Journal of Pharmacoeconomics and Pharmaceutical Management

Journal homepage: http://jppm.tums.ac.ir

Iranian Pharmaceutical Industry Future Trends: An Expert Panel Analysis

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Citation Bashirynejad, M., Soleymani, F., Nikfar S., Kebriaeezadeh, A., Majdzadeh, R., Zackery, A., Zare N. Iranian Pharmaceutical Industry Future Trends: An Expert Panel Analysis. Journal of Pharmacoeconomics and Pharmaceutical Management. 2025; 11(1):24-33.

Running Title Iranian Pharmaceutical Industry Future Trends

Article Type Original Article

Article info:

Received: 14.04.2025
Revised: 25.07.2025
Accepted: 05.08.2025

ABSTRACT

Background: The pharmaceutical industry is changing worldwide due to innovations in biotechnology, artificial intelligence (AI), and digital health. These advances are changing both drug development and healthcare systems, which must evolve to meet the demands of a rapidly aging population and rising medical care costs. This paper aims to delineate in more detail the changing face of the pharmaceutical industry in Iran's future.

Methods: A sequential exploratory mixed-methods approach was employed to collect the opinion of experts through the help of in-depth interviews (n=12), performed a thematic analysis, and further used the Analytic Hierarchy Process, validating our results through further expert reviews. Participants had averaged over 22 years of experience.

Results: Five broad categories of trends were identified and weighted based on their significance: These are weighted in regard to the relative importance of each: Technology Advancement (0.31), Digital Transformation (0.28), Biotechnological Innovation (0.22), Supply Chain & Regulatory Evolution (0.12), and Leadership & Soft Skill Development (0.07). Our study emphasizes two very modern and fast-growing trends—artificial intelligence and personalized medicine—along with the difficulties Iran might experience with these advanced technologies.

Conclusion: The future of the drug company in Iran is yet promising, with its own set of challenges. It has much to win and will have to overcome a host of regulatory bottlenecks and a lack of infrastructure so as not to stay behind in the race as AI and digital healthcare solutions seem to pick up speed around the globe.

Keywords: Pharmaceutical Industry, Future, Trends, Expert Panel, Iran

Introduction

The pharmaceutical industry is changing worldwide due to innovations in biotechnology, artificial intelligence (AI), and digital health. These advances are changing both drug development and healthcare systems, which must evolve to meet the demands of a rapidly aging population and rising medical care costs. With an estimated value of $4.5 billion by 2023, the sector has grown significantly, especially in the capacity to produce essential medicines (1). However, staying competitive in the global market requires more than capacity, it requires innovation (2,11,12).

We provide a special picture of the industry's trajectory. What makes Iran's case particularly compelling is its mix of traditional pharmaceutical approaches and its growing focus on digital and biological innovations, despite the challenges caused by international sanctions and limited access to certain technologies (3,10). As we look to the future, the questions that arise are not just about technological capability but about readiness: Is Iran's pharmaceutical industry prepared to integrate these technologies into its operations? How will these innovations interact with the country's regulatory frameworks and healthcare systems?

The industry of pharmaceutical component in the whole world is developing at a remarkable speed. Market forecasts suggest that the industry will reach a staggering $1.8 trillion by 2026, boosted by advances in artificial intelligence (AI), biologics, and personalized medicine (3,4,9). It should be noted that the industry in Iran is limited by economic sanctions and trade restrictions.

Considering the economic sanctions and trade restrictions in Iran that limit access to advanced technologies, Iran's pharmaceutical industry has taken important steps by producing about 70% of its pharmaceutical needs inside and achieving 96% self-sufficiency in generic drugs. It should be noted that the biotechnology sector has also grown with an annual growth of 30% of biotechnology products between 2019 and 2023 (5-8).

Objectives

Iran still lags in several critical areas in accessing and implementing new technologies such as AI-driven drug discovery and advanced biologics manufacturing. However, much of the infrastructure that would eventually be required to drive biopharmaceutical innovation in these emerging markets is still in its nascent stages, and the digital transformation imperative to support broad-based technology adoption for Industry 4.0 technologies is far from complete (13-15).

Besides these technological gaps, there are competitive pressures from other, especially Asian, emerging markets powered by fast technology adoption resulting in driven-down costs and accelerated production cycles. Iran will, therefore, have to tread carefully in these market dynamics if it is ever to retain regional leadership in pharmaceuticals. Technology aside, the country also faces significant regulatory challenges. Meeting the requirements for standardizing domestic regulations with international standards remains a daunting task, especially if Iran is ever to increase its export footprint in global markets (16-19).

