PROCEEDINGS OF SCIENCE

Mechanical Analysis of Dollar Index Trend

Dragana Malivuk Gak, [a,1*] **and Zoran Rajilic**[a],

[a]*University of Banja Luka,*
Bulevar vojvode Petra Bojovića 1A, Banja Luka, Bosnia and Herzegovina

Department of Physics, Faculty of Natural Sciences and Mathematics,
Mladena Stojanovica 2, Banja Luka, Bosnia and Herzegovina

E-mail: dragana.malivuk-gak@pmf.unibl.org, zoran.rajilic@pmf.unibl.org

The paper presents a mechanical analysis of the U.S. Dollar Index trend, as one of possibilities of a new review of data obtained on the currency market. The close values of the U.S. Dollar Index on every first day of the month from January 1, 1971 to January 1, 2021 and weekly values of the U.S. Dollar Index from January 3, 2021 to November 13, 2022 have been considered as coordinates of unit mass particles. The Dollar index close values time series were transformed to the time dependent force parameters using Newton's Second Law. According to the force parameter values obtained after solving differential equations, the behavior of the system can be roughly predicted.

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1. Introduction

Econophysics is a relatively new scientific field. Its main goal is the implementation of theory, models and methods originally developed by physicists in order to address problems in economics, i.e. econophysics applies the methods, models and laws of physics in the analysis of economic data. It was back in 18th century that Adam Smith, who is often referred to as the father of political economy, attempted to establish a universal law of economics based on Newton's laws in physics [1]. Smith used Newton's laws almost explicitly in his works, trying to design the theory of value in political economy. He also accounted for his concept of the organization and regulation of society in the mirror of Newton's laws of physics [2]. Since economic and financial systems are stochastically complex systems with a large number of agents interacting nonlinearly, a multidisciplinary approach is crucial for the comprehension of the evolution of economic systems worldwide. Therefore, statistical physics and nonlinear dynamics tools can provide useful solutions in describing these systems. Recently, a significant number of scientists have been focusing on research in the field of economics and generating more and more scientific papers describing the use of tools from physics for modeling financial systems [3-8]. In this paper, one possible approach in perception of the currency market through Newton's Second Law is presented.

The U. S. Dollar Index is a measure of the value of the U.S. Dollar against six other foreign currencies: Euro (EUR), Japanese Yen (JPY), British Pound (GBP), Canadian Dollar (CAD), Swedish Krona (SEK) and Swiss Franc (CHF). Since the economy of each country (or group of countries) is of different size, the U.S. Dollar Index is established as a geometric weighted average of currencies as follows: (EUR): 57.6 %, (JPY): 13.6 %, (GBP): 11.9 %, (CAD): 9.1, (SEK): 4.2, (CHF): 3.6. The U.S. Dollar Index is important in many ways: 1) as an indicator of the relative strength of the U.S. Dollar around the world; 2) as a base for technical analysis of trends related to the specified markets such as commodities price in the U.S. Dollar, currency pairs that include the U.S. Dollar; 3) for stocks and indexes because the exports of the United States depends on the strength of the dollar (US exports are less competitive internationally when the Dollar is strong and more competitive when it is weaker, which has the consequence that share prices often move to reflect changes in the value of the Dollar).

2. Method

The concept of using Newton's Second Law in the analysis of the currency market is presented.

This approach can be considered as a type of data filtering. A certain form of unconventional force that satisfies Newton's Second Law [8, 9] is introduced (1):

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$$v_{n+j} - v_{n+j-1} = az + a_2z^2 + a_3z^3 + bv_{n+j} + w + \sum_{i=2}^{6} c_i \cos\frac{6.28(n+j)}{i}, \quad (1)$$

with

$$z = x_{n+j} - S, \quad (2)$$

and

$$S = \frac{1}{12}\sum_{n=1}^{12} x_{n+j}\,;\ \ j = 0,1,2,\ldots \quad (3)$$

Monthly close values of the U.S. Dollar Index x_n $(n = 1,2,3,\ldots)$ [10] are considered as coordinates of an oscillating particle of unit mass in discrete time. The driven nonlinear oscillations of the particle are occasionally damped, unstable and amplified. The nonconventional force is acting on a point in the space of data. In the special case, when the data are about a unit mass particle position, the force and space are conventional ones.

