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Rationality and the exploitation of natural resources: a psychobiological conceptual model for sustainability

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Abstract

This article proposes a psychobiological conceptual model that incorporates the vulnerability and exhaustibility of the ecosystem into the notion of rational behavior. After providing a review of relevant literature in economics, psychology and sociology, we analyze the theoretical and practical limitations of economic rationality under conditions of climate devastation. By employing a logical consequence approach, we describe and broaden the cognitive process of rational choice to include the influence of externalities, institutions, markets, and the ecosystem. We propose two existing constructs as perceptual conditions restraining the rational exploitation of natural resources: restitution and substitution. These constructs are conditioned by the degree of the irreplaceability of materials. Under these premises, we purport that individuals act in a rational manner subject to the extent of restitution and substitution of resources, depending on their perception of economic, environmental, and social risk.

Keywords Rationality · Natural resources · Sustainable development · General system theory · Institutional theory · Progress

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1 Introduction

"We know precisely and scientifically what the effects of pollution, waste of natural resources, the population explosion… are going to be. If we do not want a theistic explanation… we seem to follow some tragic historical necessity" (von Bertalanffy, 1968, p. 8).

Our biosphere is at risk of disintegrating and perishing. Massive damage to forests (Pechony & Shindell, 2010), atmospheric and maritime contamination (Jackson, 2008; Weiss et al., 1999), air pollution (Lave & Seskin, 1970; Selden & Song, 1994), and land erosion (Klein Goldewijk et al. 2011) have initiated a new geological era, the Anthropocene. Ecosystemic disarray has led to significant changes in species, numerous extirpations, sex mutations, infectious diseases, and possibly extinctions (Root, et al., 2003; Wake & Vredenburg, 2008; Wu et al., 2003). Environmental degradation caused by human activity has reached such a dire state that in 2019, 11,258 scientist signatories from 153 countries declared, "clearly and unequivocally, that planet Earth is facing a climate emergency" (Ripple et al., 2020, p. 8). As anticipated by the recent 2021 Nobel Prize in Physics awardee, Klaus Hasselmann, "even if emissions are frozen at present levels, the accumulated emissions over several centuries still yield climate" (Hasselmann et al., 2003, p. 1923).

Empirical research has demonstrated that environmental deterioration results in scarcity of resources (Schröter et al., 2005; Vörösmarty et al., 2000), which negatively impacts pricing volatility of supply materials and production activities (Hambrick, 1981; Hymer & Resnick, 1969; Ricardo, 1992; Schumpeter, 1950). Classic economic models assume that consumer preferences and production activities are mutually dependent functions. On the one hand, customers demand specific products depending on the compatibility and economic consistency found between their preferences, expected utility maximization, and product attributes (Nickerson et al., 2001). Naturally, demand is subject to affordability and price restrictions (Smith, 1994). On the other hand, organizations extend their strategic alternatives by accelerating the production of commodities to maximize their profits. Such strategic choices are subject to price parameters based on the fixed market value of goods (Ricardo, 1992). Nevertheless, when economic models account for the exploitation of natural resources and the aforementioned assumptions, a theoretical void emerges.

Although classic economic models acknowledge the existence of natural resources as constraints to grow, they often fail to adequately account for their sustainable exploitation and optimal management, especially in terms of internalizing externalities, such as environmental degradation and resource depletion. According to Daly (1996), dominant classic economic models grounded in the pursuit of present value maximization largely disregard ecological costs under the premise that the liquidation of natural resources is optimal. Such models assume that the swifter the liquidation is, the higher the discount rate used. Their conventional presumption is that additional human-made capital can replace the natural resources that have been depleted. This approach regards manmade capital and resources, such as equipment, machinery, or infrastructure, as scarce, while natural capital and resources, such as forests or wetlands, as infinite. Another theoretical concern that becomes apparent when traditional economic models make allowance for the exploitation of natural resources involves their appropriation. These models propose that privatization or central regulation of natural resources must be met in order to achieve an equilibrium between the allocation of units and their exploitation. However, this postulate assumes that appropriators (a) perfectly know the capacity of a common-pool resource and its sustainable yield; (b) are unambiguously and unbiasedly capable of assigning such capacity; and (c) can totally monitor tasks without costs. Nevertheless, most economic agents face the paradigm of incomplete information, their monitoring capabilities are limited by their time and energy, and an efficient administration of resources seldom results in a zero-cost strategy (Ostrom, 1990). These contradictions habitually result in a market or government failure.

To adjust the price of goods, companies rely on the market cost of supplies and labor to estimate a net utility percentage. However, price and volume of supplies are not solely governed by market supply and demand, especially in open and globalized economies where public policies, global investment, and government intervention play a substantial role in macroeconomics (Keynes, 2018). In open and global economies, the scarcity of natural resources implicitly regulates the cost of goods in oligopolies and the marginal utility derived from allocating specific assets. Hence, if the strategic choice of allocating and accumulating resources is limited by incomplete information, externalities, cognitive biases, and causal ambiguity (Oliver, 1997), the central principles of classic economic models cannot adequately explain the relationship between environmental deterioration, scarcity of resources, and economic rationality.

A further crucial inquiry concerns whether the taxonomies and application of sustainable practices and pro-environmental behaviors can be deemed rational acts (Abbott & Monsen, 1979; Arlow & Gannon, 1982; Castree, 2008). Conceptual differences arise when the notion of sustainability is studied under the ontological limits of a social rationality (Leff, 2011), the economic paradigm of rational behavior (Smith, 1994; Teece, 1984; Williamson, 1975), the self-interest conduct (Keynes, 2018; Smith, 1994), the pursuit of profit maximization (Friedman, 1982; Schumpeter, 1950), and the capitalization of nature (Daly, 1990; Leff, 1995). Individuals frequently exercise financial and economic calculations when making decisions amid uncertainty (March, 1978). Engaging in such calculative cognitive processes, which frequently entail cost–benefit analysis, risk assessment, and utility maximization, gives precedence to immediate economic self-interest, rather than to collective eudaemonia. The recognition of environmental alterations, intergenerational equity, and the preservation of ecosystems necessitates a broader ethical perspective that extends beyond mere financial assessments. Deliberating through calculations inherent to economic rationality typically lessens the importance and prominence of intrinsic and moral values (Martini, 2021). In this vein, ideals and codes that are difficult to estimate and measure in the realm of economics, such as protecting the natural environment, become marginalized. Eventually, the juxtaposition of economic rationality, moral values, environmental welfare, and sustainability exposes a tension between self-interested economic calculations and large-scale ethical considerations.

