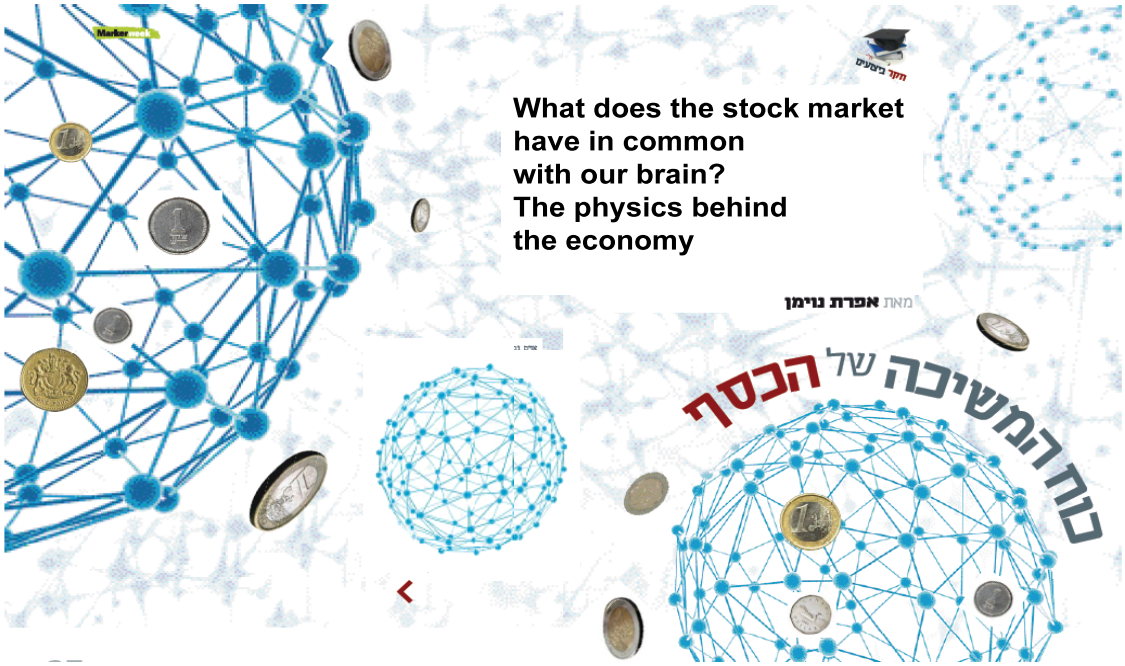
What does the stock market have in common with our brain? The physics behind the economy

TheMarker 20:02 | 23/04/2010 By Efrat Neuman



How could it have been possible to predict the market breakdown, following the collapse of Lehman Brothers? ■ How can earthquakes help us understand economic crises? ■ Econophysicist's analyze the world of economy through the glasses of physics, and explain why eventually everything is quite simple – all you need to do is look for the right method, to discover the simplicity hidden in the complexity of economies and financial markets.

Imagine yourself entering into a store in order to buy a pair of scissors, and discover that the salesman is deaf. What would you do? The solution is simple: you would gesture the motion of cutting something with a pair of scissors, thus getting your wish.

A week later you entered the same store to buy a puppy. This time, you meet a salesman who is blind. What would you do this time? "Woof - Woof" is the answer most people immediately think of, rather than just ask for a puppy. Why? This is because our brain tends to go through an immediate conditioning following the previous question.

Prof. Eshel Ben-Jacob uses this example to show that most people think in set patterns. "With children, it's a completely different story, because their brain does not use strict patterns. So, they give other answers: For example, if the salesman is deaf, they will simply ask another salesman. But, at old age there is a stronger tendency to think and act according to previous patterns."

Ben-Jacob is not a psychologist, and while he studies financial markets, he is neither an economist nor a financier. Prof. Ben-Jacob is a physicist from the school of Physics and Astronomy at Tel Aviv University, an expert in biological physics who focuses on brain research and the biological and social behavior of bacteria. Recently, among his many research topics, he has begun studying and analyzing the behavior of capital markets.

