

Coordinate pharmaceutical supply chain with two-invoice mechanism: A differential game approach

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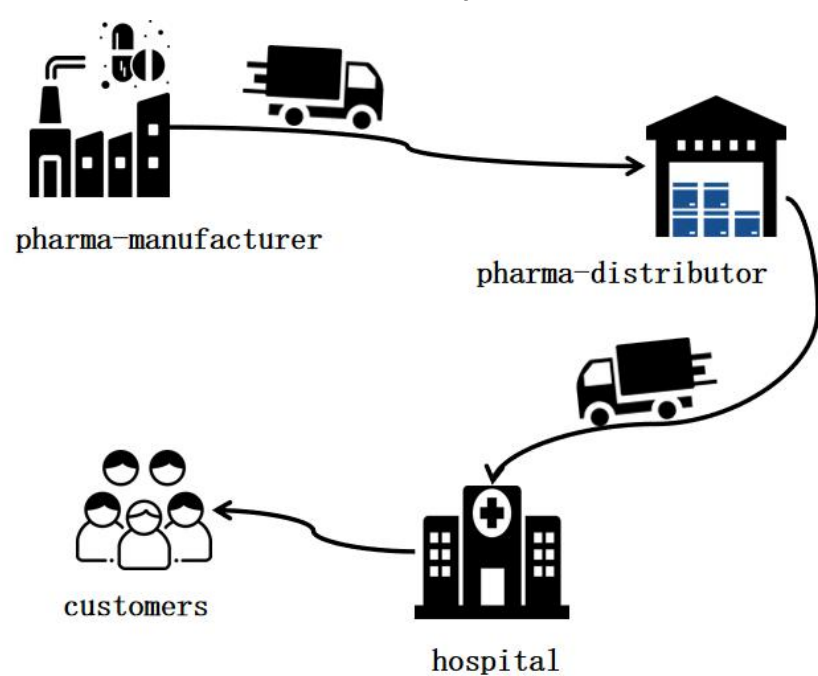
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INTRODUCTION & AIM

It is well known that the pharmaceutical industry is crucial to human health as well as social well-being. The implementation of two-invoice mechanism has engendered far-reaching transformations: this not only requires meticulous coordination among different stakeholders but also calls for the adoption of advanced management strategies to optimize the overall supply chain performance. This paper uses a differential game approach to investigate coordination strategies in China's pharmaceutical supply chain under a two-invoice mechanism.

METHOD

Using a differential game approach, this paper modeled a three-tier system to analyze dynamic interactions between R&D effort, logistics effort, market demand, and quality evolution. A state equation described drug quality evolution, influenced by R&D effort, logistics service effort, and natural decay rate. A market demand function (positively related to quality, negatively to retail price) and long-term profit functions (with quadratic convex costs for R&D and logistics efforts) were established. Three scenarios were examined: centralized optimization, decentralized Stackelberg game, and a novel combination contract incorporating government subsidies and cost-sharing. For each scenario, optimal strategies, drug quality trajectories, and profits were derived using backward induction and solving differential equations. Finally, numerical experiments were conducted to verify the models by comparing key indicators.



CONCLUSION

This paper integrates pharmaceutical supply chain performance and drug quality with time by using differential game.

The convergence of drug quality to a steady state indicates that long-term quality depends on decision behaviors, not initial conditions.

The combination contract effectively coordinates decentralized decision-making, improving quality, efforts, and profits, making it more feasible.