When moral and economic pronouncements and resolutions collide, individuals face a form of cognitive dissonance, for social norms, moral principles, and collective beliefs tend to be more salient than analyzing the costs and benefits of a choice (Bennis et al., 2010). Such cognitive conflicts along with survival impulses heavily influence individual rationality with respect to the exploitation of natural resources.

Previous studies have demonstrated that deliberative calculations and high levels of self-interest destabilize social functions and the sense of community, discourage cooperation, and foster unethical behaviors (Roca & Helbing, 2011; Wang et al., 2014; Zhong, 2011). Since self-interest tends to be an unpremeditated, unconscious behavior, actions fomenting the radicalization of self-interest and morality disengagement become psychological justifications for individuals to exploit natural resources. Thus, it is the disengagement of morality, rather than the operant behavior of being self-interested per se, which absolves individuals from self-sanctions and feelings of guilt through the cognitive reconstruction of conduct. This self-defense mechanism arises when perceived self-efficacy is weak and self-exonerations are needed to neutralize self-censure. Ultimately, it leads to a displacement of responsibility that distorts the nature of injurious behavior (Bandura, 1999), such as the overexploitation of the biosphere.

Built on general system theory, the sociological interpretation of progress, the notion of rationality, and the conceptualization of sustainability and sustainable development, we present a psychobiological conceptual model that integrates two existing constructs to estimate the degree of rationalization when exploiting natural resources: substitution and restitution of resources. We propose that the act of exploiting, utilizing, transforming, and consuming natural resources is proportionally rational to the degree of substitution and restitution of materials. Such a degree of rationalization is proportionally moderated by the degree of irreplaceability of materials or substances and the perceived risk of economic, social, and environmental loss.

2 Theoretical framework

2.1 General system theory

From the general system theory perspective, organizations are conceived as open, sensitive systems with the capacity to grow and self-reproduce (Katz & Kahn, 1978; von Bertalanffy, 1968). Organizations respond to externalities by optimizing their internal processes to exchange information, resources, knowledge, energy, and matter with the surrounding environment. These exchanges allow organizations to adopt the form of a system vis-à-vis the environment, a system constituted by interrelated subsystems which invariably interact with each other as dependent entities. When the allocation of resources is dependent on each agent, unit or entity, the natural interaction between the environment and agents will constrain their choices (Coase, 1937), irrespective of whether humans are considered as acting upon the environment or as being affected by it (Mill, 1844).

The environment as a natural setting epitomizes the supra system or macrosystem, which affects and is affected by the volatility of its subsystems or microsystems (Lovelock, 2003). If the macrosystem undergoes significant alterations or emergencies, such as climate change or global warming, its subsystems and structures will adopt a self-organizing (Folke et al., 2005) or self-regulating behavior (Lovelock, 2003), technically known as the continuous development and evolution of the unit. This process re-establishes the steady state of the system after a crisis (Capra, 2002; Capra & Luisi, 2014; Maturana & Varela, 1980, 1994; von Bertalanffy, 1950, 1981). Any interconnected macrosystem addressing crises and disruptions will adjust the range of its limits, inexorably causing interactions among subsystems (Luhmann, 2013). These synergies will generate new limits, imposing new constraints to growth (Herrington, 2021).

Traditional organizational theories and resource management postulates teleologically and ontologically focus on the foundational assumption of a steady-state view of the ecosystem. This assumption suggests a gradual, smooth, and incremental progression of environmental changes, often inconsistent with empirical observations. Furthermore, their scope is circumscribed to the prevention and control of ecological crises, ignoring interactions across scales, ecosystems, biological entities, and natural processes (Folke et al., 2005; Scheffer et al., 2001). Let us illustrate the ontological distinction between a steady-state and a dynamic-state view of the environment in the context of natural resources exploitation. Consider externalities as "any situation where some Paretian costs and benefits remain external to decentralized cost-revenue calculations in terms of prices" (Bator, 1958, p. 362). Suppose the costs of exploiting, transforming, and allocating natural resources are regarded as static externalities derived from a stable ecosystem. Given that there is no visible risk of biological loss in a stable ecosystem, agents do not have economic and social incentives to diminish any external cost of pollution (Jaffe et al., 2005). In such a case, agents may not act rationally when internalizing environmental costs of inputs. In contrast, if environmental costs are considered dynamic externalities within a fluctuating environment, agents may internalize these costs due to the perceived risk derived from scarcity of inputs and thus may be able to rationalize the exploitation of natural resources. Fundamentally, when agents operate under the assumption of a steady-state view of the ecosystem, they have more economic and social incentives to exploit natural resources. This predisposition may be attributed to the potential lack of recognition of the need to internalize environmental costs in the absence of dynamic externalities to consider.

Organizations are a social configuration of subsystems materialized in the form of humans and resources interconnected with the supra system (Luthans & Stewart, 1977). Therefore, firms circumscribed within a macrosystem facing a crisis will adjust their organizational structures and strategic choices according to environmental conditions (Cook, 1977). These adjustments denote a system effect (Hannan & Freeman, 1977), given that environmental fluctuations modify the survival and adaptation rates of organizations (Freeman & Hannan, 1983). From a population ecology approach, the environment optimizes, not the units. Such an optimization depends on the ability of the environment to grow, subject to the number of resources available (Hannan & Freeman, 1977).

3 Progress and economic growth

In sociology, progress entails a constant mobilization of human civilizations through time determined by a desirable course (Bury, 1920). From this angle, progress is observed as an aim, an objective, a goal. Postmodern societies typically define such a goal in terms of economic wealth. The accumulation of scientific knowledge, and thus technological development, continually transforms human societies by optimizing production and operational efficiency, resulting in industrial revolutions and "scientifico-technological forms of civilizations" (Burgen et al., 1997, p. 4). Thereby, the idea of progress becomes a postulate that assumes a sociocultural interpretation of history and future, denoting an ad libitum continuation of progress itself. Accordingly, this postulate can only derive from and coexist with a fundamental axiom: natural resources are to be considered unlimited.

