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Intergroup selection as a way to peace and sustainability

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Abstract. *Due to an increasing demand for resources that exceeds the biophysical system's ability to regenerate itself (Wackernagel et al., 2021), environmental resources are under stress, and society faces uncertainties related to their scarcity and climate change that can lead to violent conflicts.*

This context raises questions about mechanisms to understand the phenomenon and adapt. Therefore, Fisher and Rucki's (2017) approach becomes relevant: economic development, ecosystem functioning, peace, and conflict management are necessary components of sustainability, but how they work together is not well understood. To address this issue, a theoretical path is proposed based on three approaches: sustainability transition, complexity economics, and peace from a vision of complex systems. By promoting cooperative behaviors through intergroup selection processes, progress can be made toward sustainability and the emergence of peace as a stable behavior.

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1. Introduction

Due to an increasing demand for resources that exceeds the biophysical system's ability to regenerate itself (Wackernagel et al., 2021), environmental resources are under stress, and society faces uncertainties related to their scarcity and concomitant crises such as climate change. This context has led to conflicts that raise questions about mechanisms to understand and adapt. One of the current mechanisms that seeks to improve human conditions in this environmental context is the Sustainable Development Goals (SDGs) proposed by the United Nations (United Nations, 2023).

These goals aim to establish an agreement between society and its inhabitable world to ensure human well-being. One of these objectives is peace, as violence and insecurity have a destructive effect on a country's development, which in turn affects its capacity for sustainable economic growth (United Nations, 2023).

The absence of peace has significant costs for nations, not only in terms of suffering for their population but also in economic terms, delaying progress and access to well-being. In 2019, the economic impact of violence was estimated at 14.4 trillion dollars, equivalent to five dollars per person for each day of the year. Therefore, in the context of peace, redirecting these resources could significantly improve the well-being of large numbers of people (Institute for Economics & Peace, 2021).

Although the Sustainable Development Goals (SDGs) recognize peace as imperative for sustainable development, the term itself remains conceptually and operationally vague (Fisher et al., 2021). Furthermore, Fisher and Rucki (2017) note that there are only superficial understandings of how the drivers of any component of sustainability (economic development, ecosystem functioning, and peace) work. While it is known that environmental quality affects economic development and that access to resources affects the probability of conflict, these relations require a deeper understanding of feedback processes within the system they comprise. As these dynamics are intertwined, less disciplinary and broader approaches are required.

We propose a theoretical path based on the complex adaptive system (CAS) approach, which offers mechanisms that favor peace as an emergence from economic, social, and environmental interactions. To achieve this goal, we investigated environmental, social, and economic perspectives that work jointly. Therefore, research has been carried out on systemic approaches starting from each disciplinary field.

This study goes beyond systems understood as a certain number of interacting elements (Bertalanffy, 1986) and complex systems in which the interacting parties present an emergency (Newman, 2009). Instead, it delves into complex adaptive systems characterized by having a large number of agents that interact, adapt or learn (Holland, 2006), modifying their structure or behavior in response to external changes or to the emergence that they themselves create.

Starting from environmental approaches, research has delved into complex adaptive systems (CAS), where the sustainability transition is circumscribed. From different perspectives, the Sustainability Transitions Research Network (STRN) seeks to create a path in which society can combine economic development and social well-being with a reduction in pressure on the environment (Brauch & Oswald Spring, 2016). One of the approaches used by this current is related to CAS, in which the system presents an adaptation through a complex and non-linear response to external disturbances that can be considered an input of the system but from a multilevel perspective (Grin, 2016). For example, a response to climate change that occurs at a high level of system aggregation affects individual agents' decisions.

From an economic approach, the concept of a complex adaptive system in the economy has been investigated. This approach moves away from a mechanistic notion of equilibrium and emphasizes that people are not gears in a machine but that human behavior co-evolves with the environment. In this environment,

cooperation and competition, the formation and dissolution of alliances, and the emergence and dissolution of structures generate systematic changes in the goals pursued. This implies permanent changes that maintain microdiversity and generate emergent phenomena. Therefore, the economic system is unstable, evolutionary, and complex (Gomez & Gubareva, 2021).

From this approach to complexity economics, rationality is inductive. Arthur (2015) raises it as beliefs or hypotheses adapting to the aggregate environment they jointly create. After some initial learning, hypotheses or mental models adapt to each other. Agents compete for survival against other agents' ideas or mental models. This is a system that is both evolutionary and complex.

Following this perspective, the multi-level selection mechanisms in the evolutionary process proposed by Wilson (2016) were analyzed, which provided clues to identify behaviors at the agent level that transcend to higher levels of system aggregation. For this, the consideration made from complexity economy is relevant when accepting that human behavior is ambivalent and is influenced by both selfish instincts and authentic social practices (J. Spangenberg & Polotzek, 2020). From this perspective, sustainability contains social dilemmas that imply taking charge of a common good, such as the environment in which particular and common interests are intertwined, which is therefore determined by cooperation and/or competition actions.

In this sense, Bowels and Gintis (2002) suggest that cooperating implies deciding better for beneficial behaviors in groups to coevolve. His studies identified that cooperative behaviors benefit the members of a group, allowing those made up of highly cooperative individuals to dominate in intergroup conflicts. In this direction, Cottey (2018) suggests that cooperation can prevent conflict, since it thrives in environments where individualism, competition, and accumulation are present by showing a severe attitude towards losers.

As already mentioned, mental models are dynamic by adapting to each other. In this sense, Mebratu's (1998) contribution is relevant when proposing that sustainability is an epistemological resource for the desired future. Therefore, it is dynamic and subject to society's realities and expectations over time. Under this consideration systemic approaches from the social sciences were investigated to understand the emergence of peace.

In this context, the sustainability approach of Fisher and Rucki (2017) becomes relevant, according to which sustainability is the process of maintaining the progress achieved in the dynamics of desirable systems while other dynamics are actively changed, modified, or improved to bring the system closer to the

objective of social justice and human well-being. For this reason, economic development, the functioning of ecosystems, and peace and conflict management become necessary components of this sustainability.

