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Lost Robustness

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The current financial crisis is the expression of a systemic change that has occurred in the global economy slowly but profoundly during the last few decades. Our thesis results from an analysis of the financial world from the perspective of the theory of complex systems (which describes common features of social, traffic, economic and ecological systems). The key question guiding our analysis is: what properties make the financial system robust, and therefore stable?

Is the present financial crisis different from preceding ones? Many different answers are given to this question. However, what is more important than the answers themselves is the validity of the theoretical concepts, on which they are based. It is obvious that the prevalent mathematical models of economic processes and the risks attributed to them have failed—a failure that happened just at the time when they would have been most needed. In our opinion, it is not only the faulty use of risk evaluation models that underlies this failure, but a wrong description of the financial system itself. Since the early 1980s, the financial system has fundamentally changed, which must be viewed as a systemic change of financial markets. Keywords here are the creation of new financial instruments (e.g. derivatives), an acceleration on all process levels,

and the removal of obstacles that formerly impeded international capital flows.

Although the present analysis of the crisis touches these issues, it does not well enough elaborate its systemic aspects, leaving it inadequate and incomplete. In our opinion, it is necessary to examine the robustness of the financial system. Robustness is a concept from complexity theory, which in general focuses on universal patterns of behavior and development in complex systems. We want to show that this approach is useful for an understanding of the current crisis, because it illustrates that recent changes in the financial system have seriously undermined its robustness.

2.1 Understanding Complex Systems

Complex systems are characterized by numerous interacting actors and factors. Examples are social, economic, or traffic systems, as well as the behavior of crowds or ecosystems. The behavior of these systems is often dominated by their internal dynamics. Attempts to control them from outside frequently lead to unexpected and unintended results. Insights into the behavior of such systems, however, can be gained by a three-step procedure. First, the actors of the system and their interactions must be captured as completely as possible and mapped into a network of causal interdependencies. Second, one needs to determine the properties of the system that are most relevant for its state and dynamics. By specifying favourable states of the system, one can introduce a normative element into the model. Third, one must identify the most important external influences, which affect the system, but are not influenced by it.

Many complex systems analyzed in this way—both natural and artificial ones—show common general properties: For example, there are phases during which the overall behavior of the system

remains more or less unchanged, although interactions within the system as well as external influences may fluctuate considerably. When this is the case, the system is stable—not in the sense that nothing happens, but that changes are restricted and foreseeable, even if this is not intended by the individual actors. (This system behavior may be compared with Adam Smith's principle of the invisible hand.) However, if certain external or internal conditions of the system change beyond a certain threshold, the stability can collapse. In this case, the system behavior becomes massively different, and one speaks of a regime shift. For example, established actors may disappear or new ones may emerge. The corresponding systemic processes often occur in a cascade- or avalanche-like manner, and the frequency of such extreme events is much higher than expected. It typically follows a so-called fat-tailed distribution rather than a normal distribution, while the normal distribution is still the basis of most risk assessment models today.

The ability of a system to avoid such regime shifts is called robustness. The issue of robustness is central to an analysis of the financial system, as it is often the interactions in a system which determine its robustness. Moreover, in contrast to external factors, interactions are susceptible to regulation and, thus, to human intervention. In order to understand robustness, it is helpful to consider the stability properties of other complex systems, for example, ecological systems. During evolution, these systems have been exposed to numerous disturbances and nevertheless (or, in some way, exactly for this reason) achieved an amazing stability. Five key properties of complex systems have proved to be advantageous for robustness: variety, redundancy, compartmentalization, sparseness (i.e. a low degree of interconnectedness), and mutually adjusted time scales of processes in the system.

Variety, i.e. the existence of different kinds of actors and the application of different strategies in the system, enhances the

adaptability and guarantees that not all actors face a stability crisis at the same time. Redundancy allows the system to deal with the loss of system components (e.g. actors, resources, or process pathways). To put it simple, several safeguards must fail, before a problem develops into a crisis. Should the trouble nevertheless skyrocket, e.g. due to an unfortunate coincidence of several problems, compartmentalization can help: If the network underlying the system (such as the network of interbank loans) is subdivided into barely interdependent subnetworks, this supports a decoupling of the system into autonomous subsystems when needed. In some sense, compartementalization introduces predetermined breaking points, i.e. the idea is to transfer the principle of fuses in electrical networks to prevent serious damage in other networks as well. Such a strategy could avoid an epidemic spreading of trouble across the entire system. Demanding sparseness complies with the principle of decoupling, but it also considers the fact that interactions between actors are costly. A system with an excessive number of connections is, therefore, inefficient. Finally, adjusted time scales guarantee that the processes in the system are well coordinated, so that they do not disturb each other.

