Working Paper 03/2020

Ecological Finance Theory: New Foundations

by

Thomas Lagoarde-Segot¹, KEDGE BS & SDSN France

&

Enrique A. Martinez², Foyer de Charité de Provence, France

The Post-Crisis Finance Network Working Paper Collection presents research in progress by PoCfiN scholars and conference participants. The purpose of the series is to disseminate ideas to and elicit comments from academics and professionals.

The Post-Crisis Finance Research Network (PoCfiN), founded in 2018, is an alliance of research chairs and individuals researchers supported by KEDGE Business School, the Fondation Maison des Sciences de l’Homme (FMSH) and SDSN France. PoCfiN coordinates the activities of individual researchers, academic chairs, entrepreneurs and sustainable financial actors, with a view to renewing academic research and the content of financial education, and, more generally, to aligning the structure and the behavior of financial markets, actors and institutions with societal needs. The primary ambition of PoCfiN is to constitute an anchoring for the global movement in order to replace the 1970s neoclassical financial model with a new approach more suited to the systemic challenges of the 21st century.

¹ Contact author. Thomas Lagoarde-Segot is Professor of Economics and Finance at KEDGE BS and director of the Sustainable Finance group of SDSN France. Email: thomas.lagoardesegot@kedgebs.com.
² Enrique Martinez, PhD in Biology, ad honorem academic of Universidad Católica del Norte and CEAZA research center in Chile, is now with the Foyer de Charité de Provence, Lambesc, France. We thank Benjamin Martinez for excellent research assistance and Daisy Connon for proofreading our manuscript.
ABSTRACT

This paper puts forth Ecological Finance Theory as a valuable new vision for financial economics. Ecological Finance Theory is a mission-driven proposition seeking to re-embed financial systems within social and ecological constraints in order to ensure social resilience. Ecological Finance theory acknowledges the insufficiency of the neoclassical model to account for and respond to the socio-economic and biophysical realities of a post pandemic world. It introduces a sound ontological and epistemological framework taking into account the complex interactions between the financial, socio-economic and biophysical realms, and the impact of financial models in shaping reality. It draws on biological theory to provide insight into new metaphors and concepts for the study of financial systems. This paper paves the way for future work within this theory. We first describe its meta-theoretical hypotheses. We then introduce an initial set of metaphors. We finally develop a puzzle-solving application with a new stock-flow consistent model permitting to analyze ways to upscale the transformative power of local complementary currencies.

KEYWORDS: Ecological Finance Theory, Finance, Sustainability

JEL classification: G00
1. Introduction

The COVID19 pandemic has considerably risen global awareness that geo-biological systems, socio-economic systems, and financial systems may no longer be considered separately. Earth Science has indeed proven that economic systems are in fact part of a set of interconnected biogeochemical and social systems. These systems feed back on each other, creating high levels of uncertainty and systemic complexity (Future Earth, 2020). In recent decades, the Great Acceleration of socioeconomic trends has caused a set of ‘regime shifts’ in these systems, creating a cascade effect and causing an abrupt deterioration in human welfare (Lenton et al. 2008, Rockström et al. 2009, Steffen et al. 2015). Rescaling human actions and behavior to the load capacity of the biosphere, from the local to global levels of every scale is now widely recognized as a major civilizational stake (Clark and Munn 1986, Folke et al. 2010, Steffen et al. 2011, Leach et al. 2012, Galaz 2015).

A multi-stakeholder and interdisciplinary consensus has emerged regarding the need to take over the modern finance paradigm (also called neoclassical finance theory) in order to tackle these challenges. Earth scientists have identified ecosystem financialization as one of the key mechanisms by which human activity undermines the biosphere (Nyström et al., 2019). Multilateral institutions have also fully acknowledged the need for a structural reform of the global financial system. Even before the COVID19 crises, the European Commission High-Level Expert Group on Sustainable Finance (HLEG) famously underlined that “reaching our Paris agreement goals requires no less than a transformation of the entire financial system, its culture and its incentives” (HLEG, 2018).

In recent years, a group of financial economists has revisited conventional assumptions in finance. This group has met regularly and repeatedly pointed out the contradictions between mainstream hypotheses and the global ecological, social and economic crises, using an interdisciplinary approach. It has also systematically engaged with transformative investment platforms and policy networks, in an effort to carve out new theoretical and applied perspectives to confront the challenges of the 21st century (Lagoarde-Segot, 2015, 2019, 2020; Lagoarde-Segot and Paränque, 2018, Alijani and Karyotis, 2016; Paränque and Pérez, 2016; Revelli, 2016; Chambost et al., 2019; Walter, 2016, 2019; Dembinsky, 2009; Faugère, 2020; Dupré and Perluss, 2016).

This paper seeks to bring the various constitutive elements of this body research into a consistent theoretical framework that could be shared with (and developed by) other researchers. The COVID-19 pandemic – which is striking the world as we write this paper – may indeed be a turning point for finance studies. This pandemic is not a ‘black swan’, i.e. an extraordinary, high profile, hard-to-predict and rare

---

3 A recent survey by Future Earth (2020) of more than 200 international scientists has identified five global risks that have the potential to impact and amplify one another, in ways that might cascade to create global systemic crisis. These risks include failure of climate change mitigation and adaptation; extreme weather events; major habitat and biodiversity loss and ecosystem collapse; food crises; and water crises.

4 The UNEP-Finance initiative, which aims to foster Principles for Responsible Banking (PRB), Principles for Sustainable Insurance (PSI), and Principles for Responsible Investment (PRI) in order to interlock financial systems with the objectives of the 2030 Agenda for Sustainable Development is another example. These efforts to reform the financial system are part of a broader transformation agenda, framed around the sustainable development goal agenda (SDGs), which was adopted by all 193 UN Member States on September 25, 2015. The SDG agenda provides a new narrative for economic policy, organized around six major societal transformations, in the fields of education, health, energy systems, agriculture, urban planning and technology - all supported by good governance, peace and international cooperation (SDSN, 2018). These transformations are measured via 17 goals, which are disaggregated into a global indicator framework currently including 231 indicators. This framework was agreed upon at the 48th session of the United Nations Statistical Commission held in March 2017, and reviewed in March 2020. (United Nations Statistical Commission, 2020).

5 These meetings were held under the auspices of various institutions and associations as SDSN France, the Post-Crisis Finance Network, the Fondation Nationale pour l’Enseignement de la Gestion des Entreprises, the Association pour Renouveler la Recherche et l’Enseignement en Economie et en Finance (AREF) at the University of Fribourg, the Responsible Investment Forum, the AFEP/IIPPE conference and the INFINITI annual conference. We also greatly benefited from informal interactions with students and colleagues.
outlier event. Rather, it should be qualified as an expected secular shock, unveiling the weaknesses of the socioeconomic model that the world has consciously (and unconsciously) adopted over the past 50 years. It validates the view (until now only shared by a minority of financial economists, but backed by consensus amongst climate scientists, ecological economists as well as an increasingly large share of the world population) that the economy is embedded in biophysical and ecological constraints, and not the other way around.

The crux of the problem is that modern finance theory, by virtue of its meta-theoretical hypotheses superimposes financial logics on to the analysis of the environment, while addressing the new context instead calls upon us to turn this order upside down. However, “to reject one paradigm without simultaneously substituting another is to reject science itself” (Kuhn, 1962). This paper thus proposes Ecological Finance Theory a new vision to be adopted the community of financial economists. Ecological Finance Theory takes into account the complex interactions between the financial, socioeconomic and the biophysical realms, and the impact of financial models in shaping reality. It builds on several separate strands of literature, such as biology, financial economics, and social studies. It proposes a ground breaking meta-theoretical framework permitting to develop transformative knowledge in response to the challenges we face. To do so, Ecological Finance Theory posits new definitions, concepts, and tools, and uses these to deliver practical proposals to reform financial system structure, policies, instruments, and governance in order to ensure societal resilience. While relying, where relevant, on quantitative tools, Ecological Finance Theory is open to interdisciplinary and transdisciplinary approaches and fully acknowledges the role of values, ethics and ideologies in finance studies.

This paper lays the ground for the future development of Ecological Finance Theory by providing a comprehensive overview of its main theoretical features. The paper gives the reader an introductory tour of Ecological Finance Theory, by analyzing the three nested levels of scientific discourse. These include meta-theoretical hypotheses, research metaphors, and puzzle-solving activities. It is our hope that the reader may want to adopt these hypotheses, deepen or discuss these metaphors (or propose new ones) and contribute to puzzle-solving activities in her or his future research work.

The remainder of the article is structured as follows. The second section describes the scope and intent of the paper by reference to the nested structure of academic discourse. The third section outlines the meta-theoretical hypotheses of Ecological Finance Theory; arguing that these hypotheses are more suited to the current context than those of neoclassical finance theory. The fourth section introduces a set of biological metaphors in Ecological Finance Theory by relying on the relevant interdisciplinary streams of literature. The fifth section initiates a puzzle-solving activity within Ecological Finance Theory by modelling a prototype ecological finance policy strategy seeking to upscale the transformative power of local complementary currencies through joint innovations in monetary policy and extra-financial ratings. The sixth part brings together our conclusions and discusses future development prospects for Ecological Finance Theory.

---

6 Nearly twenty years ago, a report by the World Health Organization (2003) warned that “combined impacts of rapid demographic, environmental, social, technological and other changes in our ways-of-living” could have dramatic consequences on human health. The report demonstrated that the development of human societies, characterized by high levels of global travel, trade, connectivity, and high-density living, induces climate change and biodiversity losses, and undermines the stability and the functioning of the biosphere’s life supporting systems. According to Smith etal. (2014), the number of disease outbreaks, as well as the richness of causal diseases (bacteria, fungi, parasites, protozoa or viruses), increased very significantly between 1980 and 2013. The COVID 19 pandemic is an illustration of how such regime shifts may trigger biosphere events undermining the resilience of social provisioning systems. Public awareness is rapidly rising on these issues. Symptomatic is perhaps French President Emmanuel Macron’s address to the Nation on March 13th, 2020, at the eve of the lockdown. President Macron stated “we shall tomorrow draw all the lessons from this experience, and question the model of development in which the world is engaged for several decades, and whose weaknesses are thrown into light”. In French: “il nous faudra demain tirer les leçons du moment que nous traversons, interroger le modèle de développement dans lequel s'est engagé notre monde depuis des décennies et qui dévoile ses faiblesses au grand jour”.
https://www.elysee.fr/emmanuel-macron/2020/03/12/adresse-aux-francais
2. Scope of the paper

Three nested layers of discourse characterize scientific activities in social sciences (including economics and finance): meta-theoretical hypotheses, metaphors, and puzzle-solving (Morgan, 1980; Ardalan, 2008; Burrel and Morgan, 1979).