From this approach, in which these authors have researched, together with Coleman, the relations of conflict, development and environment from a complex systems approach, Coleman defines sustainable peace "as existing in a state where the probability of using destructive conflict and violence to solve problems is so low that it does not enter into any party's strategy, while the probability of using cooperation and dialogue to promote social justice and well-being is so high that it governs social organization and life" (Coleman, 2016, p. 150).

Although peace is complex and idiosyncratic, when operationalizing it, it was identified that positive intergroup reciprocities in this type of peaceful society far outweigh negative intergroup reciprocities (Coleman et al., 2020). From this concept, his studies have found that in contexts of stable peaceful societies the central dynamics responsible for the emergence and maintenance of sustainable peaceful relationships in societies are the thousands or millions of reciprocal intergroup interactions that occur daily between members of different groups. In those communities, peace depends on the degree to which the most positive interactions outweigh the negative ones. If the positives outweigh to a significant extent the negatives, the probability of maintaining peace will be greater. This finding constitutes a significant contribution to identifying how, from simple behaviors in a system, sustainable peace emerges as a pattern at a high level of aggregation, in which cooperative behaviors have a determining role.

Finally, some examples of self-organized cooperative behaviors originating in complex systems were identified to propose a theoretical path from economic relations to implement mechanisms to promote peaceful behaviors and thus contribute to sustainability framed in healthy ecosystems, economic development, and peace. In this way, it contributes to the Sustainable Development Goals, particularly peace.

This paper is structured as follows. The first section describes the context in which the phenomenon to be investigated is situated, indicates how it has been poorly studied, and presents a general conceptual framework for complex systems. The second part focuses on the theoretical proposal developed from three disciplinary approaches from the sciences of complexity: transition to sustainability, the economy of complexity, and peace as an emerging pattern of interactions in social systems. The theoretical elements taken from these

approaches are used for the construction of the theoretical proposal of sustainability and peace. The proposal is shown in section three. Finally, section four presents conclusions.

2. Environmental conflict: Intersystemic vision

This section examines some dynamics identified in the literature that show how peace is affected by behaviors in different systems. Then it is shown how these connections are weakly studied.

2.1 Problem context

Understanding peace as a phenomenon that gravitates around inter-systemic relationships requires considering the ontology of ecological economy. This presents the environment as a meta-system that includes the social system of which the economy is a subsystem, forming a nested order (Spangenberg, 2016).

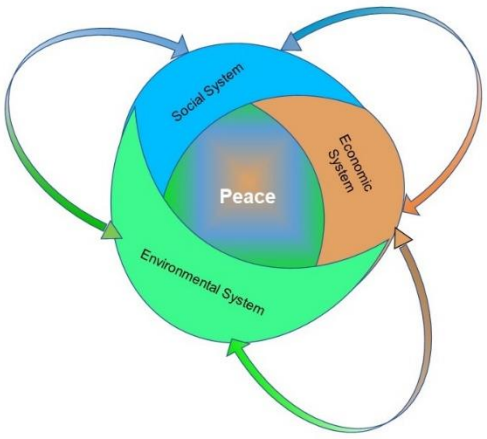

Figure 1: Peace as intersystemic emergence

In Figure 1, the three systems (economic, social, and environmental) are represented as independent but cohesive simultaneously, and, from a more aggregate perspective, they form the metasystem. At this level of abstraction,

dynamics between those systems in different directions are symbolized, and peace (or its absence) emerges from these.

The dynamics found in the literature show that behaviors are not strictly assignable to a single system; on the contrary, it is evident that, in some cases, they can operate simultaneously, among themselves, or with feedback mechanisms. Some of these dynamics to consider are:

- The continuous expansion of the human sphere (Scheffran, 2016) increases demand and puts pressure on natural and ecosystem resources.
- Different economic growth rates, combined with different rates of technological growth, contribute to the emergence or maintenance of conflicts in the social system. This situation results from a tendency to carry out activities at levels not previously experienced by society or to acquire a certain degree of influence or control over a wider expanse of space or a more significant number of people (Choucri & North, 1972, cited in Stephenson, 2016).
- Unsustainable processes exacerbate the environmental crisis, which affects infrastructure and ecosystems (U.S. Global Change Research Program, 2017), as well as social destabilization, which can generate violent actions due to scarcity of resources, such as drinking water or food (Brauch, 2016).
- Economic processes like world transport, trade, and financial markets are also subject to climate change. Financial transactions and information on prices represent virtual transactions, which link environmental events in short periods. If there is an effect in a place due to the weather, there may be production losses or bankruptcies of companies, which are reflected in the stock market and spread through global networks and markets (Scheffran, 2016).
- In areas affected by the conflict, an inefficient administration of income prevails, including those that come from natural resources (Naciones Unidas, Pacto Global, 2010).
- In periods of conflict, more significant environmental threats have been found due to increasing deforestation processes, inappropriate land use, return of the displaced population without proper planning, and great dependence on the primary sector, with significant impacts on the environment (Hochschild, 2015; Suárez et al., 2017).

As can be seen, these problems are not confined to a single system or a single level but rather present a multi-scalar structure. For example, natural disasters in a particular region can undermine the legitimacy and ability of states to protect their citizens from harm. If the agriculture of a developing country suffers

significant effects, the livelihood and existence of many people are at stake. Loss of life, income, wealth, jobs, health, family, or friends causes unrest that threatens the social contract and undermines the political order. Some of these processes occur slowly and contribute to social and political stability erosion, while others arise quickly and exceed communities' problem-solving and adaptive capacity.

Another example is that change in temperatures and rainfall accentuates human migrations and brings security problems, which is a factor of conflict. Thus, the stronger the impacts and the more subsystems are involved, the more difficult it will be for societies to face the consequences (Scheffran, 2016). Moreover, the interdependencies between the environmental and social ecosystemic dimensions generate complex cascading and combined effects (de Coning & Krampe, 2021). Therefore, given these global interdependencies, destabilizations anywhere cannot be ignored.

