Biotechnology by Mid-Century:

Assessing current capabilities.
Anticipating tomorrow's leaders.
A 12-country comparison.

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Full report available at https://www.jcvi.org/research/policy-center#projects

Table of Contents

Table of figures

List of abbreviations

BRA	Brazil
BRIICS	group of emerging economies: Brazil, Russia, Indonesia, India, China, South Africa
CHN	China
DEU	Germany
EU	European Union
GDP	Gross Domestic Product
GM	Genetically Modified
GMO	Genetically Modified Organism
ICT	Information and communications technology
IDN	Indonesia
IESE	Instituto de Estudios Superiores de la Empresa
iGEM	The International Genetically Engineered Machine competition
IND	India
IP	Intellectual Property
IRN	Iran
ISR	Israel
KOR	South Korea
MIT	Massachusetts Institute of Technology
NIH	National Institutes of Health
PPP	Purchasing Power Parity
R&D	Research & Development
RUS	Russia
S&T	Science & Technology
SGP	Singapore
STEM	Science, Technology, Engineering & Mathematics
STI	Science & Technology Innovation
UNESCO	United Nations Educational, Scientific and Cultural Organization
USA	United States of America
USD	United States Dollar
USDA FAS	United States Department of Agriculture's Foreign Agricultural Service
VC	Venture Capital
WEF	World Economic Forum
ZAF	South Africa

Aims and Scope

The esteemed physicist Freeman Dyson, in an essay in the New York Review of Books in 2007, wrote: "It has become part of the accepted wisdom to say that the twentieth century was the century of physics and the twenty-first century will be the century of biology. Two facts about the coming century are agreed on by almost everyone. Biology is now bigger than physics, as measured by the size of budgets, by the size of the workforce, or by the output of major discoveries; and biology is likely to remain the biggest part of science through the twenty-first century. Biology is also more important than physics, as measured by its economic consequences, by its ethical implications, or by its effects on human welfare." (Dyson 2007)

This report is the product of a 20-month project to anticipate the growth of biotechnology in the United States relative to other nations by mid-century. Cutting-edge biotechnologies, e.g., synthetic biology and genome engineering, offer opportunities to improve our ability to **enhance wellness and treat disease**, **address food insecurity**, **mitigate climate change**, **strengthen biodefense**, and as we have seen over recent months, **combat future pandemics**. It is among these opportunities where the United States will need to maintain leadership.

Putting Dyson's commentary into chronological context helps understand the pace of change and thus the challenge of the task we undertook. 2007 was 12 years after the sequencing of the first free-living organism, 7 years after the first draft sequence of the human genome, 3 years before the synthesis of an entire microbial genome, and 5 years before the first applications of CRISPR-Cas9 for genome editing. The fields of synthetic biology and genome engineering are changing just too rapidly to forecast their capabilities by 2050.

But Dyson correctly identified several of the societal drivers that will help determine the rate of change. Today, the United States leads the world in the biotechnological expertise and innovation. Whether it continues to do so by mid-century will depend on how the biotechnology development environment, i.e., the drivers of innovation, in the United States compares to that of other nations. In this report, we attempt to **define, describe, and semi-quantitatively characterize** the factors that may increase or decrease the rate of biotechnology innovation in selected nations around the world.

We set out to achieve three goals. First, we hoped to develop a **framework with which to understand the drivers of innovation** in the biotechnology sector. The report includes such a framework and provides publicly available data on close to 100 indicators that characterize the sector in 12 selected nations. Second, we hoped to be able to use this framework and data to construct **well-reasoned scenarios of the relative biotechnological prowess of the United States versus other nations several decades into the future**. We have provided a series of scenarios that project future biotechnological capacity in these 12 nations under varying degrees of governmental policy attention or neglect. Finally, by identifying the underlying drivers of innovation, we hope that the framework will be useful for tracking progress as future conditions change.

Part I: The Bio-enterprise, 2020 to 2050

Part I includes three sections. The first section provides an overview of methods used to develop this report, including the choice of indicators; methods used to aggregate the indicators into sector-wide and comprehensive scores for 2020; and projections of country capabilities to 2050. The second section includes a high-level comparison of the 12 countries we examined in detail, for both 2020 and 2050. The final section includes four-page summaries for each of the 12 countries.

Detailed country datasheets for 2020 can be found in Part II.

Methods: 2020 Indicators & 2050 Projections

Methods: 2020 Indicators and 2050 Projections

2020 Indicators

Within each country, we have assembled and analyzed a series of close to 100 indicators in a wide variety of categories. These include indicators of scientific, technological, policy, and broad societal drivers that enable the development of biotechnology innovation today and in the future.

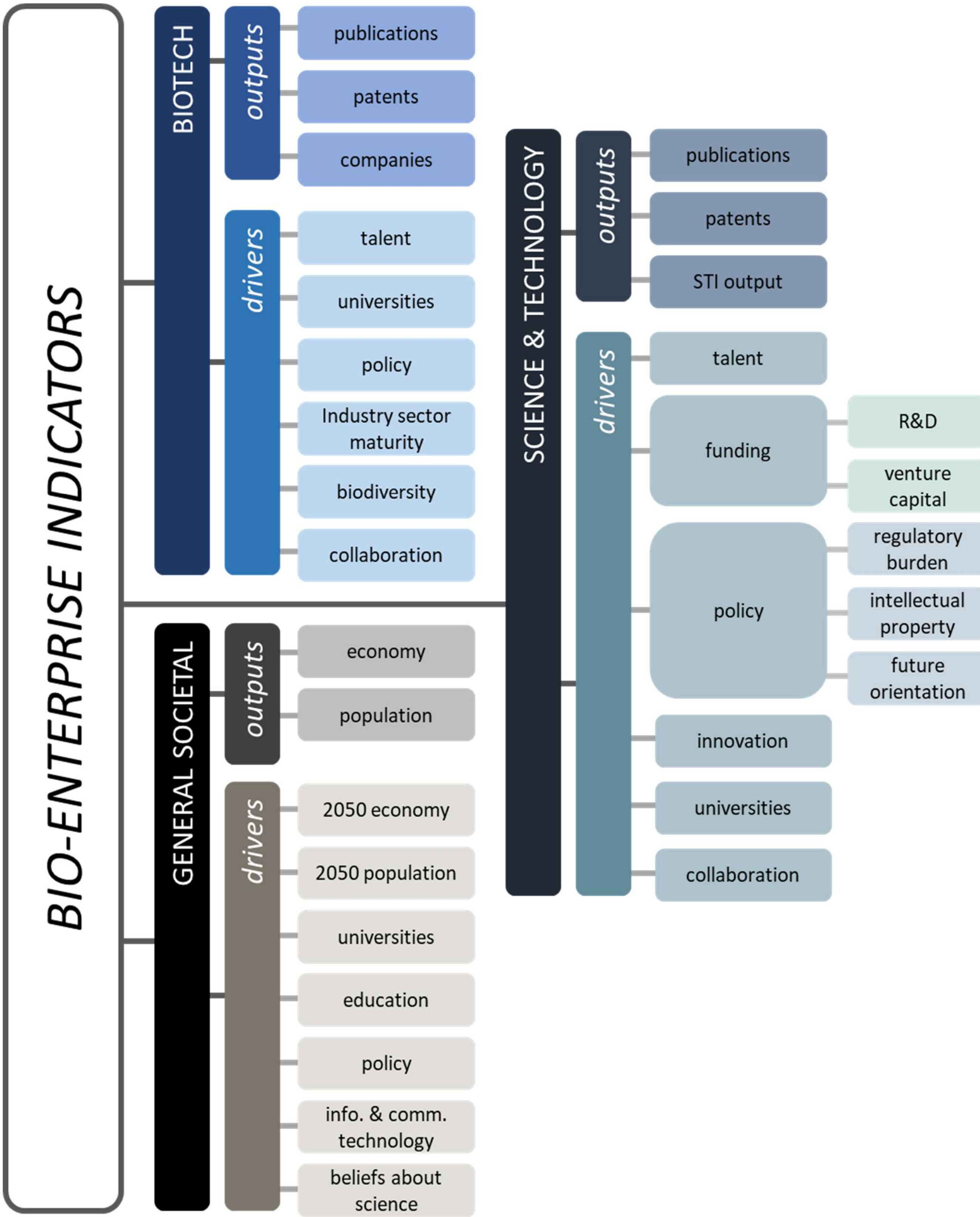
The drivers of future success in biotechnology are by no means confined to the biotechnology sector alone. Thus, our analysis of the biotechnology development environment includes sets of indicators from three expanding views: 1) the **biotechnology sector** itself; 2) the broader **science and technology environment**, concentrating on those factors most important for the growth of the biotechnology sector; and 3) **general societal** drivers of growth, and in particular, those with greatest relevance for the growth of science and technology. For lack of an existing term, we have coined the word **"bio-enterprise"** to refer to the entire biotechnology innovation and production system, including the broader science, technology, and general societal environment on which it depends.

Figure 1 displays the structure of the detailed data tables included in Part II of this report. It also illustrates the general framework we have developed for understanding and analyzing the close to 100 indicators for each of our 12 countries. Under each of the three sectors we include a series of 1) **output measures**, i.e., national-level characterizations of the output or performance of the biotechnology sector and larger science and technology sector today and 2) **drivers of innovation** that will affect the growth of biotechnology over the next several decades.

Thus, for each of our 12 countries, Part II includes 6 "tables" that graphically display our results. In order of presentation, these include:

- **Biotechnology sector, output measures.** As shown in Figure 1, output measures for this sector include scientific journal articles related to biotechnology; biotechnology patents; and biotechnology companies in each of four subsectors: biopharma, agricultural biotechnology, "industrial" biotechnology (e.g., production of biofuels, bio-based chemicals, plastics, etc.), and service companies. Ideally, we would have also included a measure of economic output from this sector, but such information is not available. A recent report from the US National Academies of Sciences (NASEM, 2020) recommends collecting such statistics for the United States. The report estimates that the US bioeconomy accounts for about 5 percent of US GDP, about $1 trillion/year. We could not identify comparable estimates for other countries.
- **Biotechnology sector, drivers of innovation.** In Figure 1, we include a list of what we believe to be important factors for future success of the biotechnology sector. These drivers of future innovation include biotechnology and synthetic biology talent, both professionals and students; top universities for biotechnology and life sciences; whether the country has a national biotechnology policy or plan; measures of the maturity of the biopharma, ag biotech, and industrial biotech subsectors; measures of the knowledge base of each country's plant and animal biodiversity and genomics, and a measure of international collaboration within the life sciences.

Figure 1: Categories of Indicators analyzed in this report. Indicators have been selected from the biotechnology sector itself; 2) the sector's broader science and technology environment, and 3) general societal drivers of growth. See text for detail.



- **Science and technology sector, output measures.** Output measures for this sector include scientific journal articles in a broad range of advanced technology fields outside of, but relevant to, biotechnology; total patents (all fields); and another study's measure of knowledge and technology outputs (Global Innovation Index, GII, by INSEAD, Cornell, and WIPO). We would have liked to include a measure of economic output from this broad sector, but such information, collected in such a way as to be comparable across our 12 countries, is not available.
- **Science and technology sector, drivers of innovation.** Within this group, we have included those drivers of science and technology innovation that we believe are most important to the future success of biotechnology. These include measures of STEM talent, both recent graduates and researchers; R&D expenditures (all fields of science and engineering) by universities, businesses, and government; venture capital funding; top computer science and engineering universities; regulatory policy; intellectual property policies; a series of aggregate measures related to innovation, acceptance of business risk, and university-industry collaboration from the GII study and the World Economic Forum's Global Competitiveness Report, GCR.
- **General societal sector, output measures.** These include measures of economic output, both GDP and GDP per capita; population measures, both total population and the ratio of working-age to elderly people; and top-ranked universities.
- **General societal sector, drivers of innovation.** Measures of general societal drivers of innovation that we believe are most relevant to future success of the biotechnology sector include GDP and population growth rates projections to 2050; projected ratio of working-age to elderly people in 2050; a series of measures related to education of the population and spending on education by government; a measure of "rule of law"; adoption of internet and communication technologies; and a series of survey results about beliefs about the benefits from science.

Within each of the 6 data tables for each of our 12 countries, we include indicators of two types: **absolute** indicators and **intensity** indicators. Absolute indicators include measures of things that are countable, such as number of people, dollars, patents, publications, universities, etc. These are not scaled to, for example, GDP or population, thus large economies and/or populous countries have an inherent size advantage when comparing among countries. The United States and China are the world's leaders by this type of accounting. Intensity indicators are either absolute indicators scaled to GDP, or measures that inherently do not depend on country size. The latter are often measures of quality, for example, quality of publications, sophistication of business, or functioning of regulatory and IP systems within a country. Given the vast differences in sizes of our 12 countries, both types of measures are important.

Because the units of the indicators vary greatly, we have scaled each indicator to 0 to 10, with 10 being the highest value among our 12 countries. Bar graphs of each indicator across all 12 countries are included to visually display how each country compares to the others. Both ranks and values for the indicator are included, as well.

To illustrate how to read these tables, a small section of one of the Biotechnology sector data tables for the United States is shown as Figure 2 below. The bottom half of the figure shows the beginning of the "Biotech: output measures" table. The US ranks #1 in the absolute measure "share of top biotech publications," with 60% of the world's total. The US ranks #2 in the intensity measure "top biotech publications relative to GDP," and as can be seen from the bar charts, far behind #1 Israel and comparable to Germany. The graphic convention that we follow in the data tables shades the names of absolute indicators in gray and leaves intensity indicators unshaded (i.e., white).

At the top of Figure 2, one can see listed two **sector scores**, labelled **aggregate capacity scores** and **aggregate innovation-driver scores**. These are weighted-aggregate scores for the biotechnology sector. The US ranks #1 on the biotech aggregate capacity score, with a score of 9.8 out of 10. The US ranks #3 on the aggregate innovation driver score, which is an *intensity* score, i.e., independent of country size. The US score of 5.6 trails both Israel and Singapore, both of which are far smaller but more “intense” in their biotech efforts.

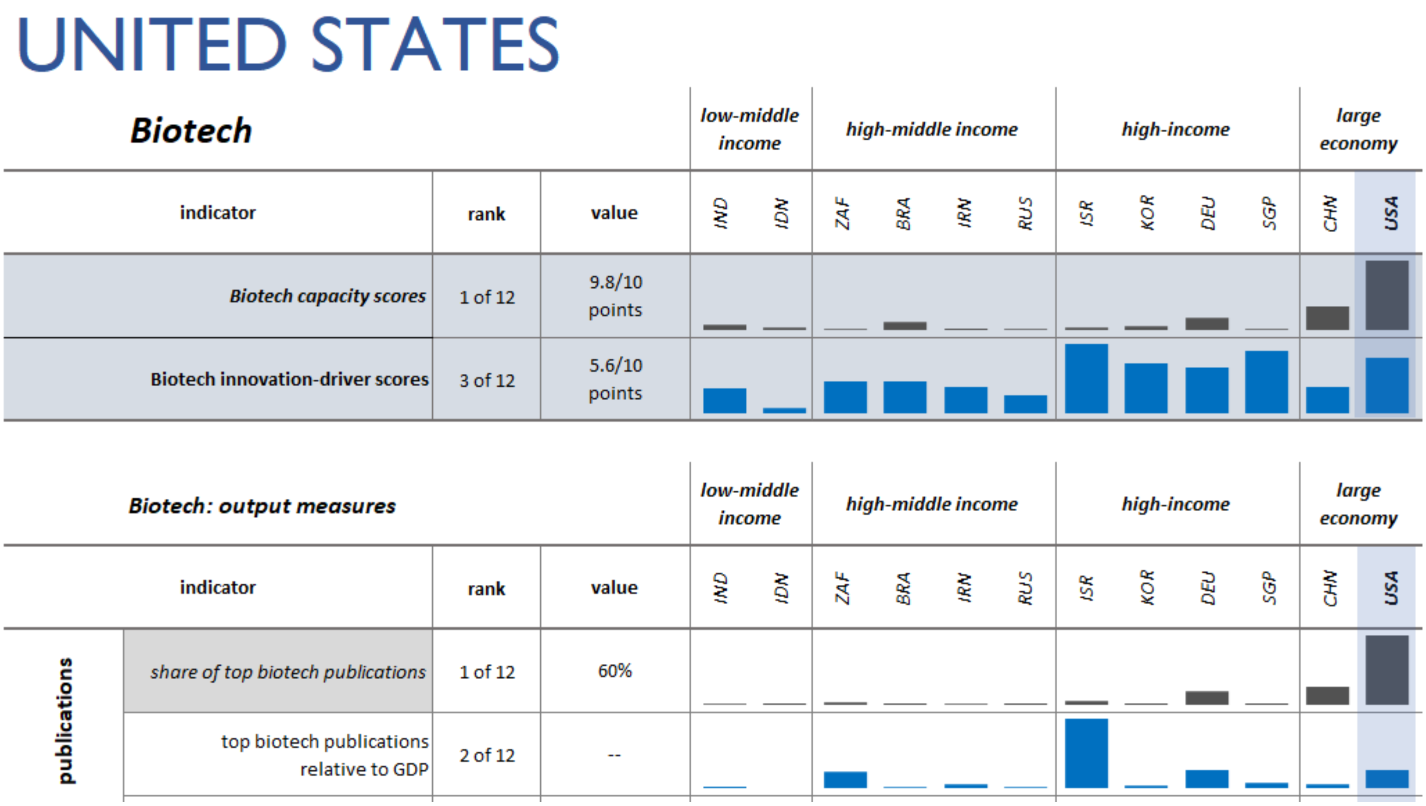
Sector Aggregate Scores and overall Bio-enterprise Scores

But what are these aggregate scores intended to reflect and how are they constructed? First, recall as shown in Figure 1, within each of the three sectors, we include nine or more categories of indicators, which include several categories of output measures, and a larger number of categories that we consider to be drivers of innovation. Within each category, some of these indicators are absolute measures and others are intensity measures.

One of the goals of this project was to construct a framework to aggregate the approximately 100 quantitative indicators that we have identified and assembled into a small number of weighted-aggregate scores. We have constructed two aggregate scores for each of the three sectors:

- **Sector *capacity scores*** are calculated as a weighted sum of all ***absolute indicators***, including ***both output measures*** and ***drivers of innovation***. The sector capacity scores are then rescaled to a 0 to 10 scale, with 10 equal to a hypothetical score for a country achieving 10 on every absolute measure.
- **Sector *innovation-driver scores*** are calculated as a weighted sum of those ***intensity indicators*** that we consider to be ***drivers of innovation***. Similarly, the sector innovation-driver scores are then rescaled to a 0 to 10 scale, with 10 equal to a hypothetical score for a country achieving 10 on every driver intensity measure.

Figure 2: Illustrative detail from indicator data tables in Part II of this report.



Our capacity scores recognize that a country's ability to participate in the global biotechnology industry should reflect both its current output ***and*** its drivers of innovation, for example, the size of its talent pool, university infrastructure, and funding devoted to R&D, etc. This is similar to the distinction that some economists make between a country's GDP and its true wealth. GDP is a measure of economic activity; wealth is a measure of the potential each country has to produce desired goods and services. Again, our capacity scores are intended to measure the potential of each sector to help invent and produce biotechnology products.

Table 1: Indicators used to calculate Bio-enterprise Capacity scores. Sectors and categories are the same as those shown in Figure 1. Weights prioritize the relative influence of each indicator to the health of a country's biotechnology endeavor, and are factored into the aggregated section scores. score 0 = least influential or not applicable for weighting. score 10 = most influential.

section	subsection	category	absolute indicators	weights
biotech	outputs	publications	*share of top biotech publications*	10
		patents	*share of world biotech patents, 2014-2019*	10
		companies	*share of world biotech companies*	6
	drivers	talent	*users of largest genetic sequence database*	4
			users of a major genetic engineering tool supplier	4
			participation in international genetic engineering competition	4
			attendance at preeminent synthetic biology conferences	1
			subscribers to a prominent synthetic biology newsletter	1
		universities	*share of top biotech universities*	4
			share of top biology universities	3
			share of top life sciences universities	3
		industry sector maturity	*share of total global biotech crops*	3
			share of total global biofuel production	2
			clinical trials of biologics since 2010	5
		biodiversity	*well-studied animal and plant species*	2
			non-human sequence entries in largest genetic sequence database	2
		collaboration	*life sciences collaboration (Nature Index)*	4
science & tech	outputs	publications	*share of top high tech publications*	10
		patents	*share of world patents, 2014-2019*	10
	drivers	talent	*share of world STEM graduates*	5
			share of world researchers	5
		funding: R&D	*total expenditures on R&D*	10
		universities	*share of top computer sciences universities*	3
			share of top engineering and technology universities	3
		collaboration	*share of top international innovation clusters*	6
general societal	outputs	economy	*current GDP, PPP*	10
		population	*current population*	4
	drivers	economy	*2050 GDP, PPP*	10
		population	*2050 population*	4
		universities	*share of top universities*	6

Table 2: Indicators used to calculate Bio-enterprise Innovation-driver scores.

section	category	intensity indicators	weights	rate of change
biotech	talent	*users of largest genetic sequence database relative to GDP*	4	20 yrs
		users of a major genetic engineering tool supplier relative to GDP	4	20 yrs
		participation in international genetic engineering competition relative to GDP	4	20 yrs
		attendance at preeminent synthetic biology conferences relative to GDP	1	20 yrs
		subscribers to a prominent synthetic biology newsletter relative to GDP	1	20 yrs
	universities	*top biotech universities relative to GDP*	4	longer
		top biology universities relative to GDP	3	longer
		top life sciences universities relative to GDP	3	longer
	policy	*presence of a national biotechnology plan*	6	10 yrs
	industry sector maturity	*biotech crops relative to total cropland*	3	20 yrs
		biotech fuels relative to total liquid fuel production	1	20 yrs
		average annual growth rate in biofuel production, 2006-2016	1	20 yrs
		clinical trials of biologics since 2010 scaled to GDP	2	20 yrs
		innovation in biopharma (Biopharmaceutical Competitiveness Index)	3	20 yrs
	biodiversity	*well-studied animal and plant species scaled to GDP*	2	20 yrs
		non-human sequence entries in largest genetic sequence database scaled to GDP	2	20 yrs
	collaboration	*life sciences collaborations relative to GDP*	4	30 yrs
science & tech	talent	*STEM graduates relative to GDP*	4	20 yrs
		retention of foreign-educated PhD students	2	20 yrs
		researchers relative to GDP	4	30 yrs
	funding: R&D	*total expenditures on R&D relative to GDP*	5	20 yrs
		R&D expenditures funded by higher ed. relative to GDP	3	10 yrs
		R&D expenditures funded by government relative to GDP	1	10 yrs
		R&D expenditures funded by business relative to GDP	1	30 yrs
	funding: venture capital	*VC availability (Global Competitiveness Report)*	3	longer
		VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	3	longer
	policy: regulatory burden	*lack of burden of government regulation (Global Competitiveness Report)*	4	10 yrs
		ease of technology transfer (US Chamber IP Index)	4	10 yrs
	policy: intellectual property	*intellectual property protection(Global Competitiveness Report)*	2 2/3	10 yrs
		patents, related rights, and limitations (US Chamber IP Index)	4	10 yrs
		tax incentives in the creation of IP assets (US Chamber IP Index)	1 1/3	10 yrs
	policy: future	*future orientation of government (Global Competitiveness Report)*	8	30 yrs
	innovation	*acceptance of risk in entrepreneurship (Global Competitiveness Report)*	2 2/3	longer
		human capital and research (Global Innovation Index)	1 1/3	20 yrs
		innovation capability (Global Competitiveness Report)	1 1/3	30 yrs
		infrastructure (Global Innovation Index)	1 1/3	30 yrs
		business sophistication (Global Innovation Index)	1 1/3	longer
	universities	*top computer sciences universities relative to GDP*	3	longer
		top engineering and technology universities relative to GDP	3	longer
	collaboration	*state of cluster development (Global Competitiveness Report)*	3	30 yrs
		university-industry collaboration (Global Competitiveness Report)	3	20 yrs
general societal	economy	*2050 GDP per capita*	8	longer
		GDP annual growth rate, 2018 to 2050	2	longer
	population	*population growth rate, 2018 to 2050*	1	longer
		2050 ratio:working age population to young plus elderly population	3	longer
	universities	*top universities relative to GDP*	6	longer
	education	*school life expectancy, primary through tertiary*	2	20 yrs
		presence of science education in secondary school	2	10 yrs
		government expenditure on education as percent of GDP	1	10 yrs
		government expenditure on primary education as percent of GDP	1	10 yrs
	policy	*rule of law (World Justice Project)*	4	20 yrs
	ICT	*ICT adoption (WEF Global Competitiveness)*	4	30 yrs
	beliefs about science	*belief in science as future national benefit*	1	longer
		belief in science as increasing jobs	1	longer
		belief in science as a personal benefit	1	longer
		trust in science over religion	1	longer

Finally, we desired a way to combine the contributions of each of the three sectors into overall "bio-enterprise" scores. Similar to the sector scores, we have constructed two combined scores:

- Our ***Bio-enterprise capacity score*** combines the three sector capacity scores, with greatest weight given to the biotechnology score and diminishing weights to the science & tech score and general societal score. Our bio-enterprise capacity score is an ***absolute measure*** that is calculated from 30 indicators from all three sectors. Table 1 includes a list of these indicators and the arithmetic weightings used to calculate each sector score. The sector scores are then combined into the bio-enterprise score as a scaled Cartesian distance.[1] Thus, the maximum bio-enterprise score can be greater than 10 (a hypothetical maximum of just over 13).
- Our ***Bio-enterprise innovation-driver score*** combines the three sector capacity scores in a similar manner. Our bio-enterprise innovation-driver score is an ***intensity measure*** that includes 53 indicators from all three sectors. Table 2 includes a list of these indicators and the arithmetic weightings used to calculate each sector score. The sector scores are then combined into the bio-enterprise score as a Cartesian distance.

Figure 3 is a schematic diagram of the method we use to combine the indicators shown in the data tables in Part II into our aggregate sector and combined bio-enterprise scores.

2050 Projections

The data tables in Part II and the combined bio-enterprise scores in the next section provide relative scores and rankings that compare our 12 countries in 2020. Our ultimate goal for this project was to explore the relative country scores and rankings in the global bio-enterprise by mid-century.

Our approach assumes that each country's ***future*** **bio-enterprise capacity score** depends on:

- The country's ***current*** **bio-enterprise capacity score**.
- The intensity or strength of its **bio-enterprise innovation-driver score**. The higher the innovation-driver score, the faster the growth in capacity.
- Forecast **GDP** growth (i.e., growth in the economy overall). A country's capacity will grow at least at the rate of its forecast GDP growth.
- Forecast growth in the average **productivity of its citizens (GDP/capita)**. Innovation-driver score appears related to GDP/capita; exactly how is unclear, as discussed below.

We constructed a series of simple models that step through time in 10-year intervals, calculating the increase in both **capacity scores** and **innovation-driver scores** for each sector through time, as GDP and GDP/capita increases.

The general form of these models, expressed as an equation, follows:

$$\text{capacity score}_{(\text{future})} = f\,[\text{capacity score}_{(\text{current})} * (1 + c * \text{innovation-driver score}_{(\text{current})})] * \text{GDP}_{(\text{future})} / \text{GDP}_{(\text{current})}$$

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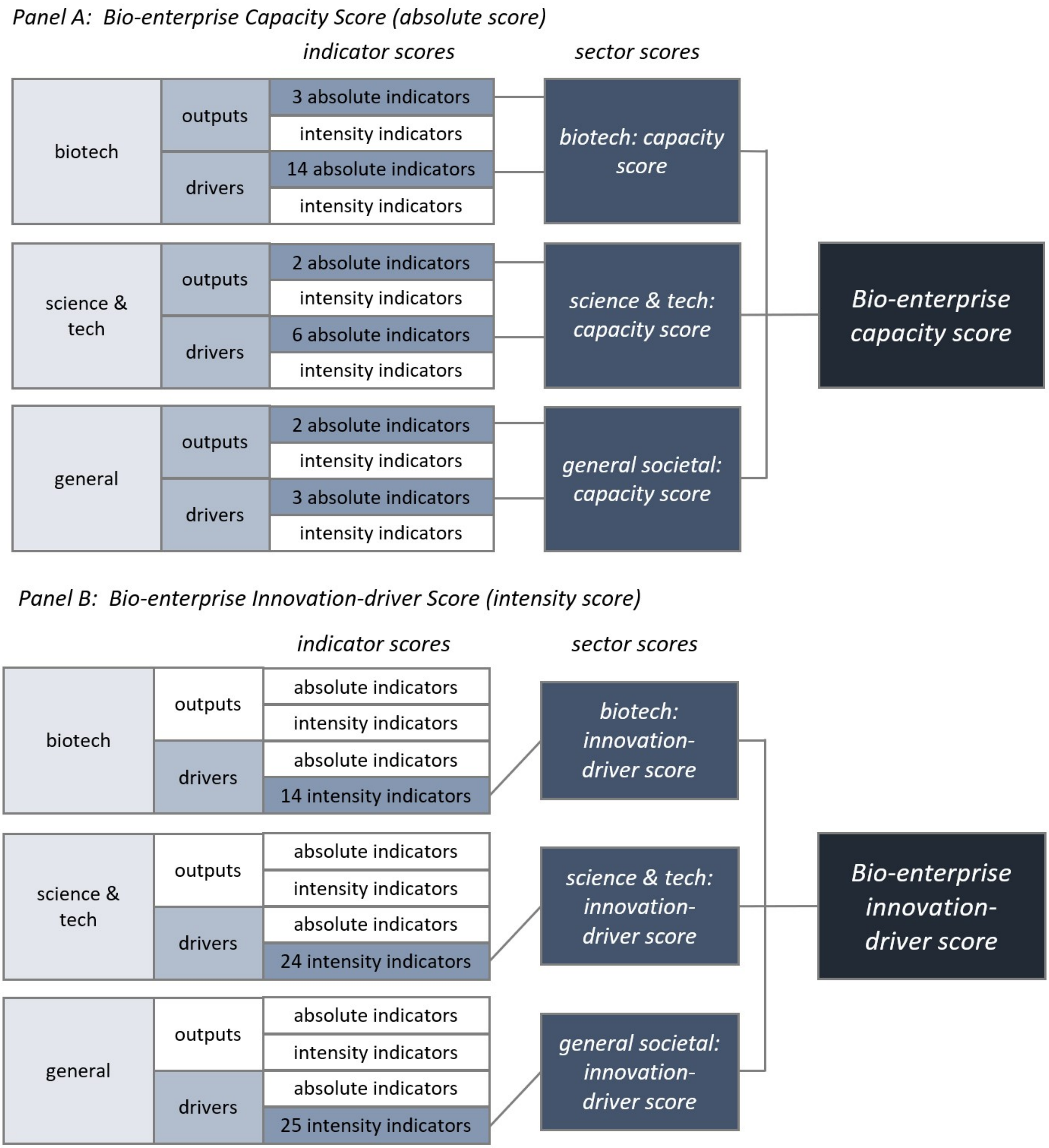
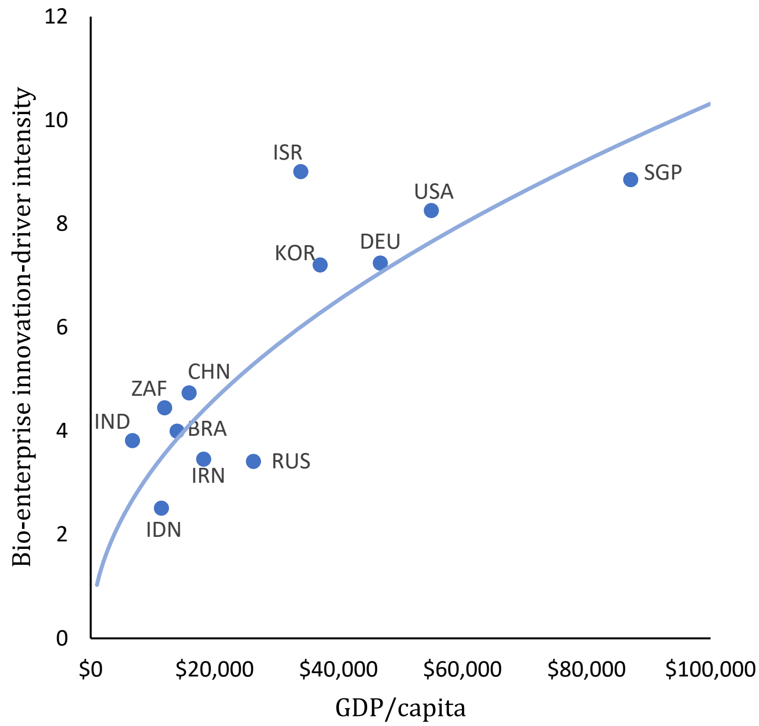
[1] Bio-enterprise scores are calculated as Cartesian distances, i.e., $bioenterprise\ score = \sqrt{(biotech\ score)^2 + 0.5 * (science\&tech\ score)^2 + 0.25 * (general\ societal\ score)^2}$

Figure 3: Schematic illustrating the types of indicators used to calculate capacity and innovation-driver scores.



We then combine these sector-specific scores into bio-enterprise scores. In essence, the **bio-enterprise capacity score** represents the size of each country's bio-enterprise at a point in time. The **bio-enterprise innovation-driver score** represents the rate at which it is increasing. Those countries with higher innovation-driver scores will see faster growth in capacity.

Figure 4: Bio-enterprise innovation-driver scores increase with economic productivity (GDP/capita), but at a declining rate.



We are assuming that global bio-enterprise capacity will grow faster than overall global GDP growth. However, just how much faster is unknown, thus we constructed two growth scenarios to test whether relative scores and rankings were sensitive to this unknown.

For the US, the low-growth scenario assumed about 4%/yr. growth of the sector between 2020 and 2050, i.e., about twice anticipated GDP growth of just under 2%/yr. The high-growth scenario assumed a much rosier picture for the sector: over 5% percent above GDP growth, for an overall growth of over 7%. These higher growth rates have been forecast by observers who are optimistic that new technology (CRISPR gene editing, synthetic biology, cheaper sequencing of human genomes) will enable the biotechnology sector to grow far faster than the overall economy. For example, Carlson (2016) estimated that revenues from the biotechnology sector grew at over 10%/yr. between 2005 and 2015.

While the absolute capacity scores are, of course, much greater in the high-growth scenarios than under our low-growth scenarios, the relative patterns of growth among countries remained quite similar. In the body of this report, we use the results from our high-growth scenarios. Detailed results from both growth scenarios are included in an Appendix.

Finally, as shown in Figure 4, we see a striking relationship between our 2020 bio-enterprise innovation-driver scores and the average productivity of a country's citizenry (measured as GDP/capita). All of our countries are forecast to become wealthier through time, but at varying rates. We wanted to incorporate these differences into our models, but because we have data from only one point in time, just how was not clear. Thus, we constructed three different models incorporating plausible alternative explanations. As with our growth scenarios, the relative patterns of growth among countries remained reasonably similar across our three different models. Table 3 below lists the assumptions embedded into the four scenarios we explored in detail.

"What-if" Scenarios

The high-growth and low-growth scenarios discussed above were developed to examine the effects of modest vs. rapid ***global technological advance***, not variations in policy emphasis among countries. To interrogate the effect of policy, we constructed an additional series of ***policy*** scenarios to test the sensitivity of our bio-enterprise capacity score to changes in policies or societal emphasis in individual countries. We believe that policy decisions within our 12 countries will have striking influences on their relative standings in the future.

We have developed three policy scenarios, which we call ***status quo***, ***policy push***, ***and policy drag.*** Our ***status-quo*** scenario assumes that for any individual country, due to little or no change in the national policy influencing our measures, the strength of its 53 innovation-drivers remains about equal to its value in 2020, increasing only slightly as average productivity (GDP/capita) increases through time. Our ***policy-push*** scenario posits that a country would like to drive biotechnology development, to help grow its economy and/or become a leader in the field, and therefore alters policy toward aggressive and sustained governmental actions supporting biotechnology growth. Under this scenario, we increase a subset of innovation-drivers amenable to policy intervention through time and calculate the resulting increase in bio-enterprise capacity. Our ***policy-drag*** scenario assumes that policy attention toward biotechnology wanes, innovation drivers decline, and thus future bio-enterprise capacity drops below the status-quo scenario.

Of course, governmental policy does not impact all of our innovation drivers equally; some are amenable to rapid change, others hardly at all. The last column of Table 2 includes our estimates of how long it might take to see the full effect of governmental policy change on each of our 53 innovation drivers. For about 20% of our innovation drivers, we believe policy change could have significant effects within a decade. These include such innovation drivers as government regulation, intellectual property protection, and investments in R&D and public education. About another 35% of our innovation drivers might significantly respond to governmental policy change within a 10- to 20-year timeframe. In this category we include such innovation drivers as building a strong scientific talent pool, a mature biotech crop industry, or strengthening the rule of law. We believe that 30 years might be a more reasonable timeframe for change in about another 15% of our innovation drivers, e.g., building strong university and industry technology clusters. The remaining 30% of our innovation-drivers will not respond to policy change quickly or are not impacted by policy changes at all.

In addition, some governments can implement change more quickly than others. We have assumed that authoritarian regimes, if they desire to, can implement policy changes more rapidly than democratic governments. Thus, we allow authoritarian regimes, such as China, Iran, and Russia, to change their innovation drivers scores rapidly in response to our policy scenarios than such democratic nations as Germany, the US, and South Korea. This applies to both the policy-push and policy-drag scenarios. Rate adjustments are based on the Economist Intelligence Unit Democracy Index scores.

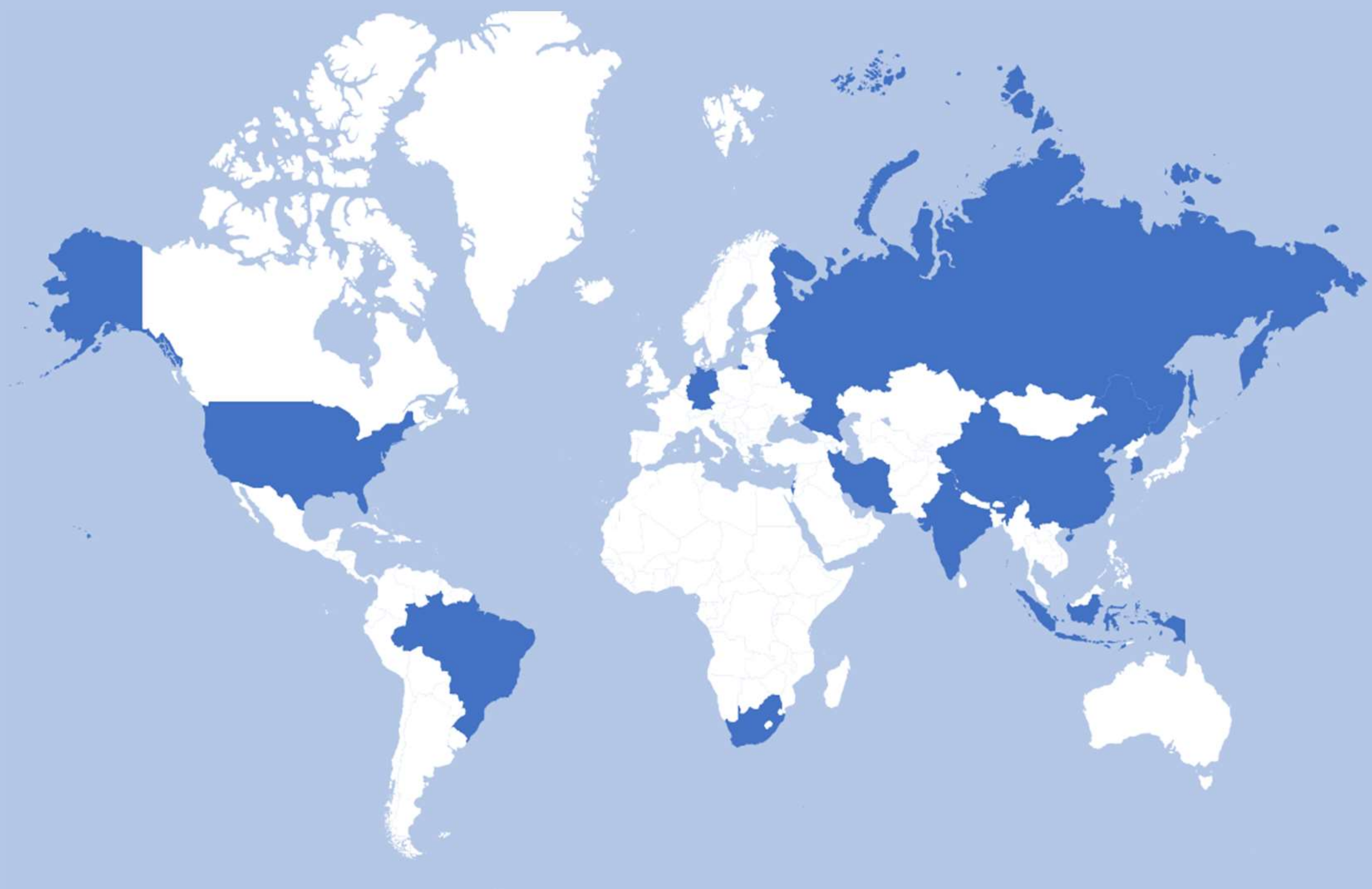
Table 3: 2050 projections of bio-enterprise capacity: key modeling assumptions

	low growth scenario		**high growth scenario**	
	model A	**model B**	**model B**	**model C**
US Bio-enterprise annual growth rate	4.2%	4.6%	7.2%	7.7%
US GDP annual growth rate	1.9%	1.9%	1.9%	1.9%
Innovation-driver potential increases with wealth?	no	yes	yes	yes
Capacity potential increases with wealth?	no	no	no	yes
Growth intervals used in calculations?	30 year	10 year	10 year	10 year

Just how much an individual innovation driver can increase under the policy-push scenario depends on its score in 2020 and its income category. We assume that our high-income countries, with political will and sufficient resource investment, could achieve "best in class" performance for that particular indicator. For example, if it chose to do so, the US could increase its rate of R&D spending (when measured as R&D expenditures relative to GDP) to that of South Korea, the current leader. For indicators for which global data was available, "best in class" was set to an average of the top fifth of global nations (to eliminate outliers), or the best of our 12 nations, whichever was higher. Middle-income countries such as Brazil also increase their scores under the policy-push scenario, but not as much. The maximum score for middle-income countries was set to either the average of the top middle-income score and top high-income score, or the average of the top fifth of global middle-income nations, whichever was higher. This recognizes that middle-income countries will be able to push further toward high-income performance as their economies develop in the coming decades.

Under the policy-drag scenario, we assume individual innovation drivers can drop by 30%, regardless of country income category. Again, as under the policy-push scenario, the rate of decline varies by indicator (as shown in Table 2), with authoritarian regimes declining faster than democratic countries.

Country Comparisons



Country Comparisons

Country demographics:

The 12 countries examined in this report include, first, the **United States** and **China**, the world's two largest economies and biotechnology leaders, on an *absolute* basis, today. In addition, we include four high-income countries (using the World Bank classification scheme): **Germany**, **South Korea**, **Singapore**, and **Israel**. All four are biotechnology leaders from a different perspective, not in absolute capacity, but the *intensity* of their biotech sectors. Four of our countries are large, rapidly expanding economies with active biotechnology sectors: **India**, **Brazil**, **South Africa**, and **Indonesia**. Finally, we include two US adversaries: **Russia** and **Iran**. The latter six are all middle-income countries today.

Figure 5 displays current (2020) and projected (2050) GDP/capita for each of our 12 countries. Seven of our 12 countries, China among them, are middle-income countries today. By 2050, all seven are forecast to increase their GDP/capita to a level that would be considered high-income today. Increasing total economic productivity, as well as increasing per capita productivity, are important factors for understanding the potential growth of the bio-enterprises of these countries by 2050.

Figure 5: Current GDP/capita and projected GDP/capita, constant USD, purchasing power parity. 2050 estimates are an average of World Bank and PwC economic projections, Wittgenstein Center of population projections.

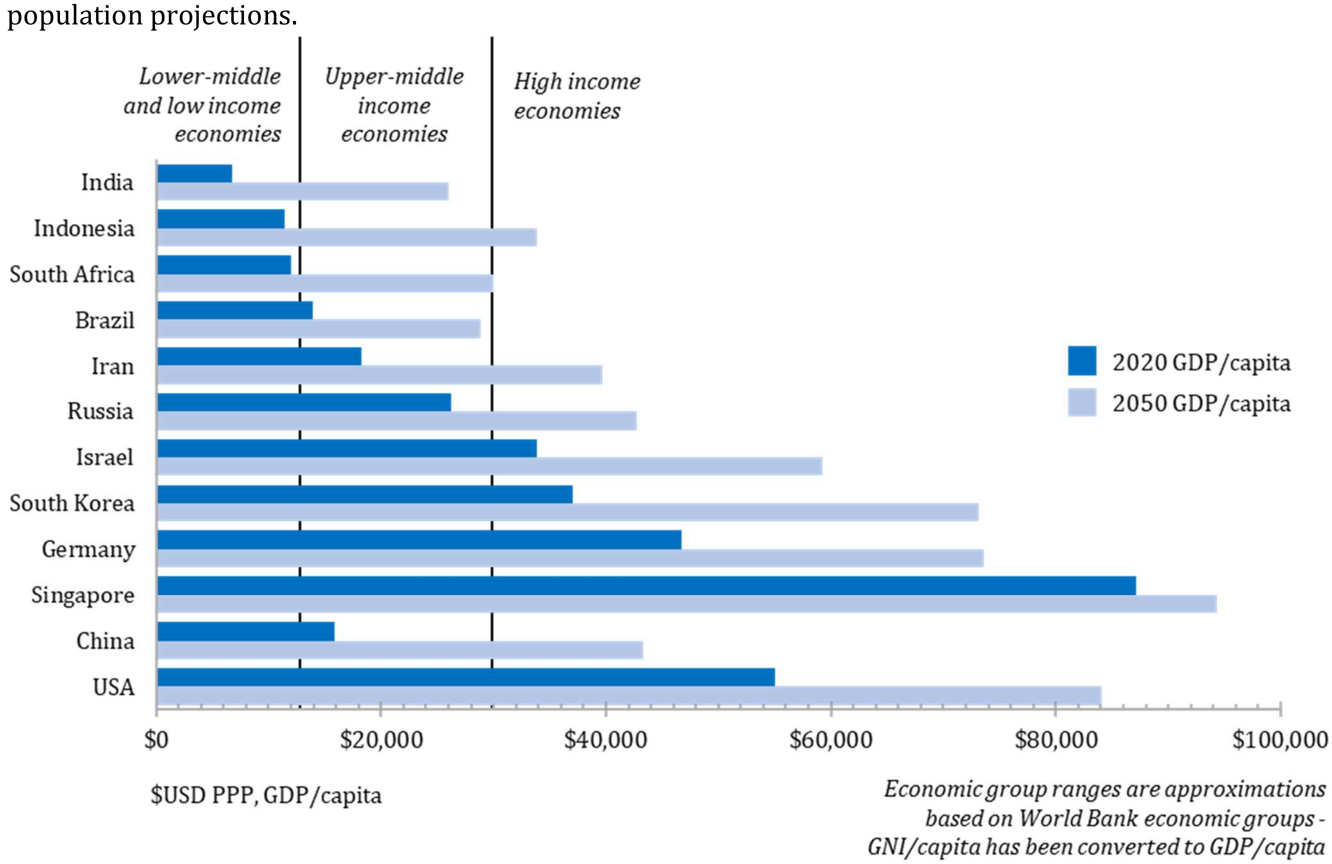


Table 4 lists the 10 largest economies, as measured by GDP, in the world today and forecast for 2050. Seven of our 12 countries are among the 10 largest in 2020; 6 of 12 are forecast to be among the largest in 2050. Together the economies of these countries contribute about two-thirds of global GDP both today and perhaps an even greater share in 2050. Half our countries are also quite populous. Table 5 shows that 6 of our 12 countries are among the top 10 most populous countries today.

Table 4: World's 10 largest economies, 2018 and projected 20ω0

2018			2050		
country	**GDP, USD $T PPP**	**share of global economy**	**country**	**GDP, USD $T PPP**	**share of global economy**
China	24.9	24%	China	54.4	25%
USA	18.6	18%	India	41.5	19%
India	10.1	10%	USA	32.0	15%
Japan	5.0	5%	Indonesia	10.4	5%
Germany	3.8	4%	Japan	7.0	3%
Russia	3.6	3%	Turkey	6.2	3%
Indonesia	3.4	3%	Brazil	5.8	3%
Brazil	3.2	3%	Germany	5.7	3%
Britain	2.7	3%	Britain	4.9	2%
France	2.7	3%	Mexico	4.9	2%

Table 5: World's 10 most populous countries, 2018 and projected 2050

2018			2050		
country	**population, millions**	**share of global population**	**country**	**population, millions**	**share of global population**
China	1417	18%	India	1642	18%
India	1382	18%	China	1302	14%
USA	331	4%	USA	393	4%
Indonesia	272	3%	Nigeria	383	4%
Brazil	214	3%	Indonesia	308	3%
Pakistan	209	3%	Pakistan	307	3%
Nigeria	205	3%	Brazil	230	2%
Bangladesh	171	2%	Bangladesh	204	2%
Russia	143	2%	Ethiopia	184	2%
Mexico	133	2%	DRC	163	2%

Bio-enterprise capacity and drivers of innovation, today and by 2050:

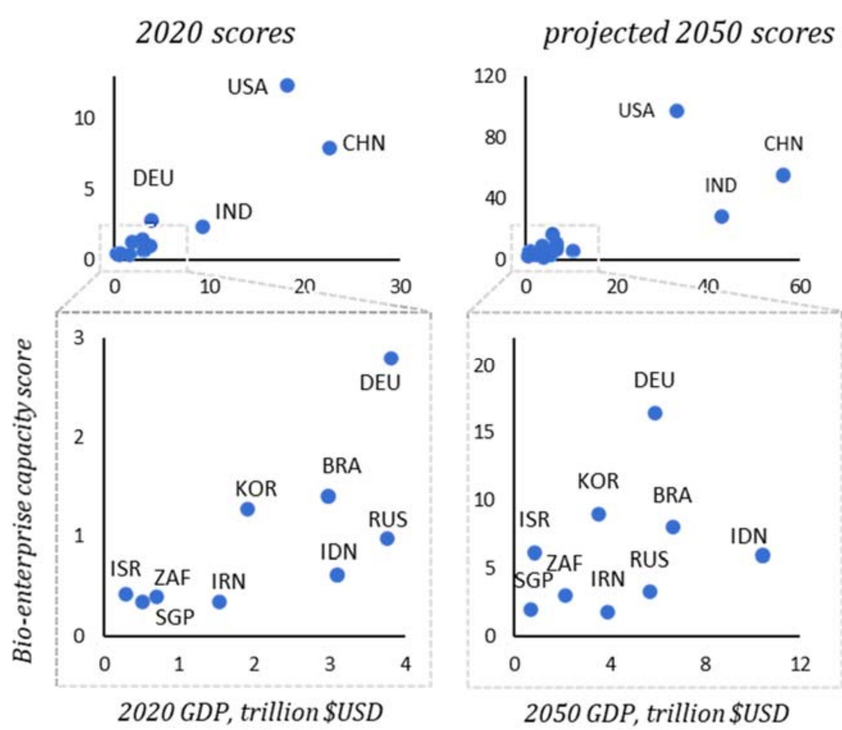
Throughout this report, we use the term **"bio-enterprise"** to refer to the entire biotechnology innovation and production system, including the scientific and societal environment on which it depends. To help us understand and compare the bio-enterprise within and among each of our 12 countries, we have collected data on approximately 100 indicators in three sectors: the biotechnology sector itself, the broader science and technology sector, and the general societal environment in which they function. We combine these indicators into two high-level bio-enterprise scores. Similar to the way a country's economic status can be described in two complementary ways, e.g., as GDP (an absolute measure) and GDP/capita (an intensity measure), for each country, we construct a **bio-enterprise capacity score** and a **bio-enterprise innovation-driver score**.

- Our **bio-enterprise capacity score** is an *absolute* measure that reflects each country's capacity, or potential to invent and produce, biotechnology products. Each of the 30 indicators included in this combined score is countable, e.g., number of patents, scientists, and top universities, dollars spent on R&D, etc. Table 2, presented earlier, lists these indicators.
- Our **bio-enterprise innovation-driver** score is an *intensity* measure that reflects each country's capability to grow its bio-enterprise over the next years. Each of the 53 indicators in this combined index are some measure of quality that does not depend on country size, or are absolute measures scaled to GDP.

Figure 6 displays our calculated **bio-enterprise capacity scores** in 2020 and projections for 2050. Scores for 2020 are shown in the left panels; projected 2050 scores, assuming high growth of biotechnology globally and a status-quo policy scenario in each country, in the right panel. The bio-enterprise capacity scores (vertical axis) are displayed in relation to each country's GDP (horizontal axis), as large countries clearly have an advantage.

Note the different scales between the top and bottom panels. The top panels display all 12 countries; the bottom panels expand both axes so that the relative positions of smaller countries are visible.

Figure 6: Bio-enterprise capacity score vs GDP: 2020 and projected 2050 (high-growth, status-quo scenario)



In 2020 (Fig. 6, left panels), the US and China are the clear bio-enterprise capacity leaders. Germany and India fall into a second tier, with Germany slightly outpacing India, even though Germany's GDP is less than half the size of India's. Brazil, South Korea, and Russia form a third tier, again on an absolute basis.

By 2050 (Fig. 6, right panels), the relative positions of countries shift somewhat. The US and China are still the two bio-enterprise capacity leaders, but we project that India will become a third country in the first tier of bio-enterprise capacity. Germany, a far smaller economy than the first three, will likely be fourth-ranked and still significantly ahead of the next tier of countries. We project these to be South Korea, Brazil, Indonesia, and perhaps even small Israel.

Figure 7: 2020 Innovation-driver scores: Bio-enterprise combined score and scores for individual sectors.

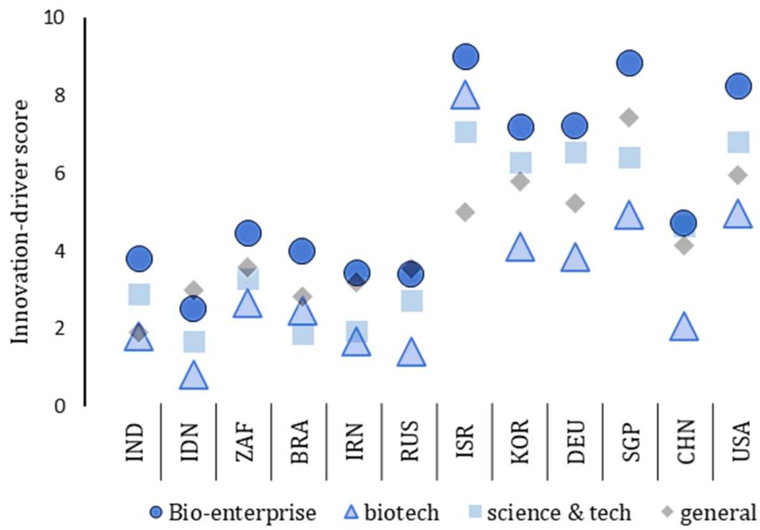


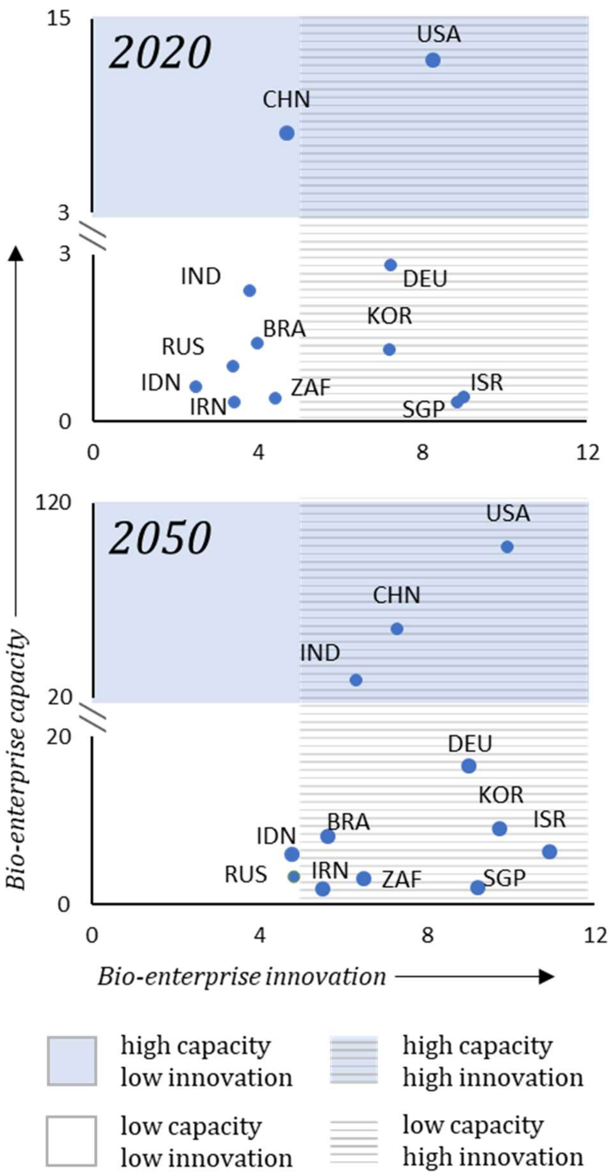
Figure 7 displays our second key measure, each country's **bio-enterprise innovation-driver** score in 2020. Again, this is an intensity measure that reflects each country's capability to grow its bio-enterprise into the future. Figure 7 displays both the combined bio-enterprise innovation-driver score and the scores of each of the individual sectors that contribute to the combined score. The combined score is shown as circles, the biotech sector alone as triangles. Note that for some countries, the combined bio-enterprise score is fairly close to the biotech sector score (e.g., Israel) and for others (e.g., the US), the spread between the two measures is greater. For the US, the combined bio-enterprise driver score receives a significant boost above its biotech driver score due to its relatively stronger science & tech driver and general societal driver scores (shown as squares as diamonds, respectively).

Focusing on the combined bio-enterprise score, we can observe two tiers of countries. The first tier, with high bio-enterprise innovation-driver scores, includes Israel, Singapore, the US, Germany, and South Korea (all above a 2020 score of 5). Second tier countries include China, South Africa, and Brazil (2020 score between 4 and 5). India, Iran, Russia, and Indonesia all fall in the third tier, again based on innovation-driver intensity.

Figure 8 displays the scores of both bio-enterprise measures together. In this graph, each country's **bio-enterprise capacity score** (vertical axis) is displayed in relation to its **bio-enterprise innovation-driver score** (horizontal axis). The left panel displays 2020 scores; the right panel displays are projections for 2050.

Each graph is divided into four quadrants. The upper-right quadrant of both the 2020 and 2050 graphs includes countries that have both high capacity scores and high innovation-driver scores. In 2020, the US is the only country that falls in this quadrant.

Figure 8: Bio-enterprise capacity score vs. Bio-enterprise innovation-driver score: 2020 and projected 2050 (high-growth, status-quo scenario)



The upper-left quadrant includes countries that have high capacity scores but low innovation-driver scores (below a score of five). China is the only country that falls in this quadrant in 2020.

The lower right quadrant includes countries that have high innovation-driver scores, but because of the smaller size of their economies, have lower capacity scores. Germany, South Korea, Israel, and Singapore fall in this quadrant in 2020. These countries, along with the US, are the current drivers of innovation for the global bio-enterprise.

Finally, the lower left quadrant includes countries that have both low capacity scores and low innovation-driver scores. Half of our countries fall into this quadrant in 2020.

The picture in 2050 may be quite a bit different. In the high-capacity, high-innovation-driver quadrant, the US is joined by both China and India. Note that we are using the same threshold for high innovation-driver in 2050 and as for 2020. Brazil, South Africa, and Iran move into the lower right quadrant, i.e., high innovation-driver scores but still low capacity scores. Indonesia and Russia remain in the lower left quadrant, i.e., having both low capacity scores and low innovation-driver scores.

The scores reported above are for our "status-quo" scenario. As discussed in the earlier methods section, we developed three scenarios for this study, which we call ***status quo***, ***policy push***, ***and policy drag.*** Our ***status-quo*** scenario presented in the graphs above, assumes that for any individual country, the bio-enterprise innovation-driver score, remains about equal to its value in 2020, increasing only as average productivity (GDP/capita) increases through time. Because the other policy scenario projections are not included here, it is necessary to keep in mind that the positions of these countries, and their positions relative to each other, could change in both capacity and innovation by 2050. These alternate policy scenarios are shown in each of the country's chapters.

Our ***policy-push*** scenario posits that a country would like to become a leader in biotechnology to help grow its economy and intervenes with aggressive and sustained governmental actions. Under this scenario, we increase a subset of innovation-drivers amenable to policy intervention through time and calculate the resulting increase in bio-enterprise capacity. Our ***policy-drag*** scenario assumes that policy attention wanes, innovation drivers decline, and thus future bio-enterprise capacity drops below the status-quo scenario.

Figure 9 displays the bio-enterprise driver-innovation score for India, between 2020 and 2050, using the 10-year intervals in our projection models. Again, note the gradual increase in the status-quo scenario, the significant decade-to-decade increases in the policy-push scenario, and decline in the policy-drag scenario. Again, our bio-enterprise driver-innovation score includes over 50 individual indicators; some will respond to governmental intervention within a decade, about half will require a 10 to 30 years to achieve significant change, and quite a few even longer. The policy-push and policy-drag scores shown in the figure are calculated using both the magnitude and rates of change for each individual driver. In addition, we assume that authoritarian governments, if they desire to, can implement policy changes more rapidly than democratic governments.

