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Article

Sustainable Finance under Viability Constraints: An Entropic Approach

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Abstract: *This paper develops three frameworks – a conceptual one, a theoretical one and an instrumental one – for sustainable finance. The academic literature reveals an insufficient conceptual distinction between sustainable finance, green finance and green financing. Their use as interchangeable terms leads to modelling issues and undermines the coherence of the paradigmatic framework. In this regard, the research proposes a taxonomic and structural differentiation between these concepts, based on a original methodology for conceptual definition and delimitation. On this basis, the Theory of Viable Sustainable Finance (TVSF) is formulated, which argues that viability is a necessary condition for persistence over time, and that persistence over time constitutes a necessary condition for sustainable finance. To operationalise the theoretical framework, a Model of Viable Sustainable Finance is presented and developed, built on an entropic approach to the ESG vector system. Within this model, the thermodynamic entropy generated (or, equivalently, the exergy destruction), social entropy operationalised via the Theil index, and informational entropy as defined by Shannon are associated with the three ESG pillars, whilst the ESG scores for each pillar are treated as empirical proxies for these entropies. The model captures the normative and structural interdependencies and trade-offs between the ESG pillars, establishes the analytical conditions for the existence of a steady state in the ESG entropic system, determines the critical threshold of the norm in relation to the viability frontier of each pillar, and establishes the viability frontiers for each individual ESG pillar.*

Keywords: *Sustainable Finance; Green Finance; Theory of Viable Sustainable Finance; Model of Viable Sustainable Finance; Entropy*

1. Introduction

In academic circles and beyond, there is increasingly intense discussion about the economy's transition towards sustainability, which has led to a significant expansion of sustainability research focused on ESG (Environmental, Social and Governance) criteria; consequently, sustainable finance has become an important area of contemporary research. What stands out in the academic literature is that sustainable finance does not yet have its own paradigm in the Kuhnian sense (for a discussion of the concept of paradigm, see Kuhn, 2012), and the concept of sustainable finance is insufficiently defined ontologically (Lagoarde-Segot, 2019). An ambiguous concept makes it difficult to construct a coherent scientific paradigm within which researchers can solve problems and propose solutions. Why? Because, in epistemology, these are mutually dependent (Kuhn, 2000). Judgements are based on concepts, and reasoning is based on judgements. If a concept is ambiguous, judgements and reasoning may be flawed and do not reflect reality. In this regard, Kuhn (2000) argues and demonstrates in his structural analysis of scientific lexicon that terms are not isolated entities, but are mutually constituted within the taxonomic network, through genus and species. This aspect was reconfirmed by Politi (2020) in his study on Kuhnian conceptual networks.

Extending this logic to the field of economics, a transition towards sustainable finance cannot be achieved by adding isolated concepts, but requires a new methodological framework that reconfigures the entire set of operational concepts. Lagoarde-Segot (2019) argues that sustainable finance attempts to address problems and provide solutions within the paradigmatic framework of positivist, mainstream finance, but this does not resolve sustainability issues. He states: ”Locked in a positivist straightjacket, mainstream academic finance – and therefore finance education – hinders the emergence of sustainable financial practices where it should be a bolster for social change”, referring to a whole series of arguments that can be found in countless academic sources listed by this author in his work.

As can be seen from the above, the conceptual issue has a significant epistemological dimension, and this paper seeks to address this issue through its own methodology for conceptual definition and delimitation. The definitions of the concepts are provided from two perspectives – an entropic perspective and a business perspective (formulated using observable ESG indicators as proxies) –, whilst the delimitation of these concepts is carried out by genus and species. Therefore, a primary research objective of this paper is to define and delimit the concepts of sustainable finance, green finance and green financing, so that the relationships between them are coherent from a taxonomic, normative and operational perspective. Why? Because conceptual ambiguity can become a source of inconsistency in modelling. Empirical models may end up describing distinct phenomena under the same label and, consequently, conceptual ambiguity may become a source of inconsistency in the modelling process. Furthermore, this issue is considered relevant from the perspective of developing a scientific paradigm specific to sustainable finance.

Based on these delimitations, a second research objective is formulated, namely to answer the question: can sustainable finance be theoretically grounded without explicitly introducing the condition of persistence over time and, implicitly, the condition of viability? In this paper, the answer is negative. The underlying logical argument is that sustainability entails persistence over time, and persistence over time entails viability (the system remains within a viability domain where its operating conditions are compatible with its future existence). Consequently, the *Theory of Viable Sustainable Finance (TVSF)* is proposed, with viability introduced as a necessary condition for persistence over time and, by transitivity, as a necessary condition for financial sustainability. From this perspective, the fact that a system exhibits favourable characteristics at a given point in time is not sufficient for it to be considered sustainable; the dynamics of such a system must persist over time.

Taking into account the conceptual and theoretical framework, a third research objective set out in this paper concerns the development of a tool for testing the theory’s hypotheses. To this end, the *Model of Viable Sustainable Finance (MVSF)* is developed by configuring a three-dimensional ESG entropy vector, where the Environmental dimension is represented by the thermodynamic entropy generated (or, equivalently, the exergy destruction), the Social dimension is operationalised via the Theil entropy index, and the Governance dimension is represented by Shannon’s information entropy. These measures are not considered ontologically identical; they represent different dimensions of the ESG system, within which pillar scores can be treated as empirical proxies for the entropic constructs, rather than as equivalents thereof. The model enables us to address issues that cannot be captured by a static assessment of ESG scores, namely: determining the steady state of the entropic system, establishing the critical threshold of the norm in relation to the viability frontiers for each ESG pillar, and determining these frontiers for each pillar.

Since the concept of entropy is used in defining the relevant concepts and in constructing the entropic model, some necessary clarifications regarding entropy are provided below (Dinga et al., 2021):

1) The main attributes of the concept of entropy (in the orthodox sense) are:
    a) it is not a process function, but a state function. Why? Because it does not depend on intermediate stages, but only on the initial and final points;
    b) it is a macroscopic quantity. Why? Because it is a measure of the observable level of unobservable components;
    c) it is a statistical quantity. Why? Because its measurement was originally formalised by Boltzmann within the framework of statistical mechanics;

d) it is an additive quantity (obtained by summation). Why? Because the number of microstates is multiplied (the possibilities multiply) and the logarithm is used to transform this multiplication of microstates into a summation in the form of the macrostate.

2) There are three types of the concept of entropy (measures):

a) phenomenological entropy, as defined by Clausius in 1865: $dS = dQ/T$, where: S = entropy; Q = the quantity of thermal energy (heat); T = absolute temperature (non-empirical, measured in Kelvin). Significance: a measure of thermal energy that cannot be converted into mechanical work; that is, the increase in entropy is directly proportional to the exergy lost (*exergy* is the capacity to produce the maximum amount of useful mechanical work);

b) statistical entropy as defined by Boltzmann (1877/2015): $S = k_B \cdot lnW$, where: k_B = Boltzmann's constant (the ratio of the universal gas constant to Avogadro's number; $1{,}380649 \cdot 10^{-23} J/K$); W = the thermodynamic probability of the system's state (the number of different ways in which this state can be realised; $\frac{N!}{n_1! \cdot n_2! \ldots}$, where: the number of permutations of N particles; $n_1! \cdot n_2! \ldots$ = the number of permutations of the particles within each group characterised by identical energy and velocity);

c) Shannon's information entropy (1948): $S(X) = -\sum_{i=1}^{n} P(x_i) \log_b P(x_i)$, for X = a discrete random variable, or $S(X) = -\int_{-\infty}^{+\infty} f(x) \log_b f(x) dx$, for X = a continuous random variable, where: $P(x_i)$ = the probability of the event x_i occurring; $\log_b$ = the *base-b* logarithm ($b = 2 \rightarrow$ *bits;* $b = e \rightarrow$ *nat*); $f(x)$ = the probability density function of a continuous random variable; a derivative of Shannon's Information Theory is the Theil entropy index (1967), which measures distributional inequality and can be used, in practice, as a measure of social entropy (T); its formal expression is: $T = \frac{1}{n} \sum_{i=1}^{n} \frac{x_i}{\bar{x}} \ln\left(\frac{x_i}{\bar{x}}\right)$, where: n = the total number of individuals (entities) in the sample/population; x_i = the observed value of the resource under analysis for individual/entity i; $\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$.

As can be seen from the above, the concept of entropy is closely linked to the concept of order. Within the analytical framework of this paper, a reduction in entropy is interpreted as a shift towards a state of higher order; however, the specific meaning of this order differs depending on the type of entropy used. For thermodynamic entropy, order is associated with a reduction in irreversible energy degradation and, equivalently, with a reduction in exergy destruction. For social entropy, operationalised via the Theil index, a reduction in entropy corresponds to a reduction in distributional inequality and a move towards distributional equality. For Shannon's informational entropy, a reduction in entropy corresponds to a reduction in informational uncertainty. Consequently, *order* is not used as a universal synonym for physical homogeneity.

This clarification is important in relation to the interpretation of Nicholas Georgescu-Roegen (1971), who associates maximum entropy with the irreversible physical homogenisation of degraded matter. In the present study, this physical meaning is not extended to all the entropy measures used; rather, the mathematical and statistical meaning specific to each measure is applied. Thus, for the proposed model, the reduction of entropy represents the general criterion for moving towards a state of order, whilst the nature of this order is specified for each of the three ESG pillars. The overall objective of this paper is to produce a scholarly study that links the definition of the concepts of sustainable finance, green finance and green financing with the formulation of a possible theory of sustainable finance grounded in viability, and with the development of a three-dimensional vector entropy ESG model to operationalise it.

