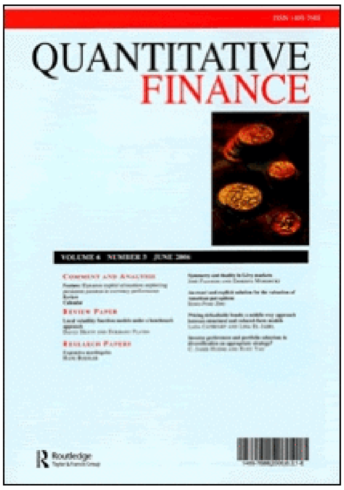

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Intelligent finance—an emerging direction

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Intelligent finance—an emerging direction

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Intelligent finance represents a new direction recently emerging from the confluence of several distinct disciplines in financial market analysis, investing and trading, removing any historical or artificial barrier between them. It is conceived as the science, technology and art of the comprehensive, predictive, dynamic and strategic analysis of global financial markets, towards a unification and integration of academic finance and professional finance. As a comprehensive approach, it is a quest for absolute positive and non-trivial returns in investing and trading by exploiting complete information about financial markets from all general perspectives, drawing ideas, theories, models and techniques from many related academic disciplines, such as macroeconomics, microeconomics, academic finance, financial mathematics, econophysics, behavioural finance and computational finance, and from professional schools of thought, such as macrowave investing, trend following, fundamental analysis, technical analysis, mind analysis, active speculation, etc. In terms of risk management, intelligent finance is expected to minimize the very last risk—the incompleteness of an investing or trading method or system. The theoretical framework of intelligent finance consists of four major components: financial information fusion, multilevel stochastic dynamic process models, active portfolio and total risk management, and financial strategic analysis. We first provide the background from which intelligent finance has recently emerged as a new direction in finance research and industry, and then provide a brief theoretical review of the predictability of financial markets since Bachelier. After these background discussions, we clarify the major research directions of intelligent finance.

Keywords: Intelligent finance; Financial information fusion; Multilevel stochastic dynamic process models; Active portfolio and total risk management; Financial strategic analysis

1. Background of academic and professional finance

The scope of finance we study here is limited to investing or trading stock markets and their derivative futures and options as well as all other standard financial markets, such as forex, interest rates, bonds, commodity futures, etc. In general, the markets underlying our discussions are stock markets, however the principles and theories under consideration may be applicable or adaptable to other financial markets. Apart from long-term investment in stock markets, all other efforts of selective investing and trading in stock markets and other financial markets or non-trivial returns will necessarily generate all kinds of market activity, from which consistent winners must be a minority among all participants. This minority of consistent winners must have a higher financial IQ and EQ, with which knowledge and information concerning the markets of interest can be properly organized into a complete trading system.

Intelligent finance is a quest for a comprehensive approach, methodology and system of investing and trading in stock markets and financial markets, aiming to generate absolute positive and non-trivial returns. Naturally, intelligent finance does not originate from scratch, but must be based on the foundation of a truthful understanding of stock markets and other financial markets, derived from all the relevant existing disciplines and schools of thought in the finance area. While the vision of intelligent finance is bright and attractive, its

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mission or goal appears ambitious, lofty or daunting. Its feasibility may well be questioned for a very long time to come. Nevertheless, a unified science of intelligent finance may be established through the collective efforts of researchers and practitioners in due course.

There are basically three schools of thought in finance: Fundamental Analysis (FA), Technical Analysis (TA) and Quantitative Analysis (QA) of financial markets. FA and TA are predominantly empirical disciplines developed and practised by professional money managers, investors and traders. QA includes financial econometrics, financial mathematics and statistics, as well as financial econophysics. Consequently, players can also be divided into three clusters: fundamental analysts (and investors), technical analysts (and traders), and quantitative analysts (and portfolio managers). In the real world of financial markets, we see legendary players such as Warren Buffett and Peter Lynch, who are typically from one school, such as fundamental analysis and investment (value or growth); but other legendary players have developed their own extraordinary approach and style beyond one specific school of thought, such as George Soros with his approach of macro investing and active speculation on the international or global scale. Therefore, there is a fourth school of thought and players: Strategic Analysis (SA), which seeks to take advantage of all the passive players via active speculation and game playing. SA includes at least game theory and intelligent agents as well as the art of trading, not to mention the positive feedback effect of being more and more connected to a network of influential people from whom information can be obtained, leading to insider trading in a broad sense and to a variety of degrees. The category of exceptionally connected people with some kind or another of insider information should not be neglected.