These behaviors reflect the interactions between individuals and their environment, as well as between individuals themselves. This implies that decisions are made based on the expectations and reality of the environment, which has been subject to change from previous decisions. However, these decisions continue to transform both the environment and the individuals themselves in continuous feedback processes that are retroactions (Florez & Thomas, 1993).

Given that individuals have different preferences, dilemmas may arise from these interactions, which even occur over time, because previous decisions or events may condition a present decision and, in turn, impact the future. Hence, analyzing these phenomena must consider the capacity for learning, adaptation, and evolution to respond to the uncertainty that all future times bring.

In a way, the dominant epistemological approach in economics has influenced these interactions of individuals. Adam Smith[1]´s reflections suggest that the human being acts for his egoism and society satisfies his needs by achieving individual benefits (Smith, 1994). This conception that each agent acts for his

[1] "Man in most circumstances claims the help of his fellow men, and in vain can he hope for it only from their benevolence. He will achieve it with greater certainty by interest in his favor, the egoism of others, and by making them see that it is advantageous for them to do what he asks. Whoever proposes a deal to another is making one of those propositions. Give me what I need, and you will have what you want is the meaning of any offer. Thus, we get most of the services we need from others. It is not the benevolence of the butcher, the brewer, or the baker that procures our food but the consideration of their own interest. We do not invoke his humanitarian sentiments but his selfishness; nor do we speak to them of our needs, but of their advantages" (Smith, 1994, pp. 45-46).

interest has persisted in economic models; the nature of economic theory has been influenced by this premise (Sen, 2007a). Economic well-being has been dominated by the utilitarian tradition, which considers interpersonal aggregations; the common welfare would be the total sum of all utilities of people involved (Sen, 2007b). The concept of utility raised by Bentham refers to the property or tendency of any object to produce benefit, advantage, pleasure, good, or happiness or prevent pain, evil, or unhappiness (Bentham, 1780).

Starting from the utility as a unit of account in which the greatest happiness minus any related penalty is sought, there derives a constituted cost-benefit relationship. In the economic model, this rationality translates into what someone is willing to pay for that utility. In this way, economic well-being is assumed to be linear. That is, the well-being of all is the sum of individual well-being. From the point of view of the logic of utility, this would be the most significant benefit for each individual who provides the goods or services at the lowest possible costs, which results in a dominant competitiveness model that promotes mass consumption, putting more significant pressure on environmental resources. From this perspective, many business models are based on constant product increases; thus, the culture of consumption is stimulated by ensuring changes in fashion, technological trends, and short product life cycles (Göpel, 2016).

Given these complex relationships, it has been identified that in international policy instruments such as the SDGs that represent an interconnected and integrated approach to development and sustainability, the links between environmental, economic, and social dimensions goals are not explicit enough to strengthen policy integration. Social and ecological justice is narrowly understood on the agenda and is limited to redress and access (Fisher et al., 2021). Similarly, the links between environmental sustainability studies and sustainable peace are known but must still be clearly identified (Stephenson, 2016). However, this type of problem could be addressed by systemic frameworks that welcome the overlap between areas of knowledge, as presented below.

3. Systemic approaches

Flórez and Thomas (1993) suggest that Comte's positivism of the 19th century, in which information is the only basis of knowledge, and this is only obtained from the study of the phenomenon whose objective reality is best determined in experimental isolation, implied a reductionist vision of the universe, which focused on disconnected objects and a disciplinary separation. That means the

sciences were developed close to themselves by feeding the various scientific fields less and less and, therefore, offering scientific, individual, restricted, and fragmented explanations. However, in the second half of the XX Century, more holistic visions emerged, which began to break through with traditional reductionism. There, the «system» emerged as a key concept in scientific research (Bertalanffy, 1986).

The subject of this research is not only circumscribed in a system but in a complex and adaptive one that concerns several disciplines. In the literature, there is no univocity in the technical definition of a complex system (Cumming *et al.*, 2013; Newman, 2009) but at least there is some consensus that it is a system of parts that interact and display emergent behavior (Newman, 2009). Cumming et al. (2013) suggest that complex systems exhibit behaviors that include, but are not limited to, properties to alter system states that maintain different regimes; the ability to process information and respond to it; the presence of feedback loops that regulate or amplify trends, regularly resulting in multiple equilibria; and, once the system ends up in a steady state, it can be highly resistant to change, and considerable shocks are needed to switch to another regime. This phenomenon is known as a lockdown (Arthur, 2013). These feedbacks make it difficult to distinguish cause from effect. At this complex system level, the agents' interactions generate an emergence, which is not found in the interacting elements. In addition, there are delays in time and space, discontinuities, thresholds, and limits. For this reason, adding the behavior of small units to obtain the aggregate result is impossible (Costanza *et al.*, 2013).

As already specified in the introduction, complex adaptive systems (CAS) are those "systems that have a large number of components, often called agents, that interact, adapt or learn" (Holland, 2006, p. 1). One of the distinctive elements of these systems is that individual "adaptive" agents continually change their environment instead of following a fixed response behavior to external stimuli (BenDor & Scheffran, 2019). These agents can then adapt to their external environment, which includes other adaptive agents, changing rules as experience accumulates. Agents learn from their environment and modify their behavior by altering the system itself (Holland, 1996).

However, complex systems, particularly adaptive ones, present characteristics that allow a better understanding of environmental problems since they allow a richer perspective on possible sudden and abrupt changes in ecosystems and a better evaluation of responses to alternative policies (Gomez & Gubareva, 2021). In the next section, three theoretical approaches from the sciences of complexity are presented, one focused on the environmental system, another on the

economic system, and another on the social system that gives rise to peace. From these theoretical instruments a mechanism that unfolds a simple behavior on individuals that boost patterns that favor environmental sustainability and peace is provided.

3.1. Environmental sustainability

As can be identified in the conceptual elements of complex adaptive systems, these are dynamic and transform and adjust themselves. Hence, the need to consider the idea of sustainability not as something static but rather it is modified according to changes that occur in the environment, since, to some extent, they may be affected by anthropogenic actions. This environment gives rise to values from which elements of judgment are established to determine what is most convenient for society.

