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FROM LAB TO JAB

*Improving Asia and the Pacific's Readiness
to Produce and Deliver Vaccines*



Edited by Rupa Chanda, Pralok Gupta, and Matthias Helble



From Lab to Jab: Improving Asia and the Pacific's Readiness to Produce and Deliver Vaccines

Edited by

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Vaccine Research and Development in Asia and the Pacific: Strengthening Partnerships among Actors at the Domestic and Regional Levels

Antonio Postigo

3.1 Introduction

Economic growth in most countries in Asia and the Pacific in the past 2 decades has contributed to slowing the spread of most infectious diseases, including neglected and newly emerging infectious diseases. At the same time, increasing urbanization, food insecurity, and/or political instability have worked in the opposite direction. While many neglected tropical diseases (e.g., malaria, typhoid fever, schistosomiasis, leishmaniasis, rabies) have been declining in Asia and the Pacific in recent decades, others (e.g., dengue, echinococcosis) have increased (Hotez 2020).

The *Sixty-Fifth World Health Assembly* in May 2012 endorsed the *Global Vaccine Action Plan 2011–2020*, which declared the 2010s the *Decade of Vaccines* with the goal of a world in which all individuals and communities enjoy lives free from preventable diseases through vaccines (WHO 2013). The importance of research and development (R&D) in biomedical and health-care innovation has always been widely recognized and further heightened by COVID-19, the disease caused by SARS-CoV-2. Developing strong vaccine R&D capacity is essential to achieving Goal 3 of the Sustainable Development Goals (SDGs) (“Ensure healthy lives and promote well-being for all at all ages”) and other SDGs related to healthy people and populations. Specifically concerning SDG targets 3.3 and 9.5, the United Nations General Assembly adopted

resolution 71/313, which includes several indicators that highlight the importance of ending communicable diseases and enhancing R&D through investment and capacity building (Table 3.1).

Table 3.1: Vaccines and the Sustainable Development Goals

Sustainable Development Goals	Targets	Indicators
Goal 3: Ensure healthy lives and promote well-being for all at all ages	3.3: By 2030, end the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases, and other communicable diseases	3.3.1 Number of new HIV infections per 1,000 uninfected population, by sex, age, and key populations
		3.3.2 Tuberculosis incidence per 1,000 population
		3.3.3 Malaria incidence per 1,000 population
		3.3.4 Hepatitis B incidence per 100,000 population
		3.3.5 Number of people requiring interventions against neglected tropical diseases
Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation	9.5: Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending	9.5.1 Research and development expenditure as a proportion of gross domestic product
		9.5.2 Researchers (in full-time equivalent) per million inhabitants

Source: United Nations Department of Economic and Social Affairs (2018).

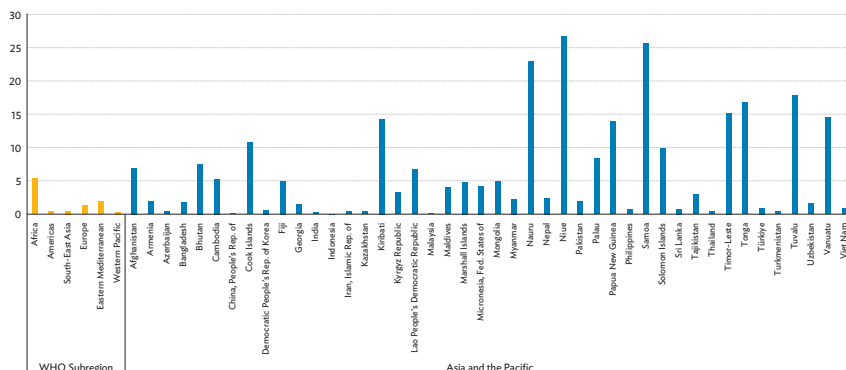
3.2 Main Indicators in the Biomedical and Vaccine R&D in Asia and the Pacific

3.2.1 R&D Input Indicators: Expenditures and Human Resources in Vaccine and Biomedical Research

In this chapter, Asia and the Pacific refers to the region comprising 49 of the 53 full members of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). France, the Netherlands, the United Kingdom, and the United States, although full members of ESCAP, are not considered part of the “Asia and the Pacific economies” group in most of the figures and tables within this chapter. Economic diversity within the ESCAP region is also reflected in its health indicators as well as in R&D investment for biomedical research. More than 80% of ESCAP members are recipients of official development assistance for medical research and basic health sectors (SDG indicator 3.b.2) (Figure 3.1). Of all World Health Organization (WHO) regions, the Western Pacific has the highest per capita average for indicator 3.b.2. At the same time, Asia and the Pacific accounts for the largest share of global R&D spending. The United Nations Educational, Scientific and Cultural Organization (UNESCO) East and Southeast Asia region alone—led by the People’s Republic of China (PRC), Japan, and the Republic of Korea—represents 40.4% of global R&D expenditures, followed by North America (27.4%) and the European Union (18.7%) (Figure 3.2) (UNESCO 2021; UIS website). Four ESCAP members are among the world’s top 15 economies with the highest R&D spending as a proportion of gross domestic product (GDP) (SDG indicator 9.5.1): the Republic of Korea (4.5%), Taipei, China (3.3%), Japan (3.2%), and the PRC (2.1%). For instance, they are ahead of the corresponding figure in the United Kingdom and the average in Europe Table 3.2 (UIS website; WHO Global Observatory on Health R&D; UNESCO 2021). Health R&D as a share of GDP in Singapore (0.37%) and the Republic of Korea (0.21%) is higher than in other high-income countries with a strong and historical long-standing biomedical sector such as the United Kingdom (0.13%) (WHO Global Observatory on Health R&D).

In economies in Asia and the Pacific with total R&D spending above 0.5% of GDP, the private sector tends to be a major, often the largest, contributor (Table 3.2). For instance, in 2018, businesses funded more than three-quarters of all R&D expenditures in the Republic of Korea (80.5%), Thailand (80.0%), Japan (79.5%), and the PRC (77.5%) (Table 3.2 and section 3.3) (UNESCO 2021; UIS website). However, public funding of R&D is higher than private sector spending on R&D in India and the Islamic Republic of Iran, which are also among the countries spending more than 0.5% of GDP on R&D (UNESCO 2021; UN DESA website; UIS website). While basic and preclinical research previously was

**Figure 3.1: Total Net Official Development Assistance
to Medical Research and Basic Health Sectors per Capita
(\$)**

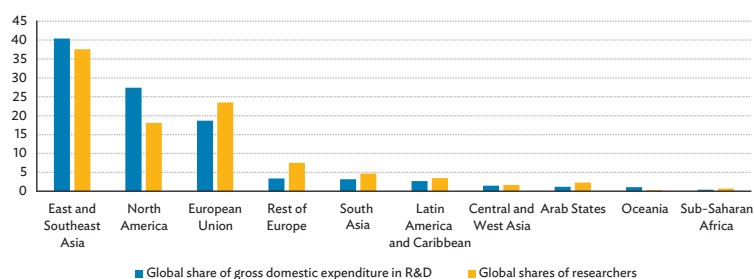


WHO = World Health Organization.

Note: Data are by recipient country (where available) and for 2019 (or latest year available).

Source: World Health Organization. Global Health Observatory. <https://www.who.int/data/gho>.

**Figure 3.2: Global Share of Gross Domestic
Expenditure in R&D, 2018
(%)**



R&D = research and development.

Source: United Nations Educational, Scientific and Cultural Organization (2021).