Stemming from the concept of evolution, sociological theories typically equate progress with evolutionary sequences of social and organizational development. This assumption conceives advancement as unilineal and deterministically applied (Carroll, 1984). If progress is deemed perpetual, infinite, and not time dependent, and given that natural resources are imperative to advance technological development, natural resources are assumed to be unlimited. This notion of progress has brought severe alterations to the ecosystem, and consequently, current environmental crises are challenging the idea of uninterrupted and permanent progress. Empirical evidence shows that growth and progress derived from the extraction and depletion of natural resources are gradually increasing the amount of energy and capital needed to preserve the natural equilibrium of material flows required by the economy (D'Arge & Kogiku, 1973). In due course, these social and environmental costs will surpass the limits of industrial growth. Should this eventuality occur, the economic surplus that stimulates expansion and growth will reverse direction. In other words, the economy will begin to contract (Meadows et al., 2004, p. 51). In point of fact, the history of civilizations exhibits a similar cyclical pattern among cultures and nations: development followed by collapse. In the words of Roca and Helbing (2011, p. 11,370), sociologists and anthropologists have concluded that systemic failures of civilizations may be explained by either (1) the growing complexity of societies during their evolution or (2) due to an overexploitation of the environment. In other words, the historical trajectory of civilizations delineates a conspicuous cyclical motif characterized by phases of growth culminating in eventual decline. On the one hand, the burgeoning complexity intrinsic to the development of societies instigates their downfall. This complexity encompasses the proliferation of socio-political structures, intricate networks, broad institutions, and interdependencies within civilizations. The greater the number of socio-political structures, institutions, social networks, and interdependence within collectives, the greater the variety of ideologies, values, culture, and canonical postures, which leads to a higher disconnectedness between citizens. Such disconnection will ultimately generate social conflicts, resulting in a possible collapse of civilization. On the other hand, the overutilization and exploitation of the environment are proffered as a causal factor precipitating the unravelling of civilizations. This perspective underscores the critical role of ecological sustainability in the sustenance of societies. The greater the development of a given civilization, the greater the number of natural resources needed to maintain it. If the availability of such supplies is limited, a point of inflexion occurs, in which resources cannot sustain a given number of needs in a particular location. In such a scenario, either the civilization migrates or perishes.

Demographic growth and inherited wealth have important implications for the natural environment. Let us examine the notion of progress along with the law of cumulative growth. Consider the notion of inherited natural wealth as the number of natural resources handed down to future generations, which differs taxonomically from the original economic idea of inherited wealth proposed by Piketty (2014) but shares similar assumptions. If demographic growth decreases inherited wealth, new generations will have to distribute and divide the remaining resources on Earth among themselves, given that most natural resources are not renewable. Such a process would notably decrease the inherited natural wealth of humans, sequentially increasing the inequality gap among collectives. This disparity will ultimately intensify the negative correlation between population growth and environmental welfare (Hart, 1995). Opposing an idea of progress resting solely on economic growth and development, environmentalists and scholars have coined the term rational progress. This stance integrates economic growth, individual self-actualization, collective security, and justice, implying a realistic, equitable, and rational production and distribution of goods and services (Boli & Thomas, 1997). Such a modern idea of progress may lead toward a practical dilemma: what exactly ought to be sustained? Is it the supply of natural resources (Castree, 2008; Hart, 1995), the assets obtained from these sources (Pryshlakivsky & Searcy, 2017), or the internal production and technologies employed? (Aall & Husabø, 2010; Birch et al., 2010; Guenster et al., 2011; Klassen & McLaughlin, 1996). The following sections will address these predicaments providing a conceptual framework based on the notion of rationality, uncertainty, risk, and institutionalization.

3.1 Rationalism and rationality

The philosophical definition of rationalism rests on one epistemological postulate: discernment is the primary source of knowledge. According to Hessen (1967), the etymology of rationalism goes back to the Latin *ratio*, which expressly conceives and defines the construction of knowledge solely when it is logically necessary and universally valid. Given that this notion of rationalism is deterministic and reductionist in its operationalization, it debilitates the scope of the concept when considering the influence of externalities and the environment, as the biosphere is nondeterministic by nature. Another philosophical interpretation can be found in the work of Kant (1998), who defined human rationality as a distancing belief that must be founded on traditions and prior experiences. This cognitive process derives from judgments and prejudices that depend on sensitive and perceptual impressions (Adorno et al., 1982; Goldstone, 1998). Some prejudices and judgments are not inherent in the individual, they are socially constructed and legitimated. Consequently, judgments are connected to morality and ethics, as they frame a sense of belongingness and familiarity between humans and their milieus. For rationality to exist, there must be a reason for having a principle or belief and a reason for the principle or belief to be. If the belief exists and has a *raison d'être*, it explains the rational state itself, as the causal relationship between the principle and behavior remains (Davidson, 2004, pp. 178–179). From this standpoint, as long as an action follows a belief that exists, rationality depends solely on the interpretation of judgments.

From a psychological perspective, various connotations have been attributed to rationality. Erich Fromm (2013) defined the term rational as the perceptual deliberation that is supposed to conform to laws of logic, which should not be distorted by emotional and pathological aspects. This postulate frames rational behavior under the existence of a system, for any thought, mental conception, or conduct is rational if and only if it stimulates the proper functioning and growth of the whole system. Inversely, irrational acts deteriorate and destroy the system. From a psychobiological standpoint, physiological instincts (organic drivers) are incontrovertibly rational. The primary function of instincts is to maintain life satisfactorily. Thus, if rational behavior stimulates the proper functioning and growth of the system, instincts become a rational principle for survival. By expansion, life-preserving actions are rational, for they stimulate the growth and well-being of the system. In contrast, destructive beings do not have sufficient conditions for further evolution, namely instincts, and therefore, they are classifiable as irrational, self-destructive beings (Ellis, 1976). When humans hinder the adequate growth, maintenance, and balance of the system, they behave irrationally. These behaviors virtually restrict and inhibit the survival and optimal development of organisms and systems (Bernard, 2011). Although cultural and sociodemographic factors attenuate irrational acts, most humans show self-destructive and ecologically disrupting behaviors, evidently against their best interests (Ellis, 1974, 1976).

