Cambodian Insights on Southeast Asia

Singapore's Position within the Top 4 Global Innovation Index:
Analysis of the Deep Tech's Talent Pipeline and Skills Development Initiatives

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Executive Summary

This insight paper examines how Singapore's innovation policies and strategic government-led research and development (R&D) investments have strengthened its deep tech ecosystem, cementing its place among the world's top four economies in the Global Innovation Index (GII). Singapore's transformation from a resource-scarce trading port to a global innovation hub is rooted in a system-oriented approach: one that systematically aligns public policy, research capability, commercialization pathways, and talent development. By integrating long-term planning with institutional agility, Singapore has developed an innovation architecture that enables the translation of scientific discoveries into scalable, high-impact technology ventures.

Drawing on historical milestones, including the National Technology Plan (1991–1995) and the successive Science and Technology Plans (1996–2005), the paper traces how Singapore's early industrial strategies evolved into the present-day Research, Innovation, and Enterprise (RIE) framework. RIE's mission-oriented model, along with platforms such as SGInnovate, A*STAR's commercialization initiatives, and IP Strategy 2030, illustrates how policy coherence and cross-sector coordination underpin Singapore's deep tech momentum.

Key findings emphasize:
- The effectiveness of ecosystem-wide orchestration in bridging research, enterprise, and regulatory alignment.
- The role of long-horizon investments in mitigating the risks inherent in high-capital, long-gestation technologies.
- The cultivation of "bilingual" talent, scientifically proficient yet enterprise-savvy, as a cornerstone of deep tech leadership.

The paper concludes with reflections on how other innovation-driven economies might adapt elements of Singapore's model. In an era marked by complex challenges and rapid global technological advancements, Singapore's experience provides critical insights into designing resilient, scalable, and future-ready innovation systems.

Introduction

Singapore's transformation from a resource-scarce port economy into a top-ranked global innovation leader is neither accidental nor linear. It is the outcome of a long-term, systemically orchestrated strategy. Consistently ranked among the top four economies in the Global Innovation Index (GII), Singapore stands as a leading example of how deliberate policy design, institutional coherence, and strategic investment can enable small states to punch far above their weight in the global knowledge economy.[1]

Exhibit 1: Singapore GII Ranking (2020-2024)

Year	GII Position	Innovation Inputs	Innovation Outputs
2020	8th	1st	15th
2021	8th	1st	13th
2022	7th	1st	14th
2023	5th	1st	12th
2024	4th	1st	11th

Source of Table: https://www.wipo.int/gii-ranking/en/singapore

While rankings offer a compelling snapshot of performance, Singapore's innovation model reveals a deeper value: its ability to convert structural limitations into strategic agility. Unlike larger economies with vast internal markets and abundant natural resources, Singapore's growth has relied on building a tightly integrated innovation ecosystem—one that combines research, enterprise, regulation, and talent into a unified national platform. This makes Singapore's

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[1] "Singapore Ranking in the Global Innovation Index 2024," World Intellectual Property Organization, September 26, 2024, https://www.wipo.int/edocs/gii-ranking/2024/sg.pdf.

experience uniquely instructive for emerging economies navigating similar constraints but aspiring toward innovation-led growth.

At the core of Singapore's model is a system-oriented approach to innovation. Rather than focusing on siloed technological breakthroughs, the country has prioritized ecosystem design—linking public R&D, industry partnerships, and human capital development through long-horizon, mission-driven planning. Key enablers include robust institutions, globally oriented policy alignment, and high public trust in strategic governance—elements that directly support Singapore's high GII rankings across pillars such as business sophistication, knowledge and technology outputs, and regulatory quality.

This paper aims to address the central question: **How have Singapore's innovation policies and government-led R&D investments contributed to strengthening its deep tech ecosystem and securing *its top-tier GII performance?***

To address this, the study traces the evolution of Singapore's innovation system—from early industrial planning and foundational policy shifts to the emergence of its Research, Innovation and Enterprise (RIE) framework, and the rise of deep tech as a national priority. By analyzing key programs such as SGInnovate and IP Strategy 2030, the paper examines how innovation inputs are systematically converted into outputs with commercial and strategic value.

Ultimately, this insight paper aims to move beyond the celebration of rankings by aiming to unpack the institutional logic, policy architecture, and long-term thinking that make Singapore's model both effective and exportable. It offers lessons for economies seeking to design resilient, scalable, and adaptive innovation ecosystems in a world increasingly defined by complexity, competition, and technological flux.
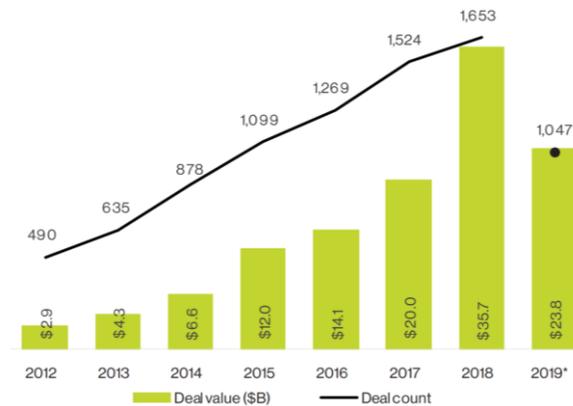
Understanding Deep Tech & Innovation Policy

What is Deep Tech?