Table 3.2: R&D Expenditure as a Share of Gross Domestic Product by Sector of Performance, 2018
(%)

	Total R&D	Government R&D	Business Enterprise R&D	Private Nonprofit R&D
Other high-income countries with advanced health and biomedical research sectors				
Germany	3.00			
United Kingdom	1.70			
United States	2.8 ^c	0.29	2.06	0.12
Asia and the Pacific				
Armenia	0.18	0.16		N/A
Australia	1.87 ^c	0.19 ^c	1.00 ^c	0.06 ^c
Azerbaijan	0.18	0.16	0.01	N/A
Brunei Darussalam	0.27	N/A	N/A	N/A
Cambodia	N/A	N/A	0.02 ^a	0.04 ^a
China, People's Rep. of	2.14	0.32	1.66	N/A
Georgia	0.28	N/A	N/A	N/A
Hong Kong, China	0.80 ^c	0.04	0.39	N/A
India	0.65	0.37	0.24	0.03 ^c
Indonesia	0.22	0.16	0.02	0.01 ^c
Iran	0.83 ^c	0.33 ^c	0.21 ^c	0.01 ^c
Japan	3.27	0.25	2.6	0.04
Kazakhstan	0.11	0.04	0.05	0.01
Kyrgyz Republic	0.1	0.06	0.03	N/A
Macau, China	0.17 ^c	0.02	0.01	N/A
Malaysia	1.04	0.14	0.46	N/A
Mongolia	0.13 ^c	0.06	0.01	N/A
Myanmar	0.03 ^c	0.02 ^c	N/A	N/A
New Zealand	1.34 ^c	0.27 ^c	0.74 ^c	N/A
Pakistan	0.23 ^c	0.09 ^c	N/A	N/A
Papua New Guinea	N/A	0.02 ^b	N/A	N/A
Philippines	N/A	0.04 ^a	0.06 ^a	N/A
Republic of Korea	4.52	0.46	3.64	0.06
Russian Federation	0.98	0.34	0.55	N/A
Singapore	1.92 ^c	0.21 ^c	1.15 ^c	N/A
Sri Lanka	0.12 ^c	0.05 ^c	0.05 ^c	N/A
Tajikistan	0.09	0.09	N/A	N/A
Thailand	1.00 ^c	0.05	0.80 ^c	0.01 ^c
Türkiye	0.95 ^c	0.09 ^c	0.55 ^c	N/A
Uzbekistan	0.13	0.05	0.05	N/A
Viet Nam	0.52 ^c	0.11 ^c	0.38 ^c	0.01 ^a

R&D = research and development.

^a Data for 2015.

^b Data for 2016.

^c Data for 2017.

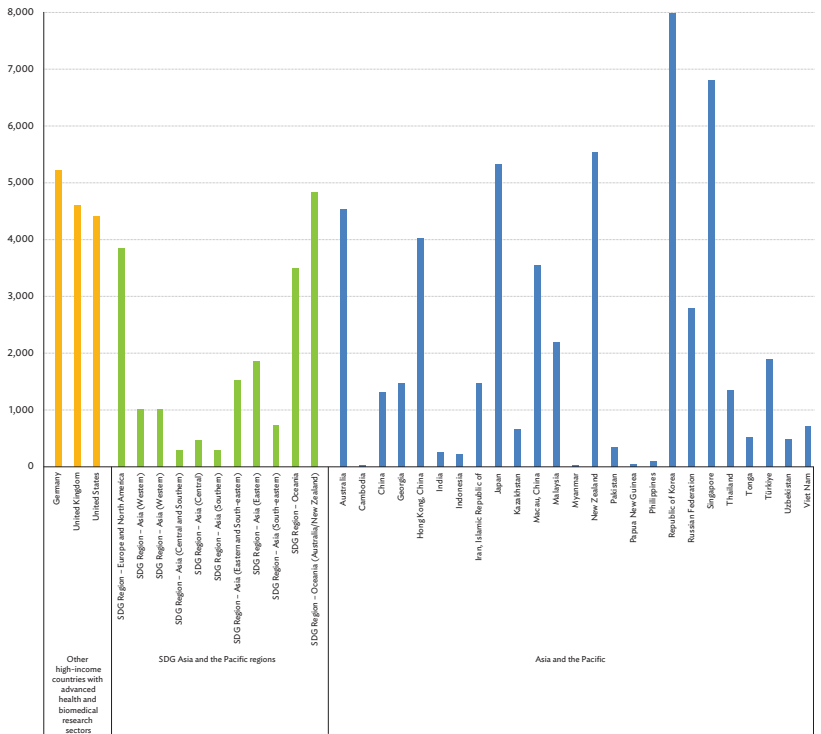
Note: Data are by economies (where available) and for 2018 unless otherwise indicated.

Sources: United Nations Department of Economic and Social Affairs website and UNESCO Institute for Statistics website.

funded almost exclusively by governments, up to a third of corporate R&D spending in some high-income countries now goes to basic science (UNESCO 2021).

The UNESCO East and Southeast Asia region had 37.6% of the world’s researchers in 2018 (Figure 3.3) (UNESCO 2021; UIS website). The PRC alone accounts for a third of the increase in the global number of researchers between 2014 and 2018 (UNESCO 2021). In 2018, the number of researchers per million inhabitants in full-time equivalents (SDG indicator 9.5.2) in Asia and the Pacific was the highest in the Republic of Korea, Singapore, Japan, and New Zealand, where this indicator was higher than in Germany, the United Kingdom, and the United States (Figure 3.3).

Figure 3.3: Number of Researchers per Million Inhabitants in Full-Time Equivalents, 2018



SDG = Sustainable Development Goal.

Note: Data are for 2018 (or latest year available).

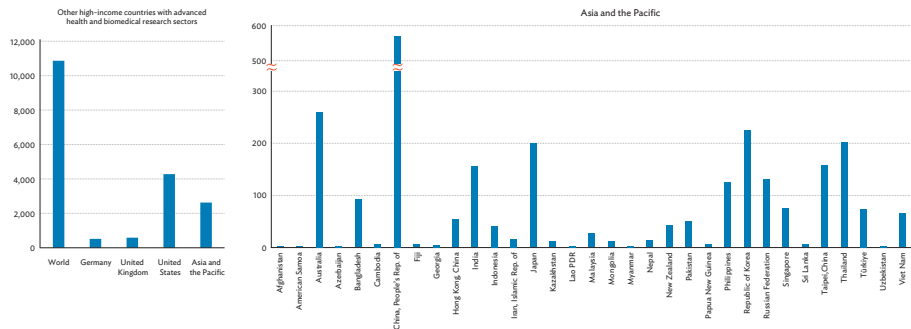
Sources: UNESCO Institute for Statistics website; UIS.Stat Statistics and Resources website; and World Bank Open Data.

3.2.2 R&D Output Indicators: Publication, Clinical Trials, and Patents on Vaccines

As of March 2022, Asia and the Pacific carried out 24.1% of all **vaccine clinical trials** in the world, led by the PRC (with a fifth of all clinical trials of vaccines in Asia and the Pacific and 5.25% in the world), Australia, and the Republic of Korea (Figures 3.4 and 3.5). Many developing countries in the region have also participated in clinical trials. Conducting clinical trials of new vaccines and drugs in developing countries is a significant challenge because of the lack of a research environment, ethical and regulatory hurdles, logistical barriers, and competing demands (Alemayehu, Mitchell, and Nikles 2018). The International Vaccine Institute has supported typhoid and cholera vaccine clinical trials in Nepal and Viet Nam and, as their success attests, carrying out clinical trials in low-income countries can have many positive side effects (Kim and McCann 2021; Saluja et al. 2021): (i) it ensures that vaccine safety and efficacy have been tested in populations of different ethnic and socioeconomic origins, (ii) it not only strengthens research capacities in low-income countries but can also improve the quality of medical care, and (iii) it helps to base R&D and health policy decision-making on locally generated data.

One of the pillars for scientific progress and the eventual translation of basic and preclinical research into new drugs, vaccines, and diagnostic tools is the timely **dissemination of scientific results through peer-**

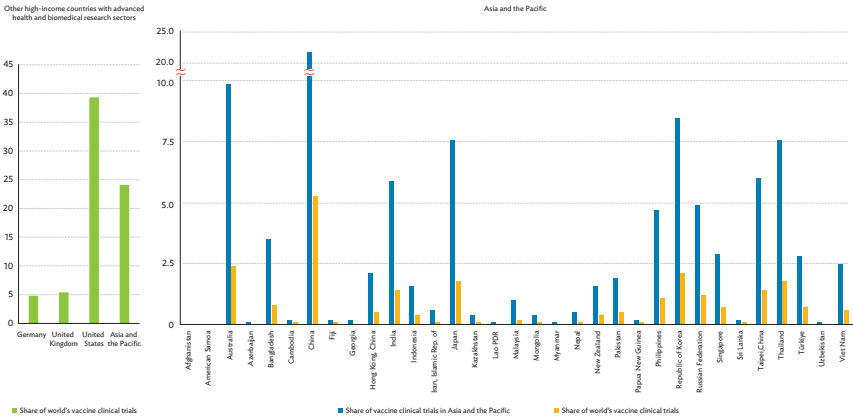
Figure 3.4: Number of Clinical Trials of Vaccines



Noted: As of March 2022.

Source: ClinicalTrials.gov.

Figure 3.5: Share of Clinical Trials of Vaccines (%)



Note: As of March 2022.

