Saudi Arabia's Biotech Renaissance: A Two-Pronged Strategy to Build a Future-Ready Innovation Ecosystem

Mohamed A. Kamal, PharmD, PhD
Senior Group Director, Regeneron
'25 eMBA, MIT Sloan School of Management

Suhail Karam Ali
Managing Partner, Integra Investment Group Limited
'25 eMBA, MIT Sloan School of Management

Khalid Alhussaini, PhD
Executive Director of Entrepreneurship Institute, King Saud University
Member of MIT Regional Entrepreneurship Acceleration Program (REAP) Team Riyadh (2023-2025)

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Table of Contents

Executive Summary 3

Introduction 4

I. Biotechnology: Global & Regional Context 6

II. Session Summaries and Key Insights 6

Global Innovation Hubs 7

The Pull of the Innovation Track 9

III. The Innovation Track: Evaluating KSA's Potential 11

System Assessment 11

Stakeholder Assessment 16

Strategy Assessment 18

IV. Sequential vs. Parallel 19

Cost Benefit of a Sequential Track 19

Cost Benefit of a Parallel Dual Track 20

V. Recommendations 21

VI. Conclusion 25

References 26

Executive Summary

Saudi Arabia is on the cusp of a biotechnology transformation. Under the bold vision of Vision 2030, the Kingdom has launched its first National Biotechnology Strategy with aspirations to become the regional leader by 2030 and a global biotech hub by 2040. The strategy sets ambitious goals: creating 11,000 biotech jobs by 2030, expanding to 55,000 by 2040, and contributing $34.6 billion - roughly 3% of non-oil GDP.

Yet this vision is not merely aspirational; it is grounded in policy, infrastructure, and momentum already under way. The Kingdom is executing what the authors refer to as a "Track 1" strategy, which is focused on large-scale biomanufacturing to ensure pharmaceutical self-sufficiency. But an essential question arises: can Saudi Arabia complement this manufacturing prowess with a parallel innovation track that turns research into homgrown biotech breakthroughs? This article argues emphatically: yes it can - and it must.

Why Dual-Track Matters

The authors define "Track 2" as a bottom-up mission to cultivate a dynamic biotech startup ecosystem, empowering entrepreneurial ventures from the laboratory bench to the marketplace. Global experience shows that nations capturing both innovation and manufacturing create significantly more value than those focusing on production alone. The U.S. and Switzerland generate most of their biotech returns from intellectual property and new drug approvals. In contrast, manufacturing-led hubs like India and Ireland deliver volume but capture only a fraction of the economic upside.

Saudi Arabia's opportunity is clear: complement its "Made in KSA" push with an "Invented in KSA" pipeline. Innovation yields higher salaries, greater export value, strategic resilience, and the multiplier effects of a knowledge economy. R&D-intensive sectors attract global partnerships, drive high-impact talent development, and provide long-term returns that compound far beyond short-term manufacturing contracts.

The Current Landscape

Saudi Arabia is well-positioned to pursue this dual-track strategy. R&D investment reached SAR 22.6 billion (approximately $6 billion) in 2023, growing 17.4% year-on-year. Institutions like King Abdullah University of Science and Technology (KAUST) and King Abdulaziz City for Science and Technology (KACST) host world-class facilities, including Good Manufacturing Practices (GMP) pilot plants and genome sequencing centers. The Saudi Human Genome Program has already sequenced over 65,000 individuals. Regulatory alignment is improving rapidly, with the Saudi Food and Drug Administration (SFDA) joining international standards bodies and streamlining clinical approvals.

Human capital is also expanding. By the end of 2023, the country employed over 49,000 R&D personnel, with women earning more than half of science degrees. King Saud University (KSU) and KAUST are climbing in global academic rankings, while young Saudis are entering STEM fields at scale. This talent base is critical to fueling innovation.

Startups: Small in Number, Big in Promise

Saudi biotech startups are still few but growing. Supported by programs like the Ministry of Health's Biotech Accelerator and the Ministry of Investment's Startup Development Program, early-stage ventures are tackling diagnostics, vaccines, regenerative medicine, and genetic therapies. Notable names include Plansulin, Novo Genomics, and CamelX. The potential is clear, but the startup density and funding ecosystem remain underdeveloped. Structural barriers persist. Government employees - including many academic researchers - are still legally restricted from registering companies. Local venture capital remains limited, with most biotech deals under $5 million. The technical complexity and long ROI timelines of biotech make it a hard sell for generalist investors.

But change is under way. Programs like TAQADAM, international VC outreach, and state-backed innovation funds (like Sanabil and the new SAR 2 billion fund-of-funds) are beginning to address the funding gap. Cultural factors also play a role: risk aversion and a preference for stable public-sector roles have historically hindered entrepreneurial capacity. Driven by the Kingdom's young and impressionable population, however, more early-career scientists are embracing entrepreneurship, signaling the potential for a meaningful cultural shift.

Parallel, Not Sequential

The report advocates strongly for a parallel approach: pursue manufacturing and innovation simultaneously. A sequential model risks cementing a low-margin identity and missing the high-value wave of IP and R&D. Global evidence suggests the most successful ecosystems like South Korea invested in R&D even as they scaled manufacturing.

Saudi Arabia already has many of the hardest-to-build assets: capital, labs, talent, and policy alignment. What it needs now is to scale entrepreneurial capacity, open access to research infrastructure, strengthen tech transfer, and activate private venture capital.

A Roadmap Forward

The article outlines ten key policy levers to activate Track 2: from building shared wet labs and launching national accelerators, to reforming university tech transfer and streamlining clinical trials. KPIs are proposed for each lever, with "traffic-light" progress indicators tracking current performance.

The authors argue that this innovation track should not be viewed as an optional extension but as a necessary complement to the Kingdom's biotech ambitions. Innovation culture, once missed, is difficult to retrofit. But if pursued in parallel with manufacturing, Saudi Arabia can unlock a self-reinforcing biotech engine that produces, exports, and owns high-value biomedical innovations. Therefore, we propose that Saudi Arabia refresh its national biotechnology strategy by formally mandating Track 2 alongside Track 1 and recruiting the necessary stakeholders to execute the dual strategy goals.

Conclusion

Saudi Arabia has the rare opportunity to leapfrog into the upper echelon of biotech nations. By coupling its manufacturing drive with an innovation ecosystem that nurtures startups, develops IP, and attracts global partners, the Kingdom can achieve both economic diversification and sustainable health sovereignty. Now is the time to move decisively on both tracks. The rewards - economic, strategic, and societal - will compound for generations.

To discover the full roadmap, stakeholder analysis, and case studies behind this transformation, read the full article.

About the Authors

Mohamed Kamal, Senior Director and Head of Immunology Clinical Pharmacology at Regeneron, has a PharmD and PhD in Pharmaceutical Sciences. He is a US drug developer with over 20 years' experience in the pharma and biotech industries.

Suhail Karam Ali, managing partner at Integra Investment Group, is an entrepreneur specializing in real estate investments in the Gulf Region.

Both Mohamed and Suhail met while completing their Executive MBAs at Sloan MIT. During their eMBA, both have visited and met members representing stakeholders of the inspiring biotech ecosystem in Saudi Arabia, enabled by Khalid Alhussaini, PhD.

Khalid Al Hussaini is an Associate Professor in Biomedical Engineering; Executive Director of the Entrepreneurship Institute, and Deputy VP for Innovation Strategy at King Saud University; and an alum of MIT REAP and therefore of MIT Sloan School of Management.

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I. Introduction

Saudi Arabia's Vision 2030 recognizes biotechnology as a strategic sector for diversifying the economy and improving public health. In January 2024, the Kingdom launched a National Biotechnology Strategy to make Saudi Arabia the Middle East's biotech leader by 2030 and a global hub by 2040. The strategy's headline goals include creating 11,000 biotech jobs in 2030, 55,000 biotech jobs 2040, and contributing $34.6 billion, which equates to 3% of non-oil GDP by 2040 (Kingdom of Saudi Arabia 2024)

The strategy focuses on four key areas: **vaccines, biomanufacturing and localization**, **genomics**, and **plant optimization** (Kingdom of Saudi Arabia 2024). Notably, the current strategy emphasizes late-stage development and large-scale biomanufacturing capacity over early-stage research and invention. The focus is on scaling up proven technologies for local production – for example, using licensed vaccine platforms or manufacturing approved biologics as biosimilars, reflecting a mandate for industrial-scale biomanufacturing to ensure health sovereignty in the near term.

Emphasizing biomanufacturing and late-stage development addresses immediate priorities: it ensures medicine supply security, creates pharma production jobs, and leverages KSA's business-friendly environment to attract multinational manufacturers. In addition to this imperative, we explore the added and reinforcing ecosystem benefits of nurturing homegrown biotech innovations through translational research, intellectual property development, and startup entrepreneurship. The augmented strategy we articulate comprises two reinforcing tracks in keeping with the ambitions of Vision 2030:

1. **Track 1: Economic Sovereignty** – This top-down strategy aims to localize vaccine, drug, and biologics production, reaching 70% self-sufficiency in pharmaceutical manufacturing by 2030.

2. **Track 2: Innovation Leadership** – A bottom-up mission to create biotech startups, strengthen IP generation, and attract global talent to build Saudi Arabia into MENA's leading biotech hub.

This report evaluates the capabilities Saudi Arabia currently has, as well as the ones it must develop to establish a parallel "Invented-in-KSA" early-stage R&D pipeline (Track 2) that complements its existing "Made-in-KSA" manufacturing focus (Track 1). It quantifies the economic and strategic gains of nurturing homegrown innovation, analyzes value-chain dynamics within the kingdom's current production-centric model, compares KSA's biotech ecosystem with leading and emerging global hubs, and presents a clear roadmap for building an integrated biotech platform that spans discovery through commercial production.

II. Biotechnology: Global & Regional Context

Biotechnology has risen to the top of national agendas worldwide in the wake of the COVID-19 pandemic, showcasing its transformative potential in human health, agriculture, and sustainability (Strategy& - PWC 2023). Governments are investing heavily in next-generation biotech fields such as mRNA vaccines, cell and gene therapies, precision medicine, and synthetic biology. As shown in Figure 1, the worldwide biotech market – valued at $1.5 trillion in 2023 – is projected to nearly triple to $4 trillion by 2030 (Grand View Research 2023) driven by rising healthcare demand and public-private investment surges. Biotech is thus not only a scientific endeavor but a geostrategic asset, conferring economic growth and resilience to countries that cultivate robust innovation ecosystems.

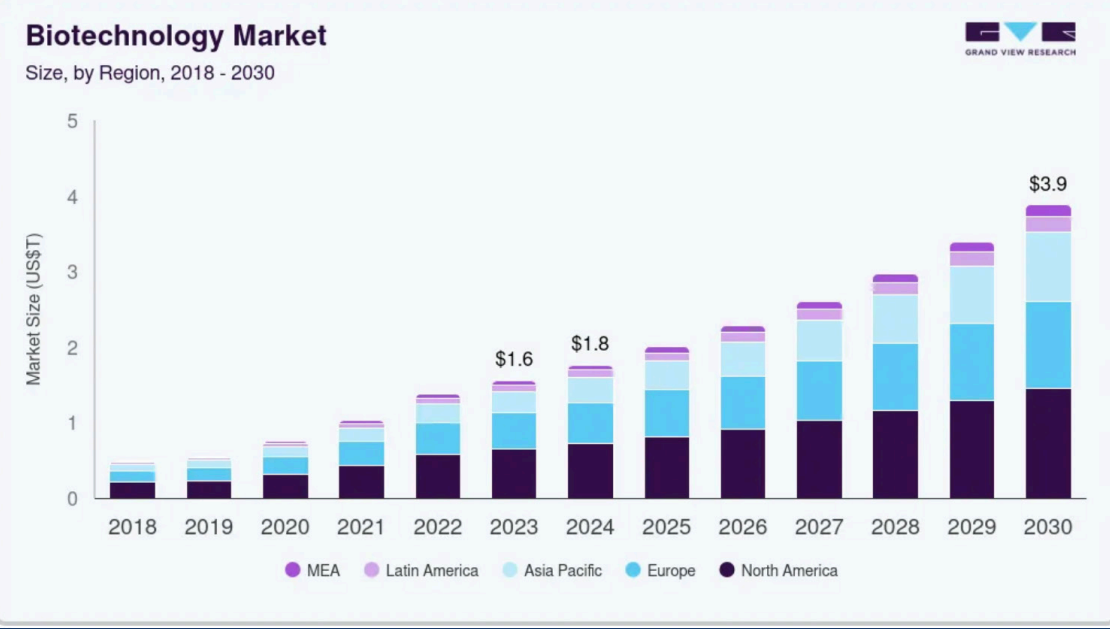


Fig 1: Worldwide Biotech Market
Source: Grand View Research

Within Middle East & North Africa (MENA) region, biotechnology is an emerging sector with most countries in early development stages. Regionally, Saudi Arabia aims to fill a void as MENA currently lacks a dominant biotech hub, importing most advanced therapeutics and conducting limited local research. By 2030, Saudi Arabia seeks to be the MENA leader in biotech, capturing regional demand for pharmaceuticals (Latham & Watkins 2024).