- **Meta-theoretical hypotheses** refer to a shared and tacit ‘world vision’ accepted within a research community. They govern the norms and rules scientific research at a very fundamental level. Two sets of assumptions are particularly crucial in any paradigm: ontological assumptions (which refer to the nature of the phenomena being investigated); and epistemological assumptions (which refer to the nature of knowledge and the way in which it can be obtained).

- **Metaphors** build upon these meta-theoretical hypotheses and refer to the gradual development of a shared language, better adapted for interdisciplinary work as well as for clarifying a nonacademic audience. These metaphors provide known mental images for understanding or for studying an object. Metaphors structure scientific activities by orienting research towards the analysis of similarities (and discrepancies) between the object of study and the shared language. Within a given paradigm new metaphors can emerge, coexist with, and eventually replace old ones.

- **Puzzle-solving** represents the bulk of scientific activities during temporary phases of ‘normal science’ when one paradigm dominates (Kuhn, 1962). It consists in the examination, operationalization and measurement of detailed implications of the metaphorical insight upon which research is based. Puzzle-solving debates concern the identification and proper implementation of the appropriate methodological tools required to examine a particular research question. Researchers engaged in puzzle-solving activities take metaphors and their underlying meta-theoretical hypotheses for granted.

The meta-theoretical hypotheses of neoclassical finance theory are discussed at length in Ardalan (2008). Neoclassical finance theory postulates a separation between the realm of finance and social provisioning, and treats the world of finance as a “concrete reality”. It “assumes a continuing order, and coherence and tries to explain what is” (Ardalan 2008, p.4). Neoclassical finance researchers affirm the independence to the observer from the observed and do not see any role for themselves in the shaping of society. Recent advances in Earth Science, however, have falsified these meta-theoretical assumptions. A clear link between financial norms, rules and practices, the destabilization of Earth Systems, and societal resilience has indeed been established (Nyström, 2019, Galaz et al., 2018). There is budding evidence that the existing paradigm has ceased to function properly and that its existing structures are not adequate to address emerging scientific challenges.

This paper thus proposes Ecological Finance Theory as a substitute for neoclassical finance theory in the post-pandemic world. Ecological Finance Theory embraces the full consequences of the observed interconnectedness between financial systems and the biophysical constraints. The remainder of the paper sets out ontological, epistemological hypotheses in Ecological Finance Theory, comparing and contrasting these hypotheses with those of neoclassical finance theory. It also attempts to carve out new metaphors and to show how these could be integrated in renewed puzzle-solving activities in the field of financial economics. We invite our readers to contribute to expanding on the metaphors presented in this paper and to develop research permitting to apply Ecological Finance Theory to the analysis of real-world problems and issues.

3. Ecological Finance Theory: meta-theoretical hypotheses

“With any phenomenon of interest, understanding its nature or essential properties allows us to relate to, and to interact with, in more knowledgeable and competent ways than would otherwise be the case” (Lawson, 2019, p.3). However, neoclassical finance theory does not pay much attention to insight bearing on the nature of its object of study (Lawson, 2019;; Lagoarde-Segot, 2015, 2019). It loosely

---

7 We could say that the “greenhouse” effect is a very used metaphor to explain climate change dynamics. “Cascade effects” is another metaphor to visualise a linked series of cause-effect process.
assumes that the financial world is a stable and independent strata of reality, which can be identified, studied and measured in terms of causes and effects, through methods derived from the natural sciences. As we shall argue, this ontological neglect renders financial tools, models and recommendation ill-suited to tackle 21st century challenges. Understanding the nature of the financial system instead requires us to position it properly with respect to socioeconomic and biological systems.

3.1. The financial system is a subsystem of socioeconomic and Earth systems

3.1.1. Earth Systems

At a whole system observation scale, Earth Science has made three important discoveries over the past twenty years. First, the Earth behaves as an integrated Earth System in which the oceans, atmosphere and land, as well as all living organisms are all connected (IGBP, 2004). Second, living organisms - the biosphere – is an “an active, essential component” in the regulation of the Earth system and interacts with the other spheres to keep the Earth’s environment within habitable limits (Steffen et al., 2005, p. 1). Third – and most crucially – socioeconomic trends (in particular, industrial development and consumption patterns) have destabilized the Earth System and induce global ecological changes happening on unprecedented scales (Rockström et al. 2009; Steffen et al. 2015; Worm and Paine, 2016). Figure 1 represents the set of interconnected sub-systems that make the Earth System. These include the geosphere, the atmosphere, the hydrosphere and the biosphere. The atmosphere is the Earth’s 100 km thick protective gas envelope composed of mainly azote, oxygen and carbon dioxide. It protects the surface of the Earth from lethal UV rays and small meteors, and regulates its temperature by radiating downwards the reflected heat of the sunrays (the ‘greenhouse effect’). It also absorbs water from the earth’s surface (via the process of evaporation) and redistributes heat and moisture (by big circulation cells) across the earth’s surface (through rainfall and other precipitations). The geosphere is the solid mineral part of the planet. Its surface is subject to processes of erosion, weathering and transport, in addition to tectonic forces and volcanic activity at deeper depth levels. The hydrosphere is composed of water in various forms. It includes the earth’s oceans and seas, water vapor, ice sheets, sea ice, glaciers, lakes, rivers, streams, atmospheric moisture, ice crystals; and areas of permafrost. The biosphere is distributed through an approximately 20 km thick layer on the surface and waters of the Earth. It contains the totality of living organisms, as well as the substances derived from these organisms (such as humus, or coal). Photosynthetic organisms (such as plants or plankton plus some chemosynthetic living beings) are the basis of biospheric production. They fixate 1/1000th of the energy transmitted from the Sun into organic molecules (together with water and periodic elements). These organic molecules then enter into the fabrication of a chain of interlocked organisms (such as fish, insects and terrestrial vertebrates, or human beings), which, eventually, die and put their constitutive elements back into circulation. In the biosphere, the Sun’s energy contained in living organisms thus circulates among species through the food web, and eventually accumulates in stocks of fossil or recent biomass. The biosphere contains about 8.7 million species, organized into a mosaic of ecosystems (Mora et al., 2011), which are defined as networks of interdependent links between a set of species (a biocenose) in a shared environment (a biotope).

8 The fact that the Earth behaves as system was put into dramatic focus in 1999 with the publication of the 420,000-year record from the Vostok ice core (Petit et al. 1999). The record shows that patterns of atmosphere CO2 and CH4 gas concentrations and inferred temperature through four glacial-interglacial cycles are highly coupled, follow a regular pattern through time and are bounded at upper and lower limits. These cycle features are typical of a self-regulating system.

9 One example is the relationship between the carbon cycle, photosynthesis and respiration. Photosynthesis (the operation by which plants and other organisms convert the sun’s energy, water and carbon dioxide into glucose) reduces the amount of CO2 and liberates oxygen in the atmosphere. Respiration by living organisms, in turn, converts oxygen and carbohydrates into energy and release carbon dioxide into the atmosphere. These interactions permit to maintain the current concentration of oxygen (around 21%) and regenerate the stock of carbon in the atmosphere (at 0.0391%, but unfortunately rapidly increasing).

10 Biomass is defined as “any form of organic matter that can be found on earth, one property that is common for all of its forms is that it is or had to be a living organism in one point of its existence” (Morgan Jr et al., 2018)
3.1.2. The socioeconomic and financial spheres

The socio-economic sphere is a sub-system of the biosphere, in which humans derive a flow of energy from the biomass for the sake of their survival and reproduction11 plus the use of other huge amounts of mass from the geosphere and hydrosphere in direct interaction with the atmosphere too. This flow of energy circulates as goods, services and labor, produced and consumed in order to ensure social provisioning. The social provisioning process relies on a wide range of activities, including market and non-market, paid and unpaid activities, undertaken by human-agents and organizations of all sizes, within the context of prevailing social norms, rules, culture and law. It can be defined as “an instituted process of interaction between man and his environment, which results in a continuous supply of want-satisfying material means” (Polanyi, 1983, p.145), interlocked in the biosphere.

The field of Earth Science has analyzed the social provisioning process through the concept of the global production ecosystem (GPE). The GPE is a worldwide social-ecological network of actors and institutions spanning sectoral, jurisdictional and geographical boundaries. The GPE stores, trades, processes and distribute mass and biomass, altering local and global ecosystems for the production of specific species in response to human wants (Bennet and Balvanera, 2007; Rist et al., 2014).

However, the relationship between the socio-economic sphere and the biosphere is one of dependency. The production of goods and services is indeed physically constrained by the amount of biomass contained in the biosphere. For instance, the energy potential of biofuels is dissipated in the form of the heat produced when fuels combine with atmospheric oxygen. The resulting cascade of trophic levels corresponds to different phases of the economic cycle: the energy industry, production of intermediary goods, and production of final goods, foods (fuel of living organisms), consumption, and wastes (Bardi et al., 2019).

Finally, the financial sphere is the stratum of the socioeconomic sphere, which issues, circulates, and destroys the flow of monetary symbols representing the (actual or expected) value of the inputs, goods and services extracted from the hydro, geo and biospheres. The contemporary socioeconomic sphere is finance-driven at multiple levels. The functioning of our modern economies rests on in a single interlinked network of electronic spreadsheets distributed over thousands of bank computers (Enhts, 2017). The creation, direction and destruction of debt and credit (that is, money) in the banking system lies at the heart of every economic decision (Lavoie, 2015). Several prominent economists have also underlined the impact of short run financial dynamics and long run financial cycles on macroeconomic business cycles (including Minsky (1980), Shiller (2009), Aglietta (2018)).

Nonetheless, the financial sphere is biologically dependent upon the socioeconomic sphere. First, the financial sphere does not participate directly in the material production of goods and services. Its existence depends on the ability of the socioeconomic sphere to derive a sustained surplus flow of energy from the biosphere (in excess of immediate needs for life reproduction). Indeed, money, accounting and finance appeared after the Neolithic agricultural revolution, which laid the material basis for the construction of a political administration through the extraction of a regular calorific surplus from the biosphere. Human societies invented modern money, accounting and finance as tools to measure and settle the compulsory debts (known as taxes) required to support political entities (Graeber, 2011; Wray, 2012). Accounting research has also shown that the financial information system – defined as the way the results of economic activity are recorded and analyzed using the conventions pertaining to a given a time and place - is primarily a social, historical and technological construct (Rambaud and Richard, 2015; Féger et al., 2018; Jouffray et al., 2019). Ecological Finance Theory begins with the observation that systems are interconnected in the following order: the Earth System, the socioeconomic sphere and

---

11 Goods and services constitute a « flow of energy » to the extent that matter is condensed energy. This was put forth in 1979 by de Rosnay (1979) in The Macroscope, a foundational book in cybernetics and systems thinking: « One may wonder how goods and services can constitute a flow of energy. In fact material goods--“products”--are the result of transformations involving energy, information, and raw materials. (...) Matter is condensed energy; information is a form of potential energy. Goods (including foodstuffs) and services are therefore equal to a flow of energy. To each item of goods there is attached an "energy cost," say in kilocalories. The feedback of energy in the form of work can be expressed easily in kilocalories expended per hour of work or in some other appropriate unit » (de Rosnay, 1979).
finally the financial sphere. We represent the embeddedness of the financial sphere within the socioeconomic sphere, the biosphere and its interactions with other Earth Systems in figure 1.a.