The structure of this paper is as follows. The next section provides a brief review of the academic literature, with the aim of highlighting the conceptual gaps identified therein. Definitions of sustainable finance, green finance, and green financing from an entropic perspective are then formulated, including their dual definitions based on ESG proxies. This is followed by the formulation of the Theory of Viable Sustainable Finance and the presentation of the Model of Viable Sustainable Finance. The paper concludes with a discussion of the findings and the main conclusions.

2. Literature review

The academic literature offers a whole range of arguments concerning many unresolved issues in sustainable finance within the positivist financial paradigm. A few illustrative examples are presented below. These unresolved issues range from greenwashing (Lagoarde-Segot, 2024) and the conflict between financial logic and sustainability objectives (Manciordini & Ahlstrom, 2022) to the financial sector's failure to interpret global systemic risks due to flawed metrics and unstable regression coefficients (Crona et al., 2025). They also include excessive fragmentation in the sustainable finance literature, which confirms the lack of an autonomous scientific identity (Kumar et al., 2025), the limited real-economy impact of holding green assets in a portfolio (Caldecott et al., 2022), and the challenge of adapting mathematical models derived from Modern Portfolio Theory to climate volatility (Walter, 2020).

Perhaps one of the most significant consequences of addressing these issues and finding solutions for sustainable finance within the mainstream finance paradigm is the *ESG Integration Paradox*. This paradox of sustainable finance is: "If the greatest benefits of ESG incorporation are achieved only through the full integration of ESG factors into the investment process, why have so few investment managers adopted the strategy?" (Cappucci, 2018).

The literature indicates that there are 126 definitions of green finance (Dhayal et al., 2025). Furthermore, the concept of green finance is often used interchangeably with the concepts of green financing or sustainable finance; as a result, many econometric models used to measure their impact have unstable coefficients. Some examples of such evidence can be found in: Berg et al. (2022), who demonstrate that the use of different metrics to assess similar concepts – such as the confusion between the G pillar and aggregate sustainability – completely dissipates the econometric effect on asset prices; Zhao et al. (2025) note that when sustainability is measured as an analytical block, the coefficients are volatile because only Pillar G has a stable and significant econometric effect on real constraints; Dahiya et al. (2026) and Migliorelli (2021) highlight that the sustainable finance landscape is characterised by loose terminology and conceptual confusion, which undermines econometric efforts and produces erroneous results; Tai et al. (2026) show that the inclusion of an ambiguously defined variable in regression models leads to severe fluctuations in the regression coefficients; Christensen et al. (2022) highlight that firms which voluntarily adopt ESG reporting receive highly divergent ratings due to the lack of a conceptual framework; Cikovic et al. (2025) reveal that the rapid evolution of the field has created terminological confusion; concepts such as green finance, sustainable finance, carbon finance, environmental finance, etc. are used without clear boundaries or ontological distinctions, thereby hindering the development of the discipline; Tung et al. (2025) note that there is an overlap in the definitions of the concepts of green finance and sustainable finance, a fact which creates confusion.

As mentioned earlier, the issues outlined above represent only a few guiding points drawn from the academic literature.

3. The Conceptual Framework: Sustainable Finance, Green Finance and Green Financing

The concept of *sustainable finance,* which is widely used in academic literature and financial practice, remains a problematic one. It is defined by the European Union (European Commission, n.d.) and the Organisation for Economic Co-operation and Development (OECD, n.d.) as follows: "Sustainable finance refers to the process of taking environmental, social and governance (ESG) considerations into account when making investment decisions in the financial sector, leading to more long-term investments in sustainable economic activities and projects."

The concept of *green finance* is also problematic. As a point of reference, the definition provided by Fleming (2020) and published on the World Economic Forum platform is considered below: "Green finance is any structured financial activity – a product or service – that has been created to ensure a better environmental outcome. It includes a range of loans, debt mechanisms and investments that are used to encourage the development of green projects or minimise the impact on the climate of more conventional projects. Or a combination of both."

It should be noted that the EU's definition of sustainable finance describes what is already sustainable, but, in fact, it should describe the transition towards sustainability (sustainability is a dynamic process). Current EU regulations require financial institutions (banks, funds, etc.) to build and report on portfolios with high ESG scores. At the same time, companies cannot achieve these scores without funding from financial institutions. In other words, the definition rewards those who are already sustainable rather than promoting the achievement of sustainability. This results in an inadequate, dysfunctional financial mechanism. It assesses an end state rather than funding the process of achieving such a state.

As can be seen from the above, these definitions do not originate from within the field of finance; that is, they are not the result of scientific developments in financial research, but rather definitions formulated by political, economic, and administrative bodies in response to a societal need arising from the recognition that the planet's natural resources are finite. Alongside this concern, there is growing recognition that social equity is essential to ensuring sound foundations for social and economic structures. As Akerlof and Shiller note in their analysis of markets, bad faith leads to a decline in confidence, and a decline in confidence leads to the collapse of systems or markets. Our worry is that when Josepha is deceived, there is a loss of confidence in markets more generally, and a serious recession will follow (Akerlof & Shiller, 2009).

In fact, CSR (Corporate Social Responsibility) can be regarded as the foundation or precursor of ESG (Environmental, Social and Governance). The transition from CSR to ESG is nothing more than an evolution in the way companies actually approach sustainability, moving from altruistic or philanthropic actions to a strategic integration geared towards social and environmental outcomes alongside financial outcomes. This shift appears to be a natural one. Why? CSR criteria, which were voluntary and based on altruism, are transforming into ESG criteria that are beginning to become mandatory (Katterling, 2026). Why is it necessary for these criteria to become mandatory? Because human nature is not inherently characterised by altruism. Naturally, biologically speaking, the human gene is not altruistic (see Dawkins, 2006, on this point). However, Dawkins notes that there is nevertheless another possibility, a weaker but natural form of altruism that does not arise through cultural mimicry, namely reciprocal altruism: "I shall argue that a predominant quality to be expected in a successful gene is ruthless selfishness. This gene selfishness will usually give rise to selfishness in individual behaviour. However, as we shall see, there are special circumstances in which a gene can achieve its own selfish goals best by fostering a limited form of altruism at the level of individual animals. 'Special' and 'limited' are important words in the last sentence. Much as we might wish to believe otherwise, universal love and the welfare of the species as a whole are concepts that simply do not make evolutionary sense." (Dawkins, 2006).

The concept of reciprocal altruism (developed by Trivers, 1971), alongside another extremely important concept, that of Maynard Smith and George Price, *the Evolutionarily Stable Strategy* (ESS) – an evolutionarily stable strategy is defined as a strategy which, if adopted by the majority of members of a population, cannot be outperformed by any alternative strategy. (Maynard Smith & George Price, 1973) – may go a long way towards explaining the necessity of mandatory ESG criteria. Furthermore, a sound philosophical explanation of such a social necessity is provided by the well-known distinction between the categorical imperative (categorical morality) and the hypothetical imperative (hypothetical morality) in the Kantian sense (Kant, 1998). Early models of CSR failed precisely because they imposed a categorical imperative on corporations, whilst the mainstream paradigm of finance is one of optimisation, which seeks to maximise a firm's value and performance.

That being said, the concepts of sustainable finance, green finance, and green financing are defined as follows. *Methodologically*, a descriptive rather than formal axiomatic system is employed, based on phenomenology and the criteria of consistency, independence, and completeness. The three definitions are successively derived using the genus-and-species method, also known as the method of proximate genus and specific difference. The following bibliographical references provide the methodological basis for this approach: Aristotelian essentialism (see Studtmann, 2024; Anstey & Bronstein, 2025), supplemented by Hilbert's vision regarding the creation of a formal axiomatic system in mathematics (see Zach, 2023; Ewald & Sieg, 2013) and Husserl's phenomenology (see Zahavi, 2025; Husserl, 2001a; Husserl, 2001b; Husserl, 2010).

Following this approach, the following definitions are proposed:

A. *The definition of the concept of sustainable finance (SF)* is: a) it entails a set of actions in the form of a prescriptive normative mechanism (in the sense of Georg Henrik von Wright); b) it aims to reduce entropy (the reduction of generated thermodynamic entropy or, equivalently, the reduction of exergy destruction, for the E pillar of ESG; the reduction of social entropy for the S pillar of ESG; the reduction of informational entropy for the G pillar of ESG) – the first-order principle (rationality); c) it entails a *finality* (the finality being persistence over time) – the second-order principle (survival).

B. *The definition of the concept of green finance (GF)* is: a) it entails sustainable finance; b) it entails reducing the thermodynamic entropy generated or, equivalently, reducing the exergy destruction, for the E pillar of ESG; c) it is *objectified* in the form of a standardised normative financial instrument (for example: *EU* Regulation *2023/2631* of 22 November 2023, European Union, 2023).

C. *The definition of the concept of green financing (Gfin)* is: a) it entails green finance; b) it is *instantiated* (manifested in practice) in the form of an operationalised normative financial instrument (e.g. the specific issuer, the bond with an ISIN, the bond contract, etc., Electrica Energy Company, 2025).

The dual definitions are set out below, together with several relevant clarifications:

a) The definitions provided above are formulated in *entropic* terms, whereas their mirror-image, dual definitions in *business* terms, expressed using observable ESG scores as proxies, can be formulated as follows:

   - *The dual definition of the concept of sustainable finance* is: a) it entails a set of actions in the form of a prescriptive normative mechanism (in the sense of Georg Henrik von Wright); b) it aims to increase ESG performance (increasing the E pillar of ESG, increasing the S pillar of ESG, increasing the G pillar of ESG) – first-order principle (rationality); c) it entails a *finality* (the finality is persistence over time) – second-order principle (survival).