First term on the right side in (1) represents elastic force if parameter a is less than zero. When parameter a is greater than zero, the equilibrium in $x_{n+j} = S$ is not stable. The second and third terms in (1) represent nonlinearity. The fourth term represents a damping force, if b is less than zero. If b is greater than zero this is the amplifying force. The force parameter w is a constant in short time interval $(3 \leq n \leq 12)$. The sixth term represents the driving force. For n = 3, 4, …, 12 in (1), a system of ten linear equations is obtained. Solving the system of 10 linear equations, 10 force parameters ($a = a(j)$, $a_2 = a_2(j)$, $a_3 = a_3(j), b = b(j), w = w(j), c_i = c_i(j), i = 1, \ldots 6$) are calculated. Thus, time series are transformed into time dependent force parameters (each force parameter is assigned to the time interval [j+1, j+12]). In this method the following assumptions are introduced:

1. A large positive value of the parameter a is related to the increase in unpredictability due to stochastics.
2. Large values of parameters (a_2) and (a_3) are related to the increase in unpredictability due to chaos.
3. The large positive value of the parameter b is related to the increase in the amplitude of the oscillations.
4. Large values of parameters (w) and (c_i) are related to great driving force.

Similar approaches can be found [11-14], but without time-dependent force parameters assigned to data.

3. Results

After solving the system of 10 linear equations (1) and obtaining the time-dependent force parameters whose values are presented in Table 1, we can analyze the specific values

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of certain force parameters and relate them to historical and political events in the corresponding period. Analyzing the values of individual force parameters from Table 1, we can find great changes in the value of only one force parameter in a certain period, but also several of them have a significant change in value simultaneously in another period. It could be interpreted as the action of different types of forces in different time intervals.

Table 1. Force parameters

Period	a	a_2	a_3	b	w	(c_2)	(c_3)	(c_4)	(c_5)	(c_6)	S
1971-1975	-0.325	0.506	0.221	1.748	-7.819	3.729	5.449	14.315	22.736	14.78.	-20
1976-1980	0.753	0.381	-0.078	2.131	-0.412	3.681	9.776	9.528	15.068	15.07	- 20
1981-1985	-1.340	-0.296	0.068	0.880	0.656	3.685	5.549	9.368	12.430	10.21	+70
1986-1990	0.011	-0.029	-0.032	1.303	1.328	2.541	5.318	6.505	6.099	7.120	-60, +10, -15
1991-1995	4.857	-0.148	-0.578	-4.933	2.074	7.345	16.081	6.479	19.001	10.89	+10, -10
1996-2000	-0.939	1.273	-0.011	0.456	-8.417	3.268	11.191	7.792	14.431	29.72	+40
2001-2005	11.677	1.028	0.162	2.652	-14.248	20.61	27.630	19.058	23.719	15.93	-40
2006-2010	-3.812	-0.702	0.222	-4.080	3.519	6.785	10.569	19.206	31.493	14.20	-10
2011-2015	4.930	1.160	-0.534	2.947	-5.115	4.067	7.682	3.014	3.940	7.857	-10
2016-2020	-5.773	-0.233	0.590	-1.086	4.052	5.133	3.967	3.949	9.911	7.369	+30,-10,+5

The values of time-dependent force parameters can also be presented graphically for better clarity (Figure 1).