**Figure 1.a Earth systems, Biosphere and Finance**

![Diagram](image)

Note: this figure positions the financial sphere with respect to the socioeconomic sphere, the biosphere and the other sphere composing the Earth system.

### 3.2. The functional inversion between finance, the economy and the biosphere

As shown in figure 1b, this view is the exact opposite of the model that has been adopted by neoclassical finance theory. Neoclassical finance theory assumes that the biosphere has a market value, and that the latter can be determined through the rational decisions of investors in financial markets, which lead up to the ‘discovery’ of an efficient vector of equilibrium prices. Tacit in this representation is the notion that financial markets provide an accurate image of reality (efficient market hypothesis) and that socioeconomic reality is equivalent to the aggregated properties of its individual units (methodological individualism hypothesis). In this representation, effects on the environment are ‘market externalities’ conceptualized in reference to a self-equilibrating process of market exchange situated within the socioeconomic sphere.

**Figure 1.b Neoclassical Finance Theory**

![Diagram](image)

Note: this figure shows the links between finance, the socioeconomic sphere and the environment (externalities) as seen through the lenses of neoclassical finance theory.
Research in Earth Science indicates, however, that this model induces a functional (and artificial) inversion of the hierarchy between financial, socioeconomic and biosphere. Financialization\(^\text{12}\) has indeed contributed to decoupling biomass from its physical form (Clapp, 2014). In particular, agricultural derivatives abstract food from its physical form into highly complex commodity derivatives, whose prices vary according to financial markets’ short-term conventions and speculative strategies; and affect the global food system (Russi, 2013). This decoupling process is magnified by the rise of high-frequency trading, which induces a ‘disjuncture’ between the representation of value and the actual production of value by biological processes (Skou Grindsted, 2018). This is constitutive of the financial hyper-reality discussed in Schinckus (2017).

Concurrently, the Global Production Ecosystem is increasingly steered by a set of vertically and horizontally integrated transnational corporations, which control the whole supply chain and have a disproportionate influence on decision-making globally through their subsidiaries (Österblom et al., 2015; Clapp and Fuchs, 2009). The governance of these corporations is regulated by the ‘shareholder value’ principle (an outgrowth of the neoclassical “agency theory”\(^\text{13}\) which emphasizes short-term financial performance, and the concentration of earnings in financial markets through mechanisms of short-term capital appreciation. Galaz et al. (2018) have shown that as a collective, the “Financial Giants”, through their common block holding power, have a considerable influence on companies shaping biomes critical for the stability of the climate system (such as the Amazon forest in Brazil and the boreal forests in Russia and Canada). Sectoral studies have also shown that the growing interest among financial institutions in investment in the seafood sector lead to adverse effects on small-scale fisheries through increased privatization and ocean grabbing (Knott and Neis, 2017).

Over time, the biosphere was transformed into an appendage of the global production ecosystem, the latter being increasingly governed in response to narrow financial logics and interests. Evidence indicates that the Global Production Ecosystem, steered by the financial sector, has responded to increased demand for biomass by intensifying other inputs used by humans (such as sand, carbonates, water, fossil fuels, fertilizers, pesticides, antibiotics and technology), and weakened biological feedback relationships and resilience. The decoupling of the Global Production Ecosystem from the natural processes sustaining it creates novel conditions for risk emergence and interaction (Nyström et al., 2019).

The functional relationship between finance, the socioeconomic sphere and the biosphere has been molded to conform to the representation of neoclassical finance theory (figure 1.c).

---

\(^{12}\) Financialization refers to “the increasing importance of financial markets, motives, institutions and elites in the operation of the economy and its governing institutions’ (Epstein, 2005), to a “pattern of accumulation in which profits accrue primarily through financial channels than through trade and commodity production” (Krippner, 2005), or, more generally, to “the increasing dominance of financial actors, markets, practices, measurements and narratives at various scales, resulting in a structural transformation of economies, firms (including financial institutions), states and households” (Aalbers, 2015).

\(^{13}\) As discussed in Crotty (2005), agency theory is at odds with the features of innovative corporations, which typically display organization integration (defined as a strong attachment to the long-run goals of the firm by its major stakeholders); and long-term financial commitment. A wide literature also indicates that the financialization of corporations has occurred to the detriment of macroeconomic stability and industrial development (Lazonick, 2013; Gleadle et al., 2014; Wang, 2019; Boyer, 2000; Plihon 2002; Aglietta, 2018; Gimet et al., 2019).
This claim is backed up by the findings from the social studies of finance, which have established that financial theory is ‘an engine, not a camera’ (McKenzie, 2006). Financial theory is a language, which fabricates institutions, legitimates corporate decisions, and conceals conflicts, oppositions, and power relations through the superposition of a veil of scientific-ness (Callon, 1998, MacKenzie and Millo, 2003, Muniesa, 2015, Chambost et al., 2019). Ecological Finance Theory therefore posits that the domination of the neoclassical finance paradigm contributes to inverting the relationship uniting the biosphere, the socioeconomic sphere and the financial sphere.

3.3. Great Acceleration, the Anthropocene and resilience

The colonization of the biosphere by financial logics poses a significant risk for societal resilience. In cybernetics, managing a higher-level system with the signals emitted by a lower-level sub-system leads to a loss of consistency and to the destruction of the higher-level system, due to a loss of information (Dron, 2015). The biosphere is more complex, works at slower rates, is less flexible, and displays less substitutability than the socio-economic sphere. It thus constitutes the higher-level system; while the socio-economic sphere is the lower-level system (Dron, 2015). The scientific literature indeed indicates that the global production ecosystem is causing a global transformation of Earth Systems due to its acceleration in the past 50 years. This transformation affects our own future in profound ways. In fact, figures 2a and 2b show selected socio-economic graphs and the parallel evolution of Earth ecosystems compiled by Steffen et al. (2015). These charts display an unambiguously positive correlation between the exponential growth of socio-economic indicators (such as real GDP, FDI, world population, energy use, water use transportation, broad money) and the destabilization of earth system trends (such as carbon dioxide, nitrous dioxide emissions, ozone depletion, territorial biosphere degradation, tropical forest loss, ocean acidification). According to the International Geosphere

---

14 This observation applies to recent research on ‘sustainable finance’ which typically superimposes a financial logic to the analysis of sustainability concerns, which it analyzes through the lens of investments and the monetary return they provide, rather than questioning the ability of financial systems to respond to the sustainability challenge. This has entailed the modelling of ‘sustainability’ as an independent variable linked to ‘investor preference’, and analyzing its impact on the variations of monetary indicators of ‘return’ (typically modelled as a dependent variable). Recent authors for instance, have documented deviations in the price and returns of ‘green’ financial instrument from standard financial instruments (Zerbib, 2017; Karpf and Mandel, 2017), or developed new asset pricing methods, using calculation formulas defining an ‘equilibrium value’ (Zerbib, 2020).

15 In cybernetics, any system consists in a set of inter-related subsystems, each subsystem being also hierarchic in structure. The whole systemic structure can thus be decomposed until one reaches some lowest level of elementary subsystems (Simon, 1962). One can identify higher-level systems based on properties such as higher complexity and richness of information. Living systems (from an anthropocentric point of view) are interlocked in the following hierarchical order: the biosphere, the socioeconomic sphere, smaller social units, and finally, the individual human being.
The Biosphere Program, "the Earth System has recently moved well outside the range of the natural variability exhibited over at least the last half million years" (IGBP, 2004, p.3). The consensus is that we now live in the Anthropocene, a human-dominated geological time unit (Lewis and Maslin, 2015, Waters et al. 2016) 16.

This destabilization has also come to threaten the reproduction of life on Earth. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IBPES) also reports that the rate of extinction is currently tens to hundreds of times higher than the average over the last 10 million years. About 1 million species face possible extinction within decades because of deforestation, climate change, global pollution and global transport17. Between 2030 and 2050, climate change is expected to cause approximately 250 000 additional deaths per year, from malnutrition, malaria, diarrhea and heat stress alone (World Health Organization, 2018). The accumulation of monetary wealth masks a destruction of real ecosystem services, which has come to threaten resilience of the global production ecosystem (Nyström et al., 2019; Galaz et al., 2019; Dron, 2015; Svartzman et al., 2019; Dafermos et al., 2018).

---

16 The Anthropocene (the notion that the activities of humankind have given age to a new geological age) was initially proposed by Nobel laureate Paul Crutzen and officially recognized by the International Geological Congress in Cape Town in August 2016 (Maitland, 2019).

17 The report identifies five extinction factors. These include deforestation, direct human exploitation of organisms, climate change, pollution, and the invasion of ecosystems by alien species due to global transport (IBPES, 2019). One should also note that biodiversity impacts are heterogeneous context-specific: some forms of biodiversity are local, some are global, and the complex relationship between local and global biodiversity declines is not yet fully understood (Cardinale et al., 2018).
Figure 2a The Great Acceleration – global socioeconomic trends, 1750-2013
Figure 2b The Great Acceleration – Earth System trends, 1750-2013

Source: Steffen et al. (2015). The full dataset, the definition of variables, original sources are not shown here for space-saving consideration but are available at www.igbp.net
3.4. Comparing Ecological Finance Theory and Neoclassical Finance Theory

These preliminary observations lead us to lay out the following meta-theoretical hypotheses for Ecological Finance Theory. As shown in table 1, these hypotheses diverge from those of neoclassical finance theory in several important ways.

Table 1 Meta-theoretical hypotheses of Neoclassical Finance and Ecological Finance Theory

<table>
<thead>
<tr>
<th>Neoclassical Finance assumptions</th>
<th>Ecological Finance Theory assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On the object of study</strong></td>
<td></td>
</tr>
<tr>
<td>The financial sphere is a concrete and independent reality</td>
<td>The financial sphere is embedded in socioeconomic systems and bio-geo-physical constraints</td>
</tr>
<tr>
<td>Financial markets are efficient, fair, and equilibrating</td>
<td>Financialization is a fundamental source of decoupling and vulnerability</td>
</tr>
<tr>
<td>Methodological individualism ('the whole is the sum of its parts')</td>
<td>Holism ('the whole is more than the sum of its part')</td>
</tr>
<tr>
<td><strong>On knowledge</strong></td>
<td></td>
</tr>
<tr>
<td>Correspondence: financial knowledge reflects how the economy works</td>
<td>Performativity: financial ‘knowledge’ shapes the economy</td>
</tr>
<tr>
<td>Disciplinary academic research methods (neoclassical economics, econometrics)</td>
<td>Multi-disciplinary (social sciences, financial economics, biology), trans-disciplinary (multi-stakeholder) research methods</td>
</tr>
<tr>
<td>Focuses on ‘what is’</td>
<td>Inquires into ‘what should be’</td>
</tr>
</tbody>
</table>

Neoclassical finance theory assumes financial systems to be stable, external, objective and independent entities, clearly separated from the socioeconomic sphere and the Earth systems. It assumes that financial markets spontaneously find their equilibrium, unless thrown off by a shock external to their own logic. It rests on a methodological individualism hypothesis (i.e. assuming that ‘the whole is the sum of its parts’). It attempts to explain and predict what happens to the financial world by searching for regularities and causal relationships between its constituent elements. It adopts a positivist stance (‘value neutrality’) on knowledge and assumes that finance models simply reflect reality. It relies heavily on the hypothetic-deductive methods, which have triumphed in natural sciences. This leads to reify temporary economic and institutional arrangements, and to focus on ‘what is’ rather than asking ‘what should be’.