Sustainability is a way of "being" in the present with a view to the future, which invites broader, more holistic, and dynamic thinking. In this way, as Fisher and Rucki (2017) propose, sustainability becomes a process to maintain the progress achieved in the dynamics of the desirable systems, while other dynamics are actively changed, modified, and improved to bring the system closer to the future objective of social justice and desired human well-being. In this sense, the approach of Mebratu (1998) to sustainability, who observes it as an epistemological resource on the desired future, becomes relevant.

Considering the above, it is found that the field of study of the transition to sustainability is a systemic research paradigm focusing on a long-term and large-scale transformation of the dominant trajectory of carbon-intensive development, leading to environmental deterioration with implications such as climate change. This approach embraces sustainable development, human security, and sustainable peace studies. It has contributed to promoting strategies, policies, and long-term proactive measures, to further sustainable development objectives that contribute significantly to sustainable peace as the possible result of the long-range transition of production, consumption, and governance systems (Brauch & Oswald Spring, 2016).

From this line of study, since 2009 a new discourse has been presented by the Sustainability Transition Research Network (STRN), which has focused on the problems of energy, water, transport, and food from different scientific perspectives in the way in which the Society could combine economic and social development with the reduction of pressure on the environment. Scholars in this field consider that sustainability problems, being ambiguous and complex,

require transformative changes at the system level that imply economic changes in both production and consumption (Brauch & Oswald Spring, 2016).

The sustainability transition approach is systemic. It is the scenario in which long-term transformation processes are carried out at different scales and, essentially, in the established socio-technical system, which seeks to change to more sustainable modes of production and consumption (Markard et al., 2012). In this framework, transitions are emergencies of interactions between social groups with myopic views and different strategies, interests, and resources, in which social groups try to find their way through searching and learning. In this journey, controversies, debates, and even power struggles can arise (Geels, 2020).

This focus moves at three levels, mainly:

• Niches: corresponding to a new structure of a small group of agents that emerges within the system and aligns with a new configuration. Usually, this new alignment is an emergent property of the system (Mesjasz, 2016).

• Sociotechnical system: referring to scientific knowledge, engineering practices, and process technologies that are socially integrated. They are linked to the expectations and skills of technology users with broader institutional structures and infrastructures (Markard *et al.*, 2012). The path of a transition to sustainability implies changes in different aspects of the technical-material, organizational, institutional, political, economic, and socio-cultural regimes, which leads to the emergence of new products, services, and business models that replace or complement those that already exist (Mesjasz, 2016). Nevertheless, it is also necessary to change the financing and administration of the system, as well as changes in governance, institutions, and value systems for the transformation towards a globally more sustainable society, which contributes to peace, freedom, material well-being, cooperation, care, and environmental health (Brauch & Oswald Spring, 2016).

• Environment: corresponding to the macro level, consisting of deep structural trends (Morone, 2018). These are long-term exogenous trends (Grin *et al.*, 2010). On this scale, individuals and nature are most acutely connected. Therefore, the composition and configuration of the environment profoundly affect and are affected by human activities (Wu, 2013). An example is climate change.

Under mostly moderate situations, the system maintains a certain balance between stocks, flows, and agents, which could be an attractor due to internal structures generated over time. However, in the case of strong external

disturbances, the agents induce non-standard responses through constant fluxes in the flow, reinforcing their own responses. This can move the system away from the stable state in which it finds itself, focusing on another attractor. That is, moving to another stable structure that implies a deep structure change, which constitutes a transition (Grin, 2016).

Those non-standard responses can be considered niches, comprising clusters undermining the socio-economic regime. Subsequently these niches are absorbed or combined with the undermined regime, which changes its structure to a new regime. This change of new structure has altered the higher level of aggregation of the environment, which again induces changes in the agents, leading to niche competition (Grin, 2016).

Here, the main challenge is identifying and overcoming structural barriers such as market conditions, regulations, technologies, and consumer routines to move in the desired direction. Hence, transition management aims to experiment, develop and learn about the potential of different innovations, such as technologies, practices, products, or organizations, with the potential to materialize strategic vision and become new, and more sustainable structures (Loorbach *et al.*, 2010). However, it is necessary to consider that each context shows a different historical beginning of dependency on the past; thus, what is proposed in one niche may not work in another one (Costanza et al., 2013).

These behaviors imply the presence of multiple feedback loops, which lead to non-linearity and the emergence of large-scale patterns, impossible to examine in the individuals who create them. In this way, CAS has an amplifying effect related to non-linearity (Paravantis, 2016), which is essential to understand environmental issues from the point of view of economics. Therefore, the transition to sustainability offers a systemic epistemological resource that allows an understanding of how technical or social innovations arise and how they operate in a dynamic that, according to its objective, can transcend the socio-technical system and be framed toward sustainable behaviors, where peace is an indispensable component.

Next, theoretical elements that show how the economy can be perceived as a Complex Adaptive System are presented, and how cooperative behaviors are identified inquiring into evolutionary dynamics mechanisms that can favor peace.

3.2. Complexity economics

In this section, from the CAS perspective, we present a view of the economy and examine the rationality of its agents. Subsequently, cooperative behaviors from evolutionary mechanisms are presented, deployed in the socio-technical system of which the transition to sustainability speaks, and how those behaviors favor peace as a stable emergent.

3.2.1 The economy as a complex adaptive system

The perspective of complexity economics allows for a systematic analysis of the interactions between heterogeneous agents at different scales. Complexity economics views the economy as a complete system and part of a larger dynamic system with which it coexists, interacts, and evolves. Composed of several agents without perfect foresight who interact through various social networks. Patterns then emerge from these micro-behaviors at macro levels (Foxon et al., 2013), which can include peace. In this sense, Arthur (2013), defines the economy as:

> a vast and complicated set of arrangements and actions among consumer agents, firms, banks, investors, government agencies that buy, sell, speculate, trade, export, import, offer services, invest in firms, strategize, explore, forecast, compete, learn, invent, and adapt. It is a massive parallel system of behaviors that concur, form prices, markets, trade agreements, institutions, industries (p. 2).

