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Ecosystems and Financial Regulation

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ABSTRACT

This note offers theoretical insight into and practical suggestions for a new approach to financial regulation, based not on abstract theorizing but on lessons drawn from natural ecosystems. Ecosystems, like financial, information, and energy systems, are all complex. The way that all these systems function can be at least partially modeled through mathematics; therefore principles of resilience identified by observing ecosystems can be legitimately assumed to remain valid in other domains.

Recent research shows that the longevity and self-regulating capacity of ecosystems rest on four principles of resilience: the existence of feedbacks, which keep the system within physically sustainable limits; a plasticity of relationships and flows due to appropriate degrees of connectivity, yet without generalized substitutability; a significant diversity of actor types; and looped material and energy cycles, allowing to preserve vital stocks.

In the current dominant financial system, these sources of resilience are either missing or highly inadequate. Consequently, the way it functions is far from the balance between resilience and effectiveness achieved in ecosystems; in fact, the current system is spontaneously evolving in the opposite direction. As a solution, this note suggests regulations that are analogous to ecosystem's principles of resilience: control of excess quantities and volatility, rationalization of substitutability, increased actor and criteria diversity, and reconnecting with other systems.

The goal is not to apply to the financial system an ecosystemic model, which would be no more than an analogy, and a reductive one at that, but, on the contrary, to identify more objectively the structural characteristics of financial systems by shedding light on how other complex systems operate, free of classical economics' theoretical assumptions.

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“Ecosystems and Financial Regulation”

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Translated from French by Michael C. Behrent

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1. FINANCE AS SUB-SYSTEM

Between 1970 and 2010, the IMF counted 208 financial crises, 145 banking crises, and 72 sovereign debt crises (affecting ten countries per year on average), and at least 48 major crises between 1637 (the year of the Dutch tulip crisis) and 1929. Recently, the world financial crisis of 2008 has reminded us of the current financial system's inherent instability, which stands in striking contrast to a different kind of complex system: natural ecosystems.¹ The latter developed and selected, over a very long period of time, regulatory principles that have proved efficient enough to resist frequent physical, chemical, and biological shocks and to restore itself in their aftermath. The efficiency of these regulations is evidenced by ecosystems' longevity and their capacity to remain in a state of equilibrium—at least until the previous century, when the impact of human activities began to affect by multiple ways the climate and living species as well as habitats, soils, and oceans.

This comparison first requires a clarification of terminology. It is possible to speak of the planetary ecosystem in the singular, for all milieus are interdependent. One of many possible examples is the fact that most of the atmosphere's oxygen comes from marine plankton, which itself depends, among other things, on nutrient and pH levels in seawater. The latter is influenced in particular by the air's consistency in CO₂, SO₂, and other acid precursors, many coming from the continents. Yet an imbalance in a given milieu—a northern forest, for example—does not necessarily have an immediate impact everywhere, for the planetary system is neither isotropic nor homogeneous, and each milieu is endowed with “buffer” capacities. Because the planetary ecosystem is thus partially compartmentalized into regional and local ecosystems, it is possible to speak about ecosystem (singular) and ecosystems (plural) in a meaningful way. Similarly, the global financial system consists of sub-compartments that are more or less intensely connected due to the degree, for example, to which currencies are convertible and financial markets open. Even if the trend in recent decades has been towards increased homogenization and interconnection, one can thus speak in this instance, too, of (a) financial system(s).

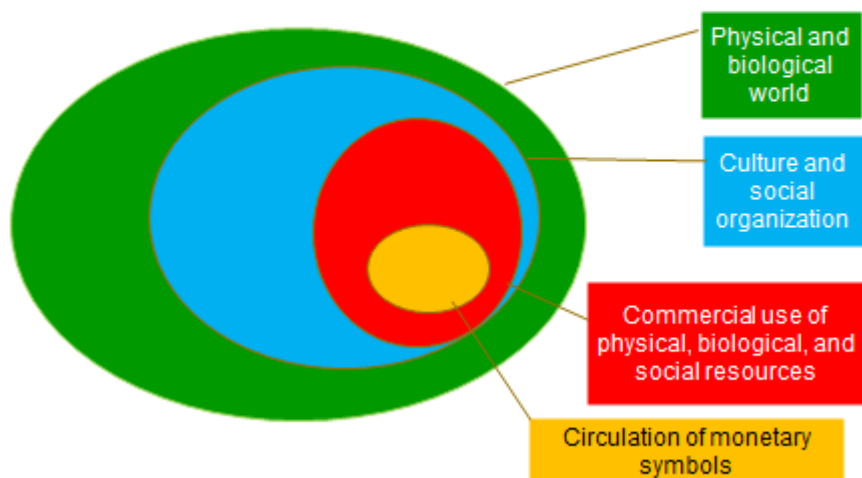
Observing ecosystemic regulations can therefore enrich the current debate on the resilience of financial systems, which, due to this symmetry, we shall refer to as “financystems.” Recent research, which brings together information theory, weighted flow-network analysis, the study of ecosystems, and the history of societies has reinvigorated theoretical and practical thinking about the topic. Meanwhile, at the level of international organizations, the United Nations and the G20 are now concerned with the

¹ Ecosystem: a group of living beings (or biosphere) in their physical and chemical environment (or biotope). A natural ecosystem can be defined, according to Luc Abbadie, the Director of the Paris Institute of Ecology and Environmental Sciences, as an “ecological system on its own spontaneous automatic pilot,” in contrast to anthropized systems, in which human influence is determinant.

impact of climate change on the financial system’s stability,² as well as the latter’s impact on the resilience of other systems.³

Sustainable development is often described as consisting of three pillars: the economy, society, and the environment (it is noteworthy that finance does not appear, as if it was implicitly included in the economic realm). Each of these realms is placed on the same level. Yet if one considers these realms—nature, society, the economy, and finance—in terms of the conditions that make their existence possible, their relationships are best represented as overlapping spheres, as authors such as René Passet and Herman Daly have suggested. Indeed, the physical and biological world makes society and culture possible: without nature and natural resources, human beings and particularly human societies could never exist. The two realms make possible, in turn, every economic activity that organizes stocks and flows by utilizing and transforming natural resources, human physical and mental faculties, and human trend towards symbolization: the economy is merely a sub-section, of varying importance, of social life. Finally, the financial sector, which handles monetary symbols tied to economic activity, can exist only insofar as it rests upon the realms upon which it is based. It is, consequently, the most restricted subsystem, and the one that is objectively most dependent on others (see figure 1).