Ecological Finance Theory starts from the observation that the world has entered the Anthropocene and posits that the fairness and efficacy of a financial system cannot be evaluated based on the monetary signals that it generates internally, but by examining feedbacks with the biophysical and socioeconomic spheres. It adopts a holist perspective (i.e. acknowledging that ‘the whole is more than the sum of its parts’). It recognizes that humankind is subject to ‘macrofoundations’ in the form of environmental, historical and societal forces that define and constrain modes of economic activity. It recognizes that financial models, tools and instruments do not merely reflect reality but contribute to shaping it. In fact, it posits that claims of ‘value neutrality’ in finance are the hypocritical articulation of a value judgement aimed at preserving the statu-quo (Reardon et al., 2018)18. At a methodological level, it welcomes

---

18 Ecological Finance Theory attempts to respond to Joan Robinson’s call on economists to “speak up on the side of humanity” (Reardon et al., 2018).
multidisciplinarity as well as transdisciplinary (engagement of societal actors in co-design or co-production of research) in its search for innovative solutions to respond to 21st century challenges. Finally, Ecological Finance Theory is mission-driven and inquires into ‘what should be’. Its main objective is to maintain social resilience by aligning financial models, tools, and policies with social and biophysical constraints.

4. Metaphors for Ecological Finance Theory

Within a given paradigm, a shared language structures scientific activities. This language defines the scope of the relevant research questions and orient the research hypotheses tested within a given paradigm. Research metaphors are the basis of such language (Ardalan, 2008). This section introduces resilience, diversity, self-thinning, mitosis/growth, and transparency as an initial set of metaphors for Ecological Finance Theory. These new metaphors are obtained by drawing analogies from biological literature. They offer consistent substitutes to metaphors used in neoclassical finance, and provide the basis of future theoretical and empirical examinations/explorations in Ecological Finance Theory. These new metaphors. We also hope that they will permit a wider understanding among people from different disciplines.

4.1. Resilience

The goal of Ecological Finance Theory is to ensure socioeconomic resilience in the age of the Anthropocene. Resilience is defined as the capacity of a system of any kind to “adapt or transform itself in response to unfamiliar, unexpected events and extreme shocks” (Folke et al., 2016).

At a theoretical level, Ulanowicz et al. (2009) have determined that any system’s (e.g. biomass, electrons, information, goods or money) total capacity for development (C) is the sum of two components: ‘throughput efficiency’ (A) and ‘resilience’ (ϕ):

\[ C = A + \Phi \] (1)

In equation (1) A refers to the system’s ability to exercise sufficient directed power to maintain its integrity over time, and \( \Phi \) refers to its ability to withstand shocks and adapt itself when necessary. \( \phi \) represents the reserve that allows the system to persist and is the key to system’s resilience. Defining \( a = \frac{A}{C} \) as the relative measure of organizing power flowing within the system, and noting that a is bounded between 0 and 1, Ulanowicz et al. (2009) defined a system’s ‘fitness for evolution’ \( F \) using Boltzmann’s formulation:

\[ F = k \log(a) \] (2)

In equation (2) \( k \) is a positive scalar. If \( a = 1 \), \( F \) tends towards zero because the system has insufficient resilience. If \( a = 0 \), then \( F \) also tends towards zero as the system has insufficient throughput efficiency. Finally, \( F \) goes up and down for intermediate values of \( a \) and peaks at \( a = \frac{1}{e} = 0.36 \). When \( a < 0.36 \), the system likely requires more efficiency. Conversely, when \( a > 0.36 \), the system may require more resilience. As shown in figure 3, there is a zone of optimal robustness, where \( F > 0.95 \). This zone, which has been observed in real ecosystems, has been named the “window of viability”. Observe that there is an asymmetry: viability requires more resilience than efficiency.

Ecological Finance Theory borrows from this approach and posits that an excessive focus on efficiency – at the financial, macroeconomic, sectoral, corporate level – carries important risks, as it is detrimental to resilience and ultimately for fitness for evolution. The concept of resilience echoes recent work in Earth Science highlighting the vulnerability of the global production ecosystem to exogenous shocks (Nyström et al., 2019).
Figure 3 Fitness for evolution and the window of resilience

Note: this chart plots system fitness for evolution $F = k \log(a)$ for different values of $0 < a < 1$. The dotted line indicates values superior to 0.954 and the window of resilience. See Ulanowicz et al. (2009), Ulanowicz (2009), Ulanowicz et al. (2009) for details.

4.1.2. Diversity

Biological diversity losses threaten the survival of ecosystems because they decrease resilience, i.e. the ability to resist external disturbances and to return to dynamic equilibrium states (Begon et al., 2005). In nature, the resilience of each ecosystem is proportional to the diversity of species and the diversity of interactions among them. The notion of diversity allows us to delineate several useful metaphors that could be used in Ecological Finance Theory. As shown in table 3, the diversity of organizations and the diversity of their interaction in the socioeconomic sphere mirrors the diversity of biological species and relationship observed in an ecosystem. The metaphor of diversity has several ramifications, which could provide the ground for a vast research agenda in years to come.

Each natural ecosystem is characterized by a biocenose, i.e. a complex system made up of a web of species governed by individual behavioral norms, and interconnected through diverse forms of relationships. These relationships take various forms. Some are harmful to other species, such as predation (e.g. a ladybird feeds from 300 to 1500 aphids during its lifetime) or parasitism (e.g. lice on a human scalp). Others are positive, such as commensalism (e.g. the remora fixes its dorsal sucker to a more efficient swimming fish, which carries it to areas abundant in food); synergies (e.g. spruce trees grow faster with an undergrowth of broom given that the latter fixates azote), mutual help (e.g. herbivores of different species in Africa graze side by side in order to signal to each other the presence of carnivores), or symbiosis (e.g. the microbe flora obligated to live in human intestines help it to digest and protects it against pathogens or dysfunction).

The diversity observed in nature mirrors diversity happening in the socioeconomic sphere. This is evidenced by the existence of many different organizations with varied statuses and sizes (charity, limited liability company – LLC, public limited company – PLC, cooperative, mixed association, small and medium-sized enterprises (SMEs), etc.). Interactions between these entities take very different forms depending on place and time (Descola, 2005; Ostrom, 2005; Meiksins-Wood, 2009, 2013, 2014; Testart, 2007; Servet, 2012; Graeber, 2011). Five types of relationships characterize circulation within or between communities: gift, reciprocity, non-market exchange, and market exchange, which can be
sub-divided to describe a specific relationship which is capitalistic market exchange [Mauss, 2012: 65; Rehn, 2014].

**Table 3: Diversity of relationship**

<table>
<thead>
<tr>
<th>In the biosphere</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predation</strong></td>
<td>One species uses another specie (prey) for food consumption</td>
</tr>
<tr>
<td><strong>Parasitism</strong></td>
<td>One species uses another specie to feed and to reproduce without inducing its death</td>
</tr>
<tr>
<td><strong>Commensalism</strong></td>
<td>One species survive thanks to the presence of another species to which it is indifferent</td>
</tr>
<tr>
<td><strong>Synergy</strong></td>
<td>The development of an organism is stimulated by the presence of another species</td>
</tr>
<tr>
<td><strong>Mutual help</strong></td>
<td>Living organisms associate with one another in order to reach a shared benefit (even if they could develop independently in normal conditions)</td>
</tr>
<tr>
<td><strong>Symbiosis</strong></td>
<td>Two protagonists beneficte from reciprocal advantages and could not survive without the union</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In the socioeconomic sphere</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gift</strong></td>
<td>Gift exchange strives to be disinterested and timeless. There is no inherent obligation or right, either for the transferer or the recipient. It remains unilateral.</td>
</tr>
<tr>
<td><strong>Reciprocity</strong></td>
<td>It implies neither synchronicity nor obligation in its inherent two-way movement.</td>
</tr>
<tr>
<td><strong>Exchanges</strong></td>
<td>They concern a causal relationship and an obligation.</td>
</tr>
<tr>
<td><strong>Non-market exchange</strong></td>
<td>Price or value considerations are not sufficient to provoke the exchange.</td>
</tr>
<tr>
<td><strong>Non-capitalistic market exchange</strong></td>
<td>The exchanger seeks use value from the good provided in return.</td>
</tr>
<tr>
<td><strong>Capitalistic market exchange</strong></td>
<td>The exchanger seeks exchange value from the good provided in return.</td>
</tr>
</tbody>
</table>

Source: Testart (2007); Lagoarde-Segot and Paranque (2018)

*Diversity* is a relevant and multifaceted metaphor with which to study the conditions for socioeconomic resilience. This metaphor allows us to study corporate governance and value creation from a macrosystemic perspective, acknowledging that accounting and finance are no more than the “subjective construction of human beings who create and sustain a world of inter-subjectively shared meaning” (Ardalan, 2008, p.7). *Diversity* is at odds with the neoclassical notion of shareholder value maximization, which reduces the company and its constituents to a set of atomistic agents adopting profit-maximizing behavior. *Diversity* is an invitation to revisit the notion of ‘value creation’ based on the acknowledgement of biophysical constraints, and with the objective of maintaining resilience.

### 4.1.3. Self-thinning and inequalities

*Resilience* and *diversity* are incompatible with the unlimited growth of individual species within an ecosystem. Growth indeed imposes constraints at individual, population, community and ecosystem levels. Biological research has shown that a trade-off exists between size and density of individuals sharing a common space. This trade-off has been empirically described as a ‘self-thinning law’ (or ‘3/2 Power law’) which posits that in denser populations of individuals, each one will have smaller average size, because space (or other resources) are limiting. For example, a forest of trees will have smaller trees if the planting density is very high. However, the *self-thinning law* is broken in ecosystems with large inequalities in individual size. These inequalities allows the possibility of obtaining or computing larger averages of individual size than
those expected for a given density. This effect was recorded for an intertidal marine algae (Figure 4). In this algae very high density can coexist, at the same time, with large averages of size. But this was possible only because their size inequalities are extreme (recorded inequality Gini coefficients were between 0.9 and 0.95). That is, a single individual of this algae, in a given space, can effectively account for almost 95% of the entire mass of individuals in the whole population (Martínez and Santelices 1992). In this biological species, observed individual growth could go beyond its limits only if inequality in the population was extremely high, with almost all plant biomass concentration in one single individual. It means that the computed average size does not exist in real individuals. It is only a mathematical result. What it really exists is a huge size inequality among individuals. The self-thinning law is illustrated with figure 4, which plots log biomass (log B) per unit area vs. log density (log D) of survivors, known as the B–D diagram together with the outlier. This outlier is a higher mean size (biomass) than the expected values (those below the limiting slope). This case is only observed when inequality in individual size is extremely high. But in such populations, such high mean size does not really exist, it is just a mathematical result of averaging sizes of highly unequal individuals.

