The statistical response of a three-dimensional REE model with random noises

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Abstract. Resources, environment that accompany economic growth are important factors to be considered in developing economy, the researches about them have attracted much attention of the government and the public. Generally, complicated interactions and non-linear dynamics are existing in the resource-environment-economy (REE) system. In this paper, we take the uncertain effects into account and model them as the Gaussian white-noises, to explore the response of this REE system by means of Langevin theory. The phase diagram shows that even very small noise intensities can change the dynamical properties from the stable limit-cycle solution to unstable solution. In addition, the coefficient associated with the environmental treatment is the critical parameter to cause bifurcation. The analytical results reply that reasonable environmental treatment can result in the lower pollution intensity at the same time stabilize economic growth to a higher level.

Introduction

The REE systems are regarded as effective mathematical models to characterize the interaction and dynamical behaviors of the coordinated subsystems. On the other hand, REE system is also a very complicated and usually characterized by the involvement of multiple subsystems, the factors related to the economy, resource and environment are rather more and various, their combination and coupling then comprise the different REE systems. For example, Fang[1] focused on the factors of energy saving and emission reduction, they explored the dynamic behaviors of a REE system by means of Silnikov theorem and artificial neural network, they suggested that the maximum carbon emissions should be limited to reduce energy consumption. From the points of pollution intensity, resource consumption and economy, Yin[2] investigated a REE system by using the methods of Lyapunov exponents and bifurcation diagrams, they found increasing the intensity of waste recycling is effective in reducing pollution intensity. In 2019, Li[3] established a REE system with consideration of environment treatment and analyzed the system by using nonlinear dynamical theory together with numerical simulation. This work found the economy can achieve a stable level if the resource extraction rate can be controlled to a certain extent.

Although the existing works are significant and meaningful to describe the performances, interactions, and dynamical change in different REE systems, the coupling REE systems are rarely studied. Meanwhile, uncertain factors those are unavoidable playing a role in the development process of REE system are neglected in most literatures. In fact, governmental policies, investment in the environmental treatment, resource distribution and so on are all important to the development of every subsystem, what the influence they are and how to control or use them to keep sustainable development are unknown questions. Therefore, in this paper, we take the factor of environmental treatment as well as the random perturbation into account, to present a coupling three-dimensional resource-environment-economy (REE) system.

Results and discussion

The phase diagrams Fig.1 (Left and Middle) show that even very small intensity $D_{11} = 0.01$ of the noises can change the dynamical properties from the stable limit-cycle solution to unstable solution. In addition, the coefficient associated with the environmental treatment b_1 is the critical parameter to cause bifurcation.

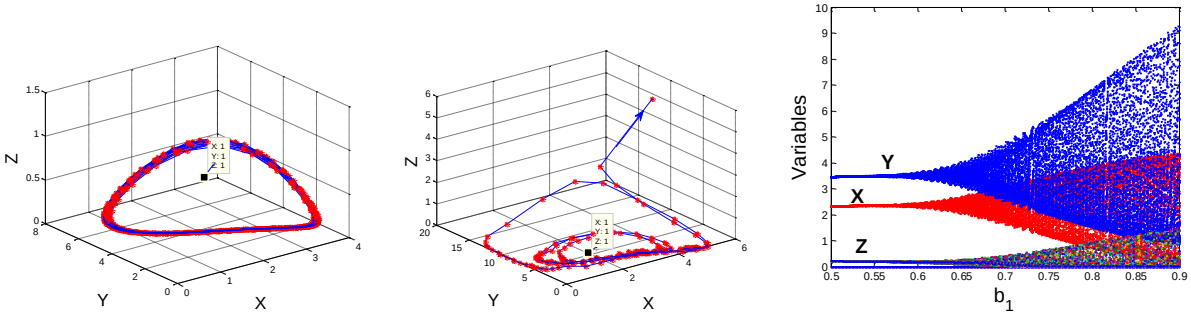

Fig.1 Phase diagrams and bifurcation diagram without (left) and with (middle) noises. Bifurcation of the three variables with the change of the parameter (right).

References

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