The term **"Deep Tech"** refers to advanced technologies with the potential to address critical global challenges, including economic development, public health, and climate change, while also

offering opportunities for commercialization.[2] Its origins trace back to a 1993 Chinese investment book that highlighted industries like electronics, biological engineering, and fine chemicals.[3] However, the term gained widespread attention in 2015 when Swati Chaturvedi of Propel(x) categorized deep tech as "companies founded on a scientific discovery or meaningful engineering innovation," specifically within life sciences, energy, clean technology, computer sciences, materials, and chemical sectors.[4]

Exhibit 2: Tough Tech VC Deal Activity (September 2019)

Source of Graph: https://engine-ventures.files.svdcdn.com/production/Reports-and-Publications/The-Engine_2019_Tough_Tech_Landscape.pdf

According to the 2019 Tough Tech Landscape report, global investment in deep tech surged from 500 deals worth USD 2 billion in 2012 to over 1,600 deals totaling USD 35.7 billion in 2018, with 101 startup exits in deep tech that year alone (as illustrated in Exhibit 2).[5] This growth is driven by advances in digital infrastructure, cloud computing, reducing costs for data-intensive experiments, and breakthroughs in basic research, enabling new applied research opportunities. Falling costs of inputs, such as hardware and materials, have also made experimentation more accessible. Additionally, COVID-19 accelerated the relevance of deep tech, as companies pivoted

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[2] Anastasia Nedayvoda, Peter Mockel, and Lana Graf, "Deep Tech Solutions for Emerging Markets," International Finance Corporation, November 2020, https://www.ifc.org/content/dam/ifc/doc/mgrt/emcompass-note-94-web.pdf.
[3] "中国市县投资指南," Google Books, 1993,
https://books.google.es/books?id=hiFKAQAAIAAJ&q=%22deep+tech%22&dq=%22deep+tech%22&hl=en&sa=X&ved=2ahUKEwjCw9-xw-TuAhW7WxUIHVF-BV44WhDoATAJegQIBxAC.
[4] "Who's Who of Deep Tech Start Ups," Global Manufacturing & Industrialisation Summit, n.d.,
https://gmisummit.com/knowledge-hub/2020/whos-who-of-deep-tech-start-ups.
[5] PitchBook, "2019 Tough Tech Landscape," The Engine, 2019, https://engine-ventures.files.svdcdn.com/production/Reports-and-Publications/The-Engine_2019_Tough_Tech_Landscape.pdf.

to create value, such as 3D printing personal protective equipment, increasing testing availability, and developing new disinfecting solutions.[6]

Despite its growing relevance, deep tech remains a "black box," often associated with high risks due to uncertain outcomes and long gestation periods. Over time, the term has gained broader usage, appearing in platforms like Crunchbase and Stifled.[7] Definitions of deep tech vary widely, which can contribute to potential misunderstandings. For instance, IIT Hyderabad described deep tech as "any startup that can execute a research group to work with them." However, such broad definitions risk oversimplification, failing to distinguish deep tech's unique focus as a specialized category of technology-driven innovation.[8]

A defining feature of deep tech is its distinction from digital tech, which often involves leveraging pre-existing technologies to address market opportunities. The term most closely associated with deep tech is **"emerging technologies,"** which typically exhibit characteristics such as:

1. Radical novelty,
2. Rapid growth,
3. Coherence in development,
4. Significant societal impact, and
5. Uncertainty and ambiguity.[9]

Other related terms, such as "radical innovation," emphasize a high degree of novelty, whereas "breakthrough" and "disruptive" innovations are distinguished by their significant impact. **Disruptive innovations** create new markets by displacing existing ones, while **breakthrough innovations** introduce entirely new technologies that do not necessarily replace earlier solutions.[10]

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[6] Massimo Portincaso et al., "How Deep Tech Can Help Shape the New Reality," Boston Consulting Group, May 2020, https://www.bcg.com/publications/2020/how-deep-tech-can-shape-post-covid-reality.

[7] Chris Metinko and Chris Metinko, "Deep Tech Investments Down, but Maybe Not as Much as You Think," Crunchbase News, February 14, 2024, https://news.crunchbase.com/venture/deep-tech-funding-down-ai-quantum-space-robotics-resilient/.

[8] Angelo Romasanta et al., "Deep Tech: Unveiling the Foundations," *SSRN Electronic Journal*, January 2022, https://doi.org/10.2139/ssrn.4009164.

[9] Daniele Rotolo, Diana Hicks, and Ben Martin, "What Is an Emerging Technology?," *Research Policy* 44, no. 10 (August 9, 2015): 1827–43, https://doi.org/10.2139/ssrn.2564094

[10] Kristina Rakic, "Breakthrough and Disruptive Innovation: A Theoretical Reflection," *Journal of Technology Management & Innovation* 15, no. 4 (2020): 93–104, https://doi.org/10.4067/s0718-27242020000400093.

Deep tech focuses on translating groundbreaking technologies from research to market, tackling large-scale, fundamental challenges. Its primary risk lies in technical development, while market risk is typically lower due to the clear societal value of its solutions.[11] Two primary approaches have been identified in the literature for defining the concept of deep tech:

Approach	Characteristics	Examples
Material Approach	Defines deep tech based on industry or sector. However, classification can evolve as technology matures	AI, blockchain, aerospace, robotics, biotech, quantum computing.
Microeconomic Approach	Focuses on barriers to entry as the central defining element: 1. **High information symmetry:** private beliefs and technical uncertainty evaluate scientific ideas difficult 2. **High capital intensity:** Requires substantial funding to resolve uncertainties and achieve scalability	Sectors requiring R&D cycles (e.g., biotech, quantum computing or AI)

While the **material approach** defines deep tech based on the sector or product type, a key limitation is that the technological status of a sector can evolve. For instance, what is considered cutting-edge deep tech today, such as materials, blockchain, or AI, may no longer qualify as such as the technology matures, similar to how personal computers and early internet tools were once viewed as high-tech but are now considered standard technologies.[12]

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[11] European Institute of Innovation & Technology, "EIT Deep Tech Talents for Europe Initiative (DTTI)," January 2023, https://www.eitdeeptechtalent.eu/wp-content/uploads/gb/2023/02/deeptech-definitions.pdf.
[12] Olihana Basilio Ruiz De Apodaca, Fiona Murray, and Lars Frolund, "What Is 'Deep Tech' and What Are Deep Tech Ventures?," MIT Regional Entrepreneurship Acceleration Program, n.d., https://reap.mit.edu/assets/What_is_Deep_Tech_MIT_2023.pdf.

