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# Competitions hatch butterfly attractors in foreign exchange markets

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## Abstract

Chaos in foreign exchange markets is a common issue of concern in the study of economic dynamics. In this work, we mainly investigate the competition effect on chaos in foreign exchange markets. As one of the main economic structures in the globalization process, competition between two target exchange rates with the same base currency forms a simple competitive exchange rate relation, where each exchange rate follows the chaotic model of De Grauwe (Exchange Rate Theory-Chaotic Models of Foreign Exchange Markets, Blackwell, Oxford, Cambridge, MA, 1993). The main discovery is, while each exchange rate is in its non-chaotic parameter regions, the effect of competition will “hatch” butterfly-like chaotic attractors in the competitive market. The positive Lyapunov exponent in the market explains the reason why chaos occurs.

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## 1. Introduction

Chaos, a typical dynamical phenomenon in non-linear systems first coined by Lorenz [1], has been found in and also applied to many fields [2], ranging from electronic circuits [3] to biomedical engineering [4], and to socio-economic systems [5]. The trace of chaos has also been captured in foreign exchange markets. Bajo-Rubio [6] first observed chaotic behaviors in peseta/USD exchange rate data. In the later empirical studies [7–10], the exchange rate data of GBP/USD, Swedish Krona/EUR, and Greek exchange market were classified as having chaotic behaviors. Holding the belief that chaos exists in foreign exchange markets, some researchers utilized deterministic chaos as predictors in exchange rates forecasting [11]. More importantly, economists tried to understand the essence of chaos in a foreign exchange market, which is regarded as a non-linear dynamical system. After studying chaos in the Dornbusch's exchange rate model [7], De Grauwe and his colleagues [8] systematically described chaotic behaviors in their exchange rate dynamical models and stated that in the combined speculations from both chartists and fundamentalists incorporated into a Dornbusch-style model, the resulting chaotic exchange rate model is much closer to the empirical data than all traditional regressing models as well as other new models. Da Silva [12] further generalized the studies of Refs. [7,8] to the framework of Obstfeld and Rogoff model [13], where chaotic solutions were also shown in exchange markets.

Economic globalization has been the main feature of the world economy today [14]. With the interactions of trade communication and capital flow, countries are cooperating more closely than ever. Every country has thrown itself into the international economic division and competition for reaping the benefits of globalization. Because of the limited world market and resources, more and more countries are becoming aware of the importance of their international competitive power. Exchange rate is one of the factors affecting a country's international competitive power. The relative change of the exchange rate, especially that of those countries with similar economic structures, can change their world market and benefits obtained from the world economic integration. Therefore, most countries tend to care more about the relative exchange rate change with their competitors in the world market, where the competitive economic structure has an important effect on the relative exchange rate behaviors.

The question is how this kind of competitive economic structures affects the behaviors of a foreign exchange market? Is the competition responsible for a certain means of chaotic behaviors of the exchange rate? This work tries to answer these questions and to illustrate the effects of competition in the economic structure on the chaotic behaviors in a foreign exchange market. For simplicity, we assume that there are two exchange rates with the same base currency in the foreign exchange market and use the model of De Grauwe [8] as the node dynamics of each exchange rate. We found that although each individual De Grauwe exchange rate is non-chaotic, the competitive economic structure hatches chaos in the form of chaotic butterfly attractors in the foreign exchange market. The reason for the existence of a chaotic transition is studied in the last part of this work.

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