

Title: **OCCF – Understanding what makes a financial market “tick”**

Summary: The Oxford Centre for Computational Finance (OCCF) at Oxford University is a new kind of financial laboratory which aims to monitor, understand and even forecast financial markets in real time. The key ingredients for achieving this goal are the software models which OCCF has developed to describe the behaviour of populations of traders. These models are themselves the result of state-of-the-art research within the University into the dynamics of complex systems and complexity. The novel insight offered by such an approach is of great potential interest to academics, practitioners, and also regulatory bodies.

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Can models of artificial markets help financial engineers, practitioners and even market regulators better understand financial market movements? Oxford University's 'financial laboratory', the Oxford Centre for Computational Finance (OCCF), is attempting to do just that. In addition, OCCF is developing a wide range of projects aimed at fine-tuning more traditional models.

Designed to support the world's financial markets through development of mathematical theory, OCCF offers access to analyses of real-time market data and other research based on the newly developing science of complexity. In addition to helping evaluate all forms of operational risk, OCCF's research is geared to help regulatory bodies develop more effective and faster reactions to extreme market events, such as predicting and dealing with market crashes.

There are currently several projects underway within OCCF involving academics, doctoral students and financial institutions. One particularly interesting example involves a close collaboration with HSBC Bank, analyzing movements across the currency markets. In wider terms, OCCF represents an unprecedented collaborative effort between academia and leading commercial firms in the IT and finance fields.

OCCF was launched on October 10, 2001 by the UK's Chief Secretary to the Treasury and the Deputy Governor of the Bank of England. The collaboration was instigated in 2000 by the Numerical Algorithms Group (NAG), a worldwide organization dedicated to developing quality mathematical and statistical components and 3D visualization software used by most of the major finance houses in the world.

NAG's vision was to bring together resources and capabilities that had not been together in the same place before so that new mathematical models and insights could be developed and applied both by individual financial firms and at the regulatory level. NAG observed that although Wall Street is amply peopled with physicists and mathematicians able to do such work, commercial pressures are such that development of new models generally receives scant attention. Conversely, academic studies had been hindered by the lack of computing and data resources that are available commercially and that are valuable tools to test various new models currently being developed in the hard sciences, mathematics, and engineering fields.

In addition to NAG, the current OCCF industrial partners are Sun Microsystems, IBM Data Management Solutions, and Reuters (which now includes Moneyline Telerate). Indeed, Reuters is set to play a pivotal role in the future, providing the integration services and market data feeds respectively.

The fact that OCCF looks at today's financial markets, and not yesterdays, is critical to the scheme. False positive results can be avoided by testing forecasts of the future before they have occurred and without using pre-selected historical datasets for comparison.

OCCF's current research using this live laboratory can be divided into three general areas: 1) improving numerical implementations within current finance models; 2) adapting standard finance models to different types of markets, including developing new types of derivative products; and 3) building dynamic models of markets using multi-agent game theory, in part to develop better understanding of extreme events such as crashes.

### **Better Numerics**

Using its extensive IT infrastructure and the latest developments in algorithms, OCCF researchers are first investigating ways to improve numerical implementation of standard finance models. Using a standard Black-Scholes approach while employing the distributed architecture of its high performance computers, OCCF is now studying American option contracts using a variety of different algorithms applied in a range of market scenarios. For example, researchers are looking at new routines that incorporate the transaction costs that are incurred over the lifetime of an option to hedge its position and that rightfully should be included in calculations of an option's price. These new algorithms are being thoroughly stress tested and then various economy versions are tested further to see which pared down routines are most reliable in less powerful computers, perhaps even identifying scaled down algorithms that are best suited for calculating on Personal Digital Assistants (PDAs).

This area of OCCF research has relatively immediate commercial impact. Outside of academia, few analysts are able to tie up computing resources for the 6+ months that such studies entail. Nor do most commercial firms have access to the most recently developed algorithms that have been developed by leading computer scientists around the world. Thus, although this is considered the more 'low-tech' aspect of OCCF endeavors, there clearly are opportunities for financial firms that partner with OCCF researchers in these projects devoted to developing better numerics.

### **Adapting Models**

The 'middle-tech' level of OCCF research involves tailoring standard finance models so that they apply to different types of markets and to different types of derivatives.

While every commercial firm understands the limits of the Black-Scholes model, for example, it is still used with various patches intended to adapt the model to real-world situations such as changes in the interest rate during the mid-life of an option. OCCF is poised to do exhaustive studies of the various patches developed by analysts to discern which ones work better or worse with different types of derivative products.

Today, most traders and analysts use Black-Scholes by more or less running it backwards through the theoretical formula to extract a number for the market's implied volatility. In contrast, OCCF researchers run this process forwards to obtain realistic market prices for derivatives by taking real option/derivatives prices to test more general option pricing formulae. This allows a pricing of structured derivatives that are

not openly traded on the market and the promise to help financial organizations invent new types of derivatives with less fear of mis-pricing.

### **Multi-Agent Game Theory**

The more 'high-tech' aspects of OCCF research are seen by OCCF researchers as the one with the potential for dramatic long-range consequences. This involves studying the markets as a dynamic output from the evolving interaction between a population of competing adaptive agents.

OCCF researchers argue that no matter how powerful the computers, or computer algorithms, and no matter how much tweaking one does with standard finance theories and formulas, there is a very scary truth that as markets evolve, so does risk. In fact, any standard model is not viable in the context of extreme events such as market crashes, which means that standard models can become worthless in light of extreme events.

OCCF researchers divide extreme market events into two types: those that are exogenous such as the unforeseen September 11th events; and those that are more predictable such as the dot.com decline in 2000. They ask if this latter fall was 'due to happen' and if so, what triggered it? They ask if there was a buildup in the market that related to trading strategies or the market volume or linkages between different sectors of the market.

This approach looks at the financial markets as a Complex Systems in the true scientific sense that the sum is more than the individual parts. As such, it is believed that such large internally produced changes such as the dot.com fall should have some kind of hidden signature associated with them and that this can be discerned by study. To discover this pattern, OCCF combines real-time data analysis across a broad range of markets and timescales, together with microscopic models of virtual (i.e. artificial) markets running alongside in order to get a picture of volatility and instantaneous risk in different markets. These studies hope to understand the strange complex movements within certain markets and across markets, e.g. when they move together and when they don't, or when volatility is high or low and how this relates to price and volume.

Thus, instead of saying that a market on average behaves a certain way and build theories on that idea of an average, this is instead a dynamic view of the market. This research begins by saying that it does not know at what scale a market behaves in a certain way, and tries instead to build dynamic models. Efforts are being made to quantify the roles played by herding and speculation, by linkages between various components of global markets, and by external perturbations and control mechanisms. Currently, these studies are looking at the market as an evolving population of interacting objects in which individual members (agents) adapt their interactions and behavior according to their past experiences, especially when competing for a limited resource.

While others have attempted this before, OCCF is guided with live data feeds and ongoing analysis of the market data as it comes in. And by applying research from the newly evolving Science of Complexity to this live laboratory, OCCF endeavors to answer if extreme events are altogether avoidable or minimally controllable in the future.

The various commercial and academic partners involved in OCCF in fact see the venture itself in dynamic terms. Models, ideas, software, and even hardware are being developed and shared in a cooperative way. OCCF research being commissioned by commercial firms remains proprietary, but one can look for many of the larger research findings to be publishable material.

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## Numerical Algorithms Group

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