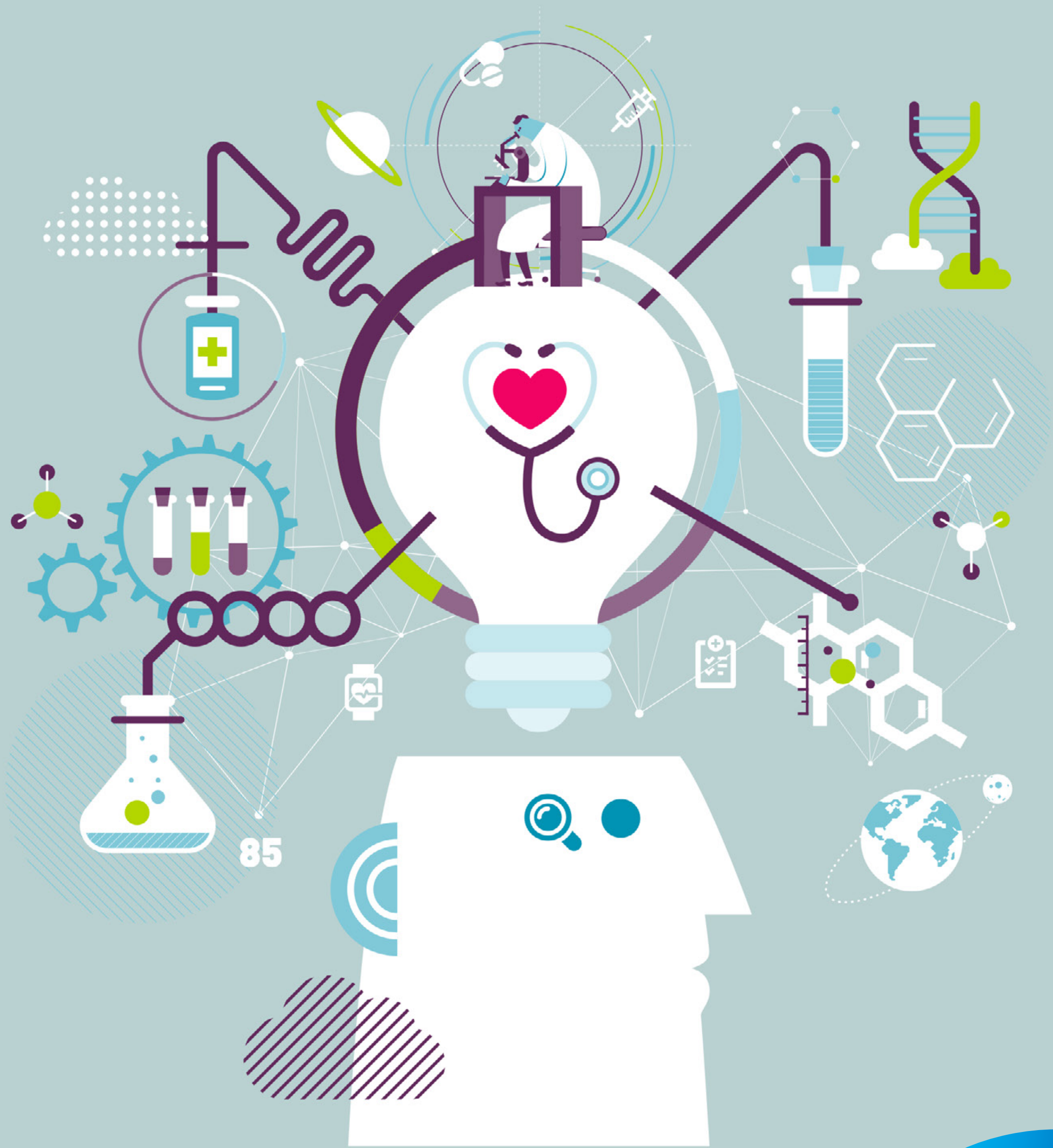
The Economist INTELLIGENCE UNIT

# Supporting an innovative life sciences ecosystem in Japan



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# Contents

# Executive summary

Medical innovation in the life sciences requires a holistic policy and market access environment that supports everything from basic science to product research and development (R&D) and, ultimately, commercialization. Though North America and Europe have historically led innovation in life sciences, Japan has been a leading contributor from Asia for decades. However, emerging life science sectors in South Korea, and more recently China, are quickly catching up after investing heavily in infrastructure, human capital, and R&D, as well as enacting national policies to further bolster their life sciences ecosystems.

This analysis by The Economist Intelligence Unit explores the enabling factors creating a supportive environment for innovation in the life sciences sector in Japan, benchmarked against three other countries: the US, South Korea, and China.

Overall, while Japan is still producing life science innovation at a high level, it appears to be stagnating while the US remains ahead, and regional competitors are either catching up to or surpassing Japan.

Our research identified several opportunities for Japan to build on early progress in fostering an innovative life sciences ecosystem and remain competitive on the global stage. **Priority areas that should be addressed include:**

**Maintaining and expanding a strong workforce:** Japan's human capital for R&D is growing more slowly than those of the other states in this study. Of the four countries in this analysis, Japan has under half of the number of R&D full time researchers as China and the US. To address this challenge, Japan may wish to bring more women into the R&D workforce—they currently make up less than 15%—and look at reskilling existing employees and enticing foreign research scientists to work in Japan.

**Investing in R&D and incentivising business enterprise:** Japan's stagnating spending levels over the last 10 years are in uncomfortable contrast to rising R&D in fast-growing neighbouring economies and the US. Company spending represents the large bulk of R&D investment and Japan's business enterprise R&D (BERD) in the pharmaceutical sector is the world's third largest. In order to encourage a higher level of life-sciences output—including high-quality journal articles, new patents and novel products brought to market—increased government spending in basic research is necessary. In addition, it might be wise for Japan to raise the cumulative government incentive for BERD spending to the same level as those in China, South Korea, and the US.

**Preserving strong intellectual property (IP) protection while enhancing enforcement and transparency:** Japan already has effective IP protection in most areas, but the US Chamber of Commerce Global IP Index sees some weaknesses in protection of pharmaceutical companies and a need to strengthen regulations dealing with disputes over the introduction of generic or biosimilar products. Coupled with a lack of public-domain information around IP compared with the US, Japan would be wise to ensure better transparency and predictability to encourage innovators.

**Increasing encouragement of technology transfer and commercialisation:** Despite notable examples of policy support, the start-up sector in the life sciences remains weaker in Japan than elsewhere. The government should not abandon its efforts in this area but accept that it may take a long time to bring about the necessary cultural change. Improving understanding of entrepreneurship within the country, especially at universities, could help.

**Ensuring health policies are consistent with those promoting new products:** In Japan, the government has sent mixed messages to the market about innovation over the past decade. The size of the pharmaceutical market remains an asset for innovation, and earlier policies were designed to encourage and reward innovative products. Meanwhile, the Japanese government has continued to press to keep prices down via more frequent price reviews, and encourage the use of generics and biosimilars in an attempt to make the system sustainable. Japan should now consider a policy focus that fosters a more predictable environment and the use of new pricing schemes and financing models for innovative, transformative medicines and medical devices.

# About this report

*Supporting an innovative life sciences ecosystem in Japan* is a report by The Economist Intelligence Unit. It describes findings from a research project to investigate the enabling factors contributing to an environment prioritising innovation in the life sciences sector and how Japan compares to global peers.

The research consisted of a benchmarking scorecard exercise conducted between December 2019 and January 2020 covering four countries: Japan, the US, South Korea, and China. This report summarises the findings from substantial desk research, along with context derived from qualitative interviews with five experts.