Similarly, the **microeconomic approach**, although focused on barriers to entry such as high information asymmetry and capital intensity, also struggles to account for the dynamic and evolving nature of technological advancements. Both approaches risk being static, as they fail to adapt to the changing innovation landscape, where the relevance and classification of deep tech continuously shift.[13]

While the material approach is straightforward, it fails to capture the dynamic evolution of technology—what is considered deep tech today (e.g., AI) may become mainstream in the future. The Microeconomic Approach provides better insight into the unique risks deep tech startups face, including uncertain commercialization pathways, regulatory complexity, and high initial costs.[14]

The Deep Tech Ecosystem: Key Players & Interconnections

Deep tech ventures do not develop in isolation. They require a structured ecosystem that connects research, investment, and commercialization to mitigate risks and accelerate innovation.[15] Unlike consumer-focused digital startups that prioritize quick market entry, deep tech ventures face long R&D cycles, high uncertainty, and capital-intensive development.

According to research by the Massachusetts Institute of Technology (MIT), deep tech ventures share defining characteristics such as:

- Positioning at the knowledge frontier, with long and uncertain R&D cycles.
- Building highly regulated, tangible products, requiring specialized supply chains.
- Strong linkages with research institutions and governments, as university spin-offs are common.
- Mission-driven innovation, tackling systemic challenges like sustainability, health, and energy.
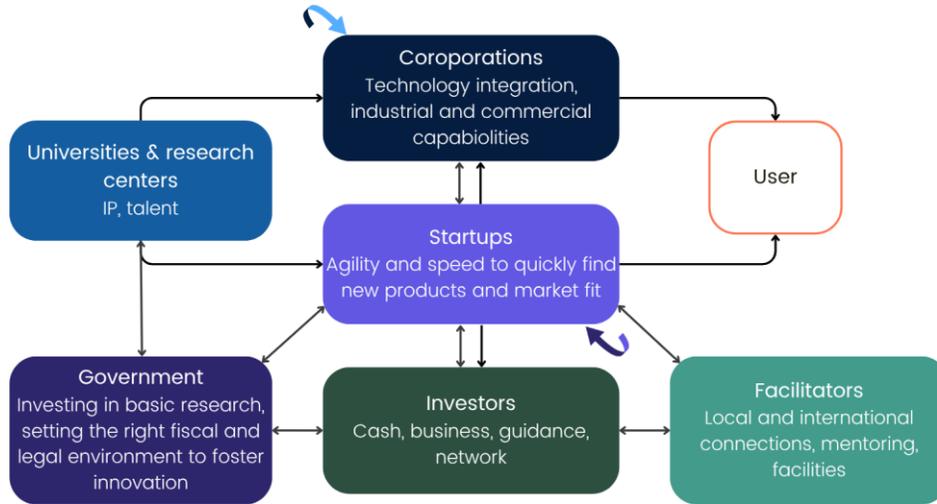- A dynamic de-risking cycle, where continuous prototyping and market alignment are critical.[16]

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[13] Ibid.
[14] Ibid.
[15] Portincaso et al., "How Deep Tech Can Help Shape the New Reality."
[16] Basilio Ruiz De Apodaca, Murray, and Frolund, "What Is 'Deep Tech' and What Are Deep Tech Ventures?"

Exhibit 3: The Deep Tech Ecosystem Encompasses Diverse Actors

Source of Inspiration: https://www.bcg.com/publications/2020/how-deep-tech-can-shape-post-covid-reality

Given these challenges, deep tech innovation relies on a well-coordinated, multi-stakeholder ecosystem to bridge the gap between scientific breakthroughs and commercialization. Exhibit 3 visually maps this interconnected system, where six key players contribute the essential infrastructure, expertise, and funding needed for deep tech ventures to scale. The table below outlines the distinct roles of each stakeholder in driving deep tech success.[17]

Key Players	Role in Deep Tech Ecosystem	Singapore's Case
Universities & Research Centers	-Provide intellectual property (IP), scientific expertise, and top-tier talent. -Enable lab-to-market transitions.	NUS, NTU, and A*STAR drive deep tech R&D and talent development
Corporations	-Offer commercialization pathways, manufacturing capabilities, regulatory expertise, and global market access.	ST Engineering, Temasek, and Grab partner with deep tech ventures to scale technologies
Startups	-Act as agile innovators, translating breakthrough research into marketable solutions. Require significant funding.	Programs like SGInnovate and Deep Tech for Good invest in high-potential startups

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[17] Portincaso et al., "How Deep Tech Can Help Shape the New Reality."

Governments	-Establish fiscal policies, regulatory frameworks, and direct R&D investments. -Support public-private partnerships.	Agencies like EDB, Enterprise Singapore, and NRF fund deep tech initiatives and talent programs
Investors	-Provide capital, mentorship, and business expertise to de-risk deep tech ventures.	Vertex Ventures, Temasek, and SEEDS Capital actively fund deep tech enterprises
Facilitators	-Bridge gaps between research, funding, and commercialization through mentorship, infrastructure, and networking.	SGInnovate, Block71, and The Engine (MIT Singapore) help deep tech scale-ups navigate the commercialization

What is Innovation Policy?

Innovation policy refers to government strategies designed to promote technological progress, economic development, and societal well-being through targeted interventions. Unlike traditional science and technology policies, innovation policy takes a holistic approach, integrating economic, social, and environmental considerations into technological advancement.[18]

Below are the three approaches to innovation policy:

Approaches	Focus & Characteristics	Examples
Mission-Oriented Policies	-Solve specific societal problems through concentrated investment in strategic technologies -Governments directly fund large-scale R&D priority sectors	U.S. Apollo Program, Singapore's AI Strategy 2030
Invention-Oriented Policies	-Emphasize early-stage R&D -Foster scientific discovery while leaving commercialization to market focus	Germany's Fraunhofer Institutes, Singapore's National Research

[18] "Asian Development Outlook 2020:," *Asian Development Outlook*, April 1, 2020, https://doi.org/10.22617/fls200119-3.

