Futures Lab: Physicists and mathematicians are a growing presence in markets. Dr. Chekhlov demystifies the link between science and trading.

"We wanted an example that illustrates this transition in an easy-to-grasp way, to demystify it as much as possible. After the crisis of 2008, there were reports that complicated financial instruments, designed in the abstract by mathematicians, wreaked havoc on the system. How could math and physics possibly fix what went wrong? Why and how does it work?"

Alexei Chekhlov graciously took the time to explain the connection, as he sees it, between his earlier work in physics and the investment approach he subsequently developed. The five main themes he highlights below are determined by his particular expertise and don't necessarily cover all the issues.

Still, these themes may be used as signposts for a conversation with a quant. One intriguing point is how human actors in markets differ from those in the laboratory. This is where intractability - the logic of behavioral finance - comes into play.

Dr. Chekhlov worked on theoretical physics in the Soviet Union before coming to the US. He has a Ph.D. from Princeton University in applied and computational mathematics and teaches financial price analysis at Columbia University's mathematics department in an evening MBA offering for job managing Systematic Alpha.

A discussion of the market-neutral statistical arbitrage strategy he uses as a commodity trading advisor is in the previous section.

Universal Descriptions of Fluctuations

In the past, scientists did not see finance as a worthwhile or noble enough field, while financepeople thought scientists were out of touch with reality. Therefore there was little interaction. Starting in mid-1980s many theoretical physicists became interested in finance because the Soviet Union disappeared and the US Congress reduced its financing of research projects in physics. That released many highly skilled mathematicians and physicists, who found their application niches in finance.

In my work in physics, I focused on such problems as instabilities between two liquids and turbulence problems that arise in nonlinear systems in response to random fluctuations. We worked on statistical analytical methods and measurement techniques which helped us to solve and explain such problems as critical phenomena and fluid turbulence.

In physics, there is the notion of universality, meaning methods are frequently useful for problems other than those they were initially developed for. As far as finance is concerned, you can use the tools of statistical physics to describe price changes statistically without even knowing the details of individual fluctuations and what exactly causes them.

Price fluctuations can be studied as a statistical ensemble. One can start by defining a probability distribution function of two-point price differences. Does this description apply universally to many markets? Probably the same parameters do not describe all markets. There are some parameters that are universal across many markets and some that are market-specific.

The best is to define which parameters are universal and define the set of markets they apply to—the universality class. Then one can go on to study more complex properties, like more the price changes influence each other.

This is not yet interesting in financial markets. In 1985, after studying the random-force driven Burgers equation, I thought of applying a similar approach to the S&P 500. I purchased the bid-ask spread option data for a pre-exchange S&P 500 futures contract and applied various physical techniques that had not been done before for this data. I had to calibrate my data in such a way that I found the statistical properties in the velocity changes that I had studied in the physics of turbulence.

Once you go deeper into statistical measurement, you get a much more accurate small-scale model than you can get by applying conventional assumptions such as Gaussian distribution and the Random-Walk model. This can lead to better modeling of future market behavior, at least hypothetically.

A probability distribution specifically tailored for a market leads to a better understanding of risk, because the so-called tail-probability naturally appears and becomes part of your model rather than remain an outlier or a "black event" of some sort. Extreme price changes are not outliers but rather an integral part of the system to be prepared for and go through in a short-term market horizon. This type of reasoning is not what the majority of finance professionals prefer. But it is an advantage for a trading strategy if you are in a minority and yet your views are correct. When a trading methodology becomes widespread, the expected returns decline.

At the time I started working on Wall Street, I tended to deal with a lot of immediate practical issues quite remote from studying the high-frequency statistics of price changes. But I continued to think that a more accurate, quantitative understanding of price fluctuations would lead to a better trading model.

At this time BNP Paribas was more open to bringing former physicists. There I was part of an all-internal team, all physicists, who developed and executed proprietary trading strategies in a wide set of futures markets, including a contract trading component.

The experience taught me that my thinking about the majority of traders would be profitable if you develop a rational forecasting algorithm. We traded our markets with the help of the Arrowsmith Group of 1980s, even though we used a purely systematic strategy, we had to execute it manually, as automation was not possible with the technology of that time.

Trading has changed so much in the past decade from a practical standpoint. I come to recognize that in one key respect the behavior underlying market price changes is different from the laws of nature. This is not a difference in liquid, for instance. Unlike the universal laws of nature, price changes of financial objects do not always follow universal laws of nature. Large parts of our market behavior do hypothetically.

The statistical description of price changes is very useful but there are limits to its applicability, which have to be carefully understood. This may be illustrated by one of the most important reasons for the Wall Street education.

We currently trade against deviations of price changes from an efficient market—or, in other words, from a Random-Walk. Our trades are taken in the direction that would bring the market into a more efficient state. Deviations occur because market participants do not always act in the most rational way. For example, we know that there is no reason for the stock market to remain one way for a long period of time. The reason is that the market is continuously changing. Therefore, we have to re-test our models against new information. This is important, because market participants frequently over-react to sudden new negative market information and under-react to certain positive information.