Figure 9: Bio-enterprise innovation-driver score: 2020 through 2050. Status-quo, Policy-push, and Policy-drag scenarios. See text for explanation of scenarios

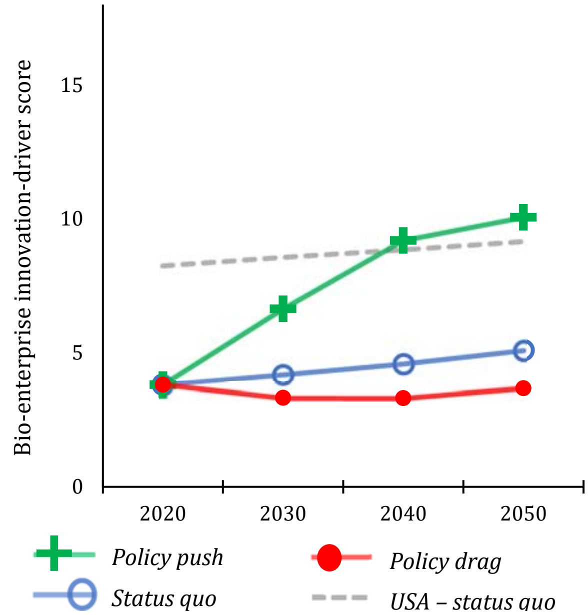


Figure 10 displays the bio-enterprise capacity scores for the US, China, and India, the top three bio-enterprise capacity countries by 2050. The figure displays the results of the status-quo, policy-push, and policy-drag scenarios, between 2020 and 2050 (under our high growth set of scenarios). Figures 6 and 8, presented earlier, displayed only the status-quo scenario for 2050. Figure 10 displays the effect that governmental action (or inaction) might alter those outcomes.

For example, the status-quo scenario for China projects that by 2050, China's bio-enterprise capacity score will remain between the US and India, as it does today. However, with very aggressive and sustained government intervention (policy push), it appears plausible that China could overtake the US, if the US stance towards its bio-enterprise remains about the same as it does today (status quo). If US policy attention wanes (policy drag), the likelihood of China overtaking the US with aggressive policy increases. Similarly, China's bio-enterprise capacity under a policy-drag scenario might drop below India's if India adopts aggressive and sustained policy push.

The following section includes summaries for each of our 12 countries that further discuss the results of our policy-push and policy-drag scenarios. As important, it identifies the individual strengths and weaknesses of each country to provide a richer understanding of the possible outcomes by 2050.

Summary tables for each country's **bio-enterprise capacity score** and a **bio-enterprise innovation-driver score** are included as Tables 6 and 7. Table 6 (left panel) includes the combined bio-enterprise capacity scores for each country, as well as the capacity scores for each of the individual sectors in 2020. Table 6 (right panel) presents innovation driver scores in a similar format. These tables are a high-level summary of the data tables presented in Part II of this report. A much deeper understanding of each country's bio-enterprise capacity and drivers of innovation can be gained by examining the eight pages of individual scores per country included in Part II.

Table 7 is a high-level summary of the results of our projections of bio-enterprise capacity and innovation-driver by 2050. The left panel includes our 2050 status-quo capacity estimates for each country, 2050 rank, and change in rank for each country between 2020 and 2050. The last two columns show the change in rank in 2050 if each country were to follow either the policy-push or policy-drag scenarios, compared to all other countries following their status quo. Table 7 (right panel) includes our 2050 status-quo bio-enterprise innovation driver scores for each country, 2050 rank, and change in rank for each country from 2050.

The appendix includes detailed tables of results from the status-quo, policy-push, and policy-drag scenarios, under assumed high-growth and low-growth conditions, and various model configurations.

Figure 10: Bio-enterprise capacity scores for top three nations: United States, China, and India, 2020 through 2050. Status-quo, Policy-push, and Policy-drag scenarios.

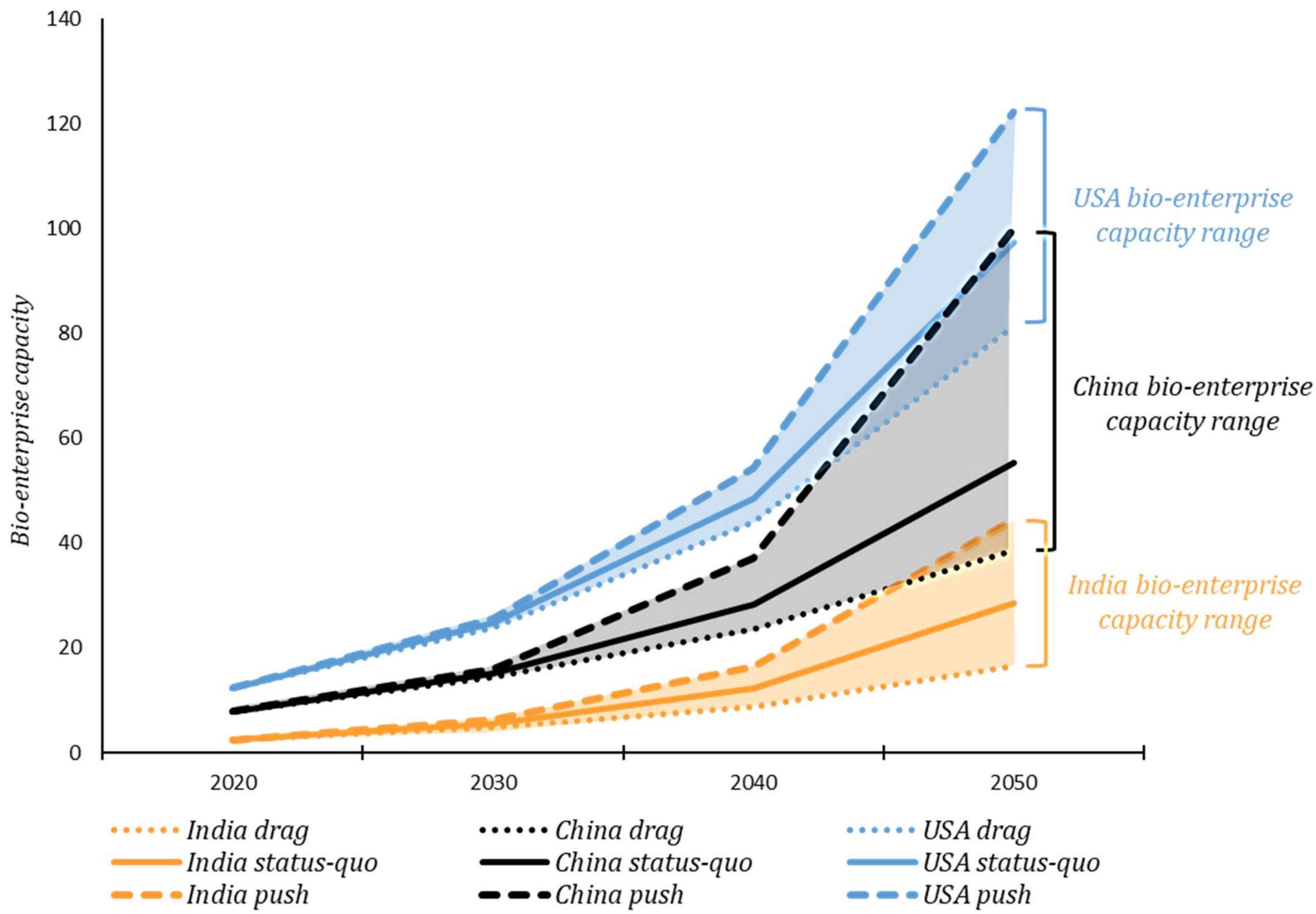


Table 6: 2020 Capacity scores and innovation-driver scores, by country. Bio-enterprise score and scores for individual sectors.

Capacity scores:

Combined bio-enterprise and sector scores

COUNTRY	Bio-enterprise	biotech	science & tech	general societal
USA	12.4	9.8	9.4	7.5
CHN	7.9	3.4	8.2	8.4
DEU	2.8	1.8	2.8	1.6
IND	2.3	0.8	1.3	4.0
BRA	1.4	1.2	0.7	1.0
KOR	1.3	0.7	1.5	0.7
RUS	1.0	0.3	1.1	1.1
IDN	0.6	0.4	0.0	1.0
ISR	0.4	0.4	0.3	0.1
ZAF	0.4	0.3	0.4	0.3
SGP	0.3	0.2	0.4	0.1
IRN	0.3	0.1	0.3	0.5

Innovation-driver scores:

Combined bio-enterprise and sector scores

COUNTRY	Bio-enterprise	biotech	science & tech	general societal
ISR	9.0	8.0	7.1	5.0
SGP	8.9	4.9	6.4	7.4
USA	8.3	5.0	6.8	6.0
DEU	7.2	3.9	6.5	5.2
KOR	7.2	4.1	6.3	5.8
CHN	4.7	2.1	4.6	4.2
ZAF	4.4	2.7	3.3	3.6
BRA	4.0	2.5	1.9	2.8
IND	3.8	1.8	2.9	1.9
IRN	3.5	1.7	2.0	3.2
RUS	3.4	1.4	2.7	3.6
IDN	2.5	0.8	1.7	3.0

Table 7: 2050 Bio-enterprise capacity scores and innovation-driver scores, by country. 2050 scores and changes in rank under various scenarios.

Bio-enterprise capacity

COUNTRY	2050 status quo score	2050 status quo rank	status quo rank Δ 2020	policy push rank Δ 2050	policy drag rank Δ 2050
USA	97.4	1	-	-	-
CHN	55.4	2	-	+1	-
IND	28.5	3	+1	-	-
DEU	16.5	4	-1	-	-
KOR	9.0	5	+1	-	-1
BRA	8.0	6	-1	+1	-
ISR	6.2	7	+2	-	-1
IDN	5.9	8	-	+3	-2
RUS	3.3	9	-2	-	-1
ZAF	3.0	10	-	+1	-
SGP	2.0	11	-	-	-1
IRN	1.8	12	-	+3	-

Bio-enterprise innovation drivers

COUNTRY	2050 status quo score	2050 status quo rank	status quo rank Δ 2020
ISR	10.9	1	-
USA	10.1	2	+1
KOR	9.7	3	+2
SGP	9.2	4	-2
DEU	9.0	5	-1
CHN	7.4	6	-
ZAF	6.5	7	-
IND	6.4	8	+1
BRA	5.7	9	-1
IRN	5.5	10	-
RUS	4.8	11	-
IDN	4.8	12	-

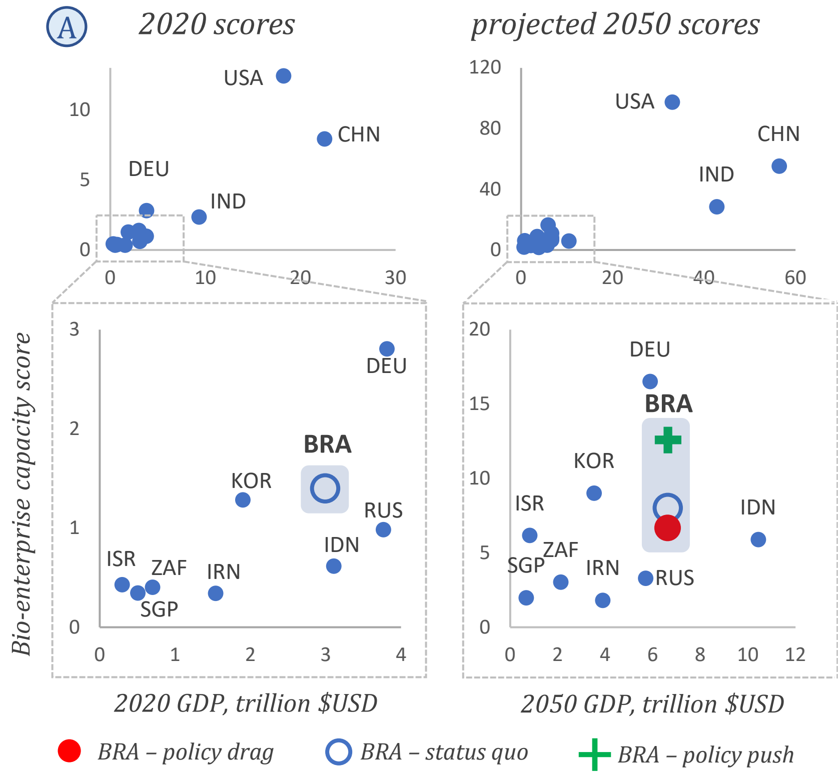
Country Summaries

BRAZIL

Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **Brazil**'s 2020 absolute score is ranked 5 of 12 in 2020 (left); dropping to 6th by 2050 (right). The absolute scores are displayed in relation to each country's GDP, as larger economies clearly have an advantage.

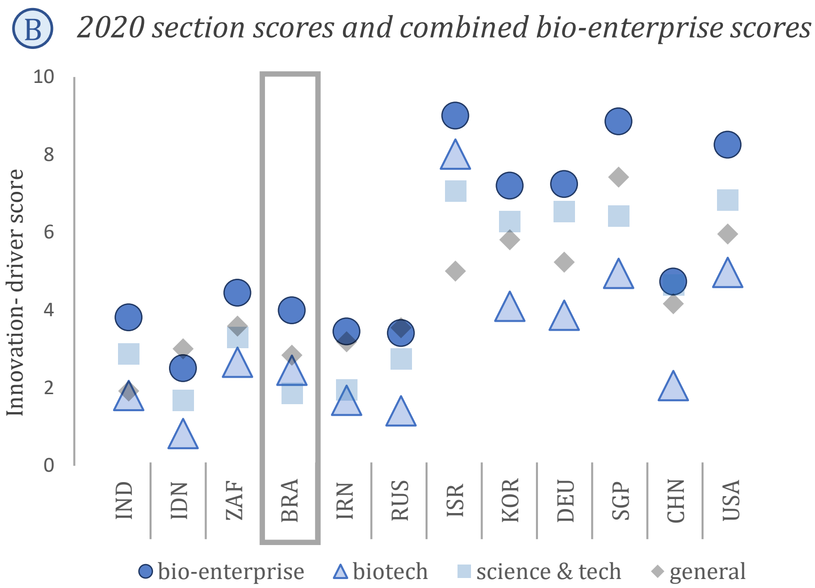
Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **Brazil** is ranked 8 of 12. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

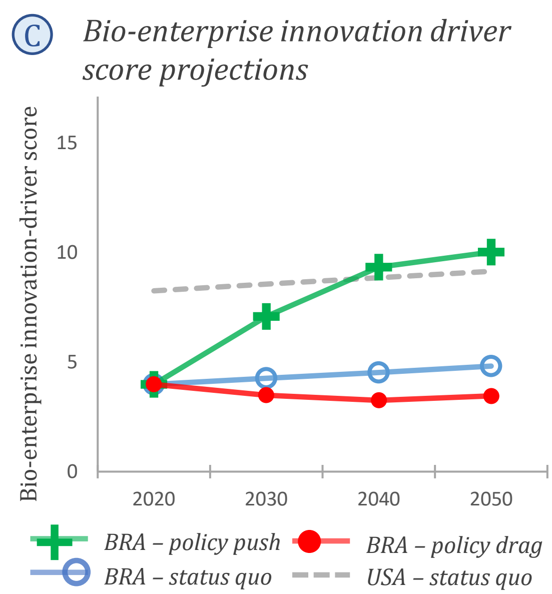
Bio-enterprise Capacity Scores



Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **Brazil**'s capacity score by 2050. Given **Brazil**'s size, under a policy-push scenario, it could conceivably advance to 5th, behind Germany and ahead of much smaller South Korea. Under a policy-drag scenario, it would still likely remain 6 of 12 in capacity.

Bio-enterprise Innovation-driver Scores





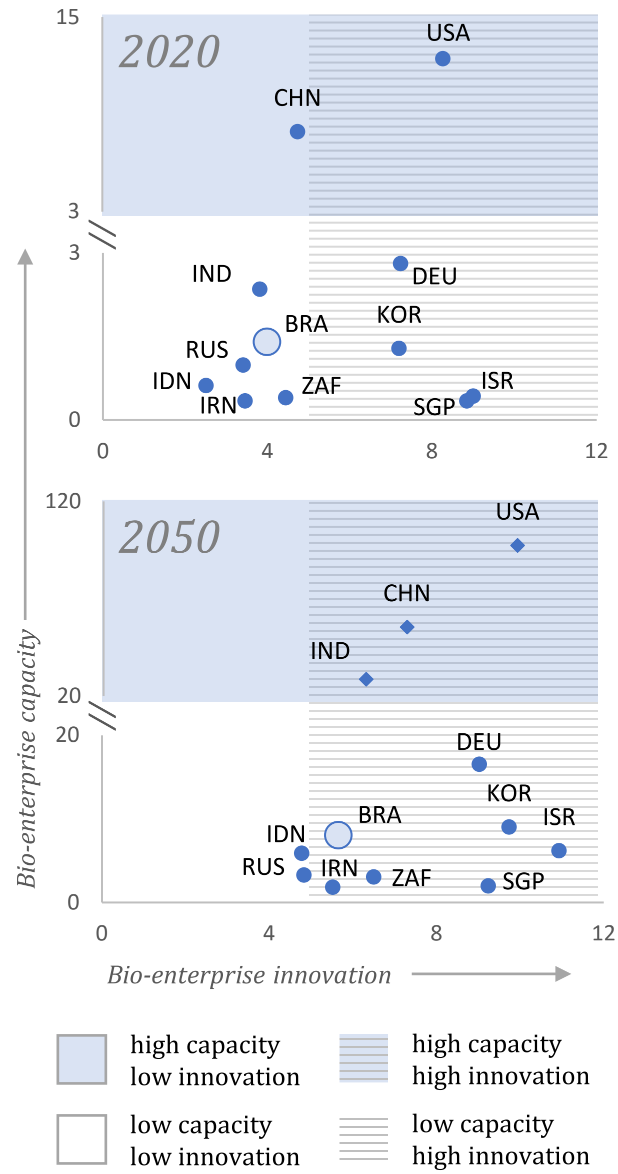
BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

BRAZIL

Bio-enterprise capacity 2020 – rank 5 of 12
Bio-enterprise innovation drivers 2020 – rank 8 of 12

As can be seen in the graph to the right, in 2020, Brazil falls into the quadrant with both lower bio-enterprise capacity and low innovation-driver scores. By 2050, Brazil might transition to an innovation-driver score we consider high by 2020 standards.

Bio-enterprise capacity and innovation, 2020 and 2050. Brazil.



Capacity

Though Brazil has a large economy and population, it does not yet have high bio-enterprise capacity. Because of its already developed biotech and scientific infrastructure, successfully enacting policies that push bio-enterprise development could pay off dramatically, with total capacity edging toward that of Germany. Because of current societal and governmental hurdles to bio-enterprise development, as well as the current low-tech state of Brazilian bio-enterprise and industries generally, Brazil is unlikely to push into a high innovation high capacity state by 2050. Without major changes, Brazil is likely to remain in line with South Korea or Israel in terms of output capacity, but without achieving their high levels of innovation.

Innovation Drivers

Brazilian bio-enterprise innovation is third in the middle-income group, with a solid base of research, education, and industry maturity. However, this level of innovation in biotech still trails far behind that seen in the high-income group. In addition, Brazil has experienced a recent downturn in growth and has struggled to meet its goals for S&T and biotech development. Governmental and societal hurdles are likely to make innovative growth in this sector more difficult.

Looking forward, a policy push toward biotech development could allow Brazilian innovative capabilities to grow substantially, which would in turn push total bio-enterprise capacity dramatically. Brazil is a major international player in both agricultural and industrial biotech. Developing in-country R&D and innovative tech in these sectors could help push bio-enterprise innovation.

Improvements that would push the bio-enterprise forward and indicators to watch:

- One of the major hurdles to growth has been called the "Brazil Cost," wherein societal, bureaucratic, and financial difficulties make it more costly to grow business in or doing business with Brazil. These policies need to be addressed at a governmental level to improve rule of law, decrease bureaucratic burden, improve education and training for citizens, and prioritize efficiency and growth.
- Centers of innovation are uncommon, but those that do exist excel in their research. Brazil could encourage growth in these high-tech regions in order to improve innovation and competitiveness. Additional innovative clusters for S&T and biotech R&D could help.

BRAZIL – biotech

biotech capacity	rank 4 / 12 score 1.2 / 10	biotech drivers	rank 6 / 12 score 3.3 / 10

Strengths
- *Internationally ranked life sciences universities*
- *Well developed agricultural biotech and biofuel industries*
- *Biotech innovation centers*
- *Biodiversity in plant and animal species*

Weaknesses
- *Unimpressive biotech publication and patenting activity*
- *Not very active in international competitions, communities, and conferences on biotechnology*
- *National policy lacks clear biotech development plans*

In most measures of biotech innovation, Brazil performs on par with other middle-income countries, but lags behind high-income countries. In publications and patenting, biotech is emphasized, but overall rates of publishing and patenting remain fairly low. Talent measures, such as participation in biotech competitions and communities, are also low. Where Brazil excels is in its biotech industries, with a world-class agricultural biotech program and a long history of biofuel development. The National Strategy for Science and Tech Innovation outlines priorities within the bioeconomy, including fostering public R&D in agriculture, biofuels, and biopharma by increasing funding for grants and research, promoting research networks, and encouraging private-public partnerships. If these policies can be effectively implemented, Brazil could leverage its existing biotech markets, university system, and biodiversity and significantly increase innovation in the future. However, given the barriers to development on the broader S&T and societal levels, rapid progress toward innovation may be difficult to achieve.

Red Biotech – biomedical sciences
- Biopharma, especially with regard to public-private partnerships, is well developed and growing, but there is room for improvement in the number of clinical trials and general biopharma IP and pricing policies. Approval for drugs and trials are long, and issues remain with patent protection and non-participation in patent prosecution highways. Biopharma and life sciences research is concentrated around the University of Sao Paulo and the surrounding biotech innovation cluster. The Brazilian Health Regulatory Agency (Anvisa) provides high regulatory standards for biopharma and evaluates biopharma patents. A national tech transfer system enables movement from academic to commercial R&D. Despite a fairly advanced biopharma system, Brazil still ranks behind the Latin American average in biopharma competitiveness, and executives do not foresee comprehensive long-term reforms to modernize Brazil's scientific infrastructure and boost the volume of researchers. Improved infrastructure and growth of the STEM educated workforce would enhance biomedical research and commercialization.

Green Biotech – agricultural biotechnologies
- Brazil is currently the second largest producer of biotech crops internationally. Agricultural biotech has a long history of support in Brazil, with the Brazilian Agricultural Research Corporation (Embrapa) leading a world-class effort in GM agriculture, accumulating over 200 international patents and developing over 250 cultivars. Regulatory processes are established and well regarded, with tech transfer processes and patenting concentrated in Embrapa. The efforts are supported through both direct government investment and public-private partnerships.

White Biotech – industrial biotechnologies
- Brazilian power generation is one of the cleanest in the world, with biofuel use mandated by law. Much of the research is focused on generating sugarcane ethanol and increasing biofuel production.

BRAZIL – science & technology

S&T capacity	*rank 7 / 12 score 0.7 / 10*	*S&T drivers*	*rank 10 / 12 score 2.4 / 10*

Strengths
- *Many engineering, tech, and computer sciences universities*
- *Large share of global STEM graduate students and researchers*

Weaknesses
- *Low relative patenting and publishing rates*
- *High burden of governmental regulation*
- *Lack of governmental dynamism when faced with technological change*
- *Poor VC and startup environment*

Brazil funds R&D at a higher percentage of GDP, 1.3%, than most of its peer countries, but has not yet reached its 2019 goal of 2% of GDP. By most measures of output, Brazil is on par with its peers in terms of S&T intensity, though often exceeds them on absolute output measures. Several clusters of innovation and quality research institutes are highly regarded, particularly in Sao Paulo. These are not common in most states, and overall Brazil's publication and patenting rates are unimpressive. States face extensive bureaucratic, federal, and financial burdens to developing their own universities and research institutes. Additionally, the general environment for S&T development is a difficult one. The increased cost of doing business in Brazil has been ascribed to a long list of causes: excessive bureaucracy, difficulties in trade and financing, high tax burdens, corruption, underdeveloped infrastructure, lack of educated or qualified labor, and other entrenched societal hurdles to development and innovation. Recent policies aim to address some of these problems, creating tech transfer systems to support the commercialization and funding for S&T startups, investing in restructuring and growing higher education, funding STEM students studying abroad, improving education, etc. Overall, policy aims to improve Brazil S&T sector, but large systemic barriers to growth may be hard to overcome.

BRAZIL – general societal

societal capacity	*rank 6 / 12 score 1.0 / 10*	*societal drivers*	*rank 11 / 12 score 3.0 / 10*

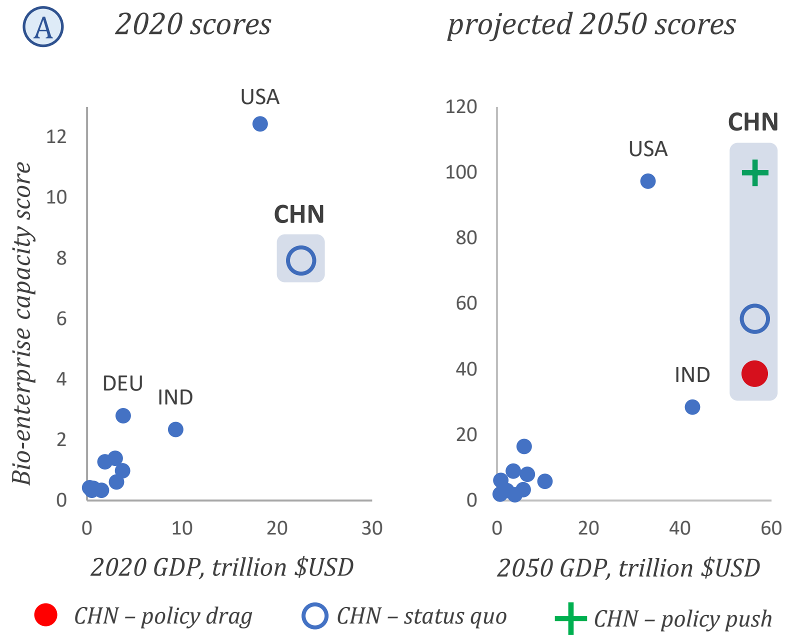
Strengths
- *Large global economy, expected to grow to the 7th largest by 2050*
- *High government spending on education and early education*
- *Large working population*

Weaknesses
- *Lack of early science education and social support for science as a national or personal benefit*
- *Poor rule of law*
- *Still significant poverty and inequality*

Brazil is a large world economy with an established university and education system on par with its peers. With projected annual growth of about 3%, it is poised to remain in the top 10 largest world economies but is likely to be surpassed in GDP/capita by both South Africa and Indonesia. After making impressive strides to reduce poverty, Brazil hit an economic downturn in 2008. Like other emerging economies such as Russia and South Africa, labor productivity has stagnated since the 1980s despite increases in social spending. Social stability is hindered by organized crime, high homicide rates, and poor rule of law. Taxes, tariffs, and bureaucracy present major challenges to trade, competition, and business development. Despite high rates of spending on education, the workforce is not highly skilled, which is a major hurdle for innovative development. Similar to South Africa, Brazil was seen as a growth leader in its region in the early 2000s, but for Brazil, a slowing economy, unemployment, and recession has stalled growth.

CHINA

Bio-enterprise Capacity Scores

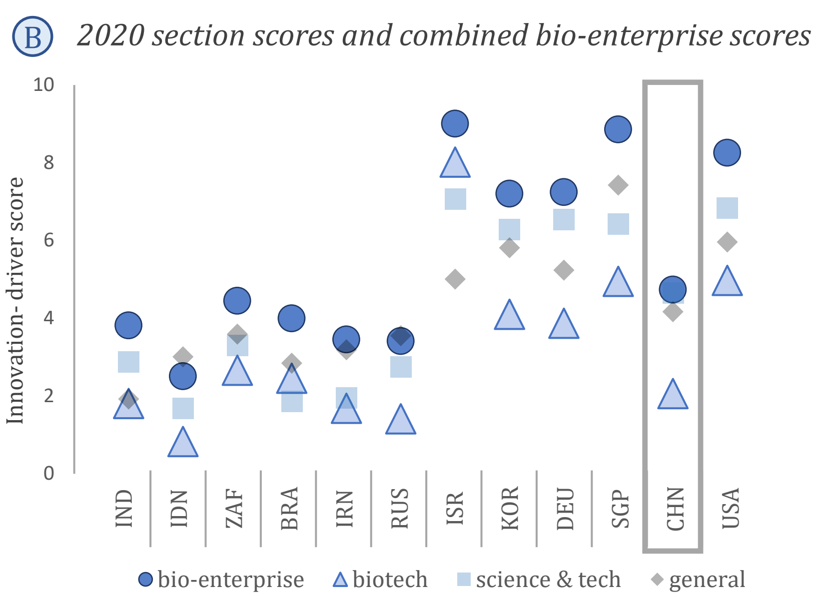


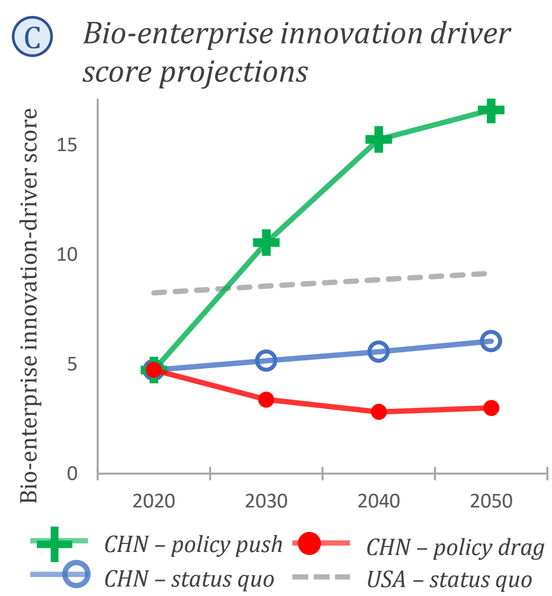
Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **China**'s 2020 absolute score is ranked 2 of 12, behind the US, in both 2020 (left) and 2050 (right). The absolute scores are displayed in relation to each country's GDP, as large economies such as China, the US, and India clearly have an advantage.

Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **China** is ranked 6 of 12, first among middle-income economies, but below all of the high-income economies. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **China**'s capacity score by 2050. Given **China**'s size and considerable opportunities to improve its innovation-drivers, under a policy-push scenario, it could conceivably advance to first, ahead of the US. Under a policy drag scenario, it would still likely remain ahead of 3rd place India.

Bio-enterprise Innovation-driver Scores





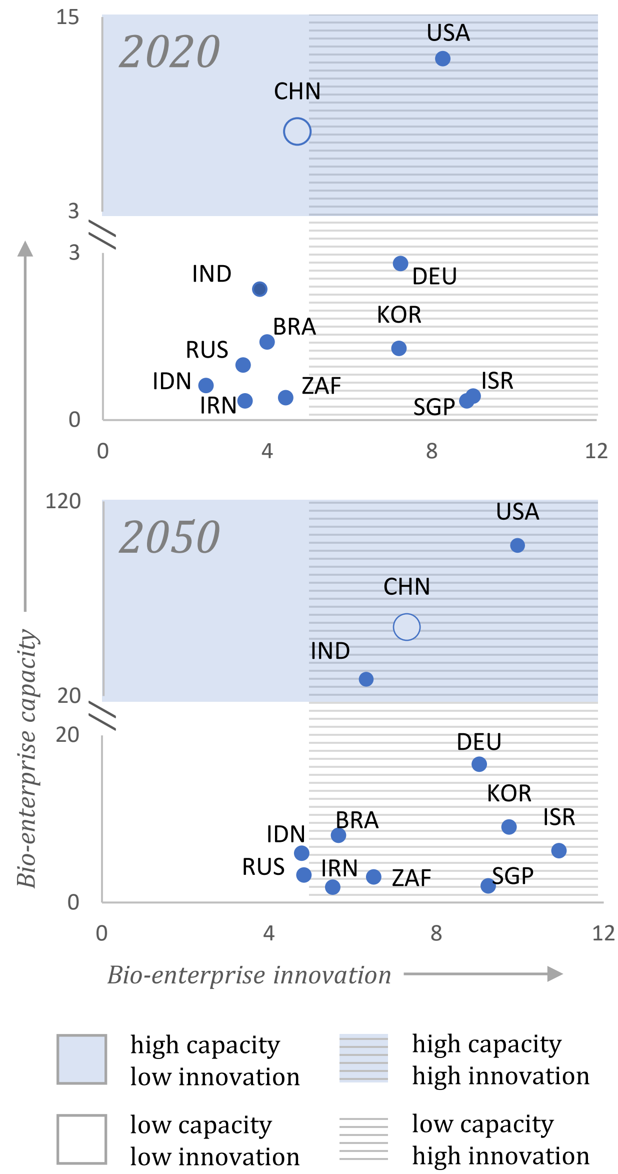
BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

CHINA

Bio-enterprise capacity 2020 – rank 2 of 12
Bio-enterprise innovation drivers 2020 – rank 6 of 12

As can be seen in the graph to the right, in 2020, China falls into the quadrant with high bio-enterprise capacity but lower drivers of future innovation. By 2050, China will likely join the US in the quadrant with both high capacity and high innovation-drivers

Bio-enterprise capacity and innovation, 2020 and 2050. China.



Capacity

China's bio-enterprise capacity is second only to the US, and substantially outranks our other countries'. China is unique among our 12 countries given the size of its market coupled with its rapid tech growth in recent decades. China has managed to transition from a poor, developing nation into a S&T and biotech power. If China continues to adopt and modernize its policies and planning to push toward increased capacity, it could surpass the US as the leading bio-enterprise.

Innovation Drivers

China currently sits on the edge of low and high bio-enterprise innovation. Considering that China is still considered a developing nation, this is not surprising, but it is unlikely to remain the case. S&T in China has quickly grown and is entering a more competitive, international stage. This environment, coupled with aggressive policy and funding supporting bio-enterprise growth, suggests that increased technical capacity and innovation in the bio-enterprise is likely. Because of China's top-down and autocratic leaning governmental setup, these policies can be instituted rapidly, suggesting that if the political will exists, China can likely fulfill its growth goals in biotech and innovation.

Improvements that would push the bio-enterprise forward and indicators to watch:

- China has made significant strides moving from a low-tech manufacturing and resource-based economy toward a high-tech manufacturing and knowledge-based economy. This is largely a result of aggressive growth policies adopted during the late 1970s, followed by a prioritization of S&T growth in the 1990s. Current leadership has further prioritized high tech development, innovation, and international S&T supremacy. Thus far, China has shown great success in implementing forward-looking policy to achieve its goals. Because biotech innovation has been identified as a priority, rapid progress in this sector would not be surprising.
- China is still developing its IP and regulatory environment. Current protectionist policies inhibit international investment. Updating these policies to adhere to international standards could benefit S&T development.
- China's current bio-enterprise model is highly productive but not yet highly innovative in the creation of new inventions or IP. Innovative start-ups and products would signal a shift in the S&T sector.
- China aims to increase talent retention and acquisition, publications, and patent numbers to be best-in-the-world in biotech.
- Problematic IP practices have facilitated quick growth of China's tech sector without much pushback internationally. Whether and how companies and countries respond could affect how China innovates moving forward.

CHINA – biotech	*biotech capacity*	*rank 2 / 12 score 3.4/ 10*	*biotech drivers*	*rank 8 / 12 score 2.7 / 10*

Strengths
- *High world share of biotech universities*
- *High participation in GenBank and international synthetic biology competition*
- *Natural resources and biodiversity*

Weaknesses
- *Very little biotech crop or biofuel production*
- *Still developing the company and industry landscape in biotech*
- *Low ranking biopharma competitiveness and clinical trial environment*

China ranks high on many absolute measures of biotech capacity, though often a far second to the US, while intensity indicators score closer to middle-income peers. China is still developing biotech capacity and modernizing policies in this sector. Given current growth and an advanced S&T sector, the biotech sector is likely to grow in both capacity and innovation moving forward. Biotech has been a priority in Chinese growth planning since the 1980s, with current measures pushing biomedicine, agriculture, and bioenergy growth. Chinese policies call bioindustry the most influential industry of the 21st century and aim for China to be a "world powerhouse of scientific and technological innovation" by 2050. Many of China's weaknesses pointed out in our analysis are targeted in China's various biotech policy documents – goals include training biotech professionals and entrepreneurs, attracting foreign talent to work in China, strengthening academic-industry ties, and increasing international collaborations and mergers. China's funding models address all steps of invention, from increased funding of basic research and academics, through supportive tech transfer policies and entrepreneurship support, into increased VC funding and business R&D funding. Overall, the rigor with which China has updated and implemented policy to meet the changing needs of the biotech sector has facilitated rapid growth in biotech capacity and innovation and has demonstrated China's ability to plan, update, and execute S&T roadmaps and policy.

Red Biotech – biomedical sciences

- Biopharma is rapidly growing in China, though this growth is primarily concentrated in biosimilars and traditional medicines. Still, the medical sciences have progressed rapidly, outpacing many other traditional STEM sectors, and now focus on high-tech biomedical areas such as stem cell research and genome engineering. Chinese university patenting rates are some of the highest in the world, and tech transfer through start-ups has increased significantly in the biopharma sector. However, protectionist policies in both IP and commercialization of biopharma products may be hampering industry. These policies aim to grow biopharma capacity in-country, but can also limit innovative growth by slowing foreign investment and R&D. These policies, along with a weak regulatory framework and reimbursement policies, are not in line with international standards.

Green Biotech – agricultural biotechnologies

- China is the 7th largest producer of biotech crops, but only a small percent of cropland grows biotech crops. Biotech crop adoption has slowed, with anti-GM protests likely affecting cultivation rates and approval of biotech events. Previously approved biotech events have been allowed to expire, farmers are often discouraged from using approved biotech crops, and new regulatory hurdles have been introduced. However, this landscape may change. About $3 billion USD was approved to develop biotech crops in-country in 2017, the same year as ChemChina's acquisition of Syngenta, a large biotech crop developer. Whether this leads to increased R&D or cultivation in the green biotech sector remains to be seen.

White Biotech – industrial biotechnologies

- China is not a large producer of biofuels, despite increasing investment in other renewable energy sources. There are certain areas of high-intensity biofuel R&D efforts, such as the Tianjin Institute, but the overall sector remains small. This sector also suffers from poor IP rights enforcement and a difficult tech transfer environment. Other industrial biotechnologies are being developed, such as enzymes, microbial biotechnology, and biocatalytics.

CHINA – science & technology

S&T capacity	*rank 2 / 12 score 8.2 / 10*	*S&T drivers*	*rank 6 / 12 score 4.5 / 10*

Strengths

- *2nd in total expenditure on R&D and of innovation clusters*
- *Most high-tech publications*
- *Highly ranked in knowledge creation and tech outputs*
- *High number of researchers*
- *2nd to US in absolute university count*

Weaknesses

- *Poor IP protections and regulations*
- *Poor international reputation in publication and patent quality and reliability*
- *Low acceptance of risk and innovation in business*

China has developed a robust S&T system that is increasingly innovative. In absolute measures of universities, patents, and publications, China scores near best in S&T measures. On many of these, China ranks among high-income countries when scaled to GDP. However, China ranks closer to its middle-income peers on many societal and policy measures, including regulatory burden, IP regulations and rights, and acceptance of risk. Previously, access to China's large market was enough for companies and countries to ignore China's protectionist IP and business acquisition policies. As China grows larger and more competitive, this may become a problem. As China moves from three decades of unprecedented growth toward a more stable, slower growth phase, policy has adapted to focus on long term planning that prioritizes increasing current R&D capacity and infrastructure, innovation and collaboration, and attractiveness of academic careers. S&T goals are increasingly focused on socially beneficial outcomes, sustainable growth, and international competitiveness in S&T excellence. China has been able to implement ambitious but achievable short-term plans for growth, using S&T as a means to drive an innovative, knowledge-based economy. A key strength in China and other innovative nations such as Singapore and South Korea is the ability to update policy quickly in response to their own stage of growth and the rapidly changing needs of the S&T sector.

CHINA – general societal

societal capacity	*rank 1 / 12 score 8.4 / 10*	*societal drivers*	*rank 7 / 12 score 4.3 / 10*

Strengths

- *Largest world economy and population, with a 2050 economy projected to be 1.7x the size of the US*
- *Large, increasingly innovative university system*
- *Social support for science as a national, job, and personal benefit*

Weaknesses

- *High poverty – massive divide between high tech modern cities and poor agrarian areas*
- *University quality has much room to improve*
- *Increasingly aging population*
- *Lack of rule of law and personal freedom*

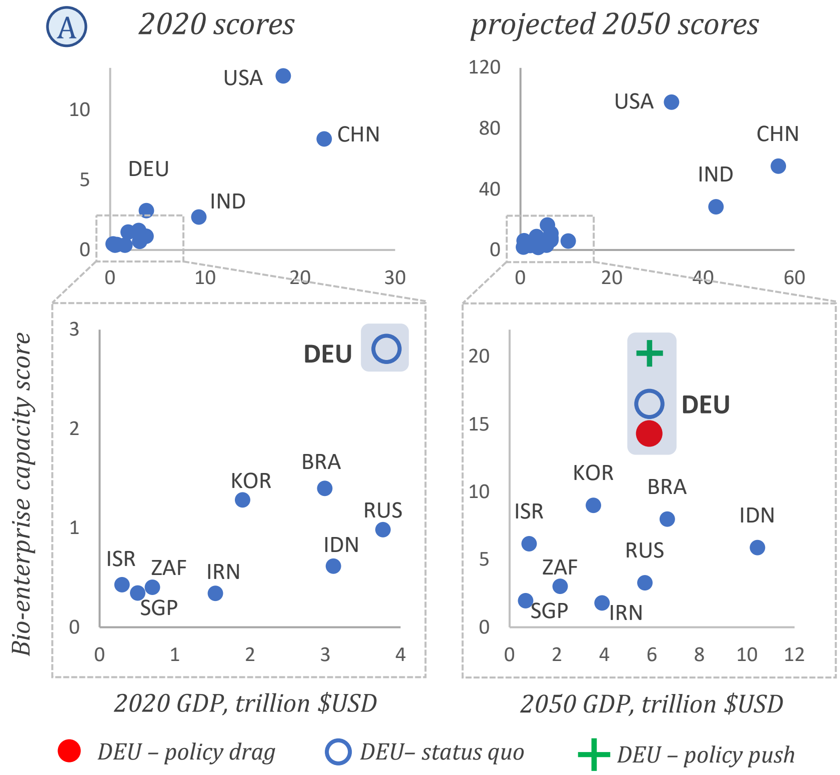
China is currently the largest world economy and has broken away from other BRIICS nations in terms of wealth, tech growth, and international power. China hosts 13% of global universities and has taken direct action to improve the R&D capacity and quality of these institutes. China has driven growth through aggressive policy and funding changes supported through specific, ambitious short- and long-term planning directed by the national government. Projections suggest that the Chinese economy will grow substantially as further development is carried out, moving China away from a labor-based economy into a high-tech manufacturing and knowledge-based economy. There is significant room for improvement in both early and higher education. China currently fills a space in higher education: top students in China still study abroad for a high-quality education, but mass numbers of students in developing and neighboring countries study abroad in China. China falls behind on rule of law metrics, such as personal freedom, restraints on government powers, and fundamental rights.

GERMANY

Bio-enterprise Capacity Scores

Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **Germany**'s 2020 absolute score is ranked 3 of 12 in 2020 (left); dropping to 4th, behind India, by 2050 (right). The absolute scores are displayed in relation to each country's GDP, as larger economies clearly have an advantage.

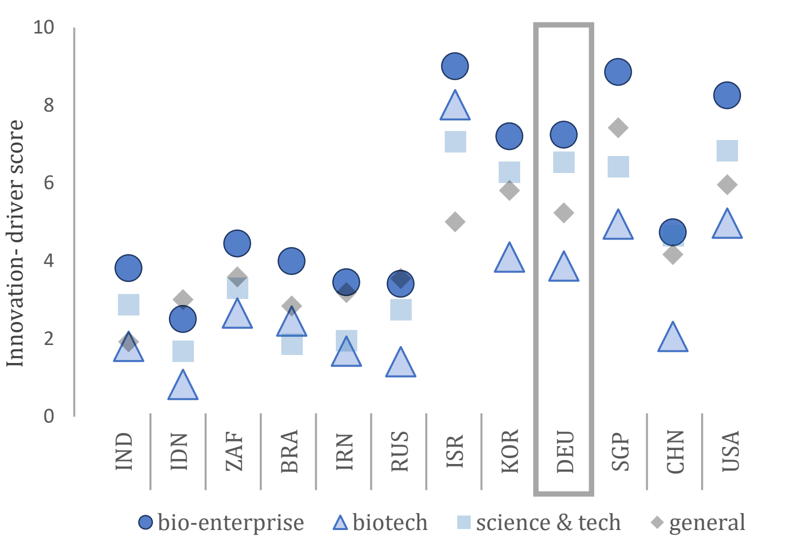
Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **Germany** is ranked 4 of 12. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.



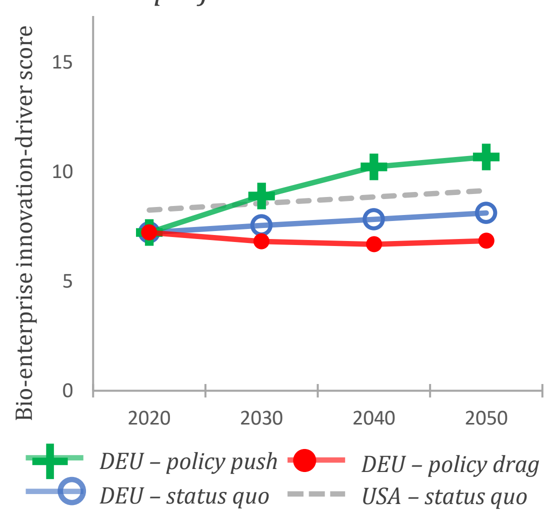
Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **Germany**'s capacity score by 2050. Though the range is substantial, it appears that Germany will remain in 4th place in 2050, between India and South Korea.

Bio-enterprise Innovation-driver Scores

B *2020 section scores and combined bio-enterprise scores*



C *Bio-enterprise innovation driver score projections*



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GERMANY

Bio-enterprise capacity 2020 – rank 3 of 12
Bio-enterprise innovation drivers 2020 – rank 4 of 12

As can be seen in the graph to the right, in 2020, Germany falls into the quadrant with lower bio-enterprise capacity but high drivers of future innovation. Germany is projected to remain in this quadrant in 2050.

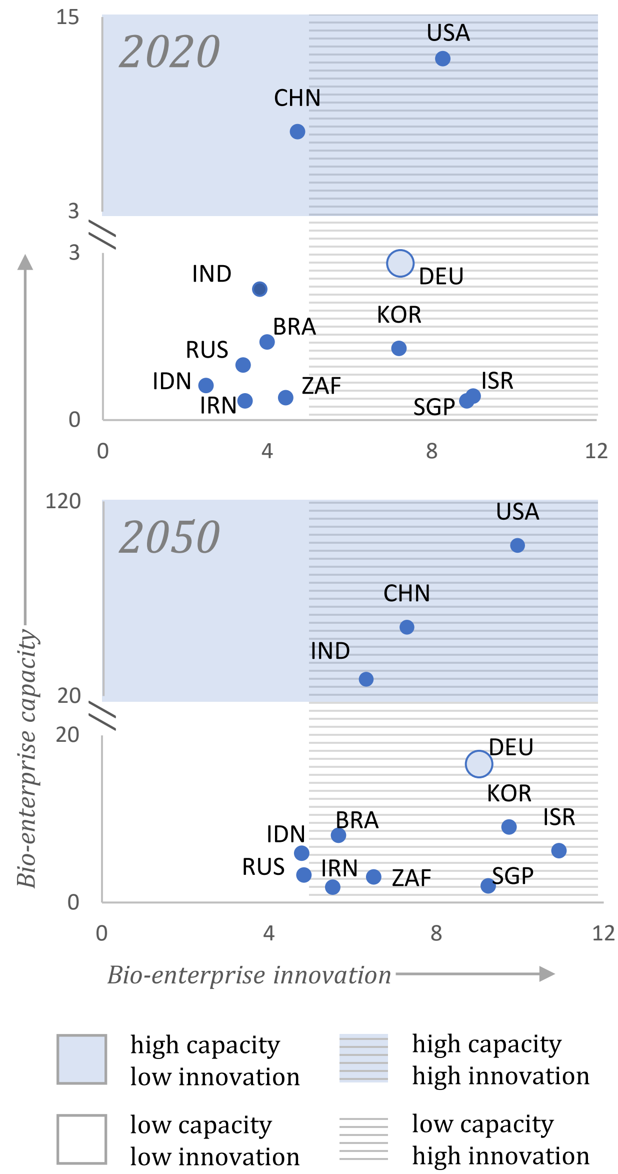
Capacity

German bio-enterprise capacity is impressively high, ranked third in 2020 behind the US and China, much larger countries. This results from Germany's well developed, high-tech biotech and S&T sectors. By 2050, Germany will likely be fourth, behind India due India's projected economic and population growth. Even if Germany were to push bio-enterprise capacity through policy measures, it would likely remain fourth due to its smaller size. However, the EU as a block might approach the bio-enterprise capacity of China or the United States.

Innovation Drivers

Germany is a highly innovative bio-enterprise, with quality education, advanced university systems, well-developed innovation clusters in S&T and biotech, and clear policy goals to continue to grow a robust and high-quality bio-enterprise. Germany is already a leader in R&D for medical, industrial, and agricultural biotechnologies, and is pushing the edge in new innovative technologies in synthetic biology. Outpacing some of the other high-tech countries, Germany is home to some of the largest multinational companies working in S&T and biotech. Germany is an obvious international power and driver in the bio-enterprise.

Bio-enterprise capacity and innovation, 2020 and 2050. Germany.



Improvements that would push the bio-enterprise forward and indicators to watch:

- Germany has an established, innovative, well-funded program in science and technology generally, and is a world leader in biotechnology specifically. Much of their policy is in line with wider EU governance on biotechnology. Namely, many stated goals of the EU and Germany regarding biotech involve the bioeconomy as a circular and sustainable system.
- Germany is likely to continue to lead innovation in biotech and other high-tech areas of R&D.
- As the German population ages, fertility rates drop, and immigration increases, Germany will have to contend with how to grow the number of skilled workers and researchers to maintain growth and innovation in S&T.
- Though Germany is home to two major multi-national agricultural biotech companies, their research facilities are located in the US and other countries. This may lead to a decline in university research and eventually contributions from smaller German companies.

GERMANY – biotech

biotech capacity	*rank 3 / 12 score 1.8/ 10*	*biotech drivers*	*rank 5 / 12 score 4.7 / 10*

Strengths
- *Many high quality biotech universities*
- *High collaboration on biotech publications*
- *Large industrial biotech sector*
- *Participation in international biotech communities*
- *Dedicated bioeconomy policy*

Weaknesses
- *Lack of biodiversity*

Germany consistently performs well in most of our biotech indicators, by both absolute and intensity measures. The science base and research infrastructure in Germany are high quality, with top ranking universities and sustained R&D investment, strong academic-industry collaborations, and stringent regulatory and review frameworks in biotech. Sector growth and R&D funding are heavily orchestrated by the government in a top-down fashion. Germany's biotech policy has been heavily influenced by EU policy, primarily with the EU Horizon 2020 plan as it relates to the Germany Bioeconomy 2030 Plan. The main focus therein is developing a sustainable bioeconomy. Germany contains dozens of "BioRegions," or innovation clusters focusing on biotechnology, to promote and advance innovative biotech development and foster collaborations between industry and academic R&D efforts.

Red Biotech – biomedical sciences
- Germany has an advanced biomedical and biopharma sector, supported by a sophisticated system for commercializing public and university research. Biomedical research is world class, with leaders in medicine, translational research, biopharma development, and basic biological research. German R&D in this sector ranges from cutting-edge neurobiology, to antibody engineering for cancer treatments, to innovative medical device development. Large international biomedical companies such as Bayer, Boehringer Ingelheim, and Merck are all German companies.
- Germany has a competitive, modern biopharma environment for R&D, tech transfer, and commercialization. Biopharma policy includes a regulated, cost-driven pricing system. However, Germany does not offer any specific R&D-based or IP-based tax incentives for biopharma development. Excellent biopharma regulatory standards are in place, and the biopharma sector is considered world-class.

Green Biotech – agricultural biotechnologies
- Germany has opted out of GM crop cultivation under the EU directive. Large societal pushback against GM cultivation in Germany suggests that adopting GM seed cultivation in the near future is highly unlikely. However, GM foods are still imported, and GM seeds are developed within Germany. Despite opposition to cultivation in Germany, agricultural biotechnology is a large area for R&D. Bayer Crop Sciences (who recently acquired Monsanto) and BASF are some of the world's largest agricultural biotech companies and producers of GM seeds, engineered microbes, and biotech fertilizers.

White Biotech – industrial biotechnologies
- Biofuels in Germany account for a large fraction of liquid fuel production, with production growing at 4.3% annually. Much of industrial biotech R&D in Germany is focused on sustainability and energy goals, including bioprocess engineering, bioreactor development, biorefinery techniques, biotech design of yeast and algae-based food products, and production of biopolymers and R&D products. Germany is a leader in industrial biotechnology, with 10% of the capital region's biotech companies focused on industrial biotech development. Some of the largest industrial biotech companies are German, including BASF and Evonik Industries.

GERMANY – science & technology

S&T capacity	*rank 3 / 12 score 2.8 / 10*	*S&T drivers*	*rank 4 / 12 score 6.8 / 10*

Strengths
- *Strong R&D funding*
- *Large share of world STEM graduates*
- *Many world renown innovation clusters*
- *High university performance and university-industry collaboration*
- *First in innovation capability*

Weaknesses
- *Weak incentives for IP creation*

Germany consistently ranks in the top 3 for most S&T indicators, scoring impressively on both absolute and intensity metrics. Well developed tech transfer, VC funding, IP regulation, and innovation scores point to an agile S&T system that is mature and likely to continue to perform on a high level. While Germany performs very well and is internationally competitive in S&T, it lacks the absolute capacity of a country like the US or the technological advancement of a small specialized nation like Singapore. Much of Germany's S&T policy is directed toward addressing societal or environmental/sustainability challenges, and generally falls in line with EU policies regarding S&T. S&T policy is first rate, wherein high-tech strategy is constantly reevaluated and updated in order to suit the needs of the S&T system. Funding of R&D from both governmental and business sources is high. German researchers are well connected internationally, and policy supports high levels of international cooperation in S&T programs. German innovation clusters are renowned and are a model for cluster development in other countries. Areas for improvement include updating the current ICT infrastructure and increasing the number of researchers relative to GDP. In all, Germany has a highly advanced, competitive, and respected S&T environment, supporting quality academic, industry, private, and international research initiatives.

GERMANY – general societal

societal capacity	*rank 4 / 12 score 1.6/ 10*	*societal drivers*	*rank 5 / 12 score 5.5 / 10*

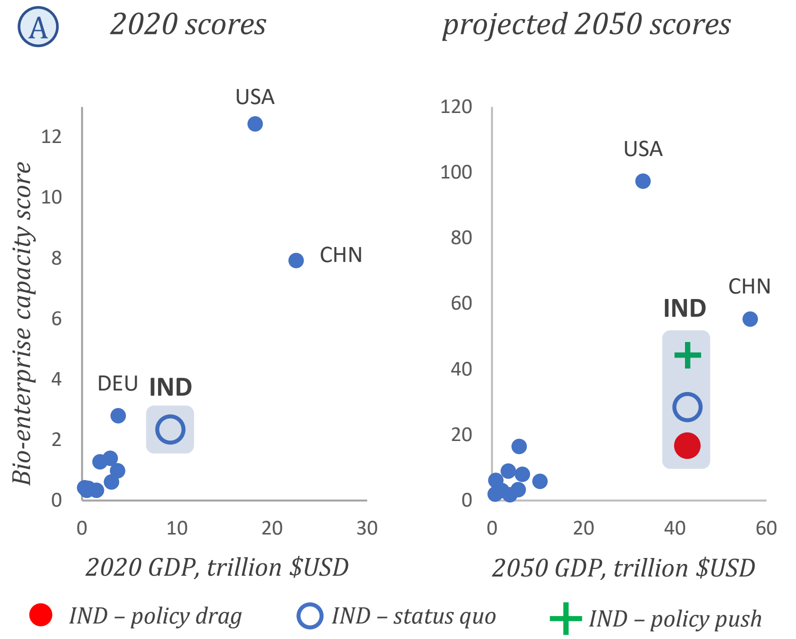
Strengths
- *Best ranked in rule of law*
- *Strong university and education system*
- *Strong societal belief in science*
- *Large market size*

Weaknesses
- *Slow projected economic growth*
- *Aging population*
- *Relatively low expenditure on education*

Germany is a wealthy, technologically developed country with good education and low poverty. The university system is well developed and internationally renowned, hosting 5% of the top world universities overall. ICT adoption is widespread but not as well developed or high tech as other developed countries. Generally, Germany performs better on competitive scoring metrics than other high income and EU countries – Germany has the 5th largest world economy and performs excellently in economic stability, business dynamism, innovative growth and capability, cluster development, quality of research, and other metrics. Germany benefits from a highly skilled labor force, but faces demographic challenges with an aging population, low birth rate, and increasing net immigration. Germany hosts many major international R&D companies, encourages entrepreneurship and investment, and has a modern IP regulatory structure. In all, Germany is an advanced economy with long historical precedent of wealth and innovation. As a leader in the EU, Germany is well respected and connected on the international stage, and supports international collaborations and agreements both with peer nations and with developing nations.

INDIA

Bio-enterprise Capacity Scores

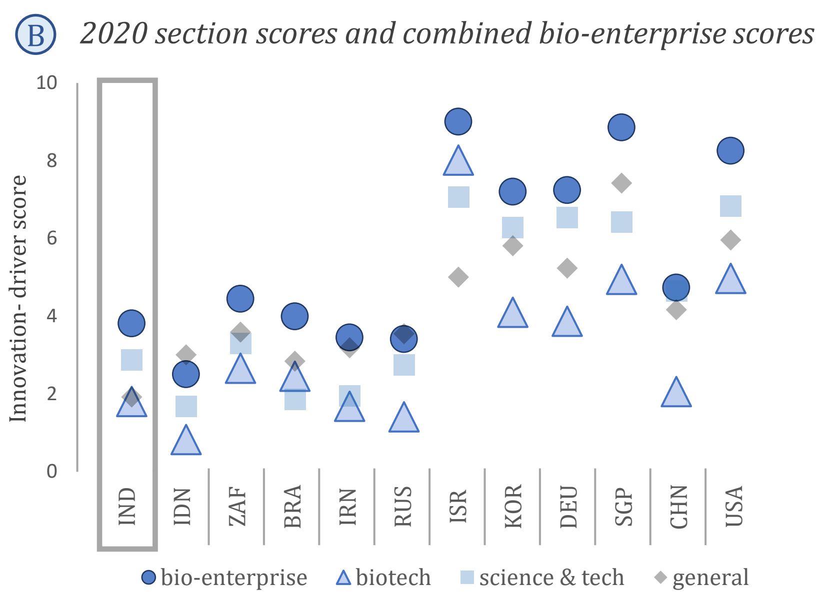


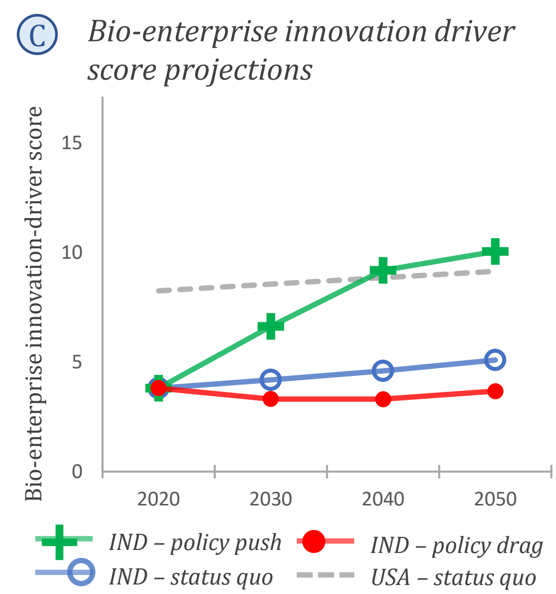
Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. India's 2020 absolute score is ranked 4 of 12 in 2020 (left); 3rd by 2050 (right). The absolute scores are displayed in relation to each country's GDP, as larger economies clearly have an advantage.

Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, India is ranked 9 of 12. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on India's capacity score by 2050: though the range is substantial, it appears that India will remain in 3rd place, between China and Germany

Bio-enterprise Innovation-driver Scores





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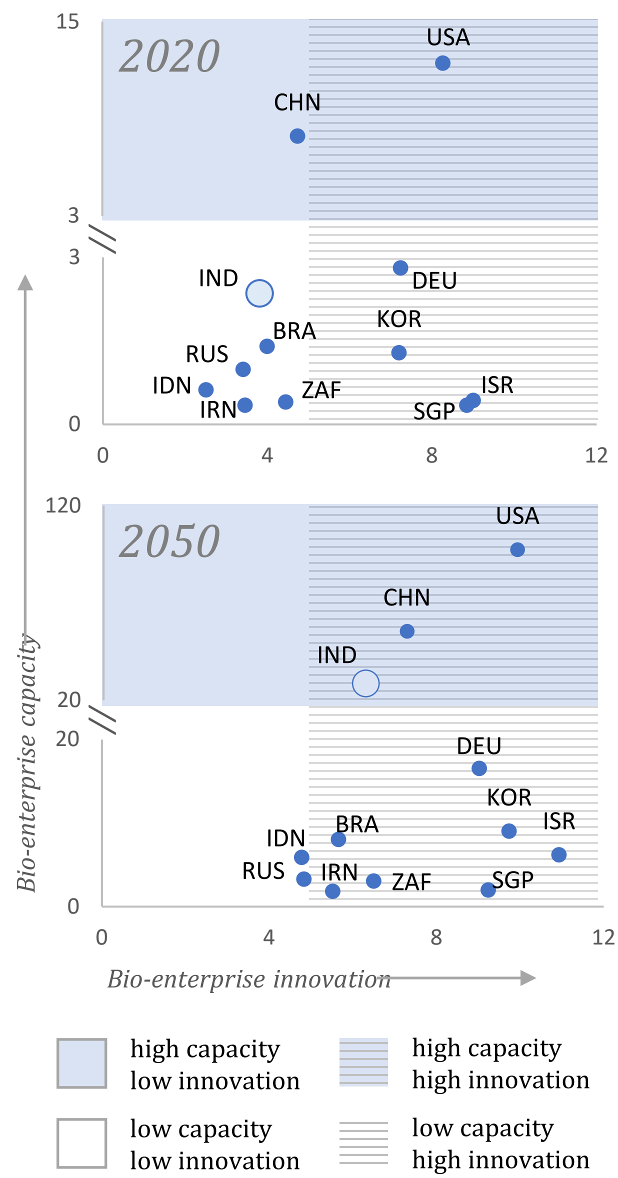
INDIA

Bio-enterprise capacity 2020 – rank 4 of 12
Bio-enterprise innovation drivers 2020 – rank 9 of 12

As can be seen in the graph to the right, in 2020, India falls into the quadrant with both lower bio-enterprise capacity and low drivers of future innovation. By 2050, India may move into the quadrant with both high capacity and high innovation drivers.