   - *The dual definition of the concept of green finance* is: a) it entails sustainable finance; b) it entails increasing the E pillar of ESG; c) it is *objectified* in the form of a standardised normative financial instrument (for example: *EU* Regulation *2023/2631* of 22 November 2023, European Union, 2023).

   - *The dual definition of the concept of green financing* is: a) it entails green finance; b) it is *instantiated* (manifested in practice) in the form of an operationalised normative financial instrument (e.g. the specific issuer, the bond with an ISIN, the bond contract, etc., Electrica Energy Company, 2025).

b) The term mechanism refers to a procedure that links a cause to an effect. The sufficiency conditions for a mechanism are (Dinga et al., 2023b): it entails a system (the mechanism can only function if it is part of a system); it entails the existence of transformation operators (the operators guarantee that a specific cause will produce a specific effect); it entails the existence of a coordination operator (the entity in question to which the mechanism is associated has a purpose distinct from the purposes of each individual transformation operator and integrates these individual purposes in a convergent manner); it entails the existence of a replication operator (the mechanism is not singular; it does not have just one cycle of operation, but its operation must be repeated); it entails a monitoring/control/adjustment operator (changes that must occur within the mechanism so that it can fulfil its functions without any reduction in its performance).

c) The term prescriptive norm is used in the sense proposed by Georg Henrik von Wright (1963), referring to norms that fulfil the following characteristics: the prescriptions are given or issued by someone and stem from the will of a normative authority; they are addressed to agents known as the subjects of the norm; the authority issuing the norm requires the subjects to adopt a certain course of conduct; the issuance of the norm expresses the authority's will to cause the subjects to behave in a certain way; in order to make its will known to the subjects, the authority promulgates the norm; these differ from rules or technical standards. In this context, the term normative is

applied here it its deontic, denoting that the financial instrument does not pre-exist empirically but is legally constituted through a presciptive norm, while its standardised character entails the invariance of its structural conditions.

d) The term generated entropy (S_{gen}) refers to the measure of entropy associated with irreversibilities, that is, the measure that quantifies irreversibilities (energy degradation, resource dissipation, loss of useful mechanical work capacity and increased carbon dioxide emissions).

e) The term exergy destruction (X_{dest}) refers to the lost potential to produce maximum useful mechanical work, and this is formally expressed by the Gouy–Stodola equation: $X_{dest} = T_0 \cdot S_{gen}$, where:$T_0$ = the ambient temperature (in Kelvin).

f) The term social entropy refers to entropy operationalised through the Theil entropy index. Within the pillar *S*, the main issues concern equity, labour relations, social inclusion, diversity, human rights, and access to opportunities, many of which relate to the distribution of resources, including income, power, access to resources, and opportunities; since the Theil index measures the inequality gap of a distribution, it can be used, in practical terms, as a measure of social entropy.

g) The term informational entropy refers to the concept as defined by Shannon. Within the pillar *G*, a range of information-related aspects is considered (transparency, disclosure of information, audit, quality of internal control, clear and simple managerial procedures, reporting, investor relations); reducing informational entropy for the G pillar of ESG will consequently lead to a reduction in information asymmetry.

h) Green financing (*Gfin*) logically generates (causes) green investment (*GInv*). In other words, if there is green financing, then there is also green investment.

The definitions provided above are formalised below using first-order logic and deontic logic.

- With regard to the first aspect, the following notation is used:

Let $\mathcal{F} = \{possible\ financial\ practices\}$; $x \in \mathcal{F}$; basic predicates: *SF(x): x* is sustainable finance, *GF(x): x* is green finance, *Gfin(x)*: *x* is green financing; structural predicates: *N(x): x* is a prescriptive normative mechanism, *Ist(x)*: *x* is a standardised normative financial instrument, *Iop(x): x* is an operationalised normative financial instrument; functional predicates (purpose/objective): R_E *(x): x* reduces the generated thermodynamic entropy; R_S *(x): x* reduces social entropy; R_G *(x): x* reduces informational entropy; *Surv(x): x* has survival as its finality.

Based on the notation introduced above, the following formal logical definitions can be successively formulated:

$$SF(x) \leftrightarrow N(x) \wedge [R_E(x) \wedge R_S(x) \wedge R_G(x)] \wedge Surv(x)$$

$$GF(x) \leftrightarrow SF(x) \wedge R_E(x) \wedge Ist(x)$$

$$Gfin(x) \leftrightarrow GF(x) \wedge Iop(x)$$

$$Gfin(x) \rightarrow Ginv(x)$$

$$\mathcal{F} \supset SF(x) \supset GF(x) \supset Gfin \rightarrow GInv$$

- With regard to the second aspect, the following notation is used:

Let the following deontic operators be defined as follows: *O(p): p* is obligatory; *P(p): p* is permitted; *F(p): p* is forbidden.

In light of the above, the following formal logical definitions can be formulated in turn (principled obligations – *norm*; standardised obligations – *rule*; operationalised obligations – *applied normative act*):

$$SF \leftrightarrow O[N(x)] \wedge O[R_E(x) \wedge R_S(x) \wedge R_G(x)] \wedge O[Surv(x)]$$

$$GF \leftrightarrow SF \wedge O[R_E(x)] \wedge O[Ist(x)]$$

$$Gfin \leftrightarrow GF \wedge O[Iop(x)]$$

$$Gfin \rightarrow O[GInv(x)]$$

$$\mathcal{F} \supset SF(x) \supset GF(x) \supset Gfin \rightarrow O[GInv]$$

4. The Theoretical Framework: Theory of Viable Sustainable Finance (TVSF)

What is a theory? Put simply, a theory is a hypothesis or a set of hypotheses about reality; this applies to both the natural sciences and the social sciences (examples of theories in finance: Eugene Fama's Efficient Market Hypothesis (EMH); Andrew Lo's Adaptive Market Hypothesis (AMH); Henry Markowitz's Modern Portfolio Theory (MPT)).

A theory is defined by its structure. What is meant by the structure of a theory? According to Dinga (2018), this refers to the list of the theory's basic components, as follows:

- Invariant components: a cognitive grounding principle (for example: economic behaviour is driven by the scarcity of resources relative to needs); a system of hypotheses within which theoretical knowledge is possible (for example: economic behaviour is rational; the economic e agent processes information correctly; the economic agent is self-interested); a set of propositions describing mechanisms of cognition (for example: choice is based on propensity).
- Variable components: a set of conjectures regarding cognitive outcomes (for example: economic decisions are made on a marginal basis); a set of proven cognitive outcomes (for example: the economic process unfolds cyclically).

Why a possible Theory of Viable and Sustainable Finance? Viability is considered a logically necessary condition (see the third predicate in the definition of sustainable finance) for finance to qualify as sustainable. This follows from the fact that persistence over time, understood as the second-order principle of survival, entails viability; consequently, finance cannot be considered sustainable unless this condition is fulfilled. Put differently, by *reductio ad absurdum* (apagogic proof in the Kantian sense), the absence of viability causes a system to lose its capacity to persist over time and ultimately to disappear from economic reality, thereby preventing it from being regarded as structurally sustainable. This criterion provides a natural justification for the existence of sustainable finance without requiring recourse to political or ethical considerations in the form of the categorical imperative, which, as argued above, cannot be regarded as an innate characteristic of human beings.

Taking the structure of a theory described previously as a reference point, the Theory of Viable Sustainable Finance is proposed. This theoretical proposal may be criticised, verified in the sense of logical positivism, or falsified in the Popperian sense. It is acknowledged that such a proposal can represent only a modest contribution towards addressing the problems of sustainable finance, a field that, as reflected in the scientific literature, is developing at an accelerated pace.

The proposed structure of the Theory of Viable Sustainable Finance is as follows:

- *The principle of cognitive grounding:* persistence over time is a necessary condition for sustainable finance
- *Hypothesis 1 – The Normativity Hypothesis*: sustainable finance takes the form of a normative mechanism that constrains the sphere of financial decisions
- *Hypothesis 2 – The entropy hypothesis:* processes relevant to sustainability can be described in terms of entropies across the ESG pillars
- *Hypothesis 3 – The rationality hypothesis*: a mechanism in the form of sustainable finance is rational if and only if it reduces at least one ESG entropy component
- *Hypothesis 4 – The viability hypothesis*: a financial system is sustainable if there exists a trajectory that keeps the entropies across the ESG pillars below their respective viability frontiers
- *Hypothesis 5 – The behavioural hypothesis:* economic agents are capable of reciprocal altruism

- *Hypothesis 6 – The duality hypothesis:* the scores for the ESG pillars serve as proxies for the entropies associated with these pillars
- *Hypothesis 7 – The interdependence hypothesis:* the ESG pillars can generate systemic and normative trade-offs
- *Proposition 1*: the behaviour of economic agents is influenced by norms
- *Proposition 2*: The behaviour of economic agents modifies the entropies across the ESG pillars
- *Proposition 3:* The dynamics of entropies across the ESG pillars influence the system's persistence over time
- *Proposition 4:* ESG scores across the pillars imperfectly reflect the quantitative change (modification) in entropies across the ESG pillars
- *Proposition 5:* entropies propagate between pillars through interdependence mechanisms
- *Conjecture 1*: The simultaneous reduction of all entropies across the ESG pillars is not possible over an unlimited time interval
- *Conjecture 2*: A reduction in structural entropy is not guaranteed by an increase in the ESG score
- *Conjecture 3:* Trade-offs between pillars reduce viability

5. The Model: Model of Viable Sustainable Finance (MVSF)

This section proposes a model of viable sustainable finance. What is a model? A model is the result of the modelling process (modelling is a rational process through which a model is obtained), that is, the outcome of this process, and can be of three types (Dinga et al., 2022): discovery model (this investigates the object of knowledge *without a pre-established target* for the scientific endeavour); corroborative model (this investigates the object of knowledge by pursuing, in a *positive* manner, a pre-established objective of the scientific endeavour); refutative models (these investigate the object of knowledge by pursuing, in a *negative* manner, a pre-established objective of the scientific endeavour).