A Human trader’s decision may be dependent on his stress level, his other trades or gains, his personal emotional state, etc., which should not be the case in an efficient market. The more the type of behavior there is, the more opportunity there is for our trading models.

But the more markets are traded in a fully rational automated algorithm, the more price changes conform to a Random-Walk model. In that sense, traders like us make our lives more efficient. For example, major exchange-traded futures markets like the British pound or the euro are quite efficient and— at least based on our research—offer no opportunities for systematic predictions.

Diversifying our trades, we expect that inefficiencies might appear in some markets for quite some time and that quantitative models will offer ways to exploit that. After we have been noticed by many researchers, human nature is not necessarily becoming more rational over time.

Skill Match

Our skills are applied to high-frequency financial price fluctuations, therefore our approach is to model these fluctuations. We describe them in a way very similar to the way statisticians describe physical phenomena. To efficiently use such information you need the financial instruments with the lowest transaction cost and the best bid-ask spread to be the best fit for the purpose.

Once you model a particular market, the next step is to turn understanding into a robust trading strategy. This brings a host of problems related to out-of-sample performance and/or over-fitting. There is no single secret magic formula; you have to just diligently work on applying a wealth of appropriate statistical techniques in a disciplined way.

Weak Stationarity

Behind the statistical modeling approach described above lies an implicit assumption that the statistical properties you’ve quantified will persist in the future. In exact sciences this property is called stationarity. We believe that in financial markets this does not exist in a strict mathematical sense. It can be only understood in a weak, somewhat time-dependent way, so that one's view on statistical properties can and has to be re-tested over time.

Some financial instruments may be more stationary than some others. For example, because equity indices are a weighted average of individual stock price indices, they are less likely to be dependent on the disappearance of particular components. For instance, the Dow Jones Industrial Average will change its composition as a result of corporate mergers and a new US president in the future. In exact sciences this property is called stationarity. We believe that in financial markets this does not exist in a strict mathematical sense. It can be only understood in a weak, somewhat time-dependent way, so that one's view on statistical properties can and has to be re-tested over time.

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In the past, scientists did not see finance as a worthwhile or noble enough field, while finance people thought scientists were out of touch with reality. Therefore there were little interactions. Starting in 1960-1980 many theoretical physicists became interested in finance partly because the Soviet Union disappeared and the US Congress reduced its financing of research projects in physics. That released highly skilled mathematicians and physicists, who found their application riches in finance.

In my work, I focused on such problems as instabilities between two liquids and turbulence problems that exist in nonlinear systems in response to random fluctuations. We worked on statistical analytical methods and measurement techniques which helped to solve some of such problems as critical phenomena and fluid turbulence.

Price fluctuations can be studied as a statistical ensemble. One can also try to define a probability distribution function of two-point price differences. Does this description apply universally to many markets? Probably the same parameters do not describe all markets. There are some markets that are universal across many markets and some that are market-specific.

The best to define which parameters are universal and to define the set of markets they apply to—the universality class. Then one can go to study more complex properties, like the price changes influence across other markets.

This is how I got interested in financial markets. In 1995, after studying the random-force-driven Burgers equation, I thought of applying a similar approach to the S&P 500. I purchased the tick-by-tick futures data for an exchange-traded S&P 500 futures contract and applied various statistical and analytical methods. But I had to look for the basics of those data. I found that the statistics of past data had a lot in common to the physics of turbulence. I realized that the statistical velocity that I had studied in the physics of turbulence is a probability distribution function of two-point price differences.

Once you delve deeper into statistical measurement, you get a much more accurate small-scale model than you can get by applying conventional assumptions such as Gaussian distribution and the Random-Walk model. This can lead to better modeling of future market behavior, at least in its universal side.

A probability distribution specifically tailored for a market leads to a clearer understanding of risk, because the so-called fat-tail properties naturally appear and become part of your model rather than remain an outlier or a "black swan" of some sort. Extreme price changes are not outliers but rather an inherent property of the system. These extreme price changes are prepared for, and go in short-term market price-fluctuations.

This type of reasoning is not what the majority of finance professionals favor. But it is an advantage for a trading strategy if you are in a minority and your views are correct. When a trading methodology becomes widespread, the expected returns decline. Market Decline.

When I started to work on Wall Street, I had to deal with a lot of immediate practical issues quite remote from studying the high-frequency statistics of price changes. But I continued to think that a more accurate, quantitative understanding of price fluctuations would lead to a better trading model.

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Once you model a particular market, the next step is to turn this understanding into a robust trading strategy. This brings a host of problems related to the way very similar to the way statistical physics describes physical phenomena. To efficiently use such information you need the financial instruments and the internal transaction costs and the speed of price future to be the best fit for the purpose.

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