Bio-enterprise capacity and innovation, 2020 and 2050. India.



Capacity

Despite being a low-middle income economy, India ranks 4th in bio-enterprise capacity. This is primarily due to the sheer size of the biotech and S&T endeavors, both outcomes of the large economy and population of India.

By 2050, without policy changes, our modeling suggests that India will join China and the US as large, high-capacity bio-enterprise economies, making clear the importance of Indian biotechnology globally. With policy improvements, India could grow total capacity to near-China levels by 2050.

Innovation Drivers

India is currently in line with its BRIICS peers in terms of biotech innovation and the intensity of its biotech efforts. Many of these countries are relatively new entrants into the biotech sector, a sector which requires a functioning S&T infrastructure, dedicated funding, and national will in order to pursue. India is still a developing economy that is relatively low-tech. The biotech sector is growing, but will require significant improvement to create an innovative, competitive biotech sector by 2050

If pro-bio-enterprise policies were aggressively implemented in India today, our projections suggest that India might achieve innovative abilities near current US levels by 2050. Under status quo policies, biotech innovation will improve, but to a less dramatic degree. We have seen little evidence to suggest that biotech policy will change significantly from the status quo.

Improvements that would push the bio-enterprise forward and indicators to watch:

- Increased R&D funding to >2% of GDP would suggest dedication to growing S&T capacity.
- Expansion and improvement of the university and biotech research systems would help to improve the quality and quantity of biotech research perhaps prevent brain drain.
- Other areas of improvement that might help India advance: improved policies for IP, tech transfer, and R&D incentives; improvements in rule of law; and increased adoption of information and communication technology.
- A general distrust of foreign technology and investment is common in India's policy and society. This might help push internal growth and innovation or might slow India from developing state-of-the-art technologies and advancing as quickly as it might otherwise.

INDIA – biotech

biotech capacity	*rank 5 / 12 score 0.8 / 10*	*biotech drivers*	*rank 10 / 12 score 2.5 / 10*

Strengths
- *Presence of a national biotech strategy*
- *High emphasis on biotechnology within patents*
- *High participation in international genetic biology competition*
- *High total acreage of biotech crops, despite general anti-GMO sentiment*

Weaknesses
- *Few top biotech universities*
- *Relatively little international collaboration on life sciences publications*
- *Low biotech patent and publication rates*
- *Low participation in international conferences, genetic databases, and communities related to biotechnology*

At present, India has low scores on most measures of biotechnological capability. However, due to the size of India's economy and population, their overall output is still significant. Initial signs of growth in biotech, such as high use of Genbank sequence databases, an emphasis on biotech within patenting, and increasing numbers of clinical trials, point to the possibility of significantly improved biotech output moving forward. However, this effort is hampered by some major hurdles:

- University performance - few of India's universities have the capacity to perform innovative biotech research or teaching. The effect of this can be seen in low biotech publication numbers as well as low biotech publication quality. With limited trained talent, technological advancement and innovation becomes stifled. Building up high-quality biotech research universities or general biotech educational capacity could allow India to leverage its large, educated population into a biotech growth industry, following the example of India's IT industry.
- International collaboration – though India is increasing international collaboration on biotech and life sciences, rates of co-publishing are low. Increased collaboration would help India advance biotech research performance and move research to a more technologically advanced level.

Overall, though, the biotech sector appears to be growing. By one estimate, India's biotech industry grew by 22% per year between 2003-2014.

Red Biotech – biomedical sciences

- Biopharma is the most developed of the biotech sectors within India. The Department of Biotechnology runs a medical biotechnology program which supports and funds research, including high-tech biomedical research. However, this effort is hampered by relatively low levels of R&D spending and available researchers in the population. The biopharma sector, specifically, faces poor IP protection, inadequate regulations on quality of medicines and production, and the lack of a comprehensive tech transfer framework and policies.

Green Biotech – agricultural biotechnologies

- India is ranked 5th in the world in total biotech cropland, due to extensive growth of GM-cotton. However, the industry appears to be losing support from both the government and population, making development or cultivation of biotech food crops increasingly difficult. Research lags, despite the creation of many centers for agricultural biotech R&D and availability of government funding. Approvals of new biotech crops are stalled or prevented, and approvals for field trials have been frozen.

White Biotech – industrial biotechnologies

- Biofuel policy is well established in India, with goals to increase biofuel production, as well as to expand research of non-agriculturally derived biofuels, such as those derived from waste or algae. Subsidies are offered for ethanol production and biofuel R&D. However, as in other biotech sectors, IP rights are unclear, and patents face long backlogs.

INDIA – science & technology

S&T capacity	*rank 5 / 12 score 1.3 / 10*	*S&T drivers*	*rank 7 / 12 score 3.7 / 10*

Strengths
- *Large share of world's STEM graduate students*
- *High total funding of R&D relative to GDP*
- *Emphasis on STEM in universities*
- *Growing venture capital sector in science and technology*

Weaknesses
- *Low patenting and publication rates*
- *Low concentration of researchers and STEM graduates relative to economy size*
- *Few innovation clusters*
- *Brain drain in students and research talent*

India has the potential to become a standout in S&T. India has one of the largest public research systems in the world and a large educated population. University performance is strong in computer technologies and engineering, which is further seen in its large IT services and industry sector. India's Council for Scientific and Industrial Research has a network of 37 national labs that undertake high quality research in a wide range of fields. Major improvements have been seen in India's international S&T programs, such as nuclear energy, space exploration, etc. India is performing well in S&T compared to its economic peers but has much room for improvement to reach the performance and innovation levels seen in wealthier nations. R&D spending as a percent of GDP has remained stagnant. High levels of STEM graduates, but low levels of researchers, suggests problems of brain drain facing India. Incentives for IP creation are mixed: tax incentives are high, but IP protection, tech transfer support, and both governmental and private funding are below par.

INDIA – general societal

societal capacity	*rank 3 / 12 score 4.0 / 10*	*societal drivers*	*rank 12 / 12 score 2.3 / 10*

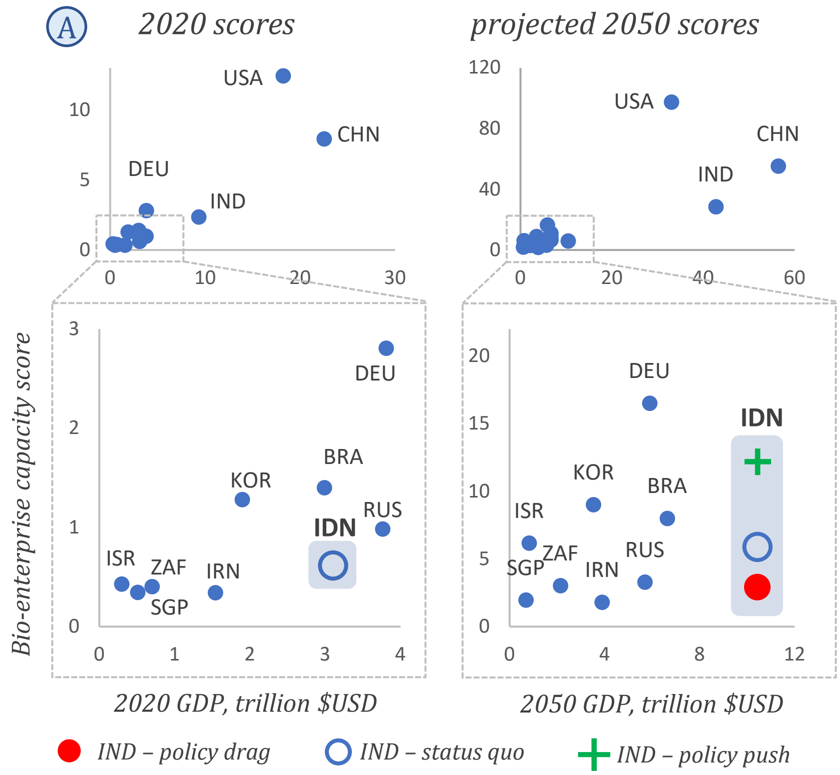
Strengths
- *Large, growing economy and population*
- *Social support for sciences and education*

Weaknesses
- *Poor information and communication technology adoption across the country*
- *Lack of top performing universities*

The promise of the biotech and S&T sectors in India stems from its large economy and population. The sheer scale means that India must be taken seriously as both a market for, and creator of, biotechnology moving forward. The expanding and educated population is likely to help foster innovation in both India and abroad. However, India's fast-growing economy is still projected to leave GDP/capita the lowest of our 12 countries, thus current difficulties may still plague India in the future. Middling rule of law, lack of ICT adoption, and poverty are barriers to developing innovative scientific capacity in the future.

INDONESIA

Bio-enterprise Capacity Scores

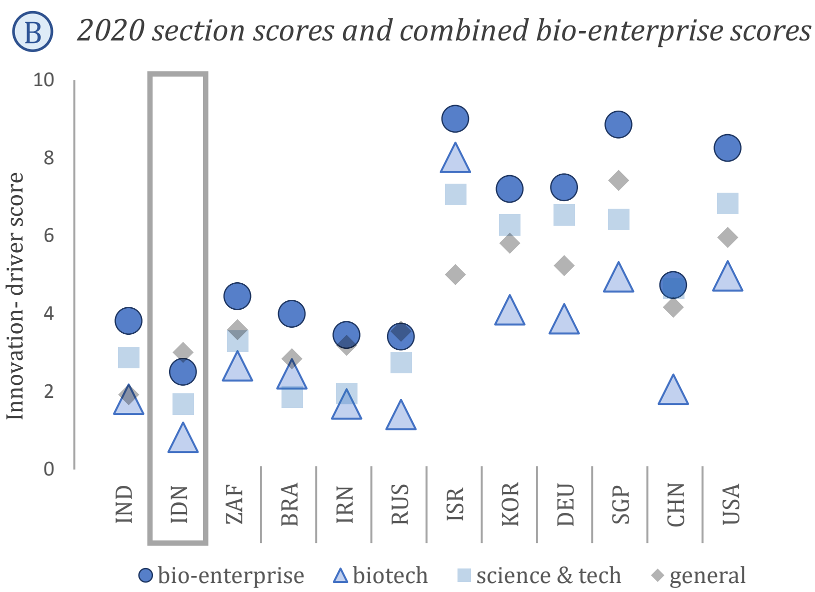


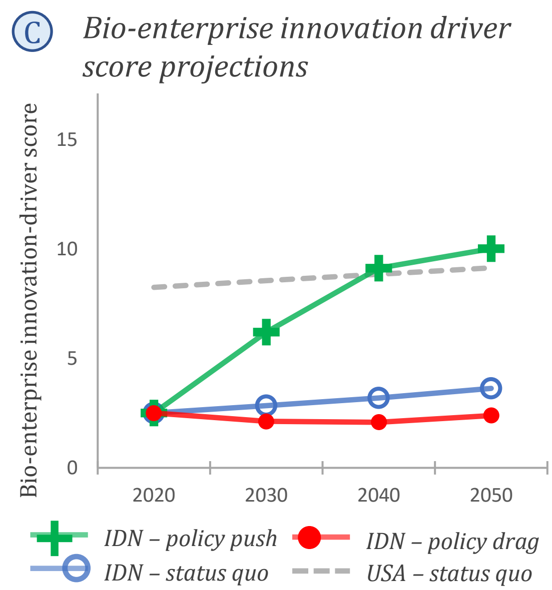
Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. Indonesia's 2020 absolute score is ranked 8 of 12 in both 2020 (left) and 2050 (right). The absolute scores are displayed in relation to each country's GDP, as larger economies clearly have an advantage.

Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, Indonesia is ranked last, 12 of 12. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on Indonesia's capacity score by 2050. Given Indonesia's size, under a policy-push scenario, it could conceivably advance from 8th to 5th, behind Germany and ahead of much smaller South Korea. Under a policy-drag scenario, it could drop to 10th.

Bio-enterprise Innovation-driver Scores





BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

INDONESIA

Bio-enterprise capacity 2020 – rank 8 of 12
Bio-enterprise innovation drivers 2020 – rank 12 of 12

As can be seen in the graph to the right, in 2020, Indonesia falls into the quadrant with both lower bio-enterprise capacity and low drivers of future innovation. Absent policy change, we project Indonesia, along with Russia, will likely remain in this quadrant in 2050.

Capacity

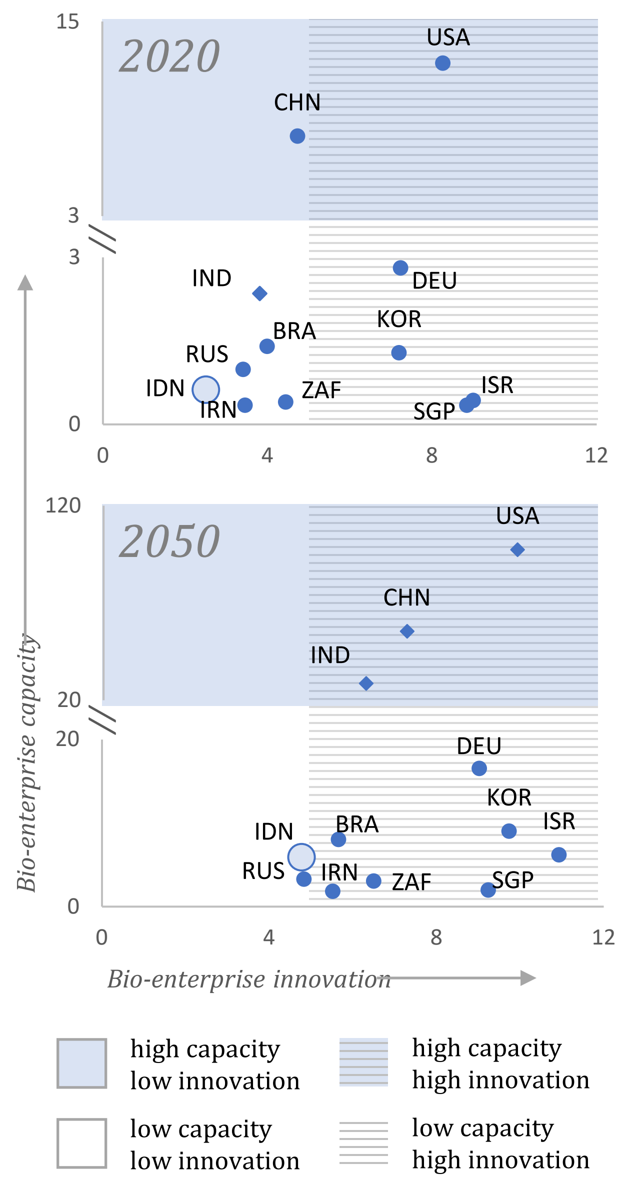
Indonesia has a large population and economy but is a relatively new entrant into the S&T and biotech space. Indonesia ranks behind many of its economically smaller peers in bio-enterprise capacity; its S&T and biotech presence are very small and undeveloped currently.

Indonesia is predicted to grow in both population and economy size through 2050, but still must overcome the hurdles of a low-wealth developing nation. Because of this difficult starting place, it is unlikely that the bio-enterprise capacity of Indonesia will grow significantly by 2050 without major societal and policy changes. However, with an aggressive pro-biotech policy push, their bio-enterprise capacity could hypothetically exceed that of Brazil by 2050.

Innovation Drivers

Indonesia ranks behind its peers in the low capacity, low innovation group in 2020, and is likely to retain that position moving into 2050 without major policy changes. Developing innovative biotechnologies requires a technologically adept scientific infrastructure, national planning and support, and funding, to start. Because Indonesia is a developing nation supporting a large, geographically distant, and agrarian population, rapid movement toward innovative biotech capabilities is not likely.

Bio-enterprise capacity and innovation, 2020 and 2050. Indonesia.



Improvements that would push the bio-enterprise forward and indicators to watch:

- Indonesia is predicted to be the 4th largest economy and 5th most populous country by 2050. This alone gives them power as a market and labor source, and may draw international investment in biofuels, agricultural biotechnologies, or other S&T endeavors. This could result in Indonesia as a user of biotechnologies (following Brazil's model, i.e., a large agricultural biotech producer, but without large agricultural biotech companies or extensive R&D) or a drive to be an innovator of biotechnologies (following China's model, i.e., using market access as leverage for tech and IP acquisition). This will largely depend on Indonesia's policies and actions regarding education, training, technology import, IP acquisition, and high-level planning.
- Before developing strengths in biotech, Indonesia must first develop societally and technologically. The first goals are likely to be improving basic infrastructure (roads, electricity, internet, etc.), improving education, and developing the economy as a whole. Only after these steps is Indonesia likely to move on to significant bio-enterprise development. But, well-developed, well-funded policy changes benefiting S&T and biotech growth could significantly improve the long-term outlooks for the sector.

INDONESIA – biotech

biotech capacity	*rank 8/ 12 score 0.4 / 10*	*biotech drivers*	*rank 12 / 12 score 0.6 / 10*

Strengths
- *Biodiversity in native species*
- *Growth in biofuel production*
- *Nascent participation in biotech conferences and publications*

Weaknesses
- *No national plan to develop biotechnology capabilities*
- *Very small biotech sector with few publications, patents, dedicated universities, clinical trials, or other indicators of biotech activity*

Biotech development is a new and small sector within Indonesia. Indonesia sits at or near zero on many standard measures of biotech capacity – biotech-specific publications, patents, companies, universities. International collaboration in biotech is low, and biotech industries are not mature.

However, certain indicators point toward a nascent but growing interest in participation in international biotech. Genbank user rates are on par with economic peer countries. Indonesian students and researchers attend international synthetic biology competitions, participate in biotech conferences, and subscribe to biotech and synbio community publications; this participation in international biotech exceeds that of peers such as Russia and South Africa. An additional strength is Indonesia's biodiversity; Indonesia is the most heavily forested world region after the Amazon. This suggests a high potential for genetic datamining, biotech development of native agricultural crops, or development of indigenous medicines. Growing their biotech capacity would likely require a national plan for biotech, a concentrated push toward life sciences and biotech education in universities, and general funding, support, and development of the underlying S&T infrastructure as a whole.

Red Biotech – biomedical sciences
- Biopharma is limited in Indonesia, and growth is faced with major systemic challenges. The IP environment for biopharma is challenging, with delays and lack of clarity in the processes involved. Tech transfer is limited, which in turn limits commercialization opportunities in Indonesia. Indonesia actively uses compulsory licensing on pharma products which undermines any IP protections that may be in place and makes investment by pharma companies less attractive. In-country R&D suffers from a lack of advanced scientific training and underdeveloped relationships between industry and academic R&D. The capacity for clinical trial management is low, with a high burden of governmental regulation and delays for approvals. In all, the biopharma environment in Indonesia is considered challenging.

Green Biotech – agricultural biotechnologies
- Agriculture is a vital part of the Indonesian economy; a third of Indonesia's labor force works in agriculture. Recently, the *Grand Strategy for Agricultural Development 2015-2045* was produced, and is the first long term strategy for agriculture, focusing on food security, climate change mitigation, and resource conservation. While green biotech could aid in many of these goals, GM adoption has been slow, with the first GM crop approved for cultivation in 2018. Due to rapidly increasing issues in climate change and food and water security, growing green biotech capacity is an obvious step forward for Indonesia.

White Biotech – industrial biotechnologies
- Biofuels are currently 7% of total liquid fuel production in Indonesia and the sector is growing rapidly. Biofuel production via palm oil provided an early jump start to this industry, but a reduction in demand and environmental damage from deforestation have slowed this growth. Innovative industrial biotechnologies are unlikely to be developed in Indonesia without first improving S&T and biotech capabilities.

INDONESIA – science & technology

S&T capacity	*rank 12 / 12 score .03 / 10*	*S&T drivers*	*rank 11 / 12 score 2.4 / 10*

Strengths
- *Scores are fair on most Global Competitiveness Indicators, including cluster development, IP protection, and the ability of government to respond to change*
- *International interest in investment, leading to nascent VC availability*

Weaknesses
- *Very few STEM graduate students or researchers*
- *Higher education system is lacking in both number and quality of universities*
- *Relatively low technical capabilities in academic and industry settings*

Current S&T capacity is low in Indonesia, but indicators point toward prioritizing a national pursuit of S&T. R&D funding as a percent of GDP is low, at only 0.3% (other BRIICS average ~1% of GDP). Many universities are spread across Indonesia, but few rank internationally – growing university capacity and quality would be a vital growth step for S&T development in Indonesia. As an outcome of low university activity, levels of publications, patents, and researchers are low. International and VC funding has increased, and exceeds rates seen in its economic peer group, pointing to possible growth in S&T. However, poor IP policy, tech transfer policy, and industry support hampers private sector growth. This is to be expected given that Indonesia is such a new entrant to the S&T space. However, this does suggest that major policy and funding support for S&T on a national level are required in order to pursue growth in S&T. Indonesia has the potential to grow substantially in S&T but would have to actively drive that growth as a nation in order to achieve it.

INDONESIA – general societal

societal capacity	*rank 7 / 12 score 1.0 / 10*	*societal drivers*	*rank 8 / 12 score 3.5 / 10*

Strengths
- *High economic growth rate*
- *Societal beliefs in science as a national and personal benefit*
- *Government expenditure on early education*

Weaknesses
- *Lacking in higher education*
- *Short school life expectancy*
- *Low GDP per capita*
- *Difficult to centralize tech and knowledge infrastructure due to a large landmass and population scattered across the archipelago*

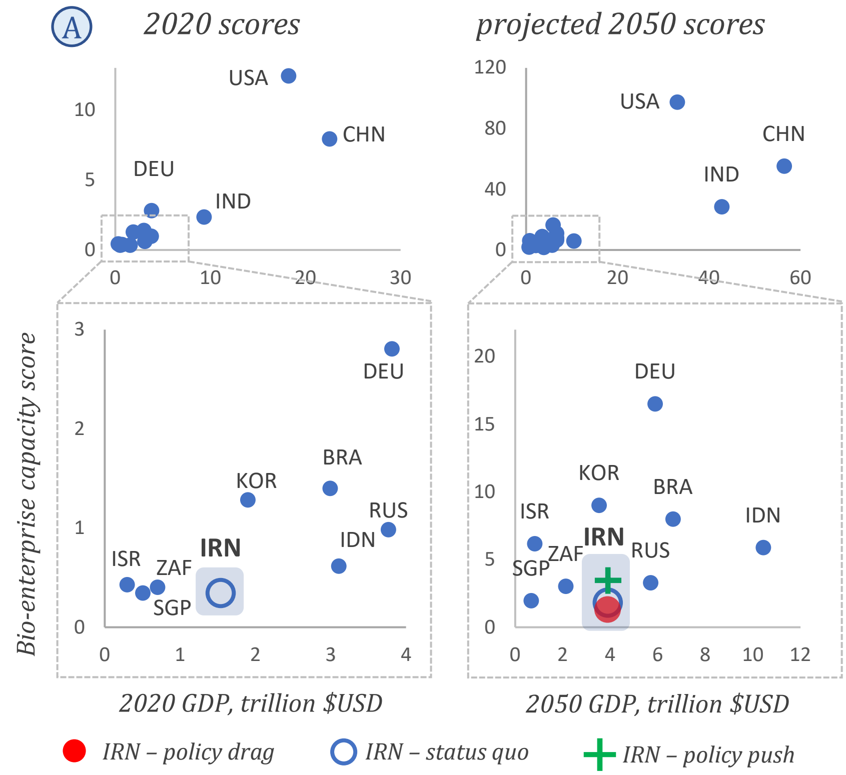
Government spending on primary education, improving governmental stability and rule of law, and a large market size are promising indicators for development in Indonesia. Human and natural resources are substantial but may require centralized policy and funding to leverage these resources toward growth. Successful development will require considerable efforts to improve infrastructure, governance, and social support systems moving forward. Improving water and food accessibility, access to basic electrical and communication infrastructure, and increasing government support for education would be a promising first step. Despite its early stage in development, Indonesia is the world's third largest democracy, and is making progress in creating and driving national and local policies to improve quality of life, national health, and governmental functionality.

IRAN

Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **Iran**'s 2020 absolute score is ranked last in both 2020 (left) and 2050 (right). The absolute scores are displayed in relation to each country's GDP, as larger economies clearly have an advantage.

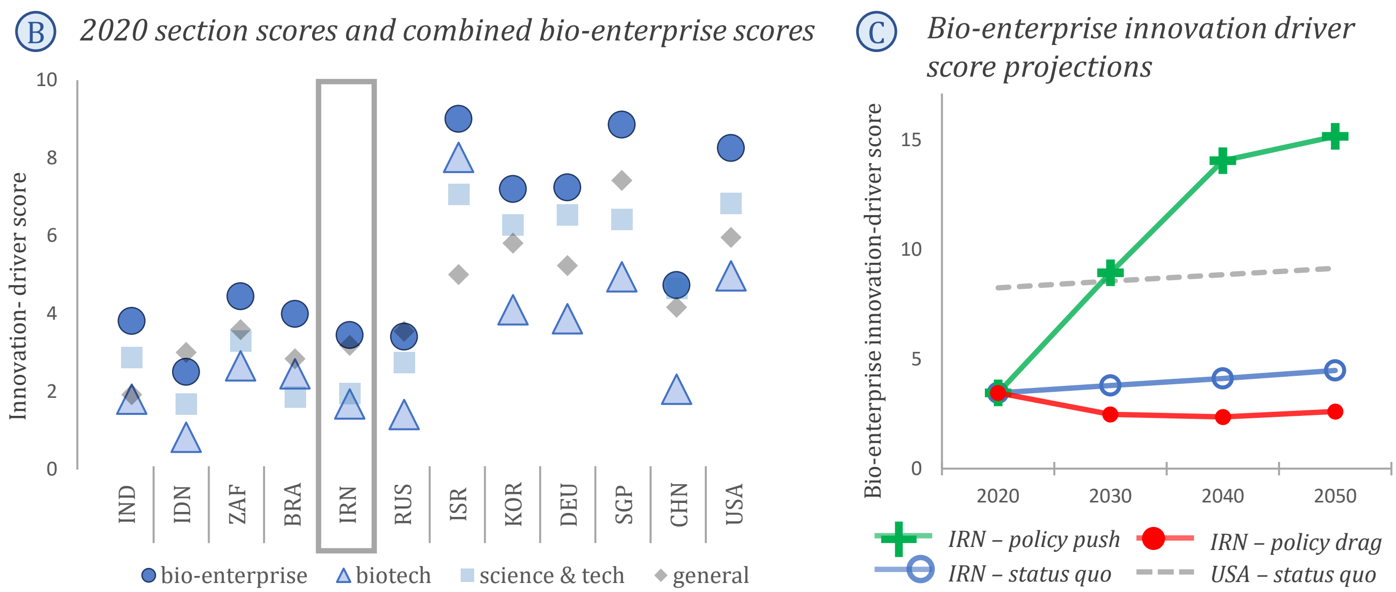
Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **Iran** is ranked 10 of 12. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

Bio-enterprise Capacity Scores



Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **Iran**'s capacity score by 2050. Given **Iran**'s size, under a policy-push scenario, it could conceivably advance from last to 9th, ahead of Russia, South Africa, and Singapore.

Bio-enterprise Innovation-driver Scores



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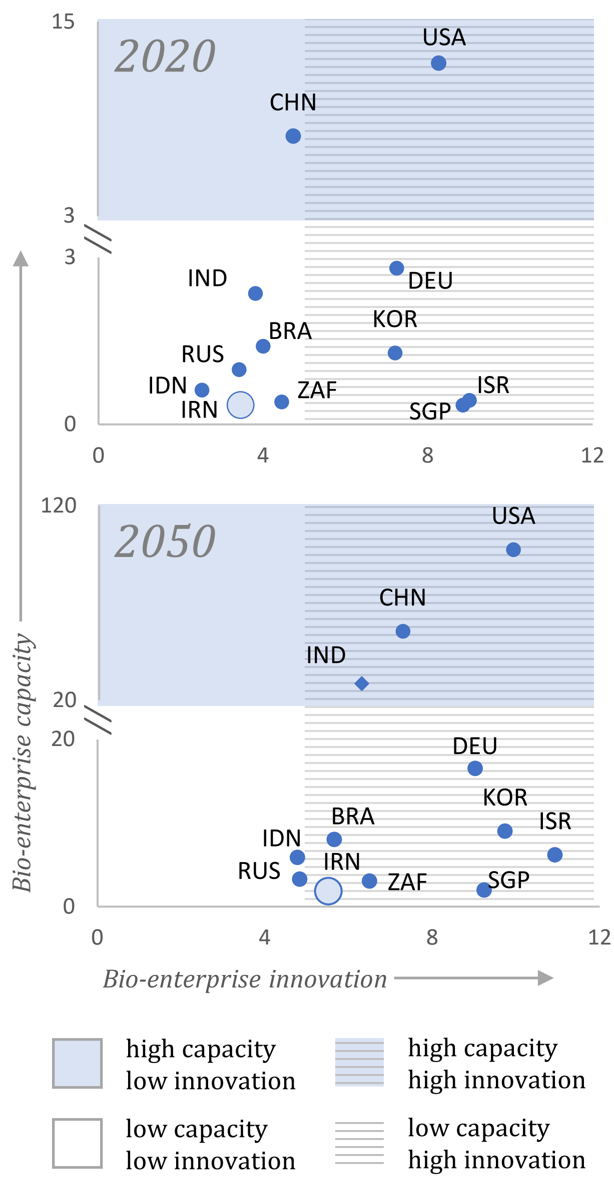
IRAN

Bio-enterprise capacity 2020 – rank 12 of 12
Bio-enterprise innovation drivers 2020 – rank 10 of 12

As can be seen in the graph to the right, in 2020, Iran falls into the quadrant with both lower bio-enterprise capacity and low innovation-driver scores. By 2050, Iran might transition to an innovation-driver score we consider high by 2020 standards.

Bio-enterprise capacity and innovation, 2020 and 2050. Iran.



Capacity

Iran currently ranks low in bio-enterprise capacity, falling behind most of its peer group. This capacity is not predicted to change dramatically by 2050, even with a pro-biotech policy push. Nevertheless, Iranian policy aims to grow its bio-enterprise and become a regional leader in both innovation and capacity. Whether this comes to fruition will be determined by Iran's drive to prioritize bio-enterprise growth and by international policies toward Iran.

Innovation Drivers

Iran ranks 10 of 12 on bio-enterprise innovation, ahead of Russia and Indonesia. Iran has an isolated economy with limited international trade and participation in international S&T and biotech, making its bio-enterprise innovation difficult to measure. It is worthwhile to note that though innovation scores low, Iran does in fact have a somewhat technologically capable biotech sector. In addition, Iran has made impressive strides in improving biotech innovation as well as overall S&T in-country since 2000. Iran has ambitious policies to continue to grow these sectors. Funding and policy goals suggests a prioritization of biotech and other high-tech sectors. Again, whether these will be achieved is not only an issue of Iranian funding and determination, but also an outcome of the international attitudes toward Iran's development and economic freedom.

Improvements that would push the bio-enterprise forward and indicators to watch:

- Societal instability is a major hurdle to development in Iran. Improving rule of law, personal freedoms, and quality of life in Iran would enhance prospects for high-tech growth.
- Both VC funding and foreign direct investment is lacking in Iran. International investors have been wary of sanctions and unstable growth. If Iran or policies toward Iran stabilize enough to become attractive to international investment, this would allow for larger growth efforts in R&D.
- Iran has outlined goals to increase R&D funding to 3% of GDP, which would constitute a major growth step for S&T. Even >2% would outpace many peer countries' R&D efforts and signal a serious drive toward S&T development.
- Increasing international collaborations on projects, papers, and conferences would improve the quality and rigor of S&T and biotech in Iran and would increase international recognition of Iran as an S&T power.
- Integration of Iran's regulatory systems with international bodies would facilitate trade; this would involve such steps as participating in major patenting highways, meeting international drug and biosimilar standards, and improving accreditation of institutes and research organizations.

IRAN – biotech

biotech capacity	*rank 12 / 12 score 0.1 / 10*	*biotech drivers*	*rank 9 / 12 score 2.7 / 10*

Strengths
- *Presence of a national biotech strategy*
- *Ranked life science and biotechnology universities*
- *Participation in GenBank*
- *Emphasis on biotech in publications*

Weaknesses
- *Few international biotech companies*
- *Low patenting rates*
- *Low international participation in conferences and competitions in biotech*

By many of our measures, biotech is not a large or thriving sector in Iran. However, it is home to several universities well-regarded in biotechnology and life sciences, suggesting a general interest in pursuing biotech. However, patenting, international collaborations, and biotech company rates are low. Iran poses a specific challenge to our analysis, in that many biotech and S&T metrics rely on the recognition of achievement by other biotech countries (internationally known companies, international citations on publications, travel to international biotech competitions, etc.). In what we can measure, Iranian policies are working to address weaknesses by increasing funding to research and academics, improving early education, modernizing tech transfer and entrepreneurship funding and policy, and updating national plans for development of biotech and S&T.

In 2012-2016, Iran supported 203 biotech projects, accounting for approximately 22% of total funding for S&T projects. The number of researchers, count of S&T parks, and counts of start-up incubators are on the rise. Iran has set specific growth targets for biotech development to 2025, including becoming the leader in biotech in the Middle East and increasing its share of the global biotech market to 3%. Iran has achieved a high degree of self sufficiency in the biotech and biopharma markets, partially benefitting from a strong higher education and research system, and partially benefitting from a local market protected from international competition. Biotech subsectors have developed as well; as of 2016, 96 knowledge-based firms were active in agricultural biotech, 144 in biopharma, 47 in environmental and industrial biotech, and 18 in biotech material and equipment in Iran.

Red Biotech – biomedical sciences
- Biopharma has grown rapidly in Iran, with high capacity pharma and biopharma industries today. Iran aims to become one of the world's leading producers of biosimilars. Despite a fairly advanced biomedical sector, Iranian red biotech still suffers from a lack of funding and S&T development. VC capital is limited, and access to any foreign investment is limited. A strength, however, is the many science parks and incubators where small start up companies are supported through their development - some have found commercial success, such as those creating the biomedical products listed above.

Green Biotech – agricultural biotechnologies
- Agricultural biotech and biomedicine are the fastest growing biotech sectors in Iran. Commercial agricultural biotech companies have produced bio-fertilizers and bio-pesticides, some of which are commercially competitive and exported. However, Iranian agricultural biotech struggles to compete with imported seeds, fertilizers, and pesticides.

White Biotech – industrial biotechnologies
- Industrial biotech companies have focused on generating biotech products for use in R&D, including restriction enzymes, monoclonal antibodies and biopolymers. Given its large and high-tech oil and gas industry, Iran does not have significant biofuel activity.

IRAN – science & technology

S&T capacity	*rank 10 / 12 score 0.3 / 10*	*S&T drivers*	*rank 12 / 12 score 2.2 / 10*

Strengths
- *Many STEM students*
- *High intensity of university performance in engineering and tech*
- *Hosts regional and international innovation clusters*

Weaknesses
- *Low overall spending on R&D*
- *Very low patenting activity and IP protections*
- *Educated students and workers abroad are unlikely to return*
- *Poor overall infrastructure*

Iran has some promising indicators in S&T, but major hurdles to overcome in order to develop a more capable S&T sector. Though collaborations can be strained by international political issues, most of Iran's scientific collaborations are west-facing (USA, Canada, UK and Germany are top collaborators). Iran hosts international research centers for nanotechnology, oceanography, and tech incubators, and collaborates on external international R&D efforts such as a thermonuclear reactor project in France. Being cut off from foreign trade has hampered S&T efforts in many ways; Iran does not have access to high tech machinery or products necessary to perform cutting edge R&D. However, this isolation also allowed Iranian startups and producers to grow without international competition, allowing for internal diversification and growth in S&T. Current policies aim to grow S&T capabilities, with a goal of being second to Turkey in S&T leadership in the region. These goals include an increase to 3% of GDP spent on R&D, improved evaluation and funding of higher education, increased foreign investment, and a reorientation of academic research toward public and socio-economic needs of the nation. Whether these policy goals are achieved will be based on international trade and sanctions, national stability, building up the research, ICT, and academic infrastructure. However, strong policy planning and a national drive to innovate in S&T suggests that if these priming factors are achieved, Iran is likely to push toward impressive S&T development.

IRAN – general societal

societal capacity	*rank 9 / 12 score 0.5 / 10*	*societal driver*	*rank 10 / 12 score 3.1 / 10*

Strengths
- *Government expenditure on education and primary education*
- *Expected growth of wealth and economy*
- *Established university system*
- *Strong belief in science as a national benefit*

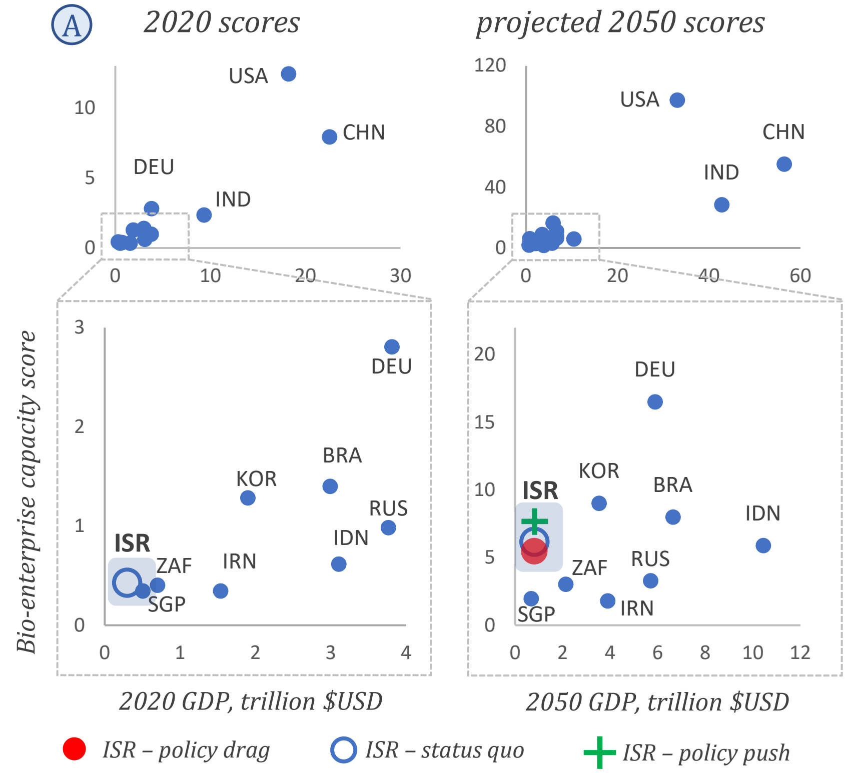
Weaknesses
- *Lack of high performing universities*
- *Poor rule of law*
- *International conflict and sanctions have restricted national stability and growth*

Iran's economy is projected to increase at "middle of the pack" growth rates among our 12 countries. However, a lack of personal freedom, rule of law, and regional stability are ongoing societal issues. Additionally, poor ICT adoption has hampered growth, and low literacy levels create barriers to innovation. Iran does have lower poverty levels than all peer countries, save Russia, by a substantial margin.

Iran's societal and economic well-being has been shaped by international politics and sanctions in recent years. The economy has been marked by statist policies, inefficiencies, and a reliance on oil and gas exports. However, embargoes on oil and gas forced Iran to shape public policy away from a resource-based economy into a knowledge-based economy. These international sanctions also moved the majority of trade from west to east, specifically growing trade with China. Iran, though still developing, is a regional leader, and seems poised to grow quickly if internal and international stability can be achieved.

ISRAEL

Bio-enterprise Capacity Scores

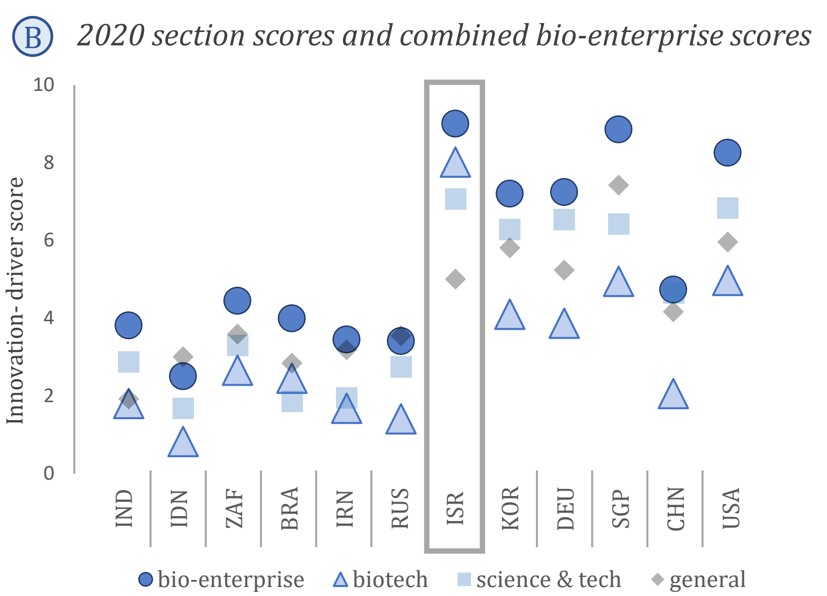


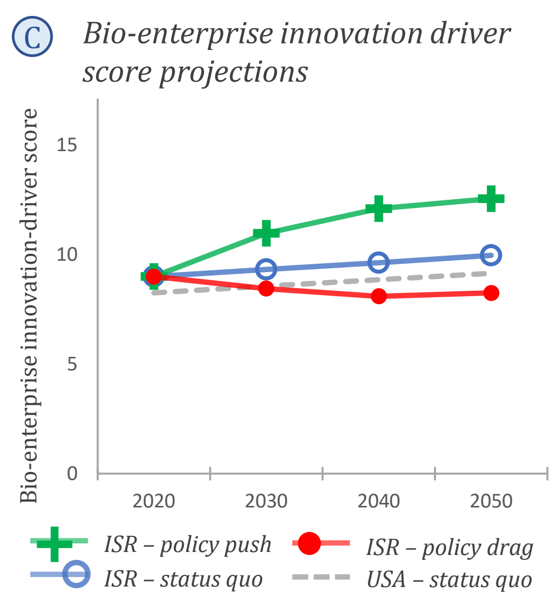
Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **Israel**'s 2020 absolute score is ranked 9 of 12 in 2020 (left) and projected to increase to 7th by 2050 (right). The absolute scores are displayed in relation to each country's GDP, as economies far larger than Israel clearly have an advantage on this absolute measure.

Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **Israel** is ranked an impressive first of 12, ahead of both Singapore and the US. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **Israel**'s capacity score by 2050. Given **Israel**'s already first ranked innovation-driver score, it remains 7 of 12 in capacity under a policy-push scenario. Under a policy-drag scenario, it could drop to 8th, below Indonesia, a far larger economy.

Bio-enterprise Innovation-driver Scores





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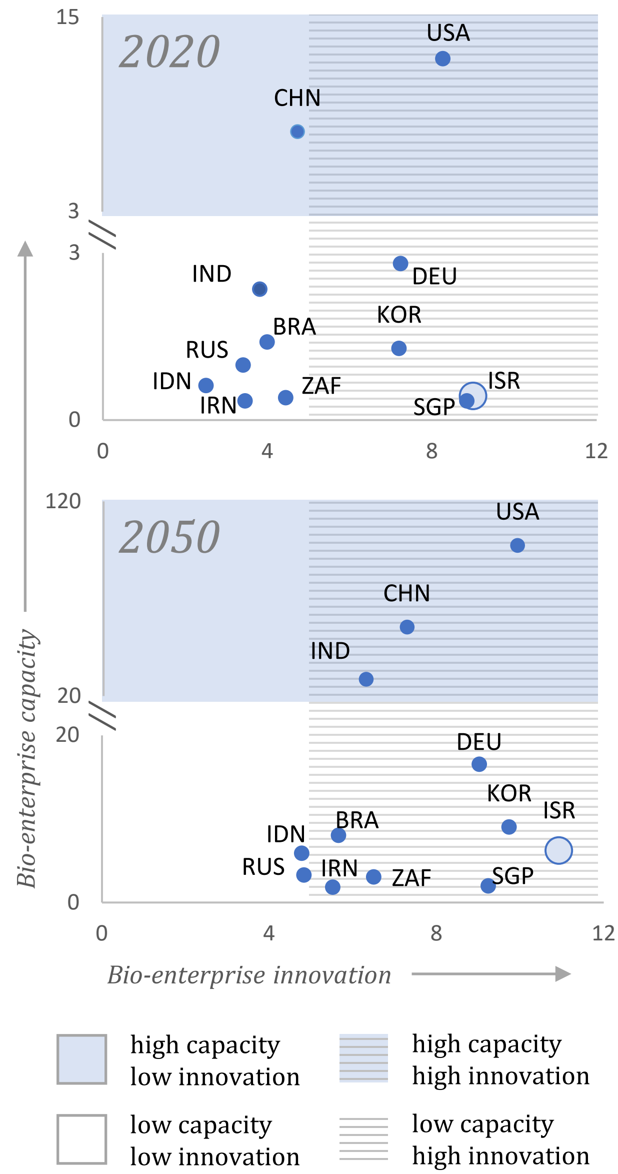
ISRAEL

Bio-enterprise capacity 2020 – rank 9 of 12
Bio-enterprise innovation drivers 2020 – rank 1 of 12

Bio-enterprise capacity and innovation, 2020 and 2050. Israel.



As can be seen in the graph to the right, in 2020, Israel falls into the quadrant with lower bio-enterprise capacity but high drivers of future innovation. Israel will remain in this quadrant in 2050.

Capacity

Israel has a small economy and population, and while it is very high performing, bio-enterprise capacity is limited by that size, even with ideal pro- bio-enterprise policies in place.

Innovation Drivers

Israel is ranked first of our 12 countries in bio-enterprise innovation, supported through strong biotech, S&T, and societal policies as well as strong international collaborations. Israeli policy prioritizes the fostering of high-tech and cutting-edge R&D, then supports the transfer and commercialization of this research into business. Innovation is largely driven through business enterprise, tech transfer, and investments by multinational companies. Biotech innovations are primarily in the biopharma and biomedical space, with increasing growth in bioinformatics and genetic technologies. Because Israel already has such a supportive policy environment for biotech and S&T growth, our policy-push scenario shows less potential for improvement . However, maintaining this high level of innovation will require continued efforts on the part of Israel.

Improvements that would push the bio-enterprise forward and indicators to watch:

- Israel is facing a rapidly aging population and concurrent loss of many older researchers and leaders in S&T. At the same time, educational quality has declined, and scientific infrastructures are becoming outdated. Improving educational quality, a push toward excellence in basic sciences (currently focused on applied sciences) and a focus on training new leaders in S&T and biotech may help Israel counter these trends.
- Israel does not employ an umbrella type organization that oversees and coordinates the goals of S&T development. Creating such an organization might improve coordination of federal funds and policy priorities. This might also help disparate parties such as medical centers, universities, innovation clusters, and corporate R&D to interact and coordinate efforts.
- Israeli society is largely divided on cultural lines, wherein the majority lives in wealthy communities focused on high-tech development, and the minority lives in relative poverty outside these areas. Integration of the society might improve educational and social outcomes across the board and benefit Israel's growth potential substantially.

ISRAEL – biotech

biotech capacity	*rank 7/ 12 score 0.4/ 10*	*biotech drivers*	*rank 1 / 12 score 7.0/ 10*

Strengths
- *High concentration of biotech patents and publications*
- *High collaboration levels on publications*
- *High participation in international biotech competitions and GenBank usage*

Weaknesses
- *No national plan for biotech development*
- *Very little development in industrial or agricultural biotech*

Israel consistently ranks as the highest or one of the highest countries on most biotech intensity indicators. Israel excels in biotech university performance, talent, and patents. Though Israel has many biotech companies, most are medical or service oriented; biofuels and agricultural biotech are not significant sectors in Israeli biotech. Israel has seen a surge in enabling policies and incentives in the last 15 years which has led to record growth of the biotech sector. Israel pushed toward improved R&D, university-industry collaborations, and a better regulatory framework for biotech development. The Israel Innovation Authority has set up two biotech incubators to encourage development and commercialization. Significant R&D incentives are in place for biotech startups and R&D. Israel recently launched an "Innovation Box", aiming to attract multinational corporations to set up R&D in Israel, with significant corporate tax breaks and other incentives. Several incubator funds have been set up encouraging development in biotech. The Life Sciences fund finances Israeli companies, primarily aiming to fund innovative biopharma projects. The Biotechnology – Tzatam program provides R&D support in life sciences by providing research organizations with equipment and assistance.

Israel primarily relies on free-market structures in which development is supported through funding and enacting pro-business policies. However, Israel lacks a single umbrella organization that coordinates goals and policy for S&T and biotech. More centralized policy might help contend with a decreasing labor force, need for improved education and infrastructure, and other societal issues that may prove problematic to maintaining biotech innovation,

Red Biotech – biomedical sciences
- Today, most of Israeli biotech is biomedical, including biopharma, tissue engineering, cell therapy, and bioinformatics. Bioinformatics is a growing area, with a strong ICT sector supporting it. The number of life science companies has increased five-fold in 15 years, with much of this growth in drug discovery and biopharma. Israel also has one of the highest clinical trial rates per capita, where it works to develop cutting edge treatments as well as more traditional drugs. Tech transfer is well established in Israel, based on a model similar to the US Bayh-Dole framework, and has been widely successful. Two tech transfer offices in Israel are ranked among the top offices worldwide. Israel has a high standard for biopharma regulation and strong IP protection laws.

Green Biotech – agricultural biotechnologies
- Biotech crops are not allowed for commercial production. Sale of imported GM crops is restricted. The only GM plant to have received approval to date is a GM tobacco strain. Israel does allow development of GM crops for research purposes. In 2017, Israel changed policy to decide that genome edited plants with no insertion of foreign DNA will not be subject to GM seed regulations.

White Biotech – industrial biotechnologies
- Biofuels production in Israel is negligible.

ISRAEL – science & technology

S&T capacity	*rank 11 / 12 score 0.3 / 10*	*S&T drivers*	*rank 3 / 12 score 6.8 / 10*

Strengths
- *Highest R&D funding as proportion of GDP*
- *High-ranking high-tech universities*
- *Large share of researchers and doctoral graduates in the population*
- *Highly collaborative internationally*
- *Very good tech transfer, VC, entrepreneurship policies*

Weaknesses
- *Small absolute numbers patents, publications, and universities*

Israel has developed a highly competitive and innovative S&T environment, largely focused on cutting-edge innovation, and funded by the Israeli government, foreign investors, and large multinationals. Government policies support innovation and entrepreneurship, with high levels of business investment in R&D and VC. In academics, Israel has world class universities which generate high impact publications and turn out high numbers of graduate students. Medicine and high-tech sectors are major drivers of economic growth. A future issue in maintaining STEM education and innovation is one of funding; much of the funding for physical development of universities and university R&D has come from philanthropy, which may diminish in the future. Other hurdles to maintaining the current S&T environment are a decreasing pool of educated workers as researchers age out of their positions and decreasing funding of primary education primary education. Though Israel is currently highly successful in S&T innovation, major investments to improve educational outcomes and modernize scientific infrastructure will be needed.

ISRAEL – general societal

societal capacity	*rank 11 / 12 score 0.1 / 10*	*societal drivers*	*rank 3 / 12 score 6.0 / 10*

Strengths
- *Highest projected population growth*
- *top concentration of high performing universities*
- *high government spending on education and early education*
- *Significantly aging population*

Weaknesses
- *Relatively low rate of early science education*
- *Low societal rate of belief in science as increasing jobs or as a national benefit*
- *ICT adoption is uneven in the country*

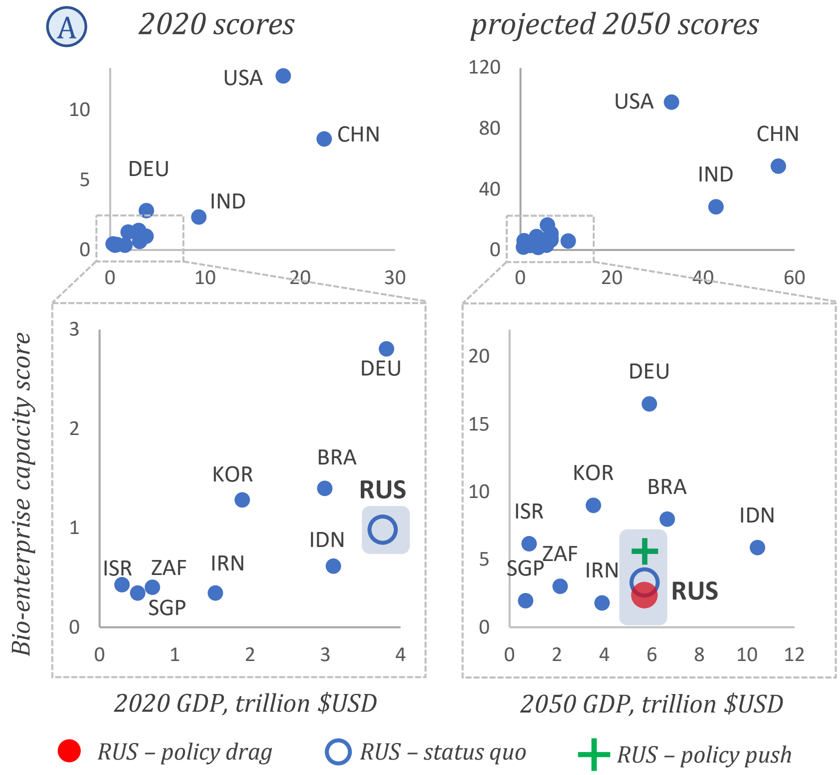
Israel is a small, relatively wealthy country with low poverty and a highly educated population. Projected economic growth through 2050 is 3.2% annually, above many high-income peer countries. Israel's population is expected to nearly double by 2050. Israeli policy does not often favor the top-down approach seen in other small innovative nations, but instead provides supportive policy to an otherwise free market for R&D. Israel ranks best in the world for VC availability, acceptance of entrepreneurial risk, growth of innovative companies, and R&D expenditures. Israel is similarly advanced in IP regulations, tech transfer, and innovation in R&D; many general and business policies are considered state-of-the-art. However, Israel suffers from relatively poor political stability, social tolerance, and national security. Israeli society has a sharp divide between the population engaging in the high-tech economy, and the poorer, often minority groups who live in communities geographically and socially removed from high-tech centers. In all, Israel's economy has grown quickly with an emphasis on developing cutting-edge high-tech sectors since its founding in 1948, and today is a technologically advanced innovative power in S&T.

RUSSIA

Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **Russia**'s 2020 absolute score is ranked 7 of 12 in 2020 (left); dropping to 9th by 2050 (right). The absolute scores are displayed in relation to each country's GDP, as larger economies clearly have an advantage.

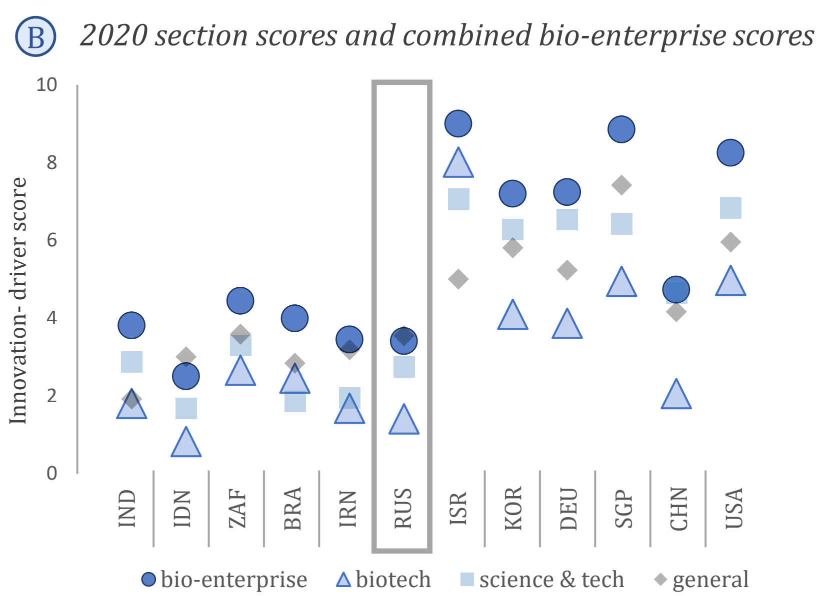
Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **Russia** is ranked 11 of 12. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

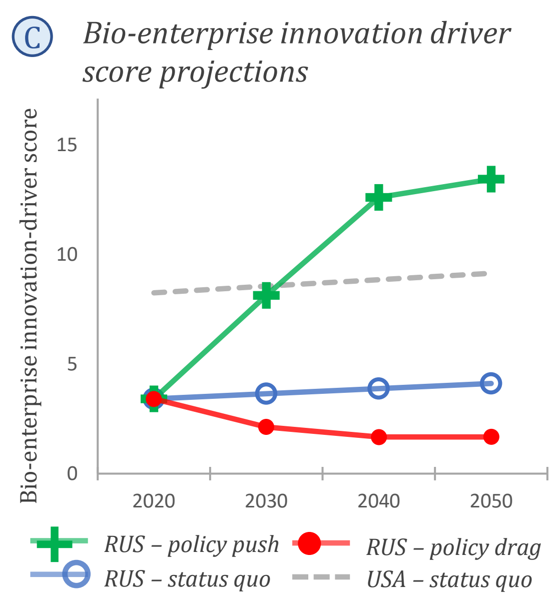
Bio-enterprise Capacity Scores



Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **Russia**'s capacity score by 2050. Under a policy-push scenario, it would likely remain ranked 9th. Under a policy-drag scenario, it could drop to 10th, behind South Africa, a much smaller economy.

Bio-enterprise Innovation-driver Scores





BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

RUSSIA

Bio-enterprise capacity 2020 – rank 7 of 12
Bio-enterprise innovation drivers 2020 – rank 11 of 12

As can be seen in the graph to the right, in 2020, Russia falls into the quadrant with both lower bio-enterprise capacity and low drivers of future innovation. Absent policy change, we project Russia, along with Indonesia, will likely remain in this quadrant in 2050.

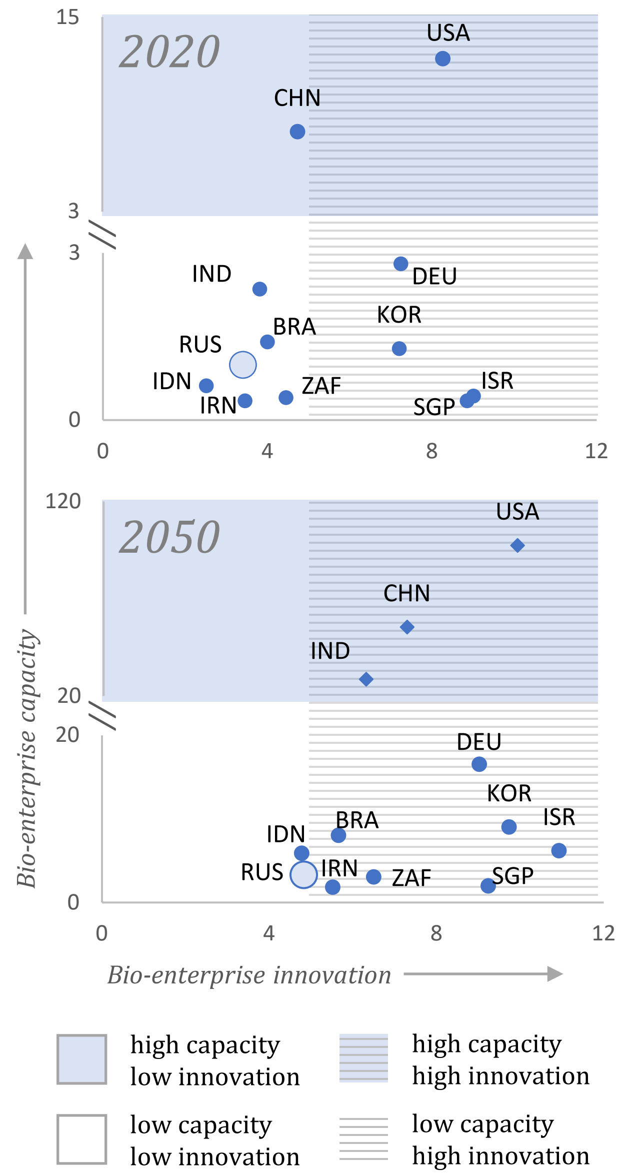
Capacity

Russia has not significantly pursued biotechnology as a national priority, which is reflected in Russia's bio-enterprise capacity score. If Russia maintains it current national policies toward biotech development, by 2050, it may be surpassed in bio-enterprise capacity by Indonesia and Israel. Even with an aggressive push to enact pro-biotech and S&T policies, it is likely that Russia will remain a relatively minor bio-enterprise by 2050.

Innovation Drivers

Russia currently scores among the lowest of our countries for innovation drivers. However, Russia does have the benefit of a previously high-performing university system and educated scientists, which could give Russia a base from which to move into more innovative biotech. Russia has proposed a series of policies that might help advance its biotech program. Given Russia's top-down governmental system, if these policy changes are implemented and set as a priority, a competitive, innovative bio-enterprise is conceivable in Russia by 2050.

Bio-enterprise capacity and innovation, 2020 and 2050. Russia.



Improvements that would push the bio-enterprise forward and indicators to watch:

- Russia stands out among our 12 countries in that at one time, it was an innovative, technologically adept nation, but has since stagnated in many S&T areas. This may give Russia greater ability to quickly advance its bio-enterprise than other BRIICS peers, which do not have the number of scientists, educational systems, or research infrastructure to lean on. In addition, Russia has outlined a series of policies that could allow it to significantly improve bio-enterprise innovation and capacity, including: increasing R&D spending to 2-5% of GDP, improving 15 universities to rank internationally in S&T, and growing tech transfer and competitive innovation programs based on merit. If Russia implements these policies, biotech and S&T could grow quickly. Some headway has been made, such as funding universities to attract leading scientists, R&D spending increase to >2% of GDP, increased publication and patents in biotech, investment in small competitive startups within biotech, and a national shift away from purchasing/importing new technologies toward in-country development and/or acquisition of biotech/high tech IP.