Global Innovation Hubs

Global biotech clusters demonstrate how different strategies – focusing on innovation, manufacturing, or a dual-track of both – impact economic outcomes. Notably, hubs that combine cutting-edge R&D with production capture far greater value than those relying on manufacturing alone (Swiss Biotech Report 2024). Figure 2 plots various global biotech hubs with their R&D pharma pipeline and biomanufacturing capacity (Raymond & Andrella 2025).

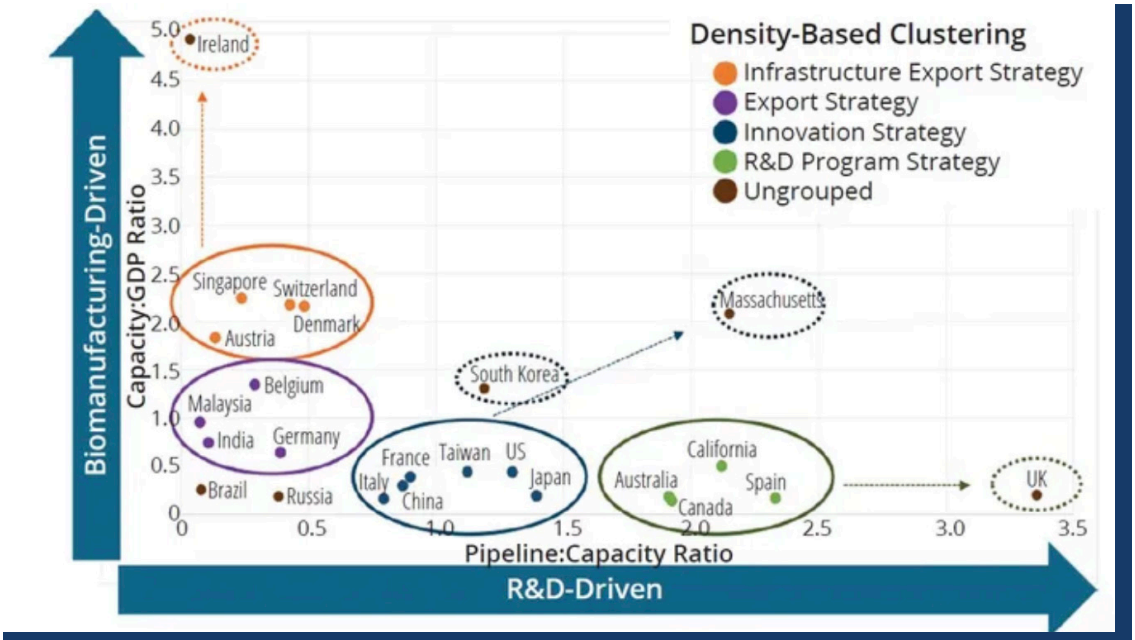


Fig 2: Map of Bioregion Value-Generation Strategies
Source: National Research Council of Canada, 2025. Reproduced in Bioprocess International, May 2025

Innovation-Driven Hubs (e.g. United States):

The U.S. biotech ecosystem, exemplified by Boston's Kendall Square, thrives on breakthrough research and startup formation (Budden and Murray 2014). This innovation focus yields high-value intellectual property (IP) and steady drug pipelines. The U.S. leads in new drug approvals and enjoys approximately 65% value capture from IP, patents and licensing, alongside over 20% from its world-class manufacturing capacity. Massive IP revenue of roughly $85 B in annual licensing royalties bolsters exports (U.S. Department of Commerce 2023). Similarly, Switzerland exported approximately $115 B in pharmaceuticals in 2022, with over 70% of value attributed to IP ownership (Swiss Biotech Report 2024).

Manufacturing-Focused Hubs (e.g. Ireland, India):

Manufacturing-led centers excel at large-scale production but capture a smaller share of value. Ireland is a top pharma exporter (~$130 B goods exports) with 90+ multinational plants. However, only ~20% of its biotech value comes from IP, reflecting limited homegrown innovation (Swiss Biotech Report 2024).

India similarly built a generics and vaccines powerhouse (supplying ~65% of WHO's vaccines) and exports ~$25 B in drugs. Yet its domestic innovative drug share is minimal (~1% of the market), yielding just ~15% value from IP (Government of India 2023).

Dual-Track Hubs (e.g. South Korea):

A combined approach of innovation and manufacturing has proven most dynamic. South Korea began with contract manufacturing (e.g. biosimilars by Samsung Biologics) and then invested heavily in R&D, filing hundreds of new drug trial applications and achieving its first homegrown novel drug (Government of South Korea 2022). As a result, nearly half its biotech value now comes from IP (~45%) – a share that is rising. Singapore hosts world-class production plants (by Pfizer, Amgen, etc.) while supporting R&D through public research institutes and talent programs (Singapore EDB 2023).

Table 1 below provides a comparison across multiple global biotech ecosystems using approximations for Biotech exports, each ecosystem's signature capability and the estimated split of value capture between IP and manufacturing.

Country	2023 Pharma/Biotech Exports	Signature Capability	Split of Value Capture
United States	~$100 Bn goods exports + $85 Bn in IP receipts (2023)	Continuous pipeline of first-in-class drugs (global leader in new approvals) and world-scale CDMO capacity (e.g. Catalent, Thermo Fisher).	~65% IP (patents/licensing) / 20% in-house Mfg / 15% outsourced CDMO
South Korea	~$11 Bn biologics exports (e.g. Samsung Biologics ~784 kL capacity)	Started with biosimilars and contract mfg; now adding innovative R&D (711 INDs in 2022) and first homegrown NME (cenobamate).	~45% IP / 35% CDMO / 20% fill–finish (rapidly rising discovery/R&D share)
Switzerland	~$115 Bn pharma exports (2022)	Global HQs of Roche & Novartis capture IP rents; Basel hosts high-throughput biologics plants. Swiss pharma labor is highly productive.	~70% IP / 15% manufacturing / 15% services (innovator-centric patents/ branding)
India	~$25 Bn drug exports (FY2023) + vaccines (~65% of WHO demand)	Low-cost generics and vaccine powerhouse; now scaling novel R&D (patented drugs ~1% of market, but ~40 pipeline NMEs).	~15% IP / 65% manufacturing / 20% CRO–CDMO (mostly production services)
Singapore	~$11 B goods exports (pharma)	Asia's pharma/biotech hub: world-class manufacturing (Pfizer, Novartis, Amgen have major plants); deep talent pool and R&D ecosystem linking to Asian markets.	~10% IP / 60% in-house manufacturing/CDMO / 30% services (e.g. supply-chain, regulatory)
China	~$13.3 B goods exports (medicines/ vaccines)	Leading global supplier of generics/ APIs; rapidly growing biotech R&D (Chinese firms now ~30% of global pharma R&D investment) and major licensors (US firms signed $18.3 B in Chinese drug licenses in H1 2025).	~30% IP / 60% manufacturing & CDMO / 10% services (distribution, CRO)
Ireland	~€116 B (≈$130 B) goods exports (3rd-largest pharma exporter)	Global pharma manufacturing hub: 90+ plants of top firms (Novartis, Pfizer, J&J, etc.); exemplary regulatory compliance (50 FDA-approved plants) and growing R&D.	~20% IP / 65% manufacturing (incl. generics/vaccines) / 15% services (CRO, supply-chain)
United Kingdom	~$27.5 B goods exports	Major R&D and biopharma center: home to GSK and AstraZeneca (together >40% of sector); leading biotech clusters in London–Cambridge–Oxford ("golden triangle" ~40% of output/turnover).	~60% IP / 30% manufacturing / 10% services (clinical trials, biotech services)

Table 1 – Global Biotech Hub Biomanufacturing & Innovation Estimated Figures

The Pull of the Innovation Track

Despite the high costs and risk associated with early-stage biotech innovation, nations seeking biotech hub status invariably look to develop the innovation track for the following reasons:

1. Economic Value Capture: Most of the economic upside in biotech lies upstream in IP creation, licensing, drug discovery platforms, and data assets (e.g. genomic, clinical trials). Focusing on manufacturing captures low-margin, low-IP portions of the biotech value chain.

   As summarized in **Table 2** below, industry reports indicate that combining large-scale biomanufacturing with a vigorous discovery pipeline would materially outperform a manufacturing/ production-only pathway, primarily due to the fact that IP owners often capture the majority of a drug's value, with such companies enjoying value capture of 60-70%, translating to around 50% Earnings Before Interest and Taxes (EBIT) (Sood et al 2017). In contrast, large-scaled GMP manufacturing is usually able to capture 15-25% of final drug value with much lower EBIT margins of 10-18% (Contract Pharma 2019).

Supply-chain activity	Share of final drug value captured	Typical EBIT margin
Basic research & IP ownership	60–70%	45–55%
Clinical development (late stage)	10–15%	15–25%
Large-scale GMP manufacturing / fill-finish	15–25%	10–18%
Distribution & retail	5–10%	5–10%

Table 2 – Drug Lifecycle: Value Capture & Profitability

Therefore, countries mastering both drug discovery and scale-up manufacturing (e.g. US and South Korea) capture 2–3× more economic value per unit of product than pure manufacturing hubs. Bain & Company's global export analysis shows that although India is already 3rd by kilogram of pharmaceuticals exported, it sits 11th by dollar value because most output is low margin generics. On the other hand, Switzerland - with high IP exports - punches above its weight (see **Figure 3**, Bain 2025).

2. ***The National Balance Sheet:*** Switzerland illustrates the macro leverage of IP ownership. In 2024 chemicals-and-pharma exports reached CHF 149 billion (≈ US $160 billion) - 52 % of all Swiss goods exports - and the sector delivered 9.8 % of national gross value added (Interpharma 2024). A country of 8.8 million people thus runs one of the world's largest goods-trade surpluses on the back of ideas it owns.

3. ***"Weightless" exports that keep earning:*** Intellectual-property revenues behave like annuities. U.S. receipts for royalties and license fees were US $134 billion in 2023 and climbed to an annualized ~US $155 billion in early 2025, cushioning the wider trade deficit even when physical exports slow (Fred 2025).

4. ***Higher Salaries:*** The wage gap mirrors the value gap. The U.S. median salary for biological scientists is US $91,100, almost double the US $52,000 earned by biomanufacturing technicians (OES 2024). Moving upstream therefore lifts household incomes and enlarges the pool of advanced-STEM talent.

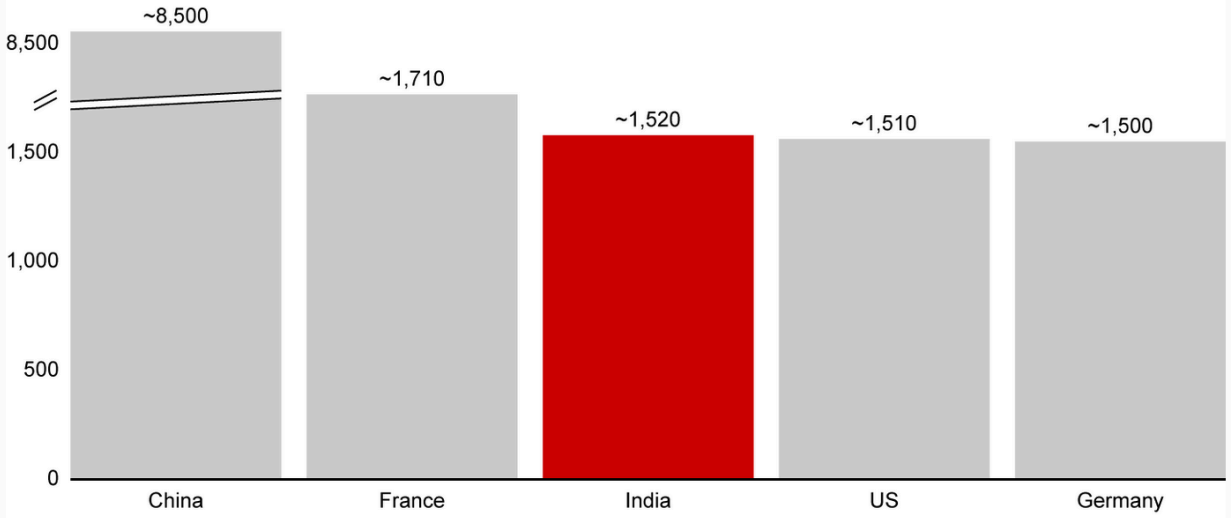
5. ***Strong Economic Multipliers:*** Every direct R&D job in the US supports 3.7 additional jobs across the economy including consultants, analytics firms, clinical CROs, venture funds and high-end services (PhRMA 2024)

6. ***Shock Resilience:*** India's generics powerhouse exported US $27.9 billion of pharmaceuticals in FY 2024, yet 31 % went to the U.S. A single 25 % tariff proposal in 2025 rattled the sector's share prices in February of 2025 (Reuters 2025). Switzerland on the other hand, with IP-rich exports spread over many markets, rode out COVID-19 and supply-chain swings while still setting export records (Swiss Biotech).