2.2 Criticality and Lack of Transparency

In complex systems, several destabilizing factors may be at work. Of particular importance in this connection is an effect called self-organized criticality. Other relevant factors are time delays and the lack of transparency as a result of growing system complexity. Moreover, in the case of the financial system, market mechanisms themselves imply a certain degree of instability, as we will show.

Self-organized criticality means that the system maneuvers itself into a critical state. In case of the financial system, this results from the fact that banks must compete for customers, which forces them to take greater and greater risks. Hence, unexpected economic developments could eventually get some banks into trouble, and the corresponding enterprises would go bankrupt or would be taken over, which is a natural adjustment process in a free market economy. However, the process may be dangerous when many actors simultaneously move towards a critical state, which has indeed been the case in the current crisis. For example, banks invested into mortgage-backed securities that promised higher net yields, but the more mortgages were taken out, the more house prices were driven up. Prices in the American housing market roughly doubled from 2000 to 2006, while US wages increased only around 14 % in the same period. It is clear that many people could not pay for housing at some point and that the real-estate bubble would burst—a typical example of self-organized criticality.

The dangers of self-organized criticality can be counteracted by the above-mentioned strategy of compartmentalization. Fighting forest fires is a good analogy. On one hand, in areas of low intervention, forest fires are frequent but spatially limited, as previous fires create natural firebreaks. On the other hand, suppressing fires in an early stage prevents many fires from spreading. However, once they manage to spread, they often become uncontrollable and result in a large-scale conflagration, because there are no natural firebreaks. The Fed's monetary policy in the last few years could be interpreted in that way: It prevented the formation of natural firebreaks in the financial system. Furthermore, allowing the packaging of mortgages and their global disposal permitted around 40 % of the values related to these mortgages to circumvent government regulations. By this, the occurrence of fires in the financial market was not even monitored, i.e. there was a serious lack of transparency.

In this context, one should be aware that, in socio-economic systems, the lack of transparency is growing naturally. The evolution of complex systems is characterized by an increasing degree of differentiation, which facilitates new structures and processes—and consequently requires new experts that are able to overlook the details of a more and more complex world. This process can be readily observed in the globalization of the economy, in legislation and jurisdiction, and in the financial market. The increasing level of complexity, however, eventually reduces the transparency of the system and, thereby, its controllability. An example for this is the creation of new and ever more complex financial products (derivatives) that were built on previously existing ones. This indeed opened up new opportunities, as reflected by the enormous expansion of the values represented in derivatives: In the spring of 2008, derivative contracts amounted to more than \$ 500 trillion (two orders of magnitude more than in 1980). However, among these were also credit-default swaps, which did not exist a few years ago and now amounted to \$ 45–60 trillion (depending on source), while they were barely attributable to real-world economic goods—an obvious problem of transparency. Moreover, the fact that financial instruments became more and more complex became particularly problematic as, with regard to expertise, the robustness criteria of variety (in terms of different approaches to risk assessment) and redundancy (requiring that different experts investigate the same risks) were compromised: In the last three decades, basically three enterprises—Standard & Poor's, Moody's and Fitch Ratings—with a worldwide market-share of more than 90 % have rated financial assets and valued the underlying real-world economic goods. This, of course, created massive correlations and serious herding effects among financial actors.

2.3 Acceleration and De-Compartmentalization

If the time scales of different processes in complex systems do not match well, a variety of delay-related problems may occur, which is reflected in financial systems on different levels. Let us first focus on short time scales: When the stock market crashed, computers sometimes did not catch up with all the requested transactions in real time anymore. As a consequence, some orders were executed with delays, which affected the efficiency of real-time trading. However, when the equilibration to the fundamental value is delayed, this may induce over-reaction of market participants and overshoots in the market, i.e. temporary disequilibria. In traffic flows, such delays can lead to so-called phantom traffic jams, i.e. breakdowns of free flow for no obvious reasons (such as accidents or bottlenecks would be). Why should such unexpected breakdown effects not show up in financial markets as well?

On a longer time-scale one finds that it took months to gain at least a partial overview of the risks and losses in the financial system. This reflects the large degree of interconnectedness, i.e. de-compartmentalization, which has occurred. Since the beginning of this decade, new financial products were developed at a rapid pace. One example are securitization products, which are composed by gathering a group of debt obligations, such as mortgages, into a pool, and then dividing that pool into portions that can be sold as securities in the secondary market. In this way, particularly due to the use of multi-level securitizations, it became decreasingly transparent, which real-world goods were actually behind these securities. In the end, one had to rely on the affirmations of rating agencies. Their operation, however, was based on the intuition that the risk could be dispersed by distributing it over different areas of economy. That approach, however,

has rather created conditions which allowed for an unobstructed spreading of the crisis.

