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Double Power Law in the Japanese Financial Market

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ABSTRACT

The authors study the persistence phenomenon in the Japanese stock market by using a novel mapping of the time evolution of the values of shares quoted on the Nikkei Index onto Ising spins. The method is applied to historical end of day data from the Japanese financial market. By studying the time dependence of the spins, they find clear evidence for a double-power law decay of the proportion of shares that remain either above or below 'starting' values chosen at random. The results are consistent with a recent analysis of the data from the London FTSE100 market. The slopes of the power-laws are also in agreement. The authors estimate a long time persistence exponent for the underlying Japanese financial market to be 0.5. Furthermore, they argue that the presence of a double power law in the decay of the persistence probability could be the signature of the presence of both speculative (short-term) and long-term traders in the market.

KEYWORDS

Econophysics, Ising Model, Nikkei Index, Non-Equilibrium Dynamics, Persistence

1. INTRODUCTION

The understanding of the underlying behaviour of financial markets is of fundamental importance. Although financial markets are very diverse, they share many similarities to complex models traditionally studied by physicists. Many phenomena found and studied in statistical physics can be found to also occur in various financial markets (equities, currencies or commodities). Whereas model systems have been extensively studied over the centuries in physics, it's only over the past two decades that the ideas and tools used in physics have been applied to financial markets. The objective is to try and understand the underlying behaviour of financial markets. The application of physics to the fields of finance and economic has led to the new discipline of "Econophysics." The main motivation of the present work is to study data resulting from the Japanese stock market using a recently discovered result in statistical physics, namely that of "persistence".

In its most generic form, the so-called "persistence" problem in physics is concerned with the fraction of space which literally persists in its initial ($t = 0$) state up to some later time t. It is a classic problem which falls into the general class of so-called "first passage" problems (Redner, 2001) and has been extensively studied over the past two decades or so for model spin systems by physicists

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(Bray, Derrida, & Godreche, 1994; Derrida, Bray, & Godreche, 1994; Stauffer, 1994; Derrida, Hakim, & Pasquier, 1995, 1996; Majumdar, Bray, Cornell, & Sire, 1996). Persistence has been investigated at both zero (Bray et al., 1994; Derrida et al., 1994; Stauffer, 1994; Derrida, et al., 1995, 1996) and non-zero (Majumdar et al., 1996) temperatures.

Typically, in the non-equilibrium dynamics of spin systems at zero-temperature (Bray et al., 1994; Derrida et al., 1994; Stauffer, 1994; Derrida, et al., 1995, 1996), the system is prepared initially in a random state and the fraction of spins, P(t), that persists in the same state as at t = 0 up to some later time t is monitored. At a finite temperature, on the other hand, one is interested in the global persistence behaviour and one monitors the change in the sign of the magnetization in a collection of non-interacting systems (Majumdar et al., 1996). It is now well established that the persistence probability decays algebraically (Bray et al., 1994; Derrida et al., 1994; Stauffer, 1994; Derrida, et al., 1995, 1996; Majumdar et al., 1996):

$$P\left(t\right) \sim t^{-\theta\left(d,q\right)} \quad (1)$$

where θ(d, q) is a new non-trivial persistence exponent. Note that the value of θ depends not only on the spatial (Stauffer, 1994) (d) and the spin (Derrida, de Oliveira, & Stauffer, 1996) (q) dimensionalities, but also on whether the temperature, T, is zero or finite. It is only for T = 0 and d = 1 that θ (1, q) is known exactly (Derrida et al., 1995, 1996); see Ray (2004) for a review. We merely mention here that at criticality, $T = T_c$, θ (2, 2) ~ 0.5 for the pure two-dimensional Ising model (Majumdar et al., 1996).

More recently it has been discovered that disorder (Jain 1999a, 1999b; Sen & Dasgupta, 2004) also alters the persistence behaviour. A key finding (Jain 1999a, 1999b; Jain & Flynn, 2006) is the appearance of 'blocking' in systems containing disorder. 'Blocked' spins are effectively isolated from the behaviour of the rest of the system in the sense that they never flip. As a result, P (∞) > 0.

The persistence exponent has also been obtained from a wide range of experimental systems and the values range from 0.19 - 1.02, depending on the system (Marcos-Martin, Beysens, Bouchaud, Godreche, & Yekutieli, 1995; Yurke, Pargellis, Majumdar, & Sire, 1997; Tam, Zeitak, Szeto, & Stavans, 1997). A considerable amount of time and effort has been taken up in trying to obtain estimates of θ (d, q) for different models and systems as it is a new critical exponent unrelated to the classical exponents. The value of the persistence exponent is presently known for a very limited number of financial markets.

The primary aim of the present study is to apply the methodology used in the investigation of persistence to financial data from the Japanese stock market. The intention is to extract a persistence exponent, compare and contrast it with the one obtained earlier for the London market in order to deduce knowledge about the underlying behaviour.

In this work, we present one of the first estimates of the persistence exponent from financial data from the Japanese stock market. A key motivation behind the present study is to compare and contrast the behaviour of the Japanese and UK stock markets. It was recently (Jain & Buckley, 2006; Jain, 2007) found that the persistence behaviour of the London stock market displays an interesting double power law behaviour. As we shall see, we find very similar features in the Japanese stock market.

We observe an interesting double power law decay of the persistence probability with time. On comparing our results with the earlier work (Jain & Buckley, 2006; Jain, 2007), it appears that the double power law behaviour is not unique to the Japanese market and is, in fact, also present in the UK market. Indeed, double power have been discovered in numerous different scenarios in nature (Pinto, Lopes, & Machado, 2014). These range from studies of income and wealth distributions (Coelho, Richmond, Barry, & Hutzler, 2008) to investigations of urban road networks (Jiang et al., 2011).

In the next section we give a brief outline of the methodology used. Section 3 presents our results and we finish with a brief conclusion in Section 4.

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