Research Gap and Objectives

Although much literature deals with emerging global pharmaceutical trends, there is no research that focuses on the industry of Iran. The omission is even more remarkable considering the rapid advances in pharmaceutical production active in this country under specific market conditions determined, among other factors, by the encounters of economic sanctions and the need for technological self-sufficiency (20). Most of the available literature also fails to discuss how sanctions have influenced the rate at which Iran's pharmaceutical industry innovates or even how target markets, such as Iran, continue to achieve such high levels of self-sufficiency in light of the restrictions (21). However, little technology adoption has been known within such highly restricted market contexts. By responding to these shortcomings, this research also tries to explore three significant questions: by defining the future trends of Iran's pharmaceutical industry between 2024-2040; assessing the relevance and potential impact of such trends on the future of the pharmacy market at home and globally; and presenting a feasible scheme that the industry players and decision-makers could use for road mapping

strategic plans and drafting appropriate and supportive policies relevant to the unique set of constrictive and facilitating parameters of Iran (22,23).

In so attaining these objectives, the research will proffer new vistas on how the emerging markets can successfully navigate complicated global challenges in striving for technological advancement and innovation within their pharmaceutical sectors.

Theoretical Framework

Guiding this research, we have utilized two of the well-established theoretical approaches: Technology Foresight Theory and Innovation Diffusion Theory. Such frameworks provide a dual lens through which we can understand both the likely future trajectory of technological innovations in Iran's pharmaceutical industry and how such innovations are likely to spread (24). Technology Foresight Theory places us in a position where we can foresee, hopefully, what types of technological developments are best suited for specific social, economic, and regulative environments; in the case of Iran, the theory locates those aspects, such as AI and personalized medicine, that are most likely to ensure growth for the sector of pharmaceuticals over the next two decades (25-27). Innovation diffusion, on the other hand, is related to the way in which new technologies are taken up and digested into industries. This theory very much applies to the Iranian pharmaceutical industry, since the speed of diffusion of new technologies, such as AI or digital health solutions, depends not only on the technology per se but also on the regulatory, economic, and infrastructural readiness of an economy (27-31). In the case of Iran, a number of barriers, including international sanctions and insufficient infrastructure, are bound to make the adoption process more complicated and slower compared with less restricted markets (31-33). Figure1 illustrates our conceptual framework, which integrates Technology Foresight Theory and Innovation Diffusion Theory. This visual representation demonstrates how these theoretical approaches intersect to provide insights into technological innovation in Iran's pharmaceutical industry. The framework highlights the key factors that influence technology adoption, including regulatory environments, economic conditions, and infrastructure readiness.

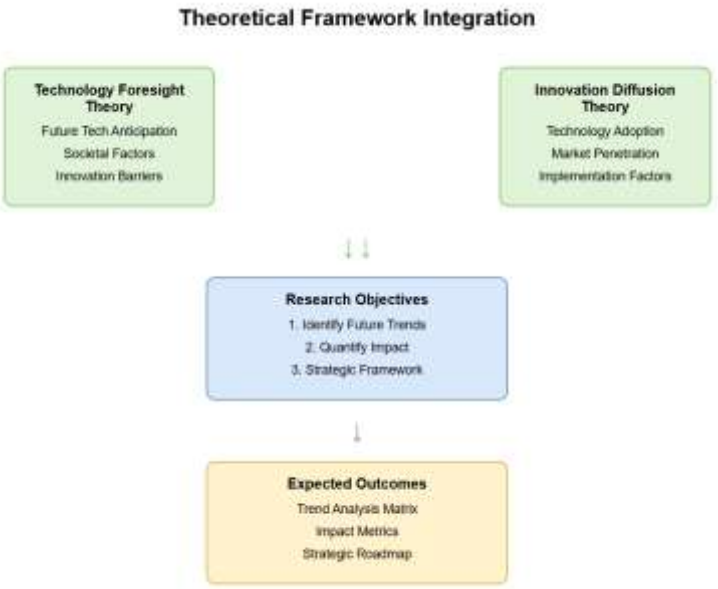

Figure 1. The conceptual framework integrating these theories

Methods

A sequential exploratory methods design is utilized in exploring the future of the Iranian pharmaceutical industry. It allowed us to take a look at both qualitative and quantitative insights, creating a comprehensive understanding of the forces that will shape the sector's future. The interviews were conducted from Sep 2024 to Nov 2024 at Tehran University of Medical Sciences, School of pharmacy, Tehran, Iran. Recruitment occurred through

[e.g., professional networks, industry conferences, academic referrals. Our research was conducted in four phases, each building on the other to ensure comprehensiveness of the analysis (34).