In accordance with the ad libitum conception of progress outlined above, rational agents, in purely economic terms, have unlimited wants and thus engage in self-destructive behaviors, which obscures both their moral and economic ability to distinguish between needs, ambitions, and desires, between inherent values and dispensable goods (Schwartz, 1986; Schwartz, et al., 2002). For as much as these traits may appear undesirable or paradoxical, they are nonetheless attested and common forms of human behavior. As a result, a discernible question emerges: Are irrational behaviors rooted in the biological and physiological nature of humans? Ellis (1976) argued that individuals have two contradictory beliefs: the "intellectual" and the "emotional." If we analyze this dyad, it may be possible to link these concepts to those used in psychodynamic theory. Sigmund Freud suggested that the cognitive process of reasoning arises in the conscious mind, the *ego*. Nevertheless, the psyche also comprises unconscious and hidden irrational thoughts, typically referred to as *id* and *superego*, which fall outside conscious control (Geraskov, 1994). Freud challenged the idea that humans behave solely on the basis of reason since individuals habitually act based on unconscious mechanisms and reflexes. Hence, human behavior functions as the irrational driver of the will per se. When those reflexes are elicited, irrationality enters consciousness and becomes conduct (Breuer & Freud, 1974; Freud, 1910). It is widely known among psychologists that consciousness operates in a dilatory and sequential manner, limited by its own cognitive capacity. According to Evans (2008), rational, systematic, and explicit thinking depends on intentional levels of control which are sustained by unconscious, automatic, and impulsive cognition. If instinctive impulses, organic drivers, social needs, and institutional expectations stimulate irrational thoughts and acts, which are continuously activated and reinforced by memory, the concept of rationality should make provision for such factors to influence rational behavior.

From a political and economic approach, John Stuart Mill (1844) contended that political economists conceive humankind interested solely in acquiring, securing, and consuming wealth. In his opinion, political economists assume there is a presumptive economic agent capable of solving and predicting an optimization problem of multiple complex scenarios to identify the best possible decision, which should maximize his or her personal utility. Neoclassic economists have denominated this agent *homo economicus* (Pareto, 2014) or *economic man* (Mill, 1844), a "strictly optimizing egoist" (Roca & Helbing, 2011, p. 11,370). Another definition of this ideal economic agent is provided by Bernoulli: a highly calculative and self-interested individual who seeks to maximize his or her personal utility in all available transactions to reduce the perceived probabilistic risk of each possible profit expectation (Bernoulli, 1954). From this angle, a perfectly rational individual has the cognitive ability to contrast, balance, and evaluate various calculations derived from a series of premeditated consequences. However, estimating an expected perfect utility presumes positioning preferences in order of predilection, subject to qualitative and moral discernments, which suggests the satisfaction of a necessity rather than the maximization of personal utility. Such cognitive overload leads to the simplification of choice mechanisms, reducing pure rational discerning (Simon, 1956). When a course of action is to be determined upon moral standards, such as protecting nature, an absolute calculative approach will not effectively consolidate and appraise non-calculable contingencies.

To examine the boundaries of rational behavior adequately, the observable object of study should entail individuals with incomplete access to information and limited calculative capacities that are actually possessed by organisms able to reason (Shafir & LeBoeuf, 2002; Simon, 1955). These taxonomical limitations restrict the extent to which individuals can be considered purely calculative, as opposed to what is prescribed by rational models. This paradox drove scholars to establish the social, psychological, and economic constraints of human reasoning and to formulate the concept of "bounded rationality" (Simon, 1955, 1957, 1991; Williamson, 1967).

In this regard, a utilitarian cost–benefit calculus can induce cognitive biases, as the assessment of conflicting moralities and interests is systematically distorted by social processes, self-sanctions, and moral justifications. As a result, calculations of long-term costs and benefits are often questionable and inconsistent in the act of evaluating humanities and nature (Bandura, 1999, p. 196). Along with moral and ethical norms enforced by institutions, individual characteristics and cognitive capabilities also influence rational deliberations. When humans continuously attempt to optimize their expected utility, cognitive resources and processes inevitably confront multiple goals and a diverse range of choice situations. In such scenarios, further simplification of choice mechanisms (heuristic) depends on perceived risk assessment, economic restrictions, individual cognitive capacities, and properties of the environment. However, the existence of multiple goals and cognitive simplifications do not impede effortless choices. Given that absolute maximization is theoretically unattainable due to biological and cognitive limitations (Simon, 1956), such simplifications hold for information processing itself. Reasoning beings can develop the ability to infer the structures and connections of the environment, as well as to generate cognitive associations between correlated events and uncertainty, only through substantial, rich representations of probabilities and predictions (Fiorillo et al., 2003). Constructing such representations entails the generation of multidimensional prospective scenarios, yet the stratification of paths and choices will hinder the accuracy of expected outcomes. When human aspirations are unchanging, the biological limits of cognition and the complexity of the environment narrow the decision path. A precise distinction between needs, adaptive behaviors, and ends is then deliberated. Axiomatically, it is in the habit of individuals to satisfy rather than maximize an absolute optimization (Bearden et al., 2011; Simon, 1956). Once human needs have reached an acceptable threshold, individuals are likely to examine their choices based on their satisfaction limits, implying a prudent and moderate use and exploitation of natural resources rather than an optimal and limitless insatiability.

Contemporary theories and principles in management, economics, marketing, finance, and accounting, such as exchange theory (Cook, 1977), rational choice theory (Scott, 2000), transaction cost economics (Williamson, 1975), costs of market transactions (Coase, 1937, 1960), or capital asset pricing theory (Statman, 1999), have established most of their theoretical postulates on the rational choice approach and the central assumption of a rational economic agent. Such theories observe utility as merely an indicator. It is not assumed to be an object of choice, but preferences ought to satisfy (Hausman & McPherson, 2006). Under these conditions, rationality refers to the real-valued function of a measurable utility, subject to an expected maximization. This utility is estimated under explicit linear axioms appropriately associated with a probability distribution, the perceived risk resulting from uncertainty, and a set of preferences (Herstein & Milnor, 1953). Risk perception consists of the subjectively observed judgment and attitude toward hazards, fatal consequences, potential adversity events, and the possible benefits or threats associated with them (Slovic, 1987). Perceived characteristics of the predicted event, such as familiarity, control, catastrophic potential, equity, and level of knowledge, also seem to influence the relation between perceived risk, perceived benefit, and risk acceptance (Slovic, 1987). When an event is observable, perceived as controllable, equitable, individual, and represents a perceived low risk to future generations, such as the use of elevators or fireworks, it will bear less importance for the public. In contrast, if an occurrence is unobservable, uncontrollable, catastrophic, and not equitable, such as radioactive waste or uranium mining, it will be magnified and considered an emergency by society. In this respect, individual and collective beliefs moderate both the perception of uncertainty and perceived risk. If cultural and social factors influence risk perception, they may also influence rationality. Since environmental deterioration has become an uncontrollable and catastrophic phenomenon, the expectation would be for individuals to assess and classify climate change, pollution, and global warming as highly risky crises.