This is an important point. All previous economic crises were clearly limited in terms of the geographical region (e.g. the Asia crisis affecting the rising tiger states in 1997/1998) or the economic sector concerned (e.g. in case of the Dotcom-bubble in 2000). Within such compartments, euphoria and panic could occur time and again—but they were contained. In our current financial system, however, changes in state regulation undermined compartmentalization. An example is the American Glass-Steagall Act which, until it was abolished in 1999, had prevented companies from doing both commercial and investment banking. Compartmentalizations like these are not only objectively important, but also stabilizing from a psychological point of view: In times of crisis, human decision-making tends to be rapid and based on intuitions oriented at clearly perceivable structures of economic reality. Compartmentalization is also a precondition to allow for effective state legislation and to ensure, in times of crisis, that the process of re-evaluation does not take too long.

2.4 Systemic Stability and Trust

Apart from the destabilizing factors discussed so far, financial markets have an additional, built-in destabilizing mechanism. The possibility of profiting not only from rising stock prices but also from falling ones (by short-selling) has important consequences. In principle, participants can earn faster and more money when the market goes up and down, as compared to a stable, steady-growing market. Hence, opportunities for profits grow with market variability, which is likely to increase the volatility of stock prices. Therefore, market mechanisms are not constructed in a way that would support stable stock prices. They rather imply an inherent

instability that needs to be continuously counterbalanced. This may be compared with human walking, which can be characterized by continuously counteracting the process of falling. If this control process of continuous counter-action fails, a free fall results, as has been recently observed in the financial system.

Such systemic instability is, of course, potentially more harmful, the smaller the financial safety margins of the involved actors are. In fact, compared to the 1980s, there has been a significant change in this regard, for example, in the United States: U.S. household debts, when measured in percentage of income, have quintupled to reach a level of 130 %. The debt of US banks increased up to 110 % of GDP. Given these conditions, changes in the value of enterprises as a consequence of the systemic instability of financial markets can have serious effects.

What makes things worse is the fact that the auction mechanism used in financial markets mixes material values with psychology. As we have seen, if actors lose interest in financial transactions, prices can fall indefinitely. It is, therefore, important to consider the social network underlying the valuation of real-world goods: Prices in a market economy also reflect the consumers trust (or distrust) with regard to the usefulness of the related good. This in-priced trust is also the reason why, mathematically speaking, economic transactions are not a zero-sum game, i.e. there are no conservation laws for economic values comparable to the law of energy conservation in physics. The valuation process of economic goods is linked to a social network of interacting actors, where the depth and duration of the interaction correlates with the degree of trust between them. We may call this a network of trust. The successful build-up of a trust network requires a minimum degree of intimacy between the actors. Trust links a real-world economic good with its price, which in this way becomes a tradable object in the financial system.

However, also the trust network has been negatively affected in the past years. For numerous reasons, the frequency and duration

of interactions during the process of valuating economic goods were reduced: Geographical distances between business partners increased, time constraints were imposed on business transactions, second opinions were not anymore obtained for financial reasons, language barriers became an issue in a globalized economy, incentive structures within companies provoked more rapid staff turnover, etc. The fact that investors currently hold stocks of Nasdaq-quoted enterprises only for two months on average, while in the 1980s, this time period was about four years - is only one indicator of this problem: Many companies are confronted with a new ownership structure at the time of each quarterly report even in research-intensive sectors, where companies are required to make long-term investments.

2.5 Utilizing Control Features of Complex Systems

An analysis of the financial system from the viewpoint of the theory of complex systems, therefore, reveals a much more differentiated picture than most public debates of the crisis do. The behavior of financial markets in early 2008 shows all the signs of a conflagration that has gone out of control. The continuing erosion of banks' reserves shows that it has become unclear what a subprime mortgage actually is and, therefore, even the name of this crisis is quite misleading. Therefore, it is not surprising that in early 2008, many different estimates regarding the overall need for depreciation have been circulated—from \$ 170 billion (Bank of England) over \$ 400 billion (OECD) up to \$ 1 trillion (IMF) or even more (\$ 4 trillion, Goldman Sachs). These estimates differ by more than one order of magnitude (compare also to the actual estimates in the previous article).

Thinking Ahead - Essays on Big Data, Digital Revolution,
and Participatory Market Society

Helbing, D.

2015, XIII, 194 p., Softcover

ISBN: 978-3-319-15077-2