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Persistence and distribution of a stochastic susceptible-infected-removed epidemic model with varying population size[1]

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Abstract In this paper, the dynamics of a stochastic susceptible-infected-removed model in a population with varying size is investigated. We firstly show that the stochastic epidemic model has a unique global positive solution with any positive initial value. Then we verify that random perturbations lead to extinction when some conditions are being valid. Moreover, we prove that the solution of the stochastic epidemic model is persistent in the mean by building up a suitable Lyapunov function and using generalized Itô's formula. Further, the stochastic epidemic model admits a stationary distribution around the endemic equilibrium when parameters satisfy some sufficient conditions. To end this contribution and to check the validity of the main results, numerical simulations are separately carried out to illustrate these results.

Keywords: Varying population size; Stochastic SIR model; Extinction; Persistence in the mean; Stationary distribution

1 Introduction

The susceptible-infected-recovered epidemic model is one of the most significant models when epidemiological patterns are taken into account. Kermack and McKendrick (1927) firstly proposed and investigated a classical SIR model. From then on, many papers studied various improved epidemic models and developed some good results and techniques, some of which assume that the populations have constant birth and mortality rates, for example, Zaman *et al.* (2008). Recently, some contributions about stochastic epidemic models introduced white noises into the corresponding deterministic models for a more real modelling and better understanding. Gray *et al.* (2011) studied an extension of a classical deterministic SIS epidemic model into a stochastic framework. Zhao *et al.* (2015) aimed at a stochastic susceptible-infected-recovered-susceptible model in a population with varying size, in which they considered that the recovered also returned to susceptible individuals and introduced randomness into the contact rate. They proved the threshold of extinction, persistence and discussed the asymptotic behavior around the epidemic proportion equilibrium. Similarly, Zhao (2016) included stochastic perturbations into SIR epidemic model with saturated incidence and investigated the threshold of a stochastic SIR epidemic model and its extensions. Later, Liu and Chen (2016) investigated the dynamics of a stochastic SIR epidemic model, in which they supposed that the removed individuals did not become the susceptible and perturbations of parameters are set in terms of white noises.

Zaman *et al.* (2008) discussed the ordinary differential equations of the deterministic SIR mode in a