Economic rationalism considers markets as systems where goods and services are exchanged via transactions among agents. Such exchanges bring external interactions that ought to be internalized as private or social costs (Dahlman, 1979). This approach assumes that, in order to trade, exchange, and commercialize, economic entities must have property rights (Dryzek, 2013). However, in the realm of nature, the vast majority of natural resources are not privatizable. This is true particularly for organic matter and resources that are movable, such as water and air, compared to immovable resources such as land and forests.

For the purpose of this study, we consider rationality as any thought, mental conception, conduct, and deliberate action that ultimately serves the purpose of maintaining the proper functioning and growth of a system. The system is a context-specific concept. It could represent an ecosystem, an organism, the human body, or an institution. Given that rationality has been predominantly operationalized through formative indicators, our conceptualization pertains to a nomological network of human behavior, not solely to a unique nomology that define the construct in a particular discipline. Mental conceptions, conducts, actions, and systems are specific constructs with different operationalizations in economics, management, and psychology. Since these domains relate observable properties reciprocally (Cronbach & Meehl, 1955), regardless of the laws to which they belong to, our conceptualization rather holds a general application. In sum, rationality exists if and only if a mental state, behavior, or act secures the survival and growth of the system.

An agentic perspective on rationality contents that individuals deliberately act, following a behavior derived from a cognitive construction, to strengthen their self-efficaciousness as to cope with the environment (Bandura, 1982). Since human actions are taken to obtain resources for personal development and functioning (Bandura, 2001), rationality is a symbiotic and bilateral concept. Humans are producers and products of interactions between them and their environments. Rationality cannot exist in an isolated universe. If there are no agents, organisms, or systems to act upon, there are no incentives for rationality to be. Structures either limit or facilitate individual agency by providing humans with justifications for their actions (Fairclough & Fairclough, 2012). The surrounding context then supplies agents with defined solution domains. Within these domains, agents employ rational deduction and inference to organize their preferences and establish priorities. This organization culminates in a probabilistic model that outlines potential actions and their subsequent outcomes. Enacted courses of action are then selected in accordance with these priorities. Thus, ordering preferences and therefore priorities, can be rendered into a numerical scale (Parikh, 2000). Formulated on this assumption, we contend that enacted courses of action and the rational inference derived from them can be translated to a variable that has degrees, depending on the order of priorities, expected benefits, and collateral consequences. Let us illustrate this argument with an example. A person is alone in the forest. She or he must eat to survive. The individual finds an endemic variety of fish and a vast plantation of a common fruit. If this person must choose between taking the life of a fish in danger of extinction or harvesting a common fruit, she or he may order these two alternatives based on the ultimate benefit of the action, in terms of the self, and the impact on the biosphere, in terms of the collateral consequence. If the individual takes the life of the fish, perhaps she or he would consider that, by so doing, there will be no more fish in a couple of days, despite obtaining a great amount of protein. If the person harvests the fruit, perhaps she or he would infer that, by so doing, she or he will have less nutrients at the cost of surviving for more days. In this scenario, any choice could be deemed rational depending upon the degree of the ultimate benefit for her or his survival and the interaction with the environment. If the individual decides to take the life of the fish to satiate her or his immediate need at the cost of her or his survival in the short term, she or he could be less or more rational depending on this interpretation.

We now proceed to elaborate a deductive statement derived from the aforementioned arguments and relevant literature. The purpose is to model a chain of logical reasoning by articulating our premises. It must be noted that we are expressing our logical sequence through interpretational semantics, and thus, we deduce an interpretational consequence (Shapiro, 1998). This deductive statement must satisfy four essential conditions:

(A) The argument is valid if and only if it is not possible for its premises to all be true and its conclusion false.
(B) Considering that we are presenting an interpretational consequence under natural language, the conclusion could be true under one interpretation and false under another (Davidson, 2001).
(C) The degree of rationality will proportionally vary to the degree of modifications in preferences and whether perceived risk holds over alternatives (Sen, 1971). If the risk is invisible to the agent, rationality becomes a strategy and not a deliberate choice. However, in this article, environmental deterioration has been theoretically proven to be highly observable, perceptible, and evident to society.
(D) Products and services require the transformation of resources, and such transformational processes create externalities.

The following deductive statement is presented in a sequential order of premises:

1. The natural capacity of the ecosystem, social institutions, and the market generate and constrain externalities.
2. Responding to externalities creates economic, social, and environmental costs.
3. Internalizing costs of externalities enables the assessment of risk.
4. Risk determines and constrains the sequential arrangement of individual preferences and priorities.
5. Arranging complete and transitionary individual preferences and priorities results in a classification of possible choices.
6. The sequential arrangement of possible choices leads to rationalization.

Conclusion: The natural capacity of the ecosystem, social institutions, and the market determine and constrain the degree of rationality.

3.2 Institutional constraints of rationality

From a sociological approach, institutional forces functioning within the same social domain where organizations are located constrain their variety and selection of choices. When the public demands companies to legitimate their conduct and conform to social norms, their capabilities and resources will also be restricted (Christmann & Taylor, 2001; DiMaggio & Powell, 1983; Oliver, 1997). If mechanisms of organizational adaptation violate social and legitimacy prerogatives, firms and individuals incur substantial costs derived from social and environmental externalities (Hannan & Freeman, 1977). When institutional entities are influential enough to model the operational structure of social norms, principles, and customs to impart a common understanding as normative (Bartsch, 1987), individuals become a socially constructed subsystem implanted within an institutional supra system rooted in a shared social reality (DiMaggio & Powell, 1983; Granovetter, 1985; Perrow, 1986; Scott, 1987).