More and more academic financial mathematicians and professional technical and fundamental analysts, as well as investors and traders, have come to realize that successful investing and trading on financial markets worldwide requires a comprehensive approach that can exploit all publicly available information about financial markets. This information includes not only market activity data and fundamental business data, but also implicit information such as trends, waves, cycles, swings, momentums, as well as inter-market correlations and influence derivable from market activities, business fundamentals, mass psychology and news events. The incompleteness, if any, of an investing or trading method, carries one of the biggest risks, which is, in fact, the very last risk, a risk which no one can afford to ignore or underestimate. History has seen enough unforgiving lessons experienced by financial institutions, money managers, investors and traders of all different kinds, styles and sizes. These include not only the innumerable common mistakes by unskilled or immature players, but also the close-down of some of the world's biggest funds applying the then most advanced financial mathematics, as well as severe draw-downs or missed opportunity costs of some of the most experienced and legendary money managers. Typically, every experienced player (money manager, investor or trader) has developed his/her own angle or perspective, approach and system (not necessarily computerized) for market monitoring and analysis, trading strategy and planning, market and trade timing, trading tactics and execution, as well as portfolio or position management and risk control. The bare fact is: a human trader is first of all a human being, he/she cannot be free from the various humanitarian limitations and constraints, such as cognitive bias, subjective judgment, limited information sources, limited memory and capability of information processing, emotions and sloppiness, which may be covered by two general concepts—bounded rationality and limited resources. If a trader has become good or extraordinary in one or more aspects, his/her attention and awareness of risk would have been concentrated on that or those aspects. Consequently, he/she may become partially or totally blind to other aspects of risk, which may silently beget severe failures or even disasters, in particular if leverage is used.

Our current understanding is that worldwide financial markets are a universe of financial agents of all different kinds, sizes and calibers. This financial universe is supported by internal tensions among interacting financial agents and is powered, but also constrained or limited, by external economic, political and social systems. Financial markets exhibit a strong tendency of evaporating chaotic processes and fractal structures with high dimensions. Usually, each school of thought or each individual player only exploits one or a few types of emerging chaotic process patterns or fractal structure levels in a few dimensions. We shall refer to these pattern types, fractal levels and market dimensions as the domains that can be accessed and known through the application of intelligence by a trader. If a trader has forgotten his own domain of specialization and tries to apply his/her domain-specific approach to other market opportunities, failure will often be assured. Therefore, we often read maxims of technical trading such as 'never switch time frames'. Of course, extraordinary traders may have developed extraordinary capabilities for planning and trading with multiple time frames. However, for a human player, it is extremely difficult to be both dynamical and masterful with multiple time frames.

Intelligent finance goes beyond any single existing discipline of academic and professional finance, and studies how to exploit complete information about financial markets and the relevant economic and political surroundings, in order to develop a comprehensive approach for absolute positive and non-trivial returns with all risks under control.