	-Government funding supports fundamental research	Foundation (NRF)
System-Oriented Policies *(Singapore's Approach)*	-Build interconnected innovation ecosystems -Strengthen collaboration between research institutions, industries, and policymakers to ensure technological advancements reach the market efficiently	Singapore's Research, Innovation, and Enterprise (RIE) 2025 Plan, SGInnovate, Block71

Singapore's innovation model is best understood through a system-oriented approach, where policy, R&D investment, industry collaboration, and talent development work together to drive deep tech progress. Unlike economies that focus on direct government-led projects (mission-oriented) or purely academic R&D (invention-oriented), Singapore prioritizes integration, ensuring research is not only encouraged but effectively translated into high-impact applications.[19]

The Global Innovation Index (GII): A Brief Overview

The Global Innovation Index (GII) is an annual ranking of economies based on their innovation capabilities and performance.[20] Established in 2007, it provides insights into how innovation contributes to economic development. The GII assesses innovation across seven key pillars, divided into two sub-indices:

1. **Innovation Input Sub-Index** – Captures the conditions that enable innovation through:
   - Institutions
   - Human capital & research
   - Infrastructure
   - Market sophistication
   - Business sophistication

2. **Innovation Output Sub-Index** – Measures the tangible results of innovation, such as:
   - Knowledge & technology outputs
   - Creative outputs

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[19] Ibid.
[20] Soumitra Dutta et al., eds., "Global Innovation Index 2024: Unlocking the Promise of Social Entrepreneurship," *WIPO* (World Intellectual Property Organization, 2024), https://doi.org/10.34667/tind.50062.

By balancing innovation inputs and outputs, the GII enables policymakers and businesses to benchmark their performance and identify areas for improvement.

Singapore ranks 4th globally in the Global Innovation Index (GII) 2024, strengthening its position among the world's top innovation hubs. Key highlights of Singapore's performance:

- **Highest Number of First-Place Rankings:** Singapore leads in 14 out of 78 indicators, surpassing the U.S. in several areas, including regulatory quality, policy stability, venture capital investment, and high-tech manufacturing.[21]
- **Strong Innovation Inputs:** Singapore excels in business sophistication, knowledge-intensive employment, and university-industry collaboration, reinforcing its status as a global leader in talent and research commercialization.[22]
- **Challenges in Innovation Outputs:** Despite strong inputs, Singapore lags behind the top three economies (Switzerland, Sweden, and the U.S.) in creative outputs, suggesting room for improvement in areas such as intellectual property generation and cultural innovation.[23]

Exhibit 4: Comparison of Singapore's Ranking in GII 2024 Report

Country	GII 2024 Rank	Strengths	Challenges
Switzerland	1st	Knowledge & technology outputs, R&D investments	Moderate infrastructure ranking
Sweden	2nd	Human capital, innovation linkages	Creative outputs improvement
United States	3rd	Global corporate R&D, unicorn valuation	Declining innovation indicator rankings
Singapore	4th	Policy stability, venture capital, talent pipeline	Creative output lag
China	11th	High-tech exports, corporate R&D	Still catching up in inputs

Source of Data: https://doi.org/10.34667/tind.50062

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[21] "Singapore Ranking in the Global Innovation Index 2024," September 26, 2024.
[22]Ibid.
[23]Ibid.

Evolution of Singapore Innovation Strategy

Singapore's rise as a top innovation economy is the result of a deliberate, phased strategy shaped by global shifts, domestic constraints, and long-term national ambition. This section traces how early industrial policies and science-led planning laid the foundation for today's deep tech ecosystem.

Early Foundations (1960s - 1980s)

In the wake of its separation from Malaysia in 1965, Singapore faced significant structural vulnerabilities, including a small domestic market, high unemployment, and a lack of natural resources. The government's response was swift and strategic: attract foreign capital and technology while building local industrial and workforce capacity.[24]

The State Development Plan (1961–1964) formalized these efforts by investing heavily in industrial infrastructure and job creation. Over SGD 871 million was allocated, primarily toward capital formation and the development of the manufacturing sector.[25] Key institutions formed during this period included:

- **Economic Development Board** (EDB, 1961): To attract foreign direct investment (FDI) and plan industrial zones.
- **Singapore Institute of Standards and Industrial Research** (SISIR, 1969): To support industrial quality and applied research.
- **Science Council of Singapore** (SCS): To provide national direction on science policy.

Recognizing that industrialization required a capable workforce, Singapore undertook reforms in technical education.[26] Early initiatives, such as the **Chan Chieu Kiat Commission** (1961) and **Lim Tay Boh Commission** (1962), emphasized aligning education with economic needs,

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[24] "Another New Industry Conies to Singapore," *Newspaper SG*, July 26, 1961, https://eresources.nlb.gov.sg/newspapers/digitised/article/straitstimes19610726-1.2.135.2.

[25] Lim Puay Ling, "State Development Plan, 1961–1964," National Library Board Singapore, October 10, 2017, https://www.nlb.gov.sg/main/article-detail?cmsuuid=00df90f2-a3ac-4e9b-b507-f338eb2f933c.

[26] Yoichi Itagaki, "A Review of the Concept of the 'Dual Economy,'" *The Developing Economies* 6, no. 2 (March 2007): 143–57, https://doi.org/10.1111/j.1746-1049.1968.tb01121.x.

successfully cultivating a pool of semi-skilled workers to support the nascent manufacturing sector by the mid-1960s.[27]

Further education refinements culminated in the **1978 Goh Keng Swee Report on Education**, which identified high attrition rates and weak bilingualism as systemic bottlenecks. In response, the government consolidated fragmented language-stream schools into a unified English-medium system by 1984, streamlining workforce development and preparing Singaporeans for future shifts toward technology-driven industries.[28]

By the end of the 1980s, Singapore's economy had grown at an average annual rate of 8.5% between 1966 and 1990, outpacing many developed economies. By 1973, the country had achieved near full employment, with sharp reductions in income inequality and the near-eradication of absolute poverty.[29]

National Technology Plan (1991 - 1995)

Singapore's first **National Technology Plan (NTP)** marked a shift from industrial growth to innovation-led development. With SGD 2 billion in government funding, the NTP explicitly targeted the creation of a science-based, industry-relevant research and development (R&D) ecosystem, setting the stage for Singapore's future as a deep-tech hub.