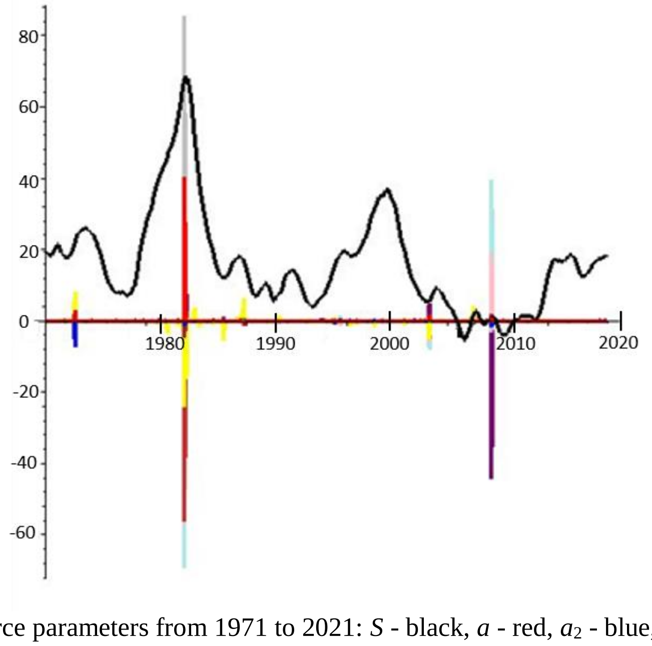

Figure 1. Force parameters from 1971 to 2021: S - black, a - red, a_2 - blue, a_3 - green, b - brown, w - yellow, c_2 - orange, c_3 - gray, c_4 - pink, c_5 - turquoise, c_6 – purple.

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3.1. Analysis in accordance with historical data

It is very interesting to look at a few exceptional values of force parameters and link events of economic and political significance with force parameter values. We can pay special attention to exceptional values of several parameters at the same time, but it is also intriguing when we come across exceptional values of only one parameter. Here, we link and interpret social, political and economic events in history using extreme values of force parameters for certain periods.

If we look at Figure 1, the first extreme parameter values (synchronized maximum of w and minimum of a_2) appeared in 1972. The United States unilaterally withdrew from the Bretton Woods Agreement in 1971 and abandoned the Gold Standard of Exchange. Shortly afterwards, other industrialized nations followed their example with their own currencies. Industrialized countries have increased their reserves, expecting that currency values will fluctuate unpredictably for some time. The result was the devaluation of the Dollar and currencies of other industrialized countries. As the price of oil was quoted in dollars, the real income of oil producers decreased. In September 1971, OPEC issued a joint statement saying that from then on they would determine the price of oil in relation to a fixed amount of gold.

In 1973 the economic crisis hit primarily Western countries, followed by the rest of the world. In the autumn of 1973, OPEC member states decided to embargo on oil exports to the United States, Britain, Canada, the Netherlands and Japan because they believed that the governments of those countries supported Israel in the Yom Kippur War [8]. The embargo lasted until March 1974 and had far-reaching consequences for the world economy. Events with the price of oil are also called the first oil shock.

The second oil shock occurred in 1979, which coincided with the appearance of the second maximum in Figure 1 (synchronized maximum of a and c_3, and minimum w, c_2 and c_5). At this time, the war between Iran and Iraq resulted in the energy crisis caused by a drop in production of oil [15]. Oil production in Iran and Iraq fell drastically leading the world economy into recession. Oil prices returned to pre-crisis levels in the mid-1980s [15-17].

In 1982, the economy of the United States suffered a major and unexpected blow: Mexico took control of private banks. Mexican banks were nationalized and all currency transactions had to be authorized by the government.

In October 1987, there was a global, sudden, severe, and largely unexpected stock market crash, so-called Black Monday. This corresponded to the exceptional value of force parameter w.

Looking back at 2000s, the beginning of recession is the prevailing thought in terms of economy. The recession first affected the European Union in 2000 and 2001, and in 2001 it had an impact on the United States. However, the recession in industrialized countries was not as significant as either of the two earlier worldwide recessions.

Perhaps the most interesting crisis was the crisis of 2007, which was the most serious financial crisis since 1929. Large maximum and minimum of c_i parameters corresponding