Expert Interviews

Twelve semi-structured interviews were conducted with experts from various areas within the industry of pharmaceutical component, including professionals, academic researchers, and regulatory specialists. These interviews, which lasted between 30 and 40 minutes for each person, provided substantial qualitative data. The use of open-ended questions allowed experts to speak freely, helping identify unexpected trends and challenges that might have been overlooked in a more structured format.

Expert Selection Criteria

Experts were selected through purposive sampling to ensure representation across key segments of the pharmaceutical industry, with criteria including a minimum of 20 years of professional experience, current leadership or senior research roles, representation from at least three professional domains (industry, academia, regulatory), and demonstrated expertise in pharmaceutical innovation and technology.

Thematic Analysis

Key trends and patterns were identified after conducting thematic analysis on the interview data. The thematic analysis followed Braun and Clarke's six-phase framework (???). Two independent researchers first familiarized themselves with the interview transcripts, generating initial codes. These codes were then sorted into potential themes through multiple iterative discussions. Theme refinement involved comparing codes across different expert interviews to ensure comprehensive coverage and minimize individual bias. By coding the transcripts, the data clustered around distinct themes, each representing a Selection to our expert panel was done with consideration to ensure a diverse and comprehensive representative look at the Iranian pharmaceutical landscape. In this, 12 professionals were included in the panel, each contributing a valued view from different segments of the industry. The members ranged from industry veterans and academic major trend shaping the future of the industry. Group discussions within the research team refined these themes, ensuring accurate capture of the experts' insights.

AHP Analysis

In the quantitative phase, the identified trends were prioritized using the Analytic Hierarchy Process (AHP). The AHP is a structured decision-making technique that prioritizes multiple criteria by decomposing a problem into a hierarchy of more manageable sub-problems. The AHP allowed us to quantify expert opinions on the impact of each trend, helping us understand which ones would play the most critical roles in shaping the future of the industry. The AHP method involved creating a hierarchical structure of trends, with experts comparing the relative importance of each trend. A 9-point scale was used, where 1 indicates equal importance and 9 indicates extreme importance of one trend over another. Consistency ratios were calculated to ensure the reliability of expert judgments. In this study, AHP was used to assign weights to the identified trends based on their perceived importance. Expert inputs were collected through pairwise comparisons, where each trend was compared against others to establish relative priorities. The weights represent the relative importance of each trend category.

Expert Review

Finally, in the final step, we returned to the expert panel for validation of our findings. This crucial step ensured that the identified trends were accurate and relevant. Experts were asked to review the conclusions and provide feedback, refining the results and adding reliability to the study.

This multi-phase approach ensured that our trend identification and analysis provided both qualitative depth and quantitative rigor. The framework of the research design is shown in Table 1.

Expert Panel Composition

researchers to regulatory specialists and consultants. It should be noted that the experts present in the interview may have overlapped in one or more areas. This study involving 12 participants from various sectors including industry, academia, regulatory, and consulting. These professionals have substantial experience, with an overall average of 23.5

years, demonstrating a highly seasoned group of experts across different professional domains. Notably, each of our experts contributed more than twenty years of experience on average to the research study. This great expertise helped ground our findings in practical, real-world knowledge, ensuring relevance to industry stakeholders. The breadth of the perspectives represented in the panel enriched the data, allowing for thoughtful consideration of the trends shaping the future of Iran's pharmaceutical sector.

Table 1: Research Design Framework

Point	Method	Output
Exploratory	Expert interviews (n=12)	Identification of Trends
Analytical	Thematic analysis	categorization of Trends
Quantitative	AHP analysis	prioritization of Trends
Validation	Expert review	validation of Trends

Result and Discussion

We identified five key categories of trends that will shape Iran's pharmaceutical industry from 2024 to 2040. The results, summarized in Tables 2 and 3.

Table 2: Identified New Trends

NO	New trends extracted from expert panel	NO	New trends extracted from expert panel
1	Personalized Medicine • Pharmaco-genomics • Biomarker	9	3D(bio)printing 3D printing
2	Artificial Intelligence (AI) • Machine Learning • Big Data • Cloud Computing • Quantum Computing	10	Computational Molecule Design
3	Robots • Internet of Things (IoT) • Smart sensors • Internet of Services (IoS) • Wireless Sensor Networks (WSN) • Smart Vehicles	11	Digital supply chain • Fully Integrated Pharma Network • Cyber-Physical System (CPS) • Enterprise Resource Planning (ERP) Pervasive Computing
4	Nanomedicine	12	New regulation
5	Biotechnology	13	New management and Technique • Mergers and Acquisitions Behavioral Economics
6	Process Analytical Technology (PAT) • Real-Time Release testing (RTRt) • Universal Testing Machine	14	New Training Technique Virtual R&D
7	Continues production • Microwave Drying • 4D printing	15	Energy and environment • Energy Storage Carbon Capture
8	Blockchain	16	Soft skills • Multidisciplinary • Communication Skills • Social Responsibility • Ethics • Crisis Management Continuing Professional Development (CPD)