Source: ClinicalTrials.gov.

reviewed journals.¹ Since the start of the COVID-19 pandemic, there has been an unprecedented increase in scientific production, in both quantity and speed, on all aspects of the disease, from basic research on the virus to data on clinical trials and therapeutic strategies. Notably, a larger share than usual of articles on COVID-19 has been open access through waivers of subscription fees, open access journals, and public repositories of articles before peer review. The free dissemination of scientific data during the pandemic has been instrumental in improvements in clinical management approaches. As of March 2022, scientists in Asia and the Pacific contributed to a fifth of all scientific publications on vaccine research at all stages—with the PRC, Japan, and India as the largest contributors—on par with figures in the United States (Table 3.3).

¹ Although the number of open access journals has grown rapidly, 72% of all biomedical research articles require a paid subscription, which creates a barrier to access knowledge for many scientists and doctors in resource-poor countries (Piwowar et al. 2017; Kruesi, Burstein, and Tanner 2020).

**Table 3.3: Number and Share of Scientific
Journal Publications on Vaccines**

	Number of Publications	Share of Publications in Asia and the Pacific (%)	Share of World's Publications (%)
Other high-income countries with advanced health and biomedical research sectors			
World	430,220		100
Germany	13,427		3.1
United Kingdom	7,693		1.8
United States	97,978		22.8
Asia and the Pacific	90,420		21
Asia and the Pacific			
Afghanistan	76	0.08	0.02
American Samoa	3	0.00	0.00
Armenia	59	0.07	0.01
Australia	12,886	14.25	3.00
Azerbaijan	26	0.03	0.01
Bangladesh	1,352	1.50	0.31
Bhutan	53	0.06	0.01
Brunei Darussalam	18	0.02	0.00
Cambodia	216	0.24	0.05
China, People's Rep. of	25,069	27.73	5.83
Cook Islands	1	0.00	0.00
Democratic People's Rep. of Korea	18	0.02	0.00
Fiji	63	0.07	0.01
French Polynesia	13	0.01	0.00
Georgia	71	0.08	0.02
Guam	7	0.01	0.00
India	10,613	11.74	2.47
Hong Kong, China	1,617	1.79	0.38
Indonesia	636	0.70	0.15
Iran, Islamic Rep. of	4,369	4.83	1.02

continued on next page

Table 3.3 *continued*

	Number of Publications	Share of Publications in Asia and the Pacific (%)	Share of World's Publications (%)
Japan	10,770	11.91	2.50
Kazakhstan	138	0.15	0.03
Kiribati	5	0.01	0.00
Kyrgyz Republic	21	0.02	0.00
Lao People's Democratic Republic	143	0.16	0.03
Macau, China	118	0.13	0.03
Malaysia	1,456	1.61	0.34
Maldives	5	0.01	0.00
Marshall Islands	1	0.00	0.00
Micronesia, Federated States of	6	0.01	0.00
Mongolia	170	0.19	0.04
Myanmar	87	0.10	0.02
Nauru	4	0.00	0.00
Nepal	385	0.43	0.09
New Caledonia	27	0.03	0.01
New Zealand	1,609	1.78	0.37
Niue	1	0.00	0.00
Northern Mariana Islands	1	0.00	0.00
Pakistan	1,541	1.70	0.36
Palau	1	0.00	0.00
Papua New Guinea	154	0.17	0.04
Philippines	654	0.72	0.15
Rep. of Korea	5,817	6.43	1.35
Russian Federation	2,102	2.32	0.49
Samoa	9	0.01	0.00
Singapore	1,967	2.18	0.46

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Table 3.3 *continued*

	Number of Publications	Share of Publications in Asia and the Pacific (%)	Share of World's Publications (%)
Solomon Islands	12	0.01	0.00
Sri Lanka	255	0.28	0.06
Tajikistan	12	0.01	0.00
Thailand	2,819	3.12	0.66
Timor-Leste	7	0.01	0.00
Tonga	1	0.00	0.00
Türkiye	2,114	2.34	0.49
Turkmenistan	0	0.00	0.00
Tuvalu	0	0.00	0.00
Uzbekistan	18	0.02	0.00
Vanuatu	4	0.00	0.00
Viet Nam	820	0.91	0.19

Note: As of March 2022.

Source: PubMed database.

Research can generate new knowledge, but it does not necessarily generate economic value. For that to happen, R&D must result in the creation of innovative products and processes. An indicator of a country's ability to innovate is the **number of granted patents**, which tends to maintain a positive correlation with its R&D spending. In 2019, the PRC, Japan, and the Republic of Korea ranked first, third, and fourth in the world, respectively, in the number of patents filed (WIPO 2022). Other ESCAP countries such as the Russian Federation, India, the Islamic Republic of Iran, and Türkiye stood among the top 15. In the biotechnology and pharmaceutical sectors, the PRC, Japan, and the Republic of Korea have the largest number of patents granted and together have as many as the United States (Table 3.4). According to a 2021 study, 3,660 patents were granted on new countermeasures for coronavirus; notably, 79.8% of the patent holders were from Asia and the Pacific, of which 82.9% were Chinese inventors (Liu et al. 2021).

Table 3.4: Number of Patents Granted in Biotechnology and Pharmaceuticals in Asia and the Pacific

	Patents in Biotechnology	Patents in Pharmaceuticals
Other high-income countries with advanced health and biomedical research sectors		
World	984,624	3,004,305
Germany	33,915	68,271
United Kingdom	16,350	38,353
United States	160,424	255,581
Asia and the Pacific	132,319	202,979
Asia and the Pacific		
Afghanistan	0	1
American Samoa	0	0
Armenia	1	33
Australia	371	4,647
Azerbaijan	25	394
Bangladesh	21	0
Bhutan	0	1
Brunei Darussalam	1	0
Cambodia	0	0
China, People's Rep. of	55,508	95,061
Cook Islands	0	1
Democratic People's Rep. of Korea	9	11
Fiji	0	0
French Polynesia	0	0
Georgia	13	191
Guam	0	0
Hong Kong, China	232	389
India	1,512	5,362
Indonesia	2	29
Iran, Islamic Republic of	17	48
Japan	39,777	49,196
Kazakhstan	0	0
Kiribati	0	12
Kyrgyz Republic	0	19
Lao People's Democratic Republic	0	0
Macau, China	0	13
Malaysia	278	280
Maldives	0	0
Marshall Islands	0	1
Micronesia, Federated States of	0	0
Mongolia	1	2
Myanmar	0	1
Nauru	0	710
Nepal	1	0
New Caledonia	0	0
New Zealand	872	0
Niue	0	0
Northern Mariana Islands	0	0
Pakistan	4	21
Palau	0	0
Papua New Guinea	0	0
Philippines	6	27

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Table 3.4 *continued*

	Patents in Biotechnology	Patents in Pharmaceuticals
Rep. of Korea	24,105	24,724
Russian Federation	8,679	20,347
Samoa	8	9
Singapore	752	775
Solomon Islands	0	1
Sri Lanka	1	2
Tajikistan	5	73
Thailand	41	47
Timor-Leste	0	0
Tonga	0	0
Türkiye	33	539
Turkmenistan	9	7
Tuvalu	0	0
Uzbekistan	30	0
Vanuatu	0	1
Viet Nam	5	4

Source: Patentscope website.

3.3 Main Actors in Biomedical and Vaccine R&D in Selected Economies in Asia and the Pacific

Many high- and middle-income countries in Asia and the Pacific have specialized **research funding government agencies**—most often within the organizational structure of the ministries of health, education, or science—that offer grants for early stages of biomedical research (discovery and preclinical stages) at universities and research institutes.

In a large and diverse region like Asia and the Pacific, the vaccine pharmaceutical industry varies greatly by country. Many pharmaceutical companies in high-income Asia and the Pacific are world leaders in vaccine R&D and manufacturing. In several countries in the region, **state-owned vaccine manufacturers** control a significant share (in some instances, the largest) of the domestic vaccine market and conduct R&D and production of high-quality vaccines, some of which are prequalified by WHO as safe and effective vaccines for purchase by United Nations agencies (Table 3.5). Several state-owned vaccine firms from the region deserve special mention: China National Biotec Group (CNBG), a subsidiary of Sinopharm, accounts for half of the vaccines produced in the PRC and is very active in R&D using both traditional and newer technologies. India has 13 state-controlled (public sector undertakings) pharmaceutical companies, of which at least five (Haffkine Institute, Central Research Institute Kasauli, Pasteur Institute of India, BCG Vaccine Laboratory, and Bharat Immunologicals and Biologicals)

are involved in vaccine R&D and production. In Indonesia, state-owned Biofarma, the country's only vaccine manufacturer, is engaged in advanced R&D for new vaccines and technologies in partnership with academia. As of March 2022, Biofarma was in talks with WHO to become one of the global manufacturing hubs for mRNA vaccines. Thailand's state-owned Government Pharmaceutical Organization manufactures vaccines for the domestic market and other countries in the Association of Southeast Asian Nations (ASEAN).