A model is a reconstruction of reality, which serves to test the hypotheses of a theory. In other words, a model is a logical and quantitative device for testing a theory.

The TVSF model comprises the following elements:

1. Let the following equation express the dynamics of an entropic system:

$$\dot{H}(t) = AH(t) + \Gamma\pi(t) \quad (1)$$

$$H(t) \in \mathcal{V}, \forall t \geq 0 \quad (2)$$

where: $H(t) = \begin{pmatrix} H_E(t) \\ H_S(t) \\ H_G(t) \end{pmatrix}$; $H_i(t)$ = entropy on pillar *i* at time *t*; $H_i(t+1)$ = entropy on pillar *i* at time *t+1*, $i \in \{E, S, G\}, H(t+1) = \begin{pmatrix} H_E(t+1) \\ H_S(t+1) \\ H_G(t+1) \end{pmatrix}$; $\dot{H}(t)$ = the derivative, i.e. the rate at which the system's state changes; A = the matrix of coefficients defining the system's internal dynamics; Γ = the matrix of coefficients measuring the direct impact of the norm (normative efficiency, exogenous impact of the norm) on the vector $H(t+1)$; $\pi(t)$ = the matrix of the prescriptive norm (external intervention); $\mathcal{V}$ = the viability domain/viability frontier.

2. Equation (1) is discretised using the Euler method, as follows:

$$\dot{H}(t) = \frac{H(t+1) - H(t)}{\Delta t} \approx AH(t) + \Gamma\pi(t) \rightarrow$$

$$\rightarrow H(t+1) - H(t) \approx AH(t)\Delta(t) + \Gamma\pi(t)\Delta t \rightarrow$$

$$\rightarrow H(t+1) \approx H(t) + AH(t)\Delta t + \Gamma\pi(t)\Delta t \rightarrow$$

$$\rightarrow H(t+1) \approx (I + A\Delta t)H(t) + \Gamma\pi(t)\Delta t \quad (3)$$

for $\Delta t = 1$, the above equation becomes:

$$H(t+1) \approx (I + A)H(t) + \Gamma\pi(t) \quad (4)$$

where I = the identity matrix.

Equation (4) can be written as:

$$H(t+1) \approx BH(t) + \Gamma\pi(t); \text{ where } B = (I + A) \quad (5)$$

To increase the degree of accuracy, exact discretisation can be applied using the following analytical relationship from dynamical systems theory (the Zero-Order Hold method), where $\pi(t)$ is kept constant over the time interval Δt :

$$H(t+1) = e^{A\Delta t}H(t) + \int_0^{\Delta t} e^{A\tau}d\tau\ \Gamma\pi(t) \quad (6)$$

In this discretised form, the following simplified notation can be used:

$$H(t+1) = \Phi H(t) + \Omega\pi(t) \quad (7)$$

where: $\Phi = e^{A\Delta t}$; $\Omega = \int_0^{\Delta t} e^{A\tau}d\tau\,\Gamma = A^{-1}\left(e^{A\Delta t} - I\right)\Gamma = A^{-1}(\Phi - \mathrm{I})\Gamma$, if matrix A is invertible.

3. The question that then arises is how the coefficients of the matrices can be determined? This can be achieved from the data, that is, through an empirical estimation of them. One solution may be to use the VARX(1) model (a simplified model for the case where each pillar depends only on itself, with a scalar environmental norm, π_E *(t)*, which, for example, may be represented by the carbon tax within the European Union, *EUA* – European Union Allowance, within the *EU ETS* – European Union Emissions Trading System), as follows:

$$\begin{cases} H_E(t+1) = \beta_E H_E(t) + \gamma_E \pi_E(t) + \varepsilon_E(t+1) \\ H_S(t+1) = \beta_S H_S(t) + \gamma_S \pi_E(t) + \varepsilon_S(t+1) \\ H_G(t+1) = \beta_G H_G(t) + \gamma_G \pi_E(t) + \varepsilon_G(t+1) \end{cases} \quad (8)$$

Consequently, the following expression can be written:

$$\begin{pmatrix} H_E(t+1) \\ H_S(t+1) \\ H_G(t+1) \end{pmatrix} = \begin{pmatrix} \beta_E & 0 & 0 \\ 0 & \beta_S & 0 \\ 0 & 0 & \beta_G \end{pmatrix} \cdot \begin{pmatrix} H_E(t) \\ H_S(t) \\ H_G(t) \end{pmatrix} + \begin{pmatrix} \gamma_E & 0 & 0 \\ 0 & \gamma_S & 0 \\ 0 & 0 & \gamma_G \end{pmatrix} \cdot \begin{pmatrix} \pi_E(t) \\ \pi_E(t) \\ \pi_E(t) \end{pmatrix} \quad (9)$$

or, more simply:

$$\begin{pmatrix} H_E(t+1) \\ H_S(t+1) \\ H_G(t+1) \end{pmatrix} = \begin{pmatrix} \beta_E & 0 & 0 \\ 0 & \beta_S & 0 \\ 0 & 0 & \beta_G \end{pmatrix} \cdot \begin{pmatrix} H_E(t) \\ H_S(t) \\ H_G(t) \end{pmatrix} + \begin{pmatrix} \gamma_E \\ \gamma_S \\ \gamma_G \end{pmatrix} \cdot \pi_E(t) \quad (10)$$

Several important clarifications regarding the equation (10) are provided below:

a) why is the residual $\varepsilon_i(t+1)$, where $i = E, S, G$, not taken into account for $H_i(t+1)$?

Because we are modelling the predicted $H_i(t+1)$, $\widehat{H_i}(t+1)$), that is, the conditional mathematical expectation of the future state conditional on the information at time *t*, $E[H_i(\mathrm{t}+1) \mid H_i(t), \pi_E(t)]$, and consequently, $E[H_i(t+1)] = E[\beta_i H_i(t) + \gamma_i \pi_E(t) + \varepsilon_i(t+1)]$, where $E[\varepsilon_i(t+1)] = 0$. Consequently, $E[H_i(t+1)] = \beta_i H_i(t) + \gamma_i \pi_E(t)$.

b) the matrix of coefficients defining the internal dynamics of the system represents the Jacobian of the discrete system, J_S, (that is, these are the partial derivatives of the evolution functions, $H_i(\mathrm{t}+1)$, with respect to the state variables, $H_i(t)$), which is in fact matrix *B*:

$$J_{\mathcal{S}} = \begin{pmatrix} \frac{\partial H_E(t+1)}{\partial H_E(t)} & 0 & 0 \\ 0 & \frac{\partial H_S(t+1)}{\partial H_S(t)} & 0 \\ 0 & 0 & \frac{\partial H_G(t+1)}{\partial H_G(t)} \end{pmatrix} \quad (11)$$

c) the coefficient matrix, which measures the direct impact of the norm, represents the control Jacobian of the system, $J_{\mathcal{N}}$, and is in fact the matrix Γ:

$$J_{\mathcal{N}} = \begin{pmatrix} \frac{\partial H_E(t+1)}{\partial \pi_E(t)} & 0 & 0 \\ 0 & \frac{\partial H_S(t+1)}{\partial \pi_E(t)} & 0 \\ 0 & 0 & \frac{\partial H_G(t+1)}{\partial \pi_E(t)} \end{pmatrix} \quad (12)$$

When interdependencies between the pillars are introduced, the following expression is obtained:

$$\begin{cases} H_E(t+1) = \beta_{EE}H_E(t) + \beta_{ES}H_S(t) + \beta_{EG}H_G(t) + \gamma_E\pi_E(t) + \varepsilon_E(t+1) \\ H_S(t+1) = \beta_{SE}H_E(t) + \beta_{SS}H_S(t) + \beta_{SG}H_G(t) + \gamma_S\pi_E(t) + \varepsilon_S(t+1) \\ H_G(t+1) = \beta_{GE}H_E(t) + \beta_{GS}H_S(t) + \beta_{GG}H_G(t) + \gamma_G\pi_E(t) + \varepsilon_G(t+1) \end{cases} \quad (13)$$

Consequently, this can be expressed as follows:

$$\begin{pmatrix} H_E(t+1) \\ H_S(t+1) \\ H_G(t+1) \end{pmatrix} = \begin{pmatrix} \beta_{EE} & \beta_{ES} & \beta_{EG} \\ \beta_{SE} & \beta_{SS} & \beta_{SG} \\ \beta_{GE} & \beta_{GS} & \beta_{GG} \end{pmatrix} \cdot \begin{pmatrix} H_E(t) \\ H_S(t) \\ H_G(t) \end{pmatrix} + \begin{pmatrix} \gamma_E & 0 & 0 \\ 0 & \gamma_S & 0 \\ 0 & 0 & \gamma_G \end{pmatrix} \cdot \begin{pmatrix} \pi_E(t) \\ \pi_E(t) \\ \pi_E(t) \end{pmatrix} \quad (14)$$

or, more simply:

$$\begin{pmatrix} H_E(t+1) \\ H_S(t+1) \\ H_G(t+1) \end{pmatrix} = \begin{pmatrix} \beta_{EE} & \beta_{ES} & \beta_{EG} \\ \beta_{SE} & \beta_{SS} & \beta_{SG} \\ \beta_{GE} & \beta_{GS} & \beta_{GG} \end{pmatrix} \cdot \begin{pmatrix} H_E(t) \\ H_S(t) \\ H_G(t) \end{pmatrix} + \begin{pmatrix} \gamma_E \\ \gamma_S \\ \gamma_G \end{pmatrix} \cdot \pi_E(t) \quad (15)$$

namely:

$$J_{\mathcal{S}} = \begin{pmatrix} \frac{\partial H_E(t+1)}{\partial H_E(t)} & \frac{\partial H_E(t+1)}{\partial H_S(t)} & \frac{\partial H_E(t+1)}{\partial H_G(t)} \\ \frac{\partial H_S(t+1)}{\partial H_E(t)} & \frac{\partial H_S(t+1)}{\partial H_S(t)} & \frac{\partial H_S(t+1)}{\partial H_G(t)} \\ \frac{\partial H_G(t+1)}{\partial H_E(t)} & \frac{\partial H_G(t+1)}{\partial H_S(t)} & \frac{\partial H_G(t+1)}{\partial H_G(t)} \end{pmatrix} \quad (16)$$

