo Marletto,* "A deliberative-participative procedure for sustainable urban mobility – Findings from a test in Bari (Italy)"

14/07 *Manuela Deidda,* "Insularity and economic development: a survey"

14/06 *Edoardo Otranto, Massimo Mucciardi, Pietro Bertuccelli* "Spatial Effects in Dynamic Conditional Correlations"

14/05 *Francesco Quatraro, Stefano Usai,* "Are knowledge flows all alike? Evidence from European regions"

14/04 *Angelo Antoci, Fabio Sabatini, Mauro Sodini* "Online and offline social participation and social poverty traps. Can social networks save human relations?"

14/03 *Anna Bussu, Claudio Detotto,* "The bi-directional relationship between gambling and addictive substances"

14/02 *Alessandro Fiori, Tadas Gudaitis,* "Optimal Individual Choice of Contribution to Second Pillar Pension System in Lithuania"

14/01 *Oliviero A. Carboni, Paolo Russu,* Measuring Environmental and Economic Efficiency in Italy: an Application of the Malmquist-DEA and Grey Forecasting Model

13/24 *Luca Deidda, José J. Cao-Alvira,* "Financial liberalization and the development of microcredit"

13/23 *Manuela Deidda,* "Economic hardship, housing cost burden and tenure status: evidence from EU-SILC"

13/22 *Vania Manuela Licio, Anna Maria Pinna,* "Measuring insularity as a state of nature. Is there a case of bad geography?"

13/21 *Vania Manuela Licio, Anna Maria Pinna,* "The European firms' export activity to the neighbouring countries"

13/20 *Kallioras Dimitris, Anna Maria Pinna,* "Trade activity between the EU and its neighboring countries: Trends and potential"

13/19 *Claudia Cigagna, Giovanni Sulis,* "On the potential interaction between labour market institutions and immigration policies"

13/18 *Romana Gargano, Edoardo Otranto,* "Financial Clustering in Presence of Dominant Markets"

13/17 *Ettore Panetti,* "Financial Liberalization with Hidden Trades"

13/16 *Adriana Di Liberto,* "Length of stay in the host country and educational achievement of immigrant students: the Italian case"

13/15 *Audrius Bitinas, Alessandro Fiori Maccioni* "Lithuanian pension system's reforms following demographic and social transitions"

13/14 *Guillermo Baquero, Malika Hamadi, Andréas Heinen* "Competition, Loan Rates and Information Dispersion in Microcredit Markets"

Finito di stampare nel mese di Dicembre 2014
Presso Centro Stampa dell'Università degli Studi di Cagliari
Via Università 40
09125 Cagliari

www.crenos.it

ISBN 978-88-8467-904-8