A number of countries in the region have a vibrant **domestically owned private pharmaceutical industry** that not only is involved in vaccine manufacturing but in many cases also conducts its own vaccine R&D (selected private vaccine manufacturers in the region are included in Table 3.5). Of the 41 manufacturers that form the Developing Countries Vaccine Manufacturers Network (DCVMN)—which includes both private and state-owned vaccine producers (see Chapter 2)—34 are based in Asia and the Pacific, most of them private companies. Around half of all WHO-prequalified vaccines are produced by DCVMN manufacturers, of which virtually all (96%) are located in Asia and the Pacific (WHO Prequalification website). As of February 2022, of the 259 presentations for 163 prequalified vaccines, almost two-thirds are developed by manufacturers in Asia and the Pacific (WHO Prequalification website). Vaccine developers across the region have successfully developed vaccine candidates and commercial vaccines for COVID-19 using most of the existing technologies, including new platforms such as viral vector vaccines and several companies in the region are now working toward developing and manufacturing mRNA-based vaccines (Table 3.6).

As the world's second-largest market for pharmaceuticals, all **multinational pharmaceutical firms** (MNPfFs) have a presence in Asia and the Pacific. These firms have not only offshored part of their vaccine and drug manufacturing to Asia and the Pacific but have also transferred some of their R&D activities, directly (to subsidiaries, opening new R&D centers) and/or indirectly (through partnerships with academic institutions or local firms). Most of the largest MNPfFs have R&D and manufacturing centers not only in the larger economies (e.g., the PRC, India, Japan, and the Republic of Korea) but also in ASEAN countries. The offshoring of R&D from global vaccine MNPfFs to developing countries in Asia and the Pacific can potentially enhance technology transfer to domestic biotechnology firms.

**Table 3.5: Vaccine Companies Involved
in R&D in Asia and the Pacific**

Economy	Company	WHO- Prequalified Vaccines (number)	DCVMN	Private or State-Owned
Bangladesh	Incepta Vaccine Ltd	No	Yes	Private
China, People's Republic of	Beijing Minhai Biotechnology Co., Ltd	No	Yes	Private
	Beijing Tiatan Biological Products Co., Ltd	No	No	State-owned
	BravoVax Co. Ltd	No	Yes	Private
	Changchun BCHT Biotechnology Co.	No	Yes	Private
	China National Biotec Group (CNBG)	Yes (2)	Yes	State-owned
	Chongqing Zhifei Biological Products Co., Ltd.	No	Yes	Private
	Hualan Biological Engineering	Yes (1)	No	Private
	Institute of Medical Biology Chinese Academy of Medical Sciences	No	Yes	Private
	Liaoning Cheng Da Biotechnology Co., Ltd.	No	Yes	Private
	Sinovac Biotech Ltd.	Yes (2)	Yes	Private
	Walvax Biotechnology Co., Ltd	No	Yes	Private
	Xiamen Innovax Biotech Co., Ltd	Yes (1)	Yes	Private
India	Bharat Biotech International Ltd	Yes (10)	Yes	Private
	Bharat Immunologicals and Biologicals Ltd	No	No	State-owned
	Biological E. Ltd	Yes (12)	Yes	Private
	Cadila Pharmaceuticals Ltd	No	No	Private
	CPL Biologicals Pvt Ltd	No	No	Private
	Green Signal Bio Pharma Pvt Ltd	Yes (5)	Yes	Private

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Table 3.5 *continued*

Economy	Company	WHO- Prequalified Vaccines (number)	DCVMN	Private or State-Owned
	Haffkine Bio- Pharmaceutical Co. Ltd	Yes (3)	No	State-owned
	Indian Immunologicals Ltd	No	Yes	Private
	Panacea Biotec Ltd	Yes (3)	Yes	Private
	Pasteur Institute of India	No	Yes	State-owned
	Serum Institute of India Ltd	Yes (62)	Yes	Private
	Vins Bioproducts Ltd	No	Yes	
	Zydus Cadila	No	Yes	Private
Indonesia	PT Bio Farma (Persero)	Yes (15)	Yes	State-owned
Japan	Astellas Pharma	No	No	Private
	Denka Seiken	No	No	Private
	Japan BCG	No	No	Private
	Kaketsuken	No	No	Private
	Kitasato Institute	No	No	Private
	Kyoto Biken	No	No	Private
	Takeda	No	No	Private
Korea, Republic of	Boryung Biopharma	No	No	Private
	Cheil Jedant (CJ Pharma)	No	No	Private
	Dong Shin Pharma	No	No	Private
	EuBiologics, Co., Ltd.	Yes (2)	Yes	Private
	GC Pharma	No	Yes	Private
	Korea Vaccine	No	Yes	Private
	LG Life Sciences Ltd	Yes (7)	Yes	Private
Malaysia	SK Bioscience Co., Ltd	Yes (5)	Yes	Private
	Pharmianaga Life Sci	No	No	Private
Pakistan	Solution Biologics	No	No	Private
	Amson Vaccines & Pharma	No	Yes	Private

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Table 3.5 *continued*

Economy	Company	WHO- Prequalified Vaccines (number)	DCVMN	Private or State-Owned
Russian Federation	Immunopreparat Research productive association, Ufa	No	No	State-owned
	Products Immunologicals and Drugs, Irkutsk RIVS	No	No	State-owned
	LLC Nanolek	No	Yes	Private
	St. Petersburg Research Institute of Vaccines and Serums	No	Yes	State-owned
Taipei, China	Medigen Vaccine Biologicals Co.	No	Yes	Private
Thailand	BioNet	Yes (1)	No	Private
	The Government Pharmaceutical Organization	No	Yes	State-owned
	Queen Saovabha Memorial Institute	No	Yes	State-owned
Viet Nam	The Company of Vaccine and Biological Production No. 1-VABIOTECH	No	Yes	State-owned
	Da Lat Pasteur Vaccines Company Ltd (DAVAC)	No	No	State-owned
	Institute of Vaccines and Medical Biologicals (IVAC)	No	No	State-owned
	Center for Research and Production of Vaccines and Biologicals (POLYVAC)	No	Yes	State-owned

DCVMN = Developing Countries Vaccine Manufacturers Network, R&D = research and development, WHO = World Health Organization.

Sources: Tsai, Rao, and Xu (2018); DCVMN website; and company websites.

Table 3.6: Main Types of Vaccine Platforms and Producers of COVID-19 Vaccines in Asia and the Pacific

Vaccine Platform	COVID-19 Vaccine Producers in the Region
Live attenuated pathogen	People's Republic of China: CoronaVac, VeroCell BBIBP-CorV/Sinopharm-Beijing, Sinopharm-Wuhan India: BBV152 (Covaxin) Islamic Republic of Iran: Shifa Pharmamed vaccine Kazakhstan: QazCovid-in Russian Federation: CoviVac Türkiye: Turkovac
Killed pathogen	N/A
Toxoid	N/A
Subunit (protein, peptide, polysaccharide)	Australia: Spikogen, CpG 1018 Islamic Republic of Iran and Australia: CinnaGen People's Republic of China: ZF2001/RBD- Dimer, West China Hospital vaccine Russian Federation: EpiVacCorona
Virus-like protein	N/A
Viral vector	People's Republic of China: Ad5-nCoV/Convidecia Russian Federation: Sputnik V
Nucleic acid (DNA, RNA)	Several firms in Asia and the Pacific are currently working toward mRNA vaccines for COVID-19.
Antigen-presenting cells (dendritic cells), T cells	N/A
Bacterial vector	N/A

N/A = not available as of March 2022.

Sources: Iwasaki and Omer (2020) and Pollard and Bijker (2021).

In developed countries, stricter ethical standards and regulatory environments make conducting clinical trials more difficult and expensive. As a result, MNPfFs have outsourced various stages of vaccine and drug R&D to **contract research organizations (CROs)** with a presence in developing countries (Sayed and Agndal 2022). Nevertheless, weaker and more unpredictable regulatory environments in developing countries can also be an obstacle to the offshoring of clinical trials and R&D. All global CROs now have a presence in Asia and the Pacific, particularly in India, the PRC, and Japan, and also carried out early stages of R&D at their locations in Asia and the Pacific. Dozens of domestically owned CROs have emerged in the region, especially the PRC and India, and some CROs in the region have gained global reach; for instance, the Chinese CRO WuXi AppTec Group ranked eighth in the world based on revenue in 2020/21 (Vietchinkina 2022).