When normative interdependencies between the pillars are introduced, the complete coefficient matrices are obtained as follows:

$$\begin{pmatrix} H_E(t+1) \\ H_S(t+1) \\ H_G(t+1) \end{pmatrix} = \begin{pmatrix} \beta_{EE} & \beta_{ES} & \beta_{EG} \\ \beta_{SE} & \beta_{SS} & \beta_{SG} \\ \beta_{GE} & \beta_{GS} & \beta_{GG} \end{pmatrix} \cdot \begin{pmatrix} H_E(t) \\ H_S(t) \\ H_G(t) \end{pmatrix} + \begin{pmatrix} \gamma_{EE} & \gamma_{ES} & \gamma_{EG} \\ \gamma_{SE} & \gamma_{SS} & \gamma_{SG} \\ \gamma_{GE} & \gamma_{GS} & \gamma_{GG} \end{pmatrix} \cdot \begin{pmatrix} \pi_E(t) \\ \pi_S(t) \\ \pi_G(t) \end{pmatrix} \quad (17)$$

namely the full control Jacobian:

$$J_{\mathcal{N}} = \begin{pmatrix} \frac{\partial H_E(t+1)}{\partial \pi_E(t)} & \frac{\partial H_E(t+1)}{\partial \pi_S(t)} & \frac{\partial H_E(t+1)}{\partial \pi_G(t)} \\ \frac{\partial H_S(t+1)}{\partial \pi_E(t)} & \frac{\partial H_S(t+1)}{\partial \pi_S(t)} & \frac{\partial H_S(t+1)}{\partial \pi_G(t)} \\ \frac{\partial H_G(t+1)}{\partial \pi_E(t)} & \frac{\partial H_G(t+1)}{\partial \pi_S(t)} & \frac{\partial H_G(t+1)}{\partial \pi_G(t)} \end{pmatrix} \quad (18)$$

4. Within this system, characterised by the three pillars, trade-offs can be made, both normative (a regulation has opposite effects on two different pillars, helping one pillar but affecting another) and structural (the evolution of one pillar has an opposite effect on the evolution of another pillar), as follows:

1) For the case of expression (15), the mathematical conditions are:

- A normative trade-off arises when:

$$\frac{\partial H_E(t+1)}{\partial \pi_E(t)} \cdot \frac{\partial H_j(t+1)}{\partial \pi_E(t)} < 0 \Leftrightarrow \gamma_E \cdot \gamma_j < 0, j = S, G \quad (19)$$

Equation (19) shows that the norm cannot decrease entropy (i.e. generate order) in pillar H_E without increasing entropy (i.e. generating disorder) in pillar H_j, resulting in a win-loss trade-off, and conversely, $\frac{\partial H_E(t+1)}{\partial \pi_E(t)} \cdot \frac{\partial H_j(t+1)}{\partial \pi_E(t)} > 0 \Leftrightarrow \gamma_E \cdot \gamma_j > 0$, there is: *win-win* complementarity (transient negentropy, transient self-organisation due to the fact that the rigidity of the linear structure of the equations does not allow this order to be maintained in the long term), that is, the average norm reduces entropy on the E pillar and on the H_j pillar, or *loss-loss* complementarity, that is, the average norm reduces entropy neither on the *E* pillar nor on the H_j pillar (entropic contagion, chaos).

Several observations regarding the above formulation are necessary:

a) The *loss-loss* case may reflect *greenwashing* (the environmental norm on pillar *E* does not reduce disorder there and increases disorder on another pillar), whilst the *win-loss* case may represent adaptation for survival, i.e. one pays for survival; *there is no free lunch* (regarding the concept of adaptation, see Dinga et al., 2022).

b) Why does greenwashing relate to the norm? Because greenwashing is a property of the norm (a design flaw in the norm).

- The structural trade-off arises when:

$$\frac{\partial H_i(t+1)}{\partial H_j(t)} \cdot \frac{\partial H_j(t+1)}{\partial H_j(t)} < 0 \Leftrightarrow \beta_{ij} \cdot \beta_{jj} < 0, i \neq j \quad (20)$$

Equation (20) tells us that the decrease in entropy (i.e. the generation of order) of pillar H_j leads to an increase in entropy (i.e. the generation of disorder) of pillar H_i (*win-loss*), and conversely, $\frac{\partial H_i(t+1)}{\partial H_j(t)} \cdot \frac{\partial H_j(t+1)}{\partial H_j(t)} > 0 \Leftrightarrow \beta_{ij} \cdot \beta_{jj} > 0, i \neq j$, there is: *win-win* complementarity (transient negentropy, transient self-organisation resulting from the fact that the rigidity of the linear structure of the equations does not allow this order to be maintained in the long term), i.e. a decrease in entropy on the H_j pillar also decreases entropy on H_i or *a 'loss-loss'* type of complementarity, i.e. an increase in entropy on the H_j pillar generates an increase in entropy on H_i as well (entropic contagion, chaos).

Several observations regarding the above formulation are provided below:

a) The $\frac{\partial H_i(t+1)}{\partial H_j(t)} \cdot \frac{\partial H_j(t+1)}{\partial H_j(t)} < 0 \Leftrightarrow \beta_{ij} \cdot \beta_{jj} < 0, i \neq j$ or '*win-loss*' case can express *resilience through adaptation* and the capacity to transfer disorder (regarding the concept of adaptation, see Dinga et al., 2022), whilst the *win-win* case can express *resilience through transient self-organisation*, ideal resilience (for the concept of self-organisation, see Dinga et al., 2023a); co-evolution can generate self-organisation processes that increase the system's resilience (for the concept of co-evolution, see Dinga et al., 2023b).

b) Why does resilience refer to the system? Because resilience is a property of the system (the system's capacity to manage interactions between pillars).

2) For the case of expression (17), the mathematical conditions are:

- The normative trade-off arises when:

$$\frac{\partial H_i(t+1)}{\partial \pi_j(t)} \cdot \frac{\partial H_j(t+1)}{\partial \pi_j(t)} < 0 \Leftrightarrow \gamma_{ij} \cdot \gamma_{jj} < 0, i \neq j \quad (21)$$

Equation (21) tells us that you cannot decrease entropy (i.e. the generation of order) on H_j by the norm π_j without increasing entropy (disorder) H_i. (*win-loss*), and conversely, $\frac{\partial H_i(t+1)}{\partial \pi_j(t)} \cdot \frac{\partial H_j(t+1)}{\partial \pi_j(t)} > 0 \Leftrightarrow$

$\gamma_{ij} \cdot \gamma_{jj}$, there is: *win-win* complementarity (transient negentropy, transient self-organisation due to the fact that the rigidity of the linear structure of the equations does not allow this order to be maintained in the long term), i.e. the norm π_j reduces entropy on the H_j pillar and on the H_i (which, in our view, is problematic in an entropic system) or *'loss-loss'* complementarity, i.e. the norm π_j does not reduce entropy on the H_j pillar or on the $H_{(i)}$ pillar (entropic contagion, chaos).

A point worth noting here is that the *loss-loss* case may reflect *greenwashing* (the rule 'π_j' on pillar H_j does not reduce disorder there but increases disorder on another pillar), whilst the *win-loss* case may reflect adaptation for survival, i.e. one pays for survival; there is no such thing as a free lunch (regarding the concept of adaptation, see Dinga et al., 2022).

- The structural trade-off arises when:

$$\frac{\partial H_i(t+1)}{\partial H_j(t)} \cdot \frac{\partial H_j(t+1)}{\partial H_j(t)} < 0 \Leftrightarrow \beta_{ij} \cdot \beta_{jj} < 0, i \neq j, \text{ identical to (20)} \tag{22}$$

5. The analytical conditions for the steady state of the system are established below. The steady state of the system (an attractor indicating that structural entropy and normative ordering forces are in equilibrium) is determined at the point where $H(t+1) = H(t) = H^*$, as follows:

$$\begin{gathered} H^* = BH^* + \Gamma\pi \\ \Rightarrow \\ H^* - BH^* = \Gamma\pi \\ \Rightarrow \\ (I - B)H^* = \Gamma\pi \\ \Rightarrow \\ H^* = (I - B)^{-1}\Gamma\pi \end{gathered} \tag{23}$$

Given the successive development in (23), several important clarifications are provided below:

a) The existence of a unique steady state of the system is guaranteed if the determinant of the matrix $(I - B)$ is non-zero ($det(I - B) \neq 0$), which implies that the matrix $(I - B)$ is invertible; the further this determinant is from zero, the less fragile the attractor is.

b) The inverse of the matrix $(I - B)$ is a multiplier of the system, showing how a change in the norm propagates across the three pillars due to the interdependencies between them.

c) The system converges to the steady state (converges to the attractor) only if all the eigenvalues of matrix B have subunitary modulus (spectral radius, or behaviour along the path: $\rho(B) < 1$; otherwise, if $\rho(B) > 1$, then the system becomes divergent, the attractor disappears and chaos takes its place). In other words, the stability of the system must satisfy the condition $\rho(B) < 1$ (a necessary and sufficient condition), where: $\rho(B) = max\{|\lambda_1|, |\lambda_2|, |\lambda_3|\}$. The eigenvalues λ are determined by solving the characteristic equation $det(B - \lambda I) = 0$;$|\lambda_i| = \sqrt{Re(\lambda_i)^2 + Im(\lambda_i)^2}$, with $i = E, S, G$.