Building Critical Infrastructure for Deep Tech

The NTP prioritized the development of specialized research institutes, including:

- **Institute of Microelectronics** (IME, 1991) – advancing capabilities in semiconductors.
- **Magnetics Technology Centre** (MTC, 1992) – later renamed the Data Storage Institute, a foundational institution to Singapore's digital hardware R&D positioning.

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[27] State of Singapore, "Report of the Commission of Inquiry Into Vocational and Technical Education in Singapore," *National Library of Singapore*, 1961, https://www.nlb.gov.sg/main/book-detail?cmsuuid=87f46daf-4346-483c-9056-84000c937c09.

[28] Janice Loo, "New Education System," National Library Board Singapore, n.d., https://www.nlb.gov.sg/main/article-detail?cmsuuid=0c0e8e39-538d-45d6-b952-abf22b4a65f8.

[29] Euston Quah, Luke Nursultan Iuldashov, and Zach Lee, "Economics of Development During the Time of Albert Winsemius," in *Albert Winsemius and Singapore* (World Scientific, 2022), 279–317, https://doi.org/10.1142/12081.

- **Bioprocessing Technology Centre** (BTC, 1990) – catalyzed the growth of biotech and, later, biomedical sciences.[30]

These investments boosted Singapore's knowledge and technology outputs, directly impacting GII indicators tied to research infrastructure and applied science.

Industry Collaboration and Business Sophistication

The NTP also helped align public research with private-sector needs:
- **Shell Research Eastern** (1994) – a SGD 25 million investment in local fuels and lubricants R&D.[31]
- **CarnaudMetalbox R&D Centre** (1994) – focused on packaging innovation through an SGD 32 million program.[32]
- **Creative Technology's NASDAQ listing** (1992) – a symbol of Singapore's growing capacity to commercialize homegrown innovation on the global stage.

These developments reflected the growing sophistication of Singapore's business environment, another key pillar of its innovation performance.

Building Deep Tech Talent

Human capital development remained central to the NTP:
- **NTU's elevation to university status** (1991) enabled greater research activity and postgraduate training in engineering.[33]
- **NUS's Postgraduate School of Engineering** (1990) expanded high-level scientific capacity.
- **NUS Medical Faculty's Advanced Specialty Training** (1992) deepened biomedical research and specialist training.[34]

[30] Chang Chieh Hang, Teck Seng Low, and Raj Thampuran, *The Singapore Research Story* (World Scientific, 2014), https://doi.org/10.1142/9417.

[31] Ibid.

[32] Ibid

[33] "Our History," Nanyang Technological University Singapore, n.d., https://www.ntu.edu.sg/about-us/history.

[34] Hang, Low, and Thampuran, *The Singapore Research Story*.

This talent-centric approach addressed the GII's human capital and research pillar, helping ensure that a skilled, innovation-ready workforce matched infrastructure investment.

Institutional and Regulatory Enhancements for Innovation

The **National Science and Technology Board (NSTB)**, established by the 1990 NSTB Act, assumed responsibility for long-term planning and coordination of science and technology policy. It acted as a critical integrator across sectors, laying the foundation for the RIE frameworks that followed.[35]

The **Patents Act (1994)** enabled domestic patent filings, improving Singapore's IP infrastructure and aligning with GII indicators for regulatory quality and innovation output.[36]

Science & Technology Plans (1996 - 2005)

Following the foundational National Technology Plan, Singapore entered a critical period of policy maturity through two consecutive five-year **Science and Technology (S&T) Plans**. These plans expanded the nation's R&D capabilities, transitioned toward commercialization, and aligned national efforts with emerging global innovation standards, pushing Singapore further up the innovation value chain.[37]

With a doubled investment of SGD 4 billion, the second S&T Plan aimed to deepen Singapore's science and technology infrastructure and reduce reliance on foreign technology.[38] It focused on:

- **Human Capital Development**: Expanding training in engineering, life sciences, and applied R&D to support future growth sectors.
- **Intellectual Capital Development**: Increasing public-sector research output and fostering local IP creation.

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[35] "National Science and Technology Board Is Formed," National Library Board Singapore, n.d., https://www.nlb.gov.sg/main/article-detail?cmsuuid=9addb3d8-62eb-420a-a10a-3727f790259c.

[36] Singaporean Parliament, "Patents Act (Chapter 221, Revised Edition 1995), Singapore," World Intellectual Property Organization, 1995, https://www.wipo.int/wipolex/en/legislation/details/3692.

[37] Reuben, Wong, and Qi Lim, "Singapore: 50 Years of Science and Technology."

[38] "Science and Technology Plan 2010," Ministry of Trade & Industry, 2005, https://www.mti.gov.sg/-/media/MTI/Resources/Publications/Science-and-Technology-Plan-2010/s-and-t-plan-2010.pdf.

- **Industrial Collaboration**: Strengthening research-industry partnerships, especially in electronics, precision engineering, and emerging biotech fields.[39]

These efforts directly impacted GII-aligned indicators, including growth in scientific publications, R&D expenditure, and local patent activity. The groundwork laid during this period also set the stage for more ambitious translational research in the decade to follow.

The third plan marked a strategic inflection point. In 2001, the government restructured the **National Science and Technology Board (NSTB)** into the **Agency for Science, Technology and Research (A*STAR),** which was a move designed to better coordinate basic research, talent development, and commercialization.[40]

Key initiatives included:
- **Biomedical Sciences (BMS) Initiative**: Launched to establish biomedical research as Singapore's fourth economic pillar. Institutes like the Genome Institute of Singapore were established, while talent attraction schemes brought in global scientists to build critical capabilities.[41]
- **Translational Research & Industry Co-location**: A*STAR emphasized turning scientific discovery into market-ready innovation, encouraging co-location of public research labs with private firms and supporting spin-offs.[42]

Notably, during the 2003 SARS outbreak, Singapore's early investments in biomedical infrastructure allowed for a rapid, coordinated national response reinforcing the country's strategic value of health and science resilience.