7. ***Talent, FDI Magnet & Soft Power:*** A biotech ecosystem driven by research and invention cultivates scientists, translational researchers, clinical and regulatory experts and venture creation talent or entrepreneurs. It also attracts global partnership and international venture capital. Countries like Singapore and Israel use innovation as a strategic soft power tool to anchor long-term foreign investment.

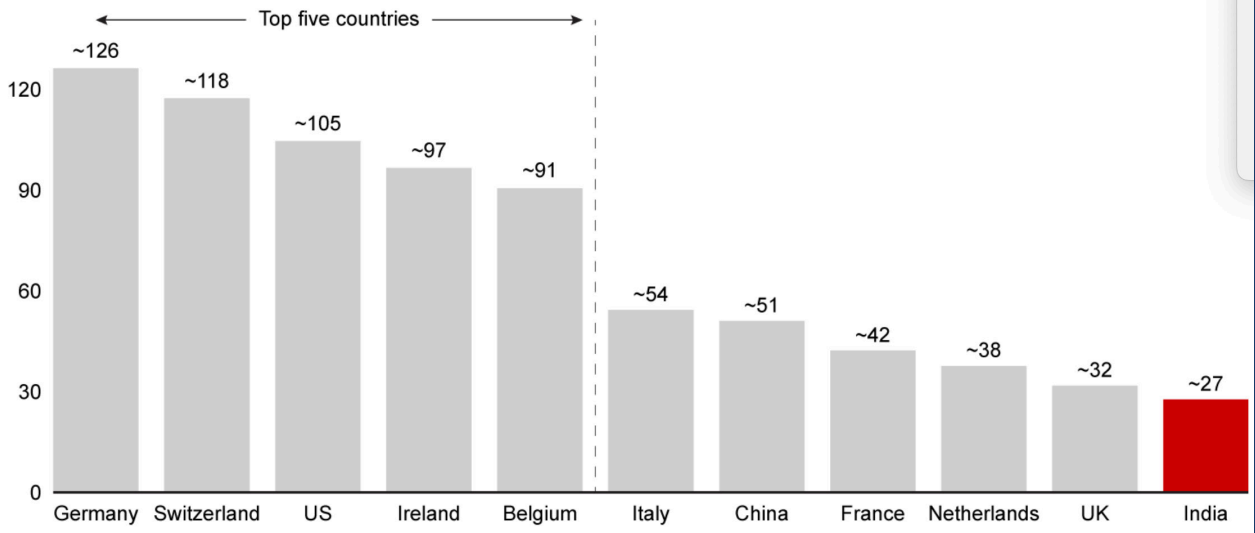
India is the third-largest nation in terms of pharma exports by volume

Pharmaceutical exports (2023) in thousands of tons



Note: Data for relevant 6-digit India Trade Classification Harmonized System (ITC-HS) codes pertaining to active pharmaceutical ingredients (APIs), formulations, biosimilars, and vaccines taken based on India exports data to enable like-for-like comparison
Source: Trade Map

Pharmaceutical Exports (2023) in $B



Notes: Data for relevant ITC-HS codes (6-digit) pertaining to APIs, formulations, biosimilars, and vaccines taken based on India exports data to enable like-for-like comparison; India's exports, excluding surgicals and others, is about $26 billion, which still ranks 11
Sources: China data from secondary; India data from Pharmexcil; Data for all other countries from Trade Map

Figure 3 – 2023 Pharmaceutical Exports by Country (Source: Bain & Co 2025)

III. The Innovation Track: Evaluating KSA's Potential

To judge whether Saudi Arabia can advance from contract biomanufacturing to genuine discovery, we adapt the MIT "3 S" innovation-ecosystem framework (Budden and Murray 2019) - System, Stakeholders and Strategy as shown in Figure 4. Rather than scoring every sub-dimension, we ask three concise questions:

Figure 4 – 3S Innovation Ecosystem Framework (Budden & Murray, 2019)

1. ***System*** – Do the hard enablers (e.g. legal regime, R&D and physical infrastructure) already support world-class science?

2. ***Stakeholders*** – Are the principal actors (government, academia, industry, investors, entrepreneurs) in place and beginning to interact productively?

3. ***Strategy*** – What is the current national plan, and what new recommendations favor developing biomanufacturing and innovation in parallel rather than sequentially?

This pared down 3 S reading focuses on foundational capacity; prescriptive recommendations follow in a later section of the wider paper.

System Assessment

Saudi Arabia's ability to commercialize new medicines from invention depends broadly on two ecosystem capacities: Innovation capacity (I-Cap) and Entrepreneurial capacity (E-cap) (Budden and Murray 2019).

Innovation Capacity (I-Cap)

I-Cap refers to the ability to generate new-to-the-world ideas, knowledge, and technology. Saudi Arabia's I-Cap has grown markedly:

R&D Expenditure and Innovation Infrastructure: Saudi Arabia has significantly increased its research and development (R&D) spending in recent years. In 2023, gross domestic expenditure on R&D reached SAR 22.6 billion (approximately $6.0 billion), reflecting a 17.4% year-on-year increase (GASTAT 2024). This growth - among the fastest within the G20 - demonstrates the impact of Vision 2030 initiatives and expanding private-sector engagement. Despite this progress however, Saudi Arabia's R&D intensity remains relatively modest at 0.49% of GDP, based on GASTAT's 2023 GDP estimate of SAR 4.57 trillion. In contrast, the United States allocates around 3.6%, South Korea over 5%, and Singapore about 2% of their GDPs to R&D. Recognizing this gap, Saudi leadership has set a strategic target of raising R&D investment to 2.5% of GDP by 2040 (Kingdom of Saudi Arabia 2024). The Kingdom has already assembled many of the expensive, slow-to-build assets that underpin life-science invention. Flagship campuses such as KAUST, King Saud University (KSU), and KACST, house next-generation sequencers, GMP-grade pilot bioreactors, and the Saudi Human Genome Program, which has already sequenced tens of thousands of citizens (Labiotech.eu 2024). Such large-scale infrastructure is rarely available this early in an emerging ecosystem.

Regulation and intellectual-property law have advanced in parallel. Vision 2030 created specialist IP courts and brought the Kingdom into leading WIPO treaty, and as a result, the Global Innovation Index shows Saudi's IP score climbing steadily (WIPO 2023). Crucially for biotech, the Saudi Food & Drug Authority joined the International Council for Harmonization in 2022, committing to FDA/EMA technical standards and introducing accelerated review pathways for critical biologics (SFDA 2025). Meanwhile, new umbrella bodies, such as Research, Development and Innovation Authority (RDIA) for research funding and the Saudi NIH for clinical trials, have replaced siloed oversight. Collectively, these policy moves signal a pro-innovation stance, giving researchers and startups a clearer, more supportive operating environment.

Human Capital:

Saudi Arabia's human capital indicators in research and development are showing strong upward momentum. By the end of 2023, the Kingdom employed 49,337 R&D personnel, including 36,832 researchers - a 22% increase from the previous year, according to the General Authority for Statistics (see Figure 5, GASTAT 2024). This translates to approximately 1,000 researchers per million inhabitants, a marked improvement from under 300 a decade ago. Although this figure remains below global innovation leaders - South Korea reports 7,000–8,000 researchers per million, and the United States around 4,800 - the gap is steadily narrowing.

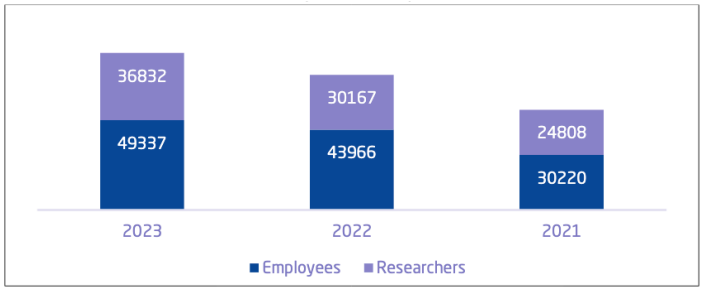


Figure 5 – KSA Human Capital in R&D (GASTAT 2024)

Importantly, female participation in science has broadened the talent base (see Figure 6) and we have witnessed this transformation upon our recent visit to the Saudi biotech Ecosystem. Saudi women now make up the majority of science graduates (about 60% of science degrees are earned by women), and increasingly they are moving into research roles and leadership posts that were once male-dominated. Women scientists hold senior lab and policy positions today, contributing to a wider talent reservoir than in the past. This is in line with global trends – women constitute roughly one-third of researchers worldwide – but represents significant progress for the Kingdom.

Continued emphasis on STEM education and inclusive hiring, through programs like L'Oréal-UNESCO "For Women in Science" is expected to further elevate female scientific contributions, enhancing Saudi's human capital for innovation.

Demographically, Saudi Arabia enjoys a young population compared to the rest of the world - of which half are under 30 (Figure 7) - with growing STEM literacy. This youthful, tech-savvy cohort is a long-term asset for innovation capacity, providing a demographic runway that many OECD countries with aging workforces lack. The challenge ahead will be to sustain high-quality training and research opportunities to fully leverage this potential.

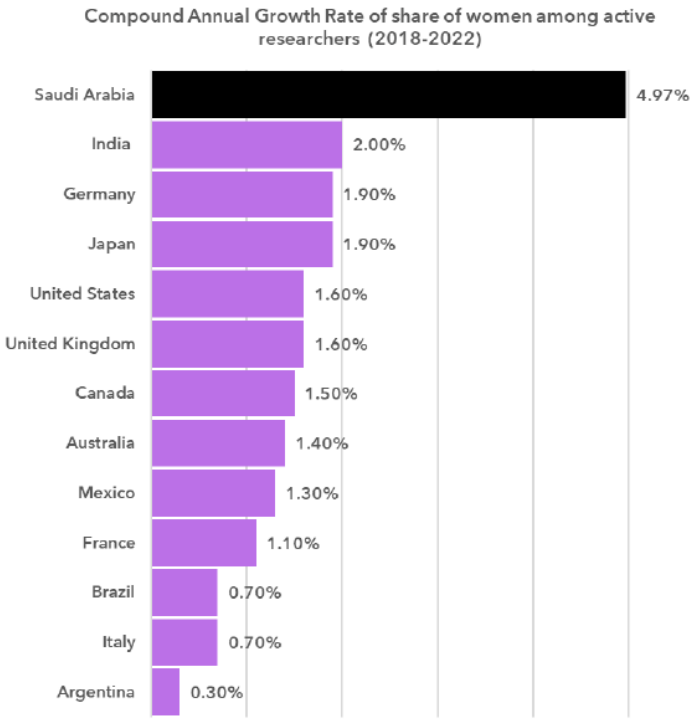


Figure 6 – Compound growth rate of share of women among active researchers, 2018-2022 (Elsevier, 2024)

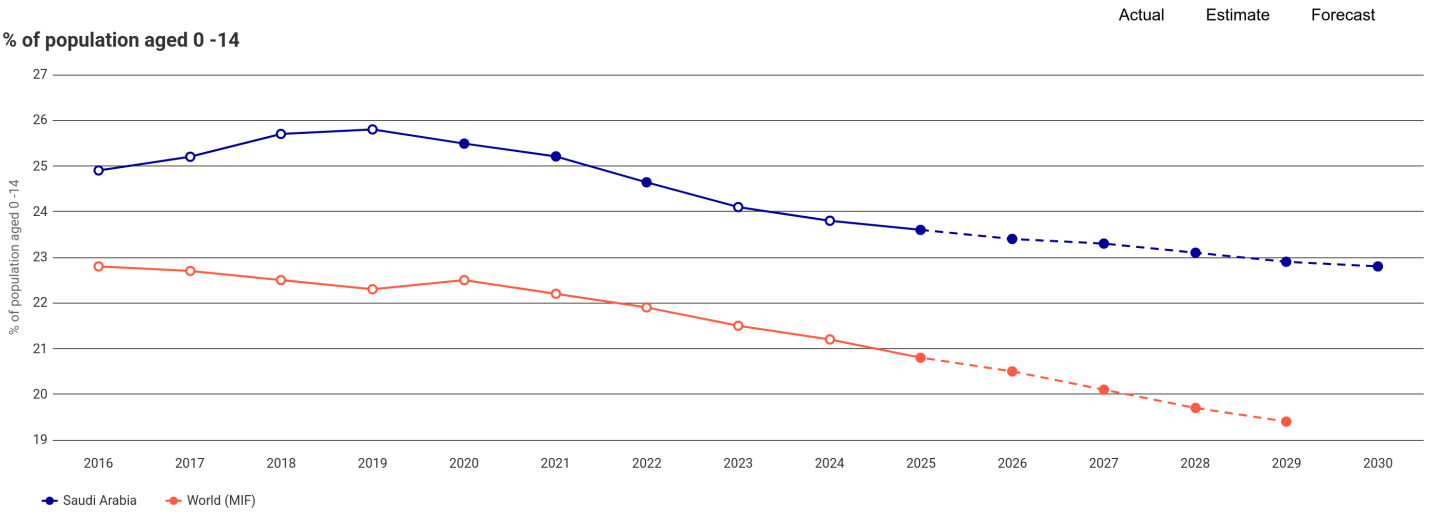


Figure 7 – Percentage of Population aged 0-14 – KSA vs World (Economic Intelligence Unit 2025)

This growth reflects not only quantitative expansion but also improvements in research quality. KAUST ranks among the top 20 globally in citation impact per faculty, highlighting the world-class caliber of researchers being cultivated in the Kingdom (Nature Index 2023). In addition, King Saud University has achieved a significant milestone by being ranked among the top 100 universities worldwide in the 2024 Academic Ranking of World Universities (ARWU) by ShanghaiRanking, reflecting the country's progress in academic research and institutional excellence (ShanghaiRanking 2024).