6. The critical threshold of the norm relative to the viability frontier of each pillar can then be calculated, $\mathcal{V} = Hmax = \begin{pmatrix} H_{maxE} \\ H_{maxS} \\ H_{maxG} \end{pmatrix}$. For this purpose, the steady-state condition of the system must be considered. If the system is stable, $\rho(B) < 1$, it will tend towards equilibrium. Consequently, the critical threshold of the norm π on the pillars is the value that makes the steady-state condition equal to $Hmax$, and thus:

$$\left.\begin{gathered} Hmax = (I - B)^{-1}\Gamma\pi \\ M = (I - B)^{-1} \\ K = M\Gamma \end{gathered}\right\} \Rightarrow Hmax = K\pi \tag{24}$$

Consequently, $\pi = K^{-1}Hmax$ and it can be written:

1) for the case of expression (15):

$$M = \begin{pmatrix} 1-\beta_{EE} & -\beta_{ES} & -\beta_{EG} \\ -\beta_{SE} & 1-\beta_{SS} & -\beta_{SG} \\ -\beta_{GE} & -\beta_{GS} & 1-\beta_{GG} \end{pmatrix}^{-1} \quad (25)$$

$$K = \begin{pmatrix} K_E \\ K_S \\ K_G \end{pmatrix} = \begin{pmatrix} 1-\beta_{EE} & -\beta_{ES} & -\beta_{EG} \\ -\beta_{SE} & 1-\beta_{SS} & -\beta_{SG} \\ -\beta_{GE} & -\beta_{GS} & 1-\beta_{GG} \end{pmatrix}^{-1} \cdot \begin{pmatrix} \gamma_E \\ \gamma_S \\ \gamma_G \end{pmatrix} \quad (26)$$

Given that in this case there is a single norm π_E (which is a scalar), the critical norm ($\pi_{Ecritical}$) can be determined by solving a system of three inequalities:

$$\begin{pmatrix} H_{maxE} \\ H_{maxS} \\ H_{maxG} \end{pmatrix} \geq \pi_E \begin{pmatrix} K_E \\ K_S \\ K_G \end{pmatrix} \quad (27)$$

Consequently:

$$\pi_{Ecritical} = min\left(\frac{H_{maxE}}{K_E}, \frac{H_{maxS}}{K_S}, \frac{H_{maxG}}{K_G}\right) \quad (28)$$

Why? Because $\pi_{Ecritical}$ is the maximum value of the norm that keeps the system within the viability frontier (or in the viability domain). In other words, if this critical threshold of the norm is exceeded, then the system moves outside the viability frontier.

The following observations should be made regarding those discussed previously, as follows:

a) For a common norm across all pillars (necessary to observe how this influences the behaviour of each pillar individually, i.e. order or its opposite (disorder), due to the interdependencies between the pillars), it is sufficient to calculate the minimum; and in this context, one must stop when the most fragile pillar reaches the critical threshold (it is not possible to optimise separately; rather, one must consider which is the weak link in the whole);

b) The minimum of the critical norm can be understood as a safety brake for a system with a single control or norm; the system's resilience is limited by the pillar with the lowest critical threshold of the norm; exceeding this value will take that pillar beyond its viability frontier;

c) The system's resilience is limited by the domain of the system's state space, determined by the value of a single critical norm (the domain of the state space takes the form of an irregular triangle).

2) for the case of expression (17):

$$M = \begin{pmatrix} 1-\beta_{EE} & -\beta_{ES} & -\beta_{EG} \\ -\beta_{SE} & 1-\beta_{SS} & -\beta_{SG} \\ -\beta_{GE} & -\beta_{GS} & 1-\beta_{GG} \end{pmatrix}^{-1} \quad (29)$$

$$K = \begin{pmatrix} K_{EE} & K_{ES} & K_{EG} \\ K_{SE} & K_{SS} & K_{SG} \\ K_{GE} & K_{GS} & K_{GG} \end{pmatrix} = \begin{pmatrix} 1-\beta_{EE} & -\beta_{ES} & -\beta_{EG} \\ -\beta_{SE} & 1-\beta_{SS} & -\beta_{SG} \\ -\beta_{GE} & -\beta_{GS} & 1-\beta_{GG} \end{pmatrix}^{-1} \cdot \begin{pmatrix} \gamma_{EE} & \gamma_{ES} & \gamma_{EG} \\ \gamma_{SE} & \gamma_{SS} & \gamma_{SG} \\ \gamma_{GE} & \gamma_{GS} & \gamma_{GG} \end{pmatrix} \quad (30)$$

Given that, in this case, norms are defined for each pillar (a normative vector), the critical norms – that is, the maximum values accepted by the system so as not to exceed the viability frontier ($\pi_{Ecritical}, \pi_{Scritical,}\ \pi_{Gcritical}$) – can be determined by solving a system of three inequalities:

$$\begin{pmatrix} H_{maxE} \\ H_{maxS} \\ H_{maxG} \end{pmatrix} \geq \begin{pmatrix} K_{EE} & K_{ES} & K_{EG} \\ K_{SE} & K_{SS} & K_{SG} \\ K_{GE} & K_{GS} & K_{GG} \end{pmatrix} \cdot \begin{pmatrix} \pi_{Ecritical} \\ \pi_{Scritical} \\ \pi_{Gcritical} \end{pmatrix} \quad (31)$$

Consequently:

$$\begin{pmatrix} \pi_{Ecritical} \\ \pi_{Scritical} \\ \pi_{Gcritical} \end{pmatrix} \leq \begin{pmatrix} K_{EE} & K_{ES} & K_{EG} \\ K_{SE} & K_{SS} & K_{SG} \\ K_{GE} & K_{GS} & K_{GG} \end{pmatrix}^{-1} \cdot \begin{pmatrix} H_{maxE} \\ H_{maxS} \\ H_{maxG} \end{pmatrix} \quad (32)$$

Several necessary clarifications are provided below:

a) When norms are defined across all pillars, they form a normative vector, and the coefficient matrix measuring their direct effects is complete. Accordingly, the resulting critical values represent the maximum admissible value of each norm.

b) The critical values can be interpreted as multiple safety constraints in a system characterised by several norms. The system's resilience is bounded by the volume of its state space, which is determined by the critical values of these norms.

c) In the case of three norms, this volume takes the form of an irregular triangular pyramid. Intuitively, an increase in one norm displaces the corresponding vertex of the pyramid, requiring adjustments in the positions of the vertices associated with the other norms in order to preserve the stability of the structure and, consequently, the coherence of the system.

7. The question that then arises is how the viability frontiers ($\mathcal{V}_i$) can be determined for each individual entropic pillar ($H_{maxi}, i = E, S, G$). This can be derived from data (i.e. through an empirical estimation of the data) and may take the form of the 90th percentile ($\mathcal{P}_{90i}, i = E, S, G$). However, we draw attention to this term known as the viability frontier ($\mathcal{V}_i = H_{maxi}$). A clear distinction must, however, be made between two levels: the theoretical (ontological) level and the operational (empirical) level. From a theoretical perspective, H_{maxi} expresses the maximum level of entropy (disorder) compatible with systemic coherence, whilst from an operational perspective, $\mathcal{P}_{90i}$ may express an empirical approximation of this, i.e. a proxy. In other words, $\mathcal{V}_i = H_{maxi}$ is empirically estimated from data with the following formal expression: $\mathcal{V}_i \approx \mathcal{P}_{90}[H_i(t+1)]$, where $H_i(t+1)$ is the forecast (residual-free) value obtained via VARX. This expression represents the empirically determined upper limit of the disorder tolerable by the entropic system.

One further technical observation is necessary. To determine the appropriate percentile, the direction (polarity) of the variable must first be established. Some variables indicate more favourable conditions when their values decrease, as in the case of entropy, whereas others indicate more favourable conditions when their values increase, as in the case of ESG pillar scores. Accordingly, for the entropic system, the viability frontier is empirically estimated using the 90th percentile, whereas for the system based on ESG pillar scores, the corresponding viability frontier is estimated using the 10th percentile ($\mathcal{V}_i \approx \mathcal{P}_{10}[H_i(t+1)] = H_{mini}$).

6. Discussion

The developments outlined above have implications at three levels and can be summarised as follows: conceptual, theoretical and instrumental. At the conceptual level, the distinction between sustainable finance, green finance and green financing highlights that the interchangeable use of these concepts is not merely a matter of terminology, but can have consequences for the way in which research questions are formulated, variables are defined in modelling, and solutions are identified. The taxonomy proposed in this paper positions sustainable finance as the genus, green finance as a species within sustainable finance, and green financing as a species within green finance. Sustainable finance is defined as a set of actions in the form of a prescriptive normative mechanism aimed at reducing entropy across the ESG pillars and having as its finality persistence over time. Green finance is a species of sustainable finance, distinguished by its focus on the environmental dimension and by its form as a standardised normative financial instrument. Green financing, in turn, is a species of green finance, distinguished by its operationalisation as a normative financial instrument. The three concepts are therefore not interchangeable. Maintaining this distinction reduces the risk of inconsistency between the theoretical object of the research and the variables used in modelling, thereby limiting operationalisation errors and, consequently, a potential source of model specification error. The distinction is not merely terminological, since the interchangeable use of concepts occupying different positions within a taxonomic structure may affect judgements, variable construction, and model specification. In this regard, the conceptual distinction made in this paper constitutes a necessary foundation for the construction of a coherent theory and a coherent model. Furthermore, this differentiation allows for the

separation of the general framework of sustainable finance from its particularization through green finance and from its concrete manifestation through green financing.