Our thanks are due to the following for their time and insight (listed alphabetically):

- Erika Elvander, director, Asia/Pacific Office, Office of Global Affairs, U.S. Department of Health & Human Services
- Yoshihide Esaki, deputy director-general for healthcare and medical policy, Ministry of Economy, Trade & Industry
- Toshio Fujimoto, general manager, Shonan Health Innovation Park, Takeda Pharmaceutical Company Limited
- Isao Kamae, project professor, Graduate School of Public Policy, University of Tokyo
- Yoshitake Yokokura, president, Japan Medical Association

The scorecard construction was led by Rohini Omkar of The Economist Intelligence Unit. This report was written by Paul Kielstra and edited by Jesse Quigley Jones of The Economist Intelligence Unit.

This research was sponsored by Pfizer Japan. The content of this report is the sole responsibility of The Economist Intelligence Unit and the views expressed are not necessarily those of the sponsor.

July 2020.

# Introduction

Medical innovation arises from the life sciences sector in response to specific unmet needs in healthcare. The current covid-19 pandemic has highlighted that even, where public health interventions and effective healthcare systems hold the line in the face of a novel virus, the tools to understand, prevent, and treat such diseases must come from an innovative life sciences ecosystem. The global response to developing novel vaccines and drugs to address the covid-19 pandemic has been swift, however the Japanese government has raised concerns around local pharmaceutical companies' response and abilities to develop and manufacture vaccines against the virus.[1] Meanwhile, the Japanese Pharmaceutical Manufacturers Association (JPMA) has highlighted the impact that the pandemic is having on new drug development—and the limitations caused by bureaucracy around the way clinical trials are regulated.[2]

Pandemics are rare and not necessarily representative of the broader burden facing modern societies. The challenges around ageing populations and the increasing burden of non-communicable diseases (NCDs) remain the dominant overall challenge. According to Global Burden of Disease figures, NCDs caused 73% of all deaths worldwide in 2017, up from 60% two decades earlier. Today, cardiovascular disease alone kills more people than all communicable diseases and injuries combined.[3]

The life sciences sector has worked extensively to address the public health burden presented by NCDs. The result has been extended lifespans across most of the world. Here, Japan is a global leader: the UN Population Division reports that Japanese life expectancy of 85 years is the second-highest national figure, exceeded only by Hong Kong's.

Increased age correlates with greater incidence of a large number of NCDs, such as cancer, dementia and diabetes. Given the current disease burden, a major target of life science innovation is finding ways to address both the common and rare NCDs which are at the frontier of medical need.

In dealing with these challenges, the life sciences sector is able to deploy a growing range of advanced tools. A greater understanding of genetics, for example, helps explain the more rapid progress being made toward a vaccine for covid-19 than would have been possible even a few years ago. As for NCDs, increased knowledge at the cellular level—not just about patient DNA but the medical implications of proteins and bacteria present in an individual's healthy and diseased cells—as well as the ever-decreasing price of rapid, next-generation genetic sequencing, is driving the push toward more targeted treatments. Of those drugs approved by the US Food and Drug Administration in 2018, 42% could be classed as personalised medicine. The most-frequently targeted conditions were cancers and rare genetic disorders.[4] Meanwhile, advances in medical devices, artificial intelligence (AI) and the use of Big

1 Pharma Japan, "Govt Officials Urge Japan Pharma Companies to Be More Proactive in Coronavirus Vaccine Development," May 2020. Available from: https://pj.jiho.jp/article/242065 (Accessed Jun 2020).

2 Pharma Japan. "COVID-19 Having "Serious Impact" on New Drug Development; JPMA Calls for Strong Systems for Emergencies," Jun 2020. Available from: https://pj.jiho.jp/article/242437 (Accessed Jun 2020).

3 Institute for Health Metrics and Evaluation, "GBD Compare Data Visualization," 2018, http://vizhub.healthdata.org/gbd-compare.

4 Economist Intelligence Unit analysis of data in Personalised Medicine Coalition, *Personalized Medicine at FDA: A Progress Report & Outlook, [2019].*

Data will further reshape how clinical trials are conducted and healthcare is delivered.

This overview is by no means comprehensive but highlights that innovation in the life sciences is at an inflection point. Innovation, however, does not just happen organically: it requires a holistic policy and market access environment that supports basic science and product R&D. Countries that are able to take the lead in life science innovation will be able to make immense medical progress to address areas of high unmet need within their borders and beyond. Countries which do not take active steps to bolster their life science ecosystems will have to fall back on the hope that researchers in other countries will meet their needs.

This Economist Intelligence Unit study, sponsored by Pfizer, looks at how prepared Japan is to take a leading role in life sciences innovation. It compares the country's performance, strengths and weaknesses with those of the United States—the acknowledged global leader in the life sciences—as well as those of China and South Korea, two nearby countries making substantial investments in the field in recent years.

## Box 1: Defining innovation

Innovation in the life sciences can be considered either to be "radical" (fundamental advances in our understanding) or "incremental" (improvements on existing technology), and can take the form of products (e.g. vaccines or robots), services (e.g. tele-medicine or robotic surgery) or processes (e.g. DNA sequencing or randomized control trial methodology). Innovation covers a vast number of activities from landmark inventions like penicillin and X-rays, through to incremental innovations such as second-generation drugs with lower toxicity and 'super generics'.[5]

5 The Economist Intelligence Unit, 2016. "Innovation in life sciences: An emerging markets perspective."

# Chapter 1. Japan's life sciences sector and government policy

Japanese life sciences companies make a substantial contribution to the economy. In 2019, the value of output from Japan's biopharmaceutical firms alone came to US$62.4 bn, or about 1.3% of GDP. In 2018, meanwhile, the medical devices industry produced US$17.7 bn worth of goods.

This production largely continues to service the domestic market. According to OECD data, Japan accounted for only 0.93% of global pharmaceutical exports in 2018, putting it in 18th place internationally.[6] In 2019, it exported 11% of its pharmaceutical production, or US$6.7 bn worth of goods, but imported much more, US$20.4 bn. As for medical devices, in 2018, the country exported just over a third of its medical device production, US$6.0 bn, but again imported a far greater amount than it sent abroad, US$14.7 bn.[7]

In recent years, foreign markets have become more attractive, especially to bigger Japanese drug companies. Foreign sales by the 14 largest Japanese branded-drug companies rose from 39% of the overall total in 2012, to 49% to 2017.[8] Meanwhile, the two largest Japanese drug companies, Takeda and Astellas, made substantial foreign acquisitions in 2019.[9]

The strong domestic focus of the Japanese life sciences sector is no accident. It reflects a decades-long history of national governments using policy to shape these industries in ways that serve the country's perceived needs. As Japan began to rebuild after 1945, the government strongly protected the pharmaceutical sector and it grew by servicing domestic demand, largely by licensing foreign discoveries and, at most, incremental innovation of its own. That began to change in the 1980s when regulators started to slowly open the market to foreign firms. Amid this competition, Japanese companies began to develop a tradition of high-level R&D that continues to the present.[10] In the last decade alone, four Japanese researchers have won or shared Nobel prizes for discoveries in medical science and today various firms are at the forefront of research on plasma-based treatments for covid-19.

Given such a history, it is not surprising that a number of current policies are encouraging this highly strategic sector to focus on what the government sees as today's national priorities. High among the state's concerns is the desire to accelerate R&D across all industries. As Japan's 2019 Integrated Innovation Strategy puts it, "the greatest source of national competitiveness is innovation," while warning against the dangers

6 OECD "Table 64 - Trade balance and export market share: Pharmaceutical industry," *Main Science and Technology Indicators*, 2019.