Country-specific breakout sessions followed thematic discussions, in the effort to adapt and apply some of the ideas discussed to select markets. Problems within each of the countries chosen were explored, alongside possible solutions.

Knowledge Output and Patents:

Saudi Arabia's knowledge output in biotechnology and life sciences is rising steeply, although from a relatively low base. Scientific publications have seen double-digit annual growth in recent years. Between 2018 and 2022, Saudi scientific publishing across all fields climbed by 146%, reaching 59,016 publications in 2022 (KAUST 2023). This represents a 25% compound annual growth in research output – a growth rate unmatched by most established countries. Saudi research is also gaining visibility: a recent analysis found Saudi publications are cited 71% more frequently than the world average, outperforming global and regional benchmarks (KAUST 2023). High-impact work, such as genomic studies from the Saudi Human Genome Program, has appeared in top-tier journals, helping put Saudi science on the global map.

Despite this progress, Saudi Arabia's publication volume remains a fraction of that of global biotech hubs. For perspective, the United States produced roughly 460,000 scientific articles in 2022 (NSF 2023); about 8 times Saudi's output. while South Korea and Singapore – both much smaller populations than Saudi – each out-publish Saudi Arabia in per capita terms. Singapore, for example, generates over 4,200 scientific papers per million people versus approximately 1,000 per million in Saudi (World Bank 2024; UN DESA 2024), reflecting a very intensive research ecosystem. The bubble chart below in Figure 8 below from Arthur D. Little's report encapsulates these differences: Saudi Arabia's bubble is still modest beside the U.S. giant, but Saudi's trajectory and progress are among the most rapid upward slopes.

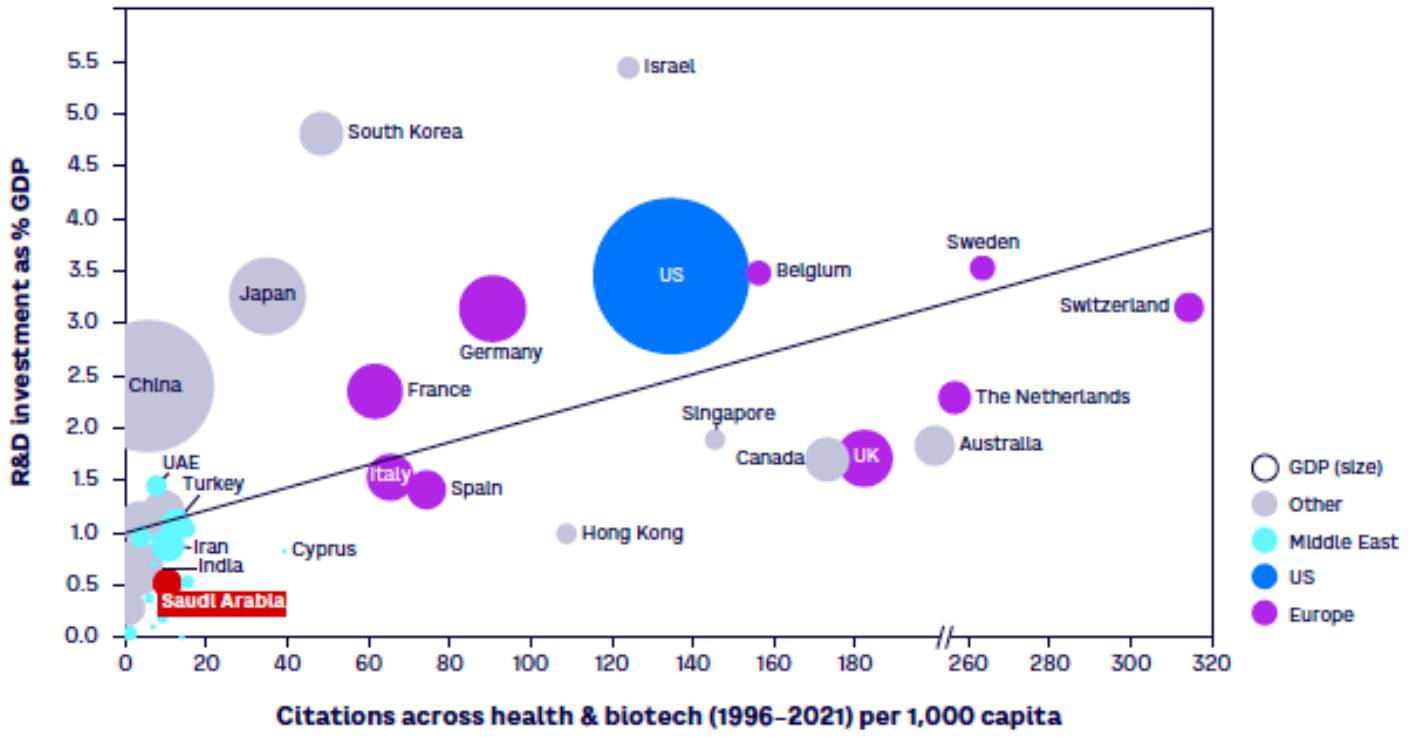


Figure 8 – R&D Intensity vs health & biotech innovation focus (Arthur D. Little 2024)

In terms of intellectual property, patent output is gradually improving but remains an area for development. According to WIPO data, annual resident patent filings in biotech have grown in Saudi Arabia, although from a low base (WIPO 2024). The conversion of these patents into commercial products or ventures is still limited, indicating that the research-to-market pipeline needs strengthening. By learning from countries like South Korea – which leverages heavy R&D investment into high patenting rates and vibrant biotech startups – Saudi Arabia can aim to boost not just invention, but innovation (commercial application of research).

I-Cap Summary:

Saudi Arabia's Innovation Capacity in biotech is strengthening across multiple dimensions. Government strategy has driven record R&D spending and built cutting-edge facilities (the innovation system); the pool of researchers, men and women alike, is growing in size and skills; and tangible outputs like papers and patents are on the rise. The Kingdom still lags behind established biotech hubs on key metrics, but the gap is narrowing.

Entrepreneurial Capacity (E-Cap)

E-Cap is the ability of the ecosystem to create and scale new ventures that bring innovations to market. Saudi Arabia's E-Cap is in early development, as evidenced by the following.

Startup Formation and Density in Saudi Arabia's Biotech Sector:

The biotech startup landscape in Saudi Arabia is still at an early stage, with only a few dozen identifiable ventures. This is considered low density for a country of over 35 million people when compared with mature hubs like Boston, which hosts several hundred biotech startups supported by dense academic, venture capital, and talent ecosystems (MassBio 2023). A new wave of Saudi startups is emerging, catalyzed by initiatives such as the Ministry of Health's Biotech Accelerator Program in partnership with BioLabs - the first of its kind in the region (Ministry of Health 2024).

Notable ventures include CamelX (camel-derived biomedical innovation), X-Genom (diagnostic kits for cancer and infectious diseases), Plansulin (plant-based insulin), cellNUA (bee-derived nanotherapies), SAGEbio (vaccine development), and Novo Genomics (genetic diagnostics). Other promising startups include MammoStem (regenerative medicine), NanoPalm and KaRama Bio (genetic disease diagnostics), and PhageTech, which focuses on antimicrobial resistance. These ventures highlight the Kingdom's growing capacity to translate research into commercial applications aligned with Vision 2030 (MISA 2024).

Startup formation is concentrated around key institutions such as KAUST, which actively supports spinoffs through its in-house venture fund, and King Saud University and the Carage Incubators, which nurture a small but growing pipeline of ventures (KAUST 2023). Emerging innovation zones such as NEOM are positioning themselves as biotech destinations by offering infrastructure, funding, and regulatory support.

Government programs, including the Biotech Startups Development Program led by the Ministry of Investment, are helping to address early-stage barriers by providing grants, mentorship, and business development support (MISA 2024). However, structural constraints persist. Notably, government employees - including academic researchers - are currently prohibited from obtaining commercial licenses (CR) for their own startups, limiting direct participation in entrepreneurship (SFDA 2023).

Cultural factors also play a role: risk aversion and a preference for stable public-sector roles have historically hindered entrepreneurial capacity (E-Cap). Yet this is shifting, with younger scientists increasingly drawn to entrepreneurship, inspired by local success stories and reinforced by the government's emphasis on innovation and commercialization under Vision 2030 (Vision 2030 2023)

Access to Early-Stage Capital:

Saudi biotech still operates with a thin layer of risk money. MAGNiTT logs only five Saudi biotech/health tech deals in 2022, all seed rounds below US $5 million (MAGNiTT 2023). Domestic venture funds, largely generalist, tend to avoid long horizon, high science bets (Strategy& 2024). Sovereign vehicles are trying to close the gap: Sanabil Investments has allocated capital to global life science funds such as ARCH and RA Capital (Sanabil 2023), while the Saudi Venture Capital Company (SVC) runs a health and biotech co-investment programme (SVC 2024). A recently announced SAR 2 billion (approximately US $530 million) innovation fund of funds adds further state backing (MISA 2024).

Yet most money still flows into research grants, leaving a "valley of death" between lab discovery and commercial proof of concept (Strategy& 2024). To import sector knowhow, the Ministry of Investment hosted two delegations of global life science investors in 2023 (MISA 2023). In a report on Saudi Biotech, Strategy& recommends structured investor education programs and syndication with international VCs to deepen the local capital stack (Strategy& 2024).

Cultural and Human Capital for Entrepreneurship:

Entrepreneurship capacity isn't just about money and labs – it's also about mindset and skills. Here, Saudi Arabia is making progress but has ground to cover. Culturally, the idea of founding a startup is gaining acceptance, supported by high-profile government campaigns and even societal shifts (a growing acceptance of women in STEM and business, for example). Vision 2030 explicitly aims to increase SME and startup contribution to GDP, signaling top-level support. In terms of skills, there is a shortage of experienced biotech entrepreneurs and managers. Saudi Arabia does not yet have a large pool of people who have taken a drug from lab to clinical trials or scaled a biotech company. These skills often come from hands-on experience in established hubs. To address this, Saudi Arabia is bringing in foreign experts and encouraging mentorship networks. Programs like Innovation Diplomats and international entrepreneurship training for Saudis (some of which MIT has hosted) are helping build know-how. The talent pipeline for entrepreneurship also intersects with education: universities are introducing entrepreneurship into curricula, and initiatives like TAQADAM Accelerator at KAUST have trained hundreds of student entrepreneurs (some in biotech). Still, fear of failure and administrative hurdles (like obtaining licenses or navigating import/export of biological materials) can stymie budding entrepreneurs. Reforms such as easier licensing for biotech startups and fast-track visas for specialized talent aim to mitigate these (MISA 2025)

Ease of Doing Business:

The broader business climate is also improving. A one-stop digital portal now integrates company registration, investment licensing, tax, and social insurance enrolment, trimming incorporation to a few days (MISA 2025). Caps on foreign ownership have been lifted in most sectors, and targeted tax incentives apply in special economic zones. Such reforms helped Saudi Arabia rank among the ten most improved economies in the World Bank's final Doing Business survey (World Bank 2019).