Chart1: Which connections between systems?



Do these different spheres interact with one another in sustainable and coherent ways? Diversity and information degrees decline considerably as one moves from the

² See, for example: <http://sustainability.thomsonreuters.com/2014/11/11/executive-perspective-g20-greening-global-finance/>.

³ See, for example: “Inquiry: Design of a Sustainable Financial System,” UNEP 2014.

supersystem⁴ to the ultimate subsystem, and the functioning of the whole requires considerable congruence between subsystems and their supersystems. Yet observation suggests that what in fact occurs is a form of contagion that obeys the reverse logic, with the financial subsystem determining the supersystems. Cybernetics teaches us that when a diversified system with an abundance of information and feedback loops is controlled by an inferior subsystem, the result is a loss of coherence and the system's destruction. In biology, a subsystem that is insensitive to the supersystem's signals suggests not robustness, but vulnerability.⁵

In the history of economics as a discipline, this loss of information is the consequence of the pursuit, for convenience's sake, of modeling and calculation: the founder of economic modeling, Léon Walras, explained that he found it convenient to represent the economy as a physical system in a state of equilibrium and that he had, for practical reasons, excluded non-commercial activities from the scope of his calculations. These explanations were subsequently occluded from economists' reasoning, introducing a quasi-epistemological break between the realm of economic calculation and the rest of the world.⁶ This can be perceived in the concepts of externality and internalization, conceived as ways to monetarize non-financial and even non-economic concerns. These concepts are ambiguous: they acknowledge financial markets' short-sightedness, but their very usage creates a misleading substitutability between temporalities, dynamics, and phenomena that cannot be compared, like the Procrustean bed⁷ of Greek mythology. While it has in fact proved very useful to translate into monetary language phenomena that elude financial analysis,⁸ this translation remains partial and, most importantly, the results are used in ways that relate not to the characteristics of the "represented" phenomena (the non-substitutability of the stakes at play, whether they are irreversible or not, ...), but according to the forms and rhythms of the financial subsystem's own objects.⁹ If the economy's original role is to find the best ways to use rare goods from among alternative uses, it is easy to see how the introduction of erroneous substitutabilities thanks to

⁴ In the remainder of this note, we will call a supersystem a system that includes the system under consideration; by the same token, we will call a subsystem any system that is included in the system being considered.

⁵ Dron, 2013

⁶ For example, economic evaluations exclude many goods and services that are essential to the proper functioning of human societies. This is the case for non-commercial environmental processes and "objects," which at one time were considered unchangeable and infinite because of their apparent non-scarcity. It is also true, from a social perspective, for the organization of a public space that is regulated (i.e., weights and measures) and peaceful (because violence is mitigated rather than provoked), which allows activities to develop on the basis of trust. The fable of "the Bee and the Economist" illustrates how an overlooked common good in fact shapes many activities, not only due to what it allows, but also because of the way it is managed. In a certain sense, the story of how intelligence became reduced to IQ tests was the consequence of developments similar to the way in which reality became not only illustrated with but reduced to models (Amzallag, 2010).

⁷ Procrustes was a giant bandit who stopped travelers and spread them across his bed of stone, reducing them to the latter's size: he amputated those who were too big and stretched out those who were too small. Few fit his bed exactly. This myth expresses the lesson that forcing reality to conform to a model frequently runs the risk of destroying it.

⁸ See, for example, Cohen de Lara and Dron, 1998

⁹ The slogans of some financial institutions, such as "Making nature a robust value" or "In the future, food chain and supply chain will be only one" illustrate this trend towards a colonization of a supersystem by the logic of a subsystem.

monetary simplification might create excessive confidence in the representativeness of results in real circumstances.¹⁰

More generally, there are numerous examples of the ways in which economists have gradually constructed the financial subsystem's autonomy vis-à-vis various supersystems.¹¹ First, in relation to society, the belief in the "natural harmony of interests" has allowed the financial sector to free itself from collective moral concerns. Next, in relation to society, the market's "law of (aggregate) demand" can occur only in a world in which there is only one good and only one "representative" consumer, which rarely happens in reality.¹² Finally, vis-à-vis nature, equilibrium models overlook the rhythms of the natural world, despite the fact that the latter constituted a crucial limit to economic capital's substitutability by physical capital. Antonin Pottier shows how the scenarios put forth by the Club of Rome were not be understood by mainstream economists due to a number of unproven but persistent hypotheses¹³: for example, standard economic theory treats consumed goods as if they disappeared when they are purchased, whereas in fact they leave behind waste and pollutants. Furthermore, the social and economic consequences of environmental damage and resource shortages are often largely underestimated due to the belittling or rejection of other realms of knowledge.¹⁴ Finally, measuring the influence of a process or resource on economic mechanisms has long been associated with measuring its share of GDP: hence the dramatic underestimation of the economic and social impact of the risks associated, for example, with energy.¹⁵

This autonomization of financial criteria and rules prevents any feedback from the real world from reaching the model, all the more since models are generally more malleable than the world itself. For example, the spread of benchmark management,¹⁶ which leads each financial actor to assess in similar terms the return on real processes in relation to that of virtual processes, is self-accelerating. The same is true of the construction of indices aggregating, for example, energy, minerals and cereals, which have, for those who use them, become little more than widgets, disconnected from their real effects.¹⁷ May and Haldane remind us that "*two-thirds of the spectacular growth in banks' balance sheet over recent decades reflected increasing claims within the financial system, rather than with nonfinancial agents.*"¹⁸ Finally, the autonomization of subsystems is also expressed in IFRS norms: the principle of "fair value" diminishes our understanding of any entity by

¹⁰ Thus it is not because one could assign a value to the Mona Lisa that it necessarily has a market price, that is, a price for which its owner would accept to part with it.

¹¹ Most of the examples in this paragraph are drawn from Steve Keen's book Debunking Economics (2011) and Antonin Pottier's thesis "L'économie dans l'impasse climatique" (2014).

¹² Keen, 82-95.

¹³ Pottier, 127-132.

¹⁴ Keen, 225-229, Pottier, 282-284, de Lara & Dron (1998).

¹⁵ Pottier, 130-139, 148-149.