7 Economist Intelligence Unit, "Pharma and biotech," *Japan: Healthcare 1st Quarter 2020*, 2020, http://www.eiu.com/industry/Healthcare/asia/japan/article/1959329379/pharma-and-biotech/2020-03-10; EIU calculations based on Japan Ministry of Health, Labour, and Welfare, "Summary of 2018 Annual Statistics of Pharmaceutical Industry Production Statistics," Tables 37, 42, and 46, https://www.mhlw.go.jp/topics/yakuji/2018/nenpo/

8 Tomoko Nagatani et al., "Change in the Japanese pharmaceutical market: Cradle of innovation or grave of corporate profits?" *McKinsey Insights*, 2018, https://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/change-in-the-japanese-pharmaceutical-market-cradle-of-innovation-or-grave-of-corporate-profits.

9 Economist Intelligence Unit, "Pharma and biotech," *Japan: Healthcare 1st Quarter 2020*, 2020, http://www.eiu.com/industry/Healthcare/asia/japan/article/1959329379/pharma-and-biotech/2020-03-10

10 Robert Neimeth, "Japan's Pharmaceutical Industry Postwar Evolution," Chapter 10 in Annetine Gelijns and Ethan Halm, eds., *The Changing Economics of Medical Technology*, 1991, https://www.ncbi.nlm.nih.gov/books/NBK234308/pdf/Bookshelf_NBK234308.pdf

of other countries being able to exercise "innovation hegemony" to Japan's detriment.[11]

Over the last decade, two broad, overlapping initiatives have created the context for policies around life sciences innovation: the so-called "Abenomics" reforms and efforts to create *Society 5.0.*

Abenomics, originally launched in 2012 after the election of Shinzo Abe as Prime Minister, was a multi-pronged effort to revive a stagnant Japanese economy. A key element was the deregulation and support of various sectors which were deemed to provide significant potential for growth through innovation. The pharmaceutical industry was among these.

Two key outcomes of this have been the adoption of the *Sakigake* (pioneer or charge ahead) strategy in 2014 and the creation of the Japan Agency for Medical Research and Development (AMED) in the following year. The Sakigake strategy sought to increase Japan's output of innovative medical products by supporting R&D. This included the streamlining of pharmaceutical, medical device and regenerative medicine approval, as well as expedited pricing and National Health Insurance reimbursement discussions and tax incentives for companies, in order to give patients earlier access to new medicines.[12]

AMED is an independent body under the Ministry of Health, Labour, and Welfare which oversees the medical R&D funding previously distributed separately by the ministries of Education, Health, and METI (Ministry of Economy, Trade, and Industry). Its aim is to provide coherent and focussed support for product development from earliest research to commercial release. Priority areas include general innovation of pharmaceuticals and medical devices as well as a particular focus on fields where the government sees a specific need or opportunity, such as regenerative and genomic medicine, along with research into cancer and rare disease.[13]

Helping Japan's transition to *Society 5.0* is a more recent policy goal introduced in 2016. The aim here is to combine the huge and growing amounts of data available from all sources with AI to promote higher quality of life and address longstanding challenges to humanity such as climate change. One particular goal is to create a better society for ageing individuals.[14]

This in turn has important implications for life sciences innovation, including deployment of the use of Big Data and AI to support drug and device development.[15] An important step in this direction was the entry intro effect of the *Jisedai Iryo-kiban Ho* (or Next Generation Medical Infrastructure Law) in 2018. The legislation, for the first time, allowed the large-scale anonymisation of patient records for use in medical research by academics, the public

11 Japan Cabinet Office, *Integrated Innovation Strategy*, 2019, https://www8.cao.go.jp/cstp/togo2019_honbun.pdf
12 Japan Ministry of Health, Labor and Welfare, *Strategy of SAKIGAKE*, 2014, https://www.mhlw.go.jp/english/policy/health-medical/pharmaceuticals/140729-01.html
13 Japan Agency for Medical Research and Development, "About AMED," https://www.amed.go.jp/en/aboutus/objectives_project.html
14 For further details, see Cabinet Office, "Strategy 5.0," https://www8.cao.go.jp/cstp/english/society5_0/index.html
15 Cabinet Office, "Examples of Creating New Value in the Fields of Healthcare and Caregiving(Society 5.0)," https://www8.cao.go.jp/cstp/english/society5_0/medical_e.html

sector, and private companies. Moreover, by 2020 the government intends to have created integrated regional databases bringing together information on tens of millions of anonymised individuals from healthcare providers, payers, and long-term care facilities. In the longer term, the *Society 5.0* policy specifically aims to promote the development of AI-enabled devices, particularly robots, across healthcare.[16]

While the Japanese government has instituted these plans, more needs to be done to improve the life sciences ecosystem. In particular, policy makers feel that the environment for pharmaceutical and device start-ups, which produce so many new products in other economies, is poor. As the government's 2019 Health Strategy put it: "Companies are becoming the main players in creating innovation [in this field], but in Japan, listing standards are strict, the supply of risk capital and the incubation function are weak, and the soil for developing them is not prepared."[17]

Accordingly, the government is redoubling its efforts in ways that combine Abenomics and *Society 5.0*-related policies. The 2019 Innovation Strategy outlines various human resource and data infrastructure development policies to strengthen the country's general R&D capacity. Meanwhile, the 2019 Health Strategy and its integrated medical R&D programme continue to support further research in AMED's priority areas and innovation into new fields of healthcare, such as prevention, all while using data more effectively and across fields rather than in silos.

16 Cabinet Office, "Examples of Creating New Value in the Fields of Healthcare and Caregiving(Society 5.0)," https://www8.cao.go.jp/cstp/english/society5_0/medical_e.html

17 https://www.kantei.go.jp/jp/singi/kenkouiryou/suisin/ketteisiryou/kakugi/r020327senryaku.pdf

# Chapter 2. Comparing life science innovation in Japan to the US, China, and Korea

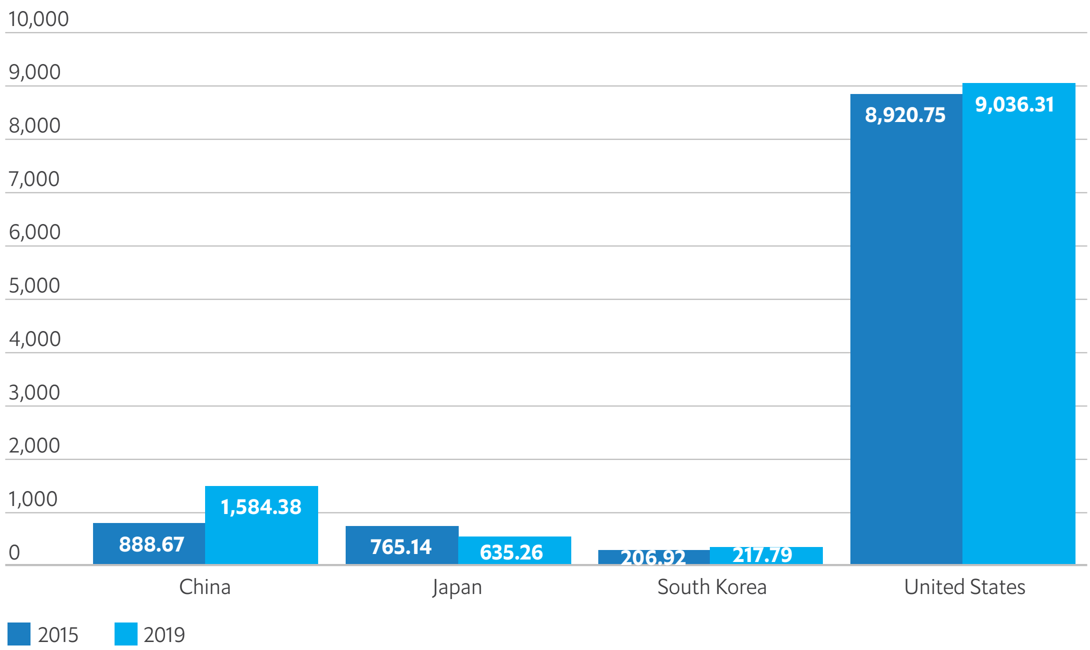
How valid are the concerns of Japanese policy makers and how well does the country's performance in life sciences R&D stand up against that of the US, China, and Korea?