Collectively, these measures signal a more hospitable environment for science-based-start-ups, even as the ecosystem continues to build the specialist human capital required for biotech success.

E-Cap Summary:

Saudi Arabia's biotech entrepreneurial capacity is still in an early nascent stage. The country has only a few dozen biotech startups so far – a very low density relative to global innovation hubs. Recognizing this gap, the government aims to foster several biotech startups by 2030, with early efforts centered around hubs like KAUST (university spin-offs), Riyadh's Biotech City, and NEOM's biotech zone. Historically, a lack of IP-focused entrepreneurship culture and risk appetite meant many Saudi scientists preferred stable academic or industry jobs over startups. Early-stage venture funding is also scarce: only a handful of small biotech deals have been reported, as local investors often shy away from biotech's long, high-risk development cycles. To bridge this gap, Saudi authorities have launched state-backed venture funds and co-investment programs and are actively courting international biotech VCs to bring in expertise and capital. These steps are meant to span the "valley of death" between lab research and commercial product – a challenge noted in the ecosystem where most funding has historically stayed on the research side. In summary, Saudi Arabia's E-Cap is gradually improving from a low base: new startups, funding initiatives, and shifting attitudes are beginning to take hold, but considerably more growth in ventures and investment is needed to reach the Kingdom's biotech ambitions.

Linking I-Cap and E-Cap

Incubators & Accelerators:

Incubators and accelerators provide the connective tissue that turns discovery (I cap) into commercial output (E cap) (Cohen et al. 2017). Until recently, Saudi Arabia had ample academic laboratories but almost no purpose built space for start ups. That gap is closing. KAUST operates a wet lab accelerator and adjoining incubator, while Dammam Techno Valley hosts an early stage biotech incubator in the Eastern Province (KAUST 2023). In Riyadh, the King Abdullah International Medical Research Center (KAIMRC) is developing a Medical Biotechnology Park next to its hospital complex (Arab News 2024). New projects in NEOM and the capital aim to replicate LabCentral style shared labs, and Strategy& notes a government plan to network these sites so a start up in Riyadh can book specialized equipment in Jeddah (Strategy& 2024).

Stakeholders Assessment

Stakeholder analysis (**Figure 9**) shows an ecosystem rich in powerful orchestrators but still light on private-sector risk takers.

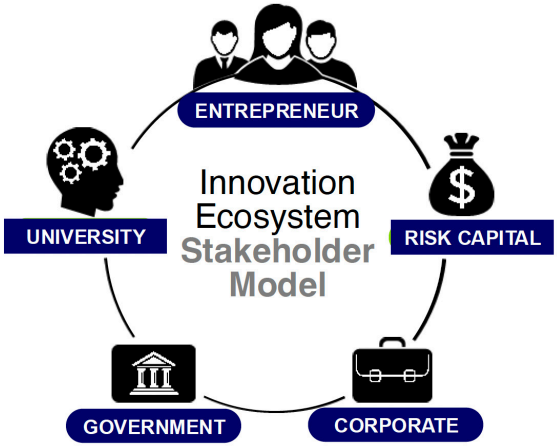


Figure 9 – Innovation Ecosystem Stakeholder Model (Budden and Murray 2019)

Government and Public Sector

Government acts as both policy architect and catalytic investor for Saudi biotech. Vision 2030 and the National Biotechnology Strategy set explicit targets for R&D intensity, manufacturing capacity, and export growth (Vision 2030 2016; National Biotechnology Strategy 2024). The Research, Development & Innovation Authority, created in 2021, aligns budgets and metrics across ministries to keep projects on those trajectories (RDIA 2021).

Funding flows through several sovereign vehicles. The Public Investment Fund's subsidiary Lifera has formed a US $3.5 billion joint venture with U.S. based Resilience to localize biologics manufacturing (PIF 2023). Sanabil Investments commits capital to global life science funds, and the Saudi Venture Capital Company runs a matched fund scheme for health tech and biotech start ups (Sanabil 2023; Strategy& 2024). The Ministry of Investment markets these opportunities abroad, mounting a national pavilion at BIO International and operating a one stop digital portal that bundles licensing, tax, and visa services for investors (MISA 2023).

On the research side, the Saudi National Institute of Health, launched in 2023, coordinates translational research and multi-center-clinical-trials, streamlining ethics review to make the Kingdom more attractive for studies (Saudi NIH 2023). Regulation is handled by the Saudi Food & Drug Authority, which in 2022 became the first Middle East agency to join the International Council for Harmonization (SFDA 2022) and in 2024 introduced an accelerated approval pathway for novel medicines (SFDA 2024).

These moves; clear strategic direction, sovereign capital, coordinated research infrastructure, and a progressively harmonized regulatory regime, constitute the public sector backbone of Saudi Arabia's emerging biotech ecosystem.

Academia and Research Institutes

Universities anchor Saudi Arabia's research talent pipeline while specialized institutes translate lab discoveries into clinical and commercial outputs. King Saud University (KSU) in Riyadh houses a technology incubator that has admitted several biotech start ups, supported by its Center of Excellence in Biotechnology Research (KSU 2024). King Abdulaziz University (KAU) in Jeddah is active in medical research, and King Abdullah University of Science & Technology (KAUST) on the Red Sea - known for international faculty and state of the art labs - runs its own innovation fund and the TAQADAM accelerator, which has spun out dozens of science-based ventures (KAUST 2023). Technology transfer offices, once nominal, now carry KPIs for patents and spin-outs, though most faculty still prioritize publications over commercialization.

Specialized centers strengthen translational capacity. The King Abdullah International Medical Research Center (KAIMRC) leverages a National Guard hospital network to run multi center clinical trials (KAIMRC 2024). King Faisal Specialist Hospital & Research Centre (KFSHRC) maintains one of the region's largest genome sequencing facilities and has generated patents in oncology and genetics (Labiotech.eu 2024). King Abdulaziz City for Science and Technology (KACST), historically the national science agency, co-leads the Saudi Genome Program, which has already sequenced more than 50,000 individuals and is creating a data trove for precision medicine start ups (Arab News 2023).

Industry and Corporates

Domestic corporates and sovereign vehicles serve as anchor tenants for Saudi Arabia's biotech ecosystem. Local drug makers such as SPIMACO and Tabuk remain focused on generics, but new entrants such as Sudair Pharma's insulin plant signal gradual movement up the value chain (Strategy& 2025). Large industrial groups add a unique dimension: Aramco and SABIC can transfer process engineering know how-to industrial biotechnology applications in fuels and specialty chemicals, a niche few markets can match (Strategy& 2025). Multinationals maintain only token R&D footprints; one of the few recent moves is Vertex Pharmaceuticals' 2024 MoU to explore gene therapy manufacturing in Riyadh (Labiotech.eu 2024). Procurement guarantees and CAPEX subsidies are intended to attract more such projects.

Investors and Risk Capital

Risk capital tells a two-tier story. At the sovereign level, the Public Investment Fund (PIF) has launched Lifera, a US $3.5 billion CDMO joint venture, and Sanabil Investments, which allocates to global life science funds (PIF 2023). A new SAR 2 billion (approximately US $533 million) innovation fund of funds extends state backing, while SVC's matched fund programme co-invests in health tech start ups (SVC 2024). Private venture money, however, is thin: MAGNiTT logged fewer than a dozen Saudi biotech checks in 2023, most under US $5 million, as local investors gravitate toward faster cycle IT and property deals (MAGNiTT 2024). The Ministry of Investment is courting global specialists such as Flagship Pioneering, but the sector has yet to reach critical density. The scarcity of VC capital in the MENA region is shown in Figure 10 below, showing the share of biotech invested VC capital raised by region.

Entrepreneurs

At the center of the ecosystem, entrepreneurs convert ideas to innovation. The current cadre of Saudi biotech entrepreneurs is small but passionate. As mentioned previously, there are fewer than fifty identifiable biotech start-ups. Many are young scientists or physicians who studied abroad and returned, or expats in Saudi Arabia's research centers who caught the entrepreneurial bug. Examples include startups working on genomics analytics, point-of-care diagnostics, or even pharmaceutical R&D. They face some barriers including navigating multiple regulators; mentorship and recruiting seasoned multidisciplinary talent that understands clinical drug development, coordination and standardization of clinical trial execution; and securing follow-on capital.

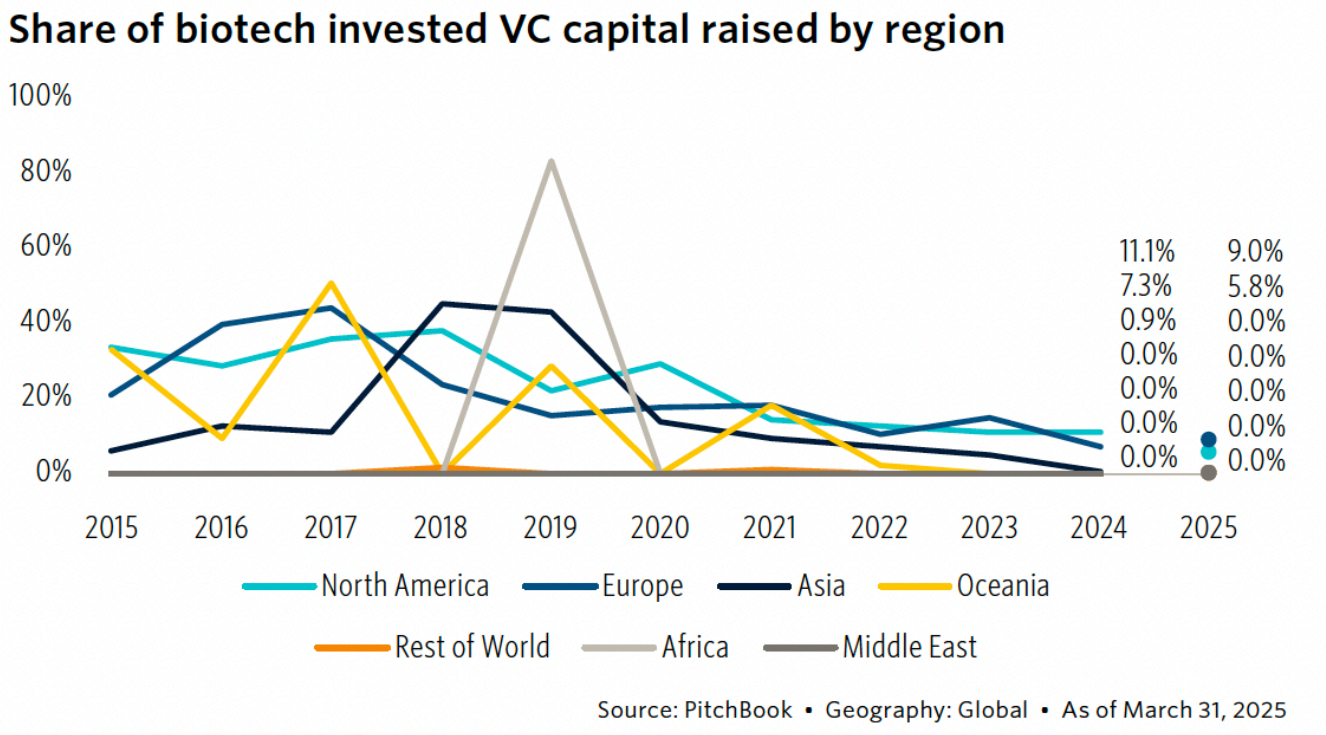


Figure 10 – Share of biotech invested VC capital raised by region (PitchBook, 2025)

Linkage of Stakeholders

Saudi Arabia's stakeholder landscape is characterized by strong top-down actors (government, public sector) and growing participation from academia and industry, whereas entrepreneurs and private investors are the weaker links that need empowerment. The ecosystem today is somewhat siloed – each stakeholder group is moving forward, but often in parallel rather than in unison. For example, the interface between academia and corporations/industry is underdeveloped. Technology Transfer Offices (TTOs) in universities (which link academia and entrepreneurs) are quite new and often understaffed; historically, universities did not prioritize patent licensing or startup creation. The opportunity now lies in building bridging institutions and networks. For example, continued creation of accelerators and incubators where the government provides funding, corporates provide mentorship, academia provides technology, and VCs provide investment to aspiring entrepreneurs– all under one roof – would integrate siloed players into a cohesive whole (see Systems section III linking I-cap and E-cap).

In short, Saudi's stakeholder map is top-heavy but converging. Government money and academic science are abundant; corporate and investor engagement is rising, but entrepreneurial density and private VC sophistication must still catch up if inventions are to leave the laboratory.