The definitions of these concepts, formulated using the methodology described above, are expressed in entropic terms. Corresponding dual definitions are then formulated in business terms using ESG pillar scores as proxies. This duality should not be understood as implying identity between the two sets of definitions, but rather as establishing a link between the theoretical and observational levels. The entropies associated with the ESG pillars constitute theoretical constructs of the model, whereas ESG pillar scores serve as variables for their empirical approximation. Consequently, an increase in an ESG pillar score cannot be interpreted as equivalent to a reduction in entropy within that pillar. The use of imperfect proxies may therefore result in discrepancies between the ESG performance reported by companies and the evolution of entropy within the ESG vector system.

An entropic approach is adopted because entropy provides a measure of disorder across the ESG pillars, reflecting a form of degradation that varies inversely with order. In addition, the three ESG pillars cannot be analysed independently. A reduction in entropy within one pillar (an increase in order) has effects on the other pillars, creating trade-offs. A normative intervention cannot be considered sustainable solely on the basis of its effect on a single ESG pillar; rather, the systemic effect of that regulation on the entire system – on the ESG entropy vector – must be taken into account. It is also worth noting that the evolution of one pillar may have the opposite effect on the evolution of another pillar. Given these situations, which take the form of trade-offs, the prescriptive normative mechanism in our definitions is understood as an intervention capable of altering the dynamics of the system.

In this paper, the ESG system is represented using a three-dimensional entropic vector. For the E (Environmental) pillar, the entropic construct is represented by thermodynamic entropy generation or, equivalently, exergy destruction. For the S (Social) pillar, social entropy is operationalised using a Theil-type entropy index. For the G (Governance) pillar, the construct is represented by Shannon's information entropy. These correspondences should not be interpreted as implying an ontological identity among the three types of entropy, as each operates within a different theoretical context. Their inclusion within the proposed theoretical framework is justified by their formal role as measures of specific properties of the system's configuration. Physical, social, and informational disorder are therefore not treated as manifestations of the same phenomenon; rather, each dimension is represented by an entropic measure appropriate to its specific nature. This distinction is reflected in the clarifications provided throughout the paper and subsequently incorporated into the definitions of sustainable finance, green finance, and green financing.

Following the conceptual definitions and delimitations, a theoretical construct is proposed: the Theory of Viable Sustainable Finance, which consists of linking the normative definition of sustainable finance to a structural condition of viability and then transposing this relationship into a dynamic model. The introduction of the notion of viability is not arbitrary or merely a conventional addition to the concept of sustainability; it is justified by the logical relationship between sustainability, persistence over time and viability. Consequently, sustainability cannot be reduced to a static property; it is, in fact, a dynamic and structural property of the system. An ESG system may have favourable scores across its pillars at a given point in time, but without being in a configuration capable of persisting over time.

Given the definitions of the concepts and the structure of the theory, the Viable Sustainable Finance Model is subsequently developed. Constructed as a three-dimensional ESG entropic vector, the model enables the analytical determination of normative and structural trade-offs, capturing greenwashing, resilience through adaptation, and resilience through transient self-organisation. It also allows analytical solutions to be derived for the critical threshold of the norm in relation to the viability frontiers across the pillars. Furthermore, the model provides a framework for analysing the conditions under which a steady state exists in the ESG entropic system and for determining the viability frontiers of the individual pillars. These results are significant because they introduce a dynamic dimension into the analysis of financial sustainability. Within this analytical framework, sustainability is not reduced to the achievement of a particular ESG score at a given point in time, but is instead associated with the system's capacity to persist over time. In this sense, the viability frontier represents the structural limit beyond which the system can no longer be considered sustainable. The model establishes structural

relationships between the components of the ESG entropy vector and the normative mechanism. VARX (Vector Autoregression with Exogenous Variables) is used to estimate the parameters of these relationships empirically from observed data. The resulting parameter estimates are naturally dependent on the quality of the underlying data.

Several further clarifications regarding the limitations of the proposals developed in this paper are provided below. Firstly, there is the issue of the status of ESG proxies. As the status of the ESG indicator proxies for the pillars is not identical to the theoretical entropies, their suitability must be assessed empirically. Secondly, the use of the Theil index and Shannon entropy for the S and G pillars is conceptually and formally sound, but requires robustness tests against alternative measures. Thirdly, the use of generated thermodynamic entropy or, equivalently, exergy destroyed for the E pillar may be limited due to the unavailability of suitable physical data, thereby affecting its empirical applicability. Finally, the estimation of parameters in the proposed model and the determination of viability frontiers on the ESG pillars depend on the model specification and the properties of the data.

7. Conclusions

This paper develops a coherent framework for defining and delineating the concepts of sustainable finance, green finance, and green financing. Building on this foundation, the *Theory of Viable Sustainable Finance* and the *Model of Viable Sustainable Finance* are formulated to capture the dynamic dimension of financial sustainability. Four main contributions emerge from this framework: the first is conceptual and taxonomic, the second formal and normative, the third theoretical, and the fourth instrumental.

The first contribution is conceptual and taxonomic. From a methodological perspective, a descriptive rather than formal axiomatic system is used to define the three concepts, drawing on phenomenology and the criteria of consistency, independence, and completeness. The three definitions are then successively derived using the method of proximate genus and specific difference, also known as the genus-and-species method. Within this framework, *sustainable finance* constitutes the genus, *green finance* is a species of sustainable finance, and *green financing* represents the instantiation of the standardised normative financial instrument, marking its transition into practical application. This distinction reduces ambiguity among concepts that perform different functions in theoretical construction and modelling.

With regard to the second contribution, which is formal and normative, the definitions were constructed in entropic terms and then translated into dual definitions, in business terms, using ESG pillar scores as proxies. These definitions were then formalised using first-order logic and deontic logic. Formalisation via deontic logic enables these concepts to be represented by reference to the prescriptive normative mechanism, to the obligations associated with reducing entropy across the ESG pillars, and to the successive levels of standardisation and operationalisation of the financial instrument.

As regards the third contribution, this is a theoretical one and consists of the formulation of the Theory of Viable Sustainable Finance. Within this theory, sustainability is linked to persistence over time, and persistence over time is linked to viability. Viability is regarded as a necessary condition for persistence over time, and persistence over time as a necessary condition for sustainable finance. Therefore, the term *viable* in the title of the theory proposed in this paper is a logical consequence of this framework and does not constitute an arbitrary addition to the concept of sustainable finance.

The fourth contribution is instrumental. The proposed theory can be operationalised through the Model of Viable Sustainable Finance, which is constructed around a three-dimensional entropic vector associated with the three ESG pillars. Thermodynamic entropy generation, or equivalently exergy destruction, is associated with the E pillar; social entropy, operationalised through the Theil index, with the S pillar; and informational entropy, as defined by Shannon, with the G pillar. In accordance with the dual definition of sustainable finance, ESG pillar scores are treated as empirical proxies rather than as equivalents of the corresponding entropic constructs. The model enables the analysis of interdependencies and trade-offs across the ESG pillars, the establishment of analytical conditions for the existence of a steady state in the ESG entropic system, the analytical determination of the critical

threshold of the norm in relation to the viability frontiers across the pillars, and the determination of viability frontiers for each individual ESG pillar.

In conclusion, sustainable finance is not treated merely as a category of financial instruments or as an aggregation of ESG scores, but rather as a prescriptive normative financial system. Its purpose is to reduce the entropies associated with the ESG pillars, while sustainability requires persistence over time and persistence, in turn, requires viability.

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Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

References

1. Akerlof, G. & Shiller, R. (2009). *Animal Spirits: How Human Psychology Drives the Economy and Why It Matters in Global Capitalism*. Princeton University Press
2. Anstey, P.R. & Bronstein, D. (2025). *Definition and Essence from Aristotle to Kant*. Routledge. https://doi.org/10.4324/9781003489252
3. Berg, F., Kölbel, J.F. & Rigobon, R. (2022). Aggregate Confusion: The Divergence of ESG Ratings. *Review of Finance*, 26(6), 1315–1344. https://doi.org/10.1093/rof/rfac033
4. Boltzmann, L. (1877/2015). Translation of Ludwig Boltzmann’s paper ‘On the Relationship between the Second Fundamental Theorem of the Mechanical Theory of Heat and Probability Calculations Regarding the Conditions for Thermal Equilibrium’ (Über die Beziehung zwischen dem zweiten Hauptsatze der mechanischen Wärmetheorie und der Wahrscheinlichkeitsrechnung respektive den Sätzen über das Wärmegleichgewicht). Translated by K. Sharp and F. Matschinsky. *Entropy*. 17(4), 1971–2009. https://doi.org/10.3390/e17041971
5. Caldecott, B., Clark, A., Harnett, E., Koskelo, K., Wilson, C. & Liu, F. (2022). Sustainable Finance and Transmission Mechanisms to the Real Economy. *Oxford Sustainable Finance Group*, Working Paper, No. 22-04. Available at: University of Warwick – Climate Finance.
6. Cappucci, M. (2018). The ESG Integration Paradox. *Journal of Applied Corporate Finance*, 30(2), 22–28. https://doi.org/10.1111/jacf.12296
7. Charles, D. (2000). *Aristotle on Meaning and Essence*. Oxford University Press
8. Christensen, D.M., Serafeim, G. & Sikochi, A. (2022). Why Is Corporate Virtue in the Eye of the Beholder? The Case of ESG Ratings. *The Accounting Review*, 97(1), 147–175. https://doi.org/10.2308/TAR-2019-0506
9. Crona, B., Petersson, G., Meacham, M., Parlato, G., Lade, S., Rocha, J. & Galaz, V. (2025). A systems approach to sustainable finance: Actors, influence, mechanisms, and potentially virtuous cycles of sustainability. *IScience*, 28(7). https://doi.org/10.1016/j.isci.2025.112785
10. Dahiya, K., Khanna, M. & Khanna, M. (2026). Green finance and sustainable development: a systematic literature review of emerging gaps and future pathways. *Sustainable Development Unveiled: Engaging Reviews and Inspiring Case Studies* (Science of Sustainable Systems). Amsterdam: Elsevier, Chapter 18, 401–420. https://doi.org/10.1016/B978-0-443-41628-6.00004-6
11. Dhayal, K.S., Shashawat, S. & Giri, A.K. (2025). Conceptualising green finance: Findings from textual and network analysis. *Helyon,* 11(4). https://doi.org/10.1016/j.heliyon.2025.e42785
12. Dinga, E. (2018). *Studies in Economic Theory and Modelling.* Romanian Academy Press, Bucharest