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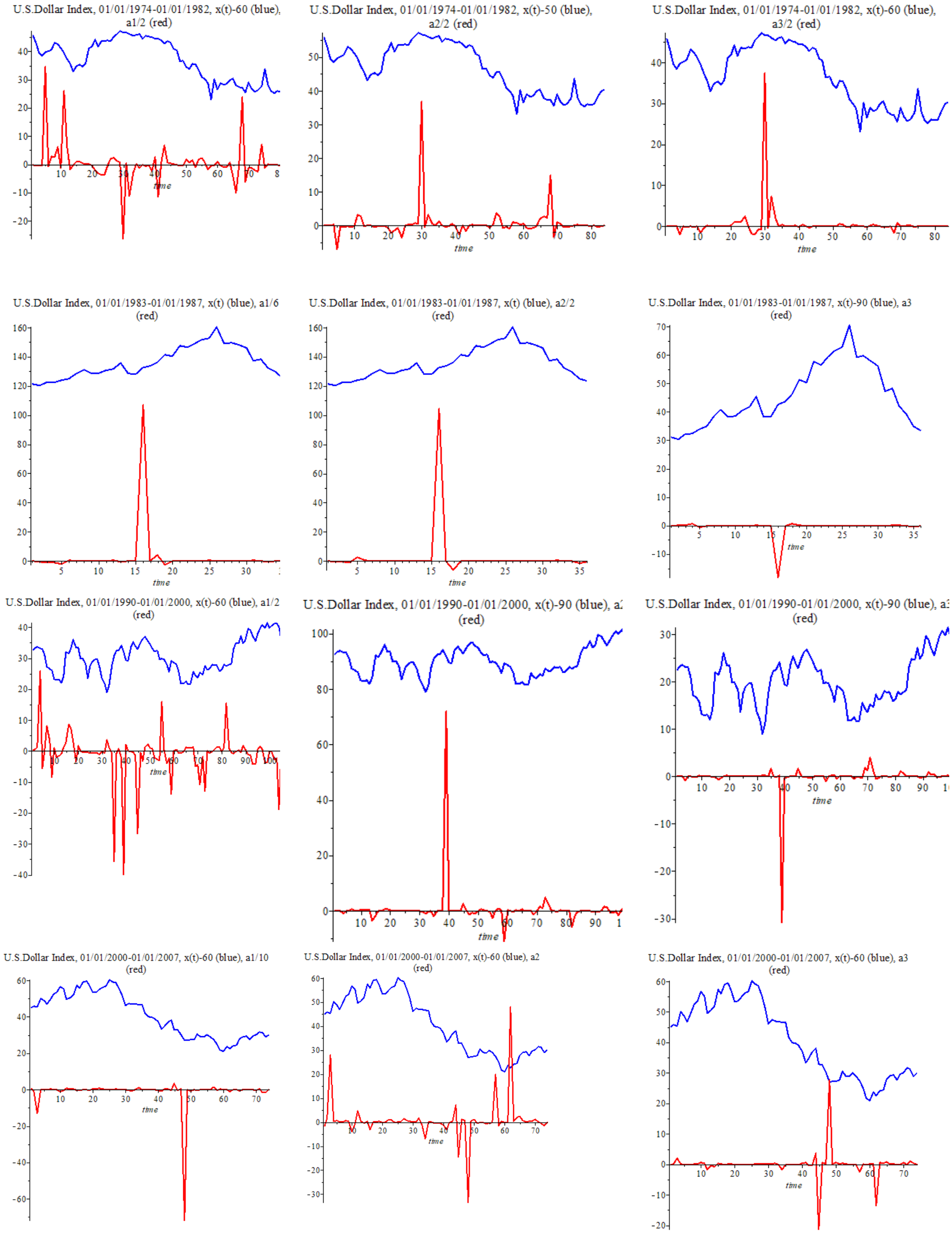
to driving force coincided with developments in the macro and micro economic markets of that period.

3.2. Analysis analysis related to certain force parameters

Special cases of the value of parameters a_1, a_2, a_3 (red) and value of U.S. Dollar Index (blue) are presented in the figures below.



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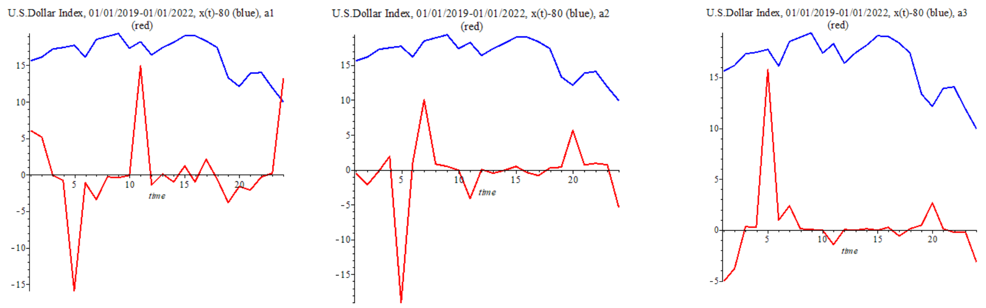

Figure 2. Force parameters a, a_2, a_3 (red) and the Dollar Index value x (blue).