RUSSIA – biotech

biotech capacity	*rank 10 / 12 score 0.3 / 10*	*biotech drivers*	*rank 11 / 12 score 1.8 / 10*

Strengths
- *Well-designed national biotech strategy*
- *Biodiversity and natural resources*
- *Some high-quality higher education in the life sciences*

Weaknesses
- *Low presence of biotech companies and researchers*
- *Little involvement in agricultural or industrial biotechnologies*
- *Little involvement in international synthetic biology or biotech initiatives*

Biotech is not a major growth area in Russia. Publications, patents, and universities do not have a strong focus in biotech, and biotech outputs are not strong. Additionally, Russia does not participate in various international competitions, conferences, or communities related to biotech. However, *The Strategy for Innovative Development of Russia 2020* outlines targets and benchmarks for S&T growth, with biotech as one of the priorities of the strategy. Biotech funding in this policy is aimed at bioenergy, biopharma, agricultural and food biotech, and industrial biotech. Funding relies both on federal funds and foreign direct investment. Despite this policy, actual numbers of researchers in biotech appear to be dropping and business investment in R&D is decreasing,

Red Biotech – biomedical sciences
- *Pharma 2020* outlines policies and plans to expand capacity into a "world-class biopharma sector" with a focus on new vaccine and antibiotic R&D, as well as development of bioclusters focusing on biopharma R&D, commercialization, and tech transfer. With the intent to drive innovation, Russia has enacted policies that impose domestic requirements for biopharma R&D, rather than policies that strengthen local innovation capabilities. This may ultimately be damaging to biopharma innovation. For example, clinical trials for medicines must be conducted in Russia if the product is to be submitted for registration in Russia, hampering international investment and forcing biopharma developers to contend with a poor regulatory system, IP protection, tech transfer pipeline, and clinical studies environment in Russia. This may discourage investment and R&D in biopharma over the long term. Rates of clinical trials and trials of innovative pharma remain low, and R&D capabilities are still considered basic.

Green Biotech – agricultural biotechnologies
- *BIO 2020* outlines policies and goals to increase crop yields, but mechanisms to review GM products are lacking. Though some GM agricultural research is ongoing in Russia, no process currently exists to legally commercialize GM seeds. Russia could likely play an important role in the future of agriculture, given its abundant land resources, which will be increasingly arable as climate change progresses. If regulatory policy is updated to allow for agricultural biotechnology cultivation, Russia might become one of the major exporters of agricultural products within the next few decades. This would, however, require improved trade relationships internationally, an overhaul of current agricultural policy, and a prioritization of green biotech within the country.

White Biotech – industrial biotechnologies
- *BIO 2020* also outlines goals for biofuel development, but currently biofuels are a very small part of Russia's energy mix. Generous tax credits are available for R&D in this space, and a regulatory push toward joint university-industry patenting and commercialization is taking place. However, for the biofuel or other bio-industries to grow, issues with IP protections, industrial espionage, and a seeming lack of interest in biofuel usage and development must be overcome.

RUSSIA – science & technology

S&T capacity	*rank 6 / 12 score 1.1 / 10*	*S&T drivers*	*rank 8 / 12 score 3.2 / 10*

Strengths
- *High share of world researchers and concentration of researchers in-country*
- *High numbers of STEM graduates among peers*
- *Universities focusing on engineering and technology*
- *Emphasis on high tech and engineering in publications*

Weaknesses
- *Low national investment in R&D spending*
- *Few top international innovation clusters*
- *Little VC investment or availability*
- *Low patenting rate*

Despite Russia's technological prowess during the years of the Soviet Union, Russia performs unimpressively in measures of S&T today. The country still employs a high number of researchers, but numbers of STEM graduates, though high among middle-income peers, are far behind more technologically innovative nations. Few students who study abroad return to Russia to work. While some universities are ranked internationally, overall university performance is not high. Federal funding for R&D is low, VC funding for businesses is not widely available, and the burden of government regulation is high. Policies that could foster growth, such as IP protections and tech-transfer programs, are not strong. However, recent policies for both short- and long-term growth have been put into place, which aim to prioritize tech innovation in top universities, fund start ups and tech-transfer systems, increase federal funding of R&D, and support science and tech clusters. These policies carefully evaluate Russia's weaknesses and how it can effectively grow S&T capacity and innovation. Whether these policies will be funded and implemented is unknown. Prior success in S&T gives Russia a definitive leg up among its economic peers in developing a strong national S&T program. However, we have not seen evidence that these ambitious policies will receive the strong financial, social, and national support that they would require to succeed.

RUSSIA – general societal

societal capacity	*rank 5 / 12 score 1.1 / 10*	*societal drivers*	*rank 9 / 12 score 3.5 / 10*

Strengths
- *High levels of ICT adoption*
- *High rate of early science education*
- *General support for science as a job creator and national benefit*

Weaknesses
- *Poor economic and population growth rates*
- *Poor rule of law*

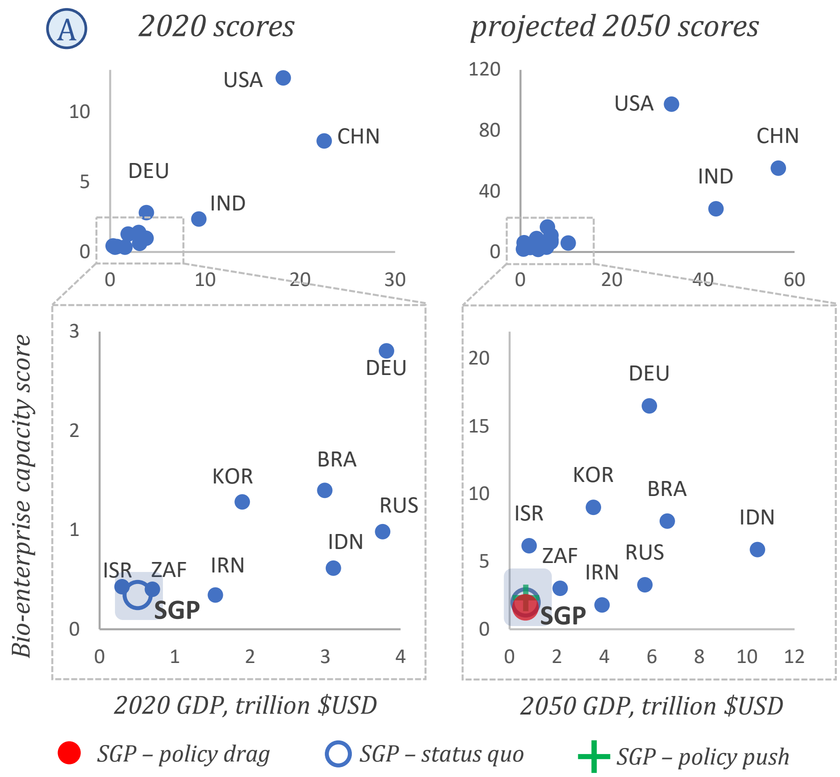
Russia has seen stalled economic growth in recent years. With an economy highly dependent on global oil and commodity prices, falling oil prices and sanctions have pushed Russia into a recession. Inertia has carried forward some technological and academic excellence in Russia, but the various social and governmental hurdles to continued success suggest future innovation and advancement may be difficult. A low share of enterprises focus on global competitiveness – pursuing innovative strategies does not appear to be a common business strategy within Russian business culture. Instead, new technology is often imported as opposed to acquiring IP or developing IP in-country. Russia's poor rule of law and political stability may hamper future high-tech growth. However, Russia does maintain some quality institutions of research and learning, as well as strong early education programs, that could be leveraged to drive economic and social growth. The policies to pursue technological growth are in place and detail ambitious plans to achieve stable, innovative growth both broadly and in S&T. However, funding, political will, and action must back these policies in order to see them through successfully.

SINGAPORE

Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **Singapore**'s 2020 absolute score is ranked 11 of 12 in both 2020 (left) and 2050 (right). The absolute scores are displayed in relation to each country's GDP, as economies far larger than Singapore clearly have an advantage on this absolute measure.

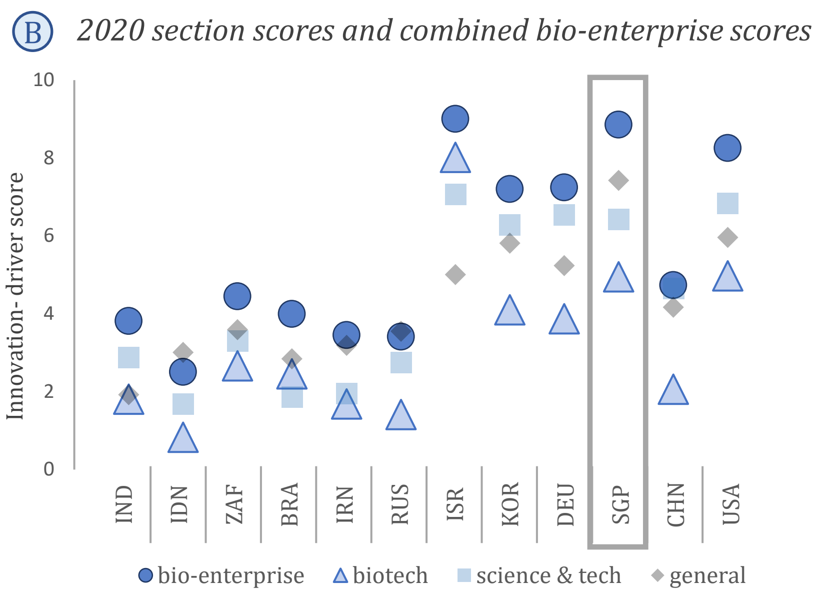
Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **Singapore** is ranked 2 of 12, ahead of the US but behind Israel. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

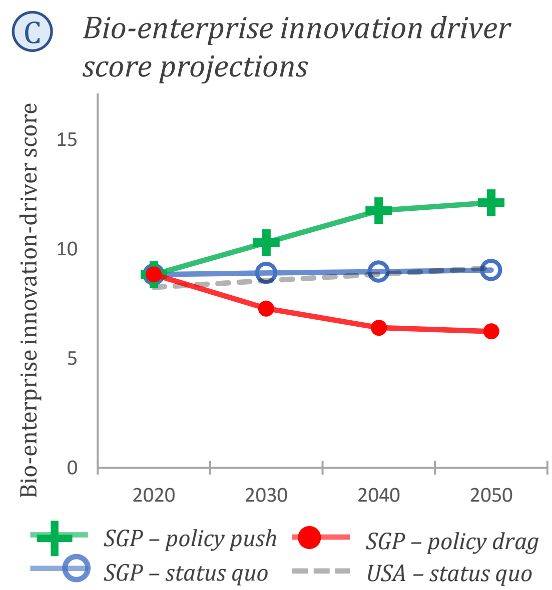
Bio-enterprise Capacity Scores



Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **Singapore**'s capacity score by 2050. Given **Singapore**'s already high innovation- driver score, even under the policy-push scenario, it would likely remain 11 out of 12, behind South Africa. Under a policy drag scenario, it might drop to last, behind far larger Iran.

Bio-enterprise Innovation-driver Scores





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SINGAPORE

Bio-enterprise capacity 2020 – rank 11 of 12
Bio-enterprise innovation drivers 2020 – rank 2 of 12

As can be seen in the graph to the right, in 2020, Singapore falls into the quadrant with lower bio-enterprise capacity but high drivers of future innovation. Singapore will remain in this quadrant in 2050.

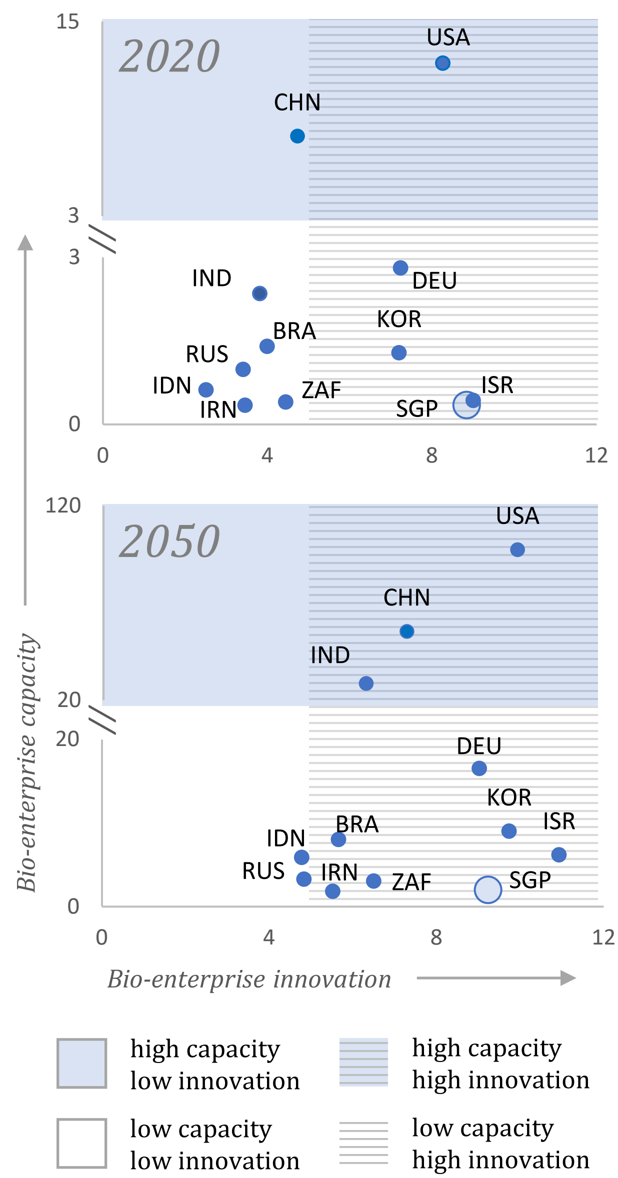
Capacity

Because of the Singapore's small economy and landmass, total bio-enterprise capacity is limited. Regardless of policy push or pull, bio-enterprise capacity is unlikely to dramatically change on an absolute scale.

Innovation Drivers

Singapore ranks second behind Israel in bio-enterprise innovation. Since independence, Singapore has fostered an incredibly successful environment for technological and scientific growth and has recently expanded that into a state-of-the-art biotech program. Singapore has some of the most advanced and supportive policies in place to grow its S&T and biotech sectors, with substantial biotech and research production. Policy is highly integrated. Policy driving biotech innovation is supported by policy on early sciences education, higher education in STEM, investment in biotech R&D, policies to promote biotech start-ups, and coordination of foreign and domestic R&D firms and academic biotech research. This is supported by an economic system designed to promote innovation and drive fields that will grow Singapore's economy, including biotech. This results-driven, top-down approach has served Singapore well, and has resulted in one of the most competitive and innovative bio-enterprises globally. Singapore is likely to continue to promote pro-biotech and pro-innovation policies. The major limiter of improving innovative capacity is still the size of the country. With a limited number of workers and GDP, Singapore may have to prioritize some growth areas over others and may not achieve the innovative capacity of a larger, more technologically diverse nation.

Bio-enterprise capacity and innovation, 2020 and 2050. Singapore.



Improvements that would push the bio-enterprise forward and indicators to watch:

- Singapore has been very successful in developing a state-of-the-art S&T environment, attracting foreign R&D and investment, and international talent and collaborations. Next steps are likely to involve improving internal innovation through improving critical thinking in early education and building research capacity.
- Many of Singapore's collaborations, especially academically, are west-facing. However, Singapore acts as a hub for advanced R&D among Southeast Asian researchers as well. Because Singapore is highly technologically advanced, watching where Singapore collaborates, or which foreign powers are investing in Singapore, may be as important as watching Singapore's own development.

SINGAPORE – biotech

biotech capacity	*rank 11 / 12 score 0.2 / 10*	*biotech drivers*	*rank 2 / 12 score 6.3 / 10*

Strengths
- *Clear, well developed national biotech strategy*
- *Highly collaborative in publications, business, and R&D*
- *High participation in biotech competitions*
- *Prolific biofuel industry*

Weaknesses
- *Low agricultural biotech activity*
- *Low participation in GenBank*
- *No strong emphasis on biotech in patents or publications*

Singapore excels in biotech performance in most sectors, however, continues to rank near last in any measures of capacity. Despite this, Singapore is still ranked 5 in absolute measure of collaboration on life sciences publications, which is remarkable given its small size.

Through various economic plans focused on transitioning to a knowledge-based economy, Singapore has created one of the most commerce and innovation friendly economies in the world, with many of these policies focusing on bringing in foreign investment in biotech. STEM education and development was originally pushed in order to feed Singapore's large high-tech manufacturing sector, but an emphasis on biomedical and biotech education was incorporated due to biotech's growth potential. Today, Singapore's Bio-Medical Research Council promotes R&D and develops human capital in the life sciences. Singapore's main biotech clusters host domestic and international firms, biotech research institutions, and are now integrating governmental R&D bodies. Singapore now has a cutting-edge biotech sector.

Red Biotech – biomedical sciences
- Singapore has an extremely well-developed biopharma and biomedical infrastructure, attracting significant private investment in biomedical manufacturing and R&D. The Biomedical Sciences Industry Partnership Office matches companies' R&D needs to academic and public research institutions, going beyond the average tech-transfer policies to encourage private-public partnerships. Singapore has also made directed efforts to attract biopharma development, and consequently is now manufacturing biopharma and innovative medicines for a global market. Other programs focus on attracting talent in biomedicine through competitive salaries, awards, and grants, leading to cutting-edge translational research in medical biotech. Singapore also supports a world-leading clinical trial research environment. Singapore excels in all metrics of biopharma competitiveness, including IP rights and protections, tech transfer policies, financing and reimbursement policies, and others.

Green Biotech – agricultural biotechnologies
- Singapore imports 90% of its food supply and has little investment in agricultural biotech cultivation. However, it has established six agricultural technical parks to promote agricultural biotech research, recognizing the importance of this technological development for the future.

White Biotech – industrial biotechnologies
- Singapore has a long history of industrial biotech and biofuel development. Many of these policies today center around the development of clean and environmental technologies.

SINGAPORE – science & technology

S&T capacity — *rank 8 / 12* — *score 0.4 / 10*

S&T drivers — *rank 1 / 12* — *score 7.5 / 10*

Strengths
- *High level of higher education R&D funding and STEM graduates*
- *Government policy is highly responsive to the changing needs of S&T*
- *IP and other business-related policies are designed to facilitate growth and investment*

Weaknesses
- *Low level of patenting and publications in high tech sectors relative to GDP*
- *Business financed R&D is mostly driven by large firms, suggesting a still developing small and medium enterprise sector in S&T*
- *Small university system*

Singapore, in the space of a few decades, brought itself up from a small country with few natural resources to the wealthiest country in its region, largely by focusing on S&T as a means to drive economic growth. Singapore adopted a cluster-based approach to develop its research ecosystem, involving leveraging foreign multinationals to promote domestic innovation. The government, in turn, invested in state-of-the-art facilities and equipment and offered attractive salaries to world-class scientists and engineers. To support this effort, vigorous educational and higher educational policies were funded, several national research institutions were developed, and modern tech transfer and business enterprise offices were developed. The public R&D budget increased ten-fold from 1990 to today. This umbrella approach allowed Singapore to learn high tech development from established companies, encourage investment, and in parallel develop its own technical and human resources to support an ongoing innovation effort. Today, Singapore has one of the most diverse R&D ecosystems, with a 30% foreign research community that fosters academic collaborations with top ranking international research institutes (MIT, Cambridge, etc.). In addition to bringing in international talent and collaborations, Singapore also actively encourages innovative partnerships internally between disparate research fields and professions to encourage innovation and technological breakthroughs.

SINGAPORE – general societal

societal capacity — *rank 12 / 12* — *score 0.1 / 10*

societal drivers — *rank 1 / 12* — *score 6.5 / 10*

Strengths
- *Highest GDP per capita*
- *High ratio of working to dependent population*
- *High scores in global competitiveness and rule of law*
- *High rate of early science education*

Weaknesses
- *Low relative rate of government spending on education*
- *Low number of top universities relative to GDP*
- *Low projected GDP growth*

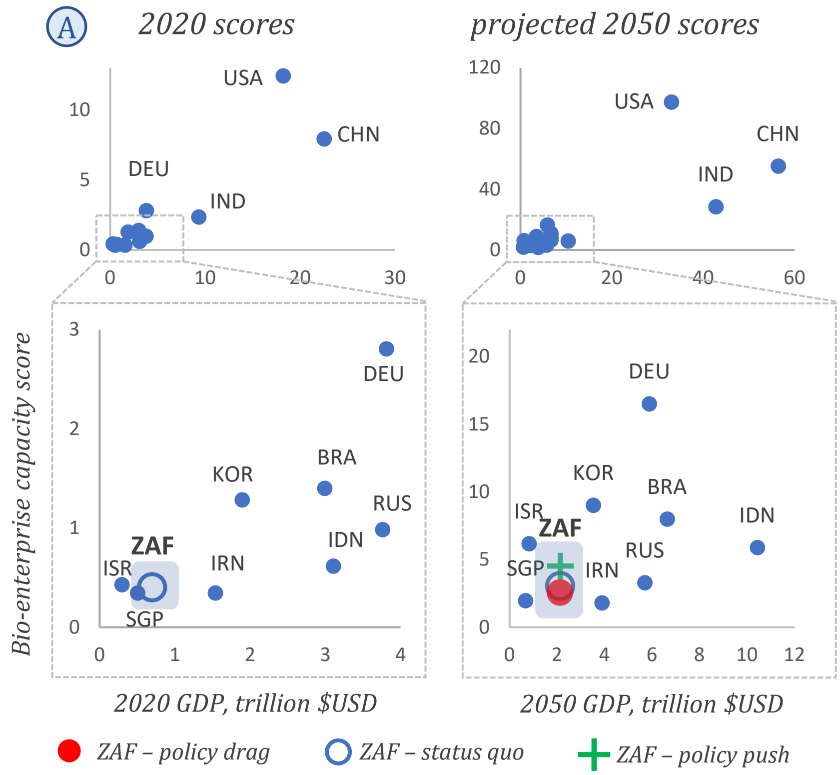
Singapore is a small, highly educated, and wealthy country. Expected GDP growth is low, at 0.94%, but is still projected to have the highest GDP/capita of the 12 countries in 2050. Though there are few by count, universities and research centers in Singapore are internationally regarded for quality of education and research. Singapore outperforms both high income countries and East Asian/Pacific country averages in most measures of competitiveness, performing well in government regulation, legal frameworks, infrastructure, and other societal measures. Since gaining independence in the 1960s, Singapore has become a highly developed and successful free-market economy. Much of this growth has centered around S&T as a means to drive the economy. Singapore enjoys a world class business and finance environment, political stability, and advanced ICT adoption. Societal indicators suggest a high standard of living, low poverty, and good health and educational outcomes – Singapore does, however, lack in the individual freedoms, privacy, and basic legal rights seen in many other advanced economies.

SOUTH AFRICA

Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **South Africa**'s 2020 absolute score is ranked 10 of 12 in both 2020 (left) and 2050 (right). The absolute scores are displayed in relation to each country's GDP, as larger economies clearly have an advantage.

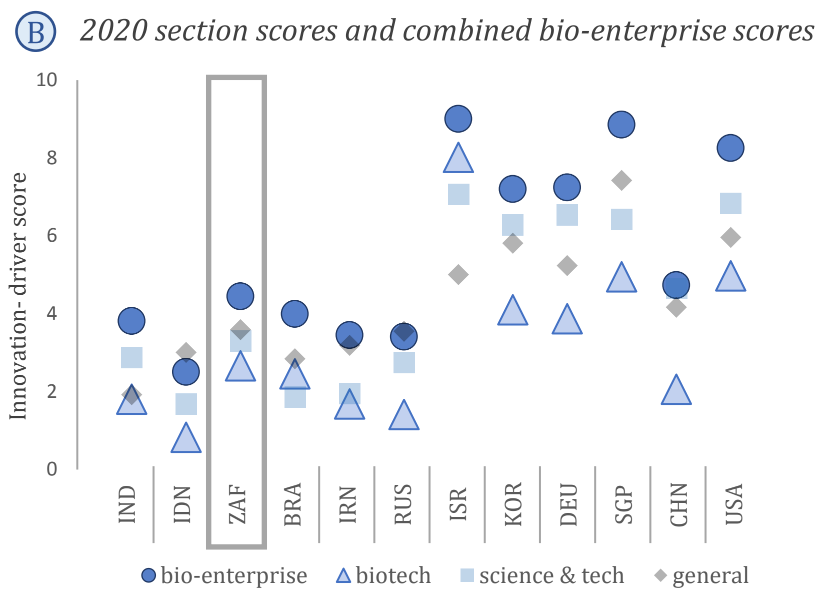
Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **South Africa** is ranked 7 of 12, one of the leaders among middle-income countries. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

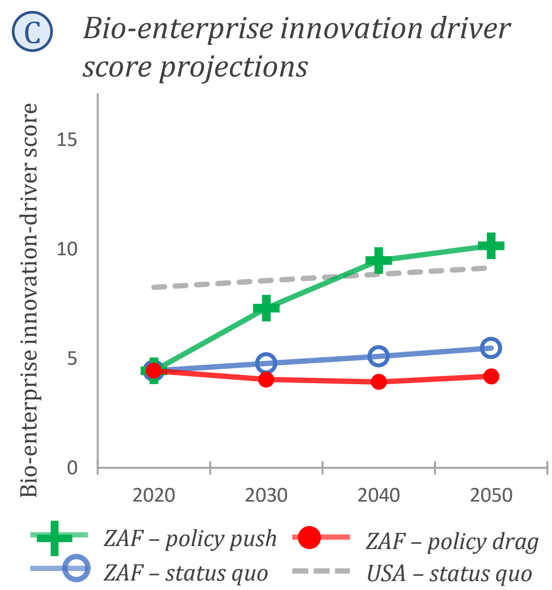
Bio-enterprise Capacity Scores



Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **South Africa**'s capacity score by 2050. Under a policy push scenario, it could advance to 9th, ahead of Russia, a far larger economy. Under a policy-drag scenario, its capacity score would likely remain at 10 of 12.

Bio-enterprise Innovation-driver Scores





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SOUTH AFRICA

Bio-enterprise capacity 2020 – rank 10of 12
Bio-enterprise innovation drivers 2020 – rank 7 of 12

As can be seen in the graph to the right, in 2020, South Africa falls into the quadrant with both lower bio-enterprise capacity and low innovation-driver scores. By 2050, South Africa might transition to an innovation-driver score we consider high by 2020 standards.

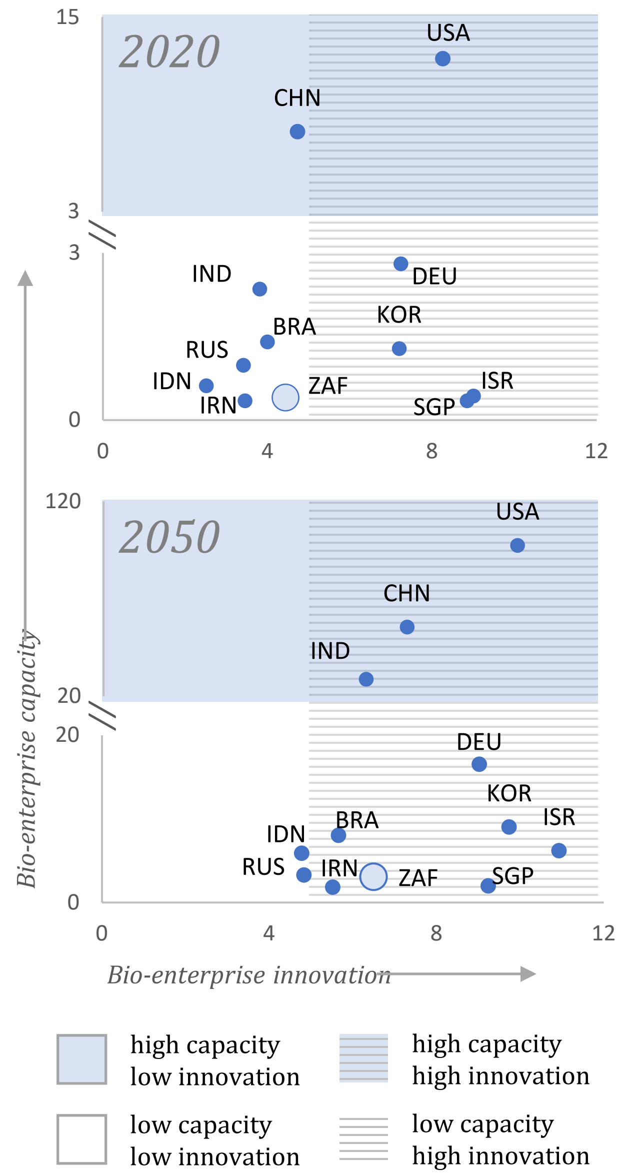
Capacity

South Africa is a growing economy with promise in the bio-enterprise. Limitations on growth include the size of the economy itself, as well as the current bio-enterprise capacity and innovation drivers. Looking forward to 2050, policy changes could improve biotech capacity, though South Africa is unlikely to catch up to such competitors as Brazil or South Korea.

Innovation Drivers

South Africa is second to only China in innovation among our middle-income economies. South Africa has made concerted strides toward developing S&T, biotech, and other high-tech fields, giving it a promising starting point to push increased innovation in the future. South Africa has unequally distributed education, academic centers, and industry clusters, making country-wide improvement in innovation difficult to achieve. But, innovation in these centers is likely to continue improving. If policies to address both systemic and specific hurdles to biotech development are put into place and enacted effectively, South Africa has the potential to be a full participator in the international bio-enterprise but is unlikely to be a country pushing the cutting edge on innovative science by 2050. Whether the promise of well-developed South African biotech is achieved will depend largely on how aggressively national funding and policy drives to improve societal, educational, and R&D efforts in this space.

Bio-enterprise h capacity and innovation, 2020 and 2050. South Africa.



Improvements that would push the bio-enterprise forward and indicators to watch:

- Funding for R&D is currently 0.8% of GDP. Increasing to >2% would signal a conscious push toward technological development in-country and is likely required before other drivers of innovation can be improved.
- South Africa is a leader in Sub-Saharan Africa for S&T and biotech, especially biopharma. Future policy will dictate whether the national goal is to continue this leadership and work to develop neighboring nations in the region, or, to become competitive in international biotech and S&T spaces.
- South Africa is home to some excellent research universities and hubs for innovation, but these are not distributed throughout the country or major attractors of international talent. Growing their university capacity and quality would be a major sign of growth. Attracting foreign scientists and increasing international R&D collaborations would signal a more innovative and high-tech research space.
- Improvements in policy toward businesses and IP in biotech are already underway. Improving the clinical trial and biopharma environment would be an obvious next step in encouraging growth in this field. Developing their own IP in biomedicine or agricultural biotech would signal a maturing biotech R&D environment.

SOUTH AFRICA – biotech

biotech capacity	*rank 9 / 12 score 0.3 / 10*	*biotech drivers*	*rank 7 / 12 score 3.2 / 10*

Strengths
- *Good university performance in life sciences and biotechnology*
- *Well developed agricultural biotech program*
- *High concentration on biotech in publications*
- *Developing company landscape for biotech*

Weaknesses
- *Relatively low biotech patenting intensity*
- *Lack of involvement in international collaborations and competitions in biotech*
- *National strategy addresses S&T development but does not prioritize biotech*

South Africa is a leader among its economic peers in biotech capabilities. Though overall publications and university performance are middling, there is a definite emphasis on life sciences and biotechnology in both. This same emphasis is not seen in patenting, though this is likely due to as-yet-underdeveloped systems for IP creation, tech transfer, and support for biotech startups. South Africa does have successful biotech service companies and has attracted international attention via some centers for biotech innovation. However, these are still small, developing clusters, and will require active work via policies and funding to grow their capacity. South Africa lags on international participation in many conferences, competitions, and collaborative efforts, but does participate in genetics databases and purchasing from genetics tools suppliers. Overall, South Africa is positioning itself to excel in the biotech space, as well as other S&T spaces, and has a lead in biotech development and innovation compared to other emerging economies. With an active, strong social and political will to drive biotech innovation, South Africa could excel in this space. However, past policies to enable growth in the bioeconomy and S&T, while ambitious and useful for outlining national priorities, did not meet their stated goals.

Red Biotech – biomedical sciences
- South Africa hosts the highest number of clinical trials in Africa as well as a large biopharma market. Many international manufacturers are present in South Africa for manufacturing and R&D, though little of the innovative R&D is performed in-country. Major tax breaks exist for pharma and biopharma development. In this sense, South Africa is ahead of many of its economic peers in biopharma development and innovation, however, it still lags far behind other new biopharma entrants, such as Singapore. The overall biopharma R&D capacity is limited, with only a handful of dedicated biopharma companies in place, a difficult system to navigate clinical trials, IP, and commercialization of products. The regulatory environment does support a modern tech transfer framework, but slow authorization processes and less than ideal IP protections limit the growth that might result from the tech transfer. Policies regarding market and regulatory burdens are currently being updated and will hopefully allow for a better environment for biomedical and biopharma growth in the future. The overall biomedical environment is satisfactory, but not excellent.

Green Biotech – agricultural biotechnologies
- South Africa has widely adopted biotech crops and is one of the largest GM crop producers in the world. Social acceptance for green biotech is high, and approvals for new biotech crops are ongoing. South Africa has a clear regulatory framework for agricultural biotech. However, most crops have been developed abroad; only recently have seeds developed in South Africa moved through the commercialization and cultivation pipeline.

White Biotech – industrial biotechnologies
- Interest in biofuels are increasing, though South Africa is not a large producer today. A push toward other white biotech products is ongoing. For example, the BioPad regional innovation center helps startups in industrial biotech, supports public-private cooperation, and supports white biotech development, while the Microbial Technology Platform supports discovery and use of microorganisms and enzymes.

SOUTH AFRICA – science & technology

S&T capacity	*rank 9 / 12 score 0.4 / 10*	*S&T drivers*	*rank 9 / 12 score 2.9 / 10*

Strengths
- *Good high-tech publication rate*
- *High ranking universities in engineering and computer sciences relative to economic group*
- *Continental leader in S&T*

Weaknesses
- *Low overall expenditure on R&D*
- *Low concentration of STEM graduates and researchers*
- *Few international innovation clusters*

South Africa is near the top of its economic peer group in terms of S&T university performance, funding of higher education, and the focus of publications on high-tech and STEM subjects. However, South Africa does not excel on other important aspects such as VC funding, ease of tech transfer, or IP policy. Though South Africa does collaborate internationally on developmental measures, international collaboration in S&T publications and innovation clusters is low. A few exceptions - such as the Cape Heath tech park, a world-class facility for pharma, research, clinical trials, and academics - are notable and signify promise moving forward. Current policies actively promote increased STEM higher education, which ideally will open up a major bottleneck: a lack of broad skills foundation and education in the workforce. Additional steps have been taken to coordinate national innovation systems and improve public policy strategies. While some improvements in publishing and STEM graduate rates have been made, overall growth in S&T seems to have slowed in recent years. Programs to build capacity in the private sector with improved VC funding, tech transfer, and IP regulation have recently been put in place, but it is not yet known whether these efforts will bear fruit. Thus far, improvements have been made, but outcomes have not met the stated goals of these policies. More aggressive funding and action on the part of South Africa may be needed to overcome the many hurdles to prosperous S&T development. While these goals may be achievable, movement toward achieving the goals is much slower than the timelines stated in policy documents.

SOUTH AFRICA – general societal

societal capacity	*rank 10 / 12 score 0.3 / 10*	*societal drivers*	*rank 6 / 12 score 4.4 / 10*

Strengths
- *Strong government spending on education*
- *Excellent university performance among economic group*
- *Strong projected economic growth*

Weaknesses
- *Low presence of early science education*
- *Poor ICT adoption*
- *Poor rule of law when compared to higher income countries*

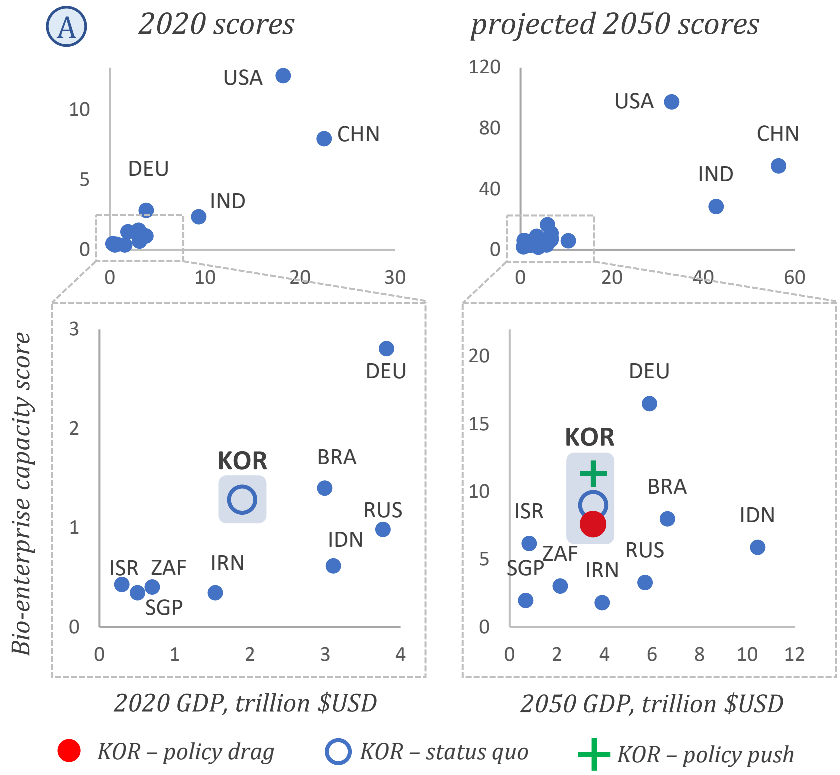
South Africa is projected to have promising economic growth through 2050, but lower than average growth in GDP/capita. The country has shifted away from a resource-based economy toward a knowledge-based economy, but growth is weak by emerging-market standards. The number of high ranked universities is higher in South Africa than among its economic peers. Though rule of law is not a strength by absolute measures, South Africa does exhibit more stable governance and rule of law than its economic peers. Overall, South Africa is an important emerging market with well-developed financial, legal, energy, and transport sectors and a stock exchange that is among the 20 largest in the world. Still, the country is heavily stratified between the wealthy and poor, with advanced education and research efforts largely restricted to wealthy cities engaging a small segment of the population. Societal policy aims to address these disparities in access and outcome, but until then, national success is restricted by high crime, disease, unemployment, poverty, and inequality rates. Still, South Africa is an important hub for development, education, and international relations within the sub-Saharan region.

SOUTH KOREA

Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **South Korea**'s 2020 absolute score is ranked 6 of 12 in 2020 (left); increasing to 5th, ahead of Brazil, by 2050 (right). The absolute scores are displayed in relation to each country's GDP, as larger economies clearly have an advantage.

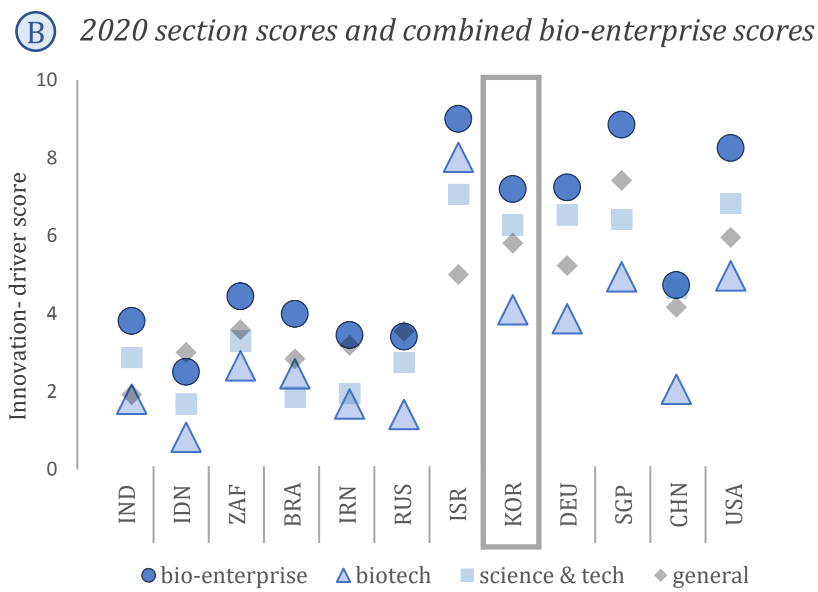
Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **South Korea** is ranked 5 of 12. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

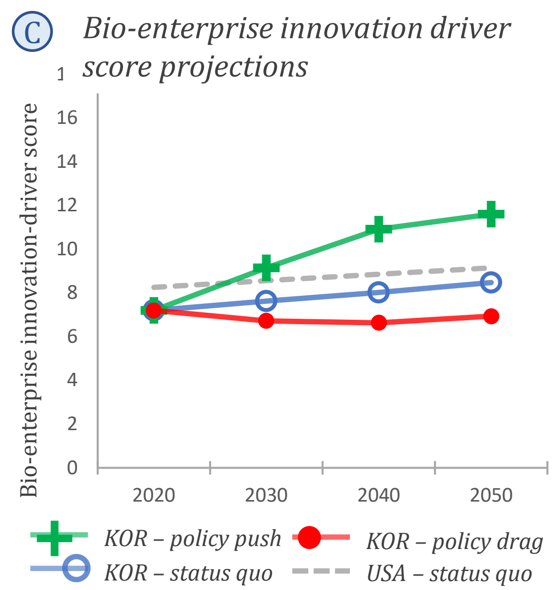
Bio-enterprise Capacity Scores



Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **South Korea**'s capacity score by 2050. Under a policy-push scenario, it would remain 5 of 12, still far behind 4th place Germany. Under a policy-drag scenario it could drop to 6 of 12, behind Brazil.

Bio-enterprise Innovation-driver Scores





BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

SOUTH KOREA

Bio-enterprise capacity 2020 – rank 6 of 12
Bio-enterprise innovation drivers 2020 – rank 5 of 12

As can be seen in the graph to the right, in 2020, South Korea falls into the quadrant with lower bio-enterprise capacity but high drivers of future innovation. South Korea is projected to remain in this quadrant in 2050.

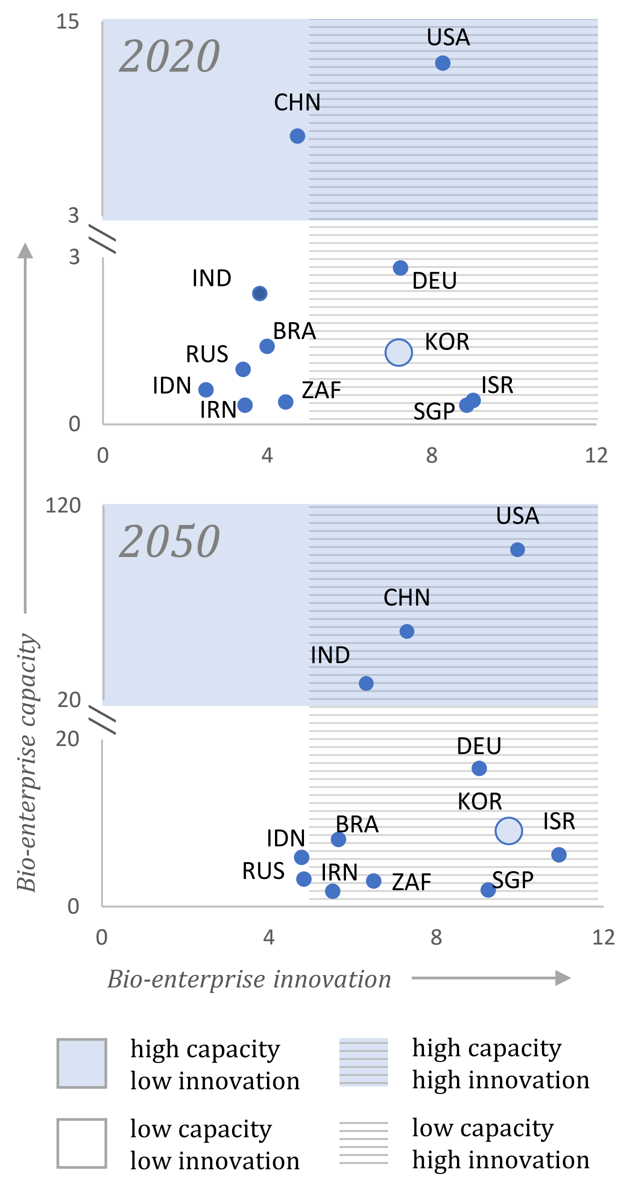
Capacity

South Korea has a strong supportive structure for S&T development and has made impressive strides in creating a high tech, high-income society in the last 50 years. With policies supporting bio-enterprise growth, Korea could see significant increases in capacity into 2050, moving closer to the capacity of Germany. However, capacity growth in Korea will depend on its ability to drive innovation, as that is a particular hurdle in Korea's bio-enterprise today.

Innovation Drivers

South Korea employs top-down policy measures to encourage rapid S&T growth and, more recently, growth in biotechnologies. Using an "umbrella" approach to S&T policy, in which all aspects of a sector's growth are addressed in concert, Korea has been able to grow and excel in S&T and biotech rapidly. STEM education, university funding, R&D excellence, infrastructure, industry-academic collaborations, etc. have been targeted for improvement in tandem. Korea has become a wealthy, innovative nation that is pushing into high-tech research in the biotech space and is likely to continue this drive. While its bio-enterprise is small today, it has been targeted for growth and is likely to gain global recognition, especially in biomedicine and industrial biotechnologies.

Bio-enterprise capacity and innovation, 2020 and 2050. Singapore.



Improvements that would push the bio-enterprise forward and indicators to watch:

- Korea already has one of the highest R&D funding rates, at 4.6% of GDP.
- Much of Korea's growth has been in partnership with China. As Korea has become more capable and specialized, China has become more of a competitor. How this relationship develops could affect the international partnerships that Korea makes in the future.
- Isolationism inherent in Korean business and research is a barrier to innovation. Despite aiming to attract foreign talent, bureaucratic and language barriers are difficult for foreign scientists to overcome, and a societal push back against foreigners makes Korea a less attractive place for foreign talent. Similarly, lack of international collaboration in publications and research and a lack of openness to multinational companies and foreign governments has stifled growth and innovation in Korea.
- Korea is ranked low on acceptance of risk in entrepreneurship and business. Building capacity for critical thinking and risk in students, and growing a dwindling STEM student pool, might enhance growth moving forward.

SOUTH KOREA – biotech

biotech capacity	*rank 6 / 12 score 0.7 / 10*	*biotech drivers*	*rank 4 / 12 score 5.0 / 10*

Strengths
- *Presence of a national biotech strategy*
- *Top performing biology universities*
- *Competitive in biopharma sector*
- *High attendance at biotech and synbio conferences*
- *Strong use of biotech genetics tools*

Weaknesses
- *Low biotech publication rate, and low citation rate on papers*
- *Biotech research and companies are still a minority of the S&T sector*
- *Low biodiversity*
- *Low international collaboration*

As part of a Creative Economy Initiative and other policies, South Korea has renewed its biotech strategy, and currently has a relatively small but growing specialization in biotech. Recently, Korea's Ministry of Science and ICT finalized the "2019 Biotechnology Promotion Plan," which gives $2.6B USD in funding to biotech R&D. Biotech R&D is currently 2.6% of overall R&D spending. Each ministry has a biotech goal (Ministry of Health promotes biomedicine and clinical trials, Ministry of Environment promotes biodiversity and clean biotech, etc.), creating a holistic governmental approach to improving biotech capacity. Policies integrate research programs in an umbrella fashion, coordinating major research institutes (The Korean Research Institute of Bioscience and Biotechnology – KRIBB – is one of the largest) and biotech agencies (Korean Biotechnology Industry Organization – BIO – aims to grow and coordinate tech transfer and bioindustry efforts in Korea). Government funding and coordination set sector growth goals and societal initiatives to support biotech. This strategy has been successful, but more recent policy aims to support research from a more bottom-up approach, allowing for more freedom of development and innovation in the industry. Despite biotech being a relatively small sector in Korea's economy, the prioritization of biotech as a growth sector can be seen in the obvious organizational efforts and policy push to develop it.

Red Biotech – biomedical sciences
- The Korean biopharmaceutical industry is growing rapidly, with biopharmaceuticals representing about 10% of total pharma products. Biopharma development is pushed through the "Pharma 2020 Vision," which allocates about $9B USD to build Korea's drug development structure, train new researchers, and support the tech transfer and commercialization of public research. Korea also hosts a competitive clinical trial environment; the Ministry of Food and Drug Safety overseeing trials is highly regarded internationally and has been praised by the US FDA. In biomedical R&D, Korea excels in stem cell research and is pushing initiatives in neurobiology, cancer research, and other biomedical fields.

Green Biotech – agricultural biotechnologies
- Agricultural biotech cultivation is limited in Korea, partially because of high levels of mistrust of GM products. As of 2017, the country committed to end the promotion of GM crops and shut down its GM crop development project. Significant research is still being done, however. Whether GM cultivation or research will continue in Korea is unknown.

White Biotech – industrial biotechnologies
- Korea has joined the European Research Area in an effort to develop next generation biofuels, working with counterparts in Germany and Austria. Supportive funding as well as new requirements for biodiesel blends are likely to drive this industry forward in Korea. Other efforts in industrial biotech include R&D in industrial enzymes, bio-refining technologies, bioplastics, and engineered microorganisms.

SOUTH KOREA – science & technology

S&T capacity	*rank 4 / 12 score 1.5 / 10*	*S&T drivers*	*rank 5 / 12 score 6.0 / 10*

Strengths
- *Strong R&D funding as a share of GDP*
- *High rate of patenting*
- *High performing universities in engineering, tech, and computer sciences*
- *Large concentration of researchers*

Weaknesses
- *Few world-class universities*
- *Inefficient use of R&D*
- *Barriers to foreign investment and low international collaboration*

At 4.6% of GDP, South Korea's R&D investment is the highest among our 12 countries – Korea aims to raise investment to 5% of GDP in coming years. Korea performs well in most business and IP indices, with strong patent rights and regulations and few barrier to tech transfer. Korea, through a strong educational and academic system, performs well in STEM categories and has prioritized STEM research as an area of growth. Korea has accelerated in publication and patent counts, though the quality of publications is still below that of high-income peer countries. Korea has moved to encourage freedom and innovation in S&T research, with improved salaries for professors and funding to attract foreign researchers. However, the Korean language requirement for grant applications, the insular nature of funding approvals in Korea, and a historical international distrust of Korean science has been a barrier to success in this area. Various policies aim to improve higher education and research in S&T to advance technological capacity to a more innovative and internationally competitive level. Supportive policies aim to increase the number of STEM students, as the population of STEM students is in decline. Pro-innovation policies are pushing for increased tech transfer, startups, and international collaboration, which have remained behind peer averages in Korea.

SOUTH KOREA – general societal

societal capacity	*rank 8 / 12 score 0.7/ 10*	*societal drivers*	*rank 4 / 12 score 5.9 / 10*

Strengths
- *Strong scoring in rule of law*
- *Advanced ICT adoption – top ranked globally*
- *Strong educational and university system*
- *Very low poverty rates*

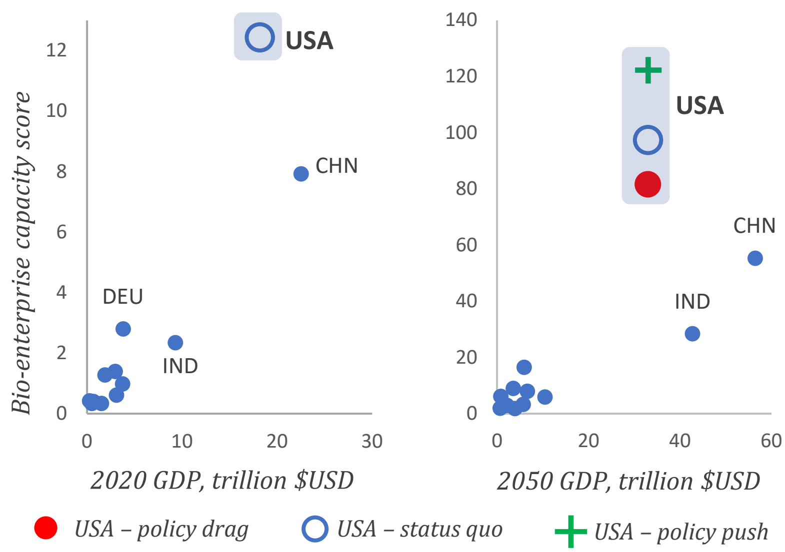
Weaknesses
- *Slowing economic growth rate*
- *Aging population*

South Korea is a modern, high tech country with high quality education and university systems. Korea performs very well in global competitiveness, ranking first in macroeconomic stability, and near the top in health, ICT adoption and infrastructure. Since the 1950s, Korea has seen rapid economic growth, moving toward a modern high-tech economy and adopting a democratic constitution in 1987. Much of this growth was achieved through governmental policy and cooperation with chaebols, large and powerful family-owned companies, which drove growth in tech and business sectors (e.g. Hyundai, Samsung, etc.). Korea excels in knowledge and tech outputs, human capital and research, and an advanced infrastructure. Currently, the country is moving from a top-down strategy in development to a more innovative and open market style, which has challenged the political and cultural norms for the country. Korea is an ethnically homogenous culture with low acceptance of outsiders, especially in corporate culture, which has created barriers to foreign investment and collaborations with foreign research institutes and multinational companies. Additionally, a societal aversion to risk and entrepreneurship has hindered innovation, though new policies aim to encourage critical thinking and improvement in this area. Korea's rapid growth has had a societal cost, in that workers and students feel high levels of stress starting from a young age, and non-workers in society are isolated and marginalized. Overall, however, Korea has driven impressive growth economically and societally, and is continuing to push into more advanced tech and S&T sectors.

UNITED STATES

Bio-enterprise Capacity Scores

Ⓐ 2020 scores   projected 2050 scores



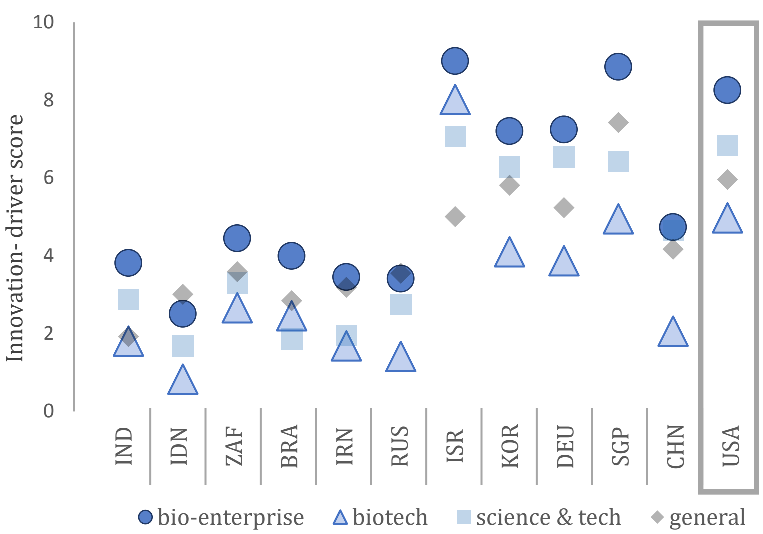
Panel A displays our combined **bio-enterprise capacity score**, an *absolute* measure calculated from 30 indicators such as numbers of patents, scientists, top universities, dollars spent on R&D, etc. **The United States'** 2020 absolute score is ranked first of 12 in both 2020 (left) and 2050 (right). The absolute scores are displayed in relation to each country's GDP, as large countries such as China, the US, and India clearly have an advantage.

Panel B displays our combined **bio-enterprise innovation-driver score**, an *intensity* measure. Each of the 53 indicators in this score are either a measure of quality that does not depend on country size or are absolute measures scaled to GDP. By this measure, **the US** is ranked 3 of 12, behind Israel and Singapore, both of which are small, biotech intensive countries. Also shown are separate subtotal scores for those indicators directly related to biotechnology, the larger science and tech enterprise, and general societal measures.

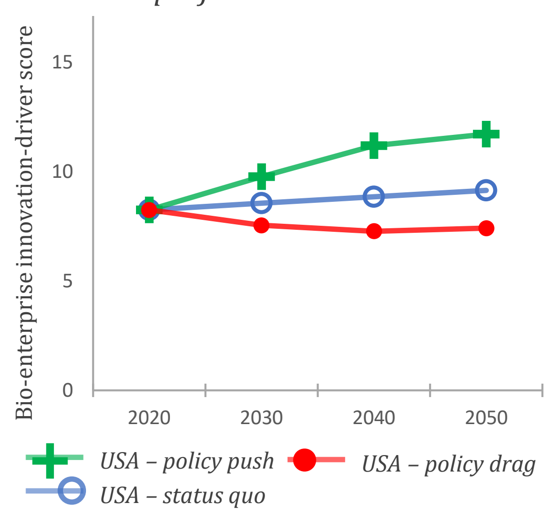
Panel C displays how the innovation-driver score may change through time under *status quo* conditions (blue), *policy push,* i.e., aggressive and sustained policy intervention (green), and *policy drag,* i.e., policy inattention (red). The right-hand graph in Panel A shows the effect of these policy scenarios on **the US**'s capacity score by 2050. Under a policy-push scenario, the US could substantially increase its lead over 2nd place China. Under a policy-drag scenario, the US would still remain in first place compared to China's status quo. However, as shown in the summary for China, China's capacity score under a policy-push scenario might exceed the US status-quo scenario.

Bio-enterprise Innovation-driver Scores

Ⓑ 2020 section scores and combined bio-enterprise scores



Ⓒ Bio-enterprise innovation driver score projections



BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

UNITED STATES

Bio-enterprise capacity 2020 – rank 1 of 12
Bio-enterprise innovation drivers 2020 – rank 3 of 12

As can be seen in the graph to the right, in 2020, the United States is the only country that falls into the quadrant with both high bio-enterprise capacity and high drivers of future innovation. It remains in this quadrant in 2050, joined by China and India.

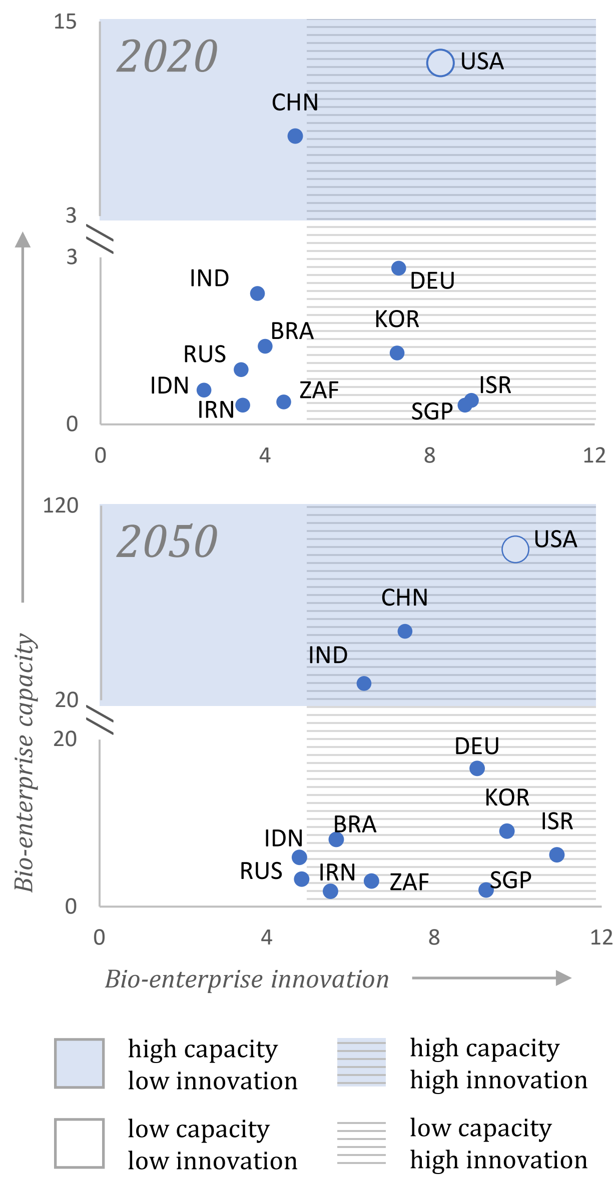
Capacity

The US is the largest bio-enterprise globally and is renowned for its S&T and biotech power. On most drivers of innovation and output measures, the US outpaces other nations on an absolute scale. Looking to 2050, the US is expected to remain first in bio-enterprise capacity. If the US were to push bio-enterprise growth as a national priority, capacity would grow significantly greater. However, if the US stagnates or pulls away from bio-enterprise development, the US could be outpaced by China as the global bio-enterprise leader by 2050.

Innovation Drivers

The US is a top innovator in biotechnology and S&T. The US leads in total R&D, international collaborations, and university-industry clusters. Some small, high-tech nations, namely Israel and Singapore, have more concentrated innovation programs in the bio-enterprise space than does the US, indicating that the US has room to improve. Though the US is likely to continue to innovate, directed policy actions will help the sector remain on the cutting-edge of innovation. Alternately, were the US to pull away from pro-biotech or pro-S&T policies and funding, it could lag behind other high-income peers in bio-enterprise innovation intensity and lose its current international status as the dominant scientific power globally.

Bio-enterprise capacity and innovation, 2020 and 2050. United States.



Improvements that would push the bio-enterprise forward and indicators to watch:
Overall, the US is a powerhouse of technological achievement, but other nations are aiming to catch up. Complacency is perhaps the greatest threat to US supremacy in tech and innovation - an expectation of indefinite US exceptionalism without purposeful drive toward continued growth and innovation. However:

- On a societal level, basic infrastructure and support for R&D could be improved. Though the US currently spends more on R&D in total dollars, it falls behind in R&D spending as a share of GDP.
- The US is falling behind in education metrics, in STEM especially, which could threaten the future high tech and biotech workforce. As the economy moves further into high-tech and knowledge-based sectors, academic and business leaders are finding that the most technologically adept and skilled workers are not always from the US.
- National research budgets are cyclical, unstable, and to many observers, underfunded.
- International collaboration and training of foreign scientists has improved both US science and foreign ties to the US. As China expands its effort to attract students and researchers and builds scientific infrastructure abroad, the US position as the leader in global science may be threatened.

UNITED STATES – biotech

biotech capacity	*rank 1 / 12 score 9.8 / 10*	*biotech drivers*	*rank 3 / 12 score 5.6 / 10*

Strengths
- *Highest share of biotech companies, publications, patents, and universities*
- *High participation in international biotech communities, competitions, and conferences*
- *Highest citation counts in biotech publications*

Weaknesses
- *Could improve number of clinical trials in innovative medicines*
- *Low relative share of biofuels in total liquid fuels*

The US has historically led in biotech development and regulatory practices. In the 1980s, a coordinated framework for the regulation of biotechnology was instrumental in promoting the US biotech industry. The Bayh-Dole and subsequent acts created a modern tech transfer system capable of utilizing advances in basic and academic sciences to drive startups and business growth in the biotech space. Federal standards for biotech products and biopharma especially are the global benchmark and highly respected internationally. Centers for biotech innovation are world class and exist throughout the country. The quality of US academics draws in international talent, both students and researchers, into biotech at a higher rate than any other country, though China is gaining ground. In all, US biotech capacity today is unmatched. Continued funding and policy support will help US biotech maintain this position going forward.

