

A Tripartite Evolutionary Game Analysis of Industrial Emission Control with Public Economic and Political Participation

Suman Kumar

Shiv Nadar Institution of Eminence, Dadri, Gautam Buddha Nagar, Uttar Pradesh, India

Dr. Samit Bhattacharyya

Shiv Nadar Institution of Eminence, Dadri, Gautam Buddha Nagar, Uttar Pradesh, India

Abstract:

Industrial emissions are a major source of global air pollution and remain one of the most pressing environmental challenges under rapid industrialization and urbanization. Addressing this problem requires coordinated action among multiple stakeholders, including firms, governments, and the public. Addressing this problem requires coordinated action among multiple stakeholders, including firms, governments, and the public. While existing studies largely focus on bilateral interactions—typically between firms and regulatory authorities—this study develops a novel tripartite evolutionary game model that explicitly incorporates firms, government, and the public into a unified analytical framework.

A key innovation of the model lies in integrating public economic participation through a Cobb–Douglas production function and modelling citizens' voting behaviour as a channel through which public support or opposition influences regulatory enforcement. We construct a detailed payoff matrix and derive the corresponding replicator dynamic equations to analyse the strategic evolution and stability of stakeholders' behaviours.

The results demonstrate that reward–punishment mechanisms play a pivotal role in incentivizing firms to comply with emission standards, while excessive reliance on either instrument may induce strategic oscillations. Moreover, the findings reveal a strong synergistic effect between public economic participation and political pressure, which enhances regulatory effectiveness and promotes long-run environmental stability. These insights provide practical policy implications for designing balanced and participatory environmental governance mechanisms in industrial pollution control.

Keywords:

Industrial emissions, Air pollution Governance, Tripartite evolutionary game.