The large positive value of parameter a is connected with the increase of instability and announces large value fluctuations of the Dollar Index in the future.

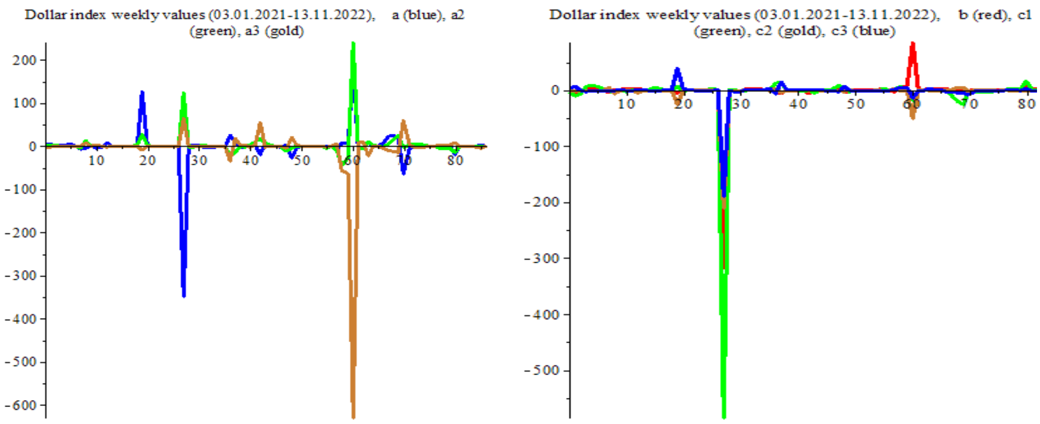

Figure 3. Force parameters obtained by solving equation (1) from January 3, 2021 to November 13, 2022

The extreme values of the force parameters presented in Figure 3. announce a probably large fluctuation in the value of the Dollar Index in the near future.

In order to better understand the sensitivity of the system to the initial conditions and the relationship between the force parameters and the delayed effect of the force, which results in a change in the system's behavior, the following computer experiments were conducted.

A function x(t) that satisfies differential equations:

$$\frac{dx}{dt} = v, \tag{4}$$

$$\frac{dv}{dt} = -\frac{x}{2} + 4\sin 2t + \left(L_{sto} f(t) - 0.1 + Qe^{-17(t-15)^2}\right)x^3 \tag{5}$$

is shown (Figure 4.) for various values of the stochasticity levels L_{sto} and Q with initial conditions: $x(0) = -1.30000002,\ v(0) = 0.90000004$ (blue) and $x(0) = -1.30000003,\ v(0) = 0.90000003$ (red).