The complexity approach allows one to ask how agents' actions, strategies, or expectations could react (endogenous changes) to the patterns they create. One way to model this is to assume that economic agents form individual beliefs about the situation they are in, and continually update it. They adapt or reject and replace the actions or strategies based on what they explored (Arthur, 2013). Consequently, it is evolutionary in nature to the extent that heterogeneous agents (or heterogeneous expectation strategies) continuously adjust to the overall situation they create together, and from there, they adapt within an "ecology" created by all. Evolution arises naturally from the construction of the model itself, not needing to be added as a complement. This approach advocates more for explaining and understanding the phenomenon (Wagner, 2012).

Complexity science proposes the existence of a middle level in economics, which can trigger events at other scales. The phenomenon at this level arrives, stays for some time, and then disappears (Arthur, 2013); this meso-level redefines a solution in economics. Therefore, focusing the attention of macro-observations on micro-interactions is to recognize the different levels of the phenomenon,

reflecting a bottom-up orientation towards a macro theorization (Wagner, 2012). The rule systems are the essential connections in the economic system, and these rules are mesoeconomic and finite in nature, not micro or macroeconomic. The rule systems are structures, and complexity theory warns that as circumstances change, they will become obsolete and degenerative if they are not adapted or replaced by new rules. So, if a rule is regarded as something static that arises for its useful properties at one point, it will tend to be useless in other circumstances (Foster, 2005). From the economics of complexity approach, this impermanent meso-level is the equivalent of the socio-technical system mentioned in the sustainability transition field.

Thus, the economic system presents a multisystemic nature that drives its dynamics. At the micro level are the agents; at the meso level, the rules; and at the macro level, the system as a whole. This representation implies that the economy constantly creates and recreates itself, to the extent that it produces new elements, sometimes technologies and institutions, which establish new structures as it evolves (Arthur, 2013). Due to these relationships between agents and between agents and networks, properties not found at the micro level (agents) arise at the macro level. Consequently, the system cannot be known, even if there is a precise understanding of its parts, since the level of aggregation is not only the sum of the behavior of the individuals (Fernández et al., 2004) but also the space in which patterns emerge.

At the micro level, the economic system is made up of many heterogeneous agents without perfect foresight but capable of learning and adapting over time. Their interactions occur with only some of the other agents in the space (Rosser & Kramer, 2000). For this reason, no global controller or competitor can exploit all the economic opportunities (Rosser & Kramer, 2000). These interactions can occur with or between networks and generate dispersed interactions (Foxon et al., 2013), whose hierarchical organization is transversal to many tangled interactions (Rosser & Kramer, 2000). Among these heterogeneities, there are asymmetries between levels that lead to their ability to interact being subject to the way the environment is structured. Economic networks appear within the conformation of these structures, constituted in dynamic entities in which the formation and elimination of links occur to form a configuration that influences economic results. Therefore, relationships matter, and the type of collective behavior that emerges is much more than the sum of its parts (Wilson et al., 2016). As a consequence, how agents interact at the micro level, determines what at the macro level is observed.

3.2.2 Agents' rationality

Economic agents use past knowledge and experience through simple decision-making heuristics to make sense of problems. Thus, they continuously update their internal model. This means they constantly adapt, discard, and replace actions or strategies based on their experience as they explore (Arthur, 2013). Thus, individual choices are made between alternatives, which are subjective representations of alternative future outcomes, and not between future results themselves (Basili & Zappia, 2010).

At the micro level, actors are understood as bounded rationales. Their rationality is limited by the manageability of the decision problem, the actor's cognitive limitations, and the time available to make the decision. Hence, individuals, in general, do not optimize (for example, utility) but instead engage in cognitive processes, such as social comparison, imitation, and repetitive behavior (habits) to use their limited cognitive resources efficiently (Arthur, 2013).

In this sense, behavioral economics, according to Arthur (2013), suggests that contexts determine how people decide, and cognitive science suggests that if a decision is important, people can take a step back and try to make sense of it from guesswork, guessing, or based on past knowledge or experience. Therefore, one way to model this is to assume that economic agents form and continually update individual beliefs about their situation. That is, they adapt or reject it and replace the actions or strategies based on what they explored by deploying rationality through induction.

The central idea of inductive reasoning, described by Arthur (2015), is that it is made up of multiple elements in the form of belief models or hypotheses that adapt to the aggregate environment that they jointly create. Therefore, economy qualifies as a complex adaptive system. After some initial learning, the hypotheses or mental models in use adapt to each other. Agents compete for survival against the ideas or mental models of other agents. It is a world both evolutionary and complex.

3.2.3 Economy, sustainability, and cooperative behaviors

The system's sustainability arises from the interrelation of links that are not in their individual elements. According to Acquier et al., (2017) products, services, technologies, and organizations cannot be considered sustainable by themselves but elements of a sustainable socio-technical system.

On the other hand, Gomez and Gubareva (2021) suggest that traditional economic models are inadequate to address sustainability issues such as climate

change, specifically for four reasons: 1) These models do not adequately address uncertainty. The economy is constantly moving as agents explore, learn and adapt. Therefore, it involves something that will occur in the future, bringing a certain degree of ignorance (Arthur, 2013). This lack of knowledge translates into uncertainty contributed by the agents and the system as a whole. 2) Inability to address aggregation and heterogeneity. 3) The preceding implies that traditional models offer insufficient explanations of innovation and technological change. 4) There is a difficulty in designing functions that realistically assess the economic impact of the consequences on the environment or climate change.

By considering the interactions of agents who can learn, adapt and evolve, the complexity approach can identify more sustainable patterns used by firms and consumers (Gomez & Gubareva, 2021). In this context, this paper proposes intergroup selection mechanisms that induce cooperative behaviors that favor peace and thus contribute to sustainability and peace. Sustainability in social terms requires cooperation since, at times, individual and short-term interests must yield to give way to general and long-term interests, that is, that future generations have the same opportunities as the present ones but also between members of this generation (Vera, 2013).