¹⁶ This trend continues: on October 12, 2015, the newspaper Les Échos identified an "era of extreme market volatility" tied notably to the "rising importance of passive management" of indices. In other words, the exact opposite of reconnecting with supersystems.

¹⁷ Master & White, 2008. This implies indifferences or a complete misunderstanding of reality, as seen for instance in this headline from Les Échos from March 2006: "Drought Boosts Cacao."

¹⁸ May & Haldane, 2011.

reducing it to the same market mechanism, rather than connecting it to its proper foundations in the supersystem.¹⁹ The effect is the same as the monetarization of externalities in a way that completely subsumes them: realities “represented” in this way become interchangeable.

2. MODELING COMPLEX NETWORKS

Structural similarities between ecosystems, information systems, and financial systems have been examined in the literature²⁰: all three cases consist of flow-networks (whether weighted or not) organized on the basis of the same principles of exchange, connection, and interdependence, but which are differentiated by the nature and rhythm of the quantities exchanged, as well as by the details of the relationship between various species and actors within each network. As for ecosystems, the first attempts to describe their behavior in dynamic terms go back several decades. They were seen as networks consisting of highly interdependent links between which the energy found in living matter circulates along—among others—trophic chains,²¹ extending from plant and animal prey to a series of consumers, before reaching detritivores and the soil. In a thermodynamic vision, energy is used at each stage with more or less efficiency (i.e., nutritional benefit—see figure 2).

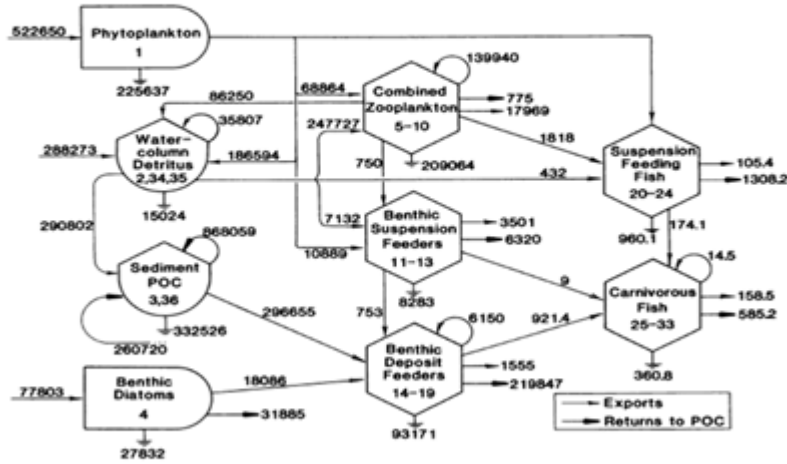
The vast diversity of life makes any modelling effort tricky: such attempts are thus based in and corroborated by on site observation and, very recently, by enormous experiment installations, the “Ecotrons”. Hundreds of observations made at different periods of the year make it possible to describe and quantify the relations between species and express them in energy units. Each species is characterized by its abundance, its preys and its predators. Scientific knowledge of their physiology and ecology makes it possible to interpret their relative and fluctuating abundance thanks to interdependencies. Ecosystems can thus be represented as a network of weighted flows:

¹⁹ It should be noted that the exponential growth of the digital industry, which has been very favorably received by the financial sector (due to the fact that it significantly increased its ability to create exponential increases that are not regulated by supersystems -see Gayraud 2014-), often consists in acquiring an ever increasing share of the value generated by already existing goods and services on behalf of new client interfaces. In doing so, assuming that the digital industry could become as autonomous as the financial sector is, this evolution could deprive the so “connected” industries of their reinvestment capacities.

²⁰ Allesina et al., 2005

²¹ Trophic chain: a sequence of plant or animal species, in which each species of the rank $n+1$ feeds of the species of rank n . A trophic chain is often represented as starting with micro-organisms and/or plants, then continuing onto increasingly large animals and ending with decomposer organisms that bring the nutrients back to the soil or the ocean, where they are reused at the early stages of the chain. This looped chain represents, in fact, the circulation of matter and energy in an ecosystem through food. The bond between a consumer species and a consumed species is known as a trophic relationship.

Chart 2: The ecosystem as a network of weighted flows (based on Ulanowicz & Baird, 1989)

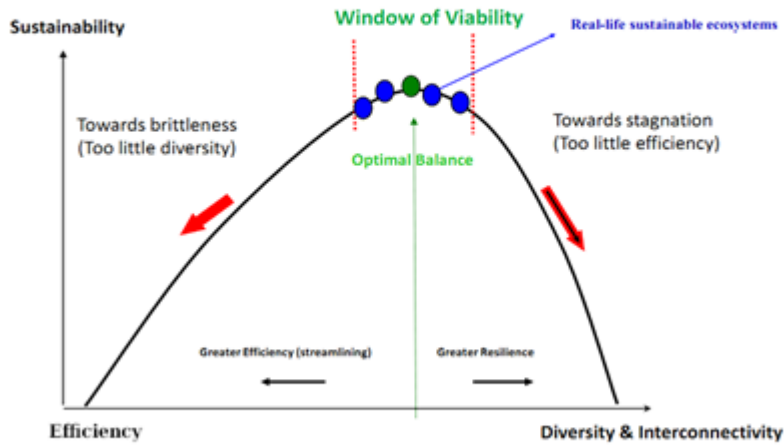


When assessing the complexity of ecosystems and the role played by various species and species groups, researchers borrow the concepts of flows, nodes, and connectivity used in information systems.²² A mesh network thus consists of actors called nodes, each representing a living species or a group of similar species. The number of links beginning and ending with each node, most frequently along trophic prey-predator networks, represents each node's degree of connectivity. Actors thus participate in various combinations of links, with each type corresponding to the roles of one category of actors. One ecosystem can, for example, consist of twelve species (nodes) and four roles (types of node connectivity). The degree of an ecosystem's functional diversity is proportional to the number of roles it harbors. The flow of these networks consists, as previously noted, of energy. These researchers discovered that real properly functioning ecosystems were not randomly organized but always located in a "window" of connectivity and diversity (see figure 3), that networks are not isotropic in link density, and present a degree of internal compartmentation.²³ Furthermore, the partial or total replacement of a weakened or extinct species A by a species B positioned vis-à-vis a predator C is only possible if A-C and B-C relations already exist, or at least if A, B, and C coexist. The other necessary condition is that the injuries that A suffered often do not affect B. If this condition is met, the circulation of energy and various other substances (water, carbon, nitrogen, phosphorus, and so on) in the entire network can be readjusted and preserved.