What could possibly interest a physicist, who is famous for his research on the brain, in economics and the behavior of stock markets? The main reason is the abiity of physical insight to understand situations in the world of economy, and to examine and search simple rules hidden in its complex behavior - as physicists have done successfully in the past in the description of physical systems. His hope, and that of other Physicists doing similar research, is that once they find the logic and mathematic regularity behind events in the markets, they will be able to establish a more effective way to prevent unhealthy behaviors of the market.

"Just as in the case of brain research and research of colonies of bacteria, analysis of capital markets is not physics per-se," agrees Ben-Jacob. "In these three areas, physicists bring in a new way of seeing things. They like to think about cause and effect, and they are more naive - or confident – in a way that allows them to look at complex models and find the simplicity and hidden regularities. The tools are mathematics or statistics and the purpose is to seek principles. I believe there are simple principles. "

From right to left: Prof. Rosario Mantegna, Dror Kenett, and Prof. Eshel Ben-Jacob

Bring out the tools of Physics

Ben-Jacob is not the first to use the logic of Physics to analyze economic situations. In the mid-90's, the physicist Gene Stanley, from the Center for the Study of polymer physics at Boston University, coined the term Econophysics, when he was asked to describe a collection of articles written during those years by physicists, particularly on matters relating to financial markets. The idea was to create a new research field, which aims to understand processes and complex problems in the fields of Economy and Finance, using tools and methodologies from Physics.

Stanley - who holds the record for number of articles published in the prestigious journal "Nature" and an enthusiastic supporter of science in Israel - realized that having such a collection of articles - including an article by physicist Prof. Rosario Mantegna of the University of Palermo, Italy - indicate a new and interesting direction. Together with Mantegna, who is an expert in network theory, they wrote a milestone paper on the subject in the mid-90's, as well as a book titled Introduction to Econophysics. Following these publications, scientists active in the field began to gain recognition and confidence. A few years later, at the beginning of the millennium, the physical theories used to analyze problems in Economics gained momentum and popularity. Together with increased accessibility to information, this new field started to receive recognition outside the world of physics.

Network theory is just one example of a tool from Physics used to investigate problems in Economics. This theory describes and quantifies the importance of nodes that are connected one to the other, for example in the case of social networking, and allows people to measure dominance of certain persons in such social networks. In these networks, If two people behave in the same way, they may really think and act in the same way; however, it is also possible that they are individually affected by a third person. In a similar way, mathematical tools can be used to examine the relationship between stocks, which may be hidden – whether there is real connection between the behavior of two stocks, or are they simply affected by a third party.

"While such network theory methodologies come from physics, it's not something that only physicists do. This creates a new way to examine the system, and to test its properties," explains Mantegna, who arrived in Israel for a brief visit as a guest of Tel Aviv University.

Mantegna explains that this type of physics-based thinking cannot predict the next crisis, but it can certainly be used to re-assess risk. "You can compare it to an earthquake. You cannot predict when exactly the next earthquake will occur, but in physics, we have found a way to describe the behavior of the after-shocks. It is not possible to know when the first aftershocks will occur, but after the first of these occur – then with a good probability you are able to predict when the following aftershocks will appear."

The basic assumptions are not always correct

When most students begin their physics studies, they imagine themselves doing research in astrophysics, quantum mechanics or string theory, but there are those who choose differently. Dror Kenett is a Ph.D. student at Tel Aviv University doing research in the field of Econophysics, focusing on the structure and dynamics of financial markets, with a focus on the Tel Aviv Stock Exchange (TASE). He works with Dr. Yoash Shapira, former head of the Atomic Energy Commission Research and currently a guest scientist at Tel Aviv University.

"I'm one of the few Physics graduate students doing this type of research in Israel, if not the only one," says Kenett. A year ago he created a close collaboration with Dr. Gitit Gur-Gershgoren, head of the Research Department of the Israel Securities Authority (ISA).

Scientists are no longer only locked up in the ivory tower of universities. Wall Street is flooded with professors of finance, mathematics and physics, who are considered well educated and sophisticated players. They work on models and mathematical formulas in order to maximize the profits of companies and the hedge funds that recruited them.