There are three reasonable proxies for success in the life sciences to consider: high quality academic output, the number of new patents awarded, and the number of novel products brought to market. In the first two of these, Japan lags behind the US, the global leader in life sciences innovation. It also appears to be stagnating in comparison to its neighbours, China and South Korea.

The Nature Index tracks the geographic and institutional affiliations of authors of high-quality scientific journals. Where multiple individuals are listed as authors, it divides up credit evenly between them. It refers to the sum of all these papers and partial papers as the country's or institution's "share."

Looking solely at life sciences papers between 2015 and 2019, the US had by far the largest country share with a very stable output over time, finishing at 9,036.3 publications in 2019 (see Figure 1). South Korea's production was almost as stable, albeit at a much lower level, at 217.8 papers in the same year. The more

**Figure 1. Nature Index Output Share by Country - Life Sciences**




Source: "Annual Tables 2016 and 2020," *Nature Index*, 2020, https://www.natureindex.com/annual-tables/2016/country/life-sciences; https://www.natureindex.com/annual-tables/2020/country/life-sciences dramatic changes in life sciences academic output occurred in Japan and China. The former saw a drop in high-quality production of 17% between 2015 and 2019, while academic output in China rose by nearly 80% in the same period.

The declining volume of Japanese life sciences output is consistent with a commonly perceived stagnation over the last 10 years in the wake of lower government investment in basic research.[18] China's growth may have more complicated explanations. Investment in basic science has certainly increased, along with R&D as a whole, but China has also been criticised for the use of cash bonuses to encourage scientists to publish. In early 2020, the Chinese government directed institutions to stop offering these payments, so future output may decrease,[19] but it is likely to remain well above Japan's.

Given this history of paying for volume, rather than necessarily quality, of academic

**Table 1. IP5 Pharmaceutical Patent Families by Inventor Country of Residence and Priority Date**

| | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| **China** | 378.3 | 498.8 | 591.6 | 736.8 | 729.8 |
| **Japan** | 840.3 | 857.9 | 922.3 | 914.6 | 783.8 |
| **South Korea** | 409.5 | 467.5 | 480.9 | 549.6 | 463.2 |
| **United States** | 3,352.4 | 3,937.7 | 3,688.0 | 3,971.7 | 3,256.0 |

Source: OECD, "Patents Statistics," OECD.Stat Database, https://stats.oecd.org/

**Table 2. IP5 Medical Technology Patent Families by Inventor Country of Residence and Priority Date**

| | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| **China** | 396.1 | 609.5 | 719.5 | 912.0 | 833.9 |
| **Japan** | 3,330.3 | 3,192.2 | 3,739.3 | 3,765.6 | 3,377.2 |
| **South Korea** | 803.7 | 998.1 | 1,252.4 | 1,162.1 | 949.0 |
| **United States** | 4,874.7 | 5,580.0 | 4,862.5 | 5,107.2 | 4,408.3 |

Source: OECD, "Patents Statistics," OECD.Stat Database, https://stats.oecd.org/

18 N Philipps, "Japan faces science decline," *Nature*, 2017, https://www.nature.com/news/polopoly_fs/1.22847!/menu/main/topColumns/topLeftColumn/pdf/550310a1.pdf
19 M Mallapaty, "China bans cash rewards for publishing papers," *Nature*, 2020, https://www.nature.com/articles/d41586-020-00574-8

output, a more reliable measure of innovation may be the number of patents awarded. Tables 1 and 2 show the country of origin of individuals and organisations granted patents for a pharmaceutical or medical technology innovation by authorities in China, Japan, Korea, and the US between 2012 and 2016. In both fields, the US and Japan are seeing some variation from year to year but little long-term change. South Korea appears to be trending upward slowly, while China has seen the highest increase in patents awarded over this time period realising a decade-long strategy of investment in the life sciences and more recent evolution of the patent system. It is noteworthy, though, that in *per capita* terms, Japan is actually ahead of all the others for medical devices but is now behind South Korea for pharmaceutical patents.

For pharmaceutical innovation in particular, the real value comes not with patents but with drug approvals. Here, Japan remains a powerful player. The US is the largest health market in the world, making it attractive for companies with a new product to seek authority to sell there. In 2018 and 2019, the US Food and Drug Administration (FDA) approved 109 new drugs. Of these, 10 were developed in whole or part by Japanese firms, only one came from a Chinese company, and none from South Korea. This puts Japan far behind the United States, whose companies accounted for 60 new drugs during this period, but far ahead of its regional neighbours.

Perhaps more worrying for Japanese policy makers is the source of this innovation. More than two-thirds of the new US products approved by the FDA were from small businesses, most of which were relatively new biotechnology companies. All of Japan's products, however, came from large, established firms. Insofar as start-ups can be a driver of innovation, this does not appear to be occurring to any great degree in Japan's pharmaceutical industry. The average deal value (early stage to exit) for life science start-ups during the last financial year in China was US$175m. Part of this may reflect exuberance within China's booming biotech sector, but the country is seeing the growth of many high-value companies. The equivalent figures for the US and South Korea (US$30m and US$10m, respectively) are more restrained but still substantial. Japan's average, however, comes in at just $917,000. This may well reflect Japan's traditionally risk-averse business environment, but is likely compounded by challenges around co-location of academia and industry and technology transfer (see Chapter 3). Indeed, Japan's METI in recognising these limitations made several recommendations to encourage up-front investment in drug discovery including better communication and disclosures, and the creation of a biotech listing system similar to the US NASDAQ Biotechnology Index.[20]

In short, South Korea and China—which are making substantial efforts to bolster their life sciences ecosystems—are rapidly catching up with or even surpassing Japan on various metrics of innovation success including academic publications and pharmaceutical patents. Although Japan is ahead of its neighbours in drug approvals and the large Japanese pharmaceutical firms can still deliver new products, most signs suggest that the country's life sciences sector continues to stagnate noticeably.

20 Japan METI. "伊藤レポート2.0 ~バイオメディカル産業版~ 「バイオベンチャーと投資家の対話促進研究会」報告書", Available from: https://www.meti.go.jp/press/2019/07/20190718008/20190718008a.pdf (Accessed Jul 2020).

# Chapter 3. Comparing key innovation drivers within the life sciences ecosystem

A comparison of the drivers contributing innovative life sciences can help explain Japan's current performance compared with other countries. These drivers include human capital, funding for R&D, IP protection, technology transfer, and market dynamics.

## Human capital

Highly trained human resources are essential for effective innovation in the life sciences. Though data on how many people are working in R&D specifically within the life sciences sector are not available, figures for R&D across the economy can serve as a proxy. This data shows that Japan has average human capital capacity among our countries and is experiencing the slowest growth.

In 2017—the latest year for which data are available—in every sector of the economy, including business, government, and education, China had about 2.5 times the number of researchers as Japan. The US also had more than double the Japanese figure.[21] Part of this reflects the smaller Japanese population. However, in *per capita* terms, despite being well ahead of China and even 25% higher than the US, Japan's R&D workforce falls well behind that of South Korea.

It is important to note that other countries are increasing their human capital in research much faster than Japan. Between 2012 and 2017, the cumulative annual growth rate of full-time equivalent research workers was just 0.9% in Japan, but 2.3% in the US, 4.0% in South Korea, and 4.4% in China.