Red Biotech – biomedical sciences
- The US is the largest biopharma market in the world, with US R&D funding the majority of global clinical research. The US itself carries out nearly half of all clinical trials and hosts the largest proportion of private biopharma investment. The National Institutes of Health funds over 300,000 researchers at over 2,500 universities, funding basic and translational research. Biomedical clusters exist throughout the country, with strong state and federal incentives for growth and innovation. A strong IP environment, leading tech-transfer and commercialization environment, and world-class regulatory environment for biomedical and biopharma tech facilitate the US's leading performance in biomedical sciences. The US consequently hosts a very large number of startups, mid-sized enterprises, and international companies working in the biomedical and biopharma space.

Green Biotech – agricultural biotechnologies
- The US is the largest producer of biotech crops (40% of global production), with wide use of and support for biotech crops. Revenues from GM crop use in the US is estimated at about $130 billion/yr. The US is at the forefront of research, development, and commercialization of biotech crops, currently supplying a large portion of biotech seeds internationally. Animal biotechnology is also gaining ground, with biotech salmon, mosquito engineering, disease-resistant livestock, and other programs in development.

White Biotech – industrial biotechnologies
- Industrial biotech is a large contributor to the economy, estimated at over $100 billion/yr. Policies promoting the use of biofuels have resulted in the US becoming the largest international producer of biofuels. Industrial biotechnology development is funded through national programs to support R&D at pre-commercial levels, further driving innovation and production in this sector.

UNITED STATES – science & technology

S&T capacity	*rank 1 / 12 score 9.4 / 10*	*S&T drivers*	*rank 2 / 12 score 7.4 / 10*

Strengths
- *Highest R&D funding in total dollars*
- *High quality and quantity of STEM universities*
- *Largest international collaborator in publications and innovative clusters*
- *Good environment for business, investment, and startups*

Weaknesses
- *Lower intensity of patenting and publishing than highest performers relative to GDP*
- *Low share of STEM doctoral graduates based on economic size*

The US excels in most measures of S&T, including university systems, collaborations, and innovation clusters. However, spending on R&D as a percent of GDP is behind that of the most innovative nations, and China is quickly catching up in terms of absolute R&D spending. Since 2008, a decrease in governmental funding for research and higher education have slowed S&T growth and have made it difficult for young scientists to establish academic careers. Moreover, irregular funding cycles have ultimately been disruptive to overall training and have damaged basic research capacity. On the other hand, the business and patent environment for startups, multinational businesses, and S&T companies is world class. Business funding for R&D has increased enough to keep total R&D funding from dropping substantially. Overall, the US is having to contend with a shift from its dominant position in the S&T hierarchy to a globalized playing field, as wealthy countries drive high tech innovation and large economies increase S&T capacity and innovation at unprecedented rates. The US response - whether it prioritizes S&T, increases funding for research science, improves education and infrastructure – will determine where the US ranks in this global S&T landscape in the future. International collaborations, inflow of foreign students and researchers, and strong university-industry innovation centers has greatly benefited US S&T.

UNITED STATES – general societal

societal capacity	*rank 2 / 12 score 7.5 / 10*	*societal drivers*	*rank 2 / 12 score 6.2 / 10*

Strengths
- *Strong societal belief in science as a personal benefit*
- *Long average length of schooling and presence of science in schools*
- *ICT adoption is prevalent*
- *Rule of law is stable*

Weaknesses
- *Lower projected economic growth rate and population growth rate than many competitors*
- *Middling societal belief in science as increasing jobs*
- *Democratic process may lead to slower policy change compared to autocratic competitors.*

The US is a large economy and leader in many tech fields and is arguably the most technologically powerful economy in the world. However, the US is facing slowing economic and population growth and an aging population moving forward. In many absolute measures, China is approaching or surpassing US scores, and is now considered the largest economy in the world, with economic growth rates surpassing that of the US for decades. India's economy is projected to outgrow the US's by 2050 as well. However, the US is alone among the three with high drivers of innovation. Innovation decisions are made by individuals and businesses, as opposed to the top-down funding and policy structure seen in some other high-innovation countries. This has led to high innovation in the business sector, often supported through tech-transfer structures in place in academic institutions. The US lags in funding for education and primary education, and is falling behind in educational quality, especially with regard to STEM education. Additionally, though the US has many more top-ranked universities, the concentration of top ranked universities relative to GDP is behind that of other innovative nations. ICT adoption, general national infrastructure, and rule of law in the US is also behind that of some other advanced nations. While the US is a technological powerhouse, improvements in existing business, academic, and societal structures can help maintain this position.

Part II:
Country Datasheets

INDICATOR DEFINITIONS

Biotech

biotech capacity scores	Relative Score Contribution: publications 15%, patents 15%, companies 9%, talent 21%, universities 15%, industry sector maturity 15%, biodiversity 6%, collaboration 6%.
biotech innovation-driver scores	Relative Score Contribution: talent 30%, universities 21%, policy 12%, industry sector maturity 22%, biodiversity 8%, collaboration 8%.

Biotech: output measures

	indicator	definition and source
publications	*share of top biotech publications*	Percentage of top 2000 biotechnology publications, sorted by number of citations. *Web of Science.*
	top biotech publications relative to GDP	above indicator, scaled to GDP.
	relative emphasis on biotech within top publications	Share of global publications in biotech relative to the share of global publications in all fields, indicating the relative emphasis or de-emphasis on biotech within publications.
	average citation count per biotech publication	Average number of citations for biotech publications by authors in-country. Only citations from journals or publications meeting Web of Science standards are included in this count. *Web of Science.*
	average citation count per biochemistry, genetics, and molecular biology publications	Average number of citations forbiochemistry, genetics, and molecular biology publications by authors in-country. Only citations from journals or publications meeting Web of Science standards are included in this count. *Web of Science.*
patents	*share of world biotech patents, 2014-2019*	Percent of global biotech patents. Country defined by patent applicant address. *World Intellectual Property Organization (WIPO) PatentScope.*
	biotech patents relative to GDP	above indicator, scaled to GDP.
	relative emphasis on biotech within patents	Share of global patents in biotech relative to the share of global patents in all fields, indicating the relative emphasis or de-emphasis on biotech within patents.
	proportion of red, green, or white biotech patents	Percent of biotech patents meeting search criteria for red (biopharma), green (agricultural biotech), or white (industrial biotech) biotech. *WIPO PatentScope.*
companies	*share of world biotech companies*	Percent of total global biotech companies, by count. Does not account for the company size or revenue. *BiotechGate.*
	biotech companies relative to GDP	above indicator, scaled to GDP.
	proportion of red, green, white, or R&D service biotech companies	Percent of biotech companies meeting search criteria for red (biopharma), green (agricultural biotech), white (industrial biotech), or blue (service biotech) biotech. *BiotechGate*

grey toned indicators are "absolute" measures, such as total counts, GDP, etc.

white toned indicators are "intensity" measures, either scaled to the size of a country's economy, or independent of country size, such as GDP/capita, universities/GDP, innovation scores, etc.

indicator definitions, continued.

Biotech: drivers of innovation

	indicator	definition and source
talent	*users of largest genetic sequence database*	Share of international users of the NIH sequence database. *GenBank.*
	users of largest genetic sequence database relative to GDP	above indicator, scaled to GDP.
	users of a major genetic engineering tool supplier	Count of laboratories requesting tools or sequences from a genetic engineering tool supplier. *Addgene*
	users of a major genetic engineering tool supplier relative to GDP	above indicator, scaled to GDP.
	participation in international genetic engineering competition	Share of international participants in the International Genetically Engineered Machine (iGEM) competitiion, a renowed synthetic biology program for students. *iGEM.*
	participation in international genetic engineering competition relative to GDP	above indicator, scaled to GDP.
	attendance at preeminent synthetic biology conferences	Share of international attendees at SynBio SBX.0 conferences, averaged over 2011-2017. *BioBricks Foundation.*
	attendance at preeminent synthetic biology conferences relative to GDP	above indicator, scaled to GDP.
	subscribers to a prominent synthetic biology newsletter	Share of subscribers to SynBioBeta, a preeminent biotech community resource and newsletter. *SynBioBeta.*
	subscribers to a prominent synthetic biology newsletter relative to GDP	above indicator, scaled to GDP.
universities	*share of top biotech universities*	Percentage of top internationally ranked biotech universities. *Academic Ranking of World Universities (ARWU).*
	top biotech universities relative to GDP	above indicator, scaled to GDP.
	relative emphasis on biotech in top universities	Share of top global biotech universities relative to the share of top global universites, indicating the relative emphasis or de-emphasis on biotech within universities.
	share of top biology universities	Percentage of top internationally ranked biology universities. *Times Higher Education.*
	top biology universities relative to GDP	above indicator, scaled to GDP.
	relative emphasis on biology in top universities	Share of top global biology universities relative to the share of top global universites, indicating the relative emphasis or de-emphasis on biology within universities.
	share of top life sciences universities	Percentage of top internationally ranked life sciences universities. *Times Higher Education.*
	top life sciences universities relative to GDP	above indicator, scaled to GDP.
	relative emphasis on life sciences in top universities	Share of top global life sciences universities relative to the share of top global universites, indicating the relative emphasis or de-emphasis on life sciences within universities.
policy	presence of a national biotechnology plan	The presence of a national biotech plan (1 point), a national science and technology plan not specific to biotech (0.5 points), or no science and technology plan (0 points).

indicator definitions, continued.

Biotech: drivers of innovation

industry sector maturity	*share of total global biotech crops*	Share of global biotech cropland. *International Service for the Acquisition of Agri-biotech Applications (ISAAA) 2018.*
	biotech crops relative to total cropland	Share of country cropland growing biotechnology crops. *ISAAA. Food and Agriculture Organization of the United Nations (FAO).*
	share of total global biofuel production	Share of global biofuel production. *US Energy Information Administration (EIA).*
	biotech fuels relative to total liquid fuel production	Share of biofuel relative to liquid fuel production in-country. *EIA.*
	average annual growth rate in biofuel production, 2006-2016	Annual growth rate of biofuel production averaged over 2006-2016. *EIA.*
	clinical trials of biologics since 2010	Share of global clinical trials for biologics. *World Health Organization International Clinical Trials Registry Platform.*
	clinical trials of biologics since 2010 scaled to GDP	above indicator, scaled to GDP.
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	Overall score in international biopharmaceutical competitiveness, based on aggregate qualitative scores and survey answers. *Pugatch Consilium Biopharmaceutical Competitiveness & Investment Survey 2017.*
biodiversity	*well-studied animal and plant species*	Percent of global known species with known conservation status. *International Union for Conservation of Nature (IUCN).*
	well-studied animal and plant species scaled to GDP	above indicator, scaled to GDP.
	non-human sequence entries in largest genetic sequence database	Percent of global sequence database entries for non-human sequences. *GenBank.*
	non-human sequence entries in largest genetic sequence database scaled to GDP	above indicator, scaled to GDP.
collaboration	*life sciences collaboration (Nature Index)*	Percent of maximum (USA) international collaboration score on high quality life sciences publications. *Nature Index.*
	life sciences collaborations relative to GDP	above indicator, scaled to GDP.

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white toned indicators are "intensity" measures, either scaled to the size of a country's economy, or independent of country size, such as GDP/capita, universities/GDP, innovation scores, etc.

indicator definitions, continued.

Science and Technology

indicator	definition and source
science & technology capacity scores	Relative Score Contribution: publications 19%, patents 19%, talent 19%, funding: R&D 19%, universities 12%, collaboration 12%.
science & technology innovation-driver scores	Relative Score Contribution: talent 13%, funding: R&D 13%, funding: VC 8%, policy 40%, innovation 11%, universities 8%, collaboration 8%.

Science and Technology: output measures

	indicator	definition and source
publications	*share of top high tech publications*	Percentage of top high tech publications, sorted by number of citations. *Web of Science.*
	top high tech publications relative to GDP	above indicator, scaled to GDP.
	relative emphasis on high tech within top publications	Share of top global high tech publications relative to the share of top global publications, indicating the relative emphasis or de-emphasis on high tech within publications.
patents	*share of world patents, 2014-2019*	Percent of global patents. Country defined by patent applicant address. *World Intellectual Property Organization (WIPO) PatentScope.*
	patents relative to GDP	above indicator, scaled to GDP.
STI output	knowledge and technology outputs (Global Innovation Index)	Aggregate score of 14 indicators based on knowledge creation, knowledge impact, and knowledge diffusion. *WIPO Global Innovation Index 2018.*

grey toned indicators are "absolute" measures, such as total counts, GDP, etc.

white toned indicators are "intensity" measures, either scaled to the size of a country's economy, or independent of country size, such as GDP/capita, universities/GDP, innovation scores, etc.

indicator definitions, continued.

Science and Technology : drivers of innovation

	indicator	definition and source
talent	*share of world STEM graduates*	Share of global graduates in science, technology, engineering, and medicine. *Organisation for Economic Co-operation and Development (OECD).*
	STEM graduates relative to GDP	above indicator, scaled to GDP.
	retention of foreign-educated PhD students	percent of foreign doctoral recipients educated in the US intending to return home
	share of world researchers	Share of global researchers. *World Bank.*
	researchers relative to GDP	above indicator, scaled to GDP.
funding: research & development	*total expenditures on R&D*	Total expenditures on R&D, in $USD PPP. (also referred to as gross expenditure on R&D, or GERD). *United Nations Educational, Scientific and Cultural Organization (UNESCO).*
	total expenditures on R&D relative to GDP	Total R&D expenditures as a percent of GDP. *UNESCO*
	R&D expenditures funded by higher ed. relative to GDP	Total R&D expenditures performed by higher education as a percent of GDP. *UNESCO*
	R&D expenditures funded by government relative to GDP	Total R&D expenditures performed by government as a percent of GDP. *UNESCO*
	R&D expenditures funded by business relative to GDP	Total R&D expenditures performed by business as a percent of GDP. *UNESCO*
funding: venture capital	VC availability (Global Competitiveness Report)	Score based on survey question regarding the ease of obtaining equity funding for start-up entrepreneurs with risky but innovative projects. *World Economic Forum, The Global Competitiveness Report 2018 (GCR).*
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	Aggregate score, based on factors that shape the attractiveness of particular venture capital and private equity markets. *IESE Venture Capital and Private Equity Country Attractiveness Index 2018.*
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	Score based survey questions regarding the how burdensone it is for companies to comply with governmental requirements and regulations. *GCR.*
	ease of technology transfer (US Chamber IP Index)	Aggregate score measures by by the extent to which laws and regulations or *de facto* practices act as barriers to technology transfer and commercialization activities of publicly funded and supported research. *US Chamber International IP Index.*
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	Score based on survey questions regarding the extent of intellectual property protection. *GCR.*
	patents, related rights, and limitations (US Chamber IP Index)	Aggregate score of 8 indicators related to patent protection and related rights and limitations, including pharmaceutical pateenting and membership in Patent Prosecution Highways. *US Chamber International IP Index.*
	tax incentives in the creation of IP assets (US Chamber IP Index)	Score based on the extent to which governments provide tax incentives for the creation and use of IP assets through various incentivization schemes. *US Chamber International IP Index.*
policy: future	future orientation of government (Global Competitiveness Report)	Aggregate score based on the opinions of executives regarding the dynamism and agility of their government in response to future change. *GCR.*

indicator definitions, continued.

Science and Technology : drivers of innovation

	indicator	definition and source
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	Aggregate score based on the opinions of executives attitudes toward entrepreneurial risk and embracing disruptive or risky business ideas in their country. *GCR.*
	human capital and research (Global Innovation Index)	Aggregate score of 12 indicators based on education, tertiary education, and R&D. *World Intellectual Property Organization Global Innovation Index 2018 (WIPO GII).*
	innovation capability (Global Competitiveness Report)	Aggregate score of 12 indicators ranging from co-inventions/patents, publications, research institutes, etc. *GCR.*
	infrastructure (Global Innovation Index)	Aggregate score of 10 indicators based on information and communication technologies, general infrastructure, and ecological sustainability. *WIPO GII.*
	business sophistication (Global Innovation Index)	Aggregate score of 15 indicators based on knowledge workers, innovation linkages, and knowledge absorption. *WIPO GII.*
universities	*share of top computer sciences universities*	Percentage of top internationally ranked computer science universities. *Academic Ranking of World Universities (ARWU).*
	top computer sciences universities relative to GDP	above indicator, scaled to GDP.
	relative emphasis on computer sciences in top universities	Share of top global computer science universities relative to the share of top global universites, indicating the relative emphasis or de-emphasis on computer science within universities.
	share of top engineering and technology universities	Percentage of top internationally ranked enginering and technology universities. *ARWU.*
	top engineering and technology universities relative to GDP	above indicator, scaled to GDP.
	relative emphasis on engineering and technology in top universities	Share of top global engineering and tech universities relative to the share of top global universites, indicating the relative emphasis or de-emphasis on engineering and tech within universities.
collaboration	*share of top international innovation clusters*	Share of the top 100 science and technology clusters internationally. *WIPO GII.*
	state of cluster development (Global Competitiveness Report)	Score based on survey questions asking regarding the development, frequency, and performance of science and technology clusters.*GCR.*
	university-industry collaboration (Global Competitiveness Report)	Score based on survey questions regarding the extent of collaboration between businesses and universities. *GCR.*

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indicator definitions, continued.

Age Distribution: by decade, comparing population distributions in 2015 and 2050 population distribution projections. *Wittgenstein Centre for Demography and Global Human Capital.*

Economy: GDP and GDP per capita (below), calculated using exchange rates to determine Purchasing Power Parity (PPP) in United States Dollars (USD). USD reference year 2015. *Organization for Economic Co-Operation and Development (OECD). Economic groups are defined by World Bank according to gross national income per capita. We have translated these ranges into GDP/capita here.*

Education Distribution: De facto population by level of educational attainment, expressed as a percentage of total population. *Centre for Demography and Global Human Capital.*

Extreme Poverty Distribution: poverty levels as a percent of total population, 2019. Ranges expressed in USD, PPP, reference year 2011. *World Development Indicators, The World Bank.*

General-societal

indicator	definition and source
general-societal capacity scores	Relative Score Contribution: economy 58%, population 24%, universities 18%.
general-societal innovation-driver scores	Relative Score Contribution: economy 38%, population 16%, universities 12%, education 12%, policy 8%, ICT 8%, beliefs about science 8%.

General-societal: output measures

	indicator	definition and source
economy	*current GDP, PPP*	Current Gross Domestic Product (GDP), calculated using exchange rates to determine Purchasing Power Parity (PPP) in United States Dollars (USD). USD reference year 2015. *Organization for Economic Co-Operation and Development (OECD).*
	current GDP per capita	Current GDP per person, calculated using exchange rates to determine PPP in USD. USD reference year 2015. *OECD.*
population	*current population*	2020 population. *Wittgenstein Centre for Demography and Global Human Capital.*
	current ratio: working age population to young plus elderly population	The ratio of the youth (0-14) and elderly (65+) population over the working age (15-64) population. *Wittgenstein Centre for Demography and Global Human Capital.*

grey toned indicators are "absolute" measures, such as total counts, GDP, etc.

white toned indicators are "intensity" measures, either scaled to the size of a country's economy, or independent of country size, such as GDP/capita, universities/GDP, innovation scores, etc.

indicator definitions, continued.

General-societal : drivers of innovation

	indicator	definition and source
economy	*2050 GDP, PPP*	Projected 2050 GDP, calculated using exchange rates to determine PPP in USD. USD reference year 2015. *Organization for Economic Co-Operation and Development (OECD). World Bank. PricewaterhouseCoopers.*
	2050 GDP per capita	Projected 2050 GDP per person, calculated using exchange rates to determine PPP in USD. USD reference year 2015. *OECD. World Bank. PricewaterhouseCoopers.*
	GDP annual growth rate, 2018 to 2050	Projected GDP annual growth rate, calculated based on 2018 GDP and 2050 GDP projections. *OECD. World Bank. PricewaterhouseCoopers.*
population	*2050 population*	Projected 2050 population, calculated using the European Commission Science Hub Medium Scenario (SSP2) which foresees that fertility and mortality follow a medium pathway that can be seen as most likely from today's perspective. *Wittgenstein Centre for Demography and Global Human Capital (Witt).*
	population growth rate, 2018 to 2050	Projected population annual growth rate, calculated based on 2018 population and 2050 population projections. *Witt.*
	2050 ratio: working age population to young plus elderly population	The projected ratio of the youth (0-14) and elderly (65+) population over the working age (15-64) population, based on the Medium Scenario growth model. *Witt.*
universities	*share of top universities*	Percentage of top internationally ranked universities. *Academic Ranking of World Universities (ARWU).*
	top universities relative to GDP	above indicator, scaled to GDP.
education	school life expectancy, primary through tertiary	Years of expected schooling, counting primary through tertiary school years. *United Nations Educational, Scientific and Cultural Organization (UNESCO)*
	presence of science education in secondary school	Survey question regarding the presence of science education in secondary school. *2018 Wellcome Global Monitor Trust In Scientists Index (Wellcome).*
	government expenditure on education as percent of GDP	Government expenditure on education as a percent of GDP. *UNESCO* .
	government expenditure on primary education as percent of GDP	Government expenditure on primary education as a percent of GDP. *UNESCO* .
policy	rule of law (World Justice Project)	Overall score, incorporating 44 indicators spanning accountability, just laws, open government, and accessible & impartial dispute resolution. *World Justice Project Rule of Law Index 2019.*
ICT	ICT adoption (WEF Global Competitiveness)	Overall score, incorporating mobile telephone subscriptions, mobile broadband subscriptions, fixed-broadband internet subscriptions, fiber internet subscriptions, and internet users. *World Economic Forum, The Global Competitiveness Report 2018.*
beliefs about science	belief in science as future national benefit	Percent responding yes to survey questions on whether science will benefit the country. *Wellcome. World Values Survey.*
	belief in science as increasing jobs	Percent responding yes to survey questions on whether science will increase jobs in the country. *Wellcome. World Values Survey.*
	belief in science as a personal benefit	Percent responding yes to survey questions on whether science will benefit them personally. *Wellcome. World Values Survey.*
	trust in science over religion	Percent responding that science should be trusted over religion when the two conflict. *Wellcome. World Values Survey.*

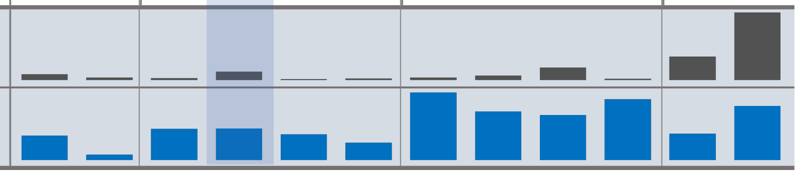
grey toned indicators are "absolute" measures, such as total counts, GDP, etc.

white toned indicators are "intensity" measures, either scaled to the size of a country's economy, or independent of country size, such as GDP/capita, universities/GDP, innovation scores, etc.

BRAZIL

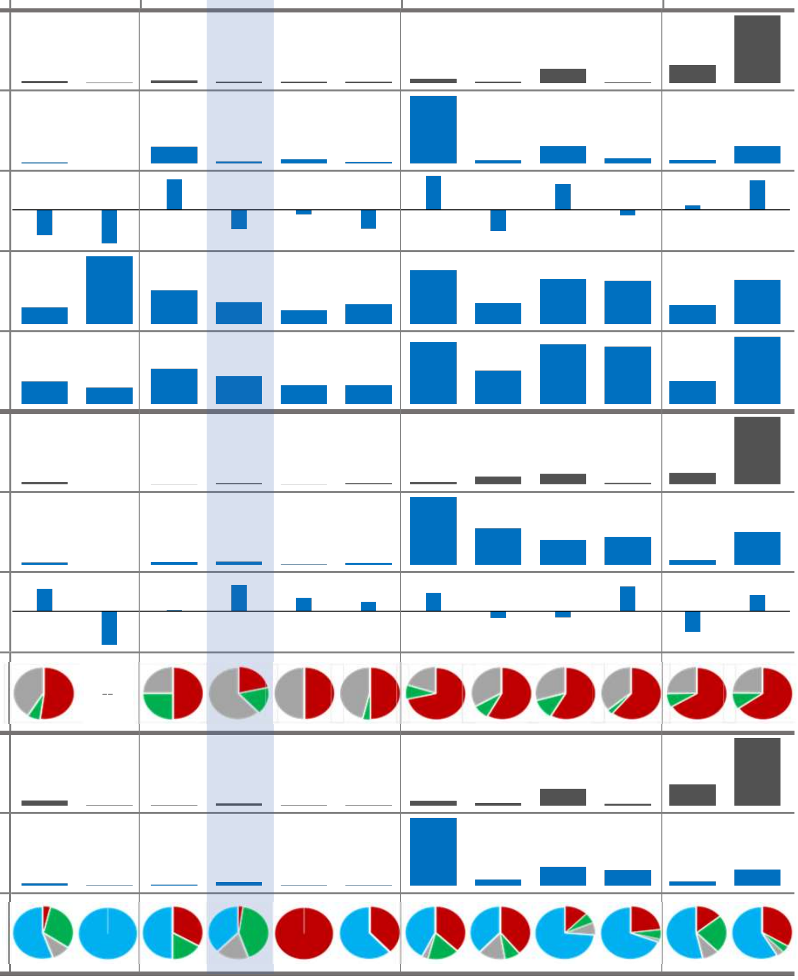
Biotech

sector scores	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
biotech capacity scores	4 of 12	1.2/10 points												
biotech innovation-driver scores	6 of 12	3.3/10 points												



Biotech: output measures

	indicator	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
publications	*share of top biotech publications*	10 of 12	1.1%												
	top biotech publications relative to GDP	9 of 12	--												
	relative emphasis on biotech within top publications	9 of 12	-0.5 (-1 to 1)												
	average citation count per biotech publication	7 of 12	--												
	average citation count per biochemistry, genetics, and molecular biology publications	7 of 12	--												
patents	*share of world biotech patents, 2014-2019*	8 of 12	2%												
	biotech patents relative to GDP	7 of 12	--												
	relative emphasis on biotech within patents	1 of 12	+0.8 (-1 to 1)												
	proportion of red, green, or white biotech patents	--	21%, 17%, 62%		--										
companies	*share of world biotech companies*	7 of 12	1.9%												
	biotech companies relative to GDP	7 of 12	--												
	proportion of red, green, white, or R&D service biotech companies	--	2%, 42%, 18%, 38%												



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

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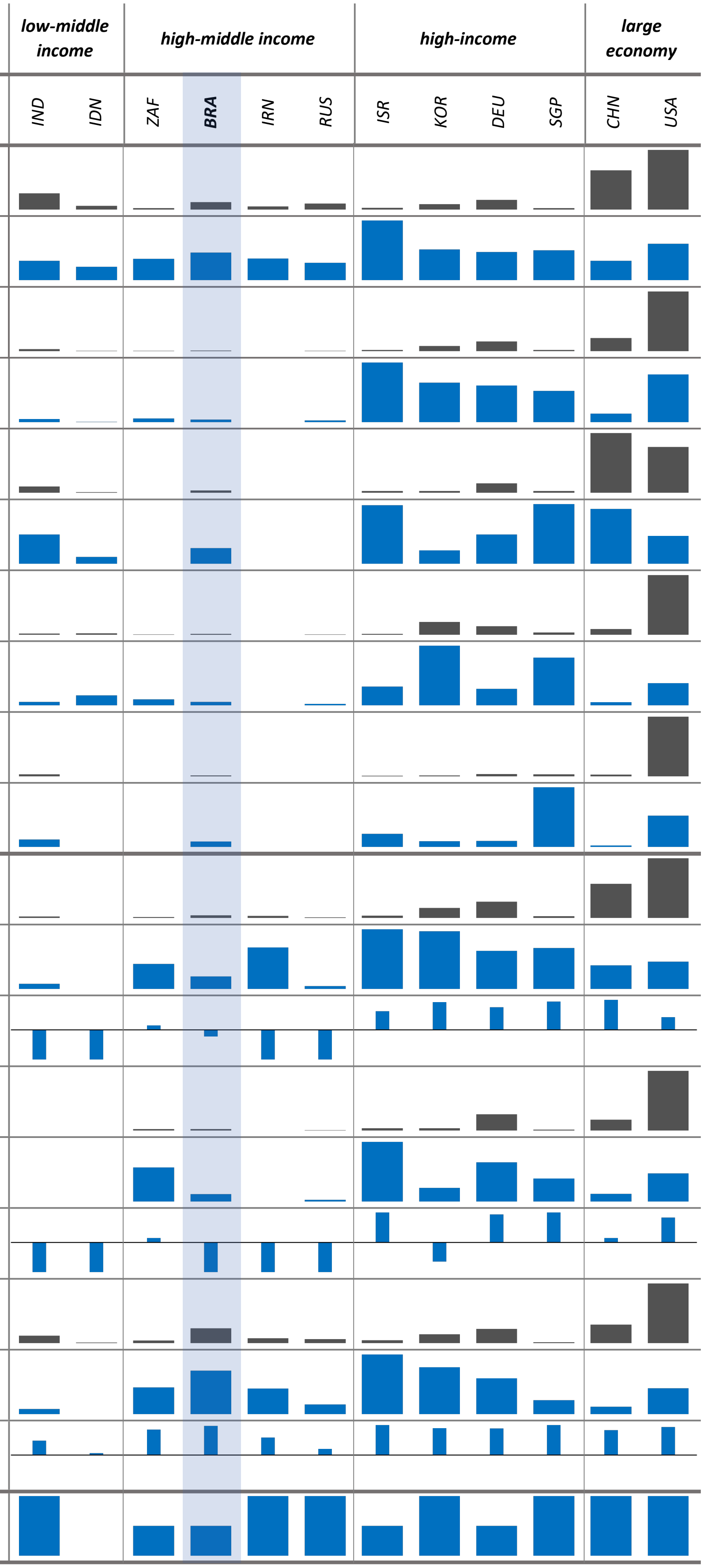
Biotech: drivers of innovation

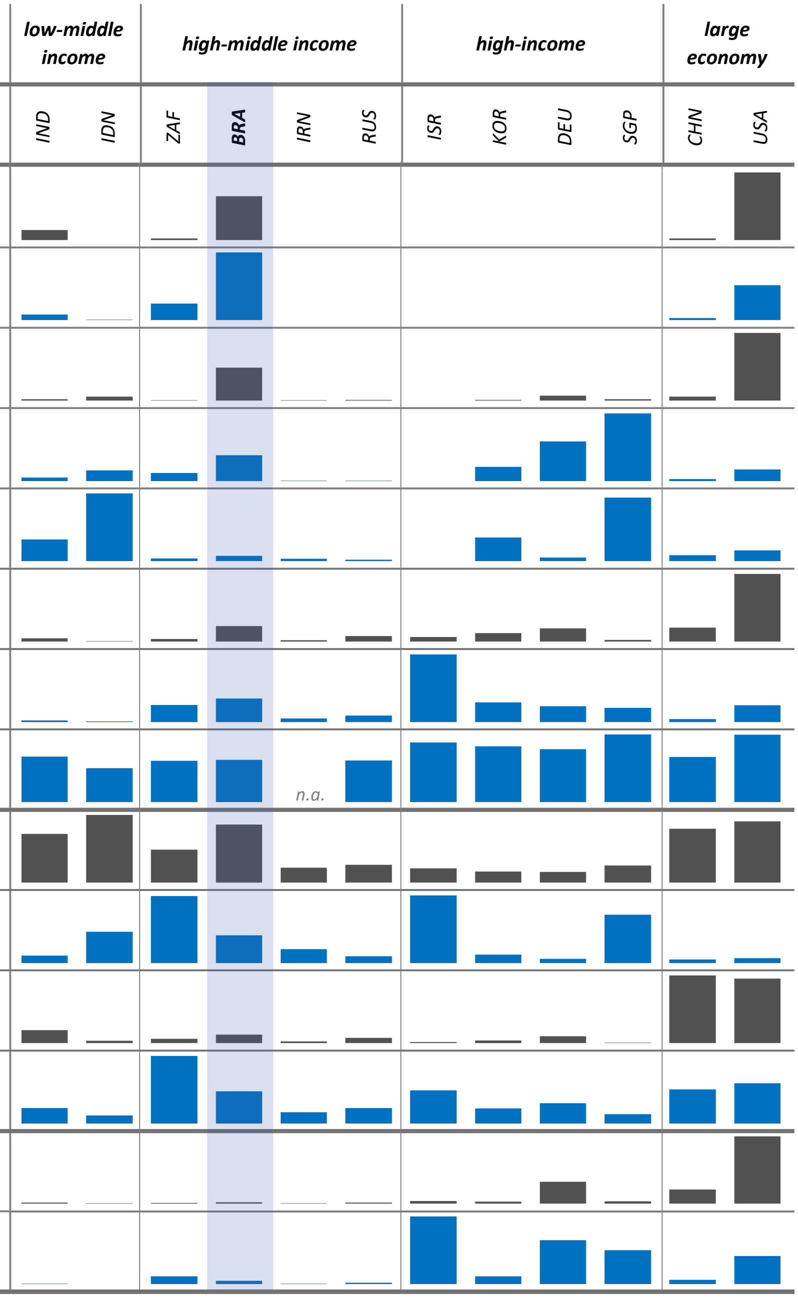
	indicator	rank	value
talent	*users of largest genetic sequence database*	5 of 12	2.8% of users
	users of largest genetic sequence database relative to GDP	6 of 12	--
	users of a major genetic engineering tool supplier	8 of 12	301 depositors
	users of a major genetic engineering tool supplier relative to GDP	9 of 12	--
	participation in international genetic engineering competition	5 of 12	1.2% of participants
	participation in international genetic engineering competition relative to GDP	7 of 12	--
	attendance at preeminent synthetic biology conferences	9 of 12	0.4% of attendees
	attendance at preeminent synthetic biology conferences relative to GDP	9 of 12	--
	subscribers to a prominent synthetic biology newsletter	6 of 12	1.0% of subscribers
	subscribers to a prominent synthetic biology newsletter relative to GDP	7 of 12	--
universities	*share of top biotech universities*	5 of 12	0.9%
	top biotech universities relative to GDP	9 of 12	--
	relative emphasis on biotech in top universities	8 of 12	-0.2 (-1 to 1)
	share of top biology universities	6 of 12	0.7%
	top biology universities relative to GDP	8 of 12	--
	relative emphasis on biology in top universities	8 of 12	-0.9 (-1 to 1)
	share of top life sciences universities	3 of 12	12.6%
	top life sciences universities relative to GDP	3 of 12	--
	relative emphasis on life sciences in top universities	3 of 12	+0.9 (-1 to 1)
policy	presence of a national biotechnology plan	8 of 12	0.5 of 1 pt



BRAZIL

Biotech: drivers of innovation

	indicator	rank	value
industry sector maturity	*share of total global biotech crops*	2 of 12	26%
	biotech crops relative to total cropland	1 of 12	93%
	share of total global biofuel production	2 of 12	22%
	biotech fuels relative to total liquid fuel production	3 of 12	16%
	average annual growth rate in biofuel production, 2006-2016	7 of 12	6.3%
	clinical trials of biologics since 2010	2 of 12	8% of trials
	clinical trials of biologics since 2010 scaled to GDP	2 of 12	--
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	8 of 11	55/100 score
biodiversity	*well-studied animal and plant species*	3 of 12	8.5% of species
	well-studied animal and plant species scaled to GDP	5 of 12	--
	non-human sequence entries in largest genetic sequence database	4 of 12	2.3% of entries
	non-human sequence entries in largest genetic sequence database scaled to GDP	5 of 12	--
collaboration	*life sciences collaboration (Nature Index)*	7 of 12	2.1% of max score
	life sciences collaborations relative to GDP	8 of 12	--



data not applicable --

data not available *n.a.*

acronym: GDP: gross domestic product.
largest genetic sequence database: NIH GenBank.
major genetic engineering tool supplier: AddGene.
international genetic engineering competition: iGEM.
preeminent synthetic biology conference: SBx.0.
prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRAZIL

Science and Technology

sector scores	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
			low-middle income		*high-middle income*				*high-income*				*large economy*	
science & technology capacity scores	7 of 12	0.7/10 points												
science & technology innovation-driver scores	10 of 12	2.4/10 points												

Science and Technology: output measures

	indicator	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
				low-middle income		*high-middle income*				*high-income*				*large economy*	
publications	*share of top high tech publications*	10 of 12	0.75%												
	top high tech publications relative to GDP	10 of 12	--												
	relative emphasis on high tech within top publications	11 of 12	-0.8 (-1 to 1)												
patents	*share of world patents, 2014-2019*	9 of 12	0.27%												
	patents relative to GDP	9 of 12	--												
STI output	knowledge and technology outputs (Global Innovation Index)	11 of 12	23/100 score; 64/126 countries												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product

STI: science and technology innovation

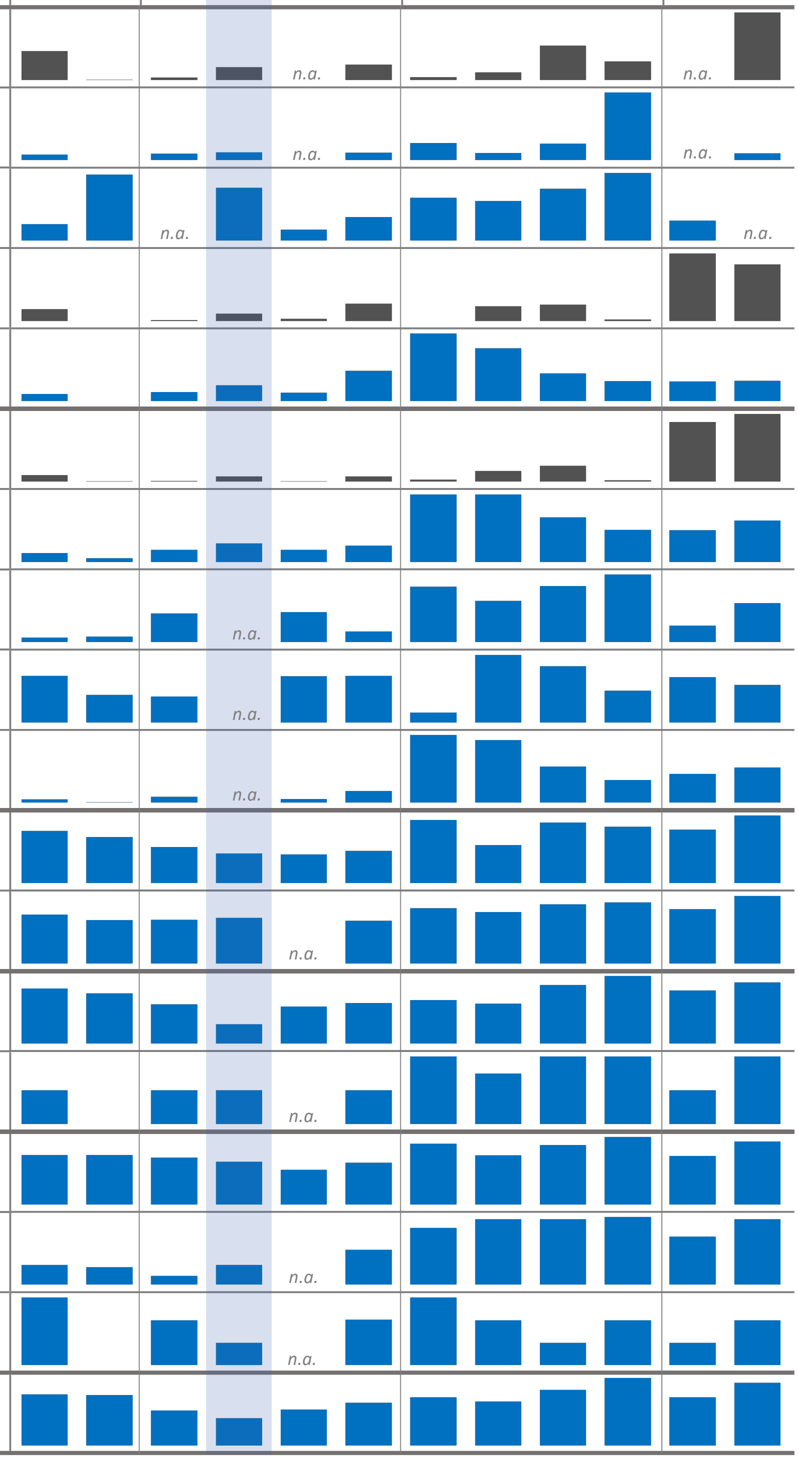
relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRAZIL

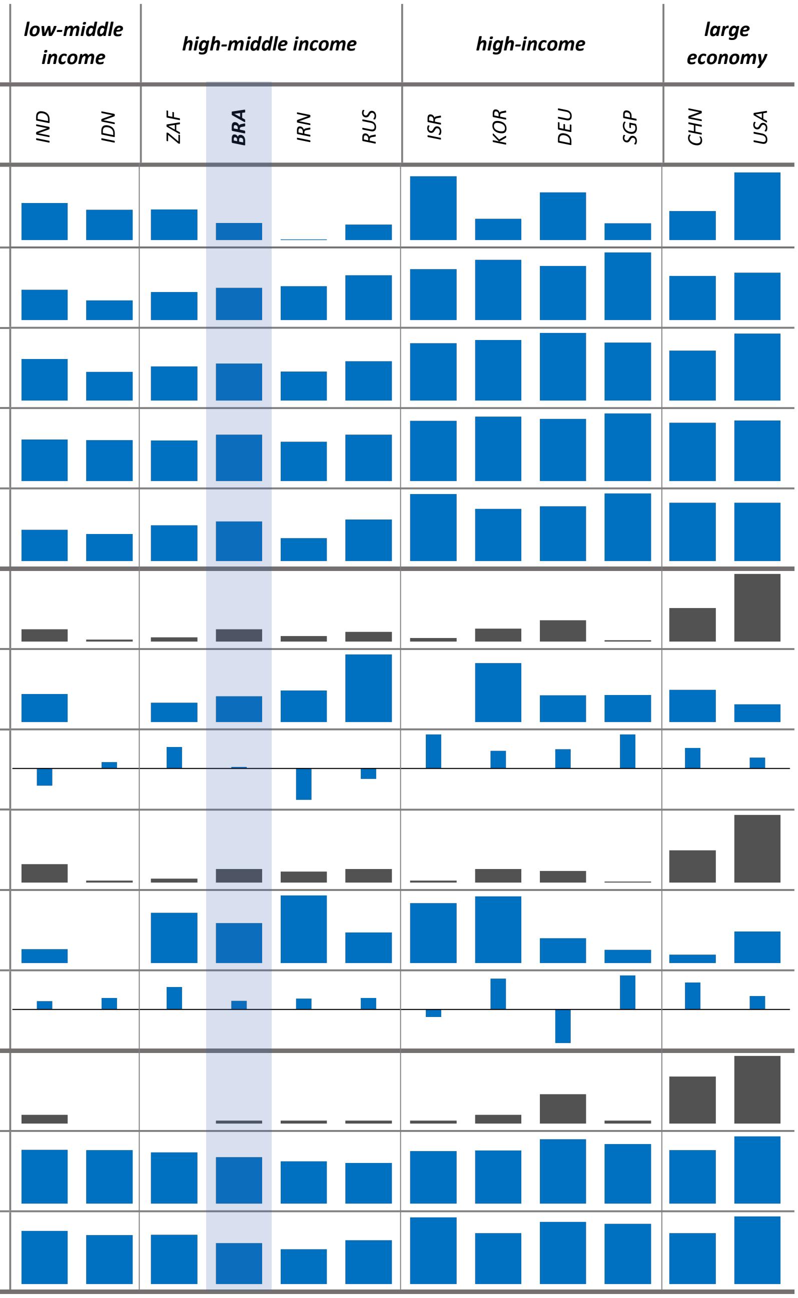
Science and Technology: drivers of innovation				*low-middle income*		*high-middle income*				*high-income*				*large economy*	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	***BRA***	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
talent	*share of world STEM graduates*	6 of 10	4.0%					*n.a.*						*n.a.*	
	STEM graduates relative to GDP	4 of 10	--					*n.a.*						*n.a.*	
	retention of foreign-educated PhD students	3 of 10	50%			*n.a.*									*n.a.*
	share of world researchers	7 of 12	1.7%												
	researchers relative to GDP	8 of 12	--												
funding: research & development	*total expenditures on R&D*	6 of 12	$40B USD PPP												
	total expenditures on R&D relative to GDP	7 of 12	1.3%												
	R&D expenditures funded by higher ed. relative to GDP	--	*n.a.*				*n.a.*								
	R&D expenditures funded by government relative to GDP	--	*n.a.*				*n.a.*								
	R&D expenditures funded by business relative to GDP	--	*n.a.*				*n.a.*								
funding: venture capital	VC availability (Global Competitiveness Report)	11 of 12	2.5/7 score 103/140 countries												
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	8 of 11	67/100 score					*n.a.*							
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	12 of 12	1.6/7 score 140/140 countries												
	ease of technology transfer (US Chamber IP Index)	6 of 11	0.5/1 score					*n.a.*							
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	10 of 12	4/7 score 77/140 countries												
	patents, related rights, and limitations (US Chamber IP Index)	8 of 11	2.3/7 score					*n.a.*							
	tax incentives in the creation of IP assets (US Chamber IP Index)	8 of 11	0.3/1 score					*n.a.*							
policy: future	future orientation of government (Global Competitiveness Report)	12 of 12	2.5/7 score 129/140 countries												



BRAZIL

Science and Technology: drivers of innovation

	indicator	rank	value
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	9 of 12	56%
	human capital and research (Global Innovation Index)	9 of 12	35/100 score; 52/126 countries
	innovation capability (Global Competitiveness Report)	9 of 12	48/100 score; 40/140 countries
	infrastructure (Global Innovation Index)	8 of 12	45/100 score; 64/126 countries
	business sophistication (Global Innovation Index)	8 of 12	38/100 score; 38/126 countries
universities	*share of top computer sciences universities*	5 of 12	2.9%
	top computer sciences universities relative to GDP	8 of 12	--
	relative emphasis on computer sciences in top universities	9 of 12	0.02 (-1 to 1)
	share of top engineering and technology universities	4 of 12	3.1%
	top engineering and technology universities relative to GDP	5 of 12	--
	relative emphasis on engineering and technology in top universities	9 of 12	+0.1 (-1 to 1)
collaboration	*share of top international innovation clusters*	6 of 12	1.0%
	state of cluster development (Global Competitiveness Report)	10 of 12	4/7 score; 52/140 countries
	university-industry collaboration (Global Competitiveness Report)	11 of 12	3.6/7 score



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data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math
R&D: research and development. VC: venture capital.
GDP: gross domestic product. IP: intelllectual property.
IESE: graduate business school of the University of Navarra.

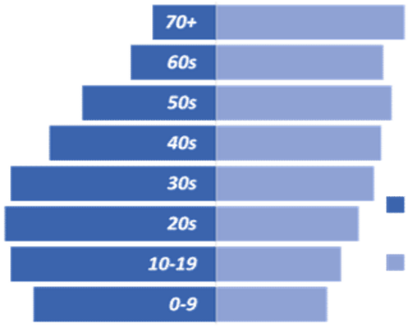
relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRAZIL

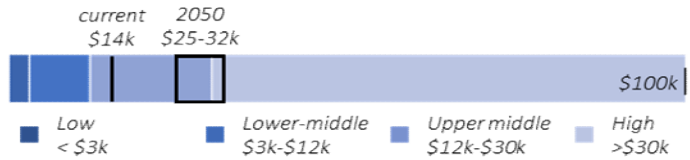
AGE DISTRIBUTION



2015: 214 million
total dependency ratio 0.44

2050: 230 million
total dependency ratio 0.59

ECONOMY: UPPER-MIDDLE INCOME

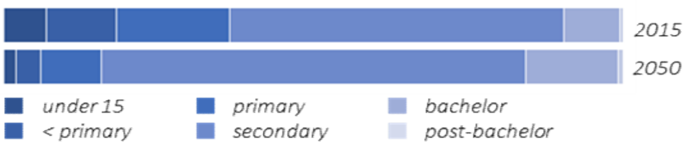


$USD PPP, GDP/capita

ranges are approximations based on World Bank economic groups - GNI/capita has been converted to GDP/capita

current GDP: $3T USD PPP
2050 GDP: $5.8-7.5T USD PPP

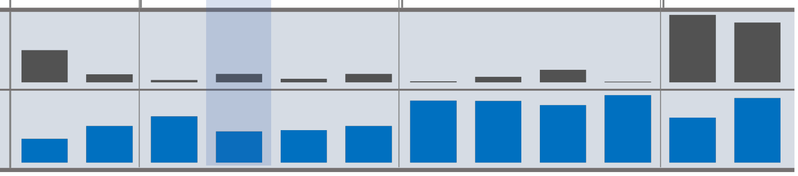
EDUCATION DISTRIBUTION



EXTREME POVERTY DISTRIBUTION

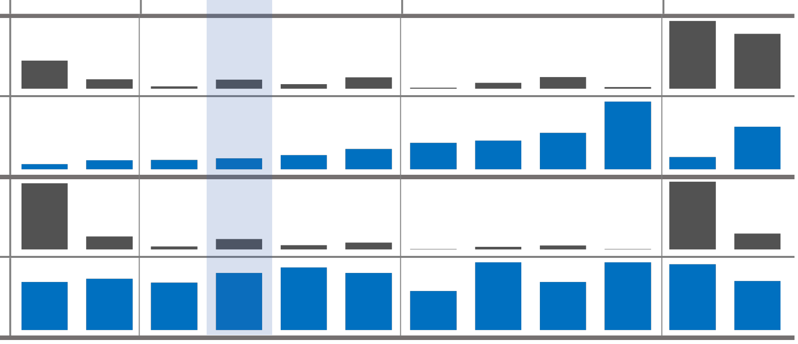
General-societal

sector scores	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
general-societal capacity scores	6 of 12	1/10 points												
general-societal innovation-driver scores	11 of 12	3/10 points												



General-societal: output measures

	indicator	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
economy	*current GDP, PPP*	7 of 12	$3T USD PPP, 2.5% of global GDP												
	current GDP per capita	7 of 12	$14k USD PPP												
population	*current population*	9 of 12	214 million 2.8% global pop.												
	current ratio: working age population to young plus elderly population	5 of 12	2.3:1												



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data not available *n.a.*
acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

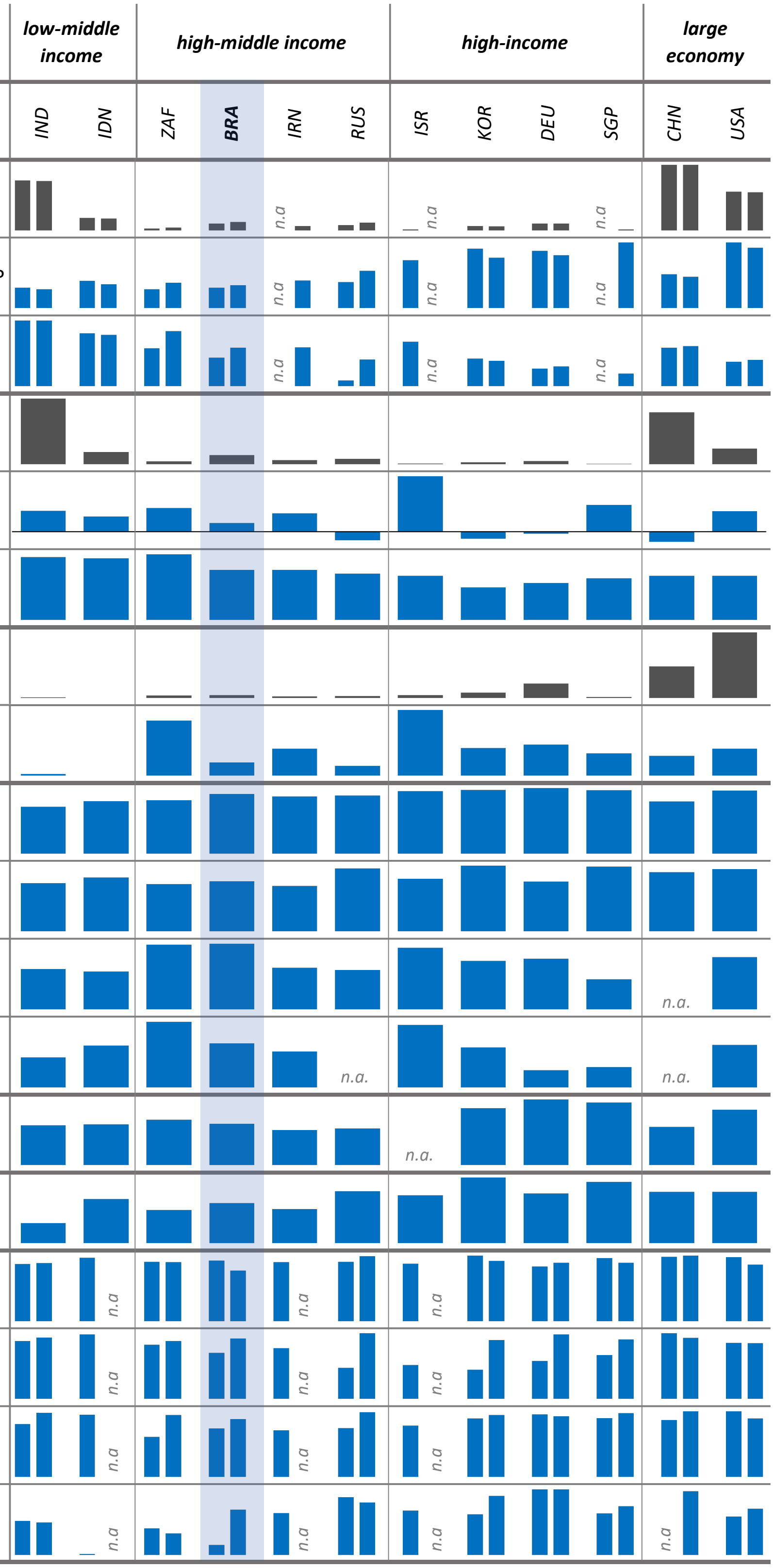
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRAZIL

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	5 of 12	$5.8-7.5T USD, 2.6-2.7% of global GDP
	2050 GDP per capita	11 of 12	$25-33k USD PPP
	GDP annual growth rate, 2018 to 2050	7 of 12	2.1-2.9%
population	*2050 population*	5 of 12	230 million, 2.5% of global pop.
	population growth rate, 2018 to 2050	5 of 12	0.2%
	2050 ratio: working age population to young plus elderly population	4 of 12	1.7:1
universities	*share of top universities*	5 of 12	1.2%
	top universities relative to GDP	9 of 12	--
education	school life expectancy, primary through tertiary	6 of 12	15.4 years
	presence of science education in secondary school	8 of 12	76%
	government expenditure on education as percent of GDP	1 of 11	6.2%
	government expenditure on primary education as percent of GDP	3 of 10	1.6%
policy	rule of law (World Justice Project)	6 of 11	53/100 score
ICT	ICT adoption (WEF Global Competitiveness)	9 of 12	56/100 score 66/140 countries
beliefs about science	belief in science as future national benefit	12 of 12	74%
	belief in science as increasing jobs	6 of 12	63%
	belief in science as a personal benefit	9 of 12	67%
	trust in science over religion	10 of 12	32%



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data not available *n.a.*

acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

two bars indicate data from two separate sources

CHINA

Biotech			low-middle income		high-middle income				high-income				large economy	
sector scores	rank	value	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	***CHN***	*USA*
biotech capacity scores	2 of 12	3.4/10 points												
biotech innovation-driver scores	8 of 12	2.7/10 points												

Biotech : output measures				low-middle income		high-middle income				high-income				large economy	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	***CHN***	*USA*
publications	*share of top biotech publications*	2 of 12	15.9%												
	top biotech publications relative to GDP	7 of 12	--												
	relative emphasis on biotech within top publications	5 of 12	+0.1 (-1 to 1)												
	average citation count per biotech publication	10 of 12	--												
	average citation count per biochemistry, genetics, and molecular biology publications	8 of 12	--												
patents	*share of world biotech patents, 2014-2019*	2 of 12	7.8%												
	biotech patents relative to GDP	6 of 12	--												
	relative emphasis on biotech within patents	11 of 12	-0.62 (-1 to 1)												
	proportion of red, green, or white biotech patents	--	66%, 8%, 25%		--										
companies	*share of world biotech companies*	2 of 12	17%												
	biotech companies relative to GDP	6 of 12	--												
	proportion of red, green, white, or R&D service biotech companies	--	14%, 23%, 9%, 54%												

pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

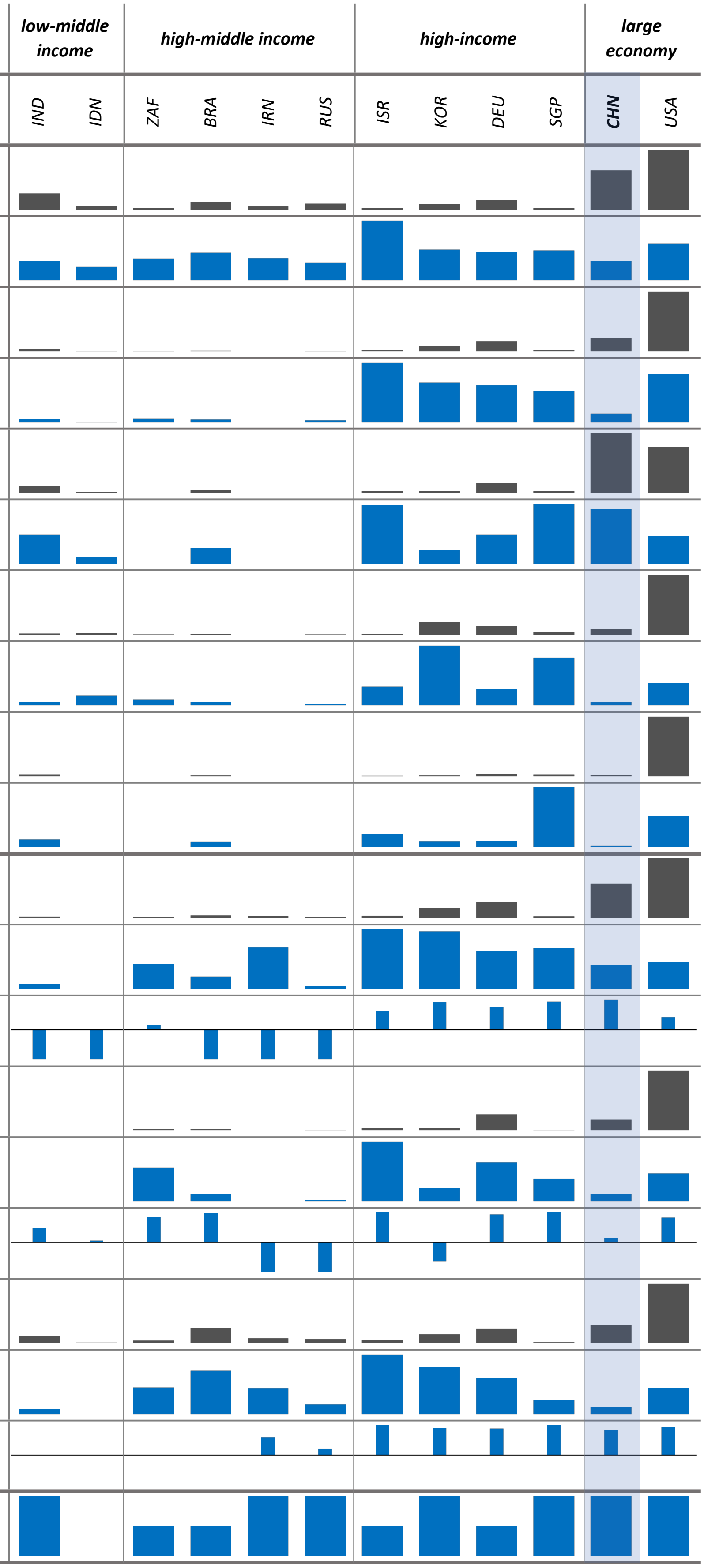
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