Physicists first entered the financial swamp many years ago. The current estimates speak about thousands of physicists on Wall Street, who received the nickname "Quants" - because they deal with quantitative finance (Quantitative finance).

However, the financial crisis of recent years proved that mathematical models simply do not work, so you cannot rely on them for defense against any crisis. One of the harshest critics of these models is the researcher and author Nassim Taleb, who claims that none of these formulas and models meets conventional scientific criteria. He claims that in the financial world there is a high probability for very significant events to happen, although they may be totally unexpected. Taleb argues that the system has reached the level of complexity in which it cannot be controlled.

In an interview with Markerweek at the height of the crisis, at the end of 2008, Taleb said: "At first, the financial system did not exist, then it began to walk, then it learned to ride a bicycle, then drive a car, and now it is at the level of complexity of a jumbo jet. However, the pilots of this jumbo jet still think they are riding bicycles. These pilots have no idea what's going on and they don't even understand the airplane anymore, which is why it is clear and known in advance that this plane will crash sooner or later. "

The academics can respond to this criticism in two ways. First, they can claim that they did not develop the existing models to maximize profits, rather to understand how the market operates. In fact the institution that can make the most out of these models is actually the regulator. Second, Ben-Jacob, Mantegna and Kenett all agree that there are many problems with these models - so it was not right to rely on them in the first place.

"The crisis emphasized that the underlying assumptions in the models are incorrect," explains Ben-Jacob. "These models are based on assumptions are not always correct, but still economists rely on them in a blind way. Theories developed by Nobel Prize winners

assume all kinds of assumptions that have never been empirically tested before, from the viewpoint of systems, such as we know how to do in physics. It is amazing that these have never been examined in a critical way."

Which of the assumptions is wrong?

Ben-Jacob: "The notion of rationality of the traders, the efficient market hypothesis, the existence of an infinite sample and all kinds of idealizations, such as the assumption that financial variables follow a normal distribution. Research has shown that in many cases such a distribution of the variables, simply does not exist."

Kenett: "We also found that the Beta coefficient is not correct in its current form. The current basic definition of risk is based on the Beta coefficient, which expresses the relative sensitivity of a stock to the market volatility. The assumption behind this is a linear relationship between the stock and the stock index, and that any change of X causes a change in Y. But in fact there is no linear relationship, rather a complicated dependency. It's not one to one, and when a stock rises, the index rises, and vice versa.

So why still use the Beta coefficient to define risk?

Kenett: "Because it's convenient and people are already used to building a portfolio according to the Beta coefficient. After all, if a young economist's will build a portfolio, but he will do it against the conventional way and will claim that what everybody uses is not true, everybody will look at him as if he is crazy. Today we have the technology to perform scientific analysis on a large scale, in which we find empirical evidence that show that the theories are incorrect. Physicists bring with them a new perspective: On the one hand their ability to simplify, and on the other they make such simplifications by making analogies to other fields - like the comparison between the market and the brain."

How is the stock market similar to the brain?

Ben-Jacob: "We think of the market as a brain suffering from epileptic seizures. We find in the market short time windows in which there are significant increases in the majority of stocks, which cause a breakdown in the healthy structure of correlations in accordance with the functional sectors. The situation is similar to that of a brain during an epileptic seizure – the brain works in a synchronized manner, thus preventing the various functional areas to perform their unique task."

Like a brain suffering epileptic seizures

Ben-Jacob and Kenett discuss a study in which they examined the state of the U.S. market before and after the Internet bubble burst. The study examined the correlation between the stocks making up the S&P500 - that is how the stocks are coordinated in terms of their return: If stocks behave the same way, i.e. every 1% increase in one stock is also observed in the second stock - the correlation is perfect. The results showed low correlation between the stocks until the end of 2001, but then a jump occurred in the

correlation between the stocks. One can think of it as if the market became very stiff - all stocks started behaving in the same way.