2. The origin of quantitative finance and the problem of predictability

Stochastic process models of financial market prices were first put forward by Bachelier (1900) in his dissertation 'The theory of speculation', which had as its central point that the fluctuations of stock markets are unpredictable and should be considered in terms of probabilities. In particular, Bachelier derived a formula for stochastic price changes, which is now popularly called Brownian motion, random walk, or the Wiener process. For times of the order of years, the stock market indeed follows Brownian motion with astonishing precision. Bachelier's assumptions on a random market were later rediscovered and reformulated in the Efficient Market Hypothesis (EMH) (Fama 1970, 1991, Fama and French 1992). Consequently, market prediction was expelled from the agenda, and a new type of question was suggested, i.e. how to get better investment returns in this random walking market without addressing the prediction problem. Attempts to answer this question led to fruitful developments. This question was first answered by Markowitz (1952) with his theory of portfolio selection in terms of the mean and variance of the expected returns. By varying the mean of expected returns, one obtains a complete set of optimal portfolios, the so-called efficient frontier, which indicates that high returns must always be associated with high risk. Tobin (1958) found that the existence of a riskless asset, such as US Treasury bills, allows one to match risk preferences with a single super-effective portfolio of risky stocks and some position in the riskless asset. However, the construction of the super-effective risky portfolio does not depend on risk preferences and is unique for all investors. Since all rational investors will do the same, the super-effective portfolio will be a market portfolio of all risky stocks, with shares defined by a ratio of their market capitalization to the capitalization of the entire market. This idea was formulated into the Capital Asset Pricing Model (CAPM) by Sharpe (1964). The main point of the CAPM is that the average return on a stock relative to the whole market can be determined by the ratio between the covariance of this stock return and the whole market return, scaled by the variance of the market return. This model can naturally serve as a basis for an investment strategy: if the return on a stock is lower than predicted by CAPM, buy it and hold the position until the market corrects the mispricing. However, since everyone will try to do the same, the supply–demand mechanism should make returns on all these riskless portfolios equal to the riskless interest rate. This idea is expressed by the Arbitrage Pricing Theory of Ross (1976). As a consequence of this line of prediction-free finance models, it is intriguing to note that a paradoxical conclusion emerges: the efficient market theory started with the assumption that the market cannot be predicted and follows a random walk, but ends up with predicting price movements in anticipation of a market correction corresponding to a discrepancy between the actual market prices and their theoretical predictions. This paradox has been famously studied by Grossman and Stiglitz (1980) in their academic paper 'On the impossibility of informationally efficient capital markets', arguing that if everybody in the market believes that the market is efficient, then the market cannot be efficient. The reason is the following: if everybody believes that the market is efficient, nobody will have an incentive to look for arbitrage opportunities. However, the EMH relies on the idea that arbitrageurs correct any mispricing in the market. Therefore, if everybody believes that the market is efficient nobody will detect and correct mispricings and hence the market will no longer be efficient.

The theory of efficient markets reached the height of its dominance in academic finance around the 1970s. Faith in this theory was eroded by a succession of discoveries of anomalies (Siegel 2002) and of evidence of excess volatility of returns (Mandelbrot 1997, 2004), found by multidisciplinary finance researchers, largely inspired by the steadfast beliefs and first-hand empirical knowledge and wisdom of professional analysts and traders since at least the 1880s throughout the entire twentieth century (Prechter 1980, Murphy 1999, William 2000, Pring 2002). This includes the blossoming of research, since the 1990s, on econophysics (Sornette 1996–2005, Mantegna and Stanley 1999, Ilinski 2001, Bouchaud and Potters 2003, Voit 2004), behaviour finance (Shiller 2002), computational finance (Farmer 2002, Farmer and Joshi 2002, Farmer *et al.* 2003, LeBaron 2005), and intelligent finance (Pan *et al.* 2004). Evidence was found of predictability at long horizons (Campbell and Shiller 1988, Sornette 1996–2005, Zhou and Sornette 2003), and at shorter horizons (Lo and MacKinlay 1988, Pan 2004). More interestingly, the professional technical analysis has been revisited by increasingly more academic researchers, such as Brock *et al.* (1992) and Caginalp and Balenovich (2003).

3. Major components of intelligent finance

3.1. *Financial information fusion from multiple perspectives of analysis*

Multiple perspectives of global financial markets have been developed since about 1900. Typically, these include macroeconomic analysis, microeconomic analysis, fundamental analysis, technical analysis, event analysis and strategic analysis. Financial information fusion studies how to integrate the information flows from these multiple perspectives into a coherent framework that will enable investors and traders to discover and select investment vehicles of good value and growth potential and to detect and capture profitable investing opportunities in real time and on multiple time frames. The basis of information fusion is economic theory and mathematical modeling of business cycles, stock market cycles and sector rotation, as well as dynamical patterns between them. Information fusion also includes real-time surveillance of global financial markets to track strategic investors who are able to influence or move markets and to monitor herding behavioural movements of the investing public.

