Kinematical Model of Currency Dynamics

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Abstract: The work is devoted to the actual topic of forecasting of sharp changes in exchange rates. The paper uses the analytical approximation of data on the dynamics of the USD and EUR currency pair, based on the physical model. The paper shows signs of an approaching sharp change in the exchange rate of a currency pair.

Keywords: Currency market, euro-dollar currency pair, physical analogies.

INTRODUCTION

In this paper we describe the models using physical analogies that describe the sharp jumps in exchange rates, both existing and proposed new model. The term "stock market bubble", qualitatively describing the situation on the foreign exchange market, precedes the jump in exchange rates (Duncan, 2008).

Scientists from Novosibirsk (Tankovsky, 1998) proposed a mechanical model for the behavior of the currency pair. The exchange rate in the model corresponds to the coordinate of the material point placed into the potential well, the width of which varies. During the movement between the walls of the pit, the momentum and energy of the material point can increase, which occurs until the energy of the point becomes sufficient to leave the potential well. The coordinate of the point is changed abruptly. This corresponds to a sharp jump in the exchange rate.

I. A QUANTUM-MECHANICAL MODEL OF EXCHANGE RATE

Let us consider a quantum-mechanical model of exchange rate. The similarity of the behavior of the exchange rate and the behavior of a quantum mechanical object is caused by the statistical nature of the process and the probabilistic (random) nature of its change.

Consider the state of the foreign exchange market, in which the rate varies in some not wide limits. At some moment, there is a sudden change in the rate. This resembles the process of radiation of an alpha particle by an atomic nucleus. In quantum mechanics, this phenomenon is associated with the so called the "tunnel" effect or seepage under the barrier that limits the potential well, which simulates the atomic nucleus. To obtain specific characteristics of the process in nuclear physics, the shape of the bottom of the potential well was selected.

If we use this analogy to describe the process of discontinuous change in the exchange rate, it is reasonable to consider in this model the analog of the exchange rate the coordinate of the quasiparticle in the phase space. Under this assumption, a sharp change in the exchange rate corresponds to the exit of the quasiparticle beyond the boundary of the potential well. Prior to this event, the exchange rate is changed within the limits, determined by the potential well size.

If we assume that the potential pit resembles a bottle with a gradually narrowing neck, it turns out that before the quasiparticle, the coordinate of which corresponds to the exchange rate, exit outside the potential well, the amplitude of the exchange rate fluctuations should also decrease.

In technical analysis it is believed that the foreshadowing of a sharp change in the exchange rate is the convergence of the lines of "support" and "resistance" (Schwager, 2001).

Indeed, the data (www.forexite.com) about the fluctuations in the exchange rate of the euro-dollar currency pair confirm this fact. For example, from the end of August to the end of September 2002, the standard deviation of the exchange rate was about 0.7 cents. And before the rate jump (from the end of September to the end of October 2002), the standard deviation decreased up to 0.5 cents.

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II. A KINEMATICAL MODEL OF EXCHANGE RATE

In the history of the change in the exchange rate of the euro-dollar currency pair (www.forexite.com), there are intervals of time in which there is an equally accelerated change in the exchange rate. The curve of such a time dependence has the form of a parabola.

This is reminiscent of the kinematics of an equally accelerated (parabola branches up) or of an equally slow motion (parabola branches down). A model of parabolic dynamics was used, providing for a change in the exchange rate (y) according to the following quadratic law with respect to time (x):

$$y=\alpha x^2+\beta x+\gamma. \tag{1}$$

The coefficients α, β, γ were determined in the environment of spreadsheets, solving the matrix equation. The top bar denotes averaging.

$$\begin{pmatrix} \overline{x^4} & \overline{x^3} & \overline{x^2} \\ \overline{x^3} & \overline{x^2} & \overline{x} \\ \overline{x^2} & \overline{x} & 1 \end{pmatrix} \begin{pmatrix} \alpha \\ \beta \\ \gamma \end{pmatrix} = \begin{pmatrix} \overline{x^2 \cdot y} \\ \overline{x \cdot y} \\ \overline{y} \end{pmatrix} \tag{2}$$

The rate of change in the exchange rate (the first derivative with respect to *x*) is expressed by the formula:

$$y`=2\alpha x+\beta. \tag{3}$$

Acceleration under the parabolic law of change is constant:

$$y''=2\alpha. \tag{4}$$

We analyzed four cases of parabolic dynamics. Descending and ascending branches of the parabola with branches down (α <0), the descending branch of the parabola branches upwards (α> 0).

III. RESULTS

We examined 47 intervals of the dynamics of this currency pair for 2001-2008. 15 sections of the dynamics could be depicted in the form of a parabola with branches down (negative acceleration). Of these, 8 corresponded to the descending branches of the parabola, and 7 to the ascending ones. 32 sections of the dynamics corresponded to a positive acceleration and could be represented by a parabolic branch upwards, including 9 descending sections and 23 ascending parabolic sections.

In the case of using of the parabolic approximation, the residual standard deviation of the experimental data from the theoretical dependence was of the order of a few thousandth of a dollar for the euro (that is, several tenths of a cent for the euro).

Sooner or later the trend stopped working and the parabolic dependence was clearly destroyed. We decided to investigate the dependence of the rate of change of the exchange rate at which the parabolic dynamics are destroyed (the "breakdown" speed). The averaging was carried out with a statistical weight equal to the reciprocal of the residual dispersion. In Table **1**, for each variable, the variation (the ratio of the mean square deviation to the mean value) is indicated.

23 ascending sections of the parabola, that is, areas of accelerated growth of the euro against the dollar, resulted in a sharp drop in the exchange rate. It is important to note that the rate at which there was a sharp change in trend in all cases was 0.35 cents / euro per day. The variation of this quantity was about 7.4%. That is, when this limited speed has been reached, the market mechanism ensuring growth ceased to function, collapsed, and the course fell.

At the same time, the acceleration of growth was varied widely from 0.0012 to 0.032 cents / euro per day per day. Therefore, the error in predicting of the date of

Table 1: Parameters of the Parabolic Exchange Rate Dynamics

Branches	Section of a parabola	Number of sections (N)	The average value of "acceleration" (2α) cents / euro / day per day	Coefficient variations of "acceleration" (%)	Speed of "breakdown" cents / euro / day	The coefficient of variation of the "breakdown" speed (%)
Down	Descending	8	– 1.484	145.5	– 0.26	100.8
Down	ascending	7	– 6.56	125	0.18	49
Up	Descending	9	8.30	100.8	– 0.067	59.6
Up	ascending	23	1.20	377	0.35	7.4

a sharp change in the rate may be from a day (with an acceleration of 0.032 cents / euro per day per day) up to three weeks (with an acceleration of 0.0012 cents / euro per day per day).

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