Strategy Assessment

National Targets (Vision 2030)

Saudi Arabia weaves its biotechnology agenda directly into Vision 2030's mandate to diversify the economy and fortify public health. As summarized in Table 3 below, the Kingdom's headline objective is to produce 70 % of all essential biologics in the country by 2030, up from 30 % in 2024 (Kingdom of Saudi Arabia 2024). Two high-stakes products show why: vaccines, whose shortages during COVID 19 exposed supply chain fragilities, and insulin for the 18 % of Saudi adults living with diabetes. Ensuring both are "Made in KSA" captures the strategy's core intent - health security through domestic manufacturing. Economic ambitions seek to expand the pharmaceutical market five fold, from US $10 billion in 2023 to US $25 billion by 2030, while lifting exports from US $1.5 billion to US $5 billion (Global Business Outlook 2024).

Category	Metric	2023–2025 Status	2030 Target
Domestic Drug Manufacturing	% of local demand met through domestic production	30%	70%
Pharma Market Size	Total value of domestic pharmaceutical market	$10B (2023)	$25B
Pharma/Biotech Exports	Annual export value	$1.5B	$5B
Drug Manufacturing Facilities	SFDA-licensed drug plants	56	N/A

Table 3 – KSA 2030 Biotech Related Targets

Strategic Pillars

The National Strategy outlines four main strategic pillars:

1. **Vaccines & Advanced Therapeutics**
   Riyadh is building sovereign capability in human health security through a national Vaccine Manufacturing Center and fill-finish agreements with Pfizer. A Vertex gene therapy partnership extends the same platform to rare disease medicines - often bundled with vaccines in Saudi policy documents - thereby capturing higher margin science while ensuring pandemic readiness.

2. **Broad Biomanufacturing**
   The Public Investment Fund's Lifera Contract Development & Manufacturing Organization (CDMO), inaugurated in 2023, anchors an ecosystem of FDA and EMA grade facilities for insulin, monoclonal antibodies, plasma derivatives, and cell and gene therapies. A complementary $133 million vaccine plant in Sadeer City adds bulk capacity (MISA 2024). Partnership remains central: Sanofi's memorandum with Arabio localizes vaccine production, while KFSHRC collaborates with U.S. firm Germfree on a 16 suite advanced therapy campus (KFSHRC 2024).

3. Genomics & Precision Medicine

The Saudi Genome Program exploits the Kingdom's unique population genetics - marked by a high prevalence of inherited disorders from consanguinity - to establish world class expertise in genetic counselling, gene discovery, and personalized medicine. Early deployments include newborn screening and population-wide carrier testing, laying a data trove for frontier R&D.

4. Agricultural & Environmental Biotechnology

Food and water secure futures drive investments in drought tolerant crops, synthetic biology fertilizers, and climate smart farming. Flagship efforts include NEOM's vertical agriculture and Red Sea Farms' saline tolerant systems, positioning Saudi Arabia as a test bed for arid land biotechnology.

Execution Progress (mid 2025)

Track 1: Biomanufacturing - "Made in KSA"

The Saudi Food & Drug Authority (SFDA) now supervises 56 licensed drug plants representing roughly US $2.7 billion in cumulative investment; these facilities have already reduced import dependence from 80 percent in 2018 to about 70 percent in 2024 (Arab News 2024). Lifera and its partners are on boarding technology transfers for plasma products, insulin, and mAbs (PIF 2023), while the Sadeer plant readies flu and pediatric vaccines (MISA 2024). Collectively, these assets aim to push domestic coverage to 40 percent of national demand by 2030 and exports rising to US$5 billion (NBS, 2024).

Track 2: Innovation - "Invented in KSA"

Although still nascent, the innovation track shows green shoots. As previously mentioned, RDIA targets an R&D intensity of 2.5 percent of GDP by 2040, up from 0.49 percent today. The SFDA is harmonizing its guidelines with FDA and EMA to streamline clinical approvals, and BioLabs accelerator welcomed its first eight biotech start ups in summer 2025.

IV. Sequential vs Parallel

In a sequential approach, a country would first build up one aspect of the biotech ecosystem, and only later invest heavily in another aspect. In contrast, a parallel approach involves simultaneously developing multiple facets – for instance, expanding manufacturing facilities and nurturing innovation capabilities at the same time. Saudi Arabia's current trajectory appears more sequential, with an initial emphasis on localizing biomanufacturing (e.g. vaccines, insulin, biosimilars) and creating a supportive environment, while major homegrown biotech innovation is expected to ramp up in later stages.

Cost Benefit of a Sequential Track

The above-mentioned approach has clear advantages. It allows KSA to focus its resource allocation investment and policy effort initially on manufacturing capabilities. This focus can yield quick wins in establishing production capacity (e.g. vaccine fill-finish plants, biogenerics facilities) and ensure early returns in supply security. Given that biotech manufacturing requires high capital and strict quality systems, a staged approach helps master these fundamentals before tackling the additional uncertainties of drug discovery. Indeed, KSA's early moves – such as PIF-owned Lifera partnering to localize insulin and gene therapy production – are building industrial know-how and regulatory experience in a controlled way. Success in contract manufacturing could generate revenue and confidence to reinvest in R&D later.

The risks, however, also remain. Economies built first on low-cost manufacturing often find it hard to climb into high-value innovation. These countries typically excel at scale production (generics, electronics assembly, basic vaccines, etc.) but suffer from cultural and structural rigidity when trying to move up the value chain (Sturgeon and Memedovic 2011). India illustrates the trap: its pharmaceutical sector supplies roughly 20 percent of global generic drugs and 62 percent of vaccines (WHO 2021), yet industry observers note that many Indian firms stay with familiar manufacturing platforms and avoid "radical modifications" that might increase regulatory risk—resulting in a general lack of risk taking in innovative manufacturing (USP NIPTE Symposium 2020)

In practice, this means few pursue the costly, iterative R&D needed for novel biologics or advanced drugs. In short, India's early contract-manufacturing success has set expectations and incentives around low-cost production rather than homegrown innovation (Chaudhuri 2019) - a risk KSA should look to avoid.

Cost Benefit of a Parallel Dual Track

Executing a dual track strategy inevitably strains resources. Capital requirements rise sharply, because R&D infrastructure (wet labs, pre clinical platforms and analytical suites) must be financed in parallel with cGMP plants. Managerial attention is divided between two very different operating models: iterative, uncertainty tolerant research versus throughput driven production. The talent gap is equally acute: Saudi Arabia will need to second expatriate scientists, regulatory specialists and process engineers while accelerating scholarships and on the job training to seed a domestic cadre with end to end drug development experience. Early stage failures, especially in clinical trials, will be visible and an unavoidable reality when success rates for novel compounds rarely exceed 10 percent from Phase I to approval.

Nevertheless, the long term payoff justifies the short term pain. International evidence shows that ecosystems willing to sustain an initial "J curve" capture far greater strategic and economic dividends once their innovation pipelines mature. Vision 2030 has already ring fenced funds for high risk technology programs, and RDIA's mandate explicitly directs ministries to tolerate experimentation and budget for attrition. Figure 11 in this paper illustrates the dynamic: the dual track pathway exhibits a deeper "worse before better" trough than a manufacturing only approach, but its subsequent value creation curve rises exponentially as patent protected products feed into domestic plants and export channels. In practical terms, policymakers must do two things. First, front load financial support such as grants, matched equity and milestone dependent loans, so that early R&D setbacks do not derail the strategy. Second, communicate clearly that initial losses and clinical failures are features, not bugs, of an innovation led model. With these safeguards in place, the delayed rewards of an integrated discovery and manufacturing ecosystem far outweigh the interim costs.

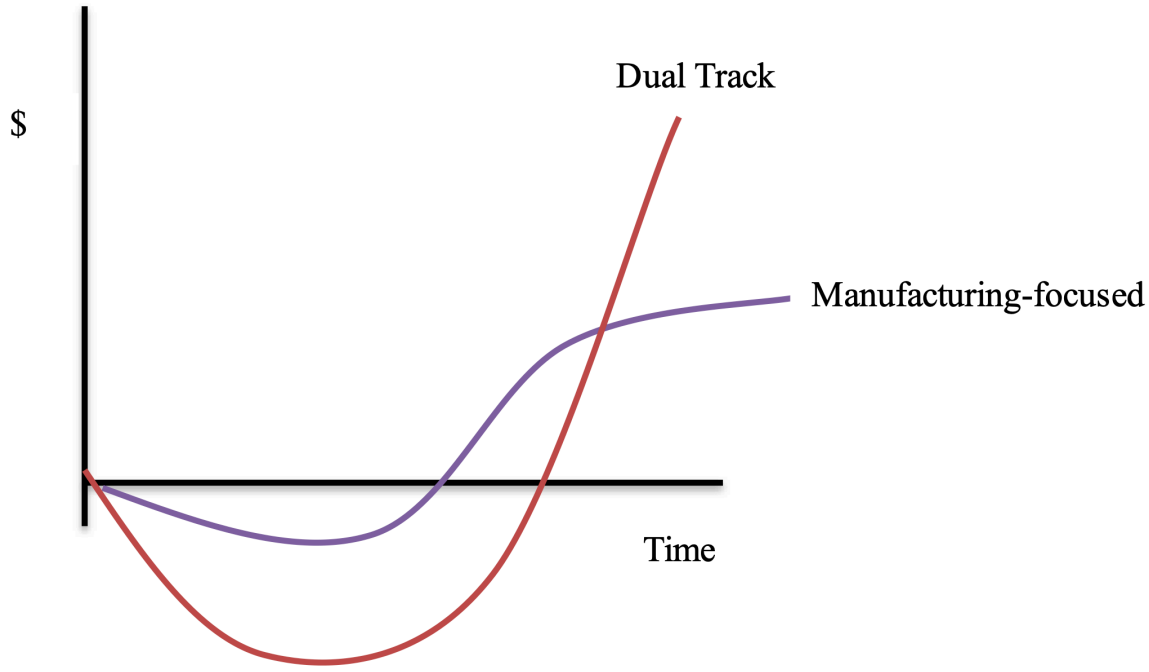


Figure 11- The Risk versus Reward Tradeoff of pursuing a Dual Track

V. Recommendations

Incorporate Track 2

Analysis of KSA's innovation potential through the 3 S framework above indicates that Saudi Arabia already possesses the hardest-to-acquire ingredients for biotech invention: well-funded laboratories, a young and expanding cadre of scientists, improving IP protection, and a regulator aligned with global norms. The remaining deficits, such as early-stage venture capital, serial entrepreneurs, cross-institutional lab access, are comparatively easier to fix and are in fact common to every new biotech hub. This paper therefore recommends Saudi Arabia formally mandate Track 2 as part of its national strategy, supported by the same institutional coordination that has enabled Track 1. A government-mandated Track 2 effort - led by RDIA, the Ministry of Investment, and key academic institutions - would accelerate implementation, de-risk participation by entrepreneurs and investors, and send a strong signal to global partners.

Specifically pursuing both tracks in parallel rather than sequentially offers four strategic payoffs:

1. ***Leveraging Existing Foundations:***
   Because world-class labs, modern regulation, and abundant capital already exist, postponing innovation until biomanufacturing "matures" would squander sunk investments and allow global technology frontiers to drift farther ahead.

2. ***Cultural Timing***
   Innovation culture is path dependent. Silicon Valley succeeded because a startup ethos took hold early, embedding tolerance for failure and dense mentorship networks (Saxenian 1994). Countries that first entrenched a low-margin manufacturing identity often struggled to pivot (Sturgeon & Memedovic 2011). India's difficulty moving from vaccine OEM to novel biologics, despite abundant scientists, illustrates the lock-in risk (Panda et al. 2023). Launching R&D ventures now helps Saudi Arabia normalize entrepreneurship before a risk-averse production mindset calcifies.

3. ***AI-Accelerated Discovery:***
   McKinsey estimates advanced AI could cut pre-clinical timelines by 25–50 % and costs by up to US$400 million per asset (McKinsey 2024).

   Saudi's parallel investments in high-performance computing, quantum research with IBM, and nationwide data initiatives position it to exploit these tools.

   A greenfield lab at KAUST can, in principle, adopt AI-first workflows without legacy overheads, compressing the journey from molecule design to IND.

4. ***Synergy Between Lab and Plant:***
   Co-locating discovery and manufacturing creates feedback loops: process engineers feed manufacturability constraints back to chemists; clinical-trial data flow straight into quality-control upgrades. South-Korea's Samsung Biologics provides a regional precedent: profits from CDMO contracts funded Celltrion's biosimilar R&D, and the presence of both activities in Incheon accelerated Korea's climb up the value chain.

5. ***Global Partner Engagement:***
   Global investors and partners are more likely to engage with ecosystems that demonstrate both technical execution and upstream innovation. Parallel tracks provide the strategic coherence that global biotech firms and VCs look for in long-term partners.