3.2. *Multilevel process modeling of financial time series*

Multilevel Stochastic Dynamic Process (MSDP) models are advanced by IIFP (Pan 2005) as a new framework for modeling non-stationary and nonlinear time series and complex systems, with possible applications of MSDP models in global financial market analysis and surveillance. Both discrete- and continuous-time forms of MSDP models have been constructed: Multilevel Structural Time Series (MSTS) with Unobserved Components (UC) and Multilevel Stochastic Differential Equations (MSDE). For the possible applications of MSDP models, attention has focused on the two most important types of financial markets: world major stock market indices and global foreign exchange (forex) rates. Based on MSDP models, a comprehensive methodology for financial market analysis and surveillance has been developed consisting of three major components: (1) developing a particular set of MSDP models for a given set of markets; (2) identification of multilevel trends, cycles and seasonality using particular models; and (3) discovery, detection and projection of high-level dynamic patterns, including turbulence and chaos, convergence of multiple time frames signaling market crashes or trend acceleration, and financial bubbles and anti-bubbles. Managing financial market and currency risks with robust scientific models is extremely important for governments and corporations. MSDP models for stock markets and forex markets will enable governments and the financial industry to implement market surveillance for the early warning of financial market crises and provide pockets of predictability on multiple time frames for making better decisions involving international stock and currency portfolios. MSDP models, as a general and powerful mathematical and computational modeling framework, have the potential to create a new generation of multilevel stochastic dynamical process models, not only in finance, but also in social, economical, natural, environmental, physical and engineering applications.

3.3. Active portfolio management and total risk control

On the platform of financial information fusion, and with the support of multilevel mathematical modeling of financial time series, financial assets will be selected based on comprehensive information, including phases of business cycles, stock market cycles, sector rotations, relative strength of national markets in the global financial market ecology, value, growth prospect, etc. Long or short trading strategies will be timed according to multilevel trends, cycles, seasonality, momentum breaks, volatility breakout, regime shift, as well as exogenous shocks and overreactions and repercussions. Therefore, the traditional portfolio theory and Value at Risk (VaR) theory need to be rewritten on the basis of fractality and the dynamics of market prices and fundamentals instead of simple efficient market hypotheses. Malevergne and Sornette (2005) and McNeil *et al.* (2005) present advanced treatments on extreme and general financial risks. As a next step it is natural to put multilevel trends as a basis for portfolio and risk management. As a comprehensive approach to high finance, intelligent finance is a quest for absolute positive and non-trivial returns in investing and trading by means of exploiting complete information about financial markets from all conceivable general perspectives. In terms of risk management, intelligent finance is expected to minimize the very last risk—incompleteness of a seemingly comprehensive investing or trading method or system.

3.4. Financial strategic analysis and intelligent agent modeling

We believe that there is a limit, beyond which objective financial mathematics and econophysics may not go, that is the proactive strategic intent of strategic investors, typically the collective minority of hedge funds, who constantly pursue absolute returns independent of market benchmark indexes. The fundamental reason why real finance is considered to be an integrated intelligence is because trading in financial markets is actually a multi-agent game between traders and will remain as a game among traders and intelligent electronic trading systems superimposed upon longer-term investment activities. Therefore, every existing part of the objective, scientific, mathematical or empirical knowledge and technique should be treated as a component of the entire toolkit (or arsenal) for profitable trading; its effectiveness is time-varying relative to the state of the art of the total toolkit currently possessed by the investing public and to the current market mode (regime) and situation. Nowadays, computational finance focuses on developing intelligent agent models of conscious investors, traders and active speculators and, consequently, this kind of modeling can be generalized to simulate the ensemble behaviour of the market as a whole.