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[39] Ibid

[40] Rahimah Moasi, "Agency for Science, Technology and Research (a*STAR)," National Library Board Singapore, n.d., https://www.nlb.gov.sg/main/article-detail?cmsuuid=e70e3f14-b6e8-4fc5-87d4-58f8c901b954.

[41] Keat-Chuan Yeoh, "Singapore's Biomedical Sciences Landscape," *Journal of Commercial Biotechnology* 14, no. 2 (December 24, 2007): 141–48, https://doi.org/10.1057/palgrave.jcb.3050083.

[42] Moasi, "Agency for Science, Technology and Research (a*STAR)."

Transition to a Knowledge-Based Innovation Ecosystem (2006 - Present)

Having laid institutional and infrastructural foundations through early initiatives and comprehensive Science & Technology plans, Singapore entered a phase of transforming into a knowledge-based innovation ecosystem from 2006 onward. This period marked a shift from infrastructure-centric growth to leveraging knowledge and intellectual property as drivers of sustainable competitive advantage.

Shift to Research, Innovation, and Enterprise (RIE) Plans

Launched in 2006, **the Research, Innovation, and Enterprise (RIE) 2010** framework marked a turning point in Singapore's innovation journey. Building upon earlier infrastructure- and institution-focused phases, the RIE approach formally integrated research, enterprise development, and economic strategy under a unified agenda, with funding led by the National Research Foundation (NRF) under the Prime Minister's Office.

Two key realizations drove this shift:

1. **Scientific research alone was insufficient**—economic value needed to be extracted through commercialization, public-private partnerships, and innovation diffusion.
2. **Fragmented governance of research institutes (RIs)** limited effectiveness, prompting tighter coordination and a move to mission-oriented, industry-aligned innovation.[43]

Structural Changes Under RIE 2006

- The **Research, Innovation and Enterprise Council (RIEC)** was formed to provide whole-of-government strategic direction, chaired by the Prime Minister himself.[44]

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[43] Lim Chuan Poh, "Evolution of Singapore's Research, Innovation and Enterprise (RIE) Strategy," Asian Bureau of Finance and Economic Research, December 3, 2019, https://abfer.org/media/abfer-events-2019/industry-outreach/ABFER-IndustryOutreach-slide-20191203.pdf

[44] "Research, Innovation and Enterprise Council," National Research Foundation Singapore, n.d., https://www.nrf.gov.sg/about/governance/riec/.

Exhibit 5: Singapore's RIE System (2010)
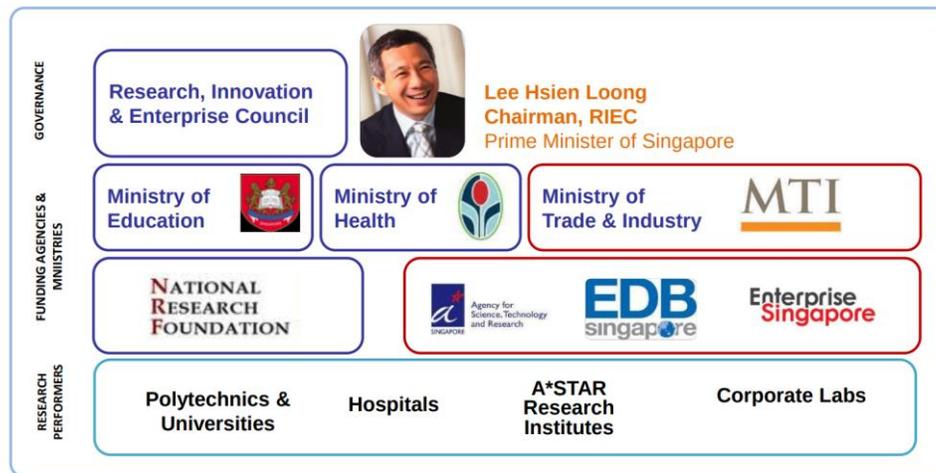
- **National Research Foundation (NRF)** was established to operationalize this direction through policy and funding.[45]
- Greater autonomy was granted to universities, enabling competitive research funding, stronger international linkages, and interdisciplinary research.

RIE2010 laid the governance foundation for future ecosystem building and emphasized the importance of aligning public R&D with national economic outcomes, thereby setting the stage for the eventual emergence of the deep tech sector.

Scaling up Innovation Through RIE2015

Under **RIE 2015, Singapore increased its investment to SGD 16 billion, with a sharper** focus on technology translation, applied research, and corporate partnership platforms. This phase significantly expanded industry collaboration.

Key developments included:

- Establishment of corporate labs, co-location models, and translational centers (e.g., NAMIC, DxD Hub), supporting commercialization in biotech, manufacturing, and medtech.[46]

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[45] "About NRF," National Research Foundation Singapore, n.d., https://www.nrf.gov.sg/about/about-nrf-singapore/nrf-singapore/.

[46] "About DxD Hub," Diagnostics Development Hub, n.d., https://www.a-star.edu.sg/dxdhub/about-dxd-hub.

- The startup ecosystem grew, with several deep tech-adjacent firms (e.g. in fintech and healthtech) maturing during this period.

RIE2020: Domain-Based Ecosystem Building and Deep Tech Foundations

RIE2020, backed by SGD 19 billion, marked a critical inflection point.[47] This was the first plan to introduce a domain-based governance model, organizing national R&D around four strategic priority areas:

- Advanced Manufacturing and Engineering (AME)
- Health and Biomedical Sciences (HBMS)
- Urban Solutions and Sustainability (USS)
- Services and Digital Economy (SDE)[48]

These domains were supported by cross-cutting horizontal initiatives in Academic Research, Manpower, and Innovation and Enterprise. For the first time, mission-oriented coordination guided funding allocations across ministries, institutes, and industry.