**Figure 4 Self-thinning and the B-D diagram**

![Figure 4 Self-thinning and the B-D diagram](image)

Note: this figure displays the Logarithmic relationship between a measurement of mean size of individuals of a population as it decreases at higher density in a given space. For plants the slope is -1.5 and it has empirical limit extreme values at both axes, related to architectural constraints given by forms. The point over the limit slope represents an unexpected combination of size and density, only found mathematically possible when there was a huge size inequality among the observed individuals.

The self-thinning law provides a useful analogy for understanding the conditions for resilience and diversity in the socioeconomic sphere. The Global Production Ecosystem (GPE) is made of a very dense network of transnational corporations (TNCs) that link production ecosystems globally through their subsidiaries (Österblom et al., 2015). The development of TNCs in turn goes hand in hand with an unprecedented concentration in global ownership. In a major study covering over forty thousand transnational corporations, Vitali et al. (2011, 2014) demonstrated that transnational corporation ownership and control is extremely concentrated. A growing network of interconnected financial intermediaries controls the network: financial intermediaries hold shares larger than 5% in 13% of non-financial companies and in 60% of other financial companies. A few financial actors dominate all segments of production, control the whole supply chain and have a disproportionate influence on decision-making (Clapp and Fuchs, 2009). These actors are marked by a high level of size, internationalization, complexity, interconnectedness, and lack of substitutability (in providing key services, such as market infrastructures). Their distress or disorderly failure would cause significant disruption to the wider financial system and economic activity (FSB, 2019).

Figure 5 develops this analogy by comparing the global network of corporate control with a marine alga, where one individual almost represents ‘the whole forest’. Ecological Finance Theory seeks to
carve out strategies that could enhance self-thinning, in order to foster diversity and resilience in the socioeconomic sphere.

**Figure 5 Self-thinning and inequalities**

The contours of a “mean sized alga” to the left of the big individual in the center is the statistical representation of an often non-existent mean individual. As a metaphor of the non-existing mean income (GDP) in the economy of many countries where inequalities are dominant. Source: Vitali et al. [2011]. A dark dot indicates a super-connected firm, a light dot indicates a very connected firm. The size of each dot is proportionate to the firm's revenues.

4.1.4. Mitosis and growth

Neoclassical finance theory urges endless growth in size because it implicitly assumes that growth is a sufficient measure of health. Growth or growing is indeed an innate goal that defines every living organism. However, one fundamental principle of biology is that each individual (and population) have growth limits (Figure 5). A bacterial cell divides in two through a mechanism called mitosis. Then, each daughter cell soon grows to the same size as the cell that gave rise to it, then remains unchanged. What grows is the number of cells, as the growth of different organs in an individual. But even this is limited. For example, the cells that make up an organ (liver, skin, muscles, the bones) all possess information allowing them to reach a certain size and then stop. The whole body also reaches a limited size (at dynamic equilibrium). Excesses of size are always signs of illness, obesity or cancer to name a few. Unlimited growth finds detention at the depletion of resources (lack of food for the case of bacterial growth) or exhaustion of the body’s energy in a patient with cancer, and the resulting body degradation and death. It is easy to imagine how this metaphor of unlimited growth exhausting the system also applies to the connections between the biosphere and the economic world.

In recent years, Earth Scientists have highlighted the dangers of unlimited and exponential growth of the Global Production Ecosystem (figures 2a and 2b). This apparently limitless expansion (which is associated with losses in diversity and self-thinning) decouples production from the natural processes required to sustain the desired production outcome. Several mechanisms have been identified. For instance the use of human input (e.g. fertilizers) has suppressed short-term variance in harvestable biomass and in consumer prices, but also suppressed important feedback signals and decreased the resilience of global and local ecosystems (Nyström et al., 2019). In the case of chemical fertilizers, they increase harvests in the short term but in the long term soils die by excess of salts. A global homogenization of species (including genes, varieties and crops) the replacement of tropical forests by spatially extensive monocultures (for instance, soy and oil palm plantations), and the homogenization of rainforest bacterial communities, as a result of land conversion to cattle pasture, have also been observed. All these factors are detrimental to the resilience of the global production ecosystem (Jefferson et al., 2015; Koh et al., 2008; Rodrigues et al., 2013). As another metaphorical analogy,
figure 5 juxtaposes a bacterial mitosis process with the Great Acceleration of GDP since 1750. Collapse can be easily suspected to come soon, on both cases because resources do have limits. Biological systems have included the internal control to growth, probably as an evolutionary retained strategy to keep alive. As the time of writing, the COVID-19 pandemic – a biological shock – has been touted as the largest recession in modern economic history. It remains to be seen whether the GDP per capita curve will eventually collapse and mirror the mitosis curve on the left-hand side of figure 5, and validate the predictions of the 1972 Meadows Report of the Club of Rome.

**Figure 5 – Mitosis process and GDP per capita**

![Graph showing exponential evolution of GDP per capita and that of a cell doubling in numbers following less than fifty steps of mitosis (doubling at each step or time interval common in cellular type of growth). The data on the right-hand side of the figure is taken from the Maddison project (2018).]

4.1.5. **Transparency**

A system is better understood (and its limits better recognized) if the functioning of all components is transparent to all those observing (and using) the system. **Transparency** concerns any signals regarding the effects uniting finance, the socioeconomic sphere and the biophysical spheres, and affecting resilience. If something is ignored (or hidden), the understanding will be partial and the managing will be more difficult. For instance, in human biology if one hides from a medical doctor the symptoms or day-to-day behaviors, it will be more difficult for the doctor to control the illness. In the economy, transparency should help controlling client fidelity, it contributes to better and sustainable relationships within and between organizations. It could also help consumers to take intelligent and healthy decisions for them and for the whole system by taking environmental aspects into full consideration.

One should note that transparency, in the context of Ecological Finance Theory, goes beyond ‘perfect information’ on prices postulated by neoclassical ‘pure and perfect competition’. As discussed in the previous sections, the socioeconomic sphere and the biophysical sphere interact through complex feedbacks at different time spans and across locations. **Transparency** applies not only to market prices, but to the decoupling of the price system from the biological effects it generates.

Consider a simple plastic pencil, which is very cheap. However, the plastic itself is made of fossil oil, which took millions of years to be formed from past biomass living on earth ecosystems. This limitation to renewal of the prime matter cannot be included in the price of this object. Lack of transparency about this simple fact leads the current model to decouple earth systems from financial theory and practice. Recycling, a solution put forth by companies, is a step ahead towards circular thinking, but it will never replenish the stock of fossil oil. Other similar metaphors of biology applied to the economy realm can be found in Martínez (2018).
4.1.6. Modern finance vs. ecological finance theory: metaphors compared

The preceding section sought to put forth an initial set of metaphors aligned with the meta-theoretical hypotheses of Ecological Finance Theory. As shown in table 4, these metaphors contrast with the metaphors used in neoclassical finance. Where neoclassical finance takes economic efficiency (defined from the shareholder perspective) as a natural goal, ecological finance analyzes policy and corporate practices from the perspective of resilience. Where neoclassical finance considers value creation narrowly defined at the company level through financial metrics (such as ROA, EVA, and others...), ecological finance theory evaluates economic and financial events from the perspective of diversity. Where neoclassical finance theory posits that corporate growth is unambiguously beneficial, ecological finance theory analyzes the relationship between corporate growth and inequalities from the perspective of self-thinning and mitotic control, opposed to exponential growth. Finally, where neoclassical finance theory assumes that perfect market information is sufficient in order to generate an equilibrating and optimal vector of relative prices, ecological finance theory calls for transparency on the effects of economic activities on the biosphere and societies. The initial set of metaphors contained in table 4 is expected to expand as Ecological Finance Theory develops.

Table 4 Metaphors in Neoclassical Finance Theory and Ecological Finance Theory compared

<table>
<thead>
<tr>
<th>Neoclassical finance theory</th>
<th>Ecological Finance Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Resilience</td>
</tr>
<tr>
<td>Shareholder value</td>
<td>Diversity</td>
</tr>
<tr>
<td>Growth (even exponential)</td>
<td>Self-thinning and organic growth as programmed mitosis in the biological realm</td>
</tr>
<tr>
<td>Perfect market prices</td>
<td>Transparency</td>
</tr>
</tbody>
</table>

5. Applying Ecological Finance Theory to puzzle solving: upscaling the transformative power of local complementary currencies

Puzzle solving refers to normal scientific activities within a given theory (or paradigm). Puzzle solving is the activity through which researchers operationalize the detailed implication of accepted meta-theoretical hypotheses and metaphors in their paradigm. Puzzle-solving entails the detailed analysis of specific phenomena. It thus involves the solution to all sorts of complex problems through specific models or tools. The primary objective of puzzle-solving activities in Ecological Finance Theory is to align financial models, tools, and policies with social and biophysical constraints. In this section, we will undertake a preliminary puzzle solving, investigating potential policy innovations permitting to upscale the transformative power of local complementary currencies. Our objective is to convince the readers of the practicality and relevance of the hypotheses and metaphors developed so far and to invite them to join the conversation.

5.1. Local complementary currencies

Puzzle-solving requires a definite study object. Local complementary currencies appear as a natural object of study for Ecological Finance Theory. A large body of literature indicates that these currencies contribute to embedding economic activities (including financial activities) within a broader sustainable relationship between humans and the environment (Dron, 2019, Aglietta, 2018, Monvoisin 2016, Blanc 2018, Blanc and Lakócai 2020, Blanc and Marie 2016). Local complementary currencies are characterized by a rich diversity. They take different forms (including time-currencies, time banks, local commercial monies, and netting agreements between companies), and rely on different circulation technologies (scriptural or electronic). They are usually convertible in the legal tender at a fixed rate.
Previous research has shown the potential of local complementary currencies to increase resilience by extending the diversity principle to the monetary sphere itself (Liettaer, 2010). Local complementary currencies circulate within a predetermined sphere corresponding to a local “ethico-political complex”. They complement the legal tender by expressing the ‘sovereignty of the common’ at the local level (Aglietta, 2018)\(^{19}\). They manifest the emergence of a new economic rationality – driven by an ethical value standard rather than a capitalist standard. Local complementary currencies promote a shift from an accumulation of money value to a form of global ethical value derived from the mechanisms of production\(^{20}\).

