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Extended nonlinear feedback model for describing episodes of high inflation

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HIGHLIGHTS

- An extended nonlinear feedback (ENLF) model for high inflations is proposed.
- In the ENLF model the consumer price index is given by a Hypergeometric function.
- This Gaussian Hypergeometric presents a singularity at a finite critical time t_c.
- Episodes of high inflation occurred in Israel, Mexico, and Iceland were studied.
- In all these cases reasonable values for t_c were determined.

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ABSTRACT

An extension of the nonlinear feedback (NLF) formalism to describe regimes of hyper- and high-inflation in economy is proposed in the present work. In the NLF model the consumer price index (CPI) exhibits a finite time singularity of the type $1/(t_c - t)^{(1-\beta)/\beta}$, with $\beta > 0$, predicting a blow up of the economy at a critical time t_c. However, this model fails in determining t_c in the case of weak hyperinflation regimes like, e.g., that occurred in Israel. To overcome this trouble, the NLF model is extended by introducing a parameter γ, which multiplies all terms with past growth rate index (GRI). In this novel approach the solution for CPI is also analytic being proportional to the Gaussian hypergeometric function ${}_2F_1(1/\beta, 1/\beta, 1 + 1/\beta; z)$, where z is a function of β, γ, and t_c. For $z \to 1$ this hypergeometric function diverges leading to a finite time singularity, from which a value of t_c can be determined. This singularity is also present in GRI. It is shown that the interplay between parameters β and γ may produce phenomena of multiple equilibria. An analysis of the severe hyperinflation occurred in Hungary proves that the novel model is robust. When this model is used for examining data of Israel a reasonable t_c is got. High-inflation regimes in Mexico and Iceland, which exhibit weaker inflations than that of Israel, are also successfully described.

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1. Introduction

When inflation surpasses moderate levels it damages real economic activities. For instance, it affects government's tax revenues because they are effectively received a period later after the declaration that fix them [1,2]. The perception of relative prices changes becomes more difficult since it is not easy to distinguish whether some price grows as a consequence of a relative price change or it is part of general inflation (the Lucas problem [3]). It produces inefficient changes of relative prices [4] if the adjustment process is different for different kinds of goods inducing misleading allocation of resources [5]. Inflation also affects currency in its property as medium of exchange, store of value, and unit of account. The degree of perturbation is greater the higher the inflation. If consumption goods become relatively more expensive than leisure due to inflation, labor market may be negatively perturbed by reduction of working hours supply [6]. Unanticipated increase in prices reduces real wages and expand employment [7], although the positive employment effect could be lowered or reversed by the effects of falling investment. Furthermore, investment demand may be especially affected because of the shorter planning time scope and growing uncertainty. In general, when the inflation is higher then the decision horizon is shorter. Moreover, with no alternative allocation to money, savings decline and investment falls at expenses of actual consumption, lowering the capital stock growth. Therefore inflation is not a pure nominal problem, but it is linked to real economy in many non trivial ways [8]. Consequently, governments try to prevent high inflation, and to lower it when reaching elevated levels. Parameters can change once policy changes [9]. The relation between sources of inflation and the evolution of parameters is complex and not direct. These issues are also analyzed in text books on econophysics [10–12].

Models of hyperinflation are especially suitable to emphasize that inflation implies bad "states of nature" in economy. Wars, changes of social regimens, states bankruptcies are the characteristics of such regimens. These factors together with the influence of pure economical variables like expectations, money demand, velocity of circulation and quantity of money, give an increase of the consumer price index (CPI) larger than exponential as can be observed in the investigated cases [13–20]. In turn, this behavior affects negatively the social network causing unpleasant situations.

The model for hyperinflation available in the literature is based on a nonlinear feedback (NLF) characterized by an exponent $\beta > 0$ of a power law. In such an approach the CPI exhibits a finite time singularity of the form $1/(t_c - t)^{(1-\beta)/\beta}$, allowing a determination of a critical time t_c at which the economy would crash. This model has been successfully applied to many cases [15–20]. However, in the most recent paper [20], it is shown that for the episode of weak hyperinflation occurred in Israel it is impossible to determine a value for t_c within the NLF model because β goes to zero. In this limit one gets the linear feedback approach which does not contain information on t_c [14]. This drawback was attributed to a permanent but partially successful efforts for stopping inflation in Israel.

In order to include in the NLF formalism information on efforts for stabilization like those observed in the case of Israel, we developed an extension of this model introducing a parameter γ, which multiplies all the past growth rate index (GRI) contributions changing the relative weight of the term with the power law. The interplay between β and γ leads to multiple equilibria phenomena for episodes of high inflation. The literature on this kind of behavior in models of economics is large and diverse [21], see also e.g. Refs. [22–27]. We use the well known multiple equilibria expression to indicate the existence of multiple trajectories compatible with data which lead to very different states of nature of the economy where the final outcome is stable or not. In the extended NLF approach the solution for CPI becomes proportional to the Gaussian hypergeometric function ${}_2F_1(1/\beta, 1/\beta, 1+1/\beta; z)$, where z is a function of β, γ, and t_c. Since for $z \to 1$ this hypergeometric function diverges, a finite time singularity shows up allowing a determination of t_c. It is important to notice that the Gaussian hypergeometric appears in a variety of physical and mathematical problems. In quantum mechanics, the solution of the Schrödinger equation for some potentials is expressed in terms of ${}_2F_1$ [28]. Moreover, the eigenfunctions of the angular momentum operators are sometimes written in terms of ${}_2F_1$ functions [29].

In the present work we also investigated the effects of the parameter γ on the nonlinear dynamic evolution of real inflations. Firstly, the robustness of the novel model is tested analyzing the severe hyperinflation occurred in Hungary after World War II. Next, it is successfully applied for studying the weaker hyperinflation developed in Israel and the high-inflation episodes observed in Mexico and Iceland. In order to understand better the evolution of prices in these countries, brief descriptions of historical events are provided. In these cases we found multiple equilibria.

The paper is organized in the following way. In Section 2 the NLF model is outlined with some details because it is the starting point for the extension proposed in Section 3. The limit $\gamma \to 1$ is discussed. Section 4 is devoted to report and discuss the results obtained by applying the novel approach. Finally, the main conclusions are summarized in Section 5.

2. Theoretical background

Let us recall that the rate of inflation $\pi(t)$ is defined as

$$\pi(t) = \frac{P(t) - P(t-\Delta t)}{P(t-\Delta t)} = \frac{P(t)}{P(t-\Delta t)} - 1, \tag{2.1}$$

where $P(t)$ is the CPI at time t and Δt is the period of the measurements. In the academic financial literature, the simplest and most robust way to account for inflation is to take logarithm. Hence, the continuous rate of change in prices is defined