CHINA

Biotech : drivers of innovation

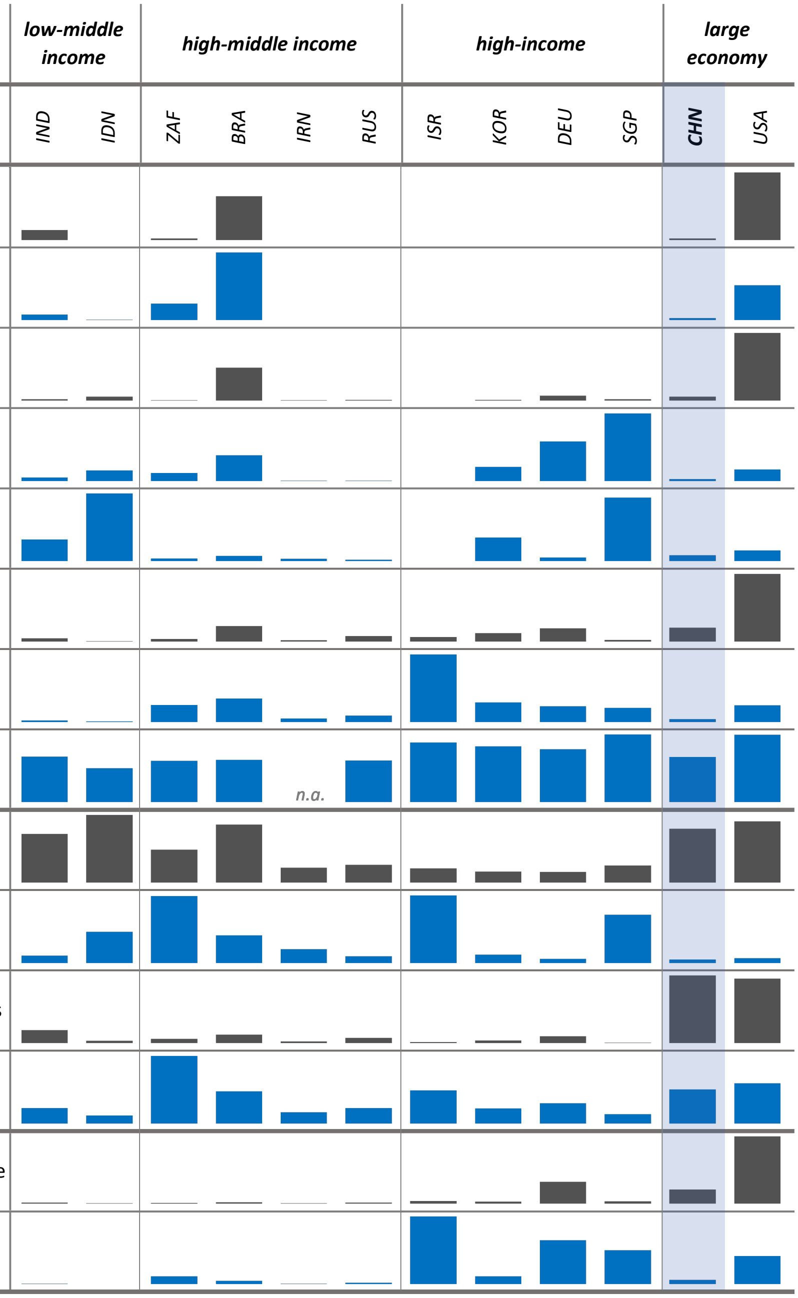
	indicator	rank	value
talent	*users of largest genetic sequence database*	2 of 12	14.9% of users
	users of largest genetic sequence database relative to GDP	9 of 12	--
	users of a major genetic engineering tool supplier	2 of 12	7257 depositors
	users of a major genetic engineering tool supplier relative to GDP	6 of 12	--
	participation in international genetic engineering competition	1 of 12	30% of participants
	participation in international genetic engineering competition relative to GDP	3 of 12	--
	attendance at preeminent synthetic biology conferences	4 of 12	2.5% of attendees
	attendance at preeminent synthetic biology conferences relative to GDP	10 of 12	--
	subscribers to a prominent synthetic biology newsletter	5 of 12	1.7% of subscribers
	subscribers to a prominent synthetic biology newsletter relative to GDP	8 of 12	--
universities	*share of top biotech universities*	2 of 12	11.8%
	top biotech universities relative to GDP	8 of 12	--
	relative emphasis on biotech in top universities	1 of 12	+0.8 (-1 to 1)
	share of top biology universities	3 of 12	5.6%
	top biology universities relative to GDP	7 of 12	--
	relative emphasis on biology in top universities	5 of 12	+0.1 (-1 to 1)
	share of top life sciences universities	2 of 12	16%
	top life sciences universities relative to GDP	10 of 12	--
	relative emphasis on life sciences in top universities	8 of 12	+0.8 (-1 to 1)
policy	presence of a national biotechnology plan	3 of 12	1 of 1 pt



CHINA

Biotech : drivers of innovation

	indicator	rank	value
industry sector maturity	*share of total global biotech crops*	4 of 12	1.0%
	biotech crops relative to total cropland	5 of 12	2.4%
	share of total global biofuel production	5 of 12	2.7%
	biotech fuels relative to total liquid fuel production	9 of 12	1.3%
	average annual growth rate in biofuel production, 2006-2016	6 of 12	7.2%
	clinical trials of biologics since 2010	3 of 12	7% of trials
	clinical trials of biologics since 2010 scaled to GDP	10 of 12	--
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	7 of 11	58/100 score
biodiversity	*well-studied animal and plant species*	4 of 12	7.9% of species
	well-studied animal and plant species scaled to GDP	12 of 12	--
	non-human sequence entries in largest genetic sequence database	1 of 12	18.1% of entries
	non-human sequence entries in largest genetic sequence database scaled to GDP	3 of 12	--
collaboration	*life sciences collaboration (Nature Index)*	3 of 12	21% of max score
	life sciences collaborations relative to GDP	7 of 12	--



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data not available *n.a.*

acronym: GDP: gross domestic product.

largest genetic sequence database: NIH GenBank.

major genetic engineering tool supplier: AddGene.

international genetic engineering competition: iGEM.

preeminent synthetic biology conference: SBx.0.

prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

CHINA

Science and Technology

sector scores	rank	value	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	***CHN***	*USA*
			low-middle income		*high-middle income*				*high-income*				*large economy*	
science & technology capacity scores	2 of 12	8.2/10 points												
science & technology innovation-driver scores	6 of 12	4.5/10 points												

Science and Technology: output measures

	indicator	rank	value	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	***CHN***	*USA*
				low-middle income		*high-middle income*				*high-income*				*large economy*	
publications	*share of top high tech publications*	1 of 12	57%												
	top high tech publications relative to GDP	3 of 12	--												
	relative emphasis on high tech within top publications	2 of 12	+0.9 (-1 to 1)												
patents	*share of world patents, 2014-2019*	2 of 12	16%												
	patents relative to GDP	6 of 12	--												
STI output	knowledge and technology outputs (Global Innovation Index)	1 of 12	57/100 score; 5/126 countries												

data not applicable --
data not available *n.a.*
acronyms: GDP: gross domestic product
STI: science and technology innovation

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

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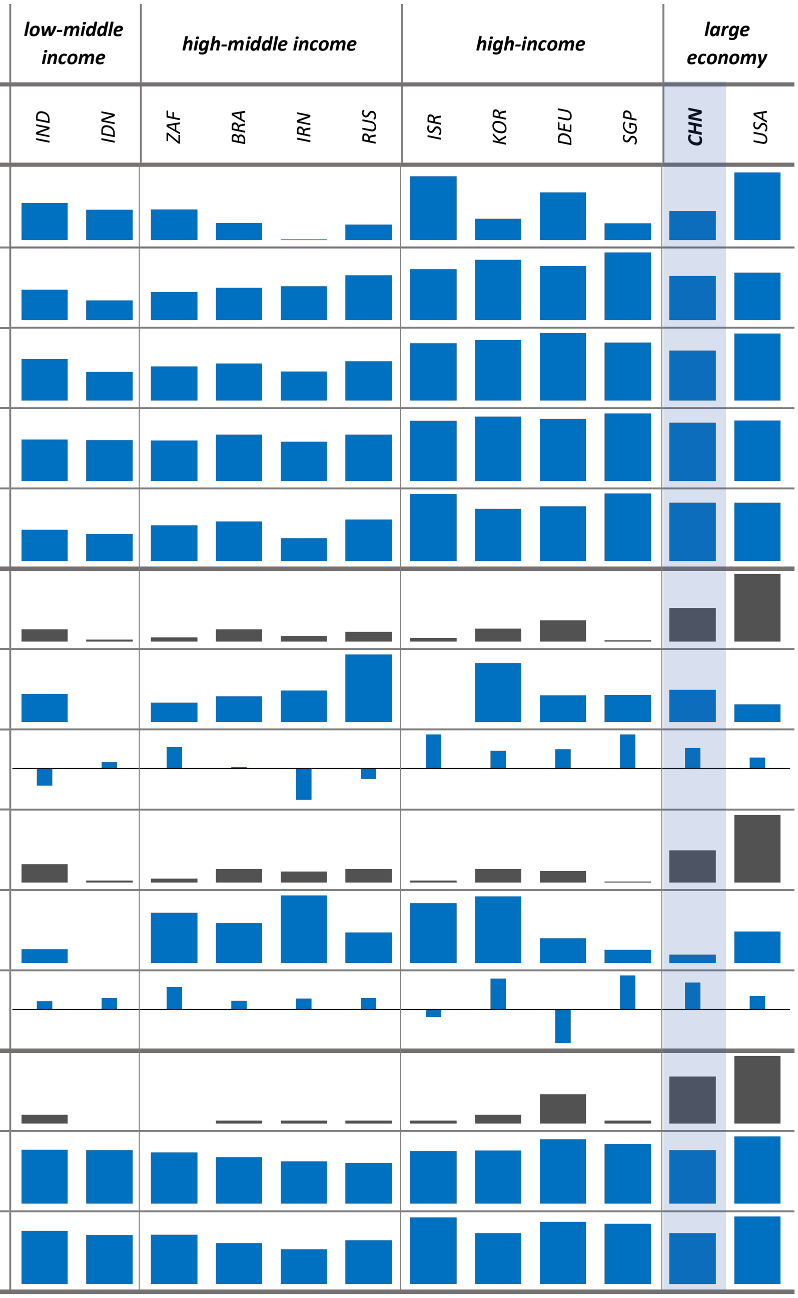
CHINA

Science and Technology : drivers of innovation				low-middle income		high-middle income				high-income				large economy	
	indicator	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
talent	*share of world STEM graduates*	--	n.a.					n.a.						n.a.	
	STEM graduates relative to GDP	--	n.a.					n.a.						n.a.	
	retention of foreign-educated PhD students	8 of 10	18.9%			n.a.									n.a.
	share of world researchers	1 of 12	15.2%												
	researchers relative to GDP	7 of 12	--												
funding: research & development	*total expenditures on R&D*	2 of 12	$451B USD PPP												
	total expenditures on R&D relative to GDP	6 of 12	2.1%												
	R&D expenditures funded by higher ed. relative to GDP	8 of 11	0.15%				n.a.								
	R&D expenditures funded by government relative to GDP	6 of 11	0.32%				n.a.								
	R&D expenditures funded by business relative to GDP	5 of 11	1.6%				n.a.								
funding: venture capital	VC availability (Global Competitiveness Report)	5 of 12	4.4/7 score 10/140 countries												
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	5 of 11	81/100 score					n.a.							
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	5 of 12	4.4/7 score 18/140 countries												
	ease of technology transfer (US Chamber IP Index)	6 of 11	0.5/1 score					n.a.							
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	8 of 12	4.5/7 score 49/140 countries												
	patents, related rights, and limitations (US Chamber IP Index)	6 of 11	5.5/7 score					n.a.							
	tax incentives in the creation of IP assets (US Chamber IP Index)	8 of 11	0.3/1 score					n.a.							
policy: future	future orientation of government (Global Competitiveness Report)	7 of 12	4.4/7 score 32/140 countries												

CHINA

Science and Technology : drivers of innovation

	indicator	rank	value
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	7 of 12	62%
	human capital and research (Global Innovation Index)	7 of 12	48/100 score; 23/126 countries
	innovation capability (Global Competitiveness Report)	6 of 12	64/100 score; 24/140 countries
	infrastructure (Global Innovation Index)	6 of 12	57/100 score; 29/126 countries
	business sophistication (Global Innovation Index)	4 of 12	56/100 score; 9/126 countries
universities	*share of top computer sciences universities*	2 of 12	8.0%
	top computer sciences universities relative to GDP	3 of 12	--
	relative emphasis on computer sciences in top universities	4 of 12	+0.3 (-1 to 1)
	share of top engineering and technology universities	2 of 12	7.4%
	top engineering and technology universities relative to GDP	11 of 12	--
	relative emphasis on engineering and technology in top universities	3 of 12	+0.3 (-1 to 1)
collaboration	*share of top international innovation clusters*	2 of 12	16%
	state of cluster development (Global Competitiveness Report)	6 of 12	4.6/7 score; 29/140 countries
	university-industry collaboration (Global Competitiveness Report)	6 of 12	4.4/7 score



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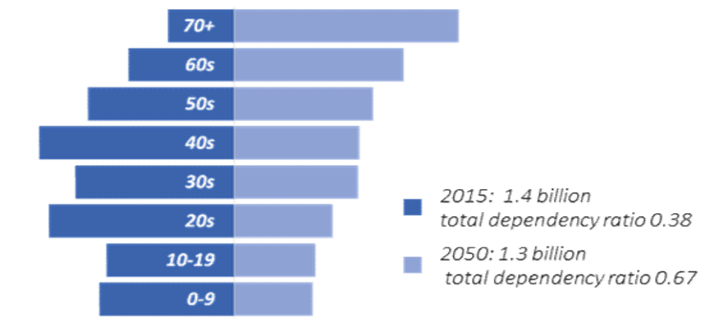
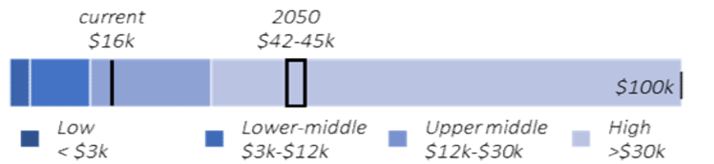
CHINA

AGE DISTRIBUTION



ECONOMY: UPPER-MIDDLE INCOME

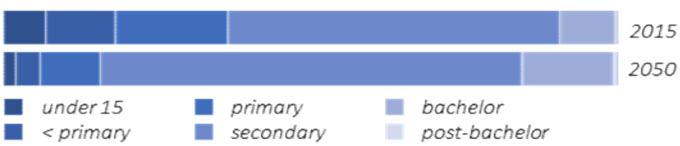


$USD PPP, GDP/capita

ranges are approximations based on World Bank economic groups - GNI/capita has been converted to GDP/capita

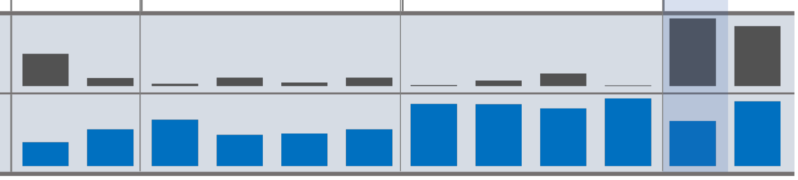
current GDP: $23T USD PPP
2050 GDP: $54-59T USD PPP

EDUCATION DISTRIBUTION

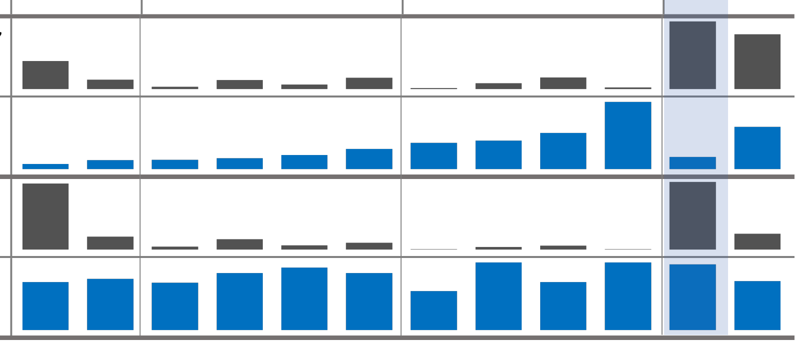


EXTREME POVERTY DISTRIBUTION

General-societal			*low-middle income*		*high-middle income*				*high-income*				*large economy*	
sector scores	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	***CHN***	*USA*
general-societal capacity scores	1 of 12	8.4/10 points												
general-societal innovation-driver scores	7 of 12	4.3/10 points												



General-societal: output measures				*low-middle income*		*high-middle income*				*high-income*				*large economy*	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	***CHN***	*USA*
economy	*current GDP, PPP*	1 of 12	$22.5T USD PPP, 18.6% of global GDP												
	current GDP per capita	8 of 12	$16k USD PPP												
population	*current population*	1 of 12	1,416 million 18% global pop.												
	current ratio: working age population to young plus elderly population	3 of 12	2.6:1												



data not applicable --
data not available *n.a.*
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PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

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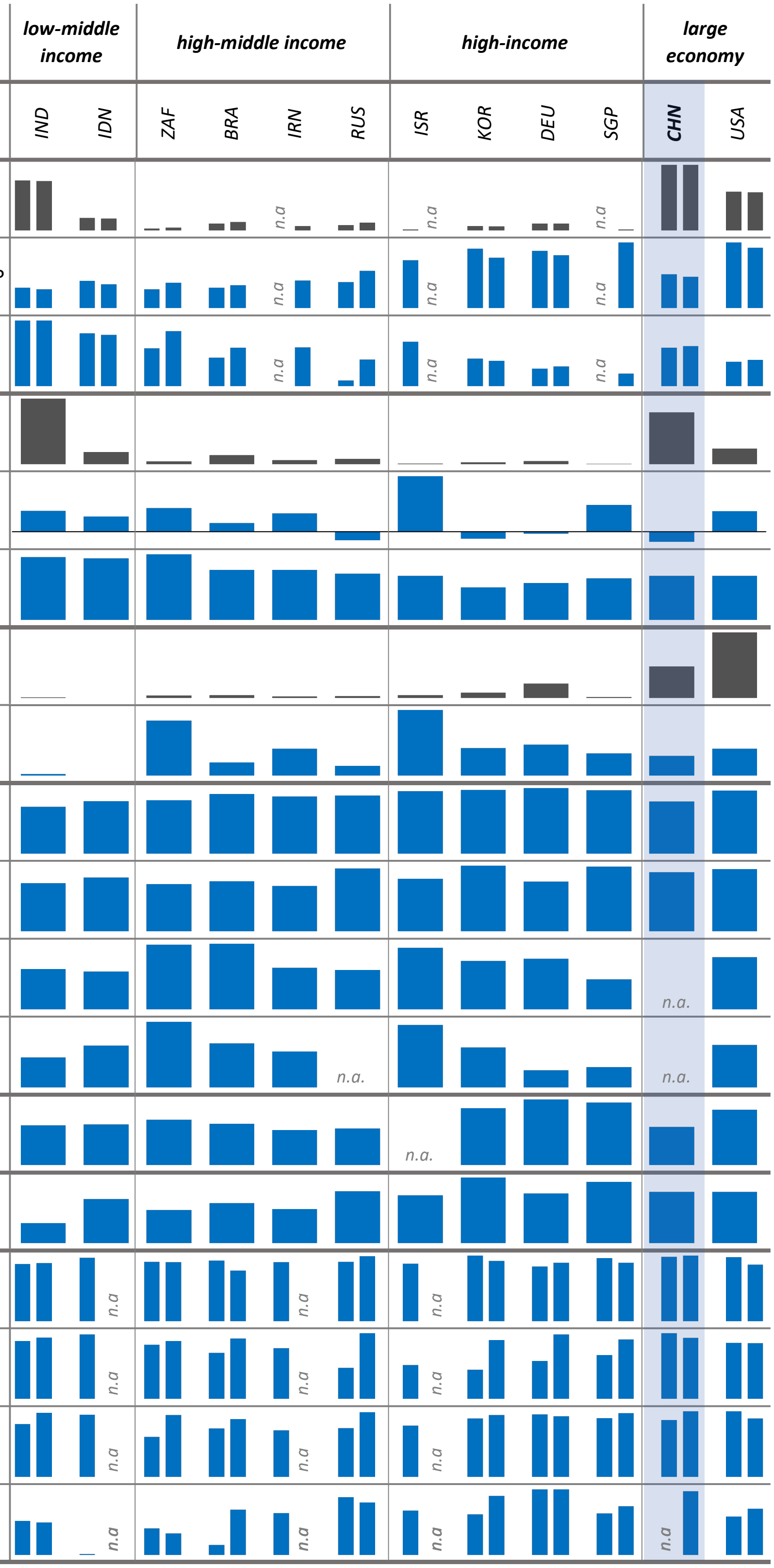
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

CHINA

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	1 of 12	$54-59T USD, 20-25% of global GDP
	2050 GDP per capita	6 of 12	$42-45k USD PPP
	GDP annual growth rate, 2018 to 2050	5 of 12	2.8-3.0%
population	*2050 population*	2 of 12	1,301 million, 14% of global pop.
	population growth rate, 2018 to 2050	12 of 12	-0.3%
	2050 ratio: working age population to young plus elderly population	7 of 12	1.5:1
universities	*share of top universities*	2 of 12	13.2%
	top universities relative to GDP	8 of 12	--
education	school life expectancy, primary through tertiary	11 of 12	13.5 years
	presence of science education in secondary school	5 of 12	89%
	government expenditure on education as percent of GDP	--	n.a.
	government expenditure on primary education as percent of GDP	--	n.a.
policy	rule of law (World Justice Project)	9 of 11	49/100 score
ICT	ICT adoption (WEF Global Competitiveness)	4 of 12	72/100 score 26/140 countries
beliefs about science	belief in science as future national benefit	1 of 12	85%
	belief in science as increasing jobs	2 of 12	75%
	belief in science as a personal benefit	4 of 12	77%
	trust in science over religion	2 of 12	78%



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relative strength compared to 12 countries (read across row)

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"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

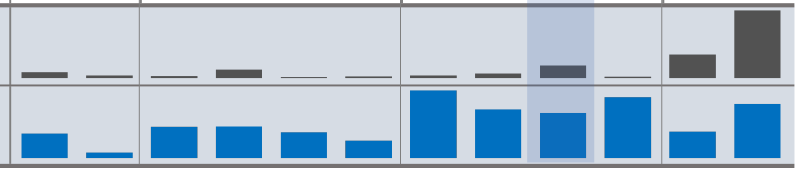
two bars indicate data from two separate sources

GERMANY

Biotech

sector scores	rank	value
biotech capacity scores	3 of 12	1.8/10 points
biotech innovation-driver scores	5 of 12	4.7/10 points

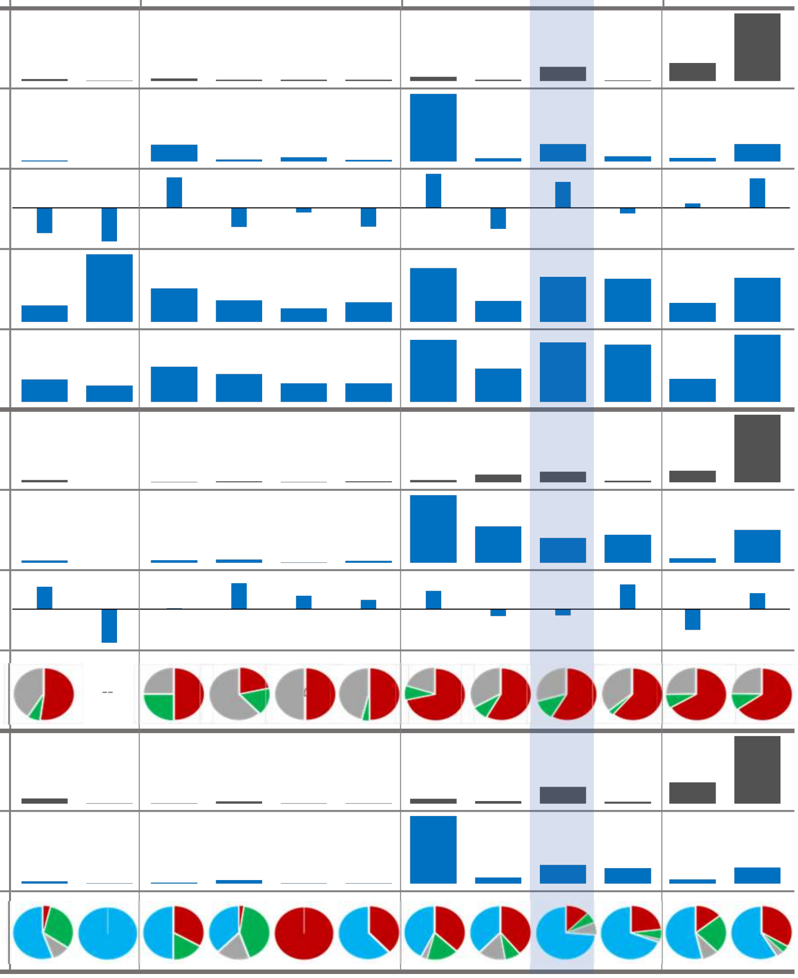
low-middle income: IND, IDN | high-middle income: ZAF, BRA, IRN, RUS | high-income: ISR, KOR, DEU, SGP | large economy: CHN, USA



Biotech: output measures

	indicator	rank	value
publications	*share of top biotech publications*	3 of 12	13%
	top biotech publications relative to GDP	3 of 12	--
	relative emphasis on biotech within top publications	4 of 12	+0.7 (-1 to 1)
	average citation count per biotech publication	3 of 12	--
	average citation count per biochemistry, genetics, and molecular biology publications	3 of 12	--
patents	*share of world biotech patents, 2014-2019*	3 of 12	7.1%
	biotech patents relative to GDP	5 of 12	--
	relative emphasis on biotech within patents	9 of 12	-0.19 (-1 to 1)
	proportion of red, green, or white biotech patents	--	58%, 12%, 29%
companies	*share of world biotech companies*	3 of 12	14%
	biotech companies relative to GDP	2 of 12	--
	proportion of red, green, white, or R&D service biotech companies	--	12%, 6%, 8%, 74%

low-middle income: IND, IDN | high-middle income: ZAF, BRA, IRN, RUS | high-income: ISR, KOR, DEU, SGP | large economy: CHN, USA



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

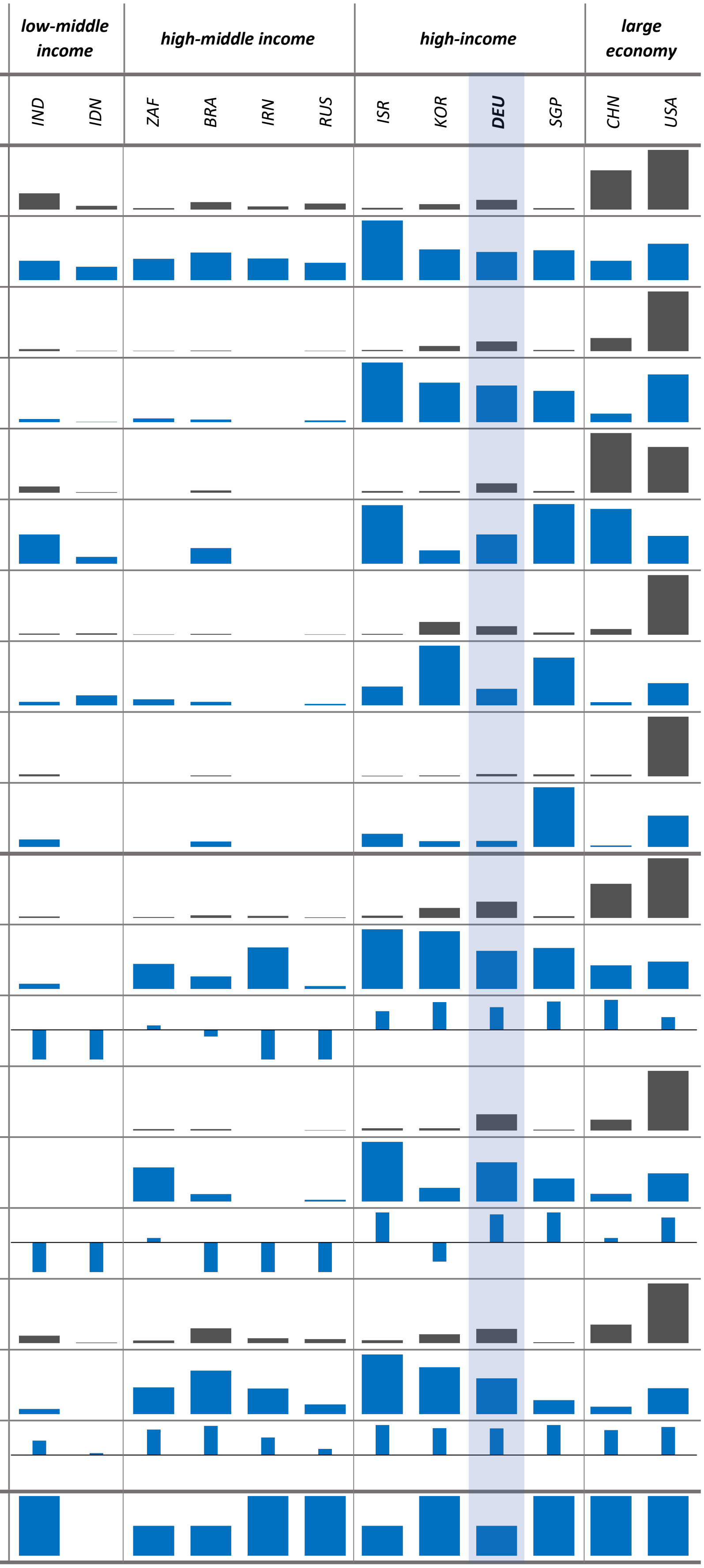
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

GERMANY

Biotech : drivers of innovation

	indicator	rank	value
talent	*users of largest genetic sequence database*	4 of 12	3.7% of users
	users of largest genetic sequence database relative to GDP	5 of 12	--
	users of a major genetic engineering tool supplier	3 of 12	5291 depositors
	users of a major genetic engineering tool supplier relative to GDP	4 of 12	--
	participation in international genetic engineering competition	3 of 12	4.7% of participants
	participation in international genetic engineering competition relative to GDP	4 of 12	--
	attendance at preeminent synthetic biology conferences	3 of 12	3.7% of attendees
	attendance at preeminent synthetic biology conferences relative to GDP	5 of 12	--
	subscribers to a prominent synthetic biology newsletter	2 of 12	2.3% of subscribers
	subscribers to a prominent synthetic biology newsletter relative to GDP	5 of 12	--
universities	*share of top biotech universities*	3 of 12	5.6%
	top biotech universities relative to GDP	5 of 12	--
	relative emphasis on biotech in top universities	4 of 12	+0.6 (-1 to 1)
	share of top biology universities	2 of 12	8.3%
	top biology universities relative to GDP	2 of 12	--
	relative emphasis on biology in top universities	3 of 12	+0.7 (-1 to 1)
	share of top life sciences universities	4 of 12	12.2%
	top life sciences universities relative to GDP	4 of 12	--
	relative emphasis on life sciences in top universities	6 of 12	+0.8 (-1 to 1)
policy	presence of a national biotechnology plan	8 of 12	0.5 of 1 pt



GERMANY

Biotech : drivers of innovation				***low-middle income***		***high-middle income***				***high-income***				***large economy***	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	***DEU***	*SGP*	*CHN*	*USA*
industry sector maturity	*share of total global biotech crops*	6 of 12	0%												
	biotech crops relative to total cropland	7 of 12	0.0%												
	share of total global biofuel production	3 of 12	3.3%												
	biotech fuels relative to total liquid fuel production	2 of 12	25.0%												
	average annual growth rate in biofuel production, 2006-2016	8 of 12	4.3%												
	clinical trials of biologics since 2010	4 of 12	6% of trials												
	clinical trials of biologics since 2010 scaled to GDP	6 of 12	--												
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	5 of 11	78/100 score					*n.a.*							
biodiversity	*well-studied animal and plant species*	12 of 12	1.6% of species												
	well-studied animal and plant species scaled to GDP	11 of 12	--												
	non-human sequence entries in largest genetic sequence database	5 of 12	1.8% of entries												
	non-human sequence entries in largest genetic sequence database scaled to GDP	6 of 12	--												
collaboration	*life sciences collaboration (Nature Index)*	2 of 12	32% of max score												
	life sciences collaborations relative to GDP	2 of 12	--												

data not applicable --

data not available *n.a.*

acronym: GDP: gross domestic product.
largest genetic sequence database: NIH GenBank.
major genetic engineering tool supplier: AddGene.
international genetic engineering competition: iGEM.
preeminent synthetic biology conference: SBx.0.
prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

GERMANY

Science and Technology

sector scores	rank	value	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	***DEU***	*SGP*	*CHN*	*USA*
			low-middle income		*high-middle income*				*high-income*				*large economy*	
science & technology capacity scores	3 of 12	2.8/10 points												
science & technology innovation-driver scores	4 of 12	6.8/10 points												

Science and Technology: output measures

	indicator	rank	value	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	***DEU***	*SGP*	*CHN*	*USA*
				low-middle income		*high-middle income*				*high-income*				*large economy*	
publications	*share of top high tech publications*	3 of 12	8.0%												
	top high tech publications relative to GDP	5 of 12	4 of 12 countries												
	relative emphasis on high tech within top publications	6 of 12	+0.5 (-1 to 1)												
patents	*share of world patents, 2014-2019*	3 of 12	8.6%												
	patents relative to GDP	3 of 12	3 of 12 countries												
STI output	knowledge and technology outputs (Global Innovation Index)	5 of 12	52/100 score; 10/126 countries												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product

STI: science and technology innovation

relative strength compared to 12 countries (read across row)

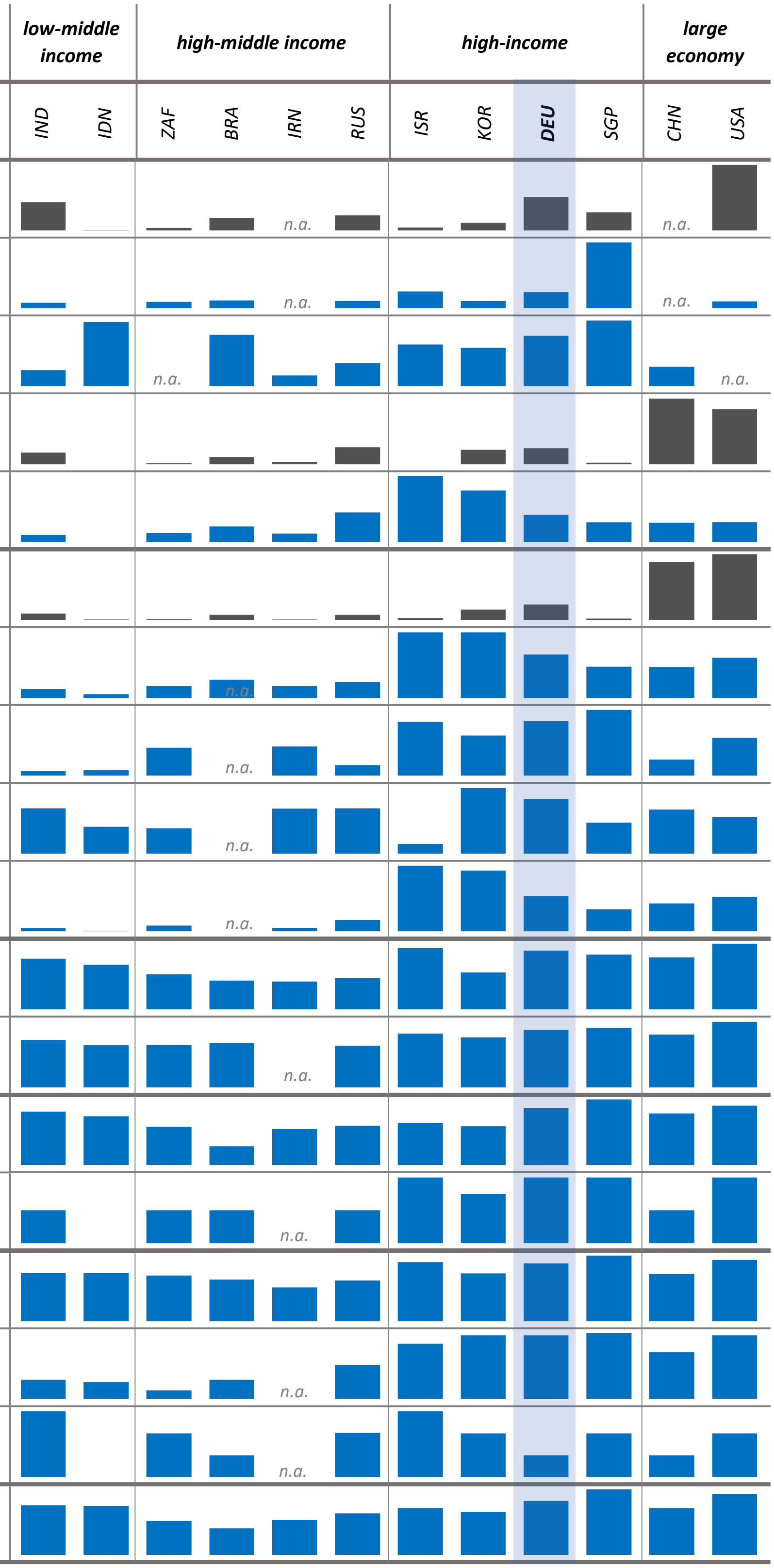
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

GERMANY

Science and Technology : drivers of innovation

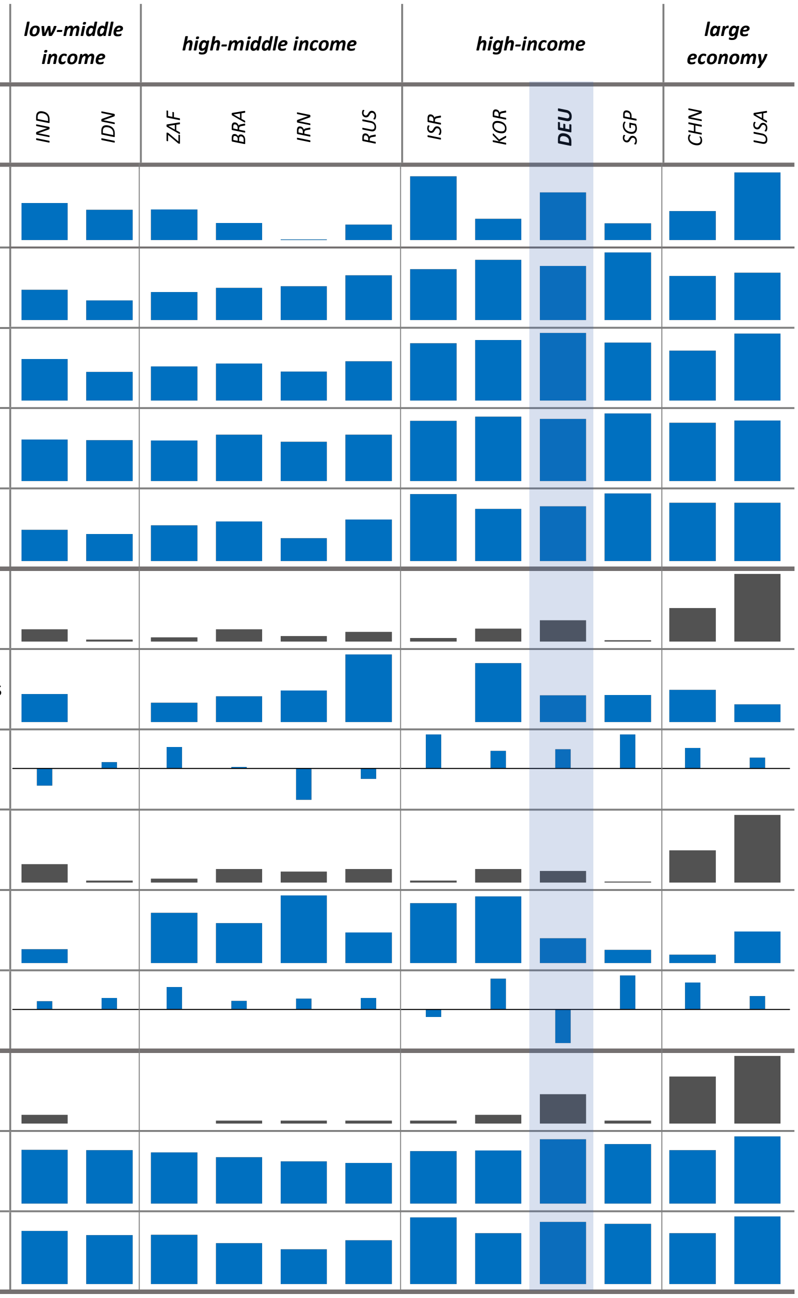
	indicator	rank	value
talent	*share of world STEM graduates*	2 of 10	10.7%
	STEM graduates relative to GDP	3 of 10	2 of 12 countries
	retention of foreign-educated PhD students	4 of 10	48.7%
	share of world researchers	4 of 12	3.7%
	researchers relative to GDP	4 of 12	4 of 12 countries
funding: research & development	*total expenditures on R&D*	3 of 12	$118B USD PPP
	total expenditures on R&D relative to GDP	--	3.0%
	R&D expenditures funded by higher ed. relative to GDP	--	0.52%
	R&D expenditures funded by government relative to GDP	--	0.41%
	R&D expenditures funded by business relative to GDP	--	2.09%
funding: venture capital	VC availability (Global Competitiveness Report)	3 of 12	5/7 score 3/140 countries
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	3 of 11	88/100 score
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	3 of 12	4.8/7 score 7/140 countries
	ease of technology transfer (US Chamber IP Index)	1 of 11	1/1 score
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	4 of 12	5.5/7 score 21/140 countries
	patents, related rights, and limitations (US Chamber IP Index)	2 of 11	7/7 score
	tax incentives in the creation of IP assets (US Chamber IP Index)	8 of 11	0/1 score
policy: future	future orientation of government (Global Competitiveness Report)	3 of 12	5.0/7 score 13/140 countries



GERMANY

Science and Technology : drivers of innovation

	indicator	rank	value
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	3 of 12	72%
	human capital and research (Global Innovation Index)	3 of 12	59/100 score; 10/126 countries
	innovation capability (Global Competitiveness Report)	1 of 12	88/100 score; 1/140 countries
	infrastructure (Global Innovation Index)	3 of 12	61/100 score; 19/126 countries
	business sophistication (Global Innovation Index)	5 of 12	53/100 score; 13/126 countries
universities	*share of top computer sciences universities*	3 of 12	5.1%
	top computer sciences universities relative to GDP	7 of 12	2 of 12 countries
	relative emphasis on computer sciences in top universities	5 of 12	+0.3 (-1 to 1)
	share of top engineering and technology universities	7 of 12	2.7%
	top engineering and technology universities relative to GDP	8 of 12	5 of 12 countries
	relative emphasis on engineering and technology in top universities	12 of 12	-0.3 (-1 to 1)
collaboration	*share of top international innovation clusters*	3 of 12	10%
	state of cluster development (Global Competitiveness Report)	2 of 12	5.5/7 score; 2/140 countries
	university-industry collaboration (Global Competitiveness Report)	3 of 12	5.4/7 score



data not applicable --

data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math
R&D: research and development. VC: venture capital.
GDP: gross domestic product. IP: intelllectual property.
IESE: graduate business school of the University of Navarra.

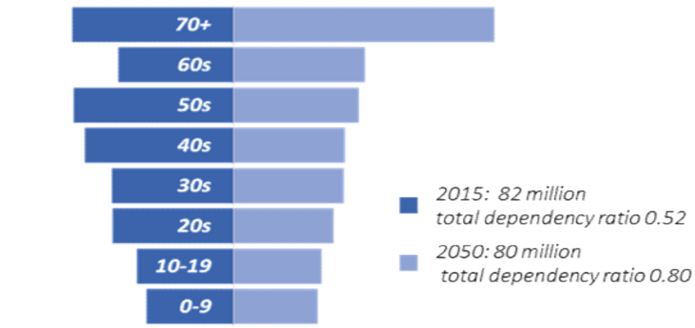
relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

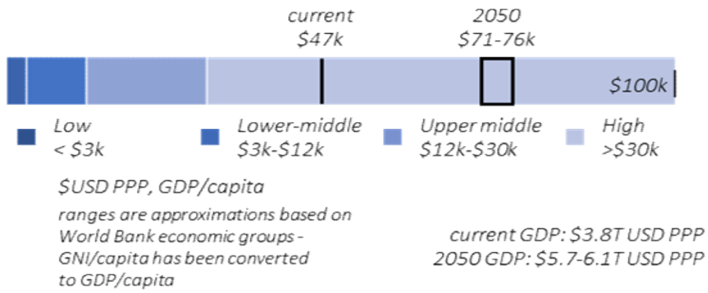
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

GERMANY

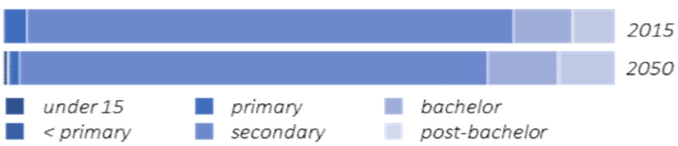
AGE DISTRIBUTION



ECONOMY: HIGH INCOME



EDUCATION DISTRIBUTION



EXTREME POVERTY DISTRIBUTION

General-societal

		low-middle income		high-middle income				high-income				large economy	
sector scores	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	***DEU***	*SGP*	*CHN*	*USA*
general-societal capacity scores	4 of 12	1.6/10 points												
general-societal innovation-driver scores	5 of 12	5.5/10 points												

General-societal: output measures

				low-middle income		high-middle income				high-income				large economy	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	***DEU***	*SGP*	*CHN*	*USA*
economy	*current GDP, PPP*	4 of 12	$3.8T USD PPP, 3.1% of global GDP												
	current GDP per capita	3 of 12	$47k USD PPP												
population	*current population*	8 of 12	82 million 1.0% global pop.												
	current ratio: working age population to young plus elderly population	9 of 12	1.9:1												

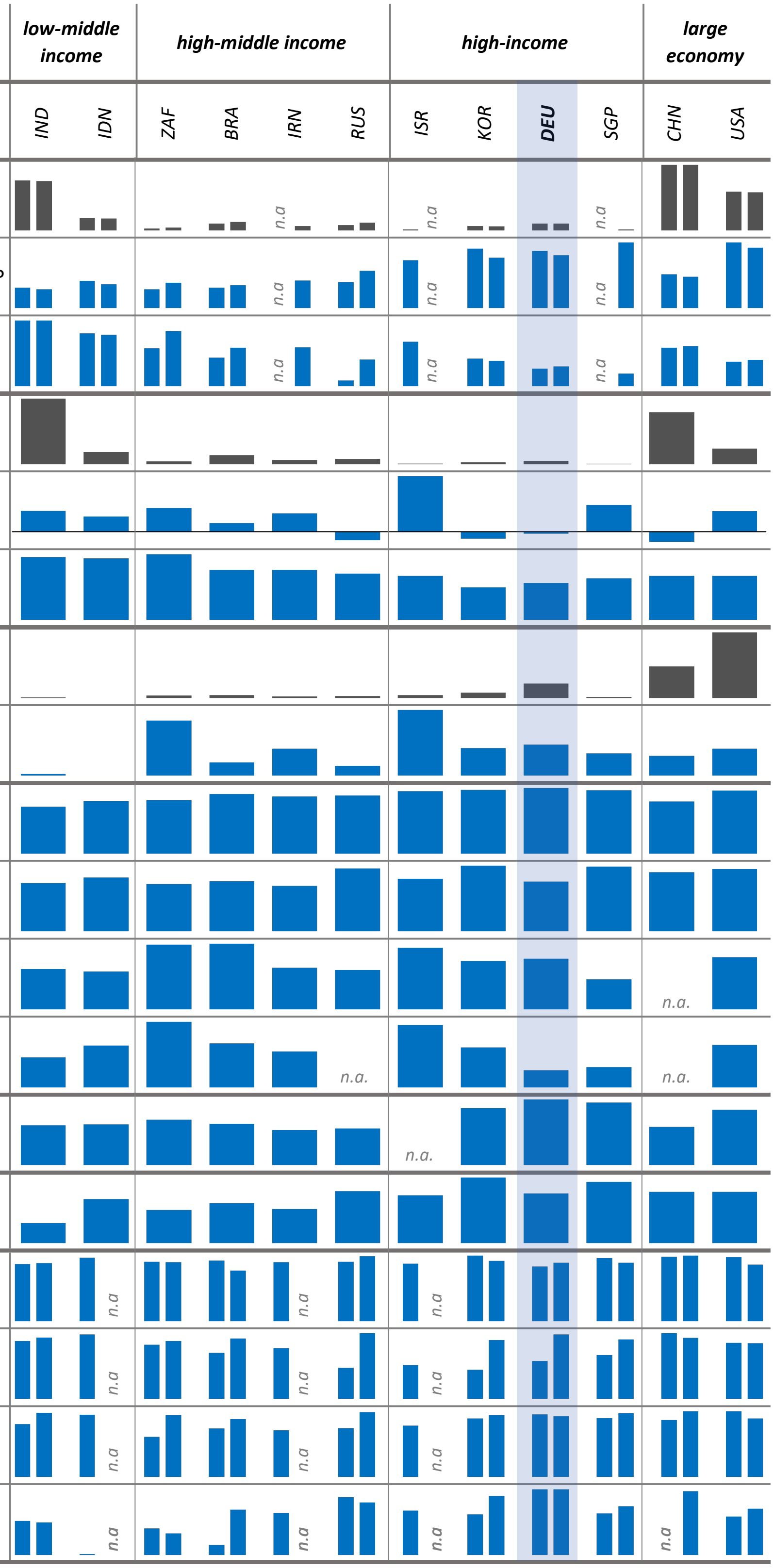
data not applicable --
data not available *n.a.*
acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

GERMANY

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	6 of 12	$5.7-6.1T USD, 2.1-2.7% of global GDP
	2050 GDP per capita	3 of 12	$71-76k USD PPP
	GDP annual growth rate, 2018 to 2050	10 of 12	1.2-1.5%
population	*2050 population*	8 of 12	80 million, 0.85% of global pop.
	population growth rate, 2018 to 2050	9 of 12	-0.1%
	2050 ratio: working age population to young plus elderly population	11 of 12	1.3:1
universities	*share of top universities*	3 of 12	6.0%
	top universities relative to GDP	3 of 12	--
education	school life expectancy, primary through tertiary	1 of 12	17.0 years
	presence of science education in secondary school	9 of 12	75%
	government expenditure on education as percent of GDP	5 of 11	4.8%
	government expenditure on primary education as percent of GDP	10 of 10	0.6%
policy	rule of law (World Justice Project)	1 of 11	84/100 score
ICT	ICT adoption (WEF Global Competitiveness)	6 of 12	69/100 score 31/140 countries
beliefs about science	belief in science as future national benefit	11 of 12	74%
	belief in science as increasing jobs	8 of 12	61%
	belief in science as a personal benefit	3 of 12	78%
	trust in science over religion	1 of 12	72%



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data not available *n.a.*

acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

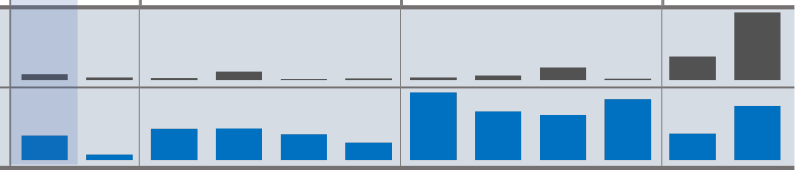
two bars indicate data from two separate sources

INDIA

Biotech

low-middle income		high-middle income				high-income				large economy	
IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA

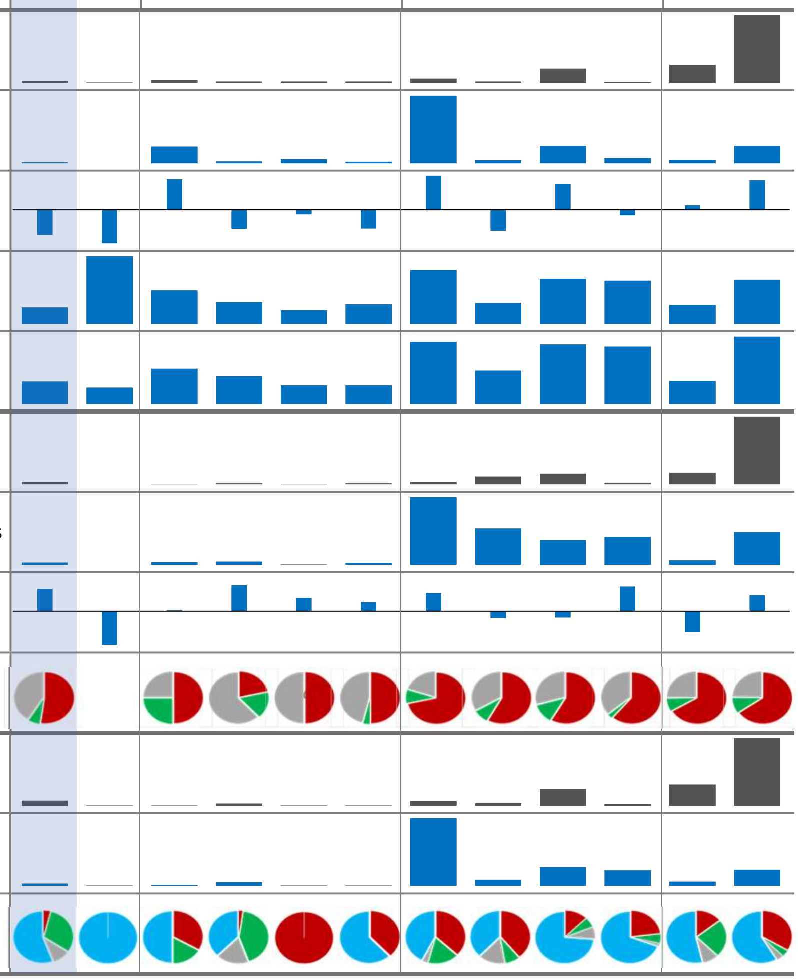
sector scores	rank	value
biotech capacity scores	5 of 12	0.8/10 points
biotech innovation-driver scores	10 of 12	2.5/10 points



Biotech: output measures

low-middle income		high-middle income				high-income				large economy	
IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA

	indicator	rank	value
publications	*share of top biotech publications*	6 of 12	1.7%
	top biotech publications relative to GDP	11 of 12	11 of 12 countries
	relative emphasis on biotech within top publications	11 of 12	-0.7 (-1 to 1)
	average citation count per biotech publication	11 of 12	11 of 12 countries
	average citation count per biochemistry, genetics, and molecular biology publications	9 of 12	9 of 12 countries
patents	*share of world biotech patents, 2014-2019*	5 of 12	1.6%
	biotech patents relative to GDP	9 of 12	8 of 12 countries
	relative emphasis on biotech within patents	3 of 12	+0.7 (-1 to 1)
	proportion of red, green, or white biotech patents	--	52%, 7%, 41%
companies	*share of world biotech companies*	4 of 12	4.1%
	biotech companies relative to GDP	8 of 12	8 of 12 countries
	proportion of red, green, white, or R&D service biotech companies	--	4%, 31%, 10%, 56%



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

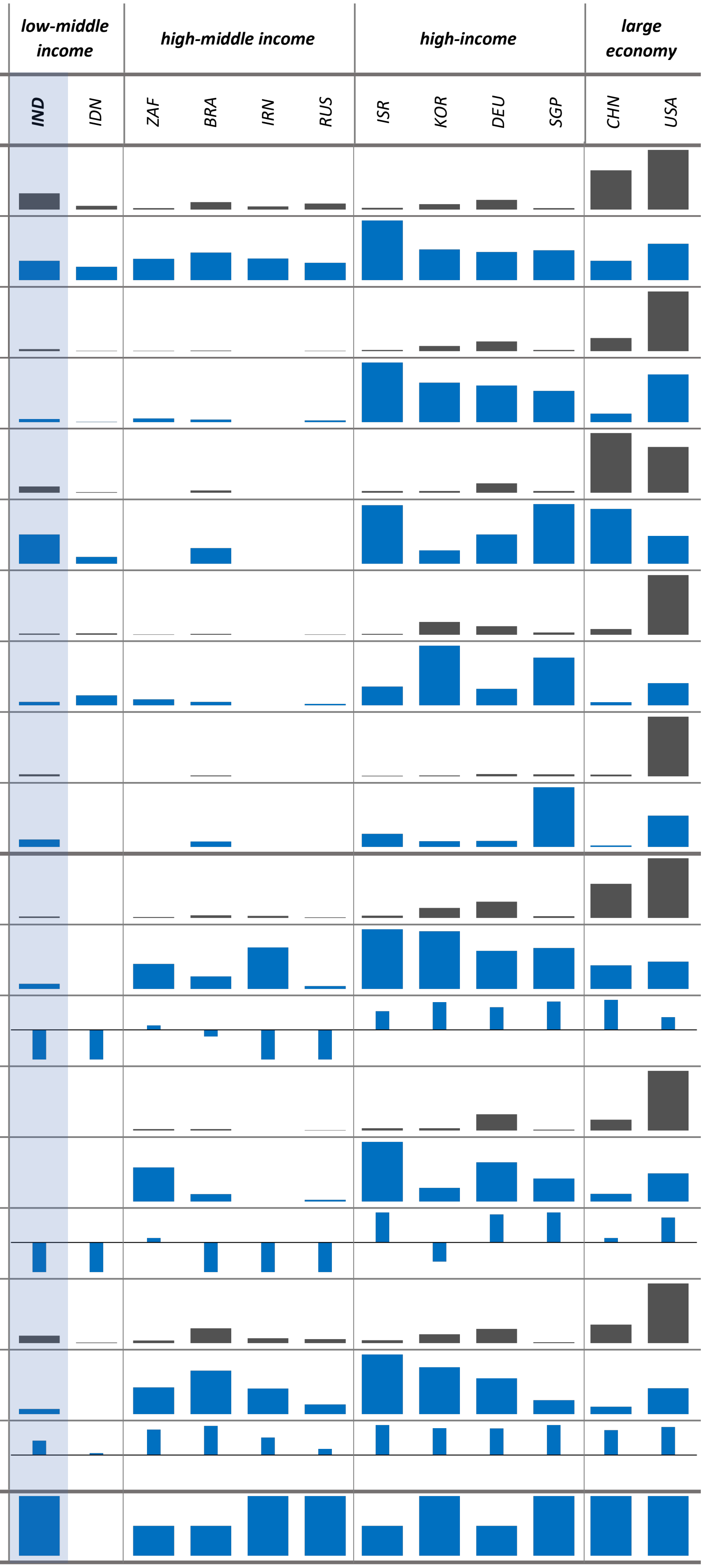
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

INDIA

Biotech : drivers of innovation

	indicator	rank	value
talent	*users of largest genetic sequence database*	3 of 12	6.2% of users
	users of largest genetic sequence database relative to GDP	10 of 12	--
	users of a major genetic engineering tool supplier	5 of 12	1151 depositors
	users of a major genetic engineering tool supplier relative to GDP	8 of 12	--
	participation in international genetic engineering competition	4 of 12	3.2% of participants
	participation in international genetic engineering competition relative to GDP	5 of 12	--
	attendance at preeminent synthetic biology conferences	7 of 12	0.54% of attendees
	attendance at preeminent synthetic biology conferences relative to GDP	8 of 12	--
	subscribers to a prominent synthetic biology newsletter	4 of 12	2.0% of subscribers
	subscribers to a prominent synthetic biology newsletter relative to GDP	4 of 12	--
universities	*share of top biotech universities*	9 of 12	0.5%
	top biotech universities relative to GDP	10 of 12	--
	relative emphasis on biotech in top universities	10 of 12	-0.8 (-1 to 1)
	share of top biology universities	10 of 12	0.0%
	top biology universities relative to GDP	10 of 12	--
	relative emphasis on biology in top universities	10 of 12	-1 (-1 to 1)
	share of top life sciences universities	6 of 12	6.3%
	top life sciences universities relative to GDP	11 of 12	--
	relative emphasis on life sciences in top universities	10 of 12	+0.5 (-1 to 1)
policy	presence of a national biotechnology plan	1 of 12	1 of 1 pt



INDIA

Biotech : drivers of innovation

				low-middle income		*high-middle income*				*high-income*				*large economy*	
	indicator	**rank**	**value**	***IND***	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
industry sector maturity	*share of total global biotech crops*	3 of 12	6%												
	biotech crops relative to total cropland	4 of 12	7.4%												
	share of total global biofuel production	6 of 12	0.9%												
	biotech fuels relative to total liquid fuel production	8 of 12	2.1%												
	average annual growth rate in biofuel production, 2006-2016	4 of 12	27.3%												
	clinical trials of biologics since 2010	8 of 12	2% of trials												
	clinical trials of biologics since 2010 scaled to GDP	11 of 12	--												
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	6 of 11	59/100 score					*n.a.*							
biodiversity	*well-studied animal and plant species*	5 of 12	7.1% of species												
	well-studied animal and plant species scaled to GDP	8 of 12	--												
	non-human sequence entries in largest genetic sequence database	3 of 12	3.4% of entries												
	non-human sequence entries in largest genetic sequence database scaled to GDP	7 of 12	--												
collaboration	*life sciences collaboration (Nature Index)*	9 of 12	1.3% of max score												
	life sciences collaborations relative to GDP	11 of 12	--												

data not applicable --

data not available *n.a.*

acronym: GDP: gross domestic product.
largest genetic sequence database: NIH GenBank.
major genetic engineering tool supplier: AddGene.
international genetic engineering competition: iGEM.
preeminent synthetic biology conference: SBx.0.
prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

INDIA

Science and Technology

sector scores	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
science & technology capacity scores	5 of 12	1.3/10 points												
science & technology innovation-driver scores	7 of 12	3.7/10 points												

Science and Technology: output measures

	indicator	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
publications	*share of top high tech publications*	6 of 12	1.7%												
	top high tech publications relative to GDP	11 of 12	--												
	relative emphasis on high tech within top publications	10 of 12	-0.7 (-1 to 1)												
patents	*share of world patents, 2014-2019*	6 of 12	0.7%												
	patents relative to GDP	10 of 12	--												
STI output	knowledge and technology outputs (Global Innovation Index)	8 of 12	30/100 score; 43/126 countries												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product

STI: science and technology innovation

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

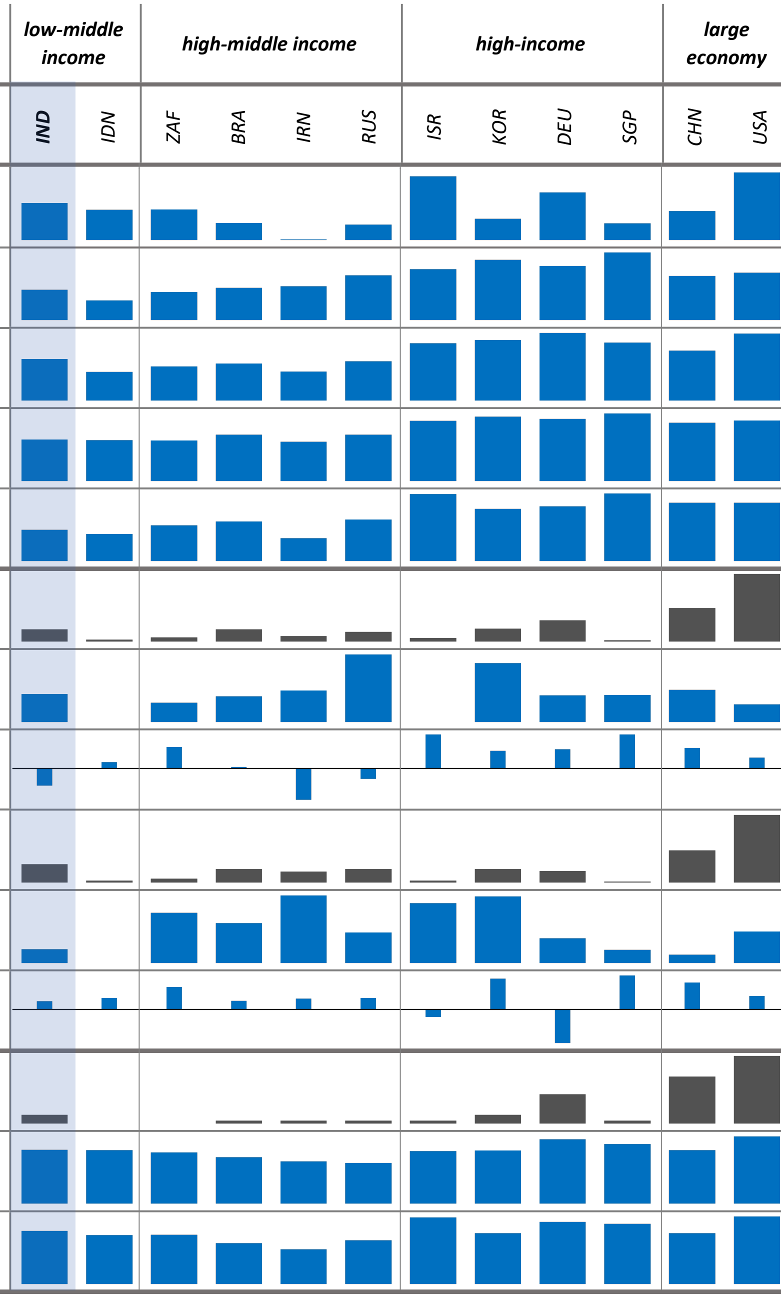
INDIA

Science and Technology : drivers of innovation				low-middle income		high-middle income				high-income				large economy	
	indicator	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
talent	*share of world STEM graduates*	3 of 10	8.9%					n.a.						n.a.	
	STEM graduates relative to GDP	9 of 10	--					n.a.						n.a.	
	retention of foreign-educated PhD students	9 of 10	15.5%			n.a.									n.a.
	share of world researchers	6 of 12	2.6%												
	researchers relative to GDP	11 of 12	--												
funding: research & development	*total expenditures on R&D*	5 of 12	$50B USD PPP												
	total expenditures on R&D relative to GDP	11 of 12	0.6%												
	R&D expenditures funded by higher ed. relative to GDP	11 of 11	0.04%				n.a.								
	R&D expenditures funded by government relative to GDP	3 of 11	0.34%				n.a.	n.a.							
	R&D expenditures funded by business relative to GDP	10 of 11	0.19%				n.a.								
funding: venture capital	VC availability (Global Competitiveness Report)	6 of 12	4.3/7 score 13/140 countries												
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	7 of 11	72/100 score					n.a.							
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	4 of 12	4.5/7 score 16/140 countries												
	ease of technology transfer (US Chamber IP Index)	6 of 11	0.5/1 score					n.a.							
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	6 of 12	4.6/7 score 45/140 countries												
	patents, related rights, and limitations (US Chamber IP Index)	8 of 11	2.3/7 score					n.a.							
	tax incentives in the creation of IP assets (US Chamber IP Index)	1 of 11	1/1 score					n.a.							
policy: future	future orientation of government (Global Competitiveness Report)	4 of 12	4.7/7 score 21/140 countries												

INDIA

Science and Technology : drivers of innovation

	indicator	rank	value
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	4 of 12	66%
	human capital and research (Global Innovation Index)	10 of 12	33/100 score 56/126 countries
	innovation capability (Global Competitiveness Report)	7 of 12	54/100 score 31/140 countries
	infrastructure (Global Innovation Index)	9 of 12	40/100 score 77/126 countries
	business sophistication (Global Innovation Index)	10 of 12	30/100 score 64/126 countries
universities	*share of top computer sciences universities*	5 of 12	2.9%
	top computer sciences universities relative to GDP	5 of 12	--
	relative emphasis on computer sciences in top universities	11 of 12	-0.3 (-1 to 1)
	share of top engineering and technology universities	3 of 12	4.2%
	top engineering and technology universities relative to GDP	9 of 12	--
	relative emphasis on engineering and technology in top universities	10 of 12	+0.1 (-1 to 1)
collaboration	*share of top international innovation clusters*	4 of 12	3.0%
	state of cluster development (Global Competitiveness Report)	4 of 12	4.6/7 score 26/140 countries
	university-industry collaboration (Global Competitiveness Report)	5 of 12	4.6/7 score



data not applicable --

data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math
R&D: research and development. VC: venture capital.
GDP: gross domestic product. IP: intelllectual property.
IESE: graduate business school of the University of Navarra.