Local complementary currencies thus foster economic diversity by promoting relationship cooperation, symbiosis, synergies, mutual help (rather than predation), and set use value (rather than exchange value) as a motivation for exchange. They also contribute to transparency in economic relations by establishing new consumption practices that respect the environment by encouraging production, which conserves ecosystems (e.g. by lowering pollution induced by transport, using of clean energy, reducing waste output and promoting principles of fairness). Such systemic transparency could help all stakeholders, from consumers to suppliers, to fight against the danger of unlimited mitosis like excessive corporation growth (in particular the development of monopolist or monopsonycal markets).

5.2. Elements of an upscaling strategy

However, these currencies (which, for the most part, result from grassroots initiatives) are still, largely excluded from mainstream financing circuits. This is due to their geographical location and to the size of enterprises that take part in it (such as individual, local small and medium sized enterprises). Identifying new policy pathways permitting to upscale the transformative power of local complementary currencies thus appears to be a relevant puzzle-solving question for Ecological Finance Theory

We put forth a strategy permitting to initiate a structural transformation of the economies by blending the “bottom up” development of local complementary currencies with a “top down” monetary and prudential policy scheme. In line with the core hypotheses of Ecological Finance Theory, our objective is not to stimulate economic activity per se, but to initiate a qualitative modification of production and consumption patterns in a given territory permitting to increase resilience\(^{21}\). As Ecological Finance Theory focuses on what should be rather than on what is, the reader is asked to exercise imagination.

The first step of the envisaged policy is the creation of European Ecological Finance Agencies (EEFA). EEFAs are extra-financial informational intermediaries, placed under the authority of European Central Bank. EEFAs are deployed in each European territory, with local branches at the regional and municipal levels. EEFAs are staffed with sustainability transition experts possessing interdisciplinary skills and competencies in the fields of sustainability, engineering, entrepreneurship and sustainable finance, and a strong knowledge of the local territorial context. Local public representatives (such as local elected representatives, delegates of chambers of commerce, trade unions, Universities, and other stakeholders…), as well as citizens chosen at random, are also involved in these Agencies.

\(^{19}\) Local complementary currencies are different from ‘cryptocurrencies’ (such as bitcoins): they do not seek to replace the legal tender but propose instead to increase its circulation at the territorial scale, and in the perimeter of SDG-compliant organizations. By contrast, cryptocurrencies (such as bitcoin) are speculative by nature, detached from any notion of the public good, and disconnected from any sovereign monetary authorities that might guarantee its liquidity and endurance (Aglietta, 2018, p.173).

\(^{20}\) Ardvidsson (2009) and Paranque and Revelli (2017) have coined the term “Philia” to describe this global ethical value. Philia is a Greek word meaning friendship, affective proximity, goodwill and positive expectations. Marx’s general formula of capital may then be amended as follows: \(\text{Philia} - M - C - P - C^* - M^* - \text{Philia}\), embedding capitalistic accumulation within a larger ethical standard.

\(^{21}\) Current ‘helicopter money’ proposals, which aim at replicating the effects of a fiscal stimulus on traditional indicators of GDP growth by credit bank accounts might be ill-suited for this task. Rather than ‘helicopter money’, we suggest instead ‘drop-by-drop irrigation’ as a relevant metaphor: the scheme backs existing complementary currencies with the monetary authorities, and provide these initiatives with targeted funding, permitting to upscale SDG transformation.
The first task of EEFAs is to identify the sphere of circulation for the local complementary currency. This is achieved by initiating a democratic (and transparent) dialogue framed by the SDG indicator agenda. Local objectives for the local complementary currencies could include, for instance, supporting Small and Medium sized Enterprises (SMEs, in response to SDG 8), developing local food systems (in response to SDG 8, 12, 13), reducing traffic congestion (SDG 13), limiting urban sprawl and deforestation (SDG 14)\(^{22}\). In any case, the chosen approach must be a ‘bottom-up’ one, given that the objectives of the local complementary currencies is to foster a shared conception of social value (the ‘common good’).

Based on this discussion EEFAs then establish a territorial ‘sustainability taxonomy’ (as recommended by the HLEG, 2018). This taxonomy identifies the firms, enterprises, and sectors eligible for loans and for receiving income in the local complementary currencies.

Finally, EEFAs monitor the efficacy of local complementary currency in fulfilling its social and ecological objectives. The Social Return on Investment (SROI) method appears to be particularly relevant in this endeavor. SROI measures “how change is being created by measuring social, environmental and economic outcomes and uses monetary values to represent them. This enables a ratio of benefits to costs to be calculated. For example, a ratio of 3:1 indicates that an investment of £1 delivers £3 of social value. SROI is about value, rather than money. Money is simply a common unit and as such is a useful and widely accepted way of conveying value”. (Nicholls et al., 2009). The SROI methodology provides a powerful frame to construct worthiness and value creation for activities, even in cases where no actual financial returns are generated (Yates and Marra, 2017; Cooney, 2017).

In what follows, we show how the SROI evaluation permits to upscale the transformative power of local complementary currencies through their integration within the broader monetary and financial system.

5.3. Certificates and the rediscounting of local complementary loans

Our proposal consists in articulating local complementary currencies, extra-financial ratings conducted by EEFAs, and monetary policy. We put forth a simple arrangement in which banks rediscount a fraction of their local currency loans, based on the social value generated by these loans. The mechanism can be described as follows. Each year, the European Ecological Finance Agency computes the SROI of the stock of local complementary currency loans issued at the previous period \((L_{s,lc-1})\). Banks thus obtain an annual flow of ‘impact certificates’. These impact certificates are represented with the letter \(\phi\) (for “Philia”):

\[
\phi = (1 + SROI)L_{s,lc-1}
\]

Banks can ask the Central Bank to convert of a fraction of these impact certificates into high-powered money. Each year, the Central Bank thus rediscount a fraction \(\tau\) of the local currency loan portfolio, in exchange for the SROI certificates issued by EEFAs. Letting \(\tau\) denote the haircut rate and \(A\) the advances to the banking system the amount of reserve issues is given by:

\[
\Delta A = \tau \cdot \frac{\phi_{t-1}}{(1 + SROI_{t-1})}
\]

Alternatively, banks may also choose to package these SROI certificates in socially responsible assets portfolios sold to other banks or investment funds. Banks could also choose to keep these SROI

\(^{22}\) The priorities identified would of course be different at each territorial level. One may imagine, for instance, that SDG 8 (creating decent work and economic growth), SDG 9 (increasing industry, innovation an infrastructure), SDG 10 (reducing inequality) and SDG 11 (mobilizing sustainable cities and communities) would be prioritized in urban areas (such as the Paris suburbs). In other areas, for instance those exposed to anarchic real-estate pressure and urban sprawling putting ecosystems and natural resources at risk (for instance the Provence region in France), SDG 13 (organize climate action) and SDG 14 (develop life below water) could be designated as the most relevant. As for what we are experiencing during the present COVID-19 pandemic, we could also imagine a priority for SDG 10, so that speed and focus of means should be addressed first to help those at lower health/social/economic/educational levels.
certificates in their balance sheets in order to improve their own Environmental and Social Governance rating.

Finally, the emission of SROI certificates and the rediscounting of local complementary currency loans is akin to a slow metamorphosis of money. This metamorphosis may seem dangerous or non-natural as seen from the perspective of neoclassical finance theory. However, money is a temporary institution, defined as “the means by which societies gives back to each of its members what it judges each of them to have given to it” (Aglietta, 2018, p.32). Money is external to economic actors: it is primarily a “relation of belonging (…) that links each member of the social group to the whole” (ibid p.6). The emission of SROI certificates by the EEFAs, and its convertibility in reserves, therefore embeds money and the evaluation of socio-economic activities within local and global ecological constraints. It contributes to the emergence of a ‘global ethical value standard’ underpinning adequate forms of economic rationality for the 21st century.

5.4. A stock-flow consistent model

We now introduce a new stock-flow consistent (SFC) model in the spirit of Godley and Lavoie (2012) in order to gain further insight into the strategy outlined in the previous section. Our model - which we call Philia 1.0 - is comprised of 35 accounting and behavioral equations interlocked in a sectoral transaction matrix. These equations, and the procedure followed to simulate the model, are both described in detail in the appendix.

Table 6 The accounting transactions flows matrix of model Philia 1.0

<table>
<thead>
<tr>
<th>Transactions</th>
<th>Households</th>
<th>Production firms</th>
<th>Banks</th>
<th>Central Bank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>Current (2)</td>
<td>Capital (3)</td>
<td>Current (4)</td>
</tr>
<tr>
<td>Consumption</td>
<td>−C</td>
<td>C_{m} + C_{lec}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>l_{m}</td>
<td>+l_{lec}</td>
<td>−l_{m}</td>
<td></td>
</tr>
<tr>
<td>[GDP]</td>
<td>[Y]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wages</td>
<td>+W</td>
<td>−W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depreciation</td>
<td>−DA</td>
<td>+DA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest on loans</td>
<td>r_{d,m}l_{m-1}l_{m-1}</td>
<td>−r_{d,m}l_{m-1}l_{m-1}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest on deposits</td>
<td>r_{d,le}(−1)l_{m−1}l_{le−1}</td>
<td>−r_{d,le}(−1)l_{m−1}l_{le−1}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changes in loans</td>
<td>Δl_{d,m} + Δl_{d,lec}</td>
<td>−Δl_{d,m}</td>
<td>−Δl_{d,lec}</td>
<td></td>
</tr>
<tr>
<td>Changes in deposits</td>
<td>ΔM_{m} − ΔM_{lec}</td>
<td>ΔM_{m}</td>
<td>+ ΔM_{lec}</td>
<td></td>
</tr>
<tr>
<td>Firm profits</td>
<td>+F</td>
<td>−F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bank profits</td>
<td>FB</td>
<td>−FB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SROI certificates</td>
<td>(Philia)</td>
<td>−Δφ</td>
<td>−Δφ</td>
<td></td>
</tr>
</tbody>
</table>

The model’s transaction matrix is shown in table 6. This transaction matrix constitutes the accounting backbone of the model and ensures that all flows and stock readjustment are interlocked in a watertight accounting structure integrating the real and financial sides of the economy. The matrix describes a simplified economy with five institutional sectors: households, production firms (divided into the sustainable and the non-sustainable sector), a banking sector and a Central Bank. There is no specification of a particular kind of government in the model. This assumption (which allows us to reach our objectives while keeping the model as simple as possible) implies that money is emitted...
through bank loans\textsuperscript{23}. In line with double entry bookkeeping principles, each economic transaction is double-sided, i.e., one sector’s income is another sector’s spending, and one sector’s asset is another sector’s liability. Changes to the stock of assets and liabilities (in columns) result from the budget constraint of each individual sector, which itself depends on annual flows of income and spending (in rows). This ensures that there are no black holes in the system (‘everything comes from somewhere and goes somewhere’) and that the real and financial sides of the economy are fully integrated. Following SFC modelling convention, a (+) sign indicates a source of funds while a (−) sign indicates a use of funds.