3.2.4 Selection mechanisms that favor cooperative behaviors

Once the inductive rationality of the agents in the complex adaptive system has been described, selection mechanisms that favor cooperative behaviors are presented. When complexity theory is intertwined with evolutionary theory, the concept of fitness stands out, an idea that represents how well an individual, group, species or strategy is performing compared to competition and, therefore, how likely to prosper (Newman, 2009). Holland (1996) explains this process within the system as an allocation of credits that provides the system with hypotheses that anticipate future consequences by strengthening the rules that lay the foundation for later activities that are openly rewarding. In this sense, the author points out that, in mathematical studies of genetics, economics, and psychology, these rewards are assigned by decree when assigning numerical values to objects of interest. Fitness is assigned to chromosomes, utility to goods, and rewards to behaviors. Through competition with local payments, the evolutionary dynamic is developing.

However, evolution occurs not only from selection processes but also from interbreeding. Therefore, as Paravantis (2016) suggests, a fundamental pattern in the evolution of CAS is the combination of old and new building blocks (groups of components), in which those with the highest fitness remain to generate

unexpected properties and, therefore, alternative futures, which can become innovations. Added to this process is mutation, which, according to Holland (1996), is the process in which each of the alternative forms is modified randomly to finally close the evolutionary cycle with the substitution in which the new agents replace the previous ones.

This coexistence between the theory of complexity science and evolutionary theory is justified by authors such as Axtell et al. (2016), who point out that a CAS is not necessarily evolutionary, although it can be. These systems are conceived as information that is remembered in the form of rules, which define the system (environment), and strategies, which determine the system's agents (or nodes). When complex adaptive systems are evolutionary, selection can occur on at least two levels: at the level of the individual agent or the level of the system as a whole when interacting with other systems. Even if the information defining the interaction of the agents resides entirely in them, the level at which the selection occurs can lead to very different results. In this way, Bowles (2004) states that the population can be hierarchically structured, individuals interacting with individuals. However, they also constitute groups (such as families and companies) and other superior entities (such as nations) with which they also interact and in which that selection occurs at more than one level.

In this same line, Wilson et al. (2016) consider that, based on complexity theory, the fact that systems are composed of elements governed by simple rules of behavior and, from there, selection can be explained as an emergence without considering natural selection, is an error since, in the absence of selection, properties that arise from complex systems are nothing more than adaptations to the environment with mutations. From this perspective, he argues that there are two types of CAS:

1. CAS 1: Complex adaptive system as a system.

2. CAS 2: Complex system composed of agents that use adaptive strategies.

The radical difference is that CAS 2 is not adaptive as a whole. According to evolutionary theory, the functional organization exists at the level of individual organisms due to processes of natural selection among individuals. For CAS 1, the system must have a selection unit; otherwise, the system would qualify as CAS 2. The central idea is that an effective self-organizing process must be selected from many less effective self-organizing regulatory processes. Thus, at the group level, the functional organization requires individuals who perform services for each other or for their group as a whole. Members who cooperate are less good at surviving or reproducing than those who are free riders or who

actively exploit cooperators. When this happens, the functional organization stops at the level of the individual organism and does not extend to the social group or to a higher level.

Cooperation can be a disadvantageous selection compared to non-cooperatives (free riders) or exploiters in the same group, but groups composed mainly of cooperators have an advantageous selection over groups of exploiters and non-cooperators. Hence natural selection occurs between members of the same group and between groups. An adaptation that benefits the group can evolve if the selection between groups is more potent than disruptive opposition within the group. In this sense, groups of prosocial individuals have a competitive advantage over groups governed by egoists. Prosocial behaviors can win from the Darwinian perspective as long as the selection between groups in a multigroup population is strong enough to prevail in selecting individuals in the groups. Then, evolution is determined by coopetition, that is, simultaneous agents' cooperation and competition (Paravantis, 2016). In intergroup selection, Bowels and Gintis (2002) found that this selection mechanism favors individual traits beneficial to the group as a whole, which has pushed altruistic forms of human sociality toward non-family or group-level institutional structures., such as resource sharing, which have emerged and spread, repeatedly, and in a wide variety.

Next, we present how these cooperative behaviors favor the emergence of patterns that contribute to peace.

3.3 Peace

This section addresses peace from the theoretical approach of complex systems, from which operating mechanisms are identified, and later examples of self-organization are presented.

Based on complexity, Coleman (2016, p. 150) has defined sustainable peace as "the state where the probability of using destructive conflicts and violence to solve problems is so low that it does not enter into any party's strategy, while the probability of using cooperation and dialogue to promote social justice and well-being is so high that it governs social organization and life". On the other hand, Eoyang (2015) argues that peace is a pattern that emerges from systemic interactions based on simple rules that are repeated in different types of relationships, and it is relevant to know the link between each individual and the systemic pattern to have an impact on problems affecting it.

In this field of complexity, the work of Coleman (2020) identified that, in the context of stable peaceful societies, although peace is complex and idiosyncratic, it can be operationalized based on the relationship of positive intergroup reciprocity (PIR) and negative intergroup reciprocity (NIR). The central dynamics responsible for the emergence and maintenance of sustainable peaceful relationships in societies are the thousands or millions of reciprocal intergroup interactions that occur daily between members of different groups in those communities. Peace depends on the degree to which positive interactions outweigh negative ones. The higher the PIR:NIR ratio, the higher the probability of stable peace.

In the same line Fry et al. (2021), in their ethnographic research, found that, over time, reciprocal prosocial relationships are developed and linked to non-war societies within a broader common social system, where cooperation and unity prevail, while war between members is no longer considered an option. Thus, the direct link between cooperation and peace is evident. According to studies by Bowels and Gintis (2002), cooperation is based, in part, on the distinctive abilities of humans to build institutional environments that limit competition inside the group by increasing the relative importance of inter-group competition, which carries high individual costs and implies deciding, better, for beneficial behaviors in groups to coevolve. For this reason, in the history of humanity, cooperation has favored evolution by improving individuals' opportunities for mating and coalition formation. In their analysis of dynamic models, the authors find that cooperative behaviors that bring benefits to group members allow groups with high cooperative ties to dominate in intergroup conflicts, which results in an evolutionary mechanism of internalizing norms since it leads to improving individual fitness in a world where social behavior has become too complex for individual rational evaluation. Thus, conflicts can decrease when agents carry out cooperative actions that give value to all agents (win-win) (BenDor & Scheffran, 2019). For this reason, as Cottey (2018) states, cooperation can prevent conflict since the latter thrives in environments of individualism, competition, and accumulation by showing a severe attitude towards losers.

