

Techno-Economic Evaluation and Market Potential of Green Synthesised Silver Nanoparticles for Sustainable Antimicrobial Healthcare Applications

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ABSTRACT: Nanobiotechnology has emerged as a transformative field driving innovation across healthcare and industrial sectors. Recent advances in green-synthesised silver nanoparticles (AgNPs) demonstrate significant antimicrobial efficiency alongside improved environmental sustainability. However, limited research addresses the techno-economic feasibility and commercialisation pathways of nano-antimicrobial technologies. This study develops a high-impact techno-economic framework integrating innovation management, healthcare economics, and market scalability analysis. The findings suggest that green nanotechnology platforms may reduce long-term healthcare expenditure associated with antimicrobial resistance while enhancing investment opportunities in emerging biomedical markets.

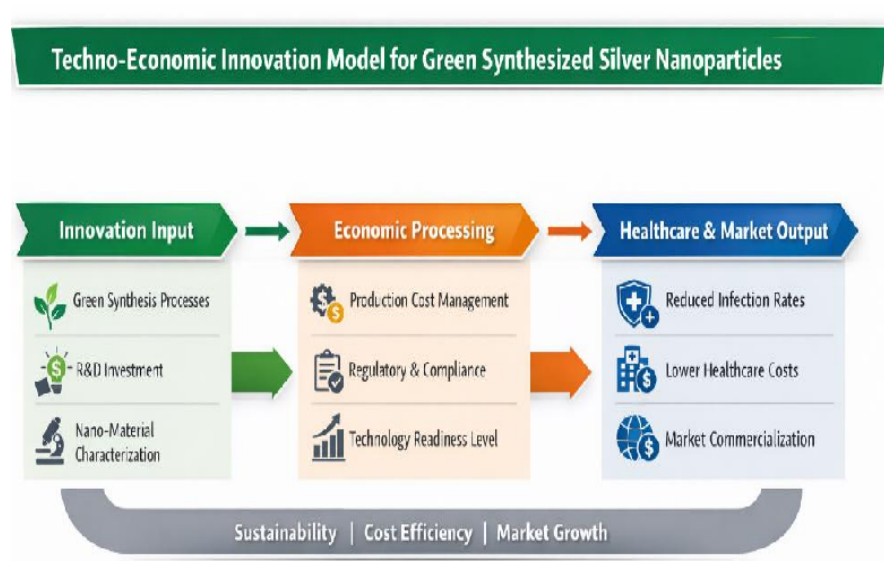
KEYWORDS: Nanobiotechnology, Techno-Economic Analysis, Green Synthesis, Silver Nanoparticles, Healthcare Innovation, Market Projection.

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Introduction

Scheme 1

Schematic illustration of Techno-Economic Evaluation and Market Potential of Green Synthesised Silver Nanoparticles.



The rapid escalation of antimicrobial resistance represents a global economic and clinical challenge, necessitating innovative therapeutic strategies beyond conventional antibiotics (Ventola, 2015; WHO, 2023). Nanotechnology offers a promising paradigm shift by

enabling nanoscale materials with enhanced antimicrobial mechanisms such as membrane disruption, reactive oxygen species generation, and inhibition of biofilm formation (Rashid et al., 2024; Khalifa et al., 2025). Among nanomaterials, green-synthesised silver nanoparticles have gained increasing attention due to their eco-friendly production, reduced toxicity, and cost-effective scalability compared with chemical synthesis approaches (Fahim et al., 2024; Shahzadi et al., 2025). Recent studies highlight that plant-mediated nanoparticle synthesis aligns with the Sustainable Development Goals and promotes commercialisation opportunities in healthcare markets (Ramzan et al., 2024). Despite extensive biological research, techno-economic evaluation remains underexplored. Integrating economic analysis with nanobiotechnology innovation is essential for bridging the gap between laboratory discoveries and market implementation (OECD, 2021; DeFrancesco, 2013).

Methodology - High-Impact Techno-Economic Framework

Conceptual Innovation Model

A three-layer techno-economic model was developed:

Innovation Layer

- Green synthesis processes
- R&D investment
- Nanomaterial characterization

Economic Layer

- Production cost structure
- Regulatory compliance
- Technology readiness level

Market Output Layer

- Healthcare cost reduction
- Market adoption potential
- Strategic commercialisation pathways

This framework aligns with contemporary innovation-economics models used in biomedical technology assessment (McKinsey & Company, 2022).

Comparative Cost Analysis

Table 1

Techno-Economic Production Comparison

Parameter	Green AgNPs	Conventional Antibiotics
Raw Material Cost	Moderate	High
Energy Consumption	Low	Moderate
Environmental Risk	Low	High
Scale-Up Efficiency	High	Moderate
Innovation Value	High	Limited

Economic assumptions were derived from recent studies on nanotechnology commercialisation (OECD, 2021; Casals et al., 2025).

Cost-Benefit Healthcare Evaluation

Table 2

Clinical and Economic Impact

Indicator	Nano-Antimicrobial Strategy	Traditional Therapy
Treatment Efficiency	High	Moderate
Biofilm Control	Strong	Weak
Resistance Development	Reduced	Elevated
Long-Term Healthcare Cost	Lower	Higher
Innovation Market Value	High	Low

Results and Techno-Economic Analysis

Recent literature demonstrates that biosynthesised AgNPs exhibit strong antibacterial activity against multidrug-resistant pathogens while maintaining lower production costs compared with chemical synthesis methods (Rodrigues et al., 2024; Yadav et al., 2024). Environmentally friendly synthesis enhances regulatory acceptance and public trust, thereby increasing the feasibility of commercialisation (Fahim et al., 2024). Techno-economic modelling indicates that nano-antimicrobial technologies could significantly reduce long-term healthcare expenditure associated with resistant infections and prolonged hospitalisation (WHO, 2023). Additionally, synergy between nanoparticles and conventional antibiotics may further enhance therapeutic efficacy while reducing the drug dosage (Casals et al., 2025).

Discussion

The integration of nanobiotechnology with healthcare economics reflects a broader shift toward innovation-driven biomedical markets. High-impact research increasingly emphasises interdisciplinary collaboration between materials science, clinical medicine, and economic strategy (OECD, 2021). Green synthesised nanoparticles demonstrate strong potential as scalable, sustainable technologies aligned with global innovation policies. From a conference-economics perspective, techno-economic modelling enables researchers to evaluate not only scientific performance but also market viability and investment attractiveness. This approach supports the transition of nanotechnology from academic research to industrial and clinical applications (McKinsey & Company, 2022).

Conclusion

Green-synthesised silver nanoparticles represent a promising intersection between nanobiotechnology innovation and healthcare economic sustainability. Integrating techno-economic analysis into research frameworks enhances commercialisation potential and supports strategic investment decisions. Future studies should incorporate real-world clinical data and lifecycle cost analysis to strengthen economic validation.

Highlights

- High-impact techno-economic framework for nano-antimicrobials
- Integration of green nanotechnology with healthcare market analysis
- Market projection model supporting sustainable innovation

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