3.5. Dynamic optimization in intelligent finance

Dynamic optimization is an inherent property of intelligent finance as we aim at maximizing the utility of comprehensive information from multiple perspectives of analysis, optimizing the dynamic selection of investing vehicles and trading opportunities, and minimizing the total risks associated with dynamic portfolios and trading strategies. The types of optimization problems in intelligent finance are not limited to parametric optimization, but, in general, involve structural and parametric optimization as well as a mixture of both. A few typical optimization problems include: for financial market prediction (1) the optimal set of influences for predicting a given target market, (2) the optimal set of features to be extracted from historical price time series to predict the future, (3) the optimal time horizon of prediction into the future, (4) the optimal model structure and parameters for prediction; for fundamental investing (5) the optimal set of financial variables for stock valuation and growth prospecting, (6) the optimal model structure and parameters for stock valuation and growth potential assessment; for technical trading (7) the optimal entry, exit and stop loss strategies and parameters; for quantitative portfolio management (8) portfolio optimization based on multifractality and dynamics of market price time series, (9) minimization of value at risk with multi-fractality and dynamics of prices, (10) portfolio optimization based on industrial categorization, business cycles and sector rotation, and (11) international portfolio optimization.

In considering optimization in finance we must be aware of the dangers of data mining—fitting past data with a plethora of methods and over-optimizing until what is left is a beautiful set of back-tested returns with no predictive power whatsoever. Some of the pitfalls of data mining as applied to the scouring of databases of investments are already described in the popular literature. For example, Paulos (2003) describes how if one looks long and hard enough, one may find seemingly good rules that resulted in large gains over a given time horizon. To overcome this problem of over-fitting and finding illusive or spurious patterns from often insufficient data, a number of methods are available, including progressive forward prediction tests with unseen out-of-sample data and sensitivity analysis of model parameters in general and extreme situations through statistical procedures or simulation tests. In fact, there must be a limit that data mining and data-driving modeling cannot go beyond. This limit exists primarily due to the fact that the signal-to-noise ratios in financial and economic data are often poor, and in many situations even all the historical data put together may not be sufficient because history does not repeat itself in a simple way, as modern science and technology as the prime driving force of the modern economy has incessantly kept surprising mankind.

3.6. *Objective prediction and intelligent trading systems*

Three types of mathematical and computational modeling frameworks and technologies have been developed for generating probabilistic predictions of financial market prices and indexes on multiple time frames: (1) Multilevel Structural Time Series (MSTS) with unobserved components, (2) Multilevel Stochastic Differential Equations (MSDE) with time-varying parameters, and (3) Super Bayesian Influence Networks (SBIN). In particular, SBIN is a meta-mathematical modeling framework that integrates dynamical Bayesian networks for probabilistic causal inference and Probability Ensemble of Neural Networks (PENN). The primary advantage of PENN in contrast to other standard neural network ensembles lies in its ability to generate a conditional probability distribution for general continuous variables. The possible and probable causality or asymmetric influence between any two given markets is detected using asymmetrical dependence tests and can also be modeled using asymmetric wavelet coherence or other transfer functions. Intelligent trading systems integrate financial information fusion, financial market prediction, market and asset selection, portfolio optimization, long or short trading strategies, entry, initial stop loss, trailing of stop loss for profit protection, position management, as well as exception handling.

3.7. *Macrowave investing and multifractal trend following*

In parallel with the fine mathematical and computational modeling of financial markets, we are not confined to academic scientific research alone. Instead, we are open to empirical knowledge, professional wisdom and the collective natural intelligence of master investors, traders and speculators. In particular, we focus on intermediate- to long-term investing with good value and growth prospects, macrowave investing with longing the strongest while shorting the weakest, and trend following to ride multilevel trends and waves. We recognize and respect the fact that human intelligence is still superior to computational intelligence with respect to multi-perspective information fusion, nonlinear dynamic pattern formation and recognition, qualitative reasoning and strategic decision making.

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All references mentioned in this article, but not listed below, can be found from the two papers Pan (2005) and Pan *et al.* (2004) that are downloadable from the permanent IIFP website: www.iifp.net, under the heading of Research Publications.

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