²² Zorach & Ulanowicz, 2002.

²³ Ulanowicz et al., 2009; Allesina, Bondoni & Bondavali, 2005.

Chart3: Diversity and resilience (Goerner et al. 2009)



Indeed, such resilience depends on the fact that the network is configured in such a way that the various trophic paths are not sensitive to the same pressures. For example, if an intermediary species is decimated by disease or hunting, but another is able to replace it and thus ensure that energy continues to circulate, the ecosystem will be resilient. On the other hand, in the case of chemical pollution to which all the species at a given trophic level are exposed or of a usage that is directed at all of them (such as all shorebirds and passerine birds in a particular region, or all carnivorous fish in a given ocean basin) over long periods of time, then no replacement is possible. It is the diversity of sensibilities, needs, and behaviors within the same class of actors, as well as the diversity of classes themselves (known as the so-called theory of “roles” in information language theory and of “ecological niches” in biology) that makes resilience possible.

In short, an ecosystem is all the more vulnerable insofar as the exposed actors and/or species are vulnerable in similar ways and are situated at the intersections of links that are either too infrequent (then an actor’s weakening does not result in a commensurate replacement) or too numerous (then the multiple roles that these “super-nodes” play in a network’s operation cannot be replaced if they fail or disappear).

As for analyses of financial networks, they often describe exposure chains,²⁴ that is, pressures on actors’ assets and solvability arising from a specific actor’s weakness. The primary issue then becomes determining to what extent and under what conditions possible weaknesses are systemic or not. The response will depend on the behaviour of actors between whom financial flows with particular characteristics do (or do not)

²⁴ See Allen & Gale, “Financial Contagion,” *Journal of Political Economy*, 2000.

circulate. It is these characteristics that this note will now consider, relying on the analysis of how long-living ecosystems function.

From Ecosystems to “Financystem”

Scholarly literature did not wait for the 2008 financial crisis to examine possible parallels between how ecosystems and financial systems.²⁵ An initial approach²⁶, which appeared in the 1980s, started from the theory of information systems. It equated a system’s adaptability with the ability of the connections linking together its various components to assume innovative configurations. It was observed that the latter’s size was inherently commensurable with and superior to all the constraints or dependencies exerted on each component by the others: this difference is known in information theory as “conditional entropy.” It is a way of measuring a system’s disorder, redundancies, gaps, and inexplicable connections, which are the very factors allowing it to readjust and readapt. It can be measured.

The parallel with financystems can thus be described analytically as follows.

The presence of a plurality of trophic chains distributing energy circulation between “upstream” (the ecosystem’s higher levels) and “downstream” (its lower levels) allows certain chains to replace others when one or several links of other chains interrupt or slow down their activity.²⁷ As a result, the activity of the remaining species increases.²⁸ In economic terms, these chains and species respond with countercyclical activity to the diminishing flows running through the damaged chains.²⁹

Within each network, the actors differ to a greater or lesser extent in how they function, the resources they prefer, and the stresses to which they are exposed. In an ecosystem, these differences allow various types of actors to cohabit, yet without a competitive relationship or the actors’ and trophic bonds’ simultaneous exposure to the same dangers and shortages, even if the latter occur at the same trophic level: some links can replace others when they are weakened. Diversity (i.e., the number of different nodes and roles in the system) is the biological equivalent of the diversity of actors and tools within

²⁵ This is presented as follows in an issue of the *Annales des Mines* devoted to this concept: “the resilience of a system is not the antithesis of its vulnerability, but a description of its behavior after it has been disturbed; in other words, a description of the way that it remains around its initial state of equilibrium, evolves towards a new state, in the form of a stable cycle, or places itself on a stable trajectory without a point of equilibrium (this is the process to which the concept of ‘attractors’ refers). The opposite of a system’s vulnerability would be its capacity to preserve its structure even when the system must abandon its original state of equilibrium (or its ‘attraction basin’)—in other words, when it moves from mere adjustments to full-fledged adaptations...” (“Resilience: more than a fashion,” 2013).

²⁶ Ulanowicz et al., 2009

²⁷ Ibid.

²⁸ A lower or higher trophic level is always a relative and dynamic concept. It can never resemble a concept such as “core/periphery” (for instance, see Hauton, Gael & Heam, Jean-Cyprien, “How to Measure Interconnectedness between Banks, Insurers and Financial Conglomerates?,” *ACPR, Débats économiques et financiers* n°15, 2014).

²⁹ Ulanowicz et al., 2009.

financystems and makes possible a kind of structural counter-cyclical response. Each link's degree of connectivity is also included between two limits (that is, more than one and less than three). It represents an intermediary situation between, on the one hand (one connection), being the tributary of only one other link and risking depletion with revitalization and, on the other (more than three connections), being in a state of abundance, an over-connected node ("too big to fail"), and thus in a strong position to transmit disturbance. These limits to connectivity, as well as the number of roles and pathways, contribute structurally to the robustness of a network in which no actor controls a disproportionate flow or lacks one entirely. The upper connectivity limit implies a degree of compartmentation, rather than intense and generalized connectivity. In such instances, the system collapses only if pressures of different kinds accumulate. To the contrary, in a system that has been insufficiently diversified, it takes only one disturbance affecting the links in the same way for the result to be destructive. The "window" of connectivity and diversity thus expresses an organizational precondition for the proper distribution of energy circulating within an ecosystem—in other words, its viability, which is analogous to proper monetary circulation across the entire financystem.

A second approach to financial resilience comes from financial literature itself. Historically, resilience was measured institution by institution, on the assumption that if each individual actor was capable of resistance, the entire system's solidity would be enhanced accordingly. In the aftermath of the 2008 financial crisis, in which systemic risk became evident, some regulators began to examine the resilience of the system itself. The method consisted of simulations of banking and market networks in which shocks were introduced: a bank failure resulting from its assets, a liquidity crisis, a price collapse, a drop in interbank trading, and so on. For example, May and Haldane's financial model³⁰ is based on the developments that British banks experienced before and after 2008. The study concludes that a greater connectivity between banks with a similar profile mitigates the risk of collapse when the shock is circumscribed, but entails the collapse of more of the system if the impact is too great, or exposes a vulnerability that all actors share. The model also shows that a network consisting of very large banks and smaller institutions results, in practice, in excessive connectivity at the level of the biggest actors. Diversity, on the other hand, allows for more robustness, at least as long as the difficulties encountered at a particular point of the network are not systemic—if they do not, in other words, result from the same kind of vulnerability or behaviour, affecting different actors (or a large number of them) in the same way.