3.4 R&D Preparedness and the Vaccine R&D Pipeline in Asia and the Pacific

In most countries of the world, national preparedness plans to deal with epidemics and pandemics have focused primarily on influenza. Still, 99 countries have no preparedness plans for influenza outbreaks (Nuzzo et al. 2019; WHO SPH Portal), of which 13 are in Asia and the Pacific: Afghanistan, Armenia, the Democratic People's Republic of Korea, the Islamic Republic of Iran, Kazakhstan, the Kyrgyz Republic, Nepal, Pakistan, the Russian Federation, Tajikistan, Türkiye, Turkmenistan, and Uzbekistan (WHO SPH Portal).

Many of the vaccines currently used not only in Asia and the Pacific but also around the world have been researched, developed, and/or manufactured by the larger pharmaceutical firms in the region, especially in Japan, the PRC, India, and Australia, and also in smaller economies like Viet Nam. Some developing countries in Asia and the Pacific that until recently only hosted vaccine fill-and-finish manufacturing operations are now also engaged in vaccine R&D for new vaccines.² Vaccines researched and developed in Asia and the Pacific for diseases of regional importance include those for severe acute respiratory syndrome (SARS), Japanese encephalitis, the Hantaan and Seoul viruses that cause hemorrhagic fever with renal syndrome, Russian spring–summer encephalitis, Kyasanur forest disease, cholera, and Q fever (Tsai, Rao, and Xu 2018). Manufacturers in Asia and the Pacific have also developed for national or regional distribution newer vaccines for measles, mumps, hepatitis A, rotavirus, and intranasally delivered vaccines for pandemic H1N1 virus. Some new vaccines developed in the region have been distributed globally such as those for hepatitis E, enterovirus A71, and COVID-19 (Tsai, Rao, and Xu 2018).

As of December 2021, the **vaccine R&D pipeline in Asia and the Pacific** includes new vaccines for tuberculosis, malaria, HIV, kinetoplastids (e.g., Chagas disease, sleeping sickness, leishmaniasis), diarrheal diseases, hepatitis C, Salmonella, bacterial pneumonia and meningitis, rheumatic fever, and COVID-19 (Table 3.7). In fact, 100% of the world's new vaccine candidates for Salmonella, 66.8% for bacterial pneumonia and meningitis, 43.8% for tuberculosis, and 36.8% for

² When technological and/or manufacturing capacities are limited or when production volumes are small, vaccine manufacturers do not conduct upstream stages of vaccine manufacturing (e.g., bioprocessing and formulation), but rather limit their activity to downstream steps where the vaccines are filled into vials and packaged for distribution (fill, finish, and packaging).

diarrheal diseases are being researched and developed in Asia and the Pacific (Table 3.7 and Policy Cures Research R&D Pipeline Tracker website). Several countries in the region have been at the forefront of R&D for COVID-19 (Table 3.5). Notably, clinical trials of the PRC's CanSino Biologics COVID-19 vaccine started in March 2020, at the same time as Moderna's clinical trials in the United States (Chakraborty et al. 2021).

Table 3.7: Vaccine Candidates in the Pipeline of Firms in Asia and the Pacific

Disease	R&D Stage	Vaccine Candidate	Pharmaceutical Firm/ Research Institute	Country
Tuberculosis	Preclinical	CysVac2/A	Tuberculosis Vaccine Initiative and University of Sydney	International Australia
	Phase I	Ad5Ag85A	CanSino Biologics Inc.	PRC
			McMaster University	Canada
		AEC/BCO2	Anhui Zhifei Longcom Biopharmaceutical Co. Ltd	PRC
		GamTBVac	Gamaleya Research Institute of Epidemiology and Microbiology	Russian Federation
	Phase II	TB-FLU-04L	Kazakhstan Ministry of Health Research Institute for Biological Safety Problems	Kazakhstan
	Phase III	MIP	Cadila Pharmaceuticals	India
		Vaccae	Anhui Zhifei Longcom Biopharmaceutical Co. Ltd and Institute of Microbiology, Chinese Academy of Sciences	PRC
		VMP1002	Serum Institute of India	India
			Vakzine Projekt Management GmbH	Germany

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Table 3.7 *continued*

Disease	R&D Stage	Vaccine Candidate	Pharmaceutical Firm/ Research Institute	Country
Malaria	Preclinical	Pfs230 fragments	Ehime University and PATH	Japan International
	Phase I	ChAd63/MVA PvDBP	International Centre for Genetic Engineering	India
			Biotechnology and Okairos	Switzerland
		PlasprotecT	Griffith University	Australia
		PvDBPII	Syngene International Limited	India
HIV/AIDS	Phase I	SeV-G (NP), Ad35-GRIN	DNAVEC Corporation	Japan
			International AIDS Vaccine Initiative	International
	Phase II	HIV DNA-rTV	Beijing Bioproduct Research Institute and Beijing You Ann Hospitals	PRC
Kinetoplastids (Chagas disease, sleeping sickness, leishmaniasis)	Preclinical	LmCen-/-	Gennova Biopharmaceuticals	India
			McGill University	Canada
	Phase I	LEISH-F3+GLA-SE	Gennova Biopharmaceuticals	India
			Infectious Disease Research Institute	US
Diarrheal diseases	Preclinical	34kDa OMP	Indian National Institute of Cholera and Enteric Diseases	India
		Heat-killed multi-serotype Shigella	Indian National Institute of Cholera and Enteric Diseases	India

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Table 3.7 *continued*

Disease	R&D Stage	Vaccine Candidate	Pharmaceutical Firm/ Research Institute	Country
	Phase I	Hexavalent BRV vaccine	Wuhan Institute of Biological Products Co Ltd and Hebei Province Center for Disease Prevention and Control	PRC
		S. Flexneriza-S. Sonei bivalent conjugate vaccine	Beijing Zhifei Lanzhou Biopharmaceutical Co. Ltd.	PRC
		VLP VP2/6/7	Mitsubishi Tanabe Pharma Corporation	Japan
	Phase II	Heat stable rotavirus (HSRV) vaccine	Hilleman Laboratories	India
			MSD (Merck)	Germany
		RV3-BB	Biofarma and Gadjah Mada University	Indonesia
	Phase III	BRV-TV	Shantha Biotechnics (Sanofi Group)	India
		P2-VP8-P[8]	SK Chemicals	ROK
			PATH	International
Hepatitis C	Preclinical	HepSeeVax	Burnet Institute	Australia
Salmonella	Preclinical	OSP-rEPA	Abasyn University	Pakistan
			Canadian National Research Council	Canada
		Trivalent typhoid/iNTS glycoconjugate vaccine	Bharat Biotech	India
			University of Maryland, Baltimore	US
		Vi-CRM197+O:2-CRM197	Biological E. Limited	India
			Novartis Vaccine Institute for Global Health	Switzerland
	Phase I	Live oral PA vaccine (CVD 1902)	Bharat Biotech	India
			University of Maryland, Baltimore	US

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Table 3.7 *continued*

Disease	R&D Stage	Vaccine Candidate	Pharmaceutical Firm/ Research Institute	Country
	Phase II	O:2-TT	Lanzhou Institute of Biological Products	PRC
			US National Institutes of Health	US
		Vi-CRM197	Biological E. Limited	PRC
			Novartis Vaccine Institute for Global Health	Switzerland
		Vi-DT	Biofarma	Indonesia
			SK Chemicals	ROK
		vi-rEPA	Lanzhou Institute of Biological Products	PRC
			United States National Institutes of Health	US
Bacterial pneumonia and meningitis	Preclinical	23-valent pneumococcal PS vaccine	Sinovac Biotech Ltd	PRC
	Phase I	A, C, Y, W135 meningococcal PS conjugate vaccine	China Air Force Medical University and Chinese National Institute for Food and Drug Control	PRC
		ASP3772	Astellas Pharma	Japan
			Affinivax	US
		GBP411	SK Chemicals	ROK
			Sanofi	France
		Tetavalent meningococcal conjugate vaccine	Wuhan Institute of Biological Products and Lanzhou Institute of Biological Products	PRC
	Phase II	Biological E 14-valent PCV	Biological E Ltd	India
		LBVE013 (multivalent)	LG Life Sci	ROK
		Pentavalent meningococcal conjugate vaccines	Serum Institute of India PATH	India International

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Table 3.7 *continued*

Disease	R&D Stage	Vaccine Candidate	Pharmaceutical Firm/ Research Institute	Country
	Phase III	MCV4	CanSino Biologics Inc.	PRC
		MCV-ACYW135	Beijing Minhai Biotechnology	PRC
		NBP606	SK Chemicals	ROK
		PNEUMOSIL	Serum Institute of India	India
			Medical Research Council Unit The Gambia	Gambia
Rheumatic fever	Phase I	MJ8VAX (J8-DT)	Australian Centre for Health Services Innovation and Q-Pharm	Australia

PCV = pneumococcal conjugate vaccine, PRC = People's Republic of China, ROK = Republic of Korea, US = United States.