According to Zucker (1977), social actions are objective when other individuals replicate them without transmuting the common understanding of the act. They become exterior when a subjective understanding of acts is recreated and socialized as a collective interpretation. In consequence, an individual action projected as a collective behavior becomes socially established by virtue of its normative ratification (Bartsch, 1987; Hughes, 1936). Thus, the identification and recognition of a constructed social reality, through its properties of exteriority and objectivity, influence the degree of responsiveness and diversity of existing routines among individuals (Oliver, 1991; Teece, 1984). Given that climate change has transformed consumption patterns to a high degree of objectivity (Giesler & Veresiu, 2014), and social institutions have increased its exteriority by forcing organizations to protect the ecosystem (Buysse & Verbeke, 2003), the institutionalization of environmental consciousness and the protection of the ecosystem has become a well-established social behavior. Such a level of public acceptability should foster a rational exploitation of natural resources.

When organizations attempt to adapt to inertial pressures, decision-makers assess and evaluate the environment based on their beliefs, social norms, and subjectivity to formulate strategic responses. This subjective representation of the environment restructures and organizes the behavior of companies (Hannan & Freeman, 1977). Since individuals subjectively construct their understanding of reality based on shared interpretations of phenomena with others (Scott, 1987), public concern on climate change is transforming the subjective strategic perception of decision-makers on the exploitation of natural resources. Individuals deploy cognitive mechanisms of self-affirmation to maintain consistent experiences and preserve self-integrity. This cognitive process associates self-conceptions with externalities as adaptively and morally satisfactory so that their self-perception is aligned with social and moral principles (Steele, 1988). The fluidity of self-adaptation entails the presence of a cognitive nexus between specific self-beliefs, values, and conducts in society. These behaviors are conveyed as extensions of the image of the self, derived from the degree of congruency found between the actions of the individual and the rational perception of himself or herself in the collective (Morris & Maisto, 2005). Hence, inertial pressures arising from environmental consciousness may influence the strategic choice of decision-makers toward attaching importance to the protection of the ecosystem.

Making allowances for the application of rationality within the boundaries of institutional actors and collectives, one of the limitations of rational behavior in contemporary economics involves general equilibria. It is inaccurate to asseverate that a rational strategy for an individual is equally rational for a group (Hannan & Freeman, 1977). When individual rationality and collective rationality compete against each other, the latter is expected to dominate and prevail. According to Baum and Oliver (1991), the collective constantly judges and determines the degree of interconnection between the strategic choice of an organization and institutional values, social norms, and beliefs. Therefore, institutions and their codes of conduct construct a symbolic ideography of the environment and its importance for society. This ideography influences the representation of individual preferences, potentially exerting a force to modify the rational behavior of organizations.

3.3 Sustainable development and sustainability

With growing awareness of an inevitable ecological crisis approaching, new studies and models have brought sustainable development and sustainability to the surface. Numerous scholars, practitioners, and experts agree that the concept of sustainable development appeared for the first time in 1987, when *Our Common Future*, also known as the Brundtland Report, was published by the United Nations (Caradonna, 2014). The definition of sustainable development coined by the United Nations can be read as follows: "[the] development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment & Development, 1987). A sustainable development model integrates three interdependent and intertwined dimensions: economic development, social development, and environmental protection (United Nations, 2005, 2019). This concept entails the supposition of a future, which implies protecting present resources and ecosystems, for without a present there can be no future.

Let us now consider the principles of progress and sustainable development together. On the one hand, progress is determined by the future direction of civilizations, subject to technological, scientific, and economic growth. In order to grow, societies must consume and exploit present resources to advance technology. Nevertheless, since human activities are part of a finite ecosystem that does not grow, permanent economic growth cannot be sustained (Daly, 1990), at least not when these activities derive from the exploitation of the biosphere. On the other hand, sustainable development involves articulating and coupling posterity and their essential human needs while preserving and protecting the ecosystem (Kates et al., 2001; Turner II, et al., 2003). Given that progress relies on present growth and sustainability implies the protection of subsequent generations, it is imperative to incorporate distinctive constructs in the academic literature to address these theoretical contradictions. Such constructs should be able to determine and assess the social and economic impact of using, transforming, and exploiting natural resources in the present, so as not to compromise the life-support structure of the planet in the future. If it is possible to reconcile the theoretical foundations of economic rationality with the taxonomies of sustainable development and sustainability, then economic growth, social development, and environmental protection should figure among those preferences individuals classify and organize to formulate rational choices.

The development of a psychobiological conceptual model to accompany future empirical work is presented in the following section. Concepts and their associated propositions are explained. At this juncture, it is important to emphasize that a sustainable depletion of the ecosystem should not exclude, but rather complement economic rationality, as it pertains to a social behavior founded on the optimal allocation and exploitation of natural resources to benefit society and nature. The sustainable development model was established on the foundations of economic rationality, and it shall remain this way (Banerjee, 2003).

4 Conceptual model

According to Hausman and McPherson (2006), there are three main environmental challenges that normative economics must analyze and quantify without imperiling ethical deliberations: pollution, depletion of natural resources, and the preservation of species and biospheres. Logically, in order to grant survival for species and biospheres, a significant decrease in pollution and depletion of natural resources should ensure their conservation. In other words, the preservation of species and biospheres is taken as given when pollution and depletion of natural resources is reduced. Built on the notion of sustainability and economic rationality, we propose two existing constructs to estimate the rational degree to which organizations contaminate and exhaust natural resources:

1. Polluting, by measuring the degree of rational *substitution* of pollutants with renewable, reusable, or biodegradable materials.
2. Depleting, by measuring the degree of rational *restitution* of natural resources.

Both constructs are to be influenced by the extent of *irreplaceability* of materials. Figure 1 illustrates the proposed conceptual model.

4.1 Irreplaceability as a condition

If the rate at which organizations survive depends on the fixed capacity of the environment to support change and units, growth is subject to the degree of exhaustion of current resources (Hannan & Freeman, 1977). Unless the environment possesses an inexhaustible natural capacity, resources are limited, temporary, and irreplaceable, and so is its population. Hotelling (1931) affirms that considering the infinite is a significant obstacle when estimating the rent of extracting non-renewable natural resources or exhaustible assets. Inasmuch as, "not only is there infinite time to consider, but also the possibility that for a necessity the price might increase without limit as the supply vanishes" (Hotelling, 1931, p. 139). Two scenarios may unfold when considering the latent practical limitation of the infinite together with the theoretical restriction of an unlimited environmental capacity. (1) If there is no intention to secure and preserve the total supply of exhaustible resources for posterity, and assuming there is an optimum rate of present production, a rational economic logic suggests controlling and fixing production rates below the optimum level to raise prices and increase profits, regardless of the lifespan of resources (Hotelling, 1931). Alternatively, (2) if the objective is to reserve supplies for future generations, and assuming there is an optimum rate of present production, *ceteris paribus*, companies should replace non-replenishable resources with renewable materials, depending on their degree of irreplaceability. While the first scenario is coherent with the premises of rationality and economic behavior, the second alludes to the principles of sustainable development. Moreover, in the second scenario, organizations may be able to determine the price of goods and services according to the demand rather than in terms of the cost and scarcity of specific