This model shows, moreover, that when an initial disturbance affects external assets (capital requirements), the system's fragility is at its height when banks are both extending credit and making investments. The two other accidents modeled by May and Haldane, relating to the value of assets (measured at market price) and interbank loans (liquidity), demonstrate a greater capacity to spread and intensify. To address systemic risk, the authors propose introducing countercyclical regulation that would reduce banks' capital requirements during recessions and increase them during periods of growth in order to reduce the risks assumed by these institutions.

³⁰ May & Haldane, 2011

In short, these two approaches converge around the idea that a robust system is a compromise between two extremes:

- a simple structure with few nodes, with significant flows passing through each of these nodes, giving it little resilience when confronted with disturbances;
- a structure with multiple nodes and relationships, which is robust in the face of disturbances, with flows that are more spread out across interdependent chains.³¹

These two poles heighten the tension between the principles of efficiency (or effectiveness³²) and resilience. In the realm of finance, however, the criterion of efficiency is generally used without taking into consideration either resilience or the impact on subsystems; the financial subsystem is considered in isolation. Efficiency will thus increase nominally, either by inflating the monetary flow, or by reducing the number of actors³³ and/or outflow paths. Thus when the efficiency of a system is evaluated point by point, the first type of structure seems more efficient, for it maximizes flows passing through each of the network's remaining nodes. Furthermore, the definition of efficiency is compatible with increase in volume which is independent of the underlying economic activity.³⁴ A larger activity volume of financial markets is often considered as a criterion of effectiveness, for it is associated with more competitive circumstances, which would facilitate and accelerate the discovery of the "true" price.³⁵ Following the major failure of 2008, the emphasis on liquidity again strengthened the trend towards large circulating volumes. Yet the case of high frequency trading (HFT), for example, shows that such reasoning becomes absurd when pushed to its limits : because it requires powerful computers, HFT is only accessible to the largest operators, which in practice reduces competition and introduces the possibility of systemic fraud.³⁶

The reduction of the number of actors is often presented as a factor contributing to the system's stability (long-term relationships) and efficiency (economies of scale). Taken to the logical extreme, the most efficient network, from this criterion's standpoint, would consist of a single chain with very few levels. But such monopolistic system would, in the first place, have few chances of surviving shocks because it would consist of many more

³¹ Ulanowicz et al., 2009

³² Efficiency and effectiveness are often cited as the financial system's goals. Efficiency is commonly defined as the ability to achieve predetermined goals through an optimal use of (human, material, and financial) resources. Effectiveness refers to the ability of an individual, group, or system to achieve set goals.

³³ Some studies indicate that fewer and larger actors (yet who are not "too big to fail") result in less competition but can lead to greater stability, in the form of long-term relationships between actors. This is the debate between "relationship lending" and "arm's length finance." Yet these long-term relationships, which depend purely on the will of the actors, must be effectively cultivated. This seems not to be the case at present, as the concentration of actors has been accompanied by increased volatility and decreased system resiliency (see [Les Échos](#), December 10, 2015).

³⁴ The relationship between financial flows and goods and services flows has apparently gone from 10:1 in the late nineties to 20:1 in 2007 and nearly 50:1 in 2014.

³⁵ A market is called efficient if prices reflect all relevant information (notably a company's future profits) and only vary as a function of the latter, i.e., arbitrarily in relation to time (Keen, 318).

³⁶ Gayraud (2014) equates it to the crime of "insider's trading" become legalized.

shared vulnerabilities and little plasticity. Secondly, the goal sought from the standpoint of the broader system is not to maximize the circulation of flows within the financial subsystem independently of the consequences for the supersystem, but to catalyze the broader system's mechanisms. Third, the systemic volatility and vulnerability grow with volume circulation and actor concentration. Finally, digital technology itself, with its network characteristics and increased capacity of "liquefaction," raises the size premium and favors the creation of monopolies; financial digitization does not escape this trend; this self-feeding dynamic thus requires a balancing effect that cannot come spontaneously from financystems.

3. FOUR PRINCIPLES OF RESILIENCE

The resilience of ecosystems is tied to four fundamental characteristics presented in this section: the existence of feedbacks which keep the system within physically sustainable limits; a plasticity of relationships and flows tied to appropriate degrees of connectivity, yet without generalized substitutability; a significant diversity of actor and criteria types; and looped material and energy cycles, able to preserve the vital stocks.

Feedbacks Ensuring the Respect of Sustainable Limits

Ecosystems are preserved within the “window of sustainability” thanks to internal regulations, such as predator-prey relations. Destabilization is often due to external factors: overuse or overkill, pollution, habitat destruction, invasive species, and so on. For example, overfishing along the Namibian coast triggered an explosion of the jellyfish population, whose larvae were no longer consumed. At present, only jellyfish can be found in these regions, which have become too toxic systems to be naturally reconstituted. These departures from the realm of sustainability are not linear: faced with continued disturbance, ecosystems can in appearance last a long time, before collapsing in very little delay.

The self-regulation of natural ecosystems stands in contrast to the exponential phenomena observed in the financial subsystem, measured by the quantity of financial products in circulation³⁷ or the monetary mass.³⁸ Various processes determine these trends. Some are very old, others more recent, but they are all intensified by the use of digital technology, notably the sharp rise in split-second transactions and the effect of simultaneous information on mimetic behavior. Similarly, the quantity of derivative products in circulation seems well above what would be required for the financial system to be somewhat balanced. This situation creates specific points around which the market deviates.³⁹ Finally, the mechanism of compound interest leads per se to an exponential growth in their amounts⁴⁰. Unless having a sufficient amount of the debt erased by inflation or restructuring, the need to pay these interests alone renders material growth (i.e., the creation of new goods and services) indispensable. If one were to assume, for illustrative purposes, that the quantity of goods and services circulating was generally stable, the demand for the permanent creation of assets in exchange for interest would result in some actor being automatically despoiled. Put differently, when the return that

³⁷ Bank of International Settlements (BIS) 2013: \$5,300 billion are traded daily in the world (including \$1,300 billion exclusively on the euro-dollar market), three times as much as in 2004 and five to six times as much as in 1992. Transactions corresponding to real goods (investments, goods and services, migrant remittances) represent less than 5% of these totals. In 2013, merchandise represented only 2% of the total.