Sources: Policy Cures Research R&D Pipeline Tracker website and email communications with individual companies.

3.5 National Strategies for Incentivizing Investment and Partnerships in Vaccine R&D

Countries in Asia and the Pacific have used several of the supply- and demand-side approaches (described in Chapter 2) to incentivize investments in vaccine R&D and manufacturing by pharmaceutical firms.

3.5.1 Supply-Side Approaches

On the supply side, many governments in the region offer grants to universities and research institutes to carry out early stages of biomedical R&D (Table 3.8). In 2013, the Australian National Health and Medical Research Council ranked seventh and the National Natural Science Foundation of China (NNSF-China) ninth among the world's top 10 public funders of biomedical and health research. Reflecting the rapid growth in biomedical and health R&D expenditures and the number of researchers in Asia and the Pacific, by 2021, the NNSF-China, the Japan Science and Technology Agency, and the National Research

Foundation of Korea respectively ranked second, third, and fourth in the world for funds disbursed. However, beyond funding for R&D in COVID-19 vaccines, the share of public funding for health R&D that countries in Asia and the Pacific earmark for vaccine R&D is either unavailable or only fragmentary, especially in middle- and low-income countries. As part of its \$5.2 billion science and technology budget for 2021, the Republic of Korea spent \$37 million on developing new vaccines and drugs for emerging infectious diseases (Sharma 2021).

Table 3.8: Government Agencies Funding Health and Biomedical R&D in Asia and the Pacific

Funding Agency	Country	Value in \$ (date)	Website
Outside Asia and the Pacific (included in the world's top 10)			
National Institutes of Health	United States	41.7 billion (2020)	https://www.nih.gov/grants-funding
Congressionally Directed Medical Research Programs (CDMRP)-Department of Defense	United States	1.3 billion (2020)	https://cdmrp.army.mil/default
European Commission	European Union	1.2 billion (2021)	https://ec.europa.eu/info/research-and-innovation_en
Medical Research Council	United Kingdom	1.1 billion (2021)	https://mrc.ukri.org/
National Institute of Health and Medical Research (INSERM)	France	967 million (2021)	https://www.inserm.fr/en/home/
Asia and the Pacific			
National Natural Science Foundation of China	PRC	4.8 billion (2019)	http://www.nsf.gov.cn/english/site_1/index.html
Japan Science and Technology Agency	Japan	2.1 billion (2021)	https://www.jsps.go.jp/english/
National Research Foundation of Korea	ROK	2.0 billion (2021)	https://www.nrf.re.kr/eng/index
National Health and Medical Research Council	Australia	1.2 billion (2019)	https://www.nhmrc.gov.au/
		497.7 million (2020)	

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Table 3.8 *continued*

Funding Agency	Country	Value in \$ (date)	Website
National Medical Research Council	Singapore	243.5 million (2017)	https://www.nmrc.gov.sg/home
Indian Council of Medical Research	India	140.3 million (2013)	https://www.icmr.gov.in/index.html
Japan Science and Technology Agency	Japan	100 million (2019)	https://www.jst.go.jp/EN/
Health Research Council	New Zealand	87.4 million (2020)	https://www.hrc.govt.nz/
National Institute of Health	ROK	N/A	https://nih.go.kr/index.es?sid=a5
Russian Foundation for Basic Research	Russian Federation	N/A	https://www.rfbr.ru/rffi/eng
Biomedical Research Council of the Agency for Science, Technology and Research	Singapore	N/A	https://www.a-star.edu.sg/
Ministry of Science and Technology of the PRC	PRC	N/A	http://en.most.gov.cn/
Department of Biotechnology	India	N/A	https://dbtindia.gov.in/
Department of Science and Technology	India	N/A	https://dst.gov.in/
Indonesian Institute of Sciences (LIPI)	Indonesia	N/A	http://lipi.go.id/
Ministry of Health of the Russian Federation	Russian Federation	N/A	https://minzdrav.gov.ru/en
Scientific and Technological Research Council of Türkiye (TÜBİTAK)	Türkiye	N/A	https://www.tubitak.gov.tr/en
Turkish Academy of Sciences (TÜBA)	Türkiye	N/A	http://www.tuba.gov.tr/

N/A = not available, PRC = People's Republic of China, R&D = research and development, ROK = Republic of Korea.

Sources: Websites of funding agencies; Viergever and Hendriks (2016); and Aars, Clark, and Schwalbe (2021).

Product development partnerships (PDPs) and non-PDP intermediaries are, together with governments, among the main sources of funding for the R&D of vaccines on neglected and/or emerging infectious diseases. As in the case of public funding, data on the share of R&D expenditures funded by philanthropic foundations in Asia and the Pacific are incomplete. Most PDPs and non-PDP intermediaries, as well as global philanthropic foundations, have funded projects for vaccine and drug R&D in developing countries in Asia and the Pacific. In total, 20 ESCAP members have benefited from vaccines for infectious diseases purchased by Gavi, the Vaccine Alliance (Gavi website). The Coalition for Epidemic Preparedness Innovations (CEPI) has created economic incentives to bring vaccine candidates from the discovery to the end of Phase II for various regionally prevalent diseases such as those caused by chikungunya and Nipah viruses. Governments in several high-income countries in Asia and the Pacific are major contributors to PDP and non-PDP intermediaries and philanthropic foundations. During 2017–2019, the Governments of Japan and Australia were among the world's top 10 donors to PDP and non-PDP intermediaries that funded vaccine and drug R&D for emerging infectious diseases (PCR 2021a). The Japanese government is also the largest contributor to the Global Health Innovative Technology (GHIT) Fund, a non-PDP intermediary that, in collaboration with the Bill & Melinda Gates Foundation, the Wellcome Trust, and the United Nations Development Programme, mobilizes the Japanese pharmaceutical industry, academia, and research institutes to create new vaccines, drugs, and diagnostics for malaria, tuberculosis, and neglected tropical diseases (PCR 2021b).

As noted earlier, public spending in R&D encourages investment by the private sector (David, Hall, and Toole 2000). Nevertheless, a survey in 53 countries around the world found that most pharmaceutical firms have relatively low interest in establishing R&D collaborations with universities (UNESCO 2021). The survey revealed that most firms—both in developed and developing countries—prefer to maintain their core R&D activities in-house rather than outsource them to academic researchers (UNESCO 2015). Less than 2% of scientific publications in New Zealand and the PRC involved coauthorship between universities and businesses. In the Republic of Korea, academia–business coauthorship was higher (3.9%) and more similar to the levels found in Germany (4.4%) and France (4.5%) (UNESCO 2021). To promote knowledge transfer and accelerate innovation, many government agencies in Asia and the Pacific, including some in developing countries, have programs to boost **university–industry R&D ties** and offer funds or provide tax incentives for firms that finance some of the total cost

of a project (DOST Philippines 2021; UNESCO 2021). In Pakistan, the World Bank has supported a fund that offers grants for collaborations between academic researchers and businesses when the latter match government funding (HEC 2021).

3.5.2 Demand-Side Approaches

The impact of demand-side strategies to incentivize vaccine R&D depends on the type of vaccines and the structure of the pharmaceutical industry. In many developing countries, vaccines included in national immunization programs are researched, developed, and manufactured by state-owned pharmaceutical firms that supply most of the doses needed. In developing countries where private firms also conduct R&D and manufacturing for vaccines in national immunization programs, demand-side approaches can incentivize local private pharmaceutical firms to invest in vaccine R&D. However, in the case of vaccines for neglected infectious diseases and in countries without vaccine R&D and manufacturing capacity that rely on imported vaccines, demand-side approaches by governments may have only limited effects on the structure of economic incentive structure for pharmaceutical firms abroad, especially for MNPfFs.

Governments can create demand for vaccines through **free vaccination, incentives for people to get vaccinated, or mandatory vaccination** in schools or the workplace. In most countries in the region, governments provide the vaccines administered in national immunization programs and those required during epidemics and pandemics free of charge. Legislation on vaccination varies across Asia and the Pacific. Several countries in the region have compulsory vaccination for their national immunization programs and/or for school enrollment, although many low-income countries have limited capacity to implement (e.g., supply, delivery, and access issues) and enforce these programs (Vanderslott and Marks 2021). In addition, there is still an open debate on whether mandatory vaccination is the best way to achieve high uptake. Japan, New Zealand, and the Republic of Korea previously had mandatory childhood immunization schedules but were later superseded by voluntary vaccination along with strong recommendations. Australia offers tax incentives and childcare benefits for parents who vaccinate their children.