Column 1 shows the budget constraint of households. Households receive income as wages (\(W\)), profits redistributed by firms (\(F\)) and banks (\(FB\)), and interests on their euro (\(r_{d,m}(-1)L_{m}(-1)\)) and local complementary currency deposits (\(r_{d,icc}(-1)L_{icc}(-1)\)). Households spend their income on consumption expenditures in euros (\(C_{m}\)) and in complementary currency (\(G_{icc}\)). At the end of each period, excess of income over spending accumulates in stocks of banking deposits, which households hold both in euros (\(\Delta M_{m}\)) and in local complementary currency units (\(\Delta M_{icc}\)).

Column 2 and 3 divide the production firm sector’s activities into a current and capital account. It amalgamates the sustainable sector (where both euros and local complementary currencies circulate) and the non-sustainable sector (where only the euro circulates). Column 2 shows the receipts and outlays of production firms. Firms receive payment flows on their sales of final goods in euros (\(C_{m}\)) and in local complementary currencies (\(G_{icc}\)), and on their sales of capital goods (in euros (\(I\)) and in local complementary currencies (\(I_{icc}\))). They pay wages to households (\(W\)), interest on their loans in euros (\(r_{l,m}(-1)L_{m}(-1)\)) and in local complementary currencies (\(r_{l,icc}(-1)L_{icc}(-1)\)) and set aside funds for depreciation allowances (\(DA\)).

Column 3 shows that firms’ capital expenditures are financed by depreciation allowances (\(DA\)), new loans in euros (\(\Delta L_{d,m}\)) and in local complementary currencies (\(\Delta L_{d,icc}\)). In our simple setting, profits (\(F\)) are a residual which is fully distributed to households.

Columns 4 and 5 show the current account and the capital account of banks. In column 4, banks receive interest payments on loans in euros (\(r_{l,m}(-1)L_{m}(-1)\)) and local complementary currencies (\(r_{l,icc}(-1)L_{icc}(-1)\)) and pay interests on deposits in euros (\(r_{d,m}(-1)L_{m}(-1)\)) and in local complementary currencies (\(r_{d,icc}(-1)L_{icc}(-1)\)). Column 5 shows that new deposits in euros (\(\Delta M_{m}\)) and in complementary local currencies (\(\Delta M_{icc}\)) appear on the liability side of banks balance sheets. They are the counterpart to the assets owned by banks, which include loans in euros (\(\Delta L_{d,m}\)) and local complementary currencies (\(\Delta L_{d,icc}\)), high-powered money (\(\Delta A\)), which is emitted through the rediscounting of local currency loans based a fraction of the SROI certificates issued by EEFAs (\(\Delta \phi\)). The difference between assets and liabilities constitutes banking profits which are redistributed to shareholders (\(FB\)).

Column 6 shows the capital account of the Central Bank. In our simplified setting, the Central Bank’s only liability is the high-powered money (reserve currency) that it issues (\(\Delta A\)), in exchange for impact certificates issued by EEFAs and provided by the banks (\(\Delta \phi\)).

5.4.2. Simulations

We proceed as follows. We first set the model’s parameters so that local complementary currencies are absent and bring the model to a stationary steady-state. A stationary steady-state is defined as a state where stock and flow variables remain in a constant relationship to each other, while also being stable in levels. Such a state, of course, is never reached in the real world, because parameters and exogenous variables are changing all the time. The steady state serves as an analytical device permitting to gain insight into the impact of the initial and terminal effects of a given shock to the economic system (Godley and Lavoie, 2012).

\textsuperscript{23} As explained by the Bank of England (2014) and in much of the post-Keynesian economics literature (e.g. Lavoie, 2015) the majority of money circulating in the real economy is issued this way.
We then introduce local complementary currencies, both through the emission of loans and reallocation of wealth in household portfolios (as described in the appendix). In our simulation, households can convert their euro holdings into local complementary currency units, and banks can issue loans in these currencies to firms in the sustainable sector. The reaction of the models’ key variables to the introduction of these schemes is shown in figure 6 and 7.

Figure 6 displays the response of the macroeconomic system to the shock. Inspection of the figures shows that accounting consistency is respected throughout the simulations. The upper-left figure shows that the introduction of local complementary currencies increases GDP, consumption and investment. The upper-right figure shows that the increase in household consumption leads to an increase in both GDP and disposable income.

The lower left figure retrieves the cyclical dynamics generated by investment behavior. In our model, the initial increase in output following the shock leads firms to increase both net investment in fixed capital (as the capital target goes up, as implied by equation 16), and increase in depreciation allowances in order to replace an increasing stock of capital (as implied by equation 4). However as the economy approaches a steady-state, net investment falls to zero given that gross investment is equal to replacement investment. The lower right figures show that household gradually rebalance their holdings towards the local complementary currencies and that their portfolio stabilizes as the economy reaches a new stationary state.

However, from the perspective of Ecological Finance Theory, this expansionary effect is only a means to an end. What differentiates our proposed strategy from a mere stimulus program is that the expansion actually stems from a reorientation of finance and consumption towards the sustainable sector. This reorientation is measured by EEFAs, which quantify the social impact of local currency emissions and circulation by delivering banks a social impact certificate. These certificates report the SROI of the local complementary loans issued in the previous period. They permit to track the accumulation of global ethical value (which we call “Philia”) at the territorial level, as the local complementary currency circulates within its ethical sphere of exchange. In our settings, these certificates enable banks to rediscount a fraction of their local currency loans with the European Central Bank. Our policy therefore entails a qualitative modification of the economy. Positive effects are felt both within the real sector and the financial sector and are measured with quantitative metrics.
Figure 6 Model simulation

Source: Authors’ simulation.

Figure 7 reports such qualitative effects as captured by our simulation. The upper-left diagram displays the cumulative growth of GDP and social value, as measured by SROI certificates (‘Philia’), throughout the transition of the system towards the new stationary state. The triggered economic expansion appears interlocked in a process of accumulation of ethical value, as GDP and Philia certificates increase, and then stabilize together following the shock. The upper-right diagram displays the plotting of the annual growth rate of GDP and Philia certificates. It reveals that two different dynamics are at play. GDP growth increases abruptly following the shock, before stabilizing, while Philia increases with a lag, but more steadily over the longer run. The shift to a global standard of ethical value should hence modify our perception of economic performance and of the adequate timeframe to measure it.

The lower left figure displays the dynamic at play the financial sector side of the economy. Banking sector profits increase. This is because our strategy results in an increase in the global volume of loans issued to meet demand from consumers and firms. In addition, the banking sector accumulates social impact certificates, which permit banks to rediscount the corresponding local complementary currency loans currency with the Central Bank (according to the process described in equations 30 to 34). In a more complex setting including capital markets, these certificates of impact may also improve banks’ extra-financial ratings and positively influence their capitalization. In our simple model, however, we posit that banks use these certificates of impact to rediscount their loans to the sustainable sector with the Central Bank. This policy ensures, as shown in the figure, that the reserve to loan ratio remains stable throughout the simulation. Finally, the lower-right diagram shows that about 25% of new bank loans are labeled in the local complementary currency by the end of the simulation. Given that the local
complementary currencies only circulate within an ‘ethical’ sphere of exchange, this indicates a significant, yet credible structural ecological transition has taken place in the economy.

**Figure 7 Model simulation**

![Model simulation graphs](image)

Source: Author’s simulation.

6. **Conclusion**

A growing consensus among various disciplines and stakeholders indicates that biological systems, socio-economic systems, and financial systems can no longer be studied separately in the 21st century. Unfortunately, modern finance theory, by virtue of its meta-theoretical hypotheses *superimposes financial logics to the analysis of the environment*, when addressing the new context would instead require the order to be turned upside down. The ecological, social and economic challenges of our generation necessitate the revisiting of financial models, systems, structure, policies, instruments, and governance.

This paper has proposed *Ecological Finance Theory* as a new vision for 21st century financial economics. We have attempted to delineate this theory by reference to the three epistemological layers of discourse that structure scientific activities. We have therefore introduced a set of comprehensive *meta-theoretical hypotheses*, new research *metaphors*, and *puzzle-solving tools*, which we have gathered from a wide spectrum of literature in finance, social science and climate studies. In particular, we have paid specific attention to ontology, systemic embeddedness, and introduced concepts of *resilience, diversity, self-thinning, self-regulated mitosis, and transparency* in the field of financial economics.
through analogy from biology. Relying on these new principles, we then put forth a strategy to initiate a structural transformation of the economies in line with these principles. This strategy seeks to upscale the transformative power of local complementary currencies.

To gain further insight on our proposal we have also developed a new stock-flow consistent (SFC) model comprised of 35 accounting and behavioral equations interlocked in a sectoral transaction matrix. One important insight of the model is that the simultaneous introduction of a multi-stakeholder dialogue regarding the objectives of local complementary currencies, the systematic implementation of social impact measurement metrics (SROI), and a simple rediscounthing mechanism by the European Central Bank could lead commercial banks to increase the proportion of loans issued in local complementary currencies. This would contribute to reorient economic activities towards the sustainable development goals (SDGs), at various scales. Incidentally, the strategy presented in the model would also increase total gross production (in comparison to a system where local complementary currencies are absent); and permit to track the qualitative dimension of that production. In future work, we will significantly extend this model. One central objective of Ecological Finance Theory is indeed to put forth innovative policy proposals aligned with new meta-theoretical hypotheses and research metaphors.

We believe that this paper contains the basic elements of a new conceptual and methodological apparatus in financial economics. This new apparatus should allow our community to incorporate the complex feedback systems between financial systems, social provisioning and Earth systems into our analyses and prescriptions. We have thus sought to describe and contribute to a budding scientific revolution in the field of finance and to offering new foundations for finance research, teaching, policy and practice in the post-pandemic world.

Finally, Ecological Finance Theory is work in progress. Over the next few years, new metaphors will likely emerge, as well as new research questions, tools, puzzles, paradoxes and controversies in this paradigm. The key meta-theoretical hypotheses outlined in this paper will also need to be discussed and refined in future work. We invite all researchers – especially junior researchers and students – as well as practitioners and policy makers to join the discussion and contribute to the development of this new body of knowledge, which, we hope, will carve out pathways for global ecological, social and economic resilience.

References

Aglietta, M., Money: 5000 years of debt and power. Odile Jacob, 2018
https://doi.org/10.1007/s41247-018-0049-0
Blanc Jérôme J. et and Fare Marie, F. . 2016. « Turning values concrete: the role and ways of business selection in local currency schemes », Review of Social economy, 2016,


Clapp, J. Financialization, distance and global food politics. J. Peasant Stud. 41, 797–814


https://doi.org/10.1126/sciadv.aax3324
Lazinick, W. The financialization of the US corporation: What has been lost, and how it can be regained (2013).