Roadmap and KPIs

A government-mandated Track 2 effort led by RDIA, the Ministries of Health and Investment, and key academic institutions would accelerate implementation, de-risk participation by entrepreneurs and investors, and send a strong signal to global partners.

Based on our analysis, we propose ten national policy levers to make Track 2 operational:

1. ***Shared translational hubs:***
   Establish three fully equipped wet lab innovation spaces - in KAUST, Riyadh, and NEOM - offering shared access to single-cell sequencers, GMP suites, and biobanking infrastructure. Target 70% utilization, 3 shared labs operational by 2027, 15+ biotech projects incubated annually by 2028.

2. ***National biotech accelerator:***
   Launch a government-backed accelerator offering $150K–$250K per team, with integrated mentorship on regulatory design, IP strategy, and investor readiness. Aim for two cohorts per year, generating 40+ startups by 2030, 30% Series A follow-on funding rate.

3. ***University tech transfer reform:***
Create a national TTO network, update academic incentive structures, and standardize IP licensing terms. Link R&D funding to commercialization KPIs. Target a 2x increase in patents licensed by 2028, 15 spinouts from academia by 2030,: 6 universities with structured TTOs by 2026.

4. ***Biotech venture capital activation:***
Establish a $250M co-investment fund via Sanabil or Jada, offering matching capital and downside protection to private VC firms. Attract 3 international biotech VCs and target $500M total investment by 2030, attract 3–4 Saudi corporate biotech VC vehicles by 2028.

5. ***Streamline clinical trials:***
Expand SFDA's digital IRB platform, harmonize trial protocols across major hospitals, and build a national CRO network. Train 500+ trial investigators. Target 150+ clinical trials per year by 2030.

6. ***Global collaboration and talent:***
Launch the Saudi Biotech Summit and Saudi Genome Conference. Establish a GCC biotech visa and offer 50 international research fellowships annually. Incentivize co-development of IP with leading biotech institutions, 200+ biotech visas issued by 2030, 2,500 biotech visitors/year by 2028.

7. ***Capitalize a SAR 1 billion "BioVentures Fund-of-Funds"***
Under SVC that matches private VC 1:1 and anchors three sector-specific funds (therapeutics, tools/AI, ag-biotech). Require each fund to place a partner in Riyadh full-time to mentor founders and rotate scientists through overseas portfolio companies.

Parallel to capital, launch "BioFounders Fellowships" - a three-year programme sending Saudi PhDs to Boston/Singapore start-ups with guaranteed seed cheques on return and "failure insurance" (forgiving 50 % of interest-free loans if the first venture folds).

8. ***Launch a National Translational Biotech Fund:***
that awards milestone-based grants (pre-seed to Series A) and guarantees subsidized access to GMP suites at Lifera and university core labs. Create a single e-portal for IND, ethics and biosafety approvals; mandate the SFDA to clear low-risk academic trials in ≤45 days (vs ~90 today).

KPIs (2028 targets)

a. ≥40 % of public life-science R-&-D budget earmarked for translational projects (up from ~15 % today Arab News 2024).

b. ≥10 Saudi-origin IND filings or CE-marked diagnostics per year.

c. Average trial-start approval ≤45 days (SFDA dashboard | SFDA 2025).

9. ***Exploit Track 1 Synergies & Demand Pull:***
Reserve 30 % of Lifera's GMP floor space for start-up tech-transfer projects at subsidized rates; pair every manufacturing contract with an R&D-ups-killing apprenticeship. Empower NUPCO to sign forward-purchase agreements for Saudi-developed biologics, diagnostics and cell-therapy services that clear Phase I or equivalent validation.

10. ***Cultural Enablers: Across all pillars, embed "learn-fast" norms:***
Award annual "Most Valuable Pivot" prizes; publish anonymized post-mortems of failed trials; and let repeat founders retain social-security benefits for up to two restarts. International evidence shows such rituals materially reduce perceived personal cost of failure (McKinsey 2024).

Table 4 (Next Page) presents each of the 10 "Track 2" biotech policy levers with a horizontal progress bar indicating percent complete toward its 2030 goal and a traffic-light indicator for status (Green = on track, Yellow = partial progress, Red = no action). All figures are estimates and are based on the latest public information and details provided in this paper.

POLICY LEVER	PROGRESS	STATUS	NOTES (CURRENT PROGRESS)
TRANSLATIONAL RESEARCH HUBS	(30%)	YELLOW	Major centers (KACST, KAUST, KFSH&RC, etc.) are building biotech R&D pipeline. Implementation has begun, but few new products yet – moderate progress.
BIOTECH ACCELERATOR	(5%)	GREEN	The Ministry of Health launched Saudi's first BioLabs accelerator at BIO 2025 (8 startups selected).
VACCINE R&D & MFG.	(20%)	YELLOW	A SR500m ($133M) JV was agreed to build a local vaccine factory and Lifera/Sanofi MOUs aim to transfer vaccine tech. Facility planning is under way
BIOLOGICS (INSULIN/PLASMA)	(10%)	YELLOW	PIF-backed Lifera is establishing local production for insulin, plasma and other biologics. These projects are in planning/ early stages
GENOMICS / GENOME SEQ.	(65%)	GREEN	Saudi's Human Genome Program (100K genomes) has sequenced >65K so far
PLANT BIOTECHNOLOGY	(0%)	RED	Vision 2030 includes a "plant optimization" priority no public programs could be found
REGULATORY REFORM	(80%)	GREEN	The SFDA achieved WHO maturity level 4 and slashed drug/ trial approvals (270→120 days)
CLINICAL TRIALS INFRASTRUCTURE	(60%)	GREEN	Saudi now has an aligned, single-window trial approval process (60% faster). The goal of streamlined internationally aligned trials is under way
BIOTECH TALENT & EDUCATION	(30%)	YELLOW	New scholarships, biotech courses and residency programs (e.g. Premium Residency) are rolling out. Progress is just beginning with pilot training initiatives under way.
INVESTMENT & PARTNERSHIPS	(20%)	GREEN	Saudi has mobilized large biotech investment funds and signed >12 new biotech MOUs at BIO2025. The funding/collaboration ecosystem is active and expanding.

Table 4 – Track 2 Policy Levers & Progress

This progress across all 10 policy levers can be captured wholistically in a longitudinal manner over time in a composite BMI (Biotech ecosystem Maturity Index). The radar chart (Figure 12) provides qualitative assessment of Saudi Arabia's biotech ecosystem maturity at baseline compared to a future-looking 2030 target using the dual track strategy across six key biotech ecosystem dimensions (R&D and Translation, Clinical Trial Infrastructure, Startup Ecosystem, Venture Capital Availability, Regulatory Environment, and Biomanufacturing capacity) using a normalized 0–10 scale (benchmarked against Boston's Kendall Square). Importantly, the chart emphasizes not only the goal of increased ecosystem maturity over time but also balance and well-roundedness across the six dimensions.

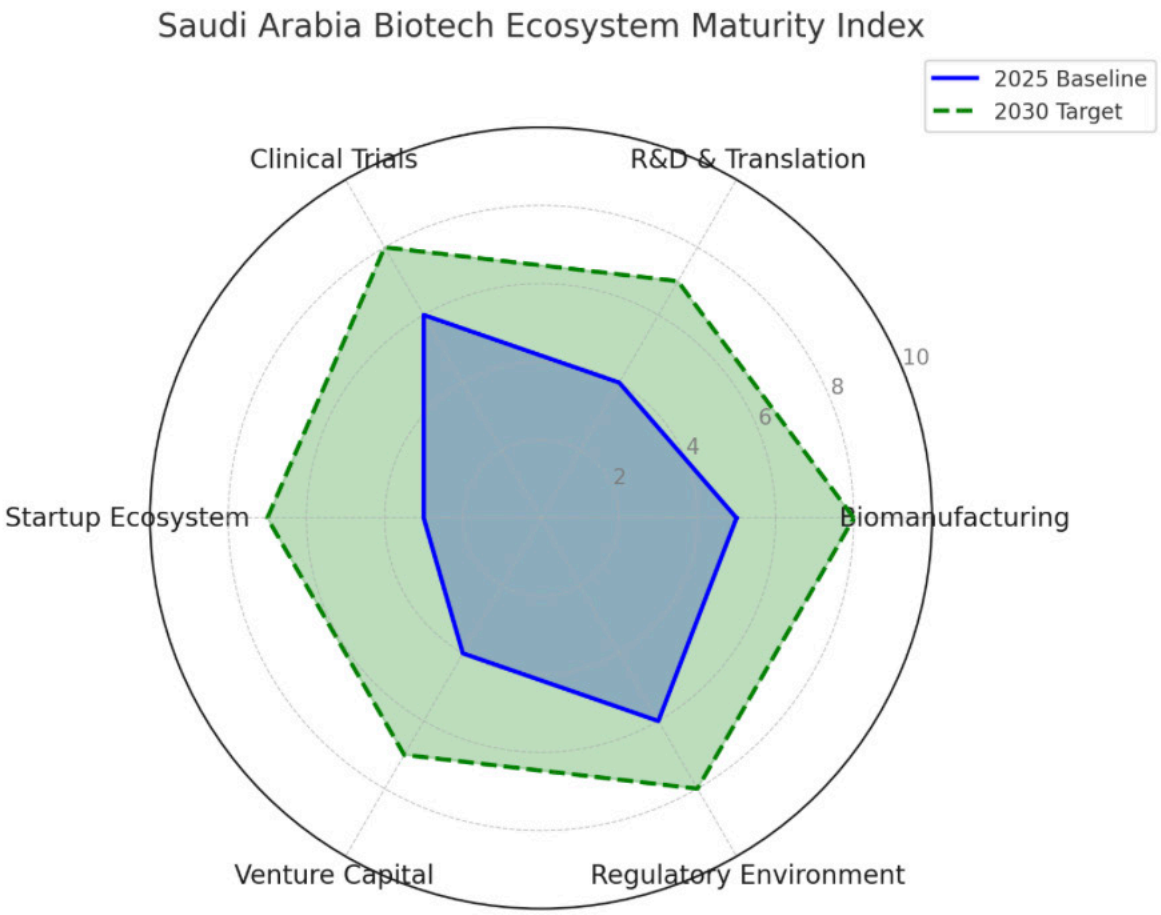


Figure 12 – KSA's Biotech Ecosystem Maturity Index

VI. Conclusion

Saudi Arabia stands at a pivotal moment in its biotechnology journey. The foundations laid under the National Biotechnology Strategy – in vaccine production, biomanufacturing, genomics, and agri-biotech – have given the Kingdom a head start towards regional leadership. However, to unlock the full economic and strategic value of biotech, Saudi Arabia must pursue a dual-track strategy that couples its top-down manufacturing capacity with bottom-up innovation and entrepreneurship. In practice, this means expanding the national vision beyond production alone to encompass the entire innovation continuum from "Petri dish to production plant," transforming Saudi Arabia from primarily a biotech adopter into a genuine biotech innovator. This two-pronged approach is not an optional add-on but a necessary complement to Track 1; like the two strands of DNA, both tracks are needed in parallel to form a resilient helix of sustainable biotech growth.

Global evidence strongly supports implementing both tracks in parallel rather than sequentially. Importantly, the dual-track approach ensures that Saudi Arabia captures the full economic value of biotechnology. In this sector, intellectual property, licensing, and platform technologies account for 60–70% of commercial value, far more than downstream manufacturing alone. Leading biotech hubs have matured by fostering research clusters alongside manufacturing might. For example, South Korea's rapid ascent up the value chain was propelled by simultaneously building large-scale biologics production and innovative R&D companies – Samsung Biologics' manufacturing profits helped fund Celltrion's drug development, and co-locating these activities created feedback loops that accelerated ecosystem growth. International examples show that pursuing manufacturing and innovation tracks together creates synergies that accelerate ecosystem maturity and economic value capture . In contrast, a sequential approach risks a lock-in effect – if a low-margin manufacturing culture calcifies before an innovation culture takes root, it can be very difficult to pivot later. The clear lesson is that Saudi Arabia should activate Track 2 now, in parallel with Track 1, to rapidly achieve a self-reinforcing, world-class biotech ecosystem.

Our assessment, structured through MIT's iEcosystem 3 S framework (Strategy, System, Stakeholders), underscores that success will require an aligned vision, robust infrastructure, and coordinated action by all stakeholders.

On Strategy, the government has signaled strong top-down commitment under Vision 2030 – the next step is to formally mandate Track 2 as a core part of the national biotech strategy (just as Track 1 was).