As discussed in Chapter 2, advanced purchase agreements (APAs) have been successfully used to incentivize investment by pharmaceutical firms in vaccine R&D and manufacturing. APAs are part of pandemic influenza preparedness plans with signatory countries paying an annual fee to the manufacturer and committing

to purchase a specified number of annual doses (Turner 2016). Before the COVID-19 pandemic, in Asia and the Pacific, only high-income countries had used APAs (Turner 2016; Pharmaceutical Technology 2021). For instance, during the 2009 H1N1 pandemic, New Zealand was the only country in Asia and the Pacific that held an APA for H1N1 vaccines. If vaccine supply is inelastic, APAs between high-income countries with pharmaceuticals can lead to higher prices and negative externalities for low-income countries. However, APAs can also foster global capacity expansion and accelerate R&D and manufacturing, creating positive externalities for third countries (Ahuja et al. 2021). To ensure equity in vaccine supply, WHO encourages developing countries to use APAs and some MNPfFs like GSK have pledged to supply vaccines to developing countries via APAs at tiered prices based on the country's GDP (WHO 2011; Turner 2016).

During the COVID-19 pandemic, pharmaceutical firms in Asia and the Pacific signed APAs with the COVID-19 Vaccines Global Access (COVAX) facility, including the Gamaleya Institute (Russian Federation), Sinovac (PRC), CanSino Biologics (PRC), Bharat Biotech (India), and the Serum Institute of India (India) (Pharmaceutical Technology 2021). As part of COVAX, Gavi has established advanced market commitments (AMCs) by pooling up to \$2.4 billion from the financial contributions of high-income countries to support R&D and manufacturing for several COVID-19 vaccines before they have been approved (Phelan et al. 2020). Thirteen ESCAP members have signed self-financing agreements with the COVAX AMC: Armenia, Australia, Azerbaijan, Brunei Darussalam, Georgia, the Islamic Republic of Iran, Japan, Nauru, New Zealand, Palau, the PRC, the Republic of Korea, and Singapore. In addition, 30 ESCAP members are among the 92 lower-income economies eligible to benefit from the COVAX AMC with vaccine doses paid through official development assistance and contributions from the private sector and philanthropy (Gavi website).

3.6 Regional Cooperation in Vaccine R&D

The advantages of regional cooperation in epidemic surveillance and health care during an epidemic or pandemic are obvious. It helps contain the spread of disease and optimize the utilization of medical infrastructure and supplies within the region. This is particularly important for developing countries with weak health systems and limited resources. Countries can also cooperate in vaccine R&D in several ways, from informal cooperation between scientists in joint R&D projects to the coordination of activities among all stakeholders—governments, regional intergovernmental organizations, or region-wide

private associations—in the pooling of R&D funding or the prioritization of diseases for vaccine R&D pipelines.

The COVID-19 pandemic has highlighted the possibilities of international cooperation but also its potential fragility. On the one hand, the pandemic has made evident how beggar-thy-neighbor policies with export restrictions on medical personal protective equipment and vaccines can impact the production networks of these products. Vaccine nationalism already took place during the H1N1 epidemic and has reemerged during the COVID-19 pandemic. These inward-looking strategies are not an option for many middle- and low-income countries that depend on the vaccines produced elsewhere. Likewise, attempts to waive intellectual property rights on COVID-19 vaccines have been blocked by pharmaceutical firms that own them. On the other hand, the pandemic has shown that cooperation between actors (governments, firms, nonprofit sector) across Asia and the Pacific and beyond was essential for accelerating the time line of COVID-19 vaccine development (Chakraborty et al. 2021). International cooperation in R&D during the COVID-19 pandemic was in part possible due to previously existing informal networks and formal institutional linkages between actors. For instance, there was sharing of data and knowledge by the scientific community, international PDPs, and other non-PDP intermediaries, channeling of funding from governments and philanthropic foundations to companies and institutes capable of developing vaccines, and international organizations and regional intergovernmental associations coordinating the activities of public and private actors. Organizations like CEPI and Gavi that existed before the pandemic pulled together with WHO to create COVAX (COVID-19 Vaccines Global Access) to accelerate R&D and production of vaccines for COVID-19.

Pharmaceutical firms in developing countries can build their vaccine R&D capabilities through technological transfer from PDPs and/or pharmaceutical firms from high-income countries. Pharmaceutical firms in developing countries have also gained technological expertise through **South–South cooperation and South–South Triangular Cooperation (SSTC)**. For instance, SSTC was used to carry out R&D when the Nepal Health Research Council conducted Phase III clinical trials in Nepal for a new typhoid conjugate vaccine, with help from the International Vaccine Institute, SK Bioscience (Republic of Korea), and Biofarma (Indonesia) and with funding from the Bill & Melinda Gates Foundation and International Vaccine Institute member states (Kim and McCann 2021; Saluja et al. 2021). Another successful example of SSTC in vaccine R&D was the oral cholera vaccines developed between Santha Biotechnics (India), VABIOTECH (Viet Nam), and EuBiologics (Republic of Korea) (WHO 2017; Odevall et al. 2018).

Regional institutions and intergovernmental organizations can help promote and coordinate regional cooperation. Amaya and De Lombaerde (2021) outlined several functions that intergovernmental organizations can play in the context of health emergencies. First, they can bridge global and national levels: vertically, by translating global agreements to national policies and targets, and horizontally, by supporting and coordinating actions by countries in addressing cross-border policy challenges. Second, intergovernmental organizations can facilitate the cross-border mobilization of medical supplies, vaccines, and their intermediates, encouraging maintaining open borders for the trade of goods while controlling the spread of the disease. Third, intergovernmental organizations can facilitate the joint procurement of medical supplies, drugs, and vaccines through pooled purchasing, ensuring a lower price for low-income countries. Finally, intergovernmental organizations can also coordinate the work of donors and partners to support countries.

During the SARS epidemic, the ASEAN Secretariat issued recommendations and supported members in their responses to contain its spread, a strategy that WHO commended (Amaya and De Lombaerde 2021). The Permanent Committee on Science, Technology and Innovation was established by ASEAN to promote cooperation in science, technology, and innovation (ST&I) among ASEAN members and to raise the level of scientific and technological advancement in member states. The ASEAN Plan of Action on Science, Technology, and Innovation (APASTI) 2016–2025 aims, among other things, to intensify R&D collaboration between the public and private sectors to address common problems in ASEAN, develop ST&I human resources, create a network of ST&I centers of excellence across the region, strengthen ST&I infrastructure, and create closer cooperation in R&D with ASEAN dialogue partners (Australia, Canada, the European Union, India, Japan, New Zealand, the PRC, the Republic of Korea, the Russian Federation, and the United States) (ASEAN 2017). In April 2020, the United States launched the US–ASEAN Health Futures initiative to strengthen public health in ASEAN through R&D, health system capacity, and the development of human capital in health. In the first area, joint R&D in ASEAN includes more than 300 active joint research projects between ASEAN members and more than 20 of the US National Institutes of Health, over \$30 million in research grants to universities and government research institutions in ASEAN, and support for clinical trials of treatments of infectious diseases (US–ASEAN 2020). ASEAN had a very active profile during the COVID-19 pandemic with at least 11 new health initiatives, including establishing the ASEAN Centre for Public Health Emergencies and Emerging Diseases to manage and coordinate

resources in health response and the ASEAN Public Health Emergency Coordination System to improve and harmonize preparedness for and response to health emergencies. The United States and the European Union donated doses of COVID-19 vaccines to low- and middle-income ASEAN countries through COVAX (ASEAN 2021; US Department of State 2021). The United States Centers for Disease Control and Prevention has established the US–ASEAN Infection Prevention and Control Task Force. The South Asian Association for Regional Cooperation (SAARC), which has had relatively little activity in health and biomedical research, during the COVID-19 pandemic created a health emergency fund of \$18 million to pool human resources and supplies and share knowledge (ESCAP 2020; LSE 2021). In addition to sharing medical supplies, SAARC countries planned to create mechanisms for coordinating R&D activities and disease surveillance. The World Bank lauded SAARC's short-term collaboration on COVID-19 for its potential longer-term spillovers to increase regional integration (LSE 2021). ESCAP can act as a catalyst for these types of collaborative R&D initiatives in Asia and the Pacific at the regional level by bringing together all stakeholders—member states, subregional organizations such as ASEAN or SAARC, multilateral development banks, companies, philanthropic foundations, and civil society—and harnessing its substantive and management expertise in regional cooperation.