Looking at the rate at which countries are adding to academic expertise in the life sciences paints another mixed picture. Doctorates awarded for physical and biological sciences, mathematics, and statistics are the most detailed relevant figures. Along this metric, the US leads with

**Table 3. Researchers (Full Time Equivalent) employed in each economy**

| | Total | Per Million Population | CAGR 2012-2017 |
|---|---|---|---|
| **China** | 1,740,442 | 1,225 | 4.4% |
| **Japan** | 676,292 | 5,304 | 0.9% |
| **South Korea** | 383,100 | 7,498 | 4.0% |
| **US*** | 1,371,290 | 4,245 | 2.3% |

*US figures for 2016. Source: Economist Intelligence Unit calculations based on "Researchers (FTE) - Total" and "Researchers per million inhabitants (FTE)" UNESCO Institute for Statistics Database, http://data.uis.unesco.org/#

21 For this discussion, the US figures used are from 2016 because those for 2017 is unavailable.

16,466 doctorates awarded in 2016, the last year for which data are available. This number may slightly overstate the availability of new expertise to the American economy because it includes foreign, as well as domestic, recipients from US schools. Nevertheless, approximately 70% of foreign students who earn doctorates are still working in the US ten years later.[22] With this caveat, the US figure is far ahead of that for China (nearly 11,000 in 2015), and both countries greatly surpass the number of doctoral recipients at Japanese and South Korean institutions (2,316 and 1,861 respectively).[23]

More positively, the growth in doctorates awarded in Japan in recent years suggests progress is being made. In 2015, after a decade of steadily awarding about 1,500 doctorates per year, the Japanese figure jumped to over 2,300, where it remained in 2016. While this gives an overall growth rate of just 2.4% between 2000 and 2016, it suggests a 10% growth rate between 2011 and 2016.[24] In comparison, the number of US doctorates awarded grew by 2.5% per year between 2011 and 2016. South Korea saw steady 6.3% growth between 2012 and 2014, and in China, the equivalent figure rose by 2.7% up to 2015, after having more than quadrupled between 2000 and 2010.

The reasons for why Japan is falling behind in establishing a skilled life sciences workforce are complex and reflect various structural barriers to opportunity. As a result of staffing budget cuts, one-third of national universities do not fill tenured positions for professors after retirement but instead have shifted to employment of researchers on short-term contracts.[25] Moreover, the culture of life-long employment in Japan appears to remain a pervasive barrier. "The opportunity to change careers between sectors (academia-industry-public-venture capital) is very limited in Japan," says Toshio Fujimoto, general manager of Takeda's Shonan Health Innovation Park. "Career options for researchers are limited as a result. Education, as well as the human resources systems, needs to be reformed to accommodate career range."

Three clear possibilities exist for workforce enhancement, however. Firstly, under 15% of researchers in Japan are female: enabling more women to work in the life sciences will be essential for a country with a shrinking working population.[26] Similarly, upskilling is also a missed opportunity. As Isao Kamae, professor in the Graduate School of Public Policy at the University of Tokyo, points out, "In addition to more PhD-degree holders for research in life sciences, more skilled managers with MBAs are needed to support innovation and bridge the transition from research to a product." Finally, the number of international students and foreign researchers that Japan attracts lags behind global peer

22 National Science Board, Science and Engineering Indicators 2020, 2020, https://ncses.nsf.gov/pubs/nsb20198/immigration-and-the-s-e-workforce#stay-rates-of-u-s-s-e-doctorate-recipients

23 "S&E doctoral degrees by selected region, country, or economy and field: 2000–16," Table S2-16, National Science Board, *Science and Engineering Indicators 2020*, 2020, https://ncses.nsf.gov/pubs/nsb20197/data

24 "S&E doctoral degrees by selected region, country, or economy and field: 2000–16," Table S2-16, National Science Board, Science and Engineering Indicators 2020, 2020, https://ncses.nsf.gov/pubs/nsb20197/data

25 Center for Research and Development Strategy, Japan Science and Technology. "Medical research and development platforms." Available from: https://www.jst.go.jp/crds/pdf/en/CRDS-FY2017-RR-01_EN.pdf (Accessed Jan 2020).

26 Noriko Osumi, "Japan's woman problem," *Nature Index*, 8 March 2018, https://www.natureindex.com/news-blog/japans-woman-problem

such as the US. In 2017, Japan's foreign research workforce was only 5.6%,[27] compared with over half (51%) of postdocs in academia and 28% of full-time science and engineering faculty members in the US in 2015.[28] This may be attributed to language and cultural barriers, but also Japan's research environment and complex immigration requirements.

## Funding of R&D

Along with people, effective R&D in the life sciences requires financial resources. The sector in the US is by far the best financed, with US$ 179bn total investment in the last financial year. This is followed closely by China with US$ 100bn. Japan trails behind at US$ 18.1bn, while South Korea has by far the lowest total investment amount, at US$ 1.3bn.

Comparable international data on changes to investment in life sciences R&D over time are not available, but the OECD does provide figures for business investment in the pharmaceutical industry (Table 4). Overall, Japan is still a common location for such R&D investment, with the third highest spending within the country. On the other hand, this outlay actually declined between 2013 and 2018 at an average rate of around 1% per year. Conversely, between 2013 and 2017 (the latest years for which the OECD has data), US pharmaceutical R&D outlay rose by 6% per year. In the same time period, China spending rose by 11%, overtaking Japan in 2016 in terms of total investment in this area. Finally, in the years for which data are available from South Korea, the average rate of increase was 12%.

The European Union's *Industrial R&D Investment Scoreboard* looks at business R&D from a different angle, giving the aggregate figure which companies headquartered in the same country spend anywhere in the world. It includes the firms making the largest 2,500 R&D investments in aggregate—in practice all

**Table 4. Business enterprise investment in pharmaceutical R&D**

| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | CAGR available years |
|---|---|---|---|---|---|---|---|
| **China** | 9,838 | 11,165 | 12,755 | 14,117 | 15,143 | - | 11% |
| **Japan** | 14,186 | 14,510 | 14,091 | 12,811 | 13,905 | 13,428 | -1% |
| **South Korea** | 1,246 | 1,287 | 1,576 | - | - | - | 12% |
| **United States** | 52,426 | 56,612 | 58,675 | 64,628 | 66,202 | - | 6% |

Source: OECD, "BERD performed in the pharmaceutical industry (current PPP $)," OECD.Stat Database, https://stats.oecd.org/ and Economist Intelligence Unit calculations.

27 Ministry of Education, Culture, Sports, Science and Technology – Japan. "国際研究交流の概況 ( 平成29 年度 の状況". Available from: https://www.mext.go.jp/content/20200117-mxt_kagkoku-000004191_02.pdf (Accessed Jul 2020).

28 US National Science Board. "Science & Engineering Indicators 2018". Available from: https://www.nsf.gov/nsb/publications/2018/foreign-born-one-pager.pdf (Accessed Jul 2020).

**Table 5. CAGR of life science R&D and GDP**

| | CAGR Life Science R&D 2016-2018/19 | CAGR GDP 2016-2018 |
|---|---|---|
| **China** | 41% | 7% |
| **Japan** | 3% | 1% |
| **South Korea** | 9% | 3% |
| **US** | 6% | 2% |

Sources: Economist Intelligence Unit calculations based on The 2019 EU Industrial R&D Investment Scoreboard, https://iri.jrc.ec.europa.eu/scoreboard/2019-eu-industrial-rd-investment-scoreboard#dialog-node-5658, The 2016 EU Industrial R&D Investment Scoreboard, https://iri.jrc.ec.europa.eu/scoreboard/2016-eu-industrial-rd-investment-scoreboard#dialog-node-5625; and Economist Intelligence Unit.

which spend €30m or more per year on R&D of any kind. It also breaks down this spending by industry, including funds going into both health equipment and biopharmaceutical R&D.

In all of the countries in our study, the CAGR of combined health equipment and biopharmaceutical R&D by national firms between 2015 and 2018/19 grew faster than GDP (Table 5). Nevertheless, the Japanese figure was by far the lowest. Its 3% average annual increase was half of that seen in the US and a third of South Korea's. Meanwhile, China's biotech boom has brought an astonishing 41% more spending per year on R&D from its companies.