Revelle, C., 2016. Re-embedding financial stakes within ethical and social values in socially responsible investing (SRI). Research in International Business and Finance 38, 1-5.


Appendix - Philia 1.0: a new stock-flow consistent (SFC) model

Stock-flow consistent (SFC) models as initiated in the groundbreaking work of Godley and Lavoie (2012) are flexible modelling tools based upon a consistent accounting framework integrating the real and the financial sides of the economy. SFC models allow incorporating banks and financial systems realistically in the analysis, as they acknowledge the endogeneity of money. SFC models are particularly appealing to researchers looking for an analytical framework in which “there is no need or room for the rational expectation hypothesis” (Godley and Lavoie, 2012, p.16). Indeed, SFC modelling does not require positing any assumption regarding firms and agents’ utility maximization behavior, or the availability of perfect information. It retains a principle of adjustment to observed disequilibria by positing that economics agents display procedural rationality, i.e. “set themselves norms and targets, and act in line with these and the expectations that they may hold about the future” (ibid, p.16). Due to their flexibility and realism, SFC models are becoming increasingly popular in a wide array of theoretical and applied literature, including finance and ecological economics literature (Gimet et al., 2019, Dafermos et al., 2018). We expect them to play a role in the development of ecological finance theory.

The model presented in this paper, which we call “Philia 1.0” is made up of 35 equations, with 35 endogenous variables. It is the simplest model we could think of to illustrate the policy scheme presented in the paper. The model is built according to principles outlined in Godley and Lavoie (2012). Given space limitations, we only offer a short description of each equations in what follows, but we advise the interested reader to consult chapters 3 and 7 in Godley and Lavoie (2012) for more details. We begin with the description of total gross production (GDP). GDP, denoted $Y$, is defined as the sum of all expenditures on goods and services, including consumption $C_s$ and investment goods $I_s$:

$$Y = C_s + I_s$$ (1)

In line with national accounting, GDP must also be equal to the sum of factor payment in the economy, that is wage bill (WB), production firms profits (F), banking profits (FB), and the depreciation and amortization funds (DA) that firms set aside to replace used-up capital:

$$Y = WB + F + FB + DA$$ (1.2)

Total personal disposable income, YD is defined as the difference between GDP net of depreciation and amortization funds:

$$YD = Y - DA$$ (3)

In the model, depreciation and amortization funds are a constant proportion $0 < \delta < 1$ of the stock of capital $K_{-1}$ that firms hold at the beginning of the fiscal year:

$$DA = \delta K_{-1}$$ (4)

The wage bill (WB) is equal to the product of the wage rate $W$ times the level of employment $N_d$. $N_d$ is determined based on output $Y$ and labor productivity $pr$:

$$WB = W \cdot N_s$$ (5)

$$N_d = \frac{Y}{pr}$$ (6)

$$W = WB_d / N_d$$ (7)

Total household depends on an autonomous component ($\alpha_0$), on disposable income (according to a factor $\alpha_1$) and banking deposits labelled in euros (according to a factor $\alpha_2$) and in local complementary currencies (according to a factor $\alpha_3$):

$$C_d = \alpha_0 + \alpha_1 (YD) + \alpha_2 (M_{h,m-1}) + \alpha_3 (M_{h,ccc-1})$$ (8)
We now define the budget constraint and the portfolio behavior of households. At the end of each year, whatever disposable income is not spent on consumption good $C_d$ is added to the stock of bank deposits $M_h$:

$$\Delta M_h = M_h - M_{h-1} = YD - C_d \quad (9)$$

At the beginning of each period, households’ demand for euros is a function of their global expected wealth ($M^e$) and expected macroeconomic income ($Y^e$). Households hold a certain proportion $\lambda_1$ of their expected wealth in the form of euros, but this proportion is modified by the level of expected disposable income. The proportion of euros demanded is expressed as follows:

$$\frac{\Delta M_{h,d,m}}{M^e} = \lambda_1 + \lambda_2 Y^e \quad (10)$$

Actual new euro holdings ($\Delta M_{h,s,m}$) are determined based on the demand for euros and actual wealth $M_h$:

$$\Delta M_{h,s,m} = \frac{\Delta M_{h,d,m}}{M^e} \times M_h \quad (11)$$

The demand for local currency by households corresponds to the gap between demand for euros and actual wealth. This means that in our model, the demand for local complementary currency deposits is a buffer, which varies according to unexpected variations in household income:

$$\Delta M_{h,ccc} = \Delta M - \Delta M_{h,s,m} \quad (12)$$

Expected wealth is the mirror of realized wealth (equation 4) in the realm of expectations. It is defined as:

$$M^e = M_{h-1} + (YD^e - C) \quad (13)$$

Expected disposable income ($YD^e$) is simply defined as the past period income:

$$YD^e = YD_{t-1} \quad (14)$$

The macroeconomic demand for investment ($I_{f,d}$) is based on the partial accelerator model. As shown in equation (15), gross demand for investment has two components. The first component is forward looking and adjusts partially ($\gamma < 1$) to the discrepancy between the targeted capital stock $K^T$ and the stock of machines $K_{-1}$ that was inherited from the previous period. The second component is simply the investment required to replace the used up machines $DA$:

$$I_{f,d} = \gamma (K^T - K_{-1}) + DA \quad (15)$$

The targeted capital stock $K^T$ is defined as a fraction of the sales achieved in the previous period:

$$K^T = \kappa Y_{t-1} \quad (16)$$

The stock of capital is equal to the stock inherited from the past period net of depreciation allowances, plus newly acquired capital:

$$K = (1 - \delta) K_{-1} + I_{f,d} \quad (17)$$
The demand for new loans is equal to the net demand for investment, i.e. to the difference between gross demand for investment minus the amortization funds:

$$\Delta L_d = I_{f,d} - DA$$  \hspace{1cm} (18)

This demand for new loans is itself divided into two components: loans in euros ($\Delta L_{d,m}$) and loans in local complementary currencies ($\Delta L_{d,icc}$):

$$\Delta L_d = \Delta L_{d,m} + \Delta L_{d,icc}$$  \hspace{1cm} (19)

At each period, the demand for new loans is split into a demand for loans in euros and a demand for loans in the local complementary currencies, according to a factor ($\rho$) comprised between 0 and 1 and which represents the level of transition towards sustainability objectives:

$$\Delta L_{d,icc} = \rho (I_{f,d} - DA)$$  \hspace{1cm} (20)

$$\Delta L_{d,m} = (1 - \rho)(I_{f,d} - DA)$$  \hspace{1cm} (21)

At each period, firm profits are equal to the difference between GDP and other factor payments:

$$F = Y - WB - FB - DA$$  \hspace{1cm} (22)

We use equation 22 instead of equation 1.2 when estimating the model.

In the financial sector, banks open lines of credit to firms such that the stock of loans increases with loan demand (equations 23 to 26). The corresponding stock of money is then split into euros and local complementary currencies based on firm demand for local currency loans and household portfolio choice (equation 27 and 28).

$$L_s = L_d$$  \hspace{1cm} (23)

$$M_s = L_s$$  \hspace{1cm} (24)

$$L_{s,lc} = L_{d,lc}$$  \hspace{1cm} (25)

$$L_{s,m} = L_{d,m}$$  \hspace{1cm} (26)

$$M_{s,icc} = M_s - M_{s,m}$$  \hspace{1cm} (27)

$$M_{s,m} = L_{s,m} + M_{h,m}$$  \hspace{1cm} (28)

Banks charge different interest on loans issued in euros and in the local complementary currency loans, and their profits are equal to the interest spread, plus the reserve assets which they can obtain from the Central Bank against Philia certificates of impact:

$$FB = r_{LM}(L_{m,-1}) + r_{l,icc}(L_{l,icc,-1}) + \Delta A_s - r_{d,M}(L_{m,-1}) - r_{d,icc}(L_{l,icc,-1})$$  \hspace{1cm} (29)

European Ecological Finance Agencies (EEFAs) compute the annual SROI of the stock of local complementary currency loans issued by banks at the previous period. Banks thus obtain an annual flow of ‘SROI impact certificates’. This impact score is denoted the letter $\phi$ (for “Philia”):

$$\phi_{d} = (1 + SROI)L_{s,lc,-1}$$  \hspace{1cm} (30)

$$\phi_{s} = \phi_{d}$$  \hspace{1cm} (31)

At each period, banks transmit these SROI impact certificates to the Central Bank, in exchange for high powered money. In these transactions, the Central Bank rediscount a fraction $\tau$ of the local currency loan portfolio, in exchange for an SROI certificate stipulating that the loan has actually met its SROI target and generated “Philia” in the economy.
\[ \Delta H_s = \Delta A_s \]  
\[ \Delta A_s = \Delta A_d \]  
\[ \Delta A_d = \tau \cdot \frac{\phi_{t-1}}{(1 + SROI_{t-1})} \]

The last equation is the savings-investment identity. For the model to be fully consistent, the quantity of money (euro and local complementary currency) held by households in circulation must always be equal to the stock of loans as implied by firms’ demands and the banks’ balance sheets:

\[ \Delta M_s = \Delta L_s \]

Interest rates and the SROI rate are exogenous parameters in the model:

\[ r_{lm} = \overline{r}_{lm} \]
\[ r_{lc} = \overline{r}_{lc} \]
\[ r_{mm} = \overline{r}_{mm} \]
\[ r_{mlc} = \overline{r}_{mlc} \]
\[ SROI = \overline{SROI} \]

For the model to be \textit{stock-flow consistent}, the \( n \)th equation (equation 35 in our case) must be redundant, that is to say, determined by the other \( n-1 \) equation. This condition holds in all the states of the model. In addition, for all simulations GDP obtained from factor payments or spending are equal. We proceed as follows. We first look at how this simplified economy behaves in the absence of a local currency scheme. To do so, we set the local currency investment (\( \rho \)) and consumption parameters (\( \alpha_3 \)), as well as household demand for local complementary currencies to zero (\( \lambda_1 = 1 \) and \( \lambda_2 = 0 \)). The model reaches a stationary state in which there are no new stocks and flows, and where the value of GDP is 1,299, after 30 replications. Using this stationary state as our baseline scenario, we then simultaneously introduce household demand for deposits in local complementary currencies, demand for consumption goods in the local complementary currencies, and demand for loans in local complementary currency by firms. We thus re-estimate the model, starting from the stationary state, by shifting the value of \( \rho \) from 0 to 15\% and \( \alpha_3 \) from 0 to 0.90 and by shifting \( \lambda_1 \) to 0.65 and \( \lambda_2 = 0.1 \). The model then adjusts to a new stationary state after 30 replications with a GDP value of 1.81. Results are shown in figure 6 and 7 and discussed in section 5.4.2. of the paper.