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REPORT

By a member of the dissertation committee of the dissertation of **Ndiaye Serigne Modou** on the topic: **Mathematical and game-theoretic modeling of malaria spread with and without vaccination**, submitted in conformity with requirements for the degree of candidate (Ph.D) of Physics and Mathematical Sciences in Specialty 1.2.3 – Theoretical informatics, cybernetics.

Ndiaye Serigne Modou's dissertation focuses on the development of generalized mathematical models for the spread of malaria, considering population mortality among subgroups. Additionally, the dissertation explores the applicability of these models in forecasting disease development. Moreover, it investigates the impact of market structures on vaccine prices. This research work is both topical and highly relevant, offering valuable contributions for policymakers and researchers in the field of epidemiology.

Ndiaye Serigne Modou's dissertation comprises four technical chapters, along with an Introduction, Conclusions, and Bibliography. In the Introduction, the candidate meticulously outlines the motivation behind the work, highlights the thesis contributions, and elucidates the adopted methodologies. A comprehensive overview of the current state of the domain is also provided.

Chapter 1 presents an epidemic model of malaria spread referred to as SEIR model. This model is an improved version of the malaria spread models studied in the literature. In particular, the subpopulation of exposed hosts is included as a parameter in the model. Investigation of the SEIR model with and without vaccination is performed. Two equilibira, associated with the disease-free and endemic population states, and their stability properties were studied in great detail. Novel aspect of the study lies in using a dimensionless quantity called as reproduction number, which captures the evolution of epidemic process, for ascertaining the stability of these two steady states.

In Chapter 2, a vector epidemic model of malaria spread is presented. The main contribution and novel aspect of this work lie in augmenting parasite spread in the vector population with the disease spread in the host population. This coupling is achieved by linking appropriate subpopulations associated with the vector and host populations. The candidate presents investigations of disease spread in this multi-population model with and without vaccination. Using the reproduction number, the stability of steady states associated with disease-free and endemic population states is illustrated in detail.

Chapter 3 of the thesis investigates two epidemic models, namely the SIR model and the CIRD balance model, along with their practical applications. To be more specific, historical data on malaria disease in Senegal is utilized to calibrate the model parameters. Subsequently, the accuracy of these models in forecasting the annual dynamics of malaria epidemics from 2000 to 2021 is studied in detail. The methods and frameworks presented in this chapter hold great importance for epidemiology researchers and policymakers.

Lastly, in Chapter 4, the candidate studies the role of vaccine makers and the effect of market structure on the vaccine price. In particular, various scenarios of cooperation and competition between the vaccine firms are considered, and conclusions are drawn towards favorable structures which are beneficial for consumers and companies. This study is very important for government regulators towards devising guidelines and policies so as to avoid inefficiencies in vaccine roll-out during an epidemic.

The dissertation is comprehensive; it not only explores the mathematical modeling of vector-borne diseases but also delves into practical aspects aimed at reducing the rate of spread. The results of the dissertation have been documented or published in high-level journals (such as Contributions to Game Theory and Management, Vestnik of Saint Petersburg University, Applied Mathematics, Computer Science, Control Processes), indexed by Scopus and Web of Science.

The dissertation of Ndiaye Serigne Modou titled “Mathematical and game-theoretic modeling of malaria spread with and without vaccination” meets the requirements established by the Order No. 11181/1 of 19.11.2021, “On the procedure for awarding academic degrees at Saint Petersburg State University.” Clauses 9 and 11 of the aforementioned Order were not broken by the candidate. Ndiaye Serigne Modou deserves the award of the degree of candidate (Ph.D) of Physics and Mathematical Sciences in Specialty 1.2.3 – Theoretical informatics, cybernetics.

Sincerely

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