Other key developments included:

- A rise in competitive R&D funding, with 40% of funds awarded based on merit, increasing research excellence and outcome focus.
- The launch of SGInnovate in 2016, which became a deep tech venture catalyst supporting startups in AI, quantum tech, robotics, and biotech.
- Stronger emphasis on talent development, including programs like Summation, Biodesign, and the I&E Fellowship to groom "bilingual" talent—scientifically trained individuals with entrepreneurial fluency.[49]

RIE2020 firmly established deep tech as a national economic engine, enabling Singapore to translate its scientific research into venture creation, IP licensing, and scalable innovation—a

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[47] National Research Foundation, Prime Minister's Office in Singapore "Research, Innovation and Enterprise (RIE) 2020," Ministry of Trade and Industry Singapore, 2016, https://www.mti.gov.sg/Resources/publications/Research-Innovation-and-Enterprise-RIE-2020.
[48] Chuan Poh, "Evolution of Singapore's Research, Innovation and Enterprise (RIE) Strategy."
[49] National Research Foundation, Prime Minister's Office in Singapore, "Research, Innovation and Enterprise (RIE) 2020."

major reason for its strong performance in the GII's innovation output and institutional quality pillars.

RIE2025: Ecosystem Maturity and Resilience-Oriented Innovation

The current **RIE2025** plan sustains Singapore's innovation investment at 1% of GDP (SGD 25 billion), with a continued emphasis on long-term competitiveness, national resilience, and enterprise innovation.[50]

Exhibit 6: Singapore's Transition to Knowledge-Based Innovation Ecosystem

Source of Data: https://lkyspp.nus.edu.sg/gia/article/singapore-50-years-of-science-and-technology
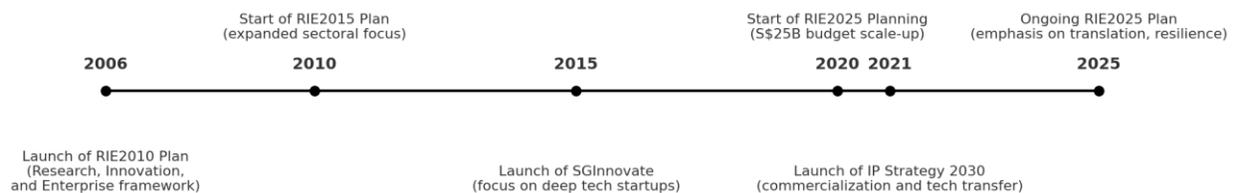
Strategic priorities under RIE2025 include:

- Expanding the RIE mission to address emerging challenges such as sustainability, pandemic resilience, and digital trust.
- Enriching the scientific base through bottom-up investigator-led funding and inter-disciplinary platforms.
- Scaling commercialization infrastructure, including enhanced IP pathways under Singapore's **Intellectual Property (IP) Strategy 2030**.[51]

RIE2025 represents a mature innovation ecosystem, where policy, funding, talent, and enterprise are tightly interlinked to deliver both economic impact and societal value. It also consolidates deep tech as a cross-domain driver—from smart health to urban solutions—contributing directly to Singapore's top-tier GII performance in areas like human capital, knowledge creation, and innovation linkages.

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[50] National Research Foundation, Prime Minister's Office in Singapore, "RIE2025 Handbook," National Research Foundation, 2020, https://www.nrf.gov.sg/rie-ecosystem/rie2025handbook/.
[51] National Research Foundation, Prime Minister's Office in Singapore, "RIE2025 Handbook."

The Rise of Deep Tech as a Policy Priority

Following the structural maturity brought by the RIE framework, Singapore began to sharpen its innovation strategy by elevating deep tech—technologies grounded in advanced science and engineering—as a core driver of long-term competitiveness. No longer treated as a standalone vertical, deep tech has become embedded across various domains, including AI, synthetic biology, precision medicine, quantum, and advanced manufacturing.

This shift was not sudden. It reflected an evolving policy logic: that scientific discovery alone was not sufficient, as what mattered was the system's ability to translate research into high-impact, commercially viable solutions. As Singapore's research base expanded through A*STAR, Research Centres of Excellence (RCEs), and universities, the need to close the lab-to-market gap became more urgent.

From Research Strength to Venture Creation: Institutional Anchors

A defining moment occurred in 2016 with the launch of SGInnovate, a government-backed platform dedicated to building and investing in deep-tech startups. Unlike general incubators, SGInnovate specifically targeted research-intensive ventures and worked closely with scientists and founders to:

- Validate product-market fit,
- Attract and place STEM talent in early-stage teams, and
- Deploy catalytic capital in frontier domains.[52]

By 2021, SGInnovate had supported over 90 deep tech startups and more than 1,200 individuals through its talent programs, feeding a new generation of scientific entrepreneurs into the national pipeline.[53]

Other key enablers included:

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[52] "SGInnovate to Drive Technology-Based Innovation Through Mindset Change and Curated Productive Interaction," Press release, SGInnovate, November 22, 2016, https://www.sginnovate.com/press-room/sginnovate-drive-technology-based-innovation-through-mindset-change-and-curated.
[53] "SGInnovate Media Statement - Leadership Updates," Press release, January 28, 2020, https://www.sginnovate.com/press-room/sginnovate-media-statement-leadership-updates.

- The Innovation & Enterprise Fellowship Programme, cultivating science-based business leadership,
- Biodesign Singapore, training medtech innovators in clinical validation and market application,
- A*STAR's expanded efforts in IP licensing, spin-offs, and industry-collaborative labs.

These initiatives collectively strengthened the feedback loop between public R&D and private enterprise, ensuring that Singapore's science ecosystem was not just productive, but commercially generative.

Deep Tech in RIE2025: A Systemic Priority

In RIE2025, deep tech is no longer a standalone objective but is embedded across all four strategic domains:

- **Health and Biomedical Sciences**: precision medicine, biotech manufacturing,
- **Smart Nation and Digital Economy**: AI, cybersecurity, digital trust,
- **Urban Solutions and Sustainability**: energy innovation, green materials,
- **Advanced Manufacturing and Engineering**: robotics, industrial automation, next-gen semiconductors.[54]

This cross-domain integration reflects Singapore's treatment of deep tech as a general-purpose innovation engine, which is a strategic infrastructure that powers not just economic growth, but national resilience.