13. Dinga, E., Oprean-Stan, C., Tănăsescu, C. R., Brătian, V., & Ionescu, G.-M. (2023b). *Co-Evolution of Symbolic Species in the Financial Market: A Framework for Economic and Political Decision-Making*. Palgrave Macmillan. https://doi.org/10.1007/978-3-031-31698-2

14. Dinga, E., Oprean-Stan, C., Tănăsescu, C., Brătian, V., & Ionescu, G. M. (2021). Entropy-based behavioural efficiency of the financial market. *Entropy*, 23(11). https://doi.org/10.3390/e23111396

15. Dinga, E., Oprean-Stan, C., Tănăsescu, C.-R., Brătian, V. & Ionescu, G.-M. (2022). *The Adaptive Preference Hypothesis*. London & New York: Routledge. https://doi.org/10.4324/9781003283690

16. Dinga, E., Oprean-Stan, C., Tănăsescu, C.-R., Brătian, V. & Ionescu, G.-M. (2023a). *Economic and Financial Market Behaviour: The Autopoietic Market Hypothesis*. Cham: Springer Nature Switzerland / Palgrave Macmillan. https://doi.org/10.1007/978-3-031-31702-6

17. Dawkins, R. (2006). *The SELFISH GENE*. 4th ed. Oxford University Press

18. Electrica Energy Company (2025). Approval of the prospectus for the issuance of green bonds [Current report]. *Bucharest Stock Exchange*, published 10 July 2025. Available at: https://www.bvb.ro/FinancialInstruments/SelectedData/NewsItem/EL-Aprobarea-prospectului-de-emisiune-a-obligatiunilor-verzi/B0701. [Accessed: 10 March 2026].

19. European Commission (n.d.). *Overview of sustainable finance*. [online] Available at: https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en. [Accessed: 15 February 2026].

20. European Union (2023). Regulation (EU) 2023/2631 of the European Parliament and of the Council of 22 November 2023 on European Green Bonds and optional disclosures for bonds marketed as environmentally sustainable and for sustainability-linked bonds, *Official Journal of the European Union*, L 2023/2631, 30 November. Available at: https://eur-lex.europa.eu/eli/reg/2023/2631/oj/eng. [Accessed: 8 March 2026].

21. Ewald, W. & Sieg, W. (eds). (2013). *David Hilbert's Lectures on the Foundations of Arithmetic and Logic 1917–1933*. Springer Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-69444-1

22. Fleming, S. (2020). What is green finance and why is it important? [online] *World Economic* Forum. Available at: https://www.weforum.org/stories/2020/11/what-is-green-finance/ [Accessed 27 February 2026]

23. Fotova Čiković, K., Cvetkoska, V. & Primorac, D. (2025). The Nexus Between Green Finance and Artificial Intelligence: A Systemic Bibliometric Analysis Based on the Web of Science Database. *Journal of Risk and Financial Management*, 18(8). https://doi.org/10.3390/jrfm18080420

24. Georgescu-Roegen, N., 1971. *The Entropy Law and the Economic Process*. Cambridge, MA: Harvard University Press. Reprinted in 1999. Bloomington, IN: iUniverse

25. Husserl, E. (2001a). *Logical Investigations* Volume 1. Moran, D. (ed), Routledge

26. Husserl, E. (2001b). *Logical Investigations,* Volume 2. Moran, D. (ed.), Routledge

27. Husserl, E. (2010). *Ideas: A General Introduction to Pure Phenomenology*. Routledge

28. Kant, I. (1998). *Groundwork of the Metaphysics of Morals*. Gregor, M. (ed.). Cambridge University Press

29. Ketterling, C.I. (2026). From voluntary CSR to binding ESG frameworks: a legal perspective on sustainability disclosure standards. *Future Business Journal*, 12(95). https://doi.org/10.1186/s43093-026-00813-w

30. Kuhn, T. (2000). *The Road Since Structure: Philosophical Essays, 1970–1993, with an Autobiographical Interview*. Conant, J. & Haugeland, J. (eds.), Chicago: University of Chicago Press

31. Kuhn, T. (2012). *The Structure of Scientific Revolutions*. 4th ed. The University of Chicago Press, Chicago

32. Kumar, S., Sharma, D., Rao, S., Liam, W.M. & Mangla, S.K. (2025). The past, present and future of sustainable finance: insights from big data analytics through machine learning applied to academic research. *Annals of Operations Research*, 345, 1061–1104. https://doi.org/10.1007/s10479-021-04410-8
33. Lagoarde-Segot, T. (2019). Sustainable finance: a critical realist perspective. *Research in International Business and Finance*, 47, 1–9. https://doi.org/10.1016/j.ribaf.2018.04.010
34. Lagoarde-Segot, T. (2024). Greenwashing and sustainable finance: an approach rooted in the philosophy of science. *Current Opinion in Environmental Sustainability*, 66. https://doi.org/10.1016/j.cosust.2023.101397
35. Migliorelli, M. (2021). What Do We Mean by Sustainable Finance? Assessing Existing Frameworks and Policy Risks. *Sustainability*, 13(2). https://doi.org/10.3390/su13020975
36. Monciardini, D. & Ahlstrom, H. (2022). The Regulatory Dynamics of Sustainable Finance: Paradoxical Successes and Limitations of EU Reforms. *Journal of Business Ethics*, 177(1), 193–212. https://doi.org/10.1007/s10551-021-04763-x
37. OECD – Organisation for Economic Co-operation and Development (n.d.). *Sustainable finance*. [online] Available at: https://www.oecd.org/en/topics/sustainable-finance.html [Accessed 22 February 2026]
38. Politi, V. (2020). Taxonomies, Networks, and Lexicons: A Study of Kuhn's Post-'Linguistic Turn' Philosophy. *International Studies in the Philosophy of Science*, 33(2), 87–103. https://doi.org/10.1080/02698595.2020.1865784
39. Shannon, Claude E. (1948). A Mathematical Theory of Communication. *Bell System Technical Journal*, 27(4), 623–656. https://onlinelibrary.wiley.com/doi/abs/10.1002/j.1538-7305.1948.tb00917.x
40. Smith, M & Price, G.R. (1973). The Logic of Animal Conflict. *Nature*, 246, 15–18. http://dx.doi.org/10.1038/246015a0
41. Studtmann, P. (2024). *Aristotle's Categories,* The Stanford Encyclopedia of Philosophy. Winter 2024 Edition. Edward N. Zalta & Uri Nodelman (eds.). https://plato.stanford.edu/archives/win2024/entries/aristotle-categories
42. Tai, M. & Xu, Q. (2026). How ESG rating divergence impacts organisational resilience: evidence from China. *Cogent Business & Management*, 13(1). https://doi.org/10.1080/23311975.2026.2646385
43. Theil, H., 1967. *Economics and Information Theory*. North-Holland Publishing Company
44. Trivers, R. L. (1971). The evolution of reciprocal altruism. *The Quarterly Review of Biology*, 46(1). https://doi.org/10.1086/406755
45. Tung, P.-H., Chiu, Y.-M. & Huang, C.-H. (2025). Exploring the research development trajectory and trends of green finance. *Asia Pacific Management Review*, 30(3). https://doi.org/10.1016/j.apmrv.2024.10.001
46. Von Wright, G.H. (1963). *Norm and Action: A Logical Enquiry*. London: Routledge and Kegan Paul; New York: Humanities Press
47. Walter, C. (2020). Sustainable Financial Risk Modelling: Aligning with the SDGs – Some Reflections. *Sustainability*, 12(18). https://doi.org/10.3390/su12187789
48. Zach, R. (2023). *Hilbert's Programme.* The Stanford Encyclopedia of Philosophy, Winter 2023 Edition. Edward N. Zalta & Uri Nodelman (eds.). https://plato.stanford.edu/archives/win2023/entries/hilbert-program/
49. Zahavi, D. (2025). *Edmund Husserl*. The Stanford Encyclopedia of Philosophy. Winter 2025 Edition. Edward N. Zalta & Uri Nodelman (eds.). https://plato.stanford.edu/archives/win2025/entries/husserl

50. Zhao, J., Wang, M., Hong, S. & Tan, S. (2025). ESG rating divergence and financing constraints: Evidence from China. *Journal of Environmental Management*, 389. https://doi.org/10.1016/j.jenvman.2025.126188



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