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Table 3: Identified Trends and Statistical Measures

Trend Category	Weight	Kappa	p-value
Technological	0.31	0.83	<0.001
Digital Transformation	0.28	0.78	<0.001
Biotechnological Innovations	0.22	0.77	<0.001
Regulatory Evolution	0.12	0.76	<0.001
Soft Skill Development	0.07	0.71	<0.001

This expert panel analysis's rated technological development as the most important trend category with a weight of 0.31, followed by digital transformation at 0.28 and biotechnological innovations at 0.22. All categories of trends showed high inter-rater agreement, reflected in the Kappa coefficients, ranging between 0.71 and 0.83, with statistically significant p-values for all categories below 0.001.

Trend Impact Analysis

Each trend was analyzed in depth to assess its impact on the future of Iran's pharmaceutical industry. The three most critical drivers of change—Technological Advancements, Digital Transformation, and Biotechnological Innovations—are expected to reshape everything from drug development to patient care, presenting both opportunities and challenges for the industry.

Implementation Timeline

To assess the feasibility of implementing these trends, the expert panel was asked to estimate their readiness across short-term, medium-term, and long-term horizons. Each trend was graded based on readiness criteria. Table 4 shows Trend Implementation Horizons. These implications suggest that while many trends are poised for near-term implementation, others will take considerable time to be fully realized.

Table 4: Trend Implementation Horizons

Horizon	Number of Trends	Readiness (%)
Short-term (0-5 years)	6	73.5%
Medium-term (5-10 years)	7	58.2%
Long-term (10-20 years)	3	31.4%

Discussion

These results have significant implications for understanding the future of Iran's pharmaceutical industry. In order to help industry stakeholders manage impending changes, we identify important trends and their relative relevance.

Theoretical Implications

Our research advances the theoretical knowledge of innovation diffusion and technology adoption, especially for developing markets like Iran. We found promising innovations like artificial intelligence (AI) and personalized medicine using the Technology Foresight Theory, which should propel future expansion. This theory aids in forecasting the ways in which these technologies will interact with the regulatory, social, and economic contexts of Iran (29). Although biotechnology and artificial intelligence (AI) have enormous promise, their uptake is largely dependent on how prepared Iran's regulatory and infrastructure systems are. The slow uptake of advanced digital health technologies, for instance, highlights the need for investment in digital infrastructure and training programs (30).

Practical Implications

Drug research durations could be shortened by up to 40% thanks to technological advancements, especially in artificial intelligence. This would result in significant cost savings. Businesses can improve their competitive edge both domestically and globally as they implement AI-driven technology (31). However, significant infrastructure investment and regulatory reform will be necessary for the integration of these technologies. With technologies like blockchain, IoT, and smart sensors predicted to improve pharmaceutical product safety and efficacy while streamlining operations and cutting costs, digital transformation is also crucial. Iran's ability to compete globally depends on these investments (32).

Technological Advancements and AI

Technological advancement, especially AI, has changed the face of the pharmaceutical industry worldwide by accelerating drug discovery, rationalizing manufacturing processes, and promoting predictive healthcare. AI-driven drug discovery has reduced R&D timelines by up to 40% in several instances across the globe, while leading players like Pfizer and Novartis have already started using AI in target identification and optimization of clinical trials. However, the readiness of Iran to adopt such technologies is limited because, due to international sanctions, there is a dire scarcity of high-performance computing infrastructure and advanced algorithms. Although Iran has done quite reasonably in becoming self-sufficient with generic drugs, it has to go a long way for further advances in its AI capabilities, needing strong investments in digital infrastructure and collaboration with global AI hubs.

Digital transformation

The integration of smart technologies like blockchain, IoT, and cloud computing in the digital transformation of the pharmaceutical industry can enhance supply chain transparency, data integrity, and improve patient outcomes. Countries such as Germany and the United States have taken the lead in adopting Industry 4.0 technologies in pharma, investing significantly in cyber-physical systems and smart manufacturing. Meanwhile, Iran remains far behind in achieving the necessary digital transformation. For instance, instead of the integrated structure that normally characterizes digital systems within an advanced economy, most Iranian firms are either partial or nonexistent in this environment. There is a relative shortage of skilled IT professionals to assist in driving the change processes. This gap would most likely require targeted policy intervention and public-private partnerships to develop the missing digital backbone upon which advanced pharmaceutical production depends.