Next, they examined what happened to the correlation between stocks after removing the effect of the index; that is, the residual correlation between stocks. In an analogy to network theory, if stock A has a strong correlation to the index it belongs to, and stock B has a strong correlation to that same index – then there will be a strong correlation between stock A and B, not because of a real relationship between the two, but rather because of their correlation to the index. Therefore removing the Index effect reveals the true correlation between stocks. The results showed that until the end of 2001, there was a real correlation between the stocks, but since then it has disappeared. That is, stocks are now affected almost exclusively by the index, in other words - by the market.

This is not a healthy situation. "One can imagine that the index is like the epileptic foci that affects brain activity and does not allow different areas to comply with the functions they need to perform," says Ben-Jacob. This analysis, carried out with the research department of the Israel Securities Authority, reveals that to date the U.S. market has not returned to a healthy state. The data also shows short periods of time in which stocks are affected even more by the index, and they all follow it, like a herd. This has a devastating effect: "In a state of panic, the lack of a fast moving solution could lead to catastrophe in the market," says Ben-Jacob.

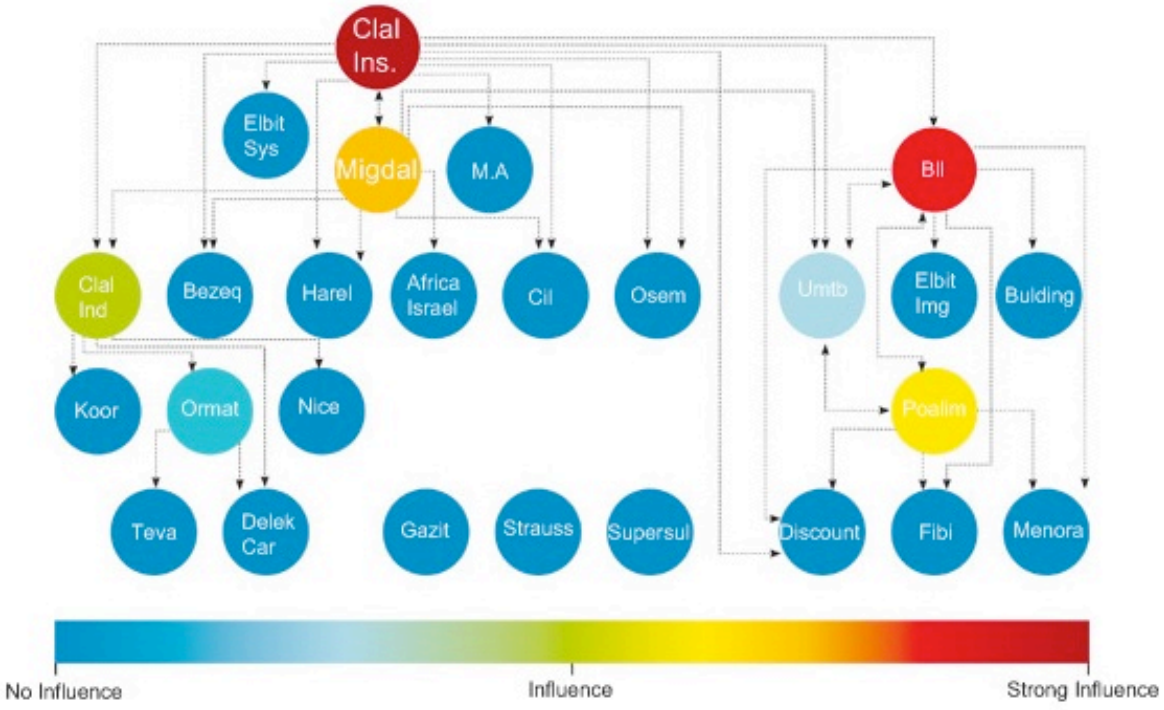
There is an intuitive connection between the different stocks in different sectors.

Kenett: "This is true mainly in Israel, but not so much in the U.S. market. The Israeli market is a small local market, and other markets influence us, which provides us with more flexibility. Using network theory, we also examined the stocks of the TA-25 index - How each stock affects the rest of the stocks, and how each stock is affected by the index.