³⁸ Lietaer et al. 2012, 70 and 147-148. According to Thierry d'Argent (who is in charge of global corporate finance for Société Générale, as interviewed by *Le Monde* on December 30, 2014, “Economie et Entreprise,” 10): “the world has created more monetary mass in recent years than in the last century.” The mass in circulation was \$3340G in 2014, or 47% more than in 2013.

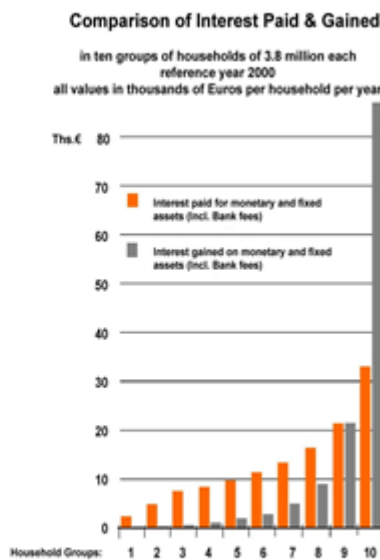
³⁹ May & Haldane 2011.

⁴⁰ Lietaer et al. 2012, 181.

capital demands is greater than the economy’s and population’s real growth, the concentration of financial resources is matched by the impoverishment of some households and companies.

The transposition of feedback of the “predator-prey” or “living being-biotope” variety to the financial system, designed from a prevention perspective, might lead one to consider, for example, if and in what ways interest rates (see figure 4) might be neither generally nor permanently greater than growth rates, in order not to handicap, structurally speaking, circulation throughout the network as a whole. As growth in material consumption brushes up against finite physical limits, even the prospect of current rates of raw material and energy consumption will quickly become unsustainable. Attempts to extend the market conception of value to other kinds of objects (natural species, the production of knowledge, and so on) do not solve this problem, in part because it also weakens another factor of resilience, namely, non-substitutability. Another option would be to limit the number of authorized derivative products, notably as they are correlated between them. A third possibility could consist in placing physical ceilings on electronic trading frequency,⁴¹ along with other ways of making monetary circulation more viscous, in such a way as to mitigate the trend towards turbulence and exponential developments.

Chart 4: Social concentration of wealth and capital income
(Lietaer et alii, 2010)



⁴¹ Which makes no contribution to the field of economics and (according to Gayraud, 2014) makes possible the self-fulfilling manipulation of markets at a mass level.

Plasticity without Substitutability

Ecosystems draw part of their resilience from the plasticity of interspecies relations: when one of the links or connections in a network fails, be it for internal or external reasons, raw material and energy flows that passed through it can be, either temporarily or permanently, taken up by other connections or species. This plasticity is proportional to the existence of redundancies or reserves, defined in relation to a theoretical network that is maximally efficient. It is tied to two characteristics that we encountered previously: on the one hand, connectivity between network nodes, which must be sufficient without being excessive; and, on the other, network nodes (or actors) capable of playing diverse roles.

The plasticity of trophic chains does not mean that ecosystems are interchangeable, either among themselves or with manufactured goods: the biological, physical and chemical, and climatic roles of oceans could never be replaced by an array of swimming pools, aquacultures and giant ventilators. Monetization of natural services, regulations and resources, if viewed as the key to connecting systems, would establish an illusory substitutability between them. The latter is particularly harmful for the processes of the physical world, since much of the resulting damage inflicted upon it is irreversible in human terms and potentially lethal for our society and even for our species; in spite of this fact, their monetary symbols are as reversible and substitutable as any financial asset. Financial tools are not neutral in relation to their supersystems.

To limit crises, one possible reform would consist in differentiating the handling of realms of activity that are not mutually substitutable. If it proved impossible to impose non-convertibility purely and simply, then one should at least make sure that operations, conventions and calculations are not systematically convertible in each other. The European Central Bank's TLTRO 2014 program, by "assigning" some monetary creation to commercial financing, could be interpreted as an attempt at compartmentation (with few control mechanisms, however). More fundamentally, an organized differentiation of actors, tools and/or exchange mechanisms could naturally contribute to curtailing substitutability. This brings us to the third characteristic of resilient systems: diversity.

Diversity

In biology, diversity allows other species to replace temporarily those that have been affected, or to recolonize a devastated natural milieu. Diversity also means that in the case of a parasitic or viral attack, an entire trophic level (such as all the trees in a forest—hence the interest of multi-species forests) will not be destroyed by an epidemic. It is even a source of abundance, as each species neither takes nor leaves the same thing in the same places and can trade its surpluses with its neighbors⁴². If all of an ecosystem's members were seeking the same resources, there would be considerably less abundance and resilience. In other words, if all an ecosystem's actors had the same criteria, needs

⁴² Diversity makes it possible to increase the return on biological production per hectare with external additions, such as by mixing legumes, trees, and cereals in the same fields.

and desires, there would be generalized competition and the system would become impoverished. Yet, to the contrary, in ecology we see more cooperation and complementarity than competition, particularly across species, thanks to the diversity of ecological niches. It is this diverse and cooperative form of cooperation that evolution has naturally selected.⁴³

Thus it is necessary to diversify the decision-making criteria, with other actors offering different rationales that are not that mutually substitutable. Vulnerability metrics and multi-criteria analyses would make it possible to re-balance efficiency and resilience⁴⁴ by reducing systemic risk. In the financial domain, this differentiation can affect actors (through the separation of deposit and business activity, the preservation of functional differences between financial actors, and so on), the use of exchange systems (for instance, the compartmentation of the use of financial products⁴⁵), or the exchange systems themselves (such as complementary currencies). It would allow for a significant reduction in the tendency of systemic risks to expand. In short, it is possible for “financial integration” to be compatible with risk reduction, insofar as it means a form of “interconnection” that respects the differences and feedback loops discussed previously. If, however, it means the adoption of the same criteria and behavior across the system, then it will be an accelerator of systemic crises.