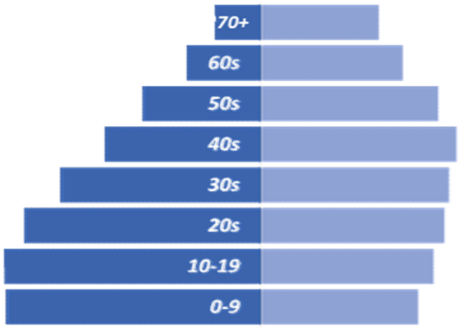
relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

INDIA

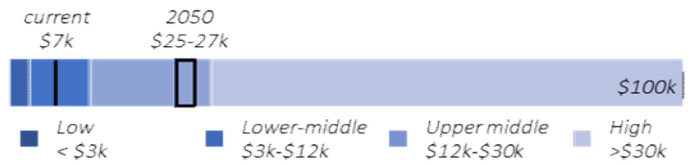
AGE DISTRIBUTION



2015: 1.3 billion
total dependency ratio 0.52

2050: 1.6 billion
total dependency ratio 0.47

ECONOMY: LOWER-MIDDLE INCOME

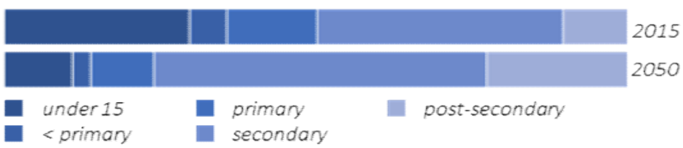


$USD PPP, GDP/capita

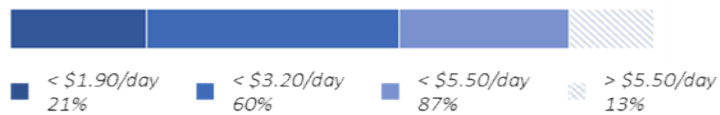
ranges are approximations based on World Bank economic groups - GNI/capita has been converted to GDP/capita

current GDP: $9.3T USD PPP
2050 GDP: $42-44T USD PPP

EDUCATION DISTRIBUTION



EXTREME POVERTY DISTRIBUTION



General-societal

sector scores	rank	value	low-middle income		high-middle income				high-income				large economy	
			IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
general-societal capacity scores	3 of 12	4/10 points												
general-societal innovation-driver scores	12 of 12	2.3/10 points												

General-societal: output measures

	indicator	rank	value	low-middle income		high-middle income				high-income				large economy	
				IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
economy	*current GDP, PPP*	3 of 12	$9.3T USD PPP, 7.7% of global GDP												
	current GDP per capita	12 of 12	$6.7k USD PPP												
population	*current population*	2 of 12	1,382 million 18% global pop.												
	current ratio: working age population to young plus elderly population	9 of 12	1.9:1												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

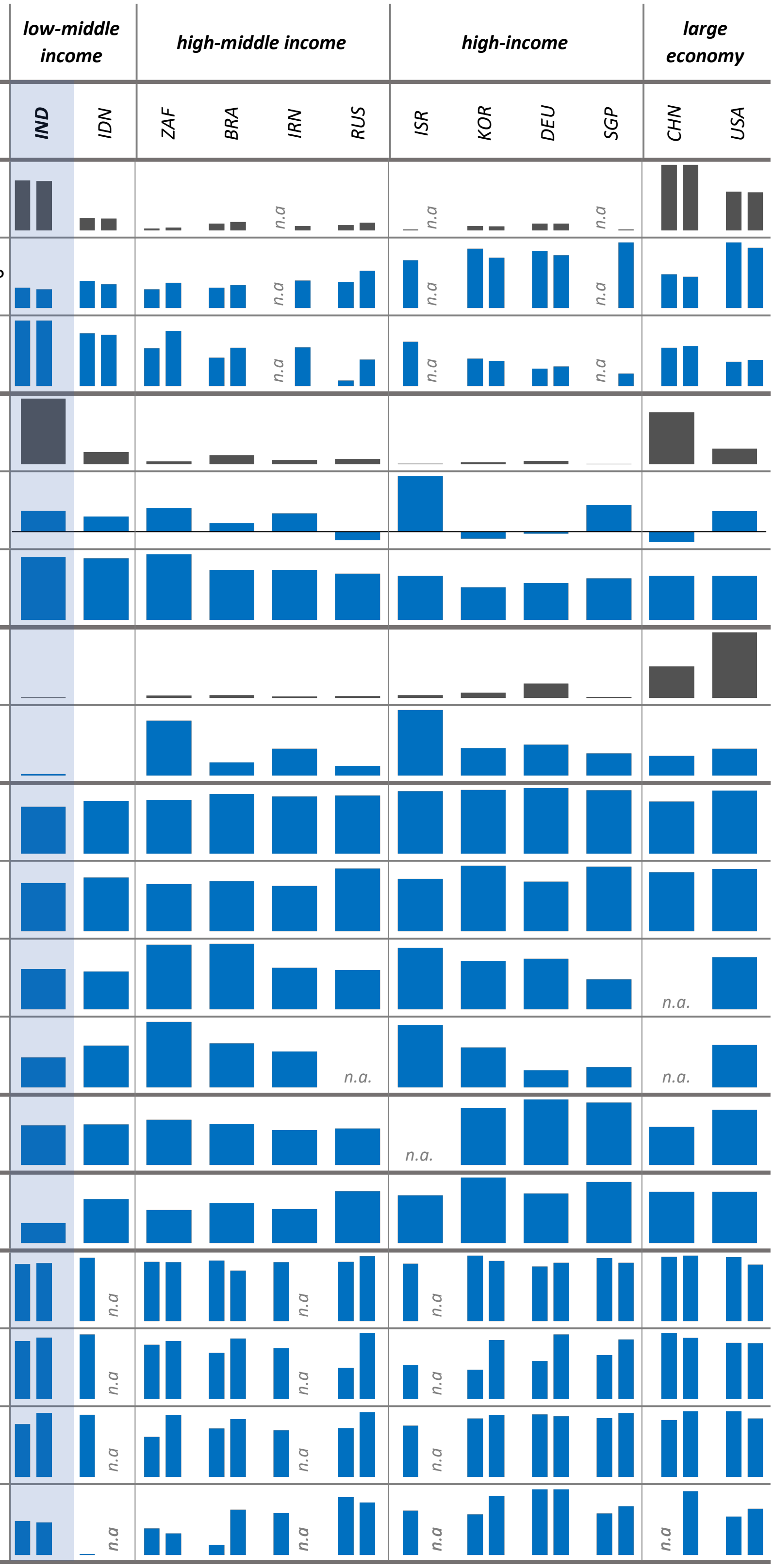
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

INDIA

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	2 of 12	$41-44T USD, 15-19% of global GDP
	2050 GDP per capita	12 of 12	$25-27k USD PPP
	GDP annual growth rate, 2018 to 2050	1 of 12	4.8-5.0%
population	*2050 population*	1 of 12	1,642 million, 17.5% of global pop.
	population growth rate, 2018 to 2050	4 of 12	0.6%
	2050 ratio: working age population to young plus elderly population	2 of 12	2.1:1
universities	*share of top universities*	11 of 12	2.0%
	top universities relative to GDP	11 of 12	--
education	school life expectancy, primary through tertiary	12 of 12	12.3 years
	presence of science education in secondary school	10 of 12	73%
	government expenditure on education as percent of GDP	8 of 11	3.8%
	government expenditure on primary education as percent of GDP	8 of 10	1.1%
policy	rule of law (World Justice Project)	8 of 11	51/100 score
ICT	ICT adoption (WEF Global Competitiveness)	12 of 12	28/100 score 117/140 countries
beliefs about science	belief in science as future national benefit	9 of 12	76%
	belief in science as increasing jobs	3 of 12	71%
	belief in science as a personal benefit	7 of 12	73%
	trust in science over religion	9 of 12	37%



data not applicable --
data not available *n.a.*
acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

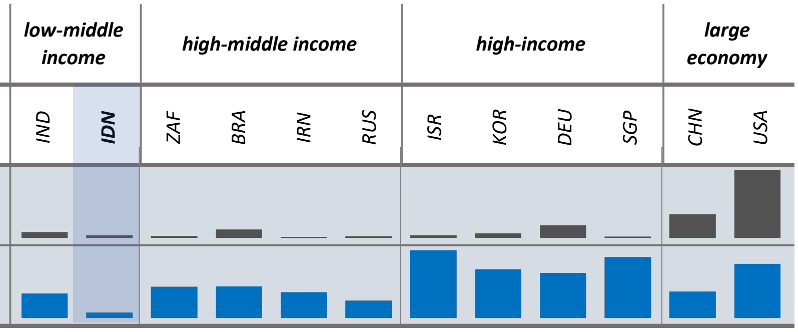
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

two bars indicate data from two separate sources

INDONESIA

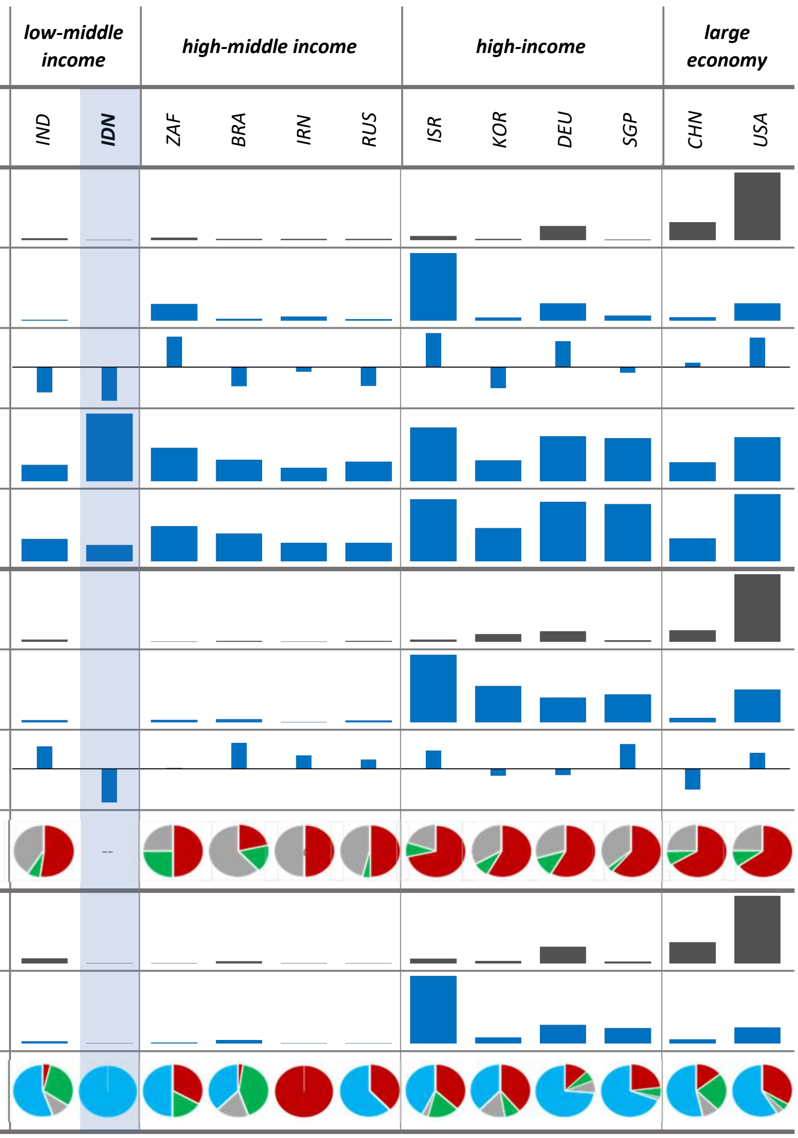
Biotech

sector scores	rank	value
biotech capacity scores	8 of 12	0.4/10 points
biotech innovation-driver scores	12 of 12	0.6/10 points



Biotech: output measures

	indicator	rank	value
publications	*share of top biotech publications*	12 of 12	0.05%
	top biotech publications relative to GDP	12 of 12	--
	relative emphasis on biotech within top publications	12 of 12	-1 (-1 to 1)
	average citation count per biotech publication	1 of 12	--
	average citation count per biochemistry, genetics, and molecular biology publications	12 of 12	--
patents	*share of world biotech patents, 2014-2019*	12 of 12	0%
	biotech patents relative to GDP	12 of 12	--
	relative emphasis on biotech within patents	12 of 12	+0 (-1 to 1)
	proportion of red, green, or white biotech patents	--	--
companies	*share of world biotech companies*	11 of 12	0.08%
	biotech companies relative to GDP	12 of 12	--
	proportion of red, green, white, or R&D service biotech companies	--	0%, 0%, 0%, 100%



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

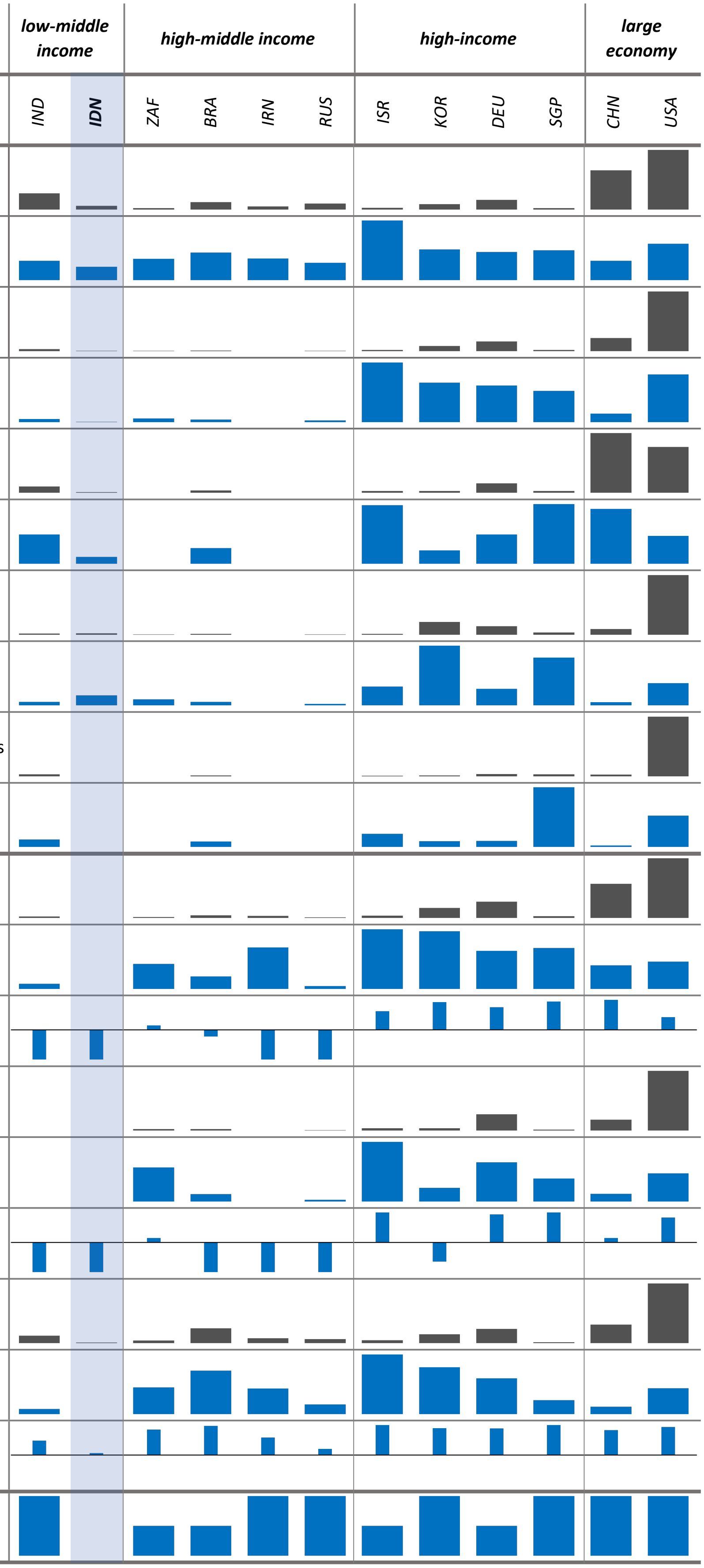
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

INDONESIA

Biotech : drivers of innovation

category	indicator	rank	value
talent	*users of largest genetic sequence database*	8 of 12	1.4% of users
talent	users of largest genetic sequence database relative to GDP	12 of 12	--
talent	*users of a major genetic engineering tool supplier*	11 of 12	23 depositors
talent	users of a major genetic engineering tool supplier relative to GDP	11 of 12	--
talent	*participation in international genetic engineering competition*	9 of 12	0.29% of participants
talent	participation in international genetic engineering competition relative to GDP	9 of 12	--
talent	*attendance at preeminent synthetic biology conferences*	6 of 12	0.6% of attendees
talent	attendance at preeminent synthetic biology conferences relative to GDP	6 of 12	--
talent	*subscribers to a prominent synthetic biology newsletter*	9 of 12	0% of subscribers
talent	subscribers to a prominent synthetic biology newsletter relative to GDP	9 of 12	--
universities	*share of top biotech universities*	12 of 12	0.0%
universities	top biotech universities relative to GDP	12 of 12	--
universities	relative emphasis on biotech in top universities	12 of 12	-1 (-1 to 1)
universities	*share of top biology universities*	10 of 12	0.0%
universities	top biology universities relative to GDP	10 of 12	--
universities	relative emphasis on biology in top universities	10 of 12	-1 (-1 to 1)
universities	*share of top life sciences universities*	12 of 12	0.4%
universities	top life sciences universities relative to GDP	12 of 12	--
universities	relative emphasis on life sciences in top universities	12 of 12	+0.1 (-1 to 1)
policy	presence of a national biotechnology plan	12 of 12	0.5 of 1 pt



INDONESIA

Biotech : drivers of innovation

	indicator	rank	value	*low-middle income*		*high-middle income*				*high-income*				*large economy*	
				IND	***IDN***	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
industry sector maturity	*share of total global biotech crops*	6 of 12	0%												
	biotech crops relative to total cropland	6 of 12	0.2%												
	share of total global biofuel production	4 of 12	2.7%												
	biotech fuels relative to total liquid fuel production	6 of 12	6.7%												
	average annual growth rate in biofuel production, 2006-2016	1 of 12	85%												
	clinical trials of biologics since 2010	12 of 12	0% of trials												
	clinical trials of biologics since 2010 scaled to GDP	12 of 12	--												
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	11 of 11	44/100 score					*n.a.*							
biodiversity	*well-studied animal and plant species*	1 of 12	9.9% of species												
	well-studied animal and plant species scaled to GDP	4 of 12	--												
	non-human sequence entries in largest genetic sequence database	9 of 12	0.6% of entries												
	non-human sequence entries in largest genetic sequence database scaled to GDP	12 of 12	--												
collaboration	*life sciences collaboration (Nature Index)*	11 of 12	0.35% of max score												
	life sciences collaborations relative to GDP	12 of 12	--												

data not applicable --

data not available *n.a.*

acronym: GDP: gross domestic product.
largest genetic sequence database: NIH GenBank.
major genetic engineering tool supplier: AddGene.
international genetic engineering competition: iGEM.
preeminent synthetic biology conference: SBx.0.
prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

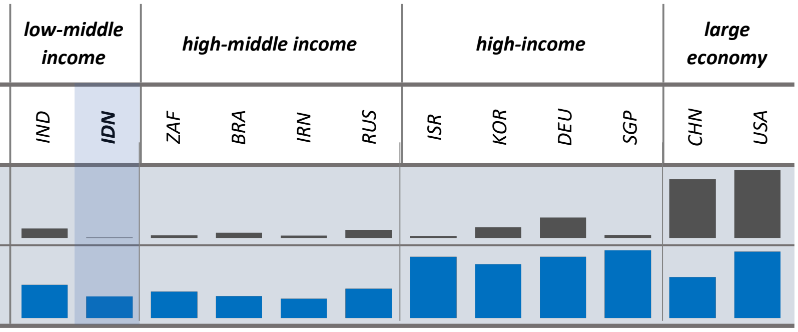
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

INDONESIA

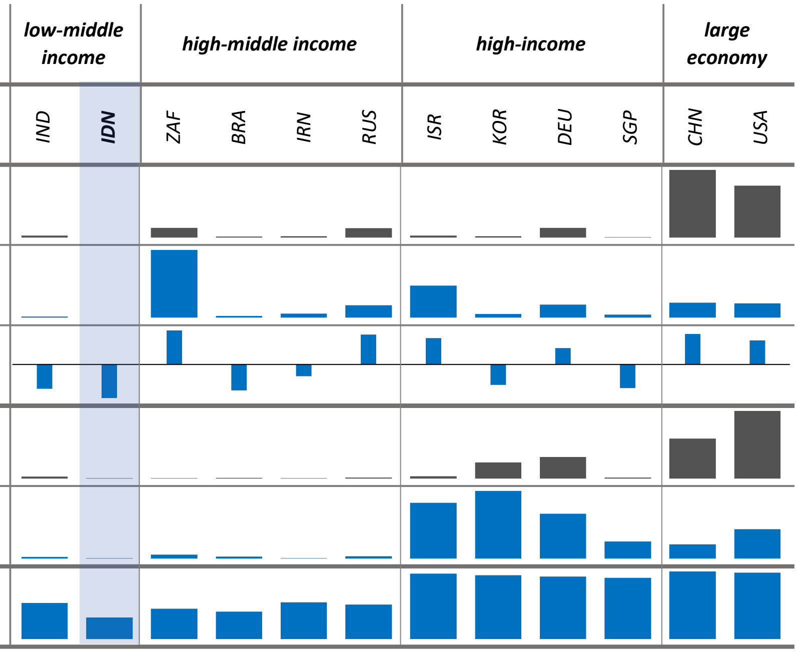
Science and Technology

sector scores	rank	value
science & technology capacity scores	12 of 12	0.03/10 points
science & technology innovation-driver scores	11 of 12	2.4/10 points



Science and Technology: output measures

	indicator	rank	value
publications	*share of top high tech publications*	12 of 12	0.0%
	top high tech publications relative to GDP	12 of 12	12 of 12 countries
	relative emphasis on high tech within top publications	12 of 12	-1 (-1 to 1)
patents	*share of world patents, 2014-2019*	12 of 12	0.01%
	patents relative to GDP	12 of 12	12 of 12 countries
STI output	knowledge and technology outputs (Global Innovation Index)	12 of 12	18/100 score; 86/126 countries



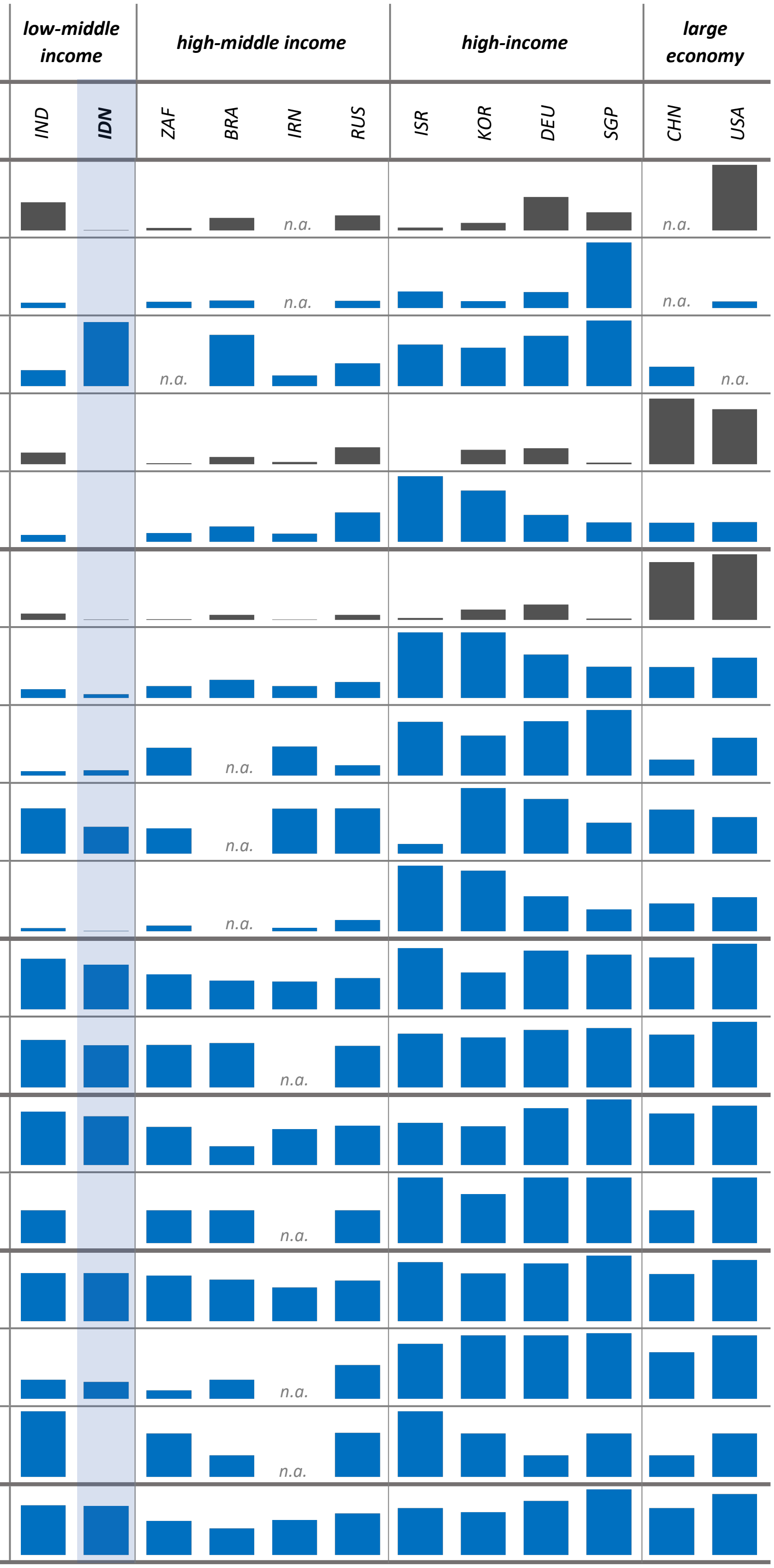
data not applicable --
data not available *n.a.*
acronyms: GDP: gross domestic product
STI: science and technology innovation

relative strength compared to 12 countries (read across row)
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

INDONESIA

Science and Technology : drivers of innovation

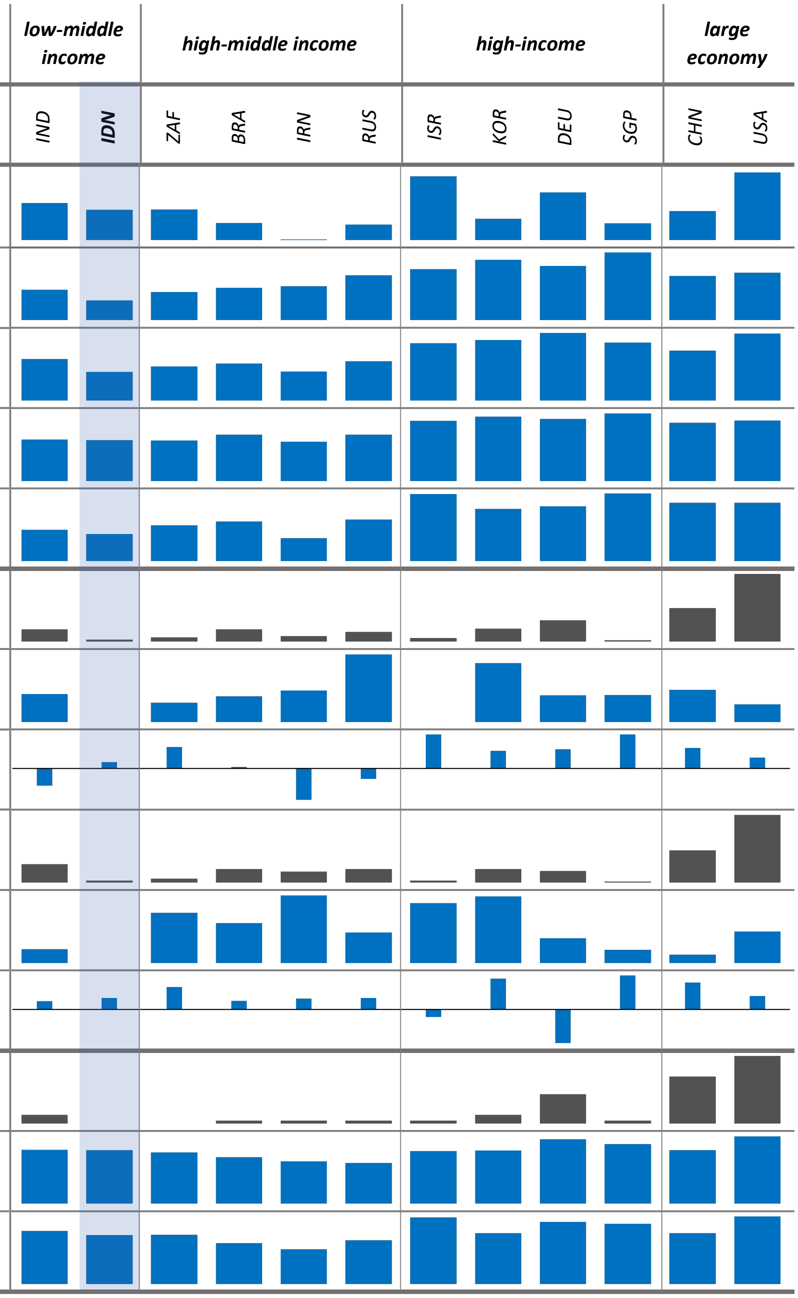
	indicator	rank	value
talent	*share of world STEM graduates*	10 of 10	0.1%
talent	STEM graduates relative to GDP	10 of 10	--
talent	retention of foreign-educated PhD students	2 of 10	62%
talent	*share of world researchers*	11 of 12	0%
talent	researchers relative to GDP	12 of 12	--
funding: research & development	*total expenditures on R&D*	12 of 12	$2.1B USD PPP
funding: research & development	total expenditures on R&D relative to GDP	12 of 12	0.27%
funding: research & development	R&D expenditures funded by higher ed. relative to GDP	10 of 11	0.05%
funding: research & development	R&D expenditures funded by government relative to GDP	9 of 11	0.20%
funding: research & development	R&D expenditures funded by business relative to GDP	11 of 11	0.02%
funding: venture capital	VC availability (Global Competitiveness Report)	7 of 12	3.8/7 score 25/140 countries
funding: venture capital	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	10 of 11	64/100 score
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	6 of 12	4.1/7 score 26/140 countries
policy: regulatory burden	ease of technology transfer (US Chamber IP Index)	11 of 11	0.0/1 score
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	5 of 12	4.6/7 score 44/140 countries
policy: intellectual property	patents, related rights, and limitations (US Chamber IP Index)	10 of 11	2.0/7 score
policy: intellectual property	tax incentives in the creation of IP assets (US Chamber IP Index)	11 of 11	0/1 score
policy: future	future orientation of government (Global Competitiveness Report)	5 of 12	4.6/7 score 24/140 countries



INDONESIA

Science and Technology : drivers of innovation

	indicator	rank	value	
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	6 of 12	63%	
	human capital and research (Global Innovation Index)	12 of 12	21/100 score	94/126 countries
	innovation capability (Global Competitiveness Report)	12 of 12	37/100 score	68/140 countries
	infrastructure (Global Innovation Index)	10 of 12	40/100 score	82/126 countries
	business sophistication (Global Innovation Index)	11 of 12	26/100 score	89/126 countries
universities	*share of top computer sciences universities*	11 of 12	0.44%	
	top computer sciences universities relative to GDP	11 of 12	--	
	relative emphasis on computer sciences in top universities	8 of 12	+0.1	(-1 to 1)
	share of top engineering and technology universities	10 of 12	0.44%	
	top engineering and technology universities relative to GDP	12 of 12	--	
	relative emphasis on engineering and technology in top universities	6 of 12	+0.1	(-1 to 1)
collaboration	*share of top international innovation clusters*	11 of 12	0.0%	
	state of cluster development (Global Competitiveness Report)	5 of 12	4.6/7 score	28/140 countries
	university-industry collaboration (Global Competitiveness Report)	9 of 12	4.2/7 score	



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data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math
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relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

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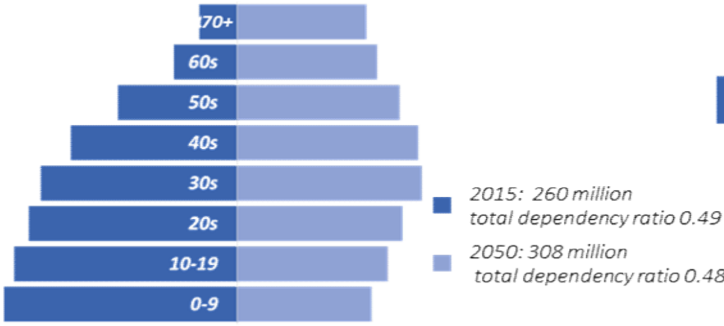
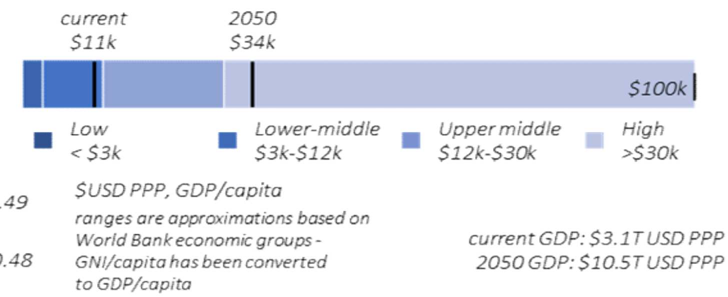
INDONESIA

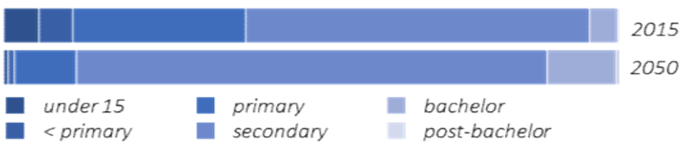
AGE DISTRIBUTION



ECONOMY: LOWER-MIDDLE INCOME



EDUCATION DISTRIBUTION



EXTREME POVERTY DISTRIBUTION

General-societal			*low-middle income*		*high-middle income*				*high-income*				*large economy*	
sector scores	**rank**	**value**	*IND*	***IDN***	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
general-societal capacity scores	7 of 12	1/10 points												
general-societal innovation-driver scores	8 of 12	3.5/10 points												

General-societal: output measures				*low-middle income*		*high-middle income*				*high-income*				*large economy*	
	indicator	**rank**	**value**	*IND*	***IDN***	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
economy	*current GDP, PPP*	6 of 12	$3.1T USD PPP, 2.6% of global GDP												
	current GDP per capita	11 of 12	$11k USD PPP												
population	*current population*	4 of 12	272 million 3.5% global pop.												
	current ratio: working age population to young plus elderly population	7 of 12	2.0:1												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

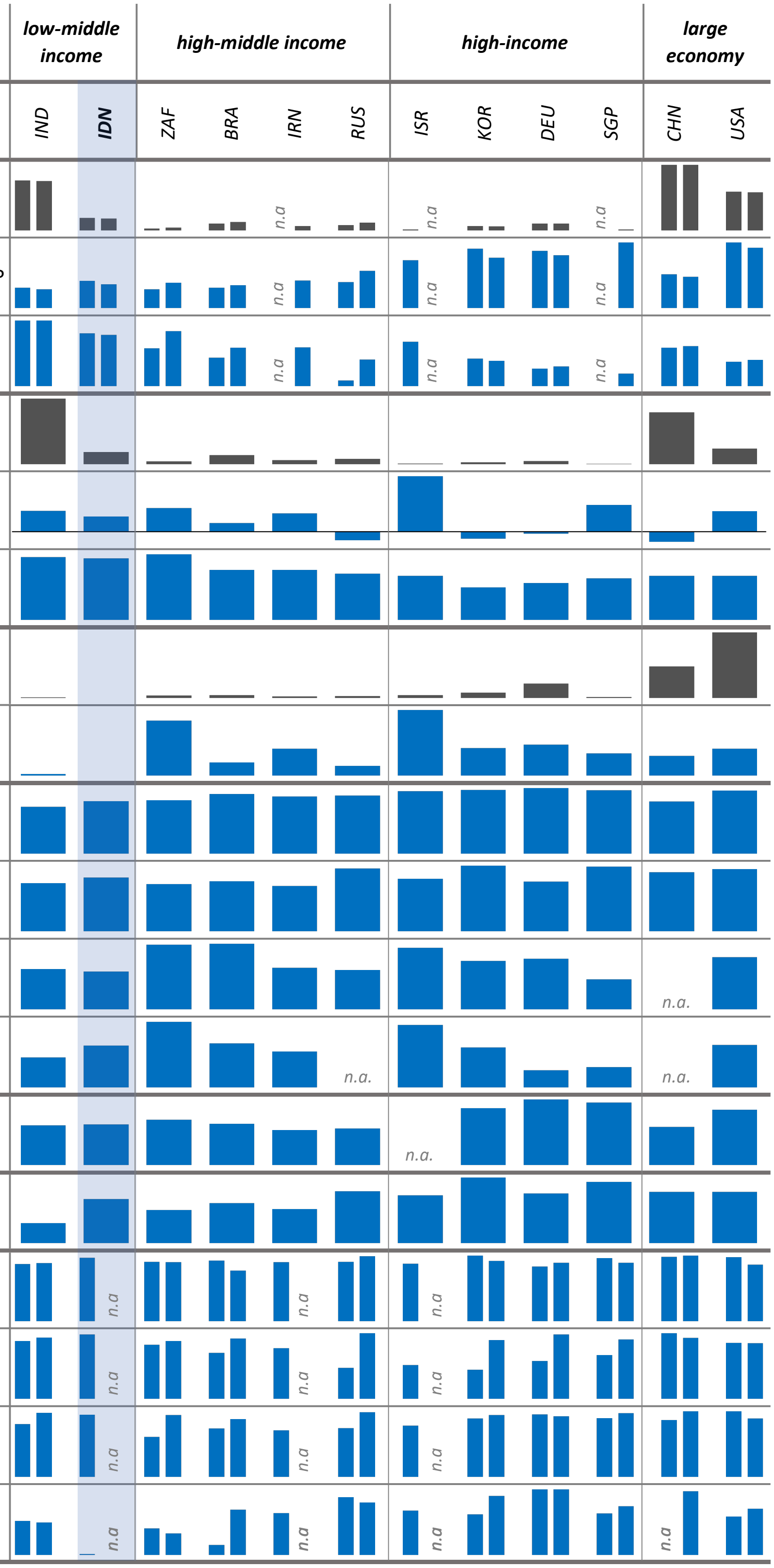
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

INDONESIA

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	4 of 12	$10T USD, 3.6-4.9% of global GDP
	2050 GDP per capita	9 of 12	$33-34k USD PPP
	GDP annual growth rate, 2018 to 2050	2 of 12	3.8-3.9%
population	*2050 population*	4 of 12	308 million, 3.3% of global pop.
	population growth rate, 2018 to 2050	7 of 12	0.42%
	2050 ratio: working age population to young plus elderly population	3 of 12	2.1:1
universities	*share of top universities*	12 of 12	0.0%
	top universities relative to GDP	12 of 12	--
education	school life expectancy, primary through tertiary	10 of 12	13.6 years
	presence of science education in secondary school	6 of 12	81%
	government expenditure on education as percent of GDP	10 of 11	3.6%
	government expenditure on primary education as percent of GDP	5 of 10	1.5%
policy	rule of law (World Justice Project)	7 of 11	52/100 score
ICT	ICT adoption (WEF Global Competitiveness)	8 of 12	61/100 score; 50/140 countries
beliefs about science	belief in science as future national benefit	2 of 12	92%
	belief in science as increasing jobs	1 of 12	74%
	belief in science as a personal benefit	1 of 12	85%
	trust in science over religion	12 of 12	0.89%



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data not available *n.a.*

acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

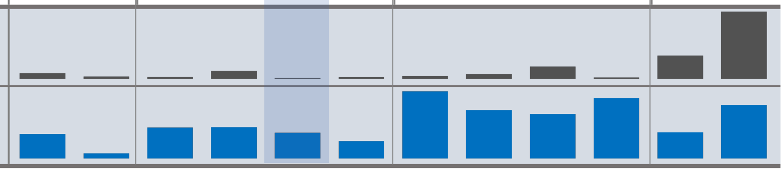
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

two bars indicate data from two separate sources

IRAN

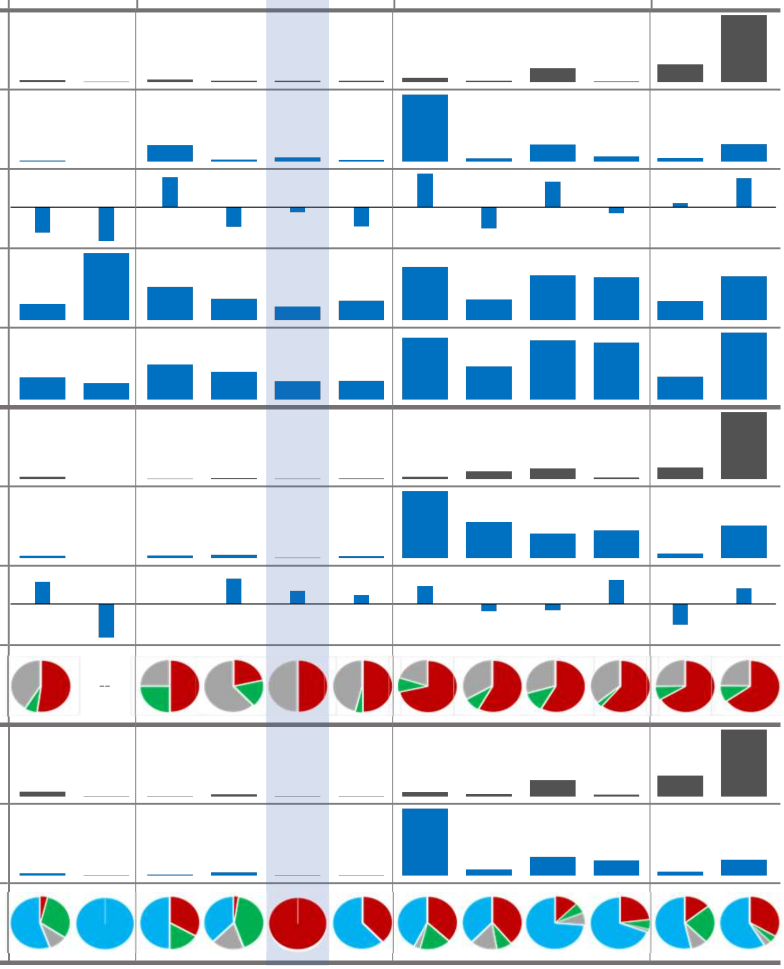
Biotech

sector scores	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
biotech capacity scores	12 of 12	0.1/10 points												
biotech innovation-driver scores	9 of 12	2.7/10 points												



Biotech: output measures

	indicator	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
publications	*share of top biotech publications*	7 of 12	1.3%												
	top biotech publications relative to GDP	6 of 12	--												
	relative emphasis on biotech within top publications	6 of 12	-0.1 (-1 to 1)												
	average citation count per biotech publication	12 of 12	--												
	average citation count per biochemistry, genetics, and molecular biology publications	11 of 12	--												
patents	*share of world biotech patents, 2014-2019*	11 of 12	0.04%												
	biotech patents relative to GDP	11 of 12	--												
	relative emphasis on biotech within patents	6 of 12	+0.4 (-1 to 1)												
	proportion of red, green, or white biotech patents	--	50%, 0%, 50%		--										
companies	*share of world biotech companies*	12 of 12	0.0%												
	biotech companies relative to GDP	11 of 12	--												
	proportion of red, green, white, or R&D service biotech companies	--	100%, 0%, 0%, 0%												



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

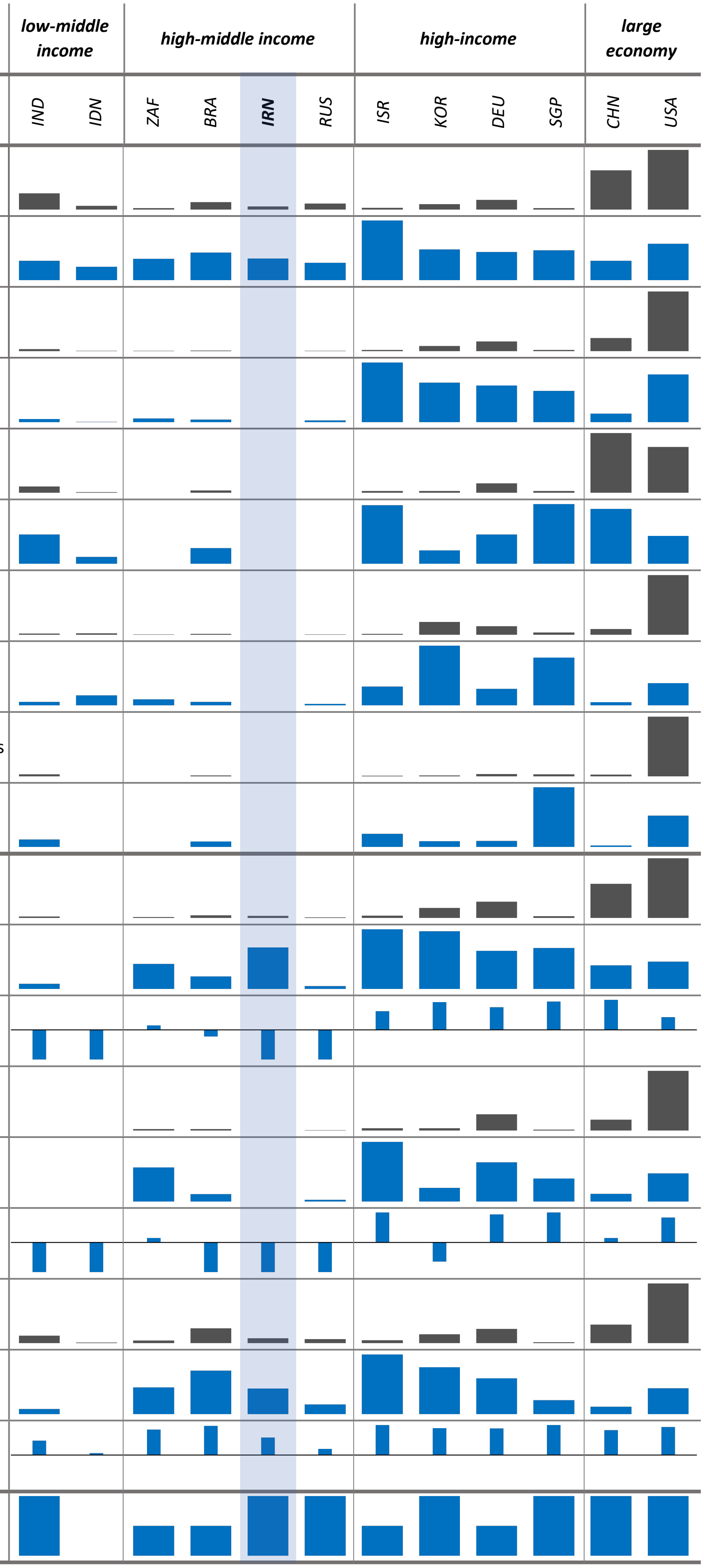
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

IRAN

Biotech : drivers of innovation

category	indicator	rank	value
talent	*users of largest genetic sequence database*	9 of 12	1.1% of users
talent	users of largest genetic sequence database relative to GDP	7 of 12	--
talent	*users of a major genetic engineering tool supplier*	12 of 12	0 depositors
talent	users of a major genetic engineering tool supplier relative to GDP	12 of 12	--
talent	*participation in international genetic engineering competition*	10 of 12	0% of participants
talent	participation in international genetic engineering competition relative to GDP	10 of 12	--
talent	*attendance at preeminent synthetic biology conferences*	12 of 12	0.0% of attendees
talent	attendance at preeminent synthetic biology conferences relative to GDP	12 of 12	--
talent	*subscribers to a prominent synthetic biology newsletter*	9 of 12	0% of subscribers
talent	subscribers to a prominent synthetic biology newsletter relative to GDP	9 of 12	--
universities	*share of top biotech universities*	7 of 12	0.7%
universities	top biotech universities relative to GDP	3 of 12	--
universities	relative emphasis on biotech in top universities	9 of 12	-0.8 (-1 to 1)
universities	*share of top biology universities*	10 of 12	0.0%
universities	top biology universities relative to GDP	10 of 12	--
universities	relative emphasis on biology in top universities	10 of 12	-1 (-1 to 1)
universities	*share of top life sciences universities*	7 of 12	4.2%
universities	top life sciences universities relative to GDP	7 of 12	--
universities	relative emphasis on life sciences in top universities	9 of 12	+0.5 (-1 to 1)
policy	presence of a national biotechnology plan	1 of 12	1 of 1 pt



IRAN

Biotech : drivers of innovation				*low-middle income*		*high-middle income*				*high-income*				*large economy*	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	***IRN***	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
industry sector maturity	*share of total global biotech crops*	6 of 12	0%												
	biotech crops relative to total cropland	7 of 12	0.0%												
	share of total global biofuel production	11 of 12	0.0%												
	biotech fuels relative to total liquid fuel production	11 of 12	0.0%												
	average annual growth rate in biofuel production, 2006-2016	10 of 12	2.8%												
	clinical trials of biologics since 2010	11 of 12	1% of trials												
	clinical trials of biologics since 2010 scaled to GDP	9 of 12	--												
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	--	n.a.					*n.a.*							
biodiversity	*well-studied animal and plant species*	9 of 12	2.2% of species												
	well-studied animal and plant species scaled to GDP	6 of 12	--												
	non-human sequence entries in largest genetic sequence database	10 of 12	0.4% of entries												
	non-human sequence entries in largest genetic sequence database scaled to GDP	10 of 12	--												
collaboration	*life sciences collaboration (Nature Index)*	12 of 12	0.25% of max score												
	life sciences collaborations relative to GDP	10 of 12	--												

data not applicable --

data not available *n.a.*

acronym: GDP: gross domestic product.
largest genetic sequence database: NIH GenBank.
major genetic engineering tool supplier: AddGene.
international genetic engineering competition: iGEM.
preeminent synthetic biology conference: SBx.0.
prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

IRAN

Science and Technology			*low-middle income*		*high-middle income*				*high-income*				*large economy*	
sector scores	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	***IRN***	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
science & technology capacity scores	10 of 12	0.3/10 points												
science & technology innovation-driver scores	12 of 12	2.2/10 points												

Science and Technology: output measures				*low-middle income*		*high-middle income*				*high-income*				*large economy*	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	***IRN***	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
publications	*share of top high tech publications*	9 of 12	1.0%												
	top high tech publications relative to GDP	7 of 12	--												
	relative emphasis on high tech within top publications	7 of 12	-0.3 (-1 to 1)												
patents	*share of world patents, 2014-2019*	11 of 12	0.03%												
	patents relative to GDP	11 of 12	--												
STI output	knowledge and technology outputs (Global Innovation Index)	7 of 12	31/100 score; 41/126 countries												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product

STI: science and technology innovation

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

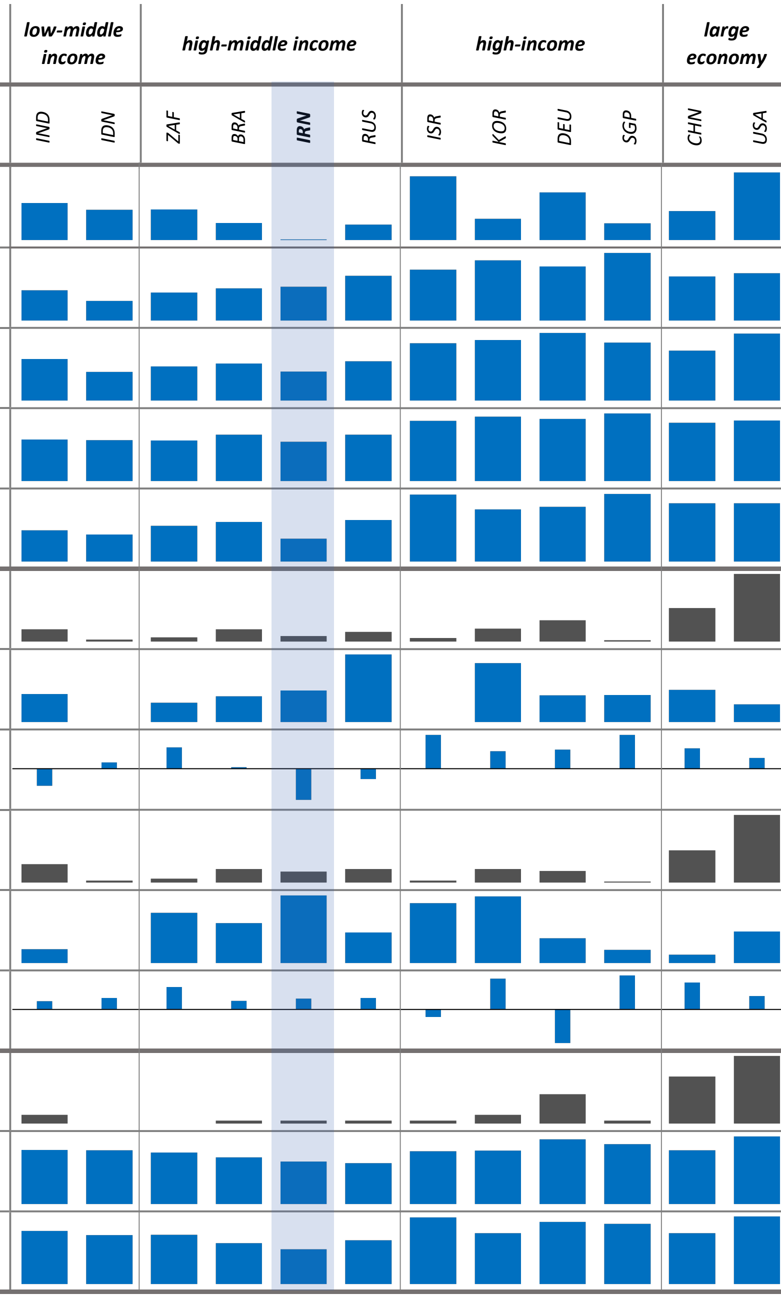
IRAN

Science and Technology : drivers of innovation				*low-middle income*		*high-middle income*				*high-income*				*large economy*	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	***IRN***	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
talent	*share of world STEM graduates*	--	n.a.					*n.a.*						*n.a.*	
	STEM graduates relative to GDP	--	n.a.					*n.a.*						*n.a.*	
	retention of foreign-educated PhD students	10 of 10	10%			*n.a.*									*n.a.*
	share of world researchers	8 of 12	0.5%												
	researchers relative to GDP	10 of 12	--												
funding: research & development	*total expenditures on R&D*	11 of 12	$3.3B USD PPP												
	total expenditures on R&D relative to GDP	9 of 12	0.8%												
	R&D expenditures funded by higher ed. relative to GDP	6 of 11	0.3%				*n.a.*								
	R&D expenditures funded by government relative to GDP	5 of 11	0.3%				*n.a.*								
	R&D expenditures funded by business relative to GDP	9 of 11	0.2%				*n.a.*								
funding: venture capital	VC availability (Global Competitiveness Report)	12 of 12	2.4/7 score 111/140 countries												
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	--	n.a.					*n.a.*							
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	11 of 12	3.1/7 score 97/140 countries												
	ease of technology transfer (US Chamber IP Index)	--	n.a.					*n.a.*							
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	12 of 12	3.2/7 score 126/140 countries												
	patents, related rights, and limitations (US Chamber IP Index)	--	n.a.					*n.a.*							
	tax incentives in the creation of IP assets (US Chamber IP Index)	--	n.a.					*n.a.*							
policy: future	future orientation of government (Global Competitiveness Report)	10 of 12	3.3/7 score 97/140 countries												

IRAN

Science and Technology : drivers of innovation

	indicator	rank	value
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	12 of 12	48%
	human capital and research (Global Innovation Index)	8 of 12	37/100 score 45/126 countries
	innovation capability (Global Competitiveness Report)	11 of 12	38/100 score 65/140 countries
	infrastructure (Global Innovation Index)	12 of 12	38/100 score 87/126 countries
	business sophistication (Global Innovation Index)	12 of 12	22/100 score 108/126 countries
universities	*share of top computer sciences universities*	8 of 12	1.3%
	top computer sciences universities relative to GDP	4 of 12	--
	relative emphasis on computer sciences in top universities	12 of 12	-0.5 (-1 to 1)
	share of top engineering and technology universities	8 of 12	2.5%
	top engineering and technology universities relative to GDP	1 of 12	--
	relative emphasis on engineering and technology in top universities	8 of 12	+0.1 (-1 to 1)
collaboration	*share of top international innovation clusters*	6 of 12	1.0%
	state of cluster development (Global Competitiveness Report)	11 of 12	3.6/7 score 82/140 countries
	university-industry collaboration (Global Competitiveness Report)	12 of 12	3.0/7 score



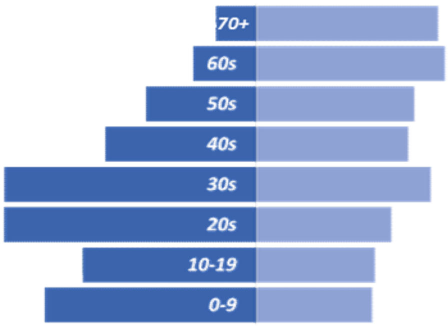
data not applicable --
data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math
R&D: research and development. VC: venture capital.
GDP: gross domestic product. IP: intelllectual property.
IESE: graduate business school of the University of Navarra.

relative strength compared to 12 countries (read across row)
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