Results show that the index controls all the stock - all are connected to it with arrows - and they are mainly coordinated with the behavior of the index. Next, we deducted the impact of the index to find the true correlation between the different stocks (see chart on the right). Unlike the case of the U.S. index, we found higher residual correlation. Here we are probably more accustomed to trauma, and the market is healthier. Not all stocks are influenced by what happens to the index, like in the U.S., but some have a healthy relationship within sectors, as should be. The effect is that of a weaker herd. "

Which of the large stocks in Tel Aviv have the highest correlation relative to others?

"Our analysis was performed on stocks listed on the TA-25 in 2007, and we found that Clal Insurance (no longer listed on the index) and the banks have the highest correlation with other stocks in the index. We were surprised to see that Teva is an outsider in these results. We also saw that Africa Israel (also no longer in the index) has a low correlation with the remaining stocks. Indeed, when this company collapsed, we did not see a dramatic impact on the market. "



Using the concept of partial correlations, it is possible to create a network that represents the influence of each stock, on all other stocks of the portfolio. In this example, Prof. Ben-Jacob and Kenett studied 26 stocks belonging to the TA25 index in 2007. The colors represent how influential is each stock, with blue signifying no influence, and red signifying strong influence. The main surprising result of this analysis was the fact that Teva, which is the largest Israeli company y traded in the Tel-Aviv market, has no influence on any of the other stocks. These results also show that the banks and the insurance companies have the strongest influence on all of the other stocks in this study.

What can be done with these findings?

"The goal is to identify sources of danger and structural changes that are unhealthy to the market. According to our analysis, we have observed that Lehman Brothers had a critical impact on the market. The relationship between other stocks was dependant on it, and in fact when the company collapsed in September 2008, it destroyed the market. It could be that if the U.S. administration had known this, though it is not clear they did not know it, it would have changed their decision. "

How much does Econophysics contribute to the understanding of the reality of investors and the different players in the market?

"You must consider this from two points of view. It will take time before the analyses of physicists will contribute to maximizing profits for the investor. But, there is also the regulator's point of view, who wishes to preserve the market. The models that examine the correlation between different markets, the correlation between the sectors' and stocks' relationship to the bond market can help to know how to keep the balance and stability of the market. In Econophysics there is also another type of methodology, known as Agent Based Model, whose purpose is to examine how the behavior of players in the market changes under the influence of different scenarios in the market, such as the effect of regulation on trading.

"The field is still evolving, but as a result of the crisis it received much more attention and suddenly people realize that there is also room to alter basic assumptions. I estimate that at least in Italy and Israel, the regulator will adopt the conclusions and understand the importance of this research. I want to believe it will give us another jump in the evolution of this field. Physicists can contribute with their naïveté. All in all, things are very simple."

Why the rich get even richer

In his book, Social Atom, physicist Mark Buchanan explains how social phenomena can be understood through the world of physics. The trick is to think of patterns and not of humans

How do you make a book that has mediocre reviews into a bestseller? Buy tens of thousands of copies, especially from stores that the best-seller lists are based on. Why are traffic jams created for no reason, and then movement suddenly released again? Patterns formed spontaneously accumulate an energy and power of their own. Why do we prefer to eat in a restaurant full of people than at an empty restaurant? Because we are mimicking the behavior of others and assume that people have good reason to be there.

These examples and many others are given by American physicist Mark Buchanan in his book, Social Atom: Why the rich get even richer, cheats get caught and why your neighbors usually look like you, published this month in Israel. Buchanan, who was editor of the scientific journal Nature, explains that humans perceive molecules or atoms acting according to rules that are rather simple, and try to learn the patterns that create these laws. The roots of the complex are often simple. In other words, it is social science research done in the way of physics.

The main idea of the book, Buchanan says, is that the only way to understand events like the eruption of ethnic nationalism, a connection between the strange birth limit of women's education, and social phenomena important or interesting to financial markets, politics or the world of fashion - is to think about patterns and not about humans.