Although China is starting to pass Japan in this area, looking beyond the life sciences to the economy as a whole reveals one potential ongoing weakness of Chinese R&D. Overall, combining business, government, and higher education R&D in every field in China, only 6% is basic research, compared to 13% in Japan, 14% in South Korea, and 17% in the US.[29] Today's biotechnology and AI advances rely on blue sky research conducted not that many years ago.

## IP protection

The presence of strong IP protection is necessary for a successful life sciences industry: a report by the US Chamber of Commerce on its International IP index estimates that economies with strong IP benefit from "fourteen times more clinical trial activities and twelve times more clinical research on biologic therapies."[30]

In the 2020 version of that index, which measures 50 indicators relevant to IP protection, the US comes first, with a score of 95%, but Japan is not far behind at 90%.

29 OECD "GERD - Basic research %," OECD Stat database, https://stats.oecd.org/
30 Source: US Chamber of Commerce, *Art of the Possible: US Chamber International IP Index*, 2020, https://www.theglobalipcenter.com/wp-content/uploads/2020/02/GIPC_IP_Index_2020_FullReport.pdf;

### Table 6. International IP Index Overall and Enforcement Domain Scores

| | 2020 | | 2015 | |
|---|---|---|---|---|
| | Overall | Enforcement | Overall | Enforcement |
| **China** | 51% | 37% | 41% | 17% |
| **Japan** | 90% | 88% | 78% | 86% |
| **South Korea** | 82% | 76% | 78% | 75% |
| **US** | 95% | 95% | 95% | 88% |

Source: US Chamber of Commerce, Art of the Possible: US Chamber International IP Index, 2020, https://www.theglobalipcenter.com/wp-content/uploads/2020/02/GIPC_IP_Index_2020_FullReport.pdf; US Chamber of Commerce, Unlimited Protection: GIPC International IP Index, 2015, https://www.theglobalipcenter.com/wp-content/uploads/2017/04/GIPC_Index_Report2015.pdf

South Korea received a score of 82%, and, among our study countries, China is the outlier at 51%. When it comes to broad enforcement of rights—without which regulations are meaningless in practice—the US, Japan, and South Korea receive similar scores, but China does much worse, scoring only 37% of possible points.

Although these differences remain pronounced, in some ways China has begun to close the gap over the last five years. In particular, while its enforcement score leaves much to be desired, it has substantially improved since the 2015 index (Table 6).

Finally, the index assesses two specific areas of direct relevance to pharmaceutical patents: the existence and enforcement of regulations to deal with disputes over the introduction of a generic or biosimilar to the market; and the ability to lengthen pharmaceutical patents in recognition of the long research time involved before commercialisation. The US gets full marks on both. Japan and South Korea, however, while allowing patent term restoration for pharmaceuticals get only half marks on dispute resolution. China does poorly in both areas, providing no term extensions and scoring only 25% for dispute resolution. Once again, although China clearly lags, it has also seen the most improvement since 2015, when it also scored zero for dispute resolution.[31]

Given Japan's strong and steadily improving record on IP protection, ways to improve are more limited. Nevertheless, the index highlighted gaps for Japan's pharmaceutical-related patent enforcement and resolution mechanism. In light of the government's

31 Source: US Chamber of Commerce, *Art of the Possible: US Chamber International IP Index*, 2020, https://www.theglobalipcenter.com/wp-content/uploads/2020/02/GIPC_IP_Index_2020_FullReport.pdf; US Chamber of Commerce, *Unlimited Protection: GIPC International IP Index*, 2015, https://www.theglobalipcenter.com/wp-content/uploads/2017/04/GIPC_Index_Report2015.pdf

strong policy push to increase the use of generic drugs and biosimilars, innovators would benefit from more predictable legal protections, and increased transparency around IP information. This is in contrast to, for example the US, where the FDA publishes in the public domain the *Orange Book* which clearly spells out therapeutic equivalence.

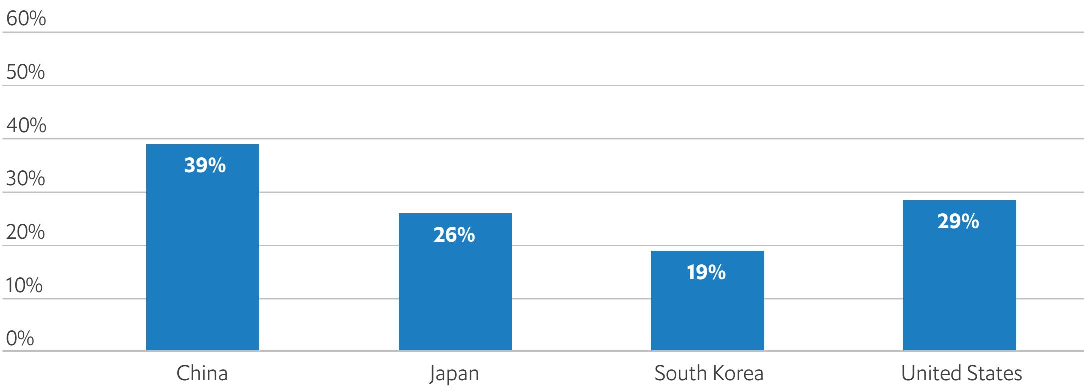
## Technology transfer and commercialisation

Companies are only one part of the life sciences ecosystem. Institutes of higher education and government facilities are common sources of pharmaceutical and medical device discoveries: as Figure 2 shows, between 19% and 39% of researchers operate outside the private sector in the four study countries. Harnessing the talents of these researchers in order to make the benefits available to the public, however, is not as straightforward as commercialisation of R&D within a single enterprise.

A common route for academic or public-sector innovations to come to market is through public-private collaboration. The World Economic Forum (WEF), in its regular surveys for its *Global Competitiveness Report*, asks "In your country, to what extent do business and universities collaborate on R&D?". On a scale of one to seven, Americans rank the US at 5.5. Japanese respondents are less positive, giving a score of 4.7, with both South Korea and China tied at 4.4.[32]

Meanwhile, the 2020 US Chamber of Commerce *International IP Index* measures

**Figure 2. Percentage of researchers in country working for public sector R&D, 2017**




Source: Economist Intelligence Unit calculations based on "Researchers (FTE) - Total" and "Researchers (FTE) - Business enterprise" UNESCO Institute for Statistics Database, http://data.uis.unesco.org/#

32 "University-industry collaboration in R&D," WEF 2020 Global Competitiveness Report database, http://reports.weforum.org/global-competitiveness-report-2019/competitiveness-rankings/#series=EOSQ072

each year the extent of formal legal barriers or government practices to technology transfer and commercialisation of publicly-supported research (with a higher score showing fewer impediments). Here the US and Japan tie for first place, getting full marks. South Korea and China come next with 75%. The Chinese score, however, gives the country the benefit of the doubt that it will enforce substantial legal improvements in 2019. Whether this occurs will become apparent in due course.[33]

The Japanese legal system, then, and the perceived level of collaboration between university and industry seem conducive to technology transfer in Japan. The government has also definitely been encouraging university start-ups: in 2013 it gave the country's four largest academic institutions a total of nearly $1bn to use as venture capital. Nevertheless, Japan still lags behind. Just 3.9% of new university-developed technologies in the country per year are licensed to start-ups, far below the 17.1% in the US.[34]

The issues may well be cultural rather than regulatory. The Global Entrepreneurship Monitor Consortium conducts annual national surveys on levels of entrepreneurship in most countries worldwide. In 2019, Japan had the smallest percentage of people in the world who saw the opportunity to start their own business, and also the lowest level in our four countries of start-ups operating for less than five years.[35] These attitudes carry over into the life sciences. As a 2019 article in *Nature* put it, "[t]he accepted wisdom is that scientists in Japan are either respected or rich; not both."[36]

Therefore, the solution may not involve simply funding start-ups but changing attitudes as well. Currently, for example, entrepreneurship education in Japanese universities is considered weak with insufficient linkage between theory and practice.[37]

Existing businesses have a role to play in building up stronger partnerships with higher education as well. Although the WEF's survey respondents may see good industry-university collaboration in Japan, this does not translate into funding practice. In 2018, Japanese businesses funded only 3.3% of higher education R&D, compared to 5.4% in the US, 14.3% in Korea and 26.6% in China.[38]

Efforts to increase start-up activity in the life sciences in Japan over the last decade have made progress, but the underlying cultural changes needed to support this activity remain a work in progress.