IRAN

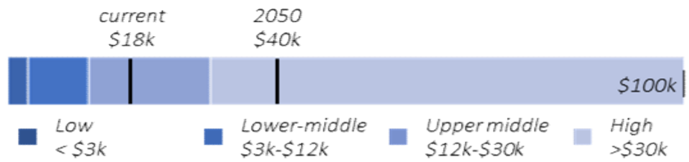
AGE DISTRIBUTION



2015: 79 million
total dependency ratio 0.40

2050: 98 million
total dependency ratio 0.59

ECONOMY: UPPER-MIDDLE INCOME

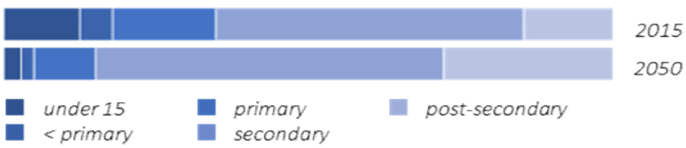


$USD PPP, GDP/capita

ranges are approximations based on World Bank economic groups - GNI/capita has been converted to GDP/capita

current GDP: $1.5T USD PPP
2050 GDP: $3.9T USD PPP

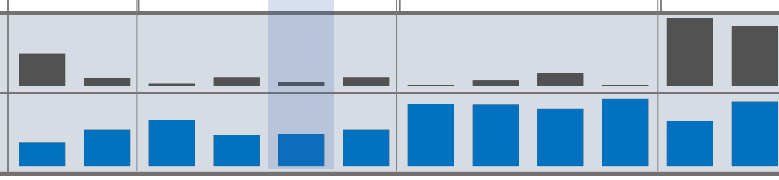
EDUCATION DISTRIBUTION



EXTREME POVERTY DISTRIBUTION

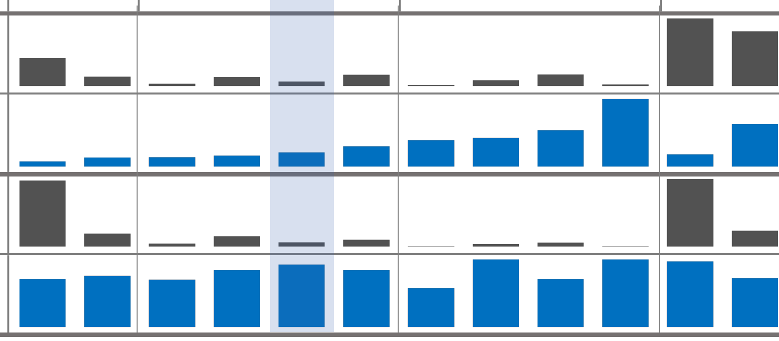
General-societal

			low-middle income		high-middle income				high-income				large economy	
sector scores	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	***IRN***	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
general-societal capacity scores	9 of 12	0.5/10 points												
general-societal innovation-driver scores	10 of 12	3.1/10 points												



General-societal: output measures

				low-middle income		high-middle income				high-income				large economy	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	***IRN***	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
economy	*current GDP, PPP*	9 of 12	$1.5T USD PPP, 1.3% of global GDP												
	current GDP per capita	9 of 12	$18k USD PPP												
population	*current population*	7 of 12	84 million 1.1% global pop.												
	current ratio: working age population to young plus elderly population	4 of 12	2.5:1												



data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

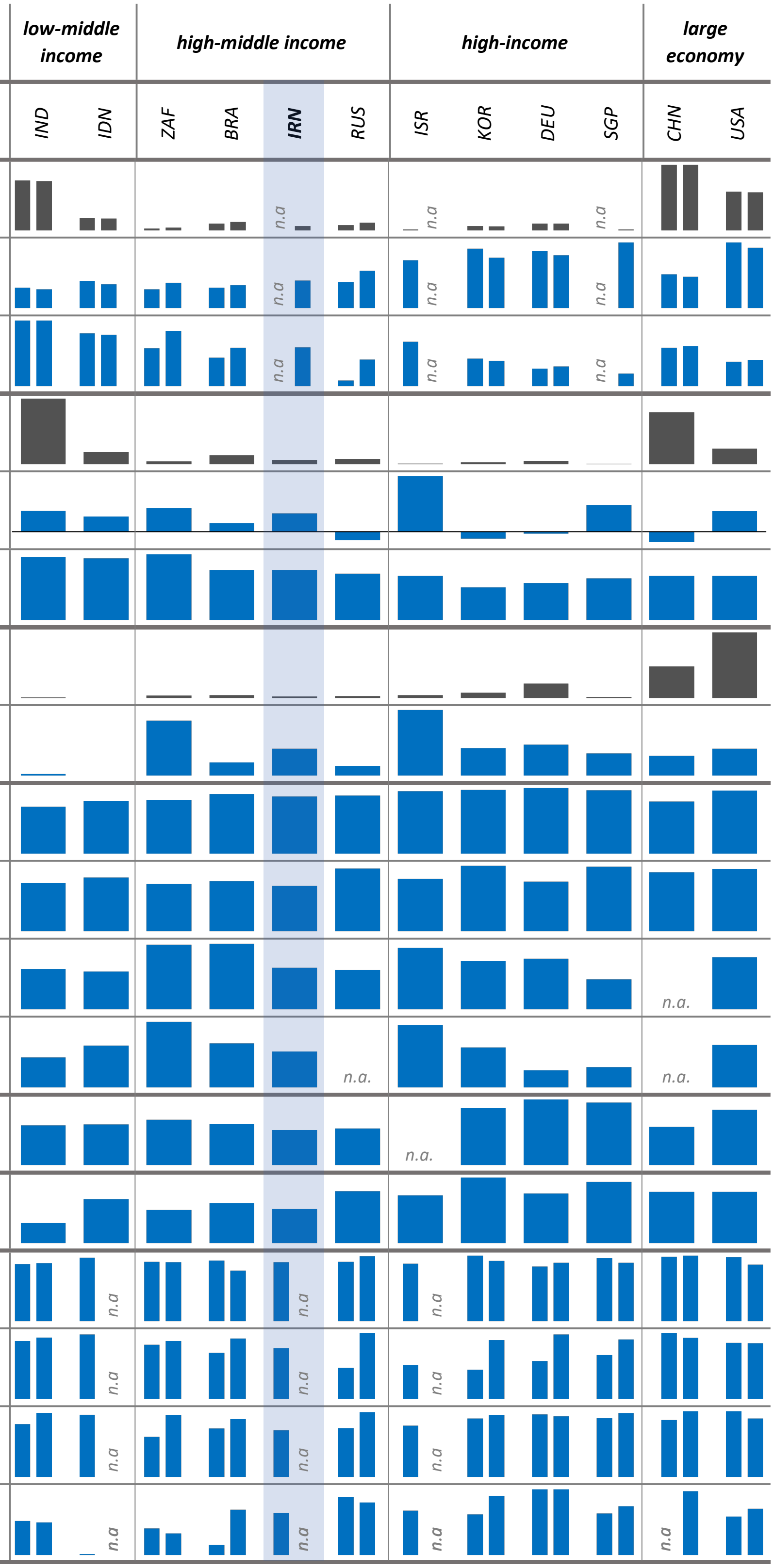
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

IRAN

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	8 of 12	$3.9T USD, 1.3% of global GDP
	2050 GDP per capita	8 of 12	$40k USD PPP
	GDP annual growth rate, 2018 to 2050	6 of 12	3.0%
population	*2050 population*	7 of 12	98 million, 1.0% of global pop.
	population growth rate, 2018 to 2050	9 of 12	0.51%
	2050 ratio: working age population to young plus elderly population	4 of 12	1.7:1
universities	*share of top universities*	9 of 12	0.6%
	top universities relative to GDP	6 of 12	--
education	school life expectancy, primary through tertiary	8 of 12	14.8 years
	presence of science education in secondary school	12 of 12	68%
	government expenditure on education as percent of GDP	7 of 11	4.0%
	government expenditure on primary education as percent of GDP	7 of 10	1.3%
policy	rule of law (World Justice Project)	11 of 11	45/100 score
ICT	ICT adoption (WEF Global Competitiveness)	10 of 12	48/100 score; 80/140 countries
beliefs about science	belief in science as future national benefit	8 of 12	86%
	belief in science as increasing jobs	9 of 12	58%
	belief in science as a personal benefit	12 of 12	64%
	trust in science over religion	8 of 12	40%



data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

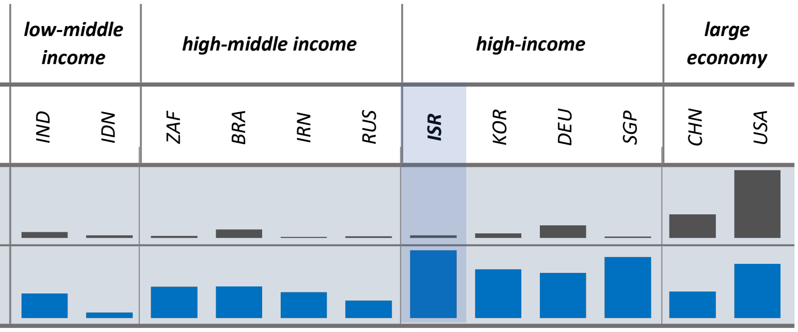
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

two bars indicate data from two separate sources

ISRAEL

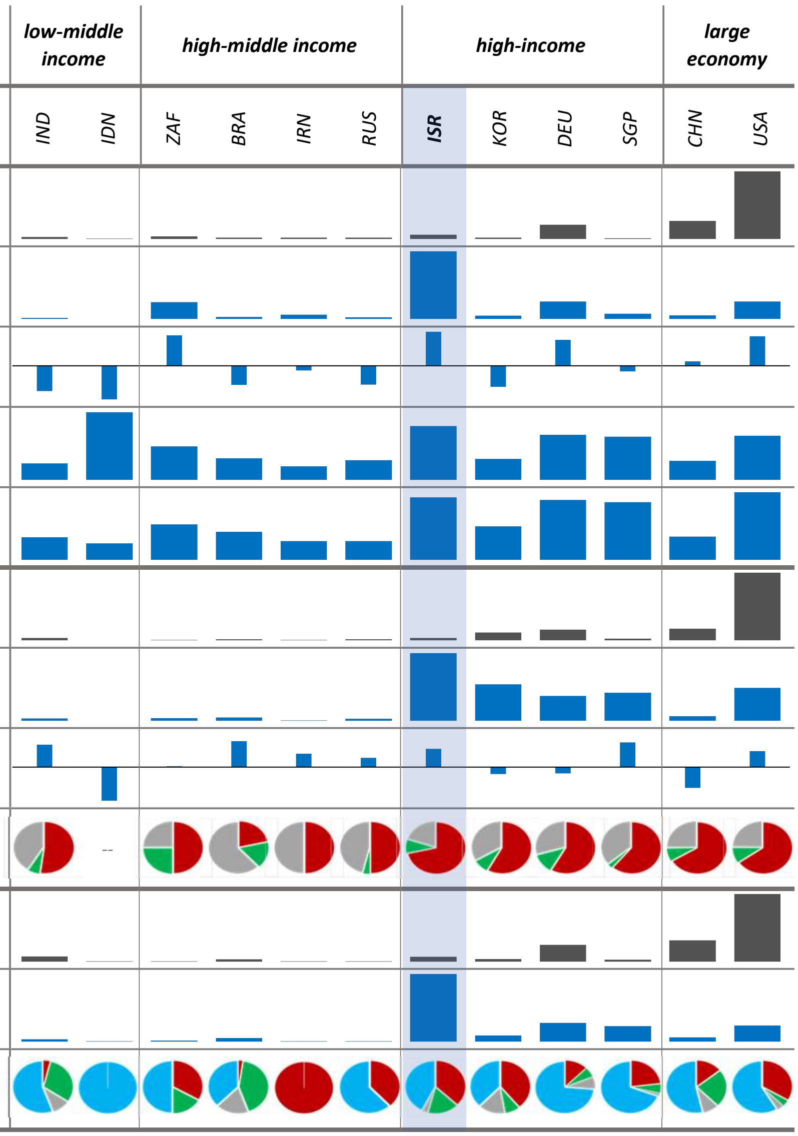
Biotech

sector scores	rank	value
biotech capacity scores	7 of 12	0.4/10 points
biotech innovation-driver scores	1 of 12	7/10 points



Biotech: output measures

	indicator	rank	value
publications	*share of top biotech publications*	4 of 12	3.8%
	top biotech publications relative to GDP	1 of 12	--
	relative emphasis on biotech within top publications	1 of 12	+1 (-1 to 1)
	average citation count per biotech publication	2 of 12	--
	average citation count per biochemistry, genetics, and molecular biology publications	2 of 12	--
patents	*share of world biotech patents, 2014-2019*	6 of 12	1.5%
	biotech patents relative to GDP	1 of 12	--
	relative emphasis on biotech within patents	4 of 12	+0.5 (-1 to 1)
	proportion of red, green, or white biotech patents	--	71%, 9% 20%
companies	*share of world biotech companies*	5 of 12	3.8%
	biotech companies relative to GDP	1 of 12	--
	proportion of red, green, white, or R&D service biotech companies	--	37%, 17%, 3%, 43%



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

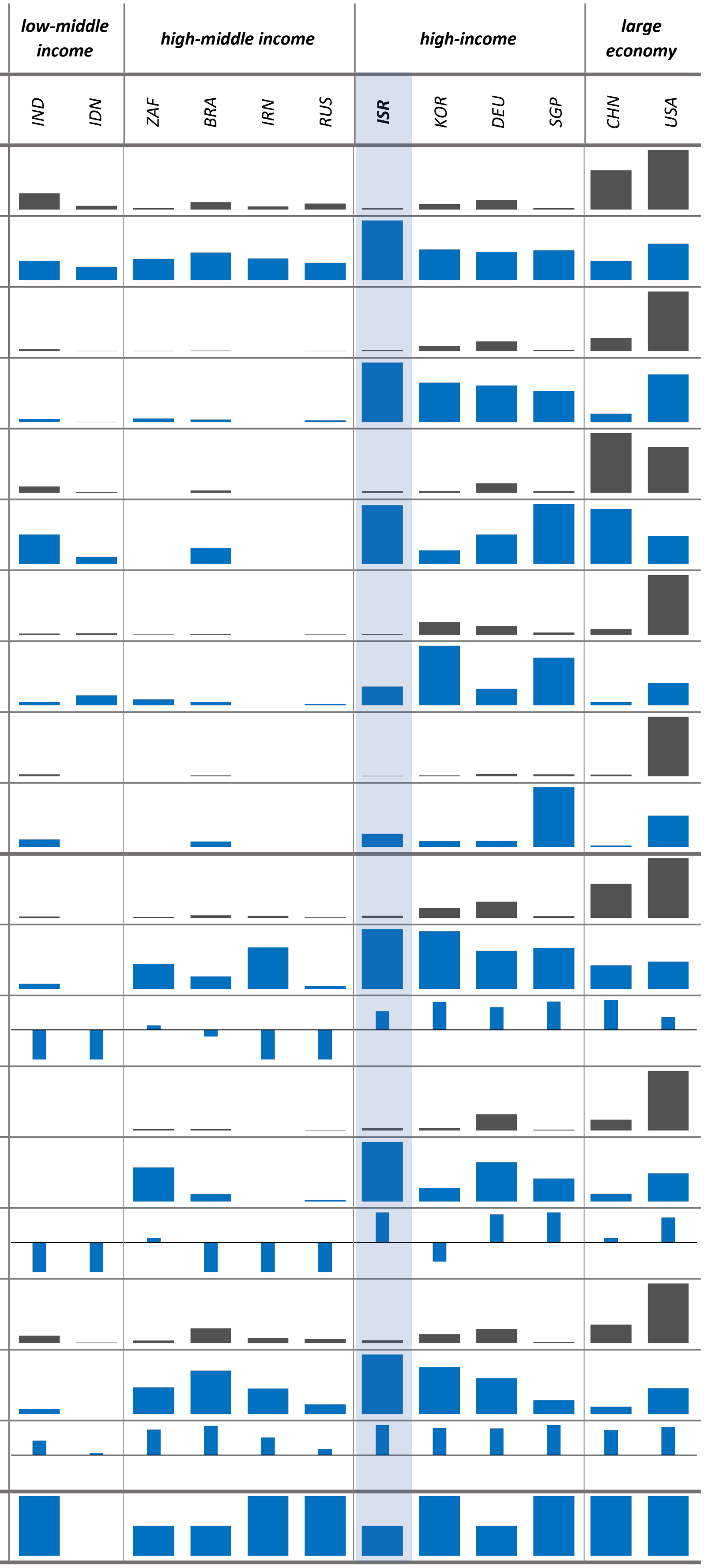
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

ISRAEL

Biotech : drivers of innovation

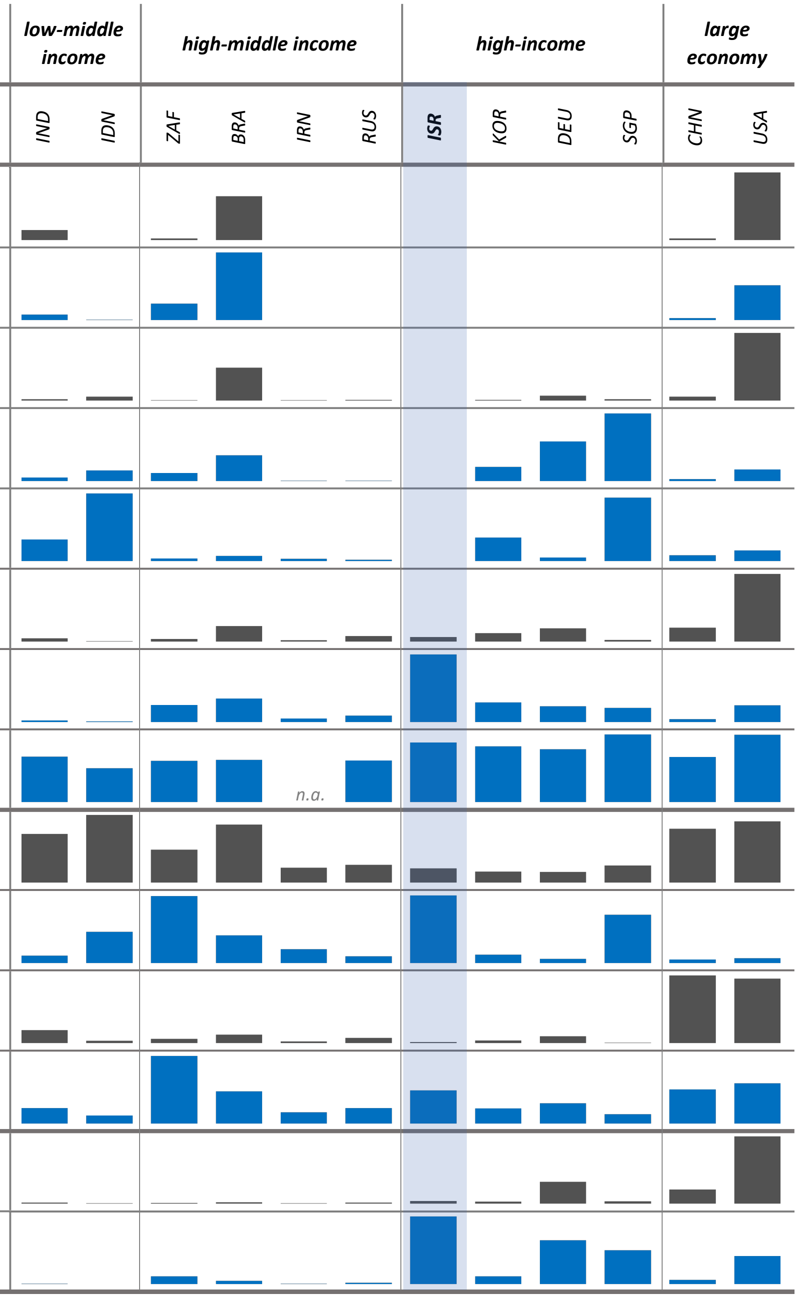
	indicator	rank	value
talent	*users of largest genetic sequence database*	10 of 12	0.6% of users
	users of largest genetic sequence database relative to GDP	1 of 12	--
	users of a major genetic engineering tool supplier	6 of 12	676 depositors
	users of a major genetic engineering tool supplier relative to GDP	1 of 12	--
	participation in international genetic engineering competition	6 of 12	0.9% of participants
	participation in international genetic engineering competition relative to GDP	2 of 12	--
	attendance at preeminent synthetic biology conferences	8 of 12	0.4% of attendees
	attendance at preeminent synthetic biology conferences relative to GDP	4 of 12	--
	subscribers to a prominent synthetic biology newsletter	8 of 12	0.5% of subscribers
	subscribers to a prominent synthetic biology newsletter relative to GDP	3 of 12	--
universities	*share of top biotech universities*	6 of 12	0.8%
	top biotech universities relative to GDP	1 of 12	--
	relative emphasis on biotech in top universities	5 of 12	+0.5 (-1 to 1)
	share of top biology universities	5 of 12	1.2%
	top biology universities relative to GDP	1 of 12	--
	relative emphasis on biology in top universities	1 of 12	+0.7 (-1 to 1)
	share of top life sciences universities	9 of 12	2.5%
	top life sciences universities relative to GDP	1 of 12	--
	relative emphasis on life sciences in top universities	1 of 12	+0.9 (-1 to 1)
policy	presence of a national biotechnology plan	8 of 12	0.5 of 1 pt



ISRAEL

Biotech : drivers of innovation

	indicator	rank	value
industry sector maturity	*share of total global biotech crops*	6 of 12	0%
	biotech crops relative to total cropland	7 of 12	0%
	share of total global biofuel production	12 of 12	0%
	biotech fuels relative to total liquid fuel production	12 of 12	0%
	average annual growth rate in biofuel production, 2006-2016	12 of 12	0.0%
	clinical trials of biologics since 2010	7 of 12	2% of trials
	clinical trials of biologics since 2010 scaled to GDP	1 of 12	--
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	3 of 11	77/100 score
biodiversity	*well-studied animal and plant species*	10 of 12	2.1% of species
	well-studied animal and plant species scaled to GDP	1 of 12	--
	non-human sequence entries in largest genetic sequence database	11 of 12	0.2% of entries
	non-human sequence entries in largest genetic sequence database scaled to GDP	4 of 12	--
collaboration	*life sciences collaboration (Nature Index)*	4 of 12	3.9% of max score
	life sciences collaborations relative to GDP	1 of 12	--



data not applicable --

data not available *n.a.*

acronym: GDP: gross domestic product.
largest genetic sequence database: NIH GenBank.
major genetic engineering tool supplier: AddGene.
international genetic engineering competition: iGEM.
preeminent synthetic biology conference: SBx.0.
prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

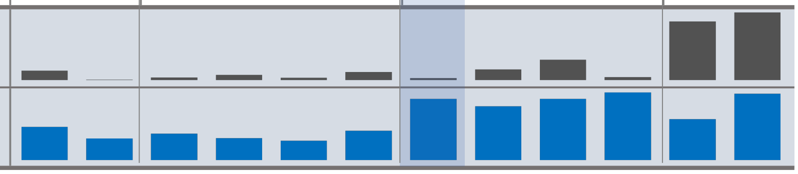
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

ISRAEL

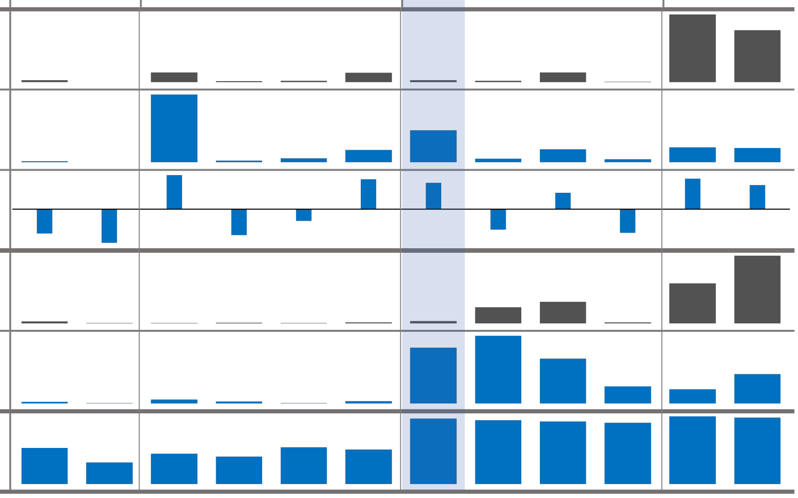
Science and Technology

sector scores	rank	value	*low-middle income*		*high-middle income*				*high-income*				*large economy*	
			IND	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	***ISR***	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
science & technology capacity scores	11 of 12	0.3/10 points												
science & technology innovation-driver scores	3 of 12	6.8/10 points												



Science and Technology: output measures

	indicator	rank	value	*low-middle income*		*high-middle income*				*high-income*				*large economy*	
				IND	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	***ISR***	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
publications	*share of top high tech publications*	7 of 12	2.0%												
	top high tech publications relative to GDP	2 of 12	--												
	relative emphasis on high tech within top publications	4 of 12	+0.8 (-1 to 1)												
patents	*share of world patents, 2014-2019*	5 of 12	0.84%												
	patents relative to GDP	2 of 12	--												
STI output	knowledge and technology outputs (Global Innovation Index)	3 of 12	55/100 score; 7/126 countries												



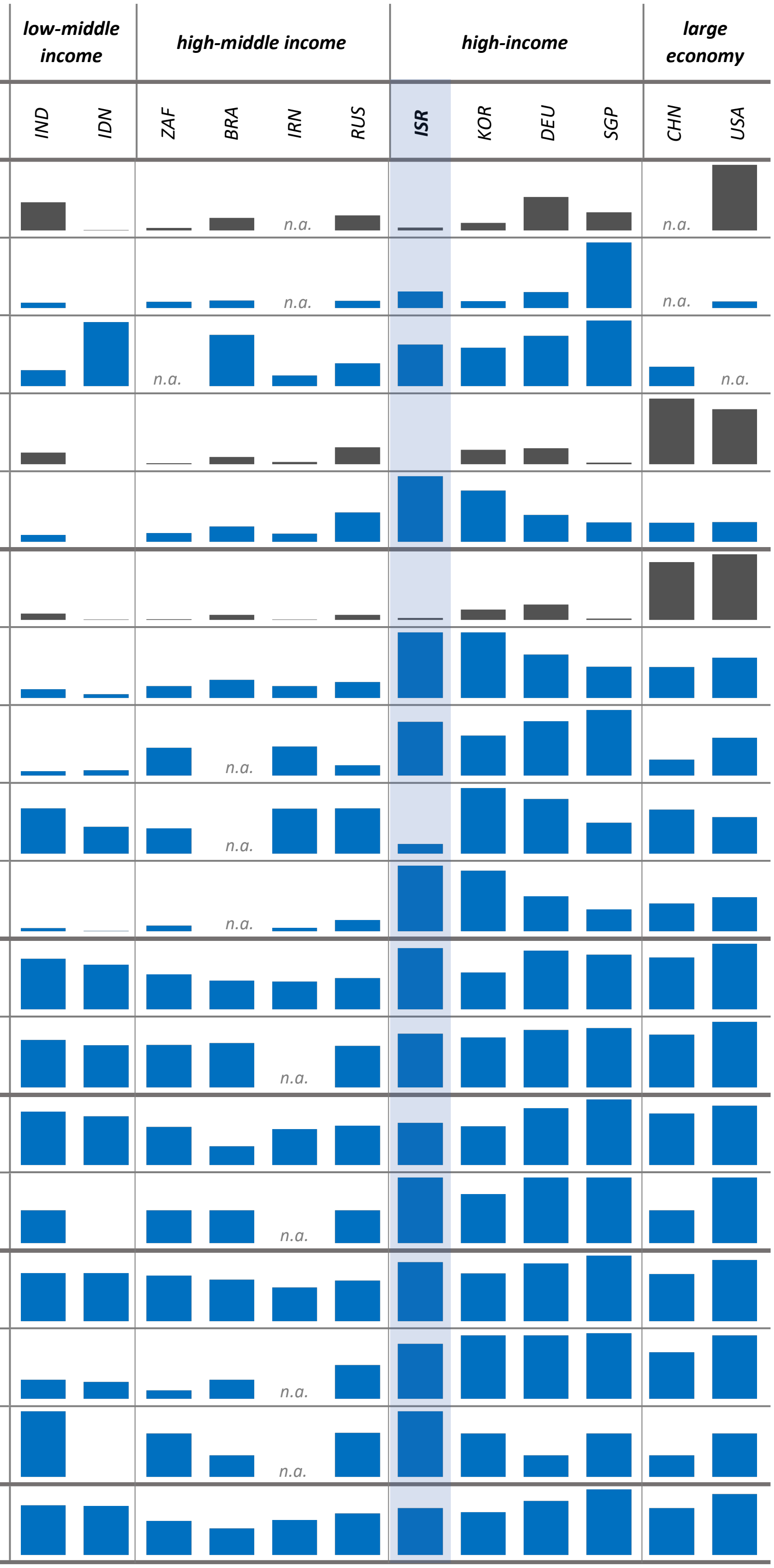
data not applicable --
data not available *n.a.*
acronyms: GDP: gross domestic product
STI: science and technology innovation

relative strength compared to 12 countries (read across row)
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

ISRAEL

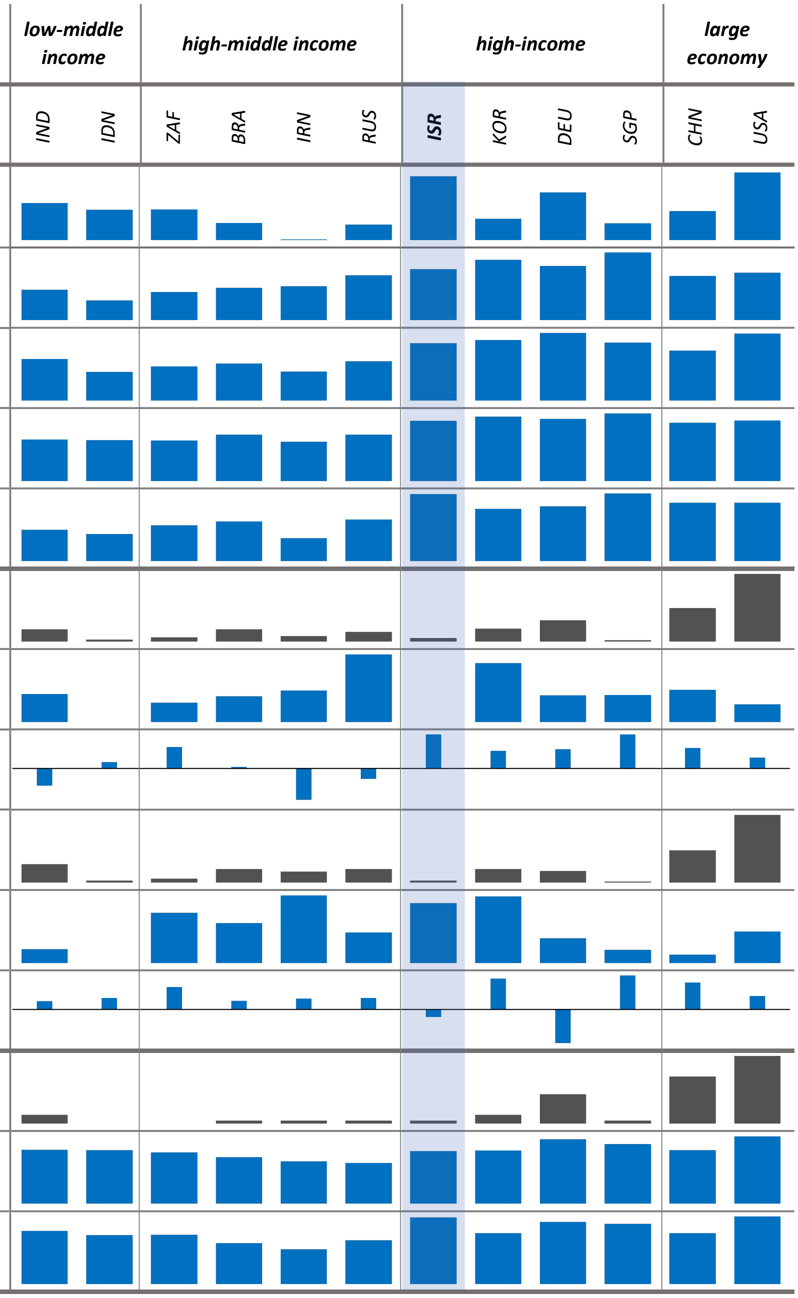
Science and Technology : drivers of innovation

	indicator	rank	value
talent	*share of world STEM graduates*	8 of 10	0.9%
talent	STEM graduates relative to GDP	2 of 10	--
talent	retention of foreign-educated PhD students	5 of 10	40.2%
talent	*share of world researchers*	11 of 12	0.4%
talent	researchers relative to GDP	1 of 12	--
funding: research & development	*total expenditures on R&D*	8 of 12	$13.5B USD PPP
funding: research & development	total expenditures on R&D relative to GDP	2 of 12	4.5%
funding: research & development	R&D expenditures funded by higher ed. relative to GDP	3 of 11	0.5%
funding: research & development	R&D expenditures funded by government relative to GDP	11 of 11	0.1%
funding: research & development	R&D expenditures funded by business relative to GDP	1 of 11	3.9%
funding: venture capital	VC availability (Global Competitiveness Report)	2 of 12	5.2/7 score; 2/140 countries
funding: venture capital	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	4 of 11	82/100 score
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	7 of 12	3.6/7 score; 59/140 countries
policy: regulatory burden	ease of technology transfer (US Chamber IP Index)	1 of 11	1/1 score
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	3 of 12	5.6/7 score; 19/140 countries
policy: intellectual property	patents, related rights, and limitations (US Chamber IP Index)	5 of 11	6.5/7 score
policy: intellectual property	tax incentives in the creation of IP assets (US Chamber IP Index)	1 of 11	1/1 score
policy: future	future orientation of government (Global Competitiveness Report)	6 of 12	4.4/7 score; 30/140 countries



ISRAEL

Science and Technology : drivers of innovation



	indicator	rank	value	
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	2 of 12	80%	
	human capital and research (Global Innovation Index)	4 of 12	55/100 score	14/126 countries
	innovation capability (Global Competitiveness Report)	5 of 12	74/100 score	16/140 countries
	infrastructure (Global Innovation Index)	5 of 12	59/100 score	25/126 countries
	business sophistication (Global Innovation Index)	2 of 12	65/100 score	3/126 countries
universities	*share of top computer sciences universities*	10 of 12	0.9%	
	top computer sciences universities relative to GDP	11 of 12	--	
	relative emphasis on computer sciences in top universities	1 of 12	+0.5	(-1 to 1)
	share of top engineering and technology universities	10 of 12	0.4%	
	top engineering and technology universities relative to GDP	3 of 12	--	
	relative emphasis on engineering and technology in top universities	11 of 12	-0.1	(-1 to 1)
collaboration	*share of top international innovation clusters*	6 of 12	1.0%	
	state of cluster development (Global Competitiveness Report)	8 of 12	4.5/7 score	31/140 countries
	university-industry collaboration (Global Competitiveness Report)	2 of 12	5.8/7 score	

data not applicable --

data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math
R&D: research and development. VC: venture capital.
GDP: gross domestic product. IP: intelllectual property.
IESE: graduate business school of the University of Navarra.

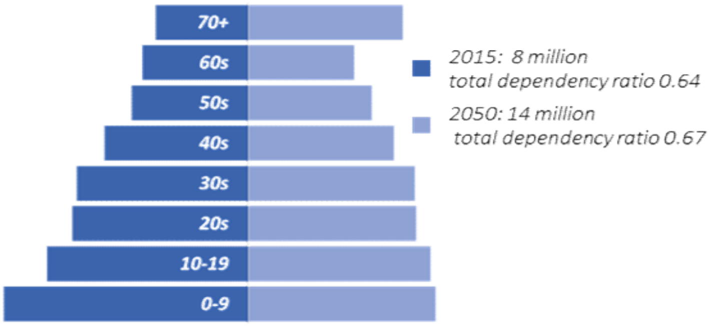
relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

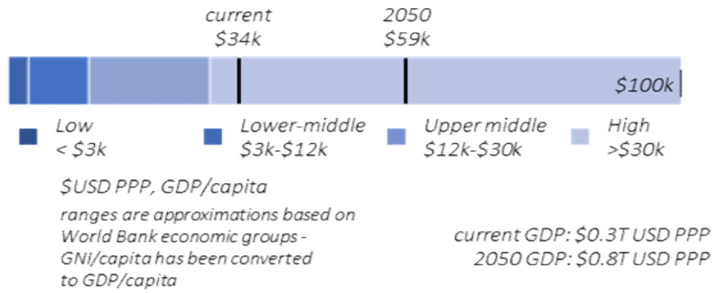
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

ISRAEL

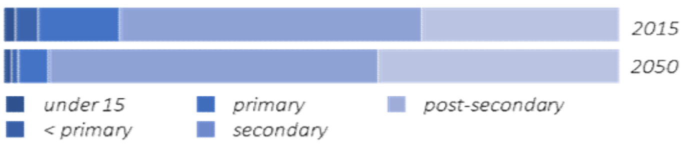
AGE DISTRIBUTION



ECONOMY: HIGH INCOME



EDUCATION DISTRIBUTION



EXTREME POVERTY DISTRIBUTION

General-societal

sector scores	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
			low-middle income		high-middle income				high-income				large economy	
general-societal capacity scores	11 of 12	0.1/10 points												
general-societal innovation-driver scores	3 of 12	6/10 points												

General-societal: output measures

	indicator	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
				low-middle income		high-middle income				high-income				large economy	
economy	*current GDP, PPP*	12 of 12	$0.3T USD PPP, 0.25% of global GDP												
	current GDP per capita	5 of 12	$34k USD PPP												
population	*current population*	11 of 12	8.8 million 0.11% global pop.												
	current ratio: working age population to young plus elderly population	12 of 12	1.6:1												

data not applicable --
data not available *n.a.*
acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

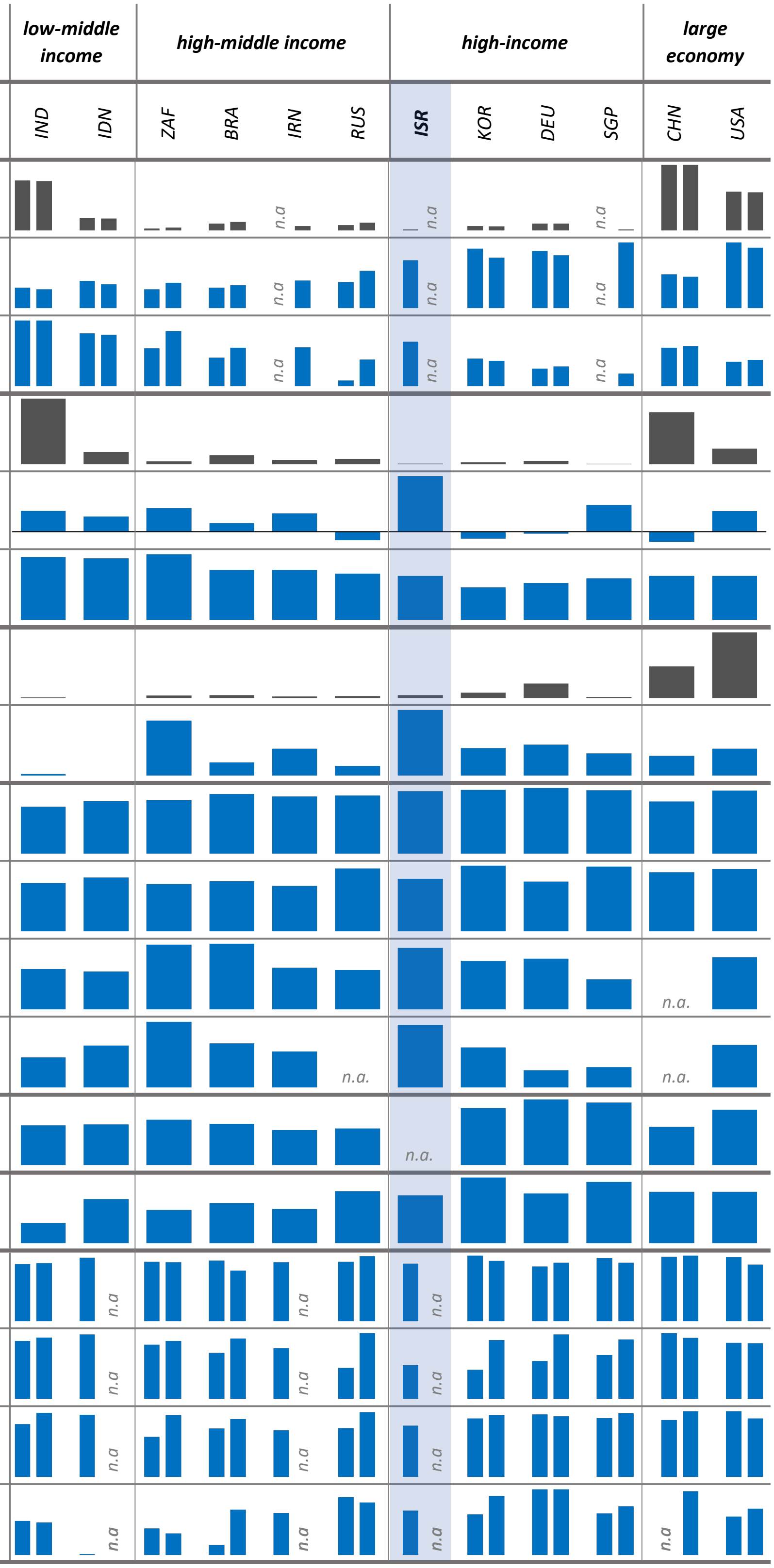
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

ISRAEL

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	11 of 12	\$0.83T USD, 0.39% of global GDP
	2050 GDP per capita	5 of 12	\$59k USD PPP
	GDP annual growth rate, 2018 to 2050	4 of 12	3.2%
population	*2050 population*	11 of 12	14 million, 0.15% of global pop.
	population growth rate, 2018 to 2050	1 of 12	1.5%
	2050 ratio: working age population to young plus elderly population	7 of 12	1.49:1
universities	*share of top universities*	5 of 12	1.2%
	top universities relative to GDP	1 of 12	--
education	school life expectancy, primary through tertiary	5 of 12	16.2 years
	presence of science education in secondary school	7 of 12	79%
	government expenditure on education as percent of GDP	3 of 11	5.9%
	government expenditure on primary education as percent of GDP	2 of 10	2.3%
policy	rule of law (World Justice Project)	--	n.a.
ICT	ICT adoption (WEF Global Competitiveness)	7 of 12	67/100 score; 39/140 countries
beliefs about science	belief in science as future national benefit	10 of 12	84%
	belief in science as increasing jobs	12 of 12	39%
	belief in science as a personal benefit	10 of 12	70%
	trust in science over religion	6 of 12	43%



data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

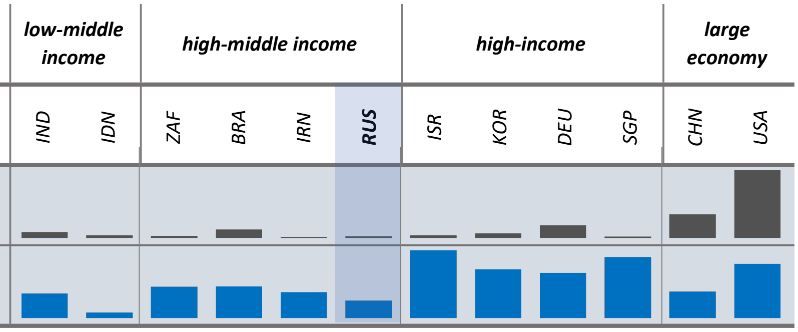
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

two bars indicate data from two separate sources

RUSSIA

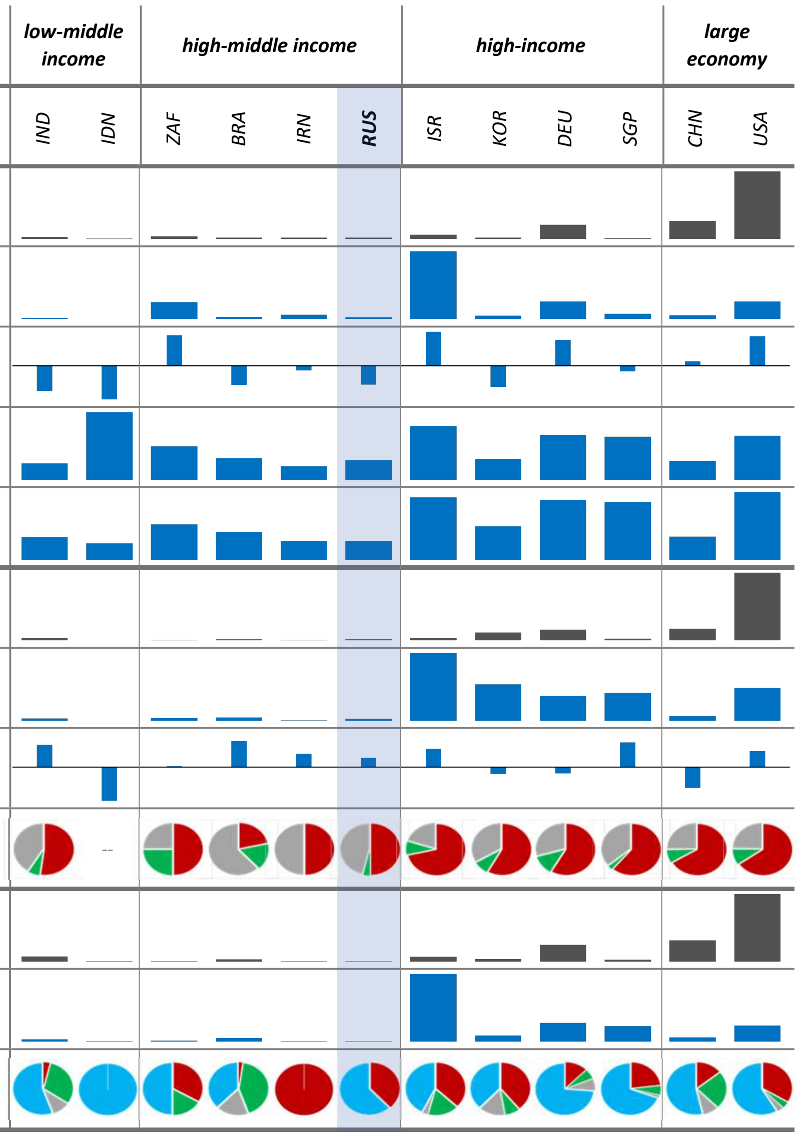
Biotech

sector scores	rank	value
biotech capacity scores	10 of 12	0.3/10 points
biotech innovation-driver scores	11 of 12	1.8/10 points



Biotech: output measures

	indicator	rank	value
publications	*share of top biotech publications*	8 of 12	1.2%
	top biotech publications relative to GDP	10 of 12	--
	relative emphasis on biotech within top publications	8 of 12	-0.5 (-1 to 1)
	average citation count per biotech publication	9 of 12	--
	average citation count per biochemistry, genetics, and molecular biology publications	10 of 12	--
patents	*share of world biotech patents, 2014-2019*	9 of 12	0.5%
	biotech patents relative to GDP	10 of 12	--
	relative emphasis on biotech within patents	7 of 12	+0.3 (-1 to 1)
	proportion of red, green, white, or R&D service biotech companies	--	50%, 4%, 46%
companies	*share of world biotech companies*	9 of 12	0.33%
	biotech companies relative to GDP	10 of 12	--
	proportion of biotech companies identifying as red, green, or white	--	38%, 0%, 0%, 62%



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

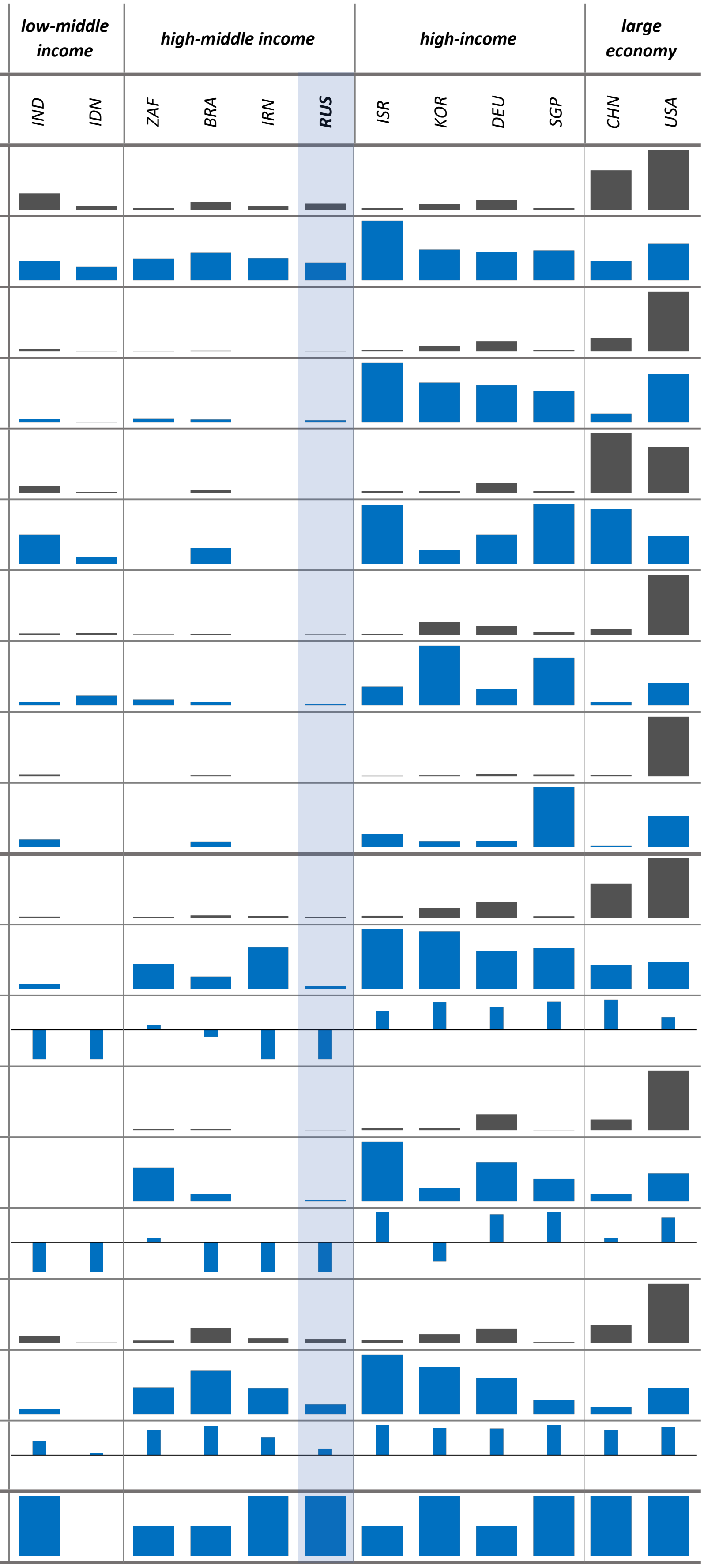
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

RUSSIA

Biotech : drivers of innovation

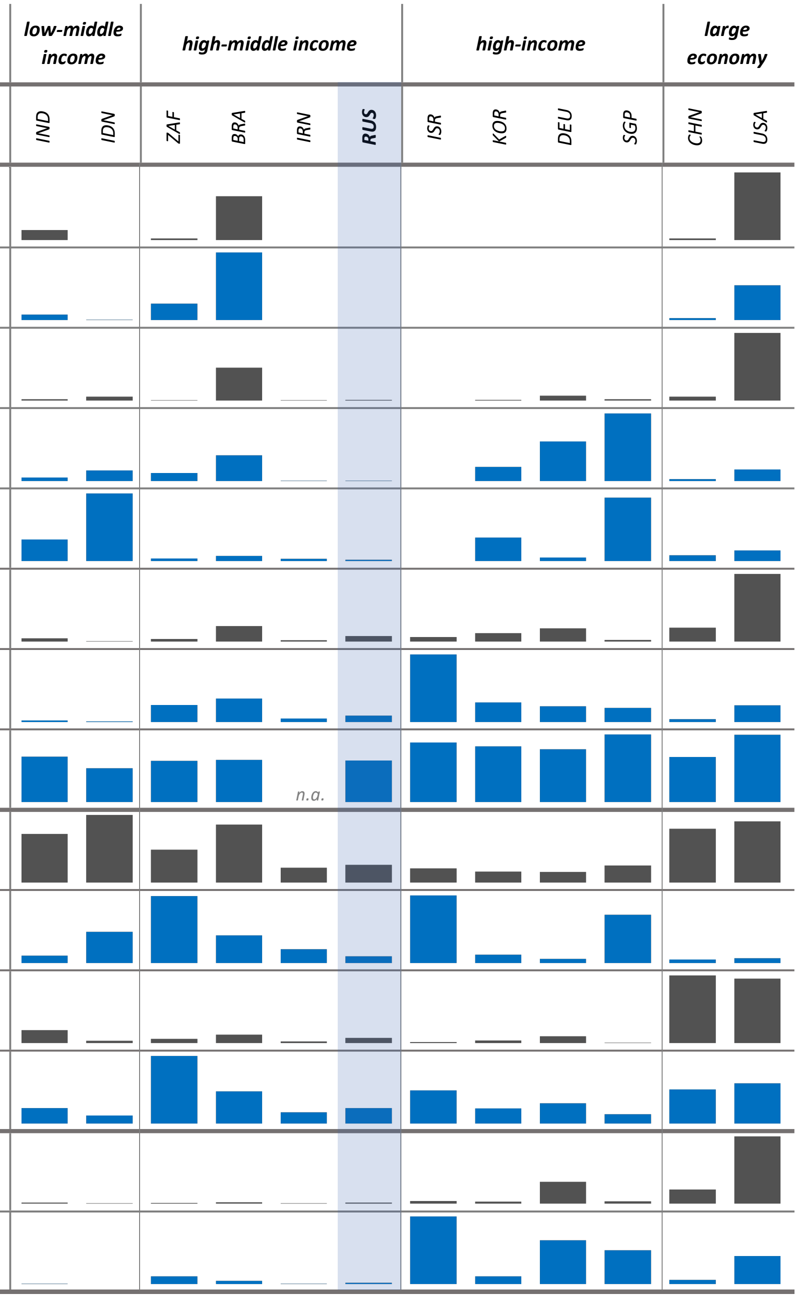
	indicator	rank	value
talent	*users of largest genetic sequence database*	6 of 12	2.2% of users
	users of largest genetic sequence database relative to GDP	11 of 12	--
	users of a major genetic engineering tool supplier	9 of 12	224 depositors
	users of a major genetic engineering tool supplier relative to GDP	10 of 12	--
	participation in international genetic engineering competition	10 of 12	0.0% of participants
	participation in international genetic engineering competition relative to GDP	10 of 12	--
	attendance at preeminent synthetic biology conferences	10 of 12	0.1% of attendees
	attendance at preeminent synthetic biology conferences relative to GDP	11 of 12	--
	subscribers to a prominent synthetic biology newsletter	9 of 12	0.0% of subscribers
	subscribers to a prominent synthetic biology newsletter relative to GDP	9 of 12	--
universities	*share of top biotech universities*	11 of 12	0.2%
	top biotech universities relative to GDP	11 of 12	--
	relative emphasis on biotech in top universities	11 of 12	-1.0 (-1 to 1)
	share of top biology universities	9 of 12	0.2%
	top biology universities relative to GDP	9 of 12	--
	relative emphasis on biology in top universities	9 of 12	-1 (-1 to 1)
	share of top life sciences universities	8 of 12	3.4%
	top life sciences universities relative to GDP	9 of 12	--
	relative emphasis on life sciences in top universities	11 of 12	+0.2 (-1 to 1)
policy	presence of a national biotechnology plan	1 of 12	1 of 1 pt



RUSSIA

Biotech : drivers of innovation

	indicator	rank	value
industry sector maturity	*share of total global biotech crops*	6 of 12	0%
	biotech crops relative to total cropland	7 of 12	0.0%
	share of total global biofuel production	8 of 12	0.4%
	biotech fuels relative to total liquid fuel production	10 of 12	0.1%
	average annual growth rate in biofuel production, 2006-2016	11 of 12	1.5%
	clinical trials of biologics since 2010	6 of 12	3% of trials
	clinical trials of biologics since 2010 scaled to GDP	8 of 12	--
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	9 of 11	54/100 score
biodiversity	*well-studied animal and plant species*	7 of 12	2.6% of species
	well-studied animal and plant species scaled to GDP	9 of 12	--
	non-human sequence entries in largest genetic sequence database	6 of 12	1.4% of entries
	non-human sequence entries in largest genetic sequence database scaled to GDP	8 of 12	--
collaboration	*life sciences collaboration (Nature Index)*	8 of 12	1.5% of max score
	life sciences collaborations relative to GDP	9 of 12	--



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data not available *n.a.*

acronym: GDP: gross domestic product.
largest genetic sequence database: NIH GenBank.
major genetic engineering tool supplier: AddGene.
international genetic engineering competition: iGEM.
preeminent synthetic biology conference: SBx.0.
prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

RUSSIA

Science and Technology

sector scores	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
			low-middle income		high-middle income				high-income				large economy	
science & technology capacity scores	6 of 12	1.1/10 points												
science & technology innovation-driver scores	8 of 12	3.2/10 points												

Science and Technology: output measures

	indicator	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
				low-middle income		high-middle income				high-income				large economy	
publications	*share of top high tech publications*	5 of 12	7.8%												
publications	top high tech publications relative to GDP	6 of 12	--												
publications	relative emphasis on high tech within top publications	3 of 12	+0.9 (-1 to 1)												
patents	*share of world patents, 2014-2019*	8 of 12	0.4%												
patents	patents relative to GDP	8 of 12	--												
STI output	knowledge and technology outputs (Global Innovation Index)	9 of 12	29/100 score; 47/126 countries												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product

STI: science and technology innovation

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

RUSSIA

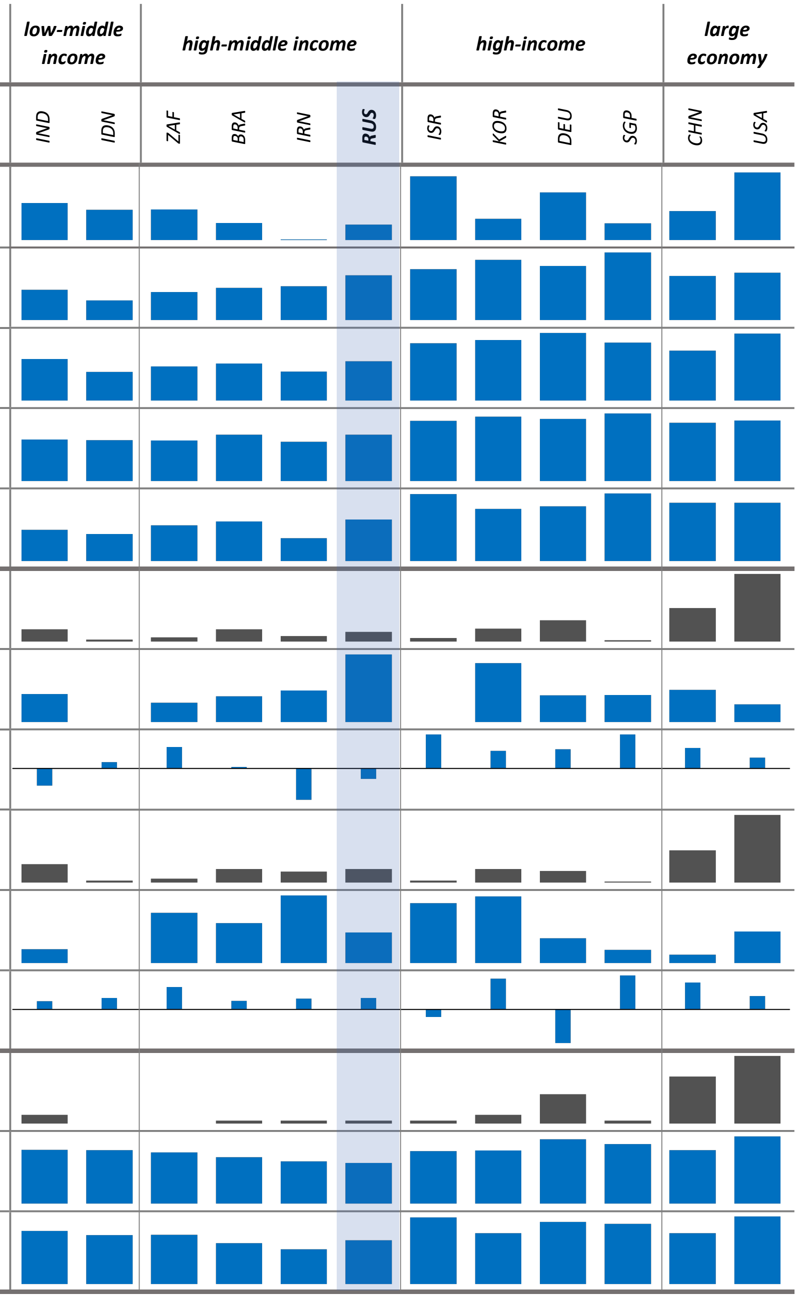
Science and Technology : drivers of innovation

				low-middle income		*high-middle income*				*high-income*				*large economy*	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	***RUS***	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
talent	*share of world STEM graduates*	5 of 10	4.8%					*n.a.*						*n.a.*	
	STEM graduates relative to GDP	5 of 10	--					*n.a.*						*n.a.*	
	retention of foreign-educated PhD students	7 of 10	22.0%			*n.a.*									*n.a.*
	share of world researchers	3 of 12	3.9%												
	researchers relative to GDP	3 of 12	--												
funding: research & development	*total expenditures on R&D*	7 of 12	$40B USD PPP												
	total expenditures on R&D relative to GDP	8 of 12	1.1%												
	R&D expenditures funded by higher ed. relative to GDP	9 of 11	0.10%				*n.a.*								
	R&D expenditures funded by government relative to GDP	4 of 11	0.34%				*n.a.*								
	R&D expenditures funded by business relative to GDP	7 of 11	0.67%				*n.a.*								
funding: venture capital	VC availability (Global Competitiveness Report)	10 of 12	2.7/7 score 93/140 countries												
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	11 of 11	64/100 score					*n.a.*							
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	8 of 12	3.3/7 score 73/140 countries												
	ease of technology transfer (US Chamber IP Index)	6 of 11	0.5/1 score					*n.a.*							
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	11 of 12	3.9/7 score 85/140 countries												
	patents, related rights, and limitations (US Chamber IP Index)	7 of 11	4/7 score					*n.a.*							
	tax incentives in the creation of IP assets (US Chamber IP Index)	3 of 11	0.7/1 score					*n.a.*							
policy: future	future orientation of government (Global Competitiveness Report)	9 of 12	3.9/7 score 54/140 countries												

RUSSIA

Science and Technology : drivers of innovation

	indicator	rank	value
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	11 of 12	56%
	human capital and research (Global Innovation Index)	6 of 12	48/100 score; 22/126 countries
	innovation capability (Global Competitiveness Report)	8 of 12	51/100 score; 36/140 countries