Continuing with the dynamics displayed by a CAS, Mesjasz (1988) states that, for social studies, in order to prevent violence, the hope of centralized control must be abandoned. Peace studies must take into account the role of self-organization in sociotechnical systems. That is crucial for sustainability transition. From this perspective, de Coning (2020) states that peacebuilding is based on stimulating and facilitating the ability of societies to self-organize. It means managing their

tensions, pressures, disputes, crises, and shocks without relapsing into violent conflict. The strength and resilience to generate this self-organization determine how much society can resist pressures and shocks that lead to violent conflict. This self-organizing process must stem from a context-specific, bottom-up local process.

Once cooperative interactions have been identified as individual mechanisms that can promote peace and give way to self-organized and evolutionary behaviors, some examples are presented below.

3.3.1 Emerging collective action (ECA)

According to Maldonado (2019), classical collective action theory is based on the rational selection theory, which: 1) Focuses on solving problems relevant to collective action through the design of incentives (such as the stick or the carrot); 2) Seeks to solve problems of lack of cooperation through psychological solutions and voluntary changes; 3) Guides people to cooperate in collective actions guided by meta-preferences (values or morality); 4) Is based on the power of coordination. Conversely, swarm collective action with strategies without central control emerges from complexity science. This phenomenon has been identified in systems such as nature, subatomic particles, culture, economics, and even politics. This practice emerges as a rationality of collective emergent behavior without a plan or strategy from the outset, but affords each individual possibilities, obstacles, and problems with greater benefits as part of the swarm rather than individually. Therefore, common objectives, goals, and evaluations become more important, which eliminates the free-rider problem.

According to Axelrod (1984), this type of cooperative behavior, when the probability of two individuals meeting each other again is high enough, promotes cooperation based on reciprocity and can be evolutionarily stable in a population without much kinship. Hence, this type of behavior is characterized by permanent communications, continuous networking, and active personal participation in assemblies and meetings, with spontaneous learning arising as an important condition of adaptation (Maldonado, 2019).

3.3.2 Adaptive governance

According to Folke et al. (2006), adaptive governance is a form of social arrangement in which actions are voluntarily coordinated by individuals and multi-individual groups with self-organization and the ability to enforce, with nested polycentric institutional arrangements and quasi-autonomous decision makers at different levels, relying on networks that connect individuals,

organizations, agencies, and institutions at multiple levels of organization and provide collaboration, flexibility and learning-based ecosystem management approaches. In other words, an evolutionary structure of multiple interactions is observed at different levels for the coordination of actions without a great central power.

Dietz, Ostrom, and Stern (2003) propose that the requirements for adaptive governance in a complex system are: 1) Providing reliable information on stocks, flows, and processes with the resources of the governed system; 2) The ability to handle conflicts: As large differences in power and values among different parties inherently lead to conflict, it is convenient to promote analytical deliberation through a well-structured dialogue represented by the different actors; 3) Providing infrastructure and being prepared for change: Institutions must be designed to support change without very fixed rules and be prepared to give great importance to the current state of knowledge; 4) Nesting: institutional arrangements nested in several layers.

3.3.3 Social learning

Foster (2005) proposes four levels of order in complex systems: 1) Imposed energy: no adaptive structures such as fractals observed in physico-chemical fields; 2) Knowledge imposition and energy acquisition: energy received is transformed into a knowledge structure that allows it to acquire energy, as in biological systems in which information is genetically provided; 3) Knowledge acquisition: a biological system interacts with the environment and a possible world, knowledge is cumulative and can be in a mental model; it is a complex and adaptive system in which adaptation is not only selection but also creativity; 4) Interactive knowledge: interaction between mental models, a type of system that prevails when people create aspirations and commitments in the future and enter into installment contracts and other agreements with end dates in the future, gathering the aspirations of individuals in "understandings" allowing the creation of organized complexity. It is in this fourth order context that the aspirations of individuals lead to "understandings" that allow the creation of organized complexity (Foster, 2005). Folk et al. (2005) suggest that the processes that generate learning, meaning, and experience of the ecosystem dynamics in terms of management practices are part of the social capacity to respond to environmental changes. They thus propose that a clear vision, complete stories and meanings, good social connections, and trust with other interested parties can mobilize interest groups at various levels and initiate a process of self-organization of learning and generation of social capital for the management of CASs.

Cumming (2013) emphasizes social learning "by doing" through experiences in successful group processes, which should change the understanding of the individuals allowing the change to go beyond individuals and incorporate not only a large number of them, but also community practices through social interactions and processes between actors with social networks (Cumming et al., 2013). Therefore, in social learning persists the idea that mutual understandings between individuals lead to practices in the community at different levels of self-organization that generate changes beyond each individual.

However, the theoretical elements discussed throughout this article can provide a clearer idea of their contribution to peace when presented in a comprehensive manner, as outlined in the following section.

4. Peace contributions

This study aimed to identify theoretical elements from a complex system approach that offers a mechanism to favor peace as an emergence due to economic, social, and environmental interactions. The following figure summarizes the ideas proposed.