Biotechnological Innovation

Globally, biotechnology is revolutionizing the development of biologics, including biosimilars, monoclonal antibodies, and gene therapies. Markets like India and South Korea have established themselves as leaders in biopharmaceutical innovation, supported by favorable policies and international collaborations. Iran, despite producing 30% of its pharmaceutical products in the biotechnology segment, faces scalability issues due to limited access to cutting-edge bioreactors and regulatory delays. Aligning domestic policies with international standards and fostering regional collaborations could help Iran tap into the growing demand for biologics.

Regulatory Evolution and Supply Chain Integration

Regulatory bottlenecks and supply chain inefficiencies are universal challenges in the pharmaceutical sector. Countries like Singapore and Switzerland have streamlined regulatory processes through digitization and harmonization with international standards, reducing time-to-market for new drugs. Iran's regulatory framework, while improving, requires further modernization to facilitate the approval and distribution of innovative therapies. Blockchain technology offers a promising solution to enhance transparency and traceability within Iran's pharmaceutical supply chain, aligning it with global best practices.

Leadership and Soft Skill Development

Leadership and multidisciplinary collaboration are critical for driving innovation in the pharmaceutical industry. Global leaders are increasingly prioritizing workforce training in digital literacy, ethics, and crisis management to navigate rapidly evolving market dynamics. Iran’s pharmaceutical sector must adopt similar strategies to cultivate leaders capable of integrating technological advances while addressing unique local challenges. Initiatives such as cross-sector mentorship programs and international exchanges could accelerate this development.

Global Comparisons and Lessons for Iran

While Iran has demonstrated resilience and ingenuity in overcoming challenges posed by sanctions, bridging the readiness gap in AI, digital transformation, and biotechnology requires learning from countries with advanced pharmaceutical ecosystems. Strategies such as fostering international partnerships, investing in cutting-edge infrastructure, and harmonizing regulations with global standards can help Iran position itself as a competitive player in the global pharmaceutical landscape.

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Study Limitations

This research has several limitations that should be considered when interpreting the results. First, the expert panel was relatively small (n=12), which may limit the generalizability of the findings. Second, the study's reliance on expert opinions introduces potential subjective bias. Additionally, the impact of international sanctions and rapidly changing technological landscapes may quickly render some predictions obsolete. The study's focus on Iran's pharmaceutical industry may also limit direct applicability to other markets with different regulatory and economic contexts.

Conclusion

The findings of this study provide valuable insights into the future trends of Iran's pharmaceutical industry. However, the generalizability of these results to other contexts must be considered cautiously. While the identified trends, such as technological advancements, digital transformation, and biotechnological innovation, resonate with global pharmaceutical developments, the unique economic and regulatory environment in Iran—shaped by international sanctions and infrastructural challenges—creates a distinct context that may not fully align with other markets. Nevertheless, similarities can be drawn to other emerging pharmaceutical markets facing economic constraints and technological adoption barriers. These findings could guide policymakers and stakeholders in comparable settings to prioritize investments in AI, personalized medicine, and regulatory harmonization. However, further research is necessary to validate the applicability of these trends in diverse global contexts, especially in countries with differing regulatory frameworks and market dynamics.

Policy Recommendations

Several evidence-based policy suggestions are suggested to support sustainable growth in Iran's pharmaceutical company:

To balance the high costs of adopting new technologies, policymakers should incentivize pharmaceutical companies with tax breaks and subsidies to encourage investment in biotechnology, AI, and personalized medicine. Cooperation between the public and commercial sectors should prioritize R&D in biotechnology and digital health. Public-private collaborations can overcome financial barriers and promote knowledge sharing (33). Blockchain can enhance transparency in the regulatory process. The government should invest in digital infrastructure to support AI, big data, and telemedicine, while expanding access to high-speed internet and digital health platforms to improve healthcare and pharmaceutical production. (34). Policymakers should also support multidisciplinary education programs on digital literacy, ethical decision-making, and leadership skills to prepare the workforce for rapid technological advancements. (35).

Acknowledgement

We extend our sincere gratitude to all the researchers and authors whose valuable contributions form the foundation of this scoping review. Their insights and findings have been instrumental in shaping our understanding of future trends within the pharmaceutical industry. This study was supported by the Tehran university of medical science. The collaboration and commitment of each contributor have been essential to the development and completion of this project.

Conflict of Interest

The authors affirm that the research was carried out without any existing commercial or financial associations that could be perceived as a potential conflict of interest.

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