A first field of application of these principles pertains to economic models. Small oil and gas companies with fewer structural costs than majors, often take over to manage wells that have become less profitable for them. Similarly, financial companies with different social goals and ways of operating could occupy distinct spheres: profit-risk ratios and the ceiling prices for particular operations (such as investment and credit) could vary significantly between companies based on their size, goals, and strategic positions. Actors guided by different rationales are less mutually substitutable: commercial banks, cooperative banks, credit unions, investment banks, public banks, “low-profit limited liability corporations” (in the USA), complementary currency banks, funds,⁴⁶ and so on. They have different “roles,” in the sense of flow networks. Actors with diverse economic models are thus indispensable to the financial system’s resilience. Conversely, mimetic behaviour, even when it is for strategic reasons,⁴⁷ is the cause of systemic risk.

Preserving the diversity of models in this way presupposes adequate regulation of the network itself, but the latter’s evolution tends to push it in the opposite direction. Keeping a system within the “window of viability” means that a ceiling must be placed on the level of connectivity, and thus on size, for too great a concentration of connections on a

⁴³ Aingrain, in Passet 2010, 625.

⁴⁴ Livre Blanc pour le financement de la transition écologique (White Paper on financing ecological transition), 2013

⁴⁵ To cite one example of the dangers of non-compartmentation, the application of foreign exchange, interest rate, and stock derivatives to the realm of credit seems to have increased rather than reduced the system’s fragility by exposing to the same disturbances realms that should have continued to react differently to them.

⁴⁶ Some actors use public resources (grants, guarantees, budget credits, and so on) to control a specific niche in relation to investment demand, but without thereby using internally criteria that differ from those of other actors. Thus they do not represent a true diversification.

⁴⁷ Farhi E. & Tirole J. 2012.

particular type of node transforms the latter into a point of accumulation, at the expense of overall circulation within the system, and contains the seed of systemic risk in the event of failure.

Another field of application of the same principle of diversity relates to the monetary system and the idea of a plurality of complementary currencies within a single monetary space. An example of structural countercyclical action is provided by the intercompany complementary currency that was created in Switzerland in 1934, the WIR, to allow small and medium businesses to overcome the period's economic and financial crisis. The currency is issued by a cooperative bank, under the authority of the Swiss national bank, and is used today by 20% of the country's small and medium sized businesses, reaching a total volume of some two billion Swiss francs.⁴⁸ The experiment shows that the demand for WIR increases during periods of economic difficulty and declines when things calm down: this countercyclical effect vis-à-vis the Swiss franc makes it possible to preserve the country's economic activity and stability.⁴⁹

Many examples of complementary currency exist in Europe and the world (including 200 in Brazil and 100 or so in Japan, adding up to 4000 in fifty countries across the world, used by around a million people⁵⁰), seeking BtoB, BtoC or CtoC transactions. They can be issued by a local entity for specific goals.⁵¹ They can be either physical (i.e., circulating bills) or virtual (written accounts) in nature. Some carry interest (such as the Palmas Bank created at Fortaleza in 1998⁵²), while others do not but are melting currencies,⁵³ in order to stimulate the local economy. They are often directed at a specific domain or territory, which introduces another dimension of compartmentation, in relation to the benchmarks and criterion of substitutability discussed previously.

It is tempting to ask how the effectiveness of a monetary system based on a plurality of currencies compares to that of a traditional system. Yet this questioning would miss the point of complementary currencies, which is to enhance resilience. At difficult times, many transactions that they make possible would not occur otherwise. To illustrate this fact with an ecosystemic parallel, some land is known to be too poor to be farmed when its productive interest is based on a single criterion: the return on a single cultivated variety (i.e., a monoculture). These lands can, however, prove to be very abundant when they adopt farming systems that blend species, including trees and annuals, because they do not use or produce the same resources at the same depths, because they do not grow at the same time, and/or because they soften the local climate, and/or some of them

⁴⁸ <http://monnaiesassociatives.blogspot.fr/2008/06/une-monnaie-de-secours-le-wir-en-suisse.html> ; http://fr.wikipedia.org/wiki/Banque_WIR ;

⁴⁹ Kalinowski, 2011

⁵⁰ Leblanc, 2011

⁵¹ Lietaer et al., 2012, Suhr, 1989

⁵² "The starting point for the creation of the 'Palmas' currency, which is indexed on the Real, in a favela in Fortaleza is the awareness that 'we are not poor because we don't have money, but because we don't spend our money here.' There are no 'poor territories,' but only 'territories that impoverish themselves as they lose their internal savings.' In 2005, 90% of purchases occurred in the favela, compared to 20% in 1998. 1,800 jobs were created in the neighborhood, and 110 banks were created on this model throughout Brazil." (Carlos de Freitas).

⁵³ See the example of the SOL in France: https://en.wikipedia.org/wiki/SOL_Project.

produce nutrients that others lack, and/or some of them harbor the predators of other plants' predators.⁵⁴ The choice to measure an agricultural system's effectiveness solely in terms of the production of a specific tonnage, such as wheat quintals per hectare, implies a bias in favor of single-crop systems, which, however, consume more fertilizers, pesticides, water and mechanical labor, and are more destructive of the soil and biodiversity, in addition to being more vulnerable to climate change than other technological systems. On the other hand, measuring the effectiveness of a mixed agricultural system by taking into consideration all its products (cereals, legumes, trees, and so on)—that is, the per hectare return on living matter (and on diverse qualities such as nutrients), in particular by relating it to inputs (energy, synthetic products, water usage) would lead to more varied options.⁵⁵ The indicator determines the direction.

A Looping of Cycles Resulting in Stocks

The looping of cycles (carbon, water, nitrogen, phosphorus, and so on) is the fourth principle of ecosystem's resilience. The temporary energy/matter concentrations that build organisms are, after their death, redistributed across the ecosystem. The difference between a renewable resource and a perishable one is a question of rhythm: human activity excels at depleting renewable resources (such as fish, forests, water tables, soil, etc.) by using them beyond their rate of renewal. Financial systems, however, engage in localized accumulation processes favored by intensifying loops,⁵⁶ such as the logical propensity of lending institutions to extend credit only to actors who already have savings, which increases monetary concentration rather than "loopbacking."⁵⁷ Interest is passed on to products and services, the sale of which makes possible the repayment of the invested capital.

