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The timing of information transmission in financial markets

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ABSTRACT

This article shows turbulent behavior in a series of financial indexes assuming that they follow a cascade process of the same type as do turbulent fluids. With such a model, the energy flux between the eddies that emerge in the fluid is analogous to the financial information flux over the course of time. The results obtained confirm the variability of variation of the indexes for the considered time scale (the turbulent intermittency typical for fluids), and they also confirm that when we descend along the cascade, that is to say, when we consider smaller time intervals, the rate at which the hypothetical eddies of information dissipate becomes greater than the rate at which the information is transmitted. This fact can explain the cyclical nature of crises: ultimately, financial events have a memory of the past. Besides, the NASDAQ singular behavior regarding the number of jumps, the degree of intermittency of the turbulence and the life time of the hypothetical eddies has been analysed.

1. Introduction

In studying fluid dynamics various parameters are used which attempt to reflect the degree of turbulence. Probably the most well known of these parameters is the Reynolds number (Re) [1], which is defined as:

$$Re = \frac{ul}{\upsilon}. \quad (1)$$

Here u is the fluid velocity, l is a length typical of the phenomenon (in the atmosphere, for example, it corresponds with height) and υ is the viscosity of the fluid.

The Reynolds number is a dimensionless constant that measures the relationship between the viscous terms of the Navier–Stokes equations [2,3] and the inertial or non-linear terms. It is used to characterize the fluid regime; by its definition, when viscous forces have a dominant effect in the energy loss, the Reynolds number is small and the flow is in a laminar regime. A large Reynolds number reflects that the viscous forces have a small influence on the energy loss and, so, that the flow is turbulent.

The turbulent movement of a flow is characterized by the existence of a collection of eddies of different sizes. The biggest eddies, with a size of the order of the scale typical of the mean flow, interact with the mean flow and draw energy from it. These eddies have a large Reynolds number, and so they turn out to be unstable and tend to break up giving rise to other minor eddies to which they transfer energy. However, in this process of birth and death, not all the energy of the generating eddies is transferred to the offspring eddies, as a small part of the energy dissipates as heat due to the viscous stresses in the fluid. The new eddies created, with a high Reynolds number, are also unstable, so they too undergo the previous process giving birth to new eddies at the expense of the old ones, losing once again energy in the process because of viscosity.

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The process repeats itself successively until the eddies created have a Reynolds number low enough so as to not be unstable and consequently to not decompose into minor eddies. These minor eddies only turn into heat because of the viscous forces. Each of these transitions of bigger eddies to smaller eddies, that we can interpret as a step of the energetic cascade [4], corresponds to a scale (spatial, l, or temporal, τ). The spatial scale is the size of the corresponding eddies at that step (and the temporal scale is the product of the spatial scale by the mean flow, assuming the Taylor hypothesis [5]).

We can consider for each of the scales of the cascade the values of different variables. So, for example, the velocity (u_l) at a certain scale l corresponds to the difference between the velocity of two points separated by that distance. That is to say:

$$u_l = u(x+l) - u(x). \tag{2}$$

Knowing the velocity at a certain scale makes it possible to know diverse variables at this scale, such as the Reynolds number, the time necessary for rotation of the eddies, t_l^{rot}, or the time necessary for the dissipation of these eddies at that scale, t_l^{dis}.

t_l^{rot}may be interpreted as the time necessary for the full transfer of the kinetic energy of the eddy of diameter l to those with lesser diameter that emerge from it. That is to say, it corresponds with the lifetime of the eddy. It may be calculated through the following expression [6]:

$$t_l^{\mathrm{rot}} = \frac{l}{u_l}. \tag{3}$$

As regards to the time necessary for the energy of an eddy to dissipate as heat, it will increase with the size of the eddy and it will decrease with the increase of the viscosity of the fluid. In particular [6]:

$$t_l^{\mathrm{dis}} \propto \frac{l^2}{\upsilon}. \tag{4}$$

According to the two former expressions, the relation between both times will be inversely proportional to the Reynolds number corresponding to the scale in question:

$$\frac{t_l^{\mathrm{rot}}}{t_l^{\mathrm{dis}}} \propto \frac{l\upsilon}{u_l l^2} = \frac{1}{Re_l}. \tag{5}$$

When $t_l^{\mathrm{rot}} \ll t_l^{\mathrm{dis}}$, then eddies have the time to transfer all their energy to the smallest eddies (the dissipative effect is negligible). In the opposite case, the energy of the eddies dissipates before they have the time to transfer their energy to the subsequent ones. In the first case, we are in the so-called inertial subrange, in the second, in the dissipative range.

From the previously described variables, it is possible to know both the kinetic energy transferred per unit of time (and unit mass) by the eddies of one scale, l, to those of the next scale, T_l, and the energy dissipation rate at that scale, D_l:

$$T_l = \frac{u_l^2}{2t_l^{\mathrm{rot}}} \propto \frac{u_l^2}{t_l^{\mathrm{rot}}} = \frac{u_l^3}{l}. \tag{6}$$

With regard to D_l:

$$D_l = \frac{u_l^2}{2t_l^{\mathrm{dis}}} \propto \upsilon \frac{u_l^2}{l^2}. \tag{7}$$

The relationship between the two flux will be:

$$\frac{T_l}{D_l} \propto \frac{u_l^3 l^{-1}}{\upsilon u_l^2 l^{-2}} = \frac{u_l l}{\upsilon} = Re_l. \tag{8}$$

That is to say, this ratio is proportional to the Reynolds number associated with the scale in question and, according to (5), it is inversely proportional to the relation between the time necessary for rotation and the time necessary for dissipation.

Therefore, as we have explained, the turbulent cascade consists of an energy transfer across different scales. This translates into behavior of the characteristic parameters at those scales that can be variable (or not); if there is variability, one speaks of the intermittency of the turbulence [7–9]. A way of determining the intermittency consists of estimating the modification of the probability density functions (PDFs) of the increments of velocity when the eddies' scales change [10–13]; another possible way is to observe the evolution of flatness (that characterizes the sharpness of the PDF) with the scale [14,15].

2. Cascade in financial markets

Certain analogies may be made between turbulent behavior in fluids and that in financial markets [16,17]. Since Keynes [18] there has been a concern about the turbulent behavior in financial markets as, in a short-term period of euphoria, investment–speculation is surrounded by fleeting emotions that make the financial community focus too heavily on the short-term random speculative returns, not on the long-term information. According to Keynes, financial fragility builds up the euphoric phase following a collapse in expectation. This picture of financial markets implies no structural nature of cycles (as Minsky [19] will put it). The concept of euphoria implies uncertainty in the absence of objective quantifiable risk and rational economic behavior. It also implies that traders have excessive confidence in themselves and do not pay attention