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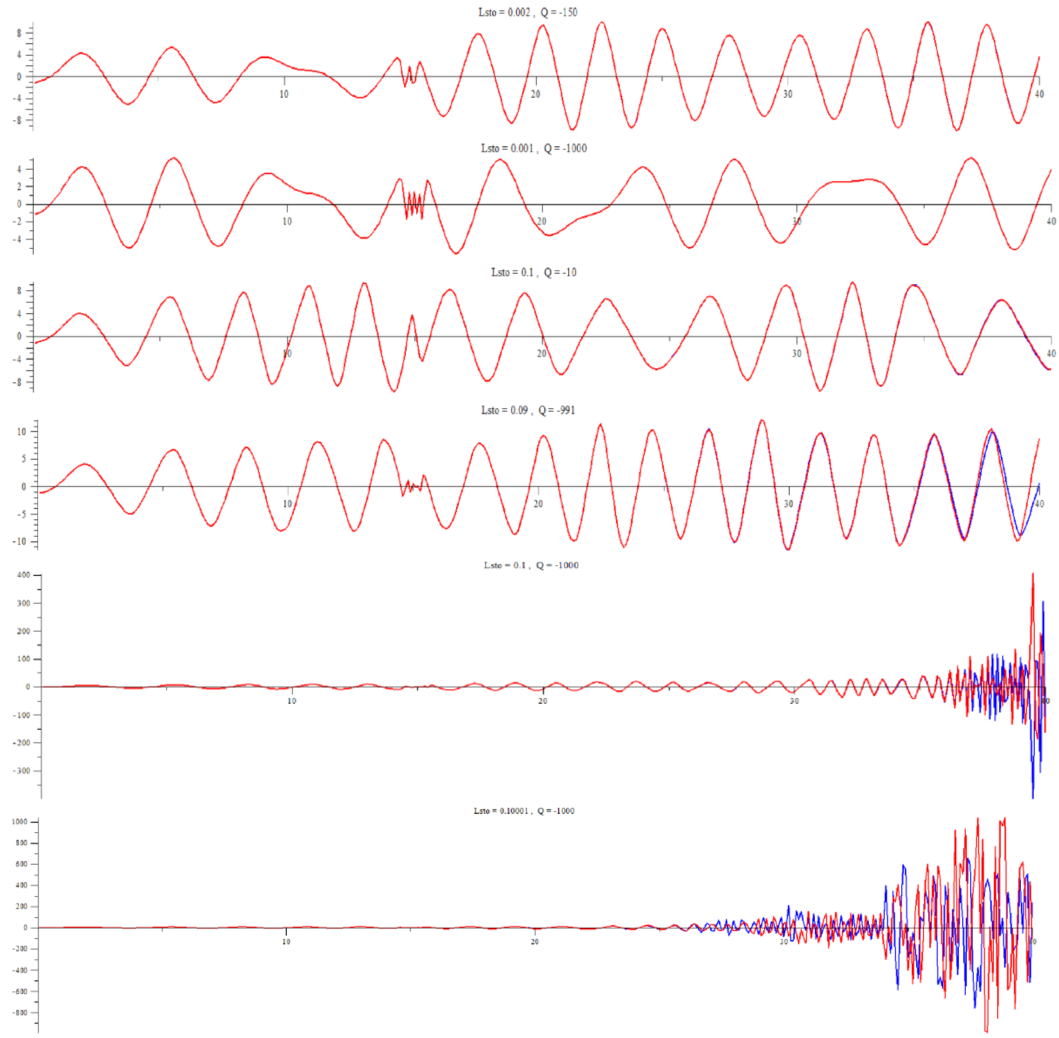

Figure 4. The force acts in a short time interval, around t =15, and has a large delayed effect (great increase in uncertainty) if $|Q|$ and L_{sto} (level of stochasticity) are large enough.

The values of the force parameters will have a great impact on the behavior of the system in the future. Large (a_2) and (a_3) in a short time interval announce the increase of the Dollar Index uncertainty. We interpret this delayed effect of the nonlinear force as sensitivity to initial conditions.

4. Conclusion

Monitoring and understanding the movement in the economic system is very important for the development of a society. The approach presented in this paper provides a new perspective on the interaction of historical events that are in certain ways related to the evolution of the economic system. Using this approach, there is a possibility of rough prediction of system behavior if the parameters of force are known in the past. The paper presents a new understanding of economic problems through Newton's Second Law. Events which took place on the political scene in given historical periods could be related to the parameters of force shown in Newton's Second Law. Some events meant that the

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driving force was growing. Some events dampened the oscillation. Some events pushed the U.S. Dollar Index down. Some events destabilized the economy. An event increased nonlinearity and thus added deterministic chaos to the stochastic one, which further reduces the possibility of prediction.

It is not important just to predict, although prediction is the most interesting thing. With the help of physics, it is crucial to have a new understanding of what is happening in finances. The role of Newton's Second Law in the physics of complex systems is interesting and offers us a new perspective of seeing the evolution and development of economic systems and the global market in general. This approach provides an extension of Newton's 2nd law beyond mechanics.

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