Buchanan describes people's social behavior using patterns of the adjusting atom, the mimicking atom, and the collaborating atom. The mimicking atom template, for example, takes place whenever two or more social atoms meet. In Physics it works like this: Atoms

are interacting with each other in a magnetic material such as scrap iron. Pressures can be in the form of tiny targets for all kinds of directions. If we place the piece of iron in a strong magnetic field, all the atoms will tend to align according to tiny arrows, like soldiers aligning in formation.

In the same way people imitate each other and change their views and their behavior depending on external factors. Buchanan explains that normally we live our lives thinking that we decide for ourselves, but in fact this is not often true. "Probably most of us are willing to accept that others' choices affect us when we choose a movie or a car, or buy a mobile phone or clothes. Much more difficult for us is to admit that they have an impact on more important elements in our lives - for example our occupation, our political and religious views, or our decision to have children. "

Buchanan explains that one of the most prominent patterns in the stock market is that a totally rational investor could lose money because the market is driven by other people's beliefs - and so it is a strange arena in which to be rational. Just as we cannot know for sure what route is best to take to work in the morning – and know that even if we choose the least busy road others may think like us and render it crowded - so it is unclear how investors will behave around us. "Perfect rationality takes place outside place and time. It is not human, and the problem lies in the eyes of rational men or machinery of automatic calculation."

Buchanan also relates to issues of wealth and explains that a completely natural process can push the most wealth into the hands of a minority, without a capitalist conspiracy. We can also expect huge differences in wealth distribution, regardless of people's talent. "A study of two physicists found that sheer luck causes some of the people to accumulate wealth more than others. These people had more wealth to invest, and they had a chance to make more wealth. And here we reach the real secret with which we can understand the distribution of wealth inequality: the lack of evaluation. The speed at which they double their own profits become larger. "

To illustrate this Buchanan presents the following example: Take a piece of paper with a thickness of 0.1 mm. Fold it in half 25 times in a row, and at each time you fold the thickness doubles. What is the total thickness you will get? The answer is that the folded paper will be about 3 km thick, much more than what people tend to think. "Similarly, a string of positive returns from investment is enough to make huge differences in wealth and population - as it builds the fortune of the connection but not a doubling. The result is that most automatic incremental capital is in the hands of a small minority."

"In Economics you first build a theory; we start from the data"

"You cannot predict crises, but you can better assess the risk," explains physicist Prof. Rosario Mantegna from the University of Palermo, Italy, who arrived in Israel for a visit as a guest of Tel Aviv University. Among other things, he gave a lecture at the Israeli Securities Authority about the importance of Econophysics and the work he is doing.

Prof. Eshel Ben-Jacob talks about the fact that Italy is the second largest scientific partner of Israel after the U.S. "Stefano Boccaletti, Italy's scientific attaché in Israel for the past four years, is a professor of physics and among the world's bigest experts on network theory, and fosters cooperation between Israel and Italy. We have published articles together on neural networks common in epileptic brain activity. He also collaborates with researchers from the Weizmann Institute, and the Bar Ilan University.

"In Economics, first you create the theory and then check what happens in reality. To some extent, we are more dynamic, we start from the data," Mantegna explains a study which examined the Finnish and Spanish stock markets. He and his colleagues examined whether investors can be categorized by groups based on their investment patterns, and the correlation between the behaviors of different investors in the stock market. Statistical findings show that there are some groups of investors, including the two main groups: a group of investors who act the same way - buy when the market goes up, and sell when the market goes down (so-called "momentum strategy") - a group of players who act the same but inversely proportional to the market, i.e., they sell when the price rises and vice versa (Contrarian Strategy).

Since the identity of the investors is also known in this analysis, the study found that the big institutional players are the ones who use the momentum strategy, thus helping to push the market in the same direction.

Why is this useful? The most useful application of this classification of investors is to find unusual patterns of investor behavior. Classification of investors and their behaviors relative to each other can be relevant for the regulator. For example, the Israel Securities Authority may be interested in knowing when a group of different investors following the market are all using the same strategy, or if they behave according to the same adapter, even excluding the impact of the market - then there is reason to think something fishy is going on.