On System, the policy levers identified in this white paper provide a concrete roadmap to build the innovation engine. Key recommendations include establishing shared translational research hubs, launching a national biotech accelerator, reforming academic tech transfer and IP commercialization, spurring venture capital investment (e.g. co-investment funds), streamlining regulatory approvals and clinical trial processes, and attracting global talent through partnerships and incentives . Implementing these measures in unison with ongoing manufacturing initiatives will create an ecosystem where lab discoveries seamlessly flow to clinical testing and domestic production

Equally important are the Stakeholders: each must play a role in this dual-track journey. The government should continue coordinating and funding strategic initiatives . Academic institutions must produce talent and research while embracing commercialization, corporate players (from startups to pharma incumbents) need to invest, partner, and scale up innovations, investors (public and private) should supply risk capital and expertise, and entrepreneurs are the engine translating Saudi science into new ventures . With clear leadership and collaboration, these stakeholders can collectively build a thriving biotech innovation ecosystem that complements the Kingdom's manufacturing base.

Executing this dual-track strategy in parallel is ambitious but well within Saudi Arabia's reach. The Kingdom's strong political will, substantial resources, and Vision 2030 support provide a solid foundation to move on both fronts now . Early signs of progress – from new startup accelerators to international research partnerships – are encouraging, but momentum must be sustained and scaled. By swiftly enacting the recommended policies and programs, Saudi Arabia can create a virtuous cycle where invention and production reinforce each other: homegrown scientific discoveries advance to clinical trials in Saudi hospitals and are then manufactured in Saudi facilities, generating returns that fuel the next round of innovation . Ultimately, this will position Saudi Arabia to capture the full value chain of biotechnology domestically. In the coming years, the Kingdom can rightfully lay claim not only to "Made in KSA" medicines, but also to "Invented in KSA" breakthroughs – life-changing innovations developed at home that improve health outcomes and power economic diversification for decades to come.

References

Kingdom of Saudi Arabia. 2024. The National Biotechnology Strategy. National Strategy , KSA.

Macrotrends. 2025. Macrotrends. https://www.macrotrends.net/global-metrics/countries/sau/saudi-arabia/foreign-direct-investment.

IMD. 2025. From Government Policy to Business Acumen. IMD World Competitiveness Center.

WIPO. 2023. World Intellectual Property Organization. https://www.wipo.int/edocs/statistics-country-profile/en/sa.pdf.

IPRI. 2024. International Property Rights Index. https://internationalpropertyrightsindex.org/country/saudi-arabia.

SFDA. 2025. Saudi Food and Drug Administration. March 03. https://www.sfda.gov.sa/en/news/2338354#:~:text=As%20the%20First%20in%20the,Saudi%20Food%20and%20Drug%20Authority.

SPA. 2023. Saudi Press Agency. https://www.spa.gov.sa/b238cd5eebo.

Agency, Saudi Press. 2023. https://www.spa.gov.sa/b238cd5eebo.

Rohra, Dileep, and Ismail Memon. 2025. "Four Decades of Progress: Evaluating Saudi Arabia's Research Publications in Pharmaceutical Sciences." Hosp Pharm 6.

Narayanan, Nrimal. 2024. Arab News. November 28. https://www.arabnews.com/node/2581035/business-economy.

Strategy& - PWC. 2023. "Accelerating Saudi Arabia's Biotechnology Sector."

Arab News. 2024. Arab News. April 24. https://arab.news/n8zp7.

Saudi Food & Drug Authority (SFDA). 2025. January 3. https://www.sfda.gov.sa/en/news/2338354#:~:text=As%20the%20First%20in%20the,Saudi%20Food%20and%20Drug%20Authority.

Budden, Phil & Fiona Murray, "A systematic MIT approach to assessing 'innovation-driven entrepreneurship' in ecosystems Download "A systematic MIT approach to assessing 'innovation-driven entrepreneurship' in ecosystems(iEcosystems)" Working Paper. https://innovation.mit.edu/assets/Assessing-iEcosystems-V2-Final.pdf

Budden, Phil & Fiona Murray, 2019. "An MIT approach to Innovation: ecosystems, capacities and stakeholders" Working Paper (MIT Innovation Initiative) https://reap.mit.edu/assets/Assessing-System-and-Capacities-in-IDE-Ecosystems_0724.pdf

Kenney, Martin & Urs von Burg. 1999. "Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128" Download "Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128". Industrial and Corporate Change (8), 67-103. (skim)

Budden, Phil & Fiona 2014. MIT Case: "Kendall Square & Greater Boston"

Cohen, Susan; Fehder, Dan; Yael Hochberg & Fiona 2017. "Design & Evaluation of Accelerators". MIT Lab for Innovation Working Paper

Budden, Phil & Fiona Murray, "A systematic MIT approach to assessing 'innovation-driven entrepreneurship' in ecosystems Download "A systematic MIT approach to assessing 'innovation-driven entrepreneurship' in ecosystems(iEcosystems)" Working Paper. https://reap.mit.edu/assets/Assessing-System-and-Capacities-in-IDE-Ecosystems_0724.pdf

Budden, Phil & Fiona Murray, 2019. "An MIT approach to Innovation: ecosystems, capacities and stakeholders" Working Paper (MIT Innovation Initiative) https://reap.mit.edu/assets/An-MIT-Approach-to-Innovation.pdf

Kenney, Martin & Urs von Burg. 1999. "Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128" Download "Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128". Industrial and Corporate Change (8), 67-103. (skim)

Budden, Phil & Fiona 2014. MIT Case: "Kendall Square & Greater Boston"

References

Cohen, Susan; Fehder, Dan; Yael Hochberg & Fiona 2017. “Design & Evaluation of Accelerators”. MIT Lab for Innovation Working Paper

Grand View Research. Biotechnology Market Size, Share & Trend Analysis Report by Technology (Nanobiotechnology, DNA Sequencing, Cell based Assays), by Application (Health, Bioinformatics), by region, and Segment Forecasts, 2024–2030. San Francisco: Grand View Research, August 2023. https://www.grandviewresearch.com/industry-analysis/biotechnology-market.

Latham & Watkins LLP, “Healthcare and Life Sciences Trends and Developments Across MENA,” JD Supra, April 19, 2024.

E. Raymond & N. Andrella, How Top Life Science Regions Position Themselves to Generate Value, BioProcess International, 7 May 2025

Neeraj Sood et al., The Flow of Money Through the Pharmaceutical Distribution System (USC Schaeffer Center, 2017), 4–5

“CDMOs on the Rise,” Contract Pharma, 2019

BAK Economics, The Importance of the Pharmaceutical Industry for Switzerland (Interpharma, 2024), 2.

FRED, “Exports of Services: Royalties and License Fees,” Q1 2025.

U.S. Bureau of Labor Statistics, “Biological Scientists, All Other,” OES May 2024; “Biological Technicians,” OES May 2024.

TEConomy Partners, The Economic Impact of the U.S. Biopharmaceutical Industry (PhRMA, 2024), 4.

General Authority for Statistics (GASTAT). 2024. Research and Development Statistics 2023. Riyadh: GASTAT. https://www.stats.gov.sa/documents/20117/2435267/Research+and+Development+Statistics+2023+EN.pdf

Labiotech.eu. 2024. “Saudi Arabia Bets on Biotech with Major Genome Programme.” Labiotech.eu, 8 April 2024. https://www.labiotech.eu/trends-news/saudi-arabia-genome-program

Nature Index. 2023. “Institution Outputs: King Abdullah University of Science & Technology.” Accessed 22 July 2025. https://www.nature.com/nature-index/institution-outputs

Saudi Food & Drug Authority (SFDA). 2025. Annual Report 2025. Riyadh: SFDA. https://www.sfda.gov.sa/en/about/publications/annual-reports

ShanghaiRanking Consultancy. 2024. Academic Ranking of World Universities 2024. ShanghaiRanking. https://www.shanghairanking.com/rankings/arwu/2024

World Intellectual Property Organization (WIPO). 2024. “IP Statistics Data Center: Resident Patent Filings in Biotechnology, Saudi Arabia.” Accessed 11 July 2025. https://www3.wipo.int/ipstats/

Elsevier. Progress Toward Gender Equality in Research & Innovation – 2024 Review: An In Depth Analysis of Research Participation, Career Progression and Research Contributions Across the Globe. Amsterdam: Elsevier, 2024. https://www.elsevier.com/insights/gender-and-diversity-in-research.

Economist Intelligence Unit. EIU CountryData Online: Population by Age Cohort – “Percentage of Population Aged 0–14, Saudi Arabia and World, 2014 2030 (Actual, Estimate, Forecast).” London: The Economist Intelligence Unit, 2023. Based on UN Population Division data. Accessed July 12, 2025

KAUST (King Abdullah University of Science & Technology). 2023. Saudi Arabia’s Leap in Research and Development Excellence: National R&D Performance Report 2023. Thuwal: KAUST Research Analytics.

National Science Foundation (NSF), National Center for Science and Engineering Statistics. 2023. “Publication Output by Region, Country, or Economy and by Scientific Field,” Science & Engineering Indicators 2024, Table PBS 1. Alexandria, VA: National Science Board.

References

World Bank. 2024. “Scientific and Technical Journal Articles (IP.JRN.ARTC.SC).” World Development Indicators database. Accessed 22 July 2025.

United Nations Department of Economic and Social Affairs (UN DESA). 2024. World Population Prospects 2024 Revision: Estimated Population 2022. New York: UN DESA, Population Division.

World Intellectual Property Organization (WIPO). 2024. World Intellectual Property Indicators 2024. Geneva: WIPO.

Arthur D. Little. Advancing Biotechnology & Genomics in Saudi Arabia. Paris: Arthur D. Little, 2024, fig. 1.

KAUST (King Abdullah University of Science & Technology). Innovation & Entrepreneurship Annual Report 2023. Thuwal: KAUST, 2023.

MassBio. The Massachusetts Biotech Startup Landscape 2023. Cambridge, MA: Massachusetts Biotechnology Council, 2023.

Ministry of Health (Saudi Arabia). Biotech Accelerator Program Press Release. Riyadh: Ministry of Health, 2024.

Ministry of Investment (MISA). Biotech Startups Development Program Overview. Riyadh: MISA, 2024.

Saudi Food & Drug Authority (SFDA). Annual Regulatory Report 2023. Riyadh: SFDA, 2023.

Vision 2030. National Transformation Program 2023 Progress Report. Riyadh: Vision 2030, 2023.

MAGNiTT. 2023. Saudi Arabia Venture Investment Report 2023. Dubai: MAGNiTT.

Ministry of Investment (MISA). 2023. “Global Biotech Funds Visit Saudi Arabia to Explore Investment Opportunities.” Press release, Riyadh, 14 November 2023.

Ministry of Investment (MISA). 2024. Launch of SAR 2 Billion Innovation Fund of Funds. Riyadh: MISA, 22 May 2024.

Sanabil Investments. 2023. Annual Review 2023. Riyadh: Sanabil Investments.

Saudi Venture Capital Company (SVC). 2024. “Health & Biotech Co Investment Programme: Guidelines for Applicants.” Riyadh: SVC.

Strategy& (PwC). 2024. Advancing Biotechnology & Genomics in Saudi Arabia: Building a World Class Innovation Ecosystem. Dubai: Strategy&, part of the PwC network.

Chaudhuri, Sudip. 2019. Indian Pharmaceutical Industry after TRIPS: From Import Substitution to Export Orientation. London: Routledge.

Sturgeon, Timothy, and Olga Memedovic. 2011. “Mapping Global Value Chains: Intermediate Goods Trade and Structural Change in the World Economy.” UNIDO Working Paper 05/2011. Vienna: United Nations Industrial Development Organization.

USP NIPTE Symposium. 2020. Proceedings of the 2020 U.S.–India Symposium on Advanced Manufacturing of Pharmaceutical Products. Rockville, MD: U.S. Pharmacopeia.

World Health Organization (WHO). 2021. “India’s Role as the ‘Pharmacy of the World’—Generic Medicines and Vaccine Supply.” WHO Policy Brief 21/2021. Geneva: WHO.

Panda, Rajesh, Tushar Kumar, and Priya Bhatt. 2023. “India—the ‘Pharmacy of the World’: Contributions to Global Generic Medicines and Vaccine Supply.” Journal of Pharmaceutical Policy and Practice 16 (1): 123–30.

Saxenian, AnnaLee. 1994. Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Cambridge, MA: Harvard University Press.

References

Sturgeon, Timothy J., and Olga Memedovic. 2011. “Mapping Global Value Chains: Intermediate Goods Trade and Structural Change in the World Economy.” UNIDO Working Paper 05/2011. Vienna: United Nations Industrial Development Organization.

McKinsey & Company. 2024. “How Advanced AI Could Cut Pre clinical Timelines by up to 50 Percent—and Save as Much as $400 Million per Asset.” Life Sciences Insights, May 2024.