'Anna Karenina principle' explains bodily stress and stockmarket crashes

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(PhysOrg.com) -- A new theory that reveals the intrinsic mechanism of adaptation crises, from human adaptation to hard living conditions, to a bank collapse or stockmarkets going from boom to bust has been put forward by a team of researchers from the University of Leicester.

The novel study which has just been published, led by Professor Alexander Gorban of the Department of Mathematics, draws on his work on how humans adapt to hard living conditions – and applies it to economic systems.

Working with colleagues at the Siberian Federal University, Russia, the researchers turned to many past experiments and observations of groups of humans, animals, trees, grassy plants, stockmarket prices, and changes in the banking sector.

Says Gorban: “In many areas, from physiology to economics, to animal behaviour and ecological adaptation, scientists have to analyze groups of similar systems, whether cells, stock prices or trees adapting to pollution levels.

"By studying the dynamics of correlation and variance in many systems facing external, or environmental, factors, we can typically, even before obvious symptoms of crisis appear, predict when one might occur, as correlation between individuals increases, and, at the same time, variance (and volatility) goes up."

This was demonstrated, for example, by an analysis of the impact of emissions from a heat power station on Scots pine. For diagnostic purposes some metabolites in needles are measured. The test group of pines grow in the emission tongue of the power station. The control group was from a stand of the same age and forest type, growing outside the industrial emission area. No reliable difference was found in the test group and control group average compositions. Nevertheless, the sample variance in the test group was 2.56 times higher, and the difference in the correlations was huge: in the test group the correlations were almost five times higher.

Many examples from human physiology support this observation: from the adaptation of healthy people to a change in climate conditions to the analysis of fatal outcomes in oncological and cardiological clinics.

The same effect is found in the stock market. For example, in the dynamics of the 30 largest companies traded on the London Stock Exchanges, from 14/08/2008 to 14/10/2008 the correlations increased five times and the variance increased seven times.

Gorban's work can explain what happens when resources are almost exhausted. He points out that one might see this as the "Anna Karenina principle" in action. In Tolstoy's novel, "All happy families are all alike; every unhappy family is unhappy in its own way." Gorban suggests that, "All well-adapted systems are alike, all non-adapted systems experience maladaptation in their own way."

He added: “In the chaos of maladaptation, there is an order. It seems, paradoxically, that as systems become more different they actually become more correlated within limits.”

Gorban and his colleagues demonstrated the validity of this hypothesis for physiological adaptation in 1987. In economics, others including

Longin and Solnik, Stanley and Mantegna and collaborators, demonstrated the effect for the market in the mid-1990s. The latest analyses and theoretical and experimental work of Gorban and his team suggests that it is a general principle for adaptation of many kinds of systems under stress.

Working with Elena Smirnova and Tatiana Tyukina, Gorban, Professor of Applied Mathematics, describes a system for uncovering correlations in physiology that can be applied to economics for risk management and crisis prediction.

The team has now come up with a general approach to explaining the dynamic effects in individuals as they adapt to new conditions regardless of the systems being observed or the specifics of the conditions.

Their approach builds on an earlier idea known as ‘adaptation energy’ first put forward by the endocrinologist Hans Selye in the 1930s. He developed the concept of physiological stress and analysed the general adaptation syndrome.

Selye's work alludes to our hidden reserves, our adaptation energy, that allow stresses to be overcome. Gorban and colleagues have used the metaphor of adaptation energy and applied it to a statistical analysis of economic systems.

They successfully tested the predictions that emerge from this analysis on historical stockmarket data from 1000 US companies during the period 1994-1995 and to 30 major companies in the UK from 2006 to 2008.

Adaptation energy as described by Selye, represents physiological resources that can be drawn on when an organism is under biological stress. Gorban and colleagues have demonstrated that the same notion

can be applied to financial systems.

This is not the end of the story. If the load increases further then the "order of maldaptation disorder" is destroyed and the systems progress to a fatal outcome in a fully disordered state. This conclusion is the complete realisation of the Anna Karenina Principle, Gorban says.

More information: The research was published in the August 15 issue of the journal *Physica A*, (Vol. 389, Issue 16, 2010, pp 3193-3217). A preprint is also available online: arxiv.org/abs/0905.0129

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