## Market dynamics and health policy

Ultimately, innovation and sales form either a virtuous or vicious circle. More of one can lead to more of the other, but a decline

33 Source: US Chamber of Commerce, *Art of the Possible: US Chamber International IP Index*, 2020, https://www.theglobalipcenter.com/wp-content/uploads/2020/02/GIPC_IP_Index_2020_FullReport.pdf;

34 Smriti Malapati, "Japan's start-up gulf," *Nature*, 20 March 2019, https://www.nature.com/articles/d41586-019-00833-3

35 Global Entrepreneurship Monitor, *2019/2020 Global Report*, 2020, https://www.gemconsortium.org/report/gem-2019-2020-global-report

36 Smriti Malapati, "Japan's start-up gulf," *Nature*, 20 March 2019, https://www.nature.com/articles/d41586-019-00833-3

37 S Birchley, "Exploring Entrepreneurship Education in Japan," *INTED 2018 Proceedings*, 2018, https://library.iated.org/view/BIRCHLEY2018EXP; Katsushiro Suzuki, "Entrepreneurship Education Based on Design Thinking and Technology Commercialization in Japanese Universities," *2016 5th IIAI International Congress on Advanced Applied Informatics (IIAI-AAI)*, 2016, https://ieeexplore.ieee.org/document/7557717.

38 "Percentage of HERD financed by the business sector," OECD.Stat database, Main Science and Technology Indicators, https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB

in one will make it harder for the other to flourish. Thus, market size does much to shape the environment for life sciences innovation. Although it can have potentially global markets, in practice a large proportion of sales—in pharmaceuticals at least—are domestic. As noted earlier, this is particularly the case in Japan.

A look at spending on pharmaceuticals suggests that the size of Japan's drug market has become a source of strength for the country's manufacturers and therefore, potentially, innovators. According to Economist Intelligence Unit data, for most of the last decade US and South Korea sales have hovered at around 2% of their respective national GDPs and those in China at about 0.8%. In Japan—the world's second largest pharmaceutical market—drug sales have risen steadily from 1.5% of GDP in 2010 to 2.7% in 2018.

The Economist Intelligence Unit, however, projects that while the pharmaceutical market's share of GDP in Japan will stay largely the same until 2024, those in the US and China will both increase slightly, to 2.1% and 0.9% respectively. This represents a substantial pool of money in such large economies. South Korea's figure, meanwhile, is expected to hit 2.5%. Once again, one of Japan's current advantages may be diminishing.

Ultimately, in the three Asian countries in this study, governments largely shape the profitability of those markets. In doing so, current policies are seeking to reward innovation or, in some cases, penalise a lack of it. In South Korea, the Economist Intelligence Unit expects that continued government pressure will increase the use of generic pharmaceuticals within the health system. At the same time, the country's "same ingredient, same price" policy is meant to widen the gap between original drugs and generic ones.

China, meanwhile, introduced several pro-generic reforms in 2018 designed to increase their use, and through a system of negotiated bulk purchase drove down the average price of such medications by 53% on average in the 2020 round of bidding. On the other hand, its inclusion of several new anti-cancer drugs on the National Essential Drug List has shown that it is ready to reward innovative products to some extent.

In Japan, over the last decade, the government has sent mixed messages to the market about innovation. On the positive side, in 2011, it began to address the so-called "drug-lag", the time it took for new pharmaceutical products to receive reimbursement after their approval as safe and effective. Over the succeeding three years, the time involved dropped from 660 days in 2011 to an average of 60.[39]

Meanwhile, the *Sakigake* policy was designed to increase the reward for innovative products. Similarly, the government put in place a Price Maintenance Premium (PMP) policy, which exempted certain innovative drugs from price reviews during their periods of exclusivity.

39 Kally Wong, "Market Access in Japan," chapter 9, in Güvenç Koçkaya and Albert Wertheimer, eds., Pharmaceutical Market Access in Developed Markets, 2018.

Other signals, however, seem less supportive of innovation as the government seeks to reduce healthcare spending. To begin with, it is seeking to raise the proportion of generic drugs in overall pharmaceutical purchases in the country to 80% by the end of 2020. This alone need not be inconsistent with support of new products, but in late 2017 the government additionally introduced greater restrictions on which medicines qualified for inclusion under the PMP. Meanwhile, it has been imposing substantial annual price cuts in recent years to prescription drugs and is switching toward more frequent price reviews especially for newer drugs.[40]

In April 2019, following a three-year pilot programme, Japan also put in place its first Health Technology Assessment (HTA) process, which is run by the Centre for Outcomes Research and Economic Evaluation for Health.[41] While still a work in progress, notable here is that this is the world's first HTA that seeks to introduce an algorithm to link price to incremental cost-effectiveness compared to earlier available treatments. While this will likely keep down the prices of incremental improvements, the approach also allows for greater reward of larger innovations.[42]

Concerns raised around this new system include the limited opportunity for manufacturers to negotiate prices after they've been set, which precludes consideration of risk-sharing or price-volume benefits, and an overall lack of transparency, consultation or understanding of HTA among parties.[43] Notably, the reliance on incremental cost effectiveness ratios alone, and not a broader definition of value, is not aligned with

**Table 7. Combined government-funding of, and tax incentives for, business enterprise research as a percentage of BERD**

| | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| **China** | 8.19 | 7.97 | 8.39 | 7.73 | 7.61 |
| **Japan** | 5.98 | 5.93 | 5.55 | 5.4 | 5.75 |
| **South Korea** | 12.09 | 11.15 | 10.95 | 8.35 | 8.63 |
| **US** | 12.66 | 11.52 | N/A | N/A | N/A |

Source: OECD, "R&D tax expenditure and direct government funding of R&D," OECD.Stat Database, https://stats.oecd.org/ and Economist Intelligence Unit calculations

40 Economist Intelligence Unit, "Japan Healthcare," March 2020, http://www.eiu.com/industry/healthcare/asia/japan; "Japan's Perilous New Pricing Policy," *Eye for Pharma*, April 2018.

41 Gordan Liu, *et al*,"The development of health technology assessment in Asia: Current status and future trends," *Value in Health Regional Issues*, 2020.

42 Isao Kamae *et al*, "Health technology assessment in Japan: a work in progress," *Journal of Medical Economics*, 2019, https://www.tandfonline.com/doi/full/10.1080/13696998.2020.1716775

43 Ibid Kamae, *et al.*

good practices for HTA as recommended by The Professional Society for Health Economics and Outcomes Research (ISPOR).[44]

The issue is not the existence of an HTA *per se*. The Japanese government, though, needs to make sure that the way its HTA works in practice really does reward innovation and is not simply a crude price management tool.

Another way that governments seek to encourage life sciences innovation is more direct than shaping markets—the use of subsidies and tax incentives to encourage research. Below are the figures for government support for R&D as a whole. While the situation of the life sciences may differ—comparable data are not available—in general the Japanese government is less generous toward R&D (see Table 7).

Government generosity in this area has also been declining across all four countries, which may provide Japan a chance to catch up to its peers at a lower cost than would have been the case previously.