Regional collaboration on R&D can also be channeled and coordinated through **scientific associations and research networks**. The Association of Academies and Societies of Sciences in Asia (AASSA) was constituted in 2012 as a nonprofit organization that encompasses 32 scientific and technological academies and science societies from 30 countries in Asia and the Pacific. AASSA organizes seminars and publishes reports on ST&I issues. However, the association's activity has been relatively low compared to counterparts in other regions. For instance, in the context of COVID-19, AASSA held a 1-day webinar aimed at identifying the key activities and recommendations of member academies in response to the pandemic. In comparison, the African Academy of Sciences has a wide range of activities, such as funding scholarships and research grants, strengthening R&D infrastructure in research institutes across Africa, fostering and funding joint R&D projects and networks between African scientists, and establishing partnerships with leading scientific organizations and research funding agencies for capacity.

In the past 2 decades, several regional and subregional research networks connecting research institutions across Asia and the Pacific have been established. Although they can play important roles in promoting vaccine R&D in the region, some of these initiatives

have exhibited relatively low levels of activity since their creation. At the subregional level, the South East Asia Infectious Disease Clinical Research Network (SEAICRN) facilitates clinical research collaborations between hospitals and research institutions in Thailand, Viet Nam, and Indonesia (SEAICRN website). The WHO Regional Office for South-East Asia (2003) has proposed the creation of regional vaccine research networks that bring together governments, research institutions, manufacturers (including firms in the DCVMN), and WHO to promote information sharing and regional R&D and to address ethical guidelines and intellectual property rights issues. It is also worth highlighting the ASEAN Network for Drugs, Diagnostics, Vaccines and Traditional Medicines Innovation (ASEAN-NDI), which was launched in 2010 (ASEAN-NDI website). Other initiatives are disease specific; for instance, the AIDS Vaccine for Asia Network (AVAN) was launched in 2011 to facilitate the development of a regional strategy that accelerates R&D of an HIV/AIDS vaccine through government advocacy, improved coordination, and harmonization of research; develops clinical trial and manufacturing capacity; supports ethical and regulatory frameworks; and ensures community participation.

3.7 Strengthening Domestic and Regional Partnerships among Actors in Vaccine R&D

In all countries, regardless of their level of development and/or geographical location, the transfer of knowledge from academia to the pharmaceutical industry faces constraints. Governments can **promote academia–industry ties** through interrelated policies and regulations, several of them already implemented in Asia and the Pacific, including (i) provide funding for joint university–private sector projects; (ii) promote financial management rules of universities to foster university–industry partnerships; (iii) better define intellectual property rights for researchers and institutions funded by public grants and protect the intellectual property rights of pharmaceutical firms and academic institution in the context of knowledge sharing and technology transfer; (iv) promote greater flexibility in universities to allow academic researchers to conduct projects in pharmaceutical companies; (v) establish business incubators at universities; and (vi) facilitate the membership of academic researchers to participate in boards of companies and of industry leaders in university committees.

Partnerships between scientists in Asia and the Pacific should be encouraged, facilitated, and, when possible, funded. Most often, scientists, universities, and research institutes share scientific

knowledge and data across countries through informal networks. Although institutionalizing these informal networks may not necessarily improve scientific collaboration, national governments, intergovernmental organizations, and scientific societies can promote it by offering travel grants for scientific meetings and research grants for international collaborative R&D projects. Creating regional and subregional vaccine research networks can bring together WHO, national governments, research institutions, and the private sector to promote sharing of data and knowledge for vaccine R&D, and these networks can serve as platforms for advocacy, establishing research priorities, promoting joint projects, and coordinating funding initiatives. Existing scientific societies and research networks should increase their activities and expand their goals to promote joint R&D projects, fellowships, and exchanges of scientists between research institutes in Asia and the Pacific.

Intergovernmental organizations in Asia and the Pacific can play a more active role in coordinating the policies and actions in vaccine R&D. They can map regional and subregional needs and elaborate, in collaboration with WHO regional offices and other stakeholders, R&D action plans for prioritized diseases. They can also promote the sharing of scientific knowledge and data, helping to coordinate the division of labor in vaccine R&D among countries according to the strengths and weaknesses of each country. WHO can provide technical support to regional and subregional intergovernmental organizations in these tasks. Intergovernmental organizations in Asia and the Pacific can also play a key role in advocacy for R&D for vaccines and drugs at the global level.

One policy option is to establish a **regional (or subregional) R&D funding agency** in Asia and the Pacific focused on infectious diseases of regional importance which offers grants for research projects and fellowships for capacity building and promotes collaborative partnerships between institutes and universities. This agency can be modeled on the European Research Council launched by the European Commission or the Alliance for Accelerating Excellence in Science in Africa launched by the African Union. Having an Asia and the Pacific research council would not only maximize investments but also prevent unnecessary overlaps in R&D funding. National contributions to this council can be adjusted by GDP per capita. Alternatively, the AASSA could expand its mission to take on these new roles.

Building R&D preparedness for existing infectious diseases within a reasonable time before an outbreak requires first prioritizing those with the highest epidemic threat for R&D to develop drug and vaccine candidates from fundamental research to Phase II clinical trials

(see Chapter 2). Individual countries and Asia and the Pacific as a whole should develop and strengthen their national and regional vaccine R&D preparedness. This means strengthening R&D platform technologies that can be used for developing vaccines for different pathogens, including still unknown diseases (Disease X). R&D preparedness requires countries and regions to fund, build, and maintain adequate research infrastructure that is not simply “epidemic specific” but mainly “epidemic sensitive” (Keusch and Lurie 2020). To better target funding for R&D preparedness and avoid overlaps, the status of funded road maps for specific and unknown diseases should be made public. The WHO Global Observatory on Health R&D can monitor the funding for different pathogens, and other organizations such as Policy Research Cures through its G-FINDER survey can also monitor financial flows for R&D, the source of funding, the identity of intermediaries, and the firms that will eventually develop vaccines.

Having in place strong R&D preparedness is essential to support a **rapid and effective R&D response** to develop vaccines and drugs once an outbreak emerges. Stakeholders in vaccine R&D should concomitantly fund a range of vaccine candidates and platforms. Newer platforms do not need to be available in each country and can be shared at a regional location. Vaccine R&D responsiveness during an outbreak demands the rapid sharing of data and the development of technology systems for rapidly identifying antigens and assessing the efficacy and safety of vaccine candidates. Even countries with strong R&D preparedness will have to mobilize new resources to respond to a major infectious disease outbreak. The search for financial resources to fund an R&D response cannot start at the time of the outbreak; such resources should be readily available at short notice. Different financial mechanisms can be explored. The Global Research Collaboration for Infectious Disease Preparedness (GLOPID-R) network can coordinate funding flows into a permanent fund modeled on the Pandemic Emergency Financing Facility that was created and managed by the World Bank to help low-income countries finance their response to epidemics (World Bank 2019). A similar mechanism can be established specifically to finance a rapid R&D response to major infectious disease outbreaks (WHO 2016).

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From Lab to Jab

Improving Asia and the Pacific's Readiness to Produce and Deliver Vaccines

The coronavirus disease (COVID-19) pandemic highlighted the complexities and challenges associated with the development, production, and distribution of vaccines and the consequent risks and vulnerabilities arising from the lack of affordable and equitable access to essential vaccines and other health products.

This book identifies the challenges across the entire vaccine value chain from “lab to jab”—from research and development to the production and cross-border delivery of vaccines and their related inputs involving trade, transport, logistics and regulatory approvals, and finally to the distribution and administration of vaccines. These challenges include market failures, financing gaps, barriers to technology transfer, tariff and non-tariff barriers, transport and logistical constraints, lack of regulatory harmonization across countries, and limitations in the capacity of national health systems.

From Lab to Jab: Improving Asia and the Pacific's Readiness to Produce and Deliver Vaccines underscores the need for unilateral and collective measures, such as coordinated efforts for financing, procurement, capacity building, needs assessments, and technology transfer. These can be implemented by leveraging trade and investment agreements, ensuring greater regulatory coordination, facilitating investments in national health systems, and sharing data, knowledge, and good practices across the region. The timely discussions call on vaccines to be viewed as a global public good. Hence, a combination of national, regional, and global mechanisms and platforms will be needed to ensure affordable and equitable access to vaccines in preparation for future pandemics.

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