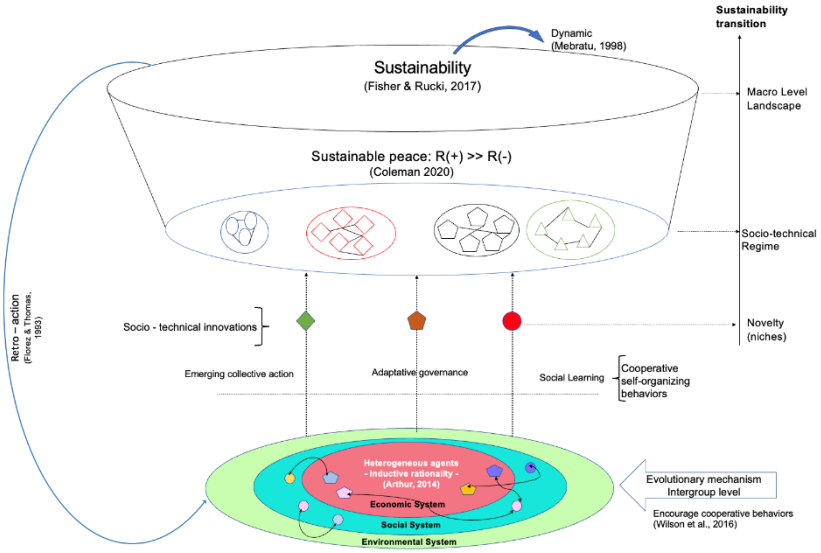

Figure 2: Peace emergence. Source: Own elaboration, based on the multilevel structure of Grin et al (2010, p. 19)

At the figure's base, the relationships between open systems are schematized based on interactions between economic, social, and environmental systems. They are made up of heterogeneous agents with cognitive capacities and limited information that, through inductive rationality, adapt or evolve about them and with the environment. Complexity Economy provides this theoretical framework.

The processes of evolution occur through selection mechanisms among various alternatives executed systematically at different scales. Mechanisms of intergroup selection are suggested, which, as Wilson et al. (2016) and Coleman (2020) describe, can favor cooperative behaviors that, in turn, radiate to the upper level of the metasystem, promoting positive reciprocity.

To the extent that the cooperative strategy dominates, it can give way to self-organized behaviors, such as emergent collective action, adaptive governance, social learning, or another of similar nature. These behaviors can promote technical and social innovations that affect the socioeconomic system and are aligned with the idea of sustainability that is dynamic, and thus change over time. For this theoretical proposal, the Fisher and Rucki (2017) sustainability concept is considered, as the process of maintaining the gains made in desirable system dynamics while actively changing, modifying, or improving other dynamics to move the system closer to the goal of social justice and human well-being. Economic development, ecosystem functioning, peace, and conflict management are necessary components.

Sustainability requires cooperation to promote the common interest. In that sense, to the extent that these cooperative behaviors are strengthened, behaviors that favor peace also begin to emerge. It would be an additional or collateral benefit that the search for sustainability brings through stimulating cooperative behaviors through intergroup selection. Studies by Coleman (2020) indicate that, in a society characterized by stable peace, the difference between positive intergroup reciprocities far exceeds negative intergroup reciprocities. Given that, to the extent that the difference between cooperative and non-cooperative actions is greater, peace, as an emergence, can be established as a stable behavior.

Since sustainability is the epistemological resource of how the future is desired (Mebratu, 1998), which is subject to the relationships within the system, its nature is dynamic. This same idea of sustainability, created by all agents of the system, once again permeates the decisions of individuals, generating feedback to give way to individual decision processes. These decisions go through evolutionary processes to generate innovations or niches as are called by sustainability

transition studies. Later, these niches permeate the socio-technical system and then impact the landscape, restarting the loop systematically.

This theoretical proposal, framed in a complex systems approach, has the advantage, as Gomez and Gubareva (2021) suggested, of allowing a dynamic representation of a network of relationships on which public authorities must act. Complexity economics does not advocate that state policies are solutions to the market, but rather recognizes their interdependence and co-evolutionary character. In this sense, the state can intervene through policies to favor processes of differentiation, selection, and amplification of business plans (Beinhocker, 2006). This type of interference is not through specific policies, but by stimulating the co-evolutionary context between the state and the market, which can be useful for stimulating CAS1 by promoting selection among more effective groups in terms of cooperation in self-organization processes.

One of the benefits of the implementation of inter-group selection to promote cooperative behaviors is the emergence of peace and sustainability as an endogenous result of the system. Therefore, according to the characteristics of each system, of its past that constitutes it, from a cooperative but self-organized (not imposed) perspective, the niches and structures for each system are formed. That is different from a solution used for several systems and implemented exogenously.

In this way, as observed in the first section where the problem was introduced, the economic, environmental, and social systems are interconnected. Recognizing dynamics that create intertwining between them is relevant to direct the systems to display desired patterns.

5. Conclusions

To understand how peace in a context of sustainability can emerge as a pattern in a complex adaptive system, the holistic and systemic view of the complexity science provides epistemological elements to understand better the dynamics between the economic, social, and environmental systems. From a bottom-up analysis, it can be located at a privileged point of high aggregation, not of the agents, but of the system as a whole, to spot emergences that are not found in individual agents, nor the aggregation of the same type of agent without participating in the system. In this way, it is possible to understand the behaviors in the forest, that cannot be explained by the trees. Typical in social systems that, as Coning (2020) states, are highly dynamic, non-linear, and emergent.

Intergroup selection is identified as a trigger for peace in the sustainability transition context from complexity and evolutionary frameworks. Bowels and Gintis (2002) found that this selection mechanism favors individual traits that are beneficial to the group as a whole. In this sense, Wilson (2016) argues that an adaptation that benefits the group as a unit can evolve if the selection between groups is strong enough in the face of disruptive opposition within the group. For this to happen, groups composed primarily of cooperators are in advantageous selection compared to exploitative and non-cooperative groups. Therefore, intergroup selection favors prosocial behaviors (Wilson, 2016). It is connected with Coleman's finding that peace emerges as a stable behavior when the difference between positive intergroup reciprocities is much greater than negative ones (Coleman et al., 2020). Hence, implementing intergroup selection mechanisms can favor the emergence of lasting peace. From niche innovations, new behaviors, in this case, more prosocial ones, are disseminated on the social-technical level where strong rules and structures are established. Then, those affect the highest level of aggregation. Consequently, an intergroup selection that promotes cooperation should affect the state of the environment and society's relationship with it through self-organized structure and endogenous feedback. This intergroup selection mechanism can become a tool to fulfill the sustainable development objective of peace, justice, and strong institutions by promoting peaceful societies in a context of sustainability.

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