44 Ibid Kamae, *et al*.; DN Lakdawala, *et al*, "Defining elements of value in health care—a health economics approach: An ISPOR special task force report," 2018

# Conclusion: Opportunities to improve the Japanese life sciences ecosystem

Japan has a tradition of strength in the life sciences and many strong contributing drivers for innovation in this field. Like any country, however, areas for improvement exist. This study suggests that policy makers and business leaders may wish to consider the following:

**Maintaining and expanding a strong workforce:** Japan's human capital for R&D is growing more slowly than those of the other states in this study: Of our four countries, Japan has under half of the number of R&D full time research equivalents as China and the United States. To address this challenge, Japan may wish to bring more women into the R&D workforce—they currently make up less than 15%—and look at reskilling existing employees and enticing foreign researchers to Japan.

**Investing in R&D and incentivising business enterprise:** Japan's stagnating spending levels over the last 10 years are in uncomfortable contrast to rising R&D not only in fast growing neighbouring economies but also in the US. Company spending represents the large bulk of R&D investment and Japan's BERD in the pharmaceutical sector is the world's third largest. In order to encourage a higher level of life-sciences output—including high-quality journal articles, new patents and novel products brought to market—increased government spending in basic research is necessary. In addition, it might be wise for Japan to raise the cumulative government incentives for BERD spending to the same level as those in China, South Korea, and the US.

**Preserving strong IP protection while enhancing enforcement and transparency:** Japan already has effective IP protection in most areas, but the US Chamber of Commerce Global IP Index sees some weaknesses in protection of pharmaceutical companies and a need to strengthen regulations dealing with disputes over the introduction of generic or biosimilar products. Coupled with a lack of public-domain information around IP compared with the US, Japan would be wise to ensure better transparency and predictability to encourage innovators.

**Increasing encouragement of technology transfer and commercialisation:** Despite notable examples of policy support, the start-up sector in the life sciences remains weaker in Japan than elsewhere. The government should not abandon its efforts in this area but accept that it may take a long time to bring about the necessary cultural change. Improving understanding of entrepreneurship within the country, especially at universities could help.

**Ensuring health policies are consistent with those promoting new products:** In Japan, the government has sent mixed messages to the market about innovation over the last decade. The size of the pharmaceutical market is currently an asset for innovation, and earlier policies were designed to encourage and reward innovative products. Meanwhile, the Japanese government has continued to press to keep prices down via more frequent price reviews, and encourage the use of generics and biosimilars in an attempt to make the system sustainable. Japan should now consider a policy focus that fosters a more predictable environment and the use of new pricing schemes and financing models for innovative, transformative medicines and medical devices.

# Appendix: Scorecard methodology and country scoring

| Domain | Sub Domain | Indicator | Question |
|---|---|---|---|
| **1. Finance and Support** | 1.1 Investment Landscape | 1.1.1 Investment Amount | What is the total amount of funding the life sciences ecosystem received through investment in the last financial year |
| | 1.2 Financial Incentives | 1.2.1 Govt. Incentives | Are there any govt incentives/schemes/programs for innovation in the country |
| | 1.2 Financial Incentives | 1.2.2 Tax Incentives | Are there any tax subsidies for innovation in the country |
| | 1.3 Legal Environment | 1.3.1 Intellectual Property Regulations | Does the country have clear guidelines to safeguard IP rights |
| | 1.4 Regulatory and Approval Process | 1.4.1 Existence of Regulatory Process | Are there clear guidelines for the regulatory and approval process |
| | 1.4 Regulatory and Approval Process | 1.4.2 Existence of Regulatory Process | Do the guidelines specify timelimits for different stages or the whole process? |
| **2. Infrastructure** | 2.1 R&D Expenditure | 2.1.1 Public Spending on R&D | What is the percentage of GDP spent on R&D in the country |
| | 2.2. R&D Facilities | 2.2.1 Focussed R&D facilities in the country | How many a) science parks and b) biotech clusters or equivalents exist in the country |
| | 2.3 Research Agencies | 2.3.1 Public funded research agencies or programs | What is the number of public funded research agencies or programs in the country |
| | 2.4 IT Infrastructure | 2.4.1 Data Sharing | Does the country have data sharing policies that foster innovation |
| | 2.4 IT Infrastructure | 2.4.2 Digital Health | Does the country have polices on digital health technology that foster or encourage innovation |
| **3. Knowledge** | 3.1 Knowledge Workers | 3.1.1 Number of knowledge workers | What is the number of doctoral graduates in a year in the country |
| | 3.1 Knowledge Workers | 3.1.1 Number of knowledge workers | What is the number of graduates with tertiary education in a year in the country |
| | 3.2 Knowledge Formation | 3.2.1 Relevant Education | What is the number of relevant university courses |
| **4. Market** | 4.1 Domestic Demand | 4.1.1 Purchasing power | What is the purchasing power/capita of the country |
| | 4.2 Burden of Disease | 4.2.1 Expenditure on Disease | What are the top 3 most expensive conditions in the country to treat |
| **5. Economic Output** | 5.1 Commercialisation | 5.1.1 Average deal value | What is the average deal value (early stage to exit) for life science startups for the last FY in the country |
| | 5.1 Commercialisation | 5.1.2 Number of Exits | Exit deals form what percentage of total deals made for life sc startups |
| **6. Intellectual Output** | 6.1 Patents and Licenses | 6.1.1 Number of patents | What is the number of patents granted in last 3 years in the life sc industry |
| | 6.2 Publications | 6.2.1 Number of publications | What is the number of International publications from top 3 universities in last year |
| | 6.3 Clinical Trials | 6.3.1 Number of Clinical Trials | What is the number of clinical trials ongoing in last 3 years in the country |

| Domain | Scoring System | South Korea | US | China | Japan |
|---|---|---|---|---|---|
| **1. Finance and Support** | Quantitative | $1.3bn | $179bn | $100bn | Public investment (2016): US$2.6bn<br>Private investment (2018): US$15.5bn |
| | "Yes = 1 No = 0" | 1 | 1 | 1 | 1 |
| | "Yes = 1 No = 0" | 1 | 1 | 1 | 1 |
| | "Yes = 1 No = 0" | 1 | 1 | 1 | 1 |
| | "Yes = 1 No = 0" | 1 | 1 | 1 | 1 |
| | "Yes = 1 No = 0" | 1 | 1 | 1 | 0 |
| **2. Infrastructure** | Quantitative | 4.81% | 0.28% | 2.19% | 3.56% |
| | Quantitative | 25 | "a)72<br>b)Data not available" | 574 | 34 |
| | Quantitative | 25 | 46 | 3306 | 1101 |
| | "Yes = 1 No = 0" | 1 | 1 | 1 | 1 |
| | "Yes = 1 No = 0" | 1 | 1 | 1 | 1 |
| **3. Knowledge** | Quantitative | 14,316 | 71,042 | 56,500 | 15,674 |
| | Quantitative | 359,362 | 1,958,757 | 604,400 | 562,485 |
| | Quantitative | 1,017 | No data available | No data available | No data available |
| **4. Market** | Quantitative | 46,450 PPP Intl $ | 67430 PPP Intl $ | 19,500 PPP Intl $ | 46,830 PPP Intl $ |
| | Qualitative | Hypertension, diabetes, chronic renal failure | Diabetes, ischemic heart disease, low back and neck pain | Cardiovascular disease, respiratory disease, cancer | Cardiovascular disease, cancer and musculoskeletal & connective tissue disorders |
| **5. Economic Output** | Quantitative | $10m | $30m | $175m | $917,000 |
| | Quantitative | 13.20% | Data not available | Data not available | Data not available |
| **6. Intellectual Output** | Quantitative | 15,994 | 283431.1 | 37,988 | 62,444 |
| | Quantitative | 1,146 | 5,873 | 1,271 | 2198 |
| | Quantitative | 1,965 | 87966 | 7,011 | 2225 |

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