Supporting these ambitions is a broader institutional architecture:

- Continued investment in talent pipelines, including National Science Scholarships and A*STAR attachment programs,
- Strengthened IP Strategy 2030, accelerating technology transfer and commercialization,
- Expanded public-private research centers, focused on application-driven innovation in areas from sustainability to quantum security.[55]

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[54] National Research Foundation, Prime Minister's Office Singapore, "RIE2025 Handbook."
[55] Ibid.

Challenges and Opportunities

Despite the deep tech ecosystem has matured significantly under the RIE framework, but Singapore's next phase of growth depends on navigating structural challenges and capitalizing on emergent opportunities. The strength of the system lies not just in resources, but in its ability to convert scientific discoveries into transformative economic outcomes.

Challenges

First, while Singapore ranks 1st globally in innovation inputs (GII 2024), it ranks only 11th in outputs revealing a conversion gap. Patent filings declined by 15.35%, and Singapore ranks only 34th for scientific publication impact. Despite strong infrastructure, this indicates that high-quality research has not fully translated into commercial or societal outcomes. [56]

Second, Singapore ranks just 93rd globally in domestic industry diversification (GII 2024). Despite its dominance in semiconductors and biotech, the innovation landscape remains concentrated in a few verticals. This overconcentration exposes the system to sectoral shocks, and suggests a need for deeper diffusion of deep tech into areas like agritech, maritime, and circular economy models.[57]

Third, Singapore's education system ranks high in outcomes (PISA Rank 2; 36% STEM graduates), but R&D investment in human capital is not yet keeping pace with demand. Education spending remains low at 2.4% of GDP (Rank 116), and talent bottlenecks persist in core areas like AI engineering, computational biology, and deep tech venture leadership.[58] A*STAR's own report notes a growing reliance on cross-agency fellowships, secondments, and upskilling pathways, signaling a need for more integrated, industry-ready talent pipelines[59]

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[56]"Singapore Ranking in the Global Innovation Index 2024," September 26, 2024.

[57] Ibid.

[58] Ibid.

[59] "Impact Through Innovation Annual Report (April 2023 - March 2024)," *Agency for Science, Technology, and Research*, n.d., https://www.a-star.edu.sg/docs/librariesprovider1/default-document-library/annualreports/astar_annualreport_fy23-24.pdf?sfvrsn=17587468_1.

Fourth, despite the rise of SGInnovate-backed startups, only 1 in 3 deep tech startups in Singapore secured follow-on funding in 2023. The small domestic market limits opportunities for rapid scaling, and high-risk capital for science-based ventures remains thin beyond seed stage.[60]

While early-stage support has improved, the "valley of death" for translating deep tech remains a pressing issue.

Opportunities

First, Singapore ranks 1st in Human Capital, Business Sophistication, and Institutions (GII 2024). It also leads globally in:

- High-tech manufacturing output (82% of total industrial production)
- Venture capital activity (Rank 1 in VC value, deal count, and startup density)
- Unicorn valuation relative to GDP (18.2%), indicating a growing private appetite for high-impact venturess[61]

Second, the establishment of SGInnovate, Biodesign Singapore, MedTech Catapult, and sectoral research institutes like NATi and NSTIC reflects a deliberate move to build a cross-functional commercialization infrastructure. As of FY2023:

- SGInnovate has supported over 90 deep tech startups and 1,200 talent placements[62]
- 50%+ of deep tech ventures originated from public research spin-offs or venture studios[63]

Third, with rising geopolitical competition in areas like semiconductors, AI safety, and quantum, Singapore's neutrality and regulatory clarity position it as a trusted node for R&D partnerships, pilot deployments, and joint IP platforms

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[60] "Mapping Singapore's Early-stage Emerging Technology Startups," SGInnovate, April 4, 2024, https://www.sginnovate.com/blog/mapping-singapores-early-stage-emerging-technology-startups.

[61]"Impact Through Innovation Annual Report (April 2023 - March 2024)."

[62] "Mapping Singapore's Early-Stage Emerging Technology Startups."

[63]"Impact Through Innovation Annual Report (April 2023 - March 2024)."

Fourth, with SGD 25B committed over 2021–2025, RIE2025 emphasizes translation across four domains: AME, HBMS, USS, and SDE. These domains house deep tech initiatives in:

- Precision medicine, digital trust, green materials, and industrial robotics
- Strengthened linkages through platforms like the Innovation & Enterprise Fellowship Programme and IP Strategy 2030[64]

Conclusion

Singapore's innovation journey demonstrates how strategic policy coherence, long-term investment, and institutional alignment can elevate a small nation to the forefront of global innovation. Through the evolution of the Research, Innovation and Enterprise (RIE) framework, the country has transitioned from infrastructure-building to a system that integrates research excellence with enterprise development and national strategy.

The elevation of deep tech from a peripheral sector to a core policy pillar marks a critical shift, embedding science-based innovation into health, sustainability, manufacturing, and digital trust. This approach has enabled Singapore to lead in innovation inputs, while expanding its deep tech infrastructure through platforms like SGInnovate, A*STAR's commercialization initiatives, and domain-based governance under RIE2025.[65]

However, structural challenges remain. Despite its strengths, Singapore faces a persistent input–output gap, with translation of research into market-ready innovation still uneven. Talent bottlenecks, scale limitations, and sectoral concentration highlight the need for enhanced cross-domain integration and commercialization capabilities.[66]

These are not setbacks, but design tensions inherent to a system still in progress. Singapore's strength lies in its capacity to refine, adapt, and learn. As deep tech becomes central to addressing global challenges from climate resilience to digital trust, Singapore's model offers a compelling

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[64] National Research Foundation, Prime Minister's Office Singapore, "RIE2025 Handbook."
[65] Ibid.
[66] "Singapore Ranking in the Global Innovation Index 2024," September 26, 2024.

lesson: that sustainable innovation leadership requires not only scientific excellence, but systems that are coherent, coordinated, and built to last.

Singapore's innovation journey illustrates how a small state can achieve global relevance through deliberate, long-term policy design. From its early focus on research infrastructure to the strategic evolution of the Research, Innovation and Enterprise (RIE) framework, Singapore has built a system that integrates scientific excellence, enterprise development, and national strategic planning.

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