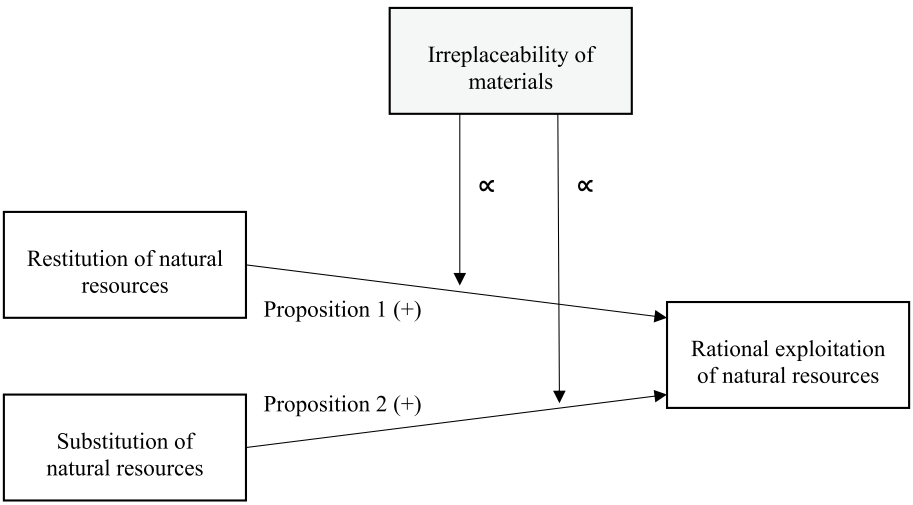

Fig. 1 Psychobiological Conceptual Model. where $\propto$ denotes a proportional relationship. The higher (lower) the degree of irreplaceability, the stronger (weaker) the positive association between restitution or substitution and the rational exploitation of natural resources

resources. If the actual price of exhaustible resources properly reflects their irreplaceability, their environmental and social costs of extraction, and their future productivity value (Richards, 2006), customers would ultimately benefit from such price fixation. Consequently, decision-makers must assess the degree of the irreplaceability of materials before surpassing the optimum rate of present production if they are to guarantee a sustainable consumption of natural resources.

At this point, it could be argued that the degree of the irreplaceability of certain materials is subjective. Indeed, if resources are unknown or if there is a distinct lack of knowledge about their origin and replenishment capacity, the level of irreplaceability may be difficult to determine. Depending on the respective attributes, application and accessibility of a particular resource, its level of irreplaceability will vary; nonetheless, there are some natural resources whose irreplaceability is not open to debate. For instance, oxygen and water stand as quintessential life-sustaining resources. Their indispensability derives from their central role in aerobic respiration, temperature regulation, toxins disposal and nutrients conduction for any living being. Therefore, the irreplaceability of oxygen and water is supported by the principle that no alternative element or resource can perform their biological functions, they are unparalleled resources for terrestrial life. Hence, their degree of irreplaceability should be immensely high, and thus, the effect of substitution and restitution on the rational exploitation of natural resources should be enhanced. In the case of energy sources and feedstock, such as petroleum or lithium, their degree of irreplaceability may be more subjective and difficult to establish. Their indispensability derives from their ability to generate power through combustion and the storage of energy, which primarily serves industrial ends. However, potential substitutes and alternative processes and materials, such as solar and wind energy sources, sodium-ion batteries, or hydrogen cells, should diminish their level of irreplaceability; therefore, the effect of substitution and restitution on the rational exploitation of natural resources should be lessened. Essentially, depending on the level of irreplaceability, the impact of substitution and restitution on the rational exploitation of natural resources will be augmented or diminished. In statistical terms, we suggest that the degree of irreplaceability of a given resource will proportionally moderate the relationship between substitution and restitution, and the rational exploitation of natural resources, either as an enhancing interaction relationship or as a buffering interaction relationship.

4.2 Substitution

Competition among organizations is expected to emerge when resources are finite and populations have an unlimited capacity to expand (Hannan & Freeman, 1977). As resources become scarcer and rarer, the capacity of expansion for firms in such locations decreases. This phenomenon increases regional competition leading to an overall reduction in survival rates among organizations by virtue of selection and adaptation principles. Therefore, higher competition, which assumes finite resources and restricted levels of expansion, demands more efficient and suitable operations to use and exploit natural resources for organizations to survive. In this vein, the reconfiguration of production activities based on sustainable technologies and eco-innovation to decrease greenhouse gas emissions and foment carbon sequestration has shown promising results (Ripple et al., 2020; Selden & Song, 1994; Serrano Barquín & Serrano Barquín, 2008; Thomas et al., 2004). According to Greenstone (2003, p. 443), companies can scale down pollution by reducing outputs or altering production processes. In addition, these operational modifications improve the allocation of raw materials and final products, decreasing costs associated with stock of supplies and eliminating waste. In highly competitive environments and industries, innovation in production processes ensues a competitive advantage for companies. Therefore, developing and adopting organizational capabilities to substitute pollutant materials allow firms to optimize their internal processes and decrease external threats from competitors. In economics, attempting to survive by preventing the rise of competitors is considered a rational act. If substituting pollutant materials with renewable resources increases efficiency, which results in a competitive advantage and a reduction in competition, decision-makers adopting such practices are engaging in an economically rational behavior. Since the sustainable rate of exploitation and use of natural resources cannot be greater than the rate at which a resource can be substituted (Daly, 1990), we state that:

Proposition one (1):

The higher the degree of substitution of pollutant materials, subject to the degree of irreplaceability of the non-renewable substitute, the higher the degree of rationality.