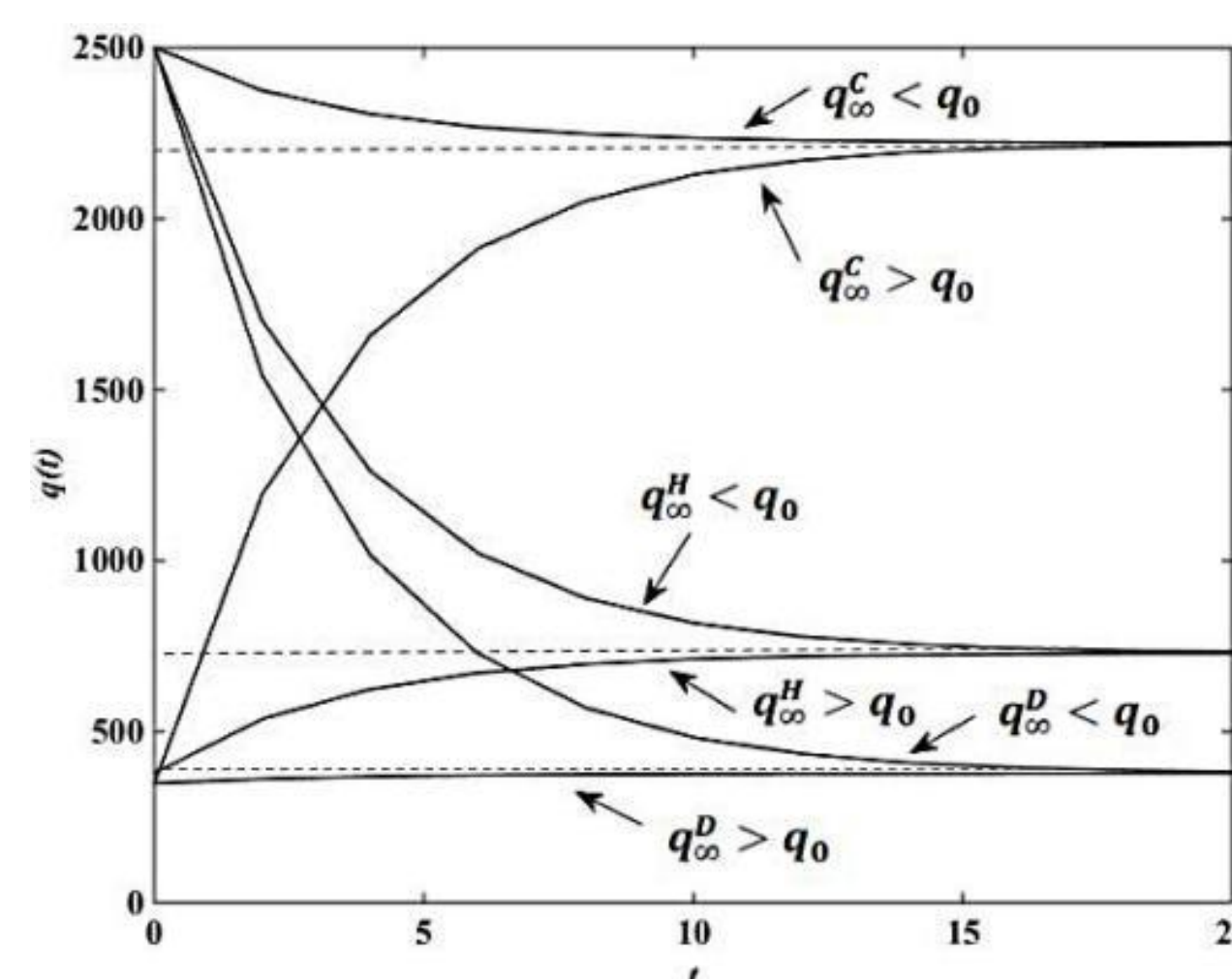
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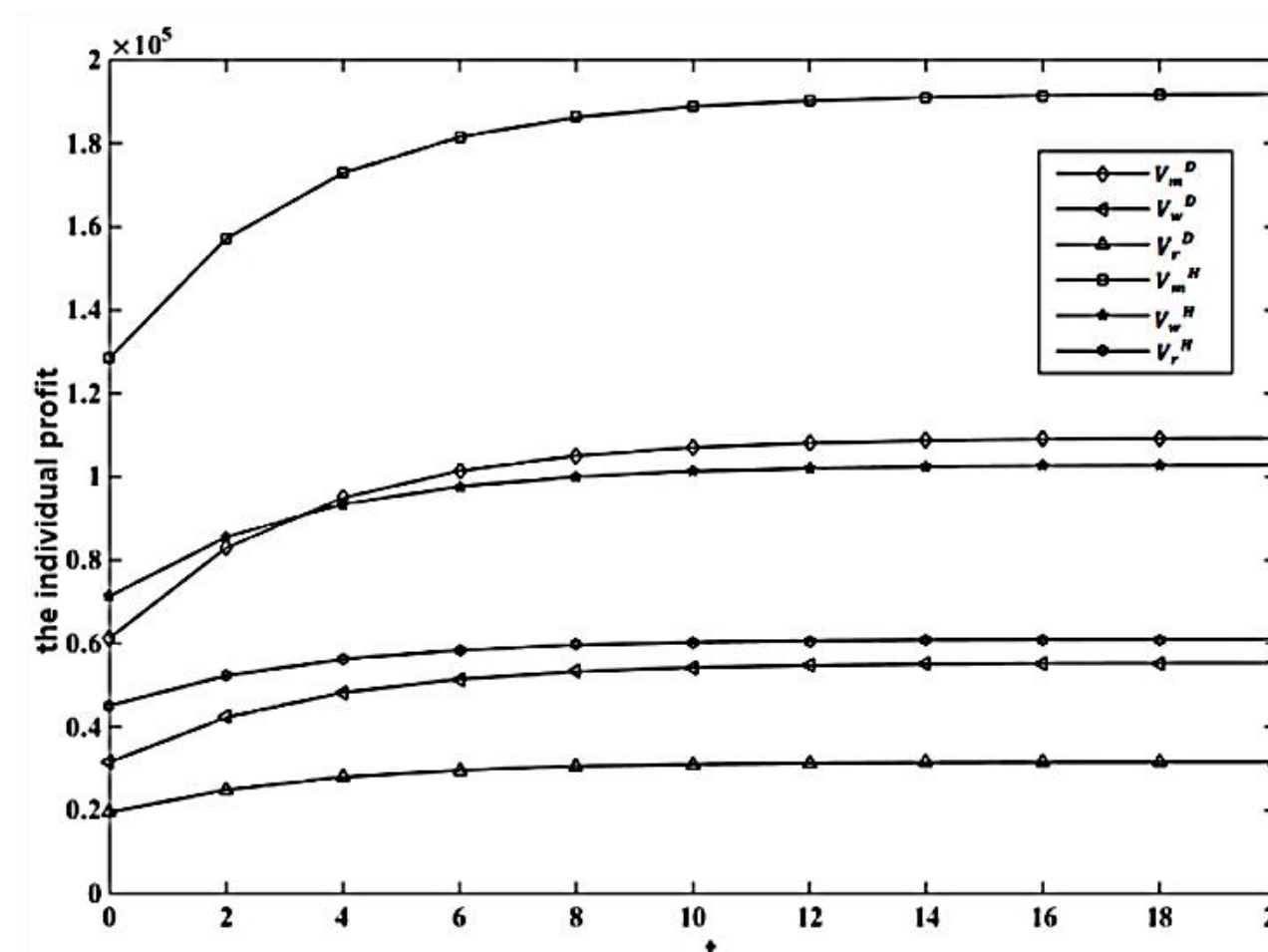
RESULTS & DISCUSSION

(1) Under all three scenarios, drug quality eventually converges to a steady state that is independent of its initial value. Notably, for low initial quality, centralized decision-making accelerates quality improvement by optimally allocating R&D and logistics investments. Conversely, for high initial quality, centralized decision-making effectively slows quality degradation.

(2) The centralized decision yields the highest steady-state quality level. The decentralized scheme exhibits the marginal effect, resulting in the lowest equilibrium quality. The combination contract (government subsidies + logistics cost-sharing) significantly improves the steady-state drugs quality.



(3) The centralized scheme is the optimal strategy, while the decentralized decision-making scenario is the least favorable. Compared to the decentralized scheme, the combination contract with government subsidy and logistics cost-sharing maintains price stability for consumers, simultaneously increases R&D intensity, logistics service, and stakeholder profits.



FUTURE WORK

Future studies may investigate the impact of competitive dynamics on supply chain performance and resource allocation

ACKNOWLEDGEMENTS

This work was supported by National Social Science Fund of China ((No.22BGL111).