Do financial resources created indirectly by lending at interest or monetary creation (quantitative easing, or QE) connect elsewhere? For example, do they stimulate supply if not demand, or employees and investment if not consumers? This does not seem to be what usually happens.⁵⁸ Furthermore, finance threatens the preservation of primary stocks by imposing discount rates which presume that future generations will be wealthier

⁵⁴ See, for example, the work of M. Meuret, INRA, in Dron, 2003

⁵⁵ "AFTERRES 2050: un scénario soutenable pour l'agriculture et l'utilisation des terres en France à l'horizon 2050. "

⁵⁶ See the distribution by decile of the interest collected and paid by the German population (Lietaer et al. 155), or the zero median patrimony of American people in 2007, which follows a near Dirac curve (source: Federal Reserve).

⁵⁷ It is worth recalling that loans at interests were not appreciated by Aristotle for functional reasons: usury "*is increasing our fortune by money itself, and not employed for the purpose it was originally intended, namely exchange...For as offspring resemble their parents, so usury is money bred of money. Whence of all forms of money-making it is most against nature.*" Aristotle, [A Treatise on Government \[Politics\]](#), 1:10, trans. William Ellis.

⁵⁸ According to Martin Wolf, monetary creation does not for the most part finance activity: "*only about 10 per cent of UK bank lending has financed business investment in sectors other than commercial property.*" <https://postjorion.wordpress.com/2014/05/09/289-wolf-soutient-le-smart/> See, too, [Les Echos](#), October 13, 2015: QE and low interest rates lead to "inflating enormous speculative bubbles throughout the financial world." (12).

than the current generation, which is clearly false in the case of environmental goods (and now absolutely not sure in general).⁵⁹

4. WHICH LESSONS FOR FINANCIAL REGULATION?

The characteristics of the current financial system are the opposite of the conditions of resilience observed in ecosystems:

- There is little regulatory (negative) feedback (whether internal or by connecting financial systems to supersystems), producing uncontrolled exponential phenomena (monetary masses, currency markets, financial derivatives, compound interest, bubbles, and so on);
- Money created a generalized substitutability, resulting in a permanent benchmark between virtual processes and goods, on the one hand, and real processes and goods, on the other, which means that the financial system's rationality spreads to the supersystem—a contagion that is damaging for the latter as well as for the whole, due to the insufficiency and inadequacy of its criteria;
- Actors are fewer and fewer in number (and are thus more concentrated), more and more similar in how they operate (due to the control and classification principles), and in practice driven by a single principle (financial return, monetarily denominated : the so called "run to liquidity"), which is the cause of intense mimetic activity (decisions about resource allocations, crashes, and bubbles) that affect much of the ways that supersystems (economic, social, environmental) operate;
- Circulation of money is not systematically reconnected to primary stocks, resulting in an intensification of hoarding rather than redistribution across the network, a tendency that is strengthened by the discount rates ;
- Effectiveness, which is maximized in too narrow a sense, has weakened three necessary conditions of resilience, namely the preservation of viable limits, actor and criteria diversity, and plasticity. Consequently, the more effective (in the narrow sense of the term) a subsystem is, the less adaptable and resilient it becomes. The shocks affecting a system with a limited number of actors, weak diversity, and large circulating flows become more intense when concentration and flows are lower and diversity greater, which is hardly an ecosystemic surprise.

⁵⁹ In this case, according to Roger Guesnerie, the discount rate must not only be zero but even completely negative.

Most of the financial system's failures—bubbles, dry spells and accumulations, alignment of the real on the virtual, short-term outlooks, moral hazard, and so on⁶⁰—seem tied to these shortcomings. This logic contributes, moreover, to threaten the supersystems on an unprecedented scale, due notably to the physical and biological irreversibility of this deterioration once it has begun, and to their vital and simultaneous impact at a global level.

French law⁶¹ recently instituted three measures relating to the structure of the monetary and financial system: a status for complementary currencies, a legal framework for participatory finance (crowdfunding), and the extension to institutional investors of a sustainability report with binding information on how related voting rights are exercised. If continuing along these lines, it could become possible to bring the financial system structurally closer to the principles of resilience presented in this note. Various tools relating to the four principles discussed above could thus be tested:

- To remain within sustainable limits: technological ceilings on actors' size, on trading frequency, and on the number of derivative products; vulnerability diagnoses from the standpoint of supersystems (such as carbon fossils or water consumption)⁶²; introduction of limit metrics; ceilings on interest compounding; and systemic resilience tests for supersystem stress;
- To strengthen plasticity and reduce sustainability: extend management mandates to social and environmental specifications, along the lines, for instance, of the GSC,⁶³ and integrate them into fiduciary responsibility⁶⁴; reduce substitutability by differentiating monetary rationalities according to the characteristics of real monetarized processes; and better compartment financial products' scopes of application;
- To strengthen diversity: modulate IFRS norms in relation to long-term goals⁶⁵; establish statutory diversity for financial activities and actor types⁶⁶ and analyze their respective contributions to resilience ; and analyze the economic effects of various kinds of complementary currencies;

⁶⁰ Haldane, 2009; the Kay report (2011), OECD.

⁶¹ The law on energy transitioning (2015), the law on the social and solidarity economy (2014), and order on participatory financing (2014).

⁶² The law on energy transitioning thus provides for a test on "climate resilience" for companies.

⁶³ German Sustainability Code, a reporting standard promoting transparency for some twenty criteria of corporate social and environmental sustainability.

⁶⁴ French authorities' response to the Green Book on the long-term financing of the European economy, July 2013.

⁶⁵ Livre Blanc pour le financement de la transition écologique (White Paper on financing the ecological transition), 2013.

⁶⁶ Ibid.

- To resupply basic stocks: strictly negative discount rate for environmental processes and subjects; introduction of complementary currencies; allocation of resources to real targeted investments.

In conclusion, it may seem surprising to seek to model and regulate financial systems by drawing on the principles on which real systems operate, especially from systems that are not made by human beings. Even so, our understanding of ecosystems converges with a growing number of financial analyses as they relate to diagnoses of structural problems that trigger increasingly serious and recurrent accidents. It thus seems sensible to abandon the conceptual framework that produced these results or failed to prevent them and to consider systems that have long proved to be resilient. This work has only just begun.

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