4.3 Restitution

If humans continue polluting and exhausting natural resources to the degree to which the biosphere cannot recover, resources will become exclusive and costly, affordable by only a few. If we assume a constant marginal cost of extraction in terms of utility, extracting firms may become temporal monopolies, which would allow them to regulate prices. Dominant organizations would control free markets and, indirectly, the purchasing power of customers. This disparity of private and social optima would create external diseconomies in production (Smith 1968, p. 412), inasmuch as the market outcome is not expected to be optimal in a monopolistic state (Kemp & Van Long, 1980). However, the ecosystem may be able to stabilize if firms manage to produce and return to the Earth the same number of resources they exploit. In this vein, a proper model of sustainable exploitation must consider that by the end of the natural lifecycle of a non-renewable resource, renewable substitutes must produce an annual sustainable yield equal to the income component of the non-renewable receipts (Daly, 1990, p. 4). Let us visualize this argument through a practical example. Suppose that a manufacturing company requires 540 kg of paper a day, obtainable from a standard pine tree. This variety of trees needs between 20 and 25 years to mature for harvesting (Gong & Yin, 2004). To simplify a possible estimation of maximum sustained gross yield, we consider a Faustmann optimal rotation solution to determine the ideal time for pines to reach maturity for harvesting (Samuelson, 1976). It is then assumed that pine prices remain constant, the land is small relative to the aggregate supply (Hartman, 1976), and externalities derived from harvesting, such as taxes, labor, income, soil erosion, geographical location, land rent, etcetera, are not considered in this calculation. Everything else constant and assuming a steady state of plantation, a sustainable production cycle would require the firm to plant a mature pine tree daily, as to restore what has been exploited, and one pine seed to ensure the reproductive cycle remains steady over time. This process should guarantee that the degree of extraction never exceeds the degree of natural replenishment, as both the level of natural recovery and aggregate recovery depend on the decreasing function of cumulative current outputs of a given resource (Smith, 1968, 2003). Hence, the sustainable rate of exploitation and use of natural resources cannot be greater than the rate of regeneration of its source (Daly, 1990). According to Vernon Smith (1968), there are two fundamental kinds of naturally occurring resources: replenishable and non-replenishable. However, as he stated, “both types of resources are capable of exhaustion" (Smith, 1968, p. 409). Therefore, to ensure that the exploitation of natural resources proceeds at a slower pace than the rate of natural replenishment (Heinberg & Lerch, 2010), companies must return to the ecosystem the same number of resources they use based on the degree of irreplaceability of materials. We define restitution as the biological and structural process through which a lost or damaged natural resource is renewed or returned to the ecosystem.

Proposition two.

(2) The higher the degree of restitution, subject to the degree of irreplaceability of the resource, the higher the degree of rationality.

5 Discussion

A review of dedicated literature has led us to support a position that seems not to follow the conjectures advocated by previous studies on rationality and natural resources exploitation. When examining the central premises of rationality within the boundaries of a limited ecosystem, we theoretically demonstrated that purely rational individuals who seek constant progress and unlimited growth cannot practically live longer than the source of supply, in other words, the ecosystem. Inasmuch as in order to progress, technological development must take place, which demands exploiting natural resources to the same degree as technological progress requires. Given that resources are not finite, progress per se revolves on the capacity of the ecosystem. We argue that a rational decision-maker should be able to assess to which degree his or her survival imbricates those limits to progress and grow without surpassing the limits of survival of the ecosystem. This argument considers that physiological instincts, observed as organic drivers, are indisputably rational, as their main occupation is to maintain life. From an evolutionary perspective, animals behave rationally, for they are regulated primarily by instinct and their goal is to survive, which implies not consuming all available resources in their environment. Inversely, species primarily oriented by the exclusive and sole desire to exhaust resources appear to exhibit a behavior that is not regulated by instincts, as their observable conduct is not indexical of a rational propulsion toward the survival of the species, and thus do not possess the organic drivers required for evolution. Such conduct is categorizable as a non-rational behavior. When humans impede the adequate growth of the system by overconsuming natural resources, they behave irrationally, as the overexploitation of the biosphere antithetically affects their survival.

Traditional economic and management theories parsimoniously explain the subprocesses of categorization and arrangement of preferences and priorities that occur within the cognitive process of rationalization. However, the theoretical identification of the underlying factors constraining the algorithmic operation of ordering preferences and priorities following risk assessment when exploiting natural resources is still absent. In this regard, we present a deductive statement to interpret the influence of external forces on rationality. Using a logical consequence approach, we deconstructed and extended the cognitive process of rationalization up to and including institutions, markets, and the ecosystem. In essence, we argue that, for individuals to make rational decisions, they must sequentially arrange a set of possible choices based on their perception of the environment. This deduction assumes that the transformation of resources creates externalities through their exploitation and allocation. Such externalities are influenced by the natural capacity of the ecosystem. Therefore, rationality itself is moderated by the perception of the environment, the natural capacity of the ecosystem, social institutions, and the market. The aforementioned deductive statement confirms that integrating the influence of external forces into a constructivist model is vital to understand the degree of rationality when exploiting natural resources. Certainly, current economic models of rationality account for externalities and institutional forces; nevertheless, the perceived limitless nature of the biosphere within a cognitive process of rationalization has not been well established. If we solely consider the value of natural resources based on the production cycle of certain products and services, and the demand of such resources grounded on a consumption pattern without taking into account individual preferences and principles toward the biosphere, we may be overlooking some unobservable factors.

In an attempt to integrate an indicator that contemplates individual preferences and principles toward the environment, we propose two existing constructs to assess the rational degree of polluting and depleting: substitution and restitution. Based on the conceptual model and constructs proposed in this study, we call on scholars to develop a systematic scale to measure the degree of substitution and restitution, along with further empirical testing to assess the validity, generalizability, and consistency of such items.

5.1 Limitations and further research

Further empirical studies should ensure controls for psychological and sociocultural factors to narrow the conditions under which the degree of substitution and restitution may reveal a stronger or weaker influence on the rational exploitation of natural resources. For instance, construal level theory (CLT) suggests that psychological distance influences the basis of evaluations, representations, and choices (Trope et al., 2007). Concrete representations (low-level construals) focus on specific and immediate details to portray near events. Abstract representations (high-level construals) focus on general and central features to visualize distant events (Liberman et al., 2007). Given that increasing psychological distance leads to high-level construals (Fujita et al., 2006), it may be possible that individuals who perceive climate change as a geographically and temporally distant event could show a lower degree of rationality when exploiting natural resources.

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Declarations

Conflict of interest The authors have no financial or non-financial interests to disclose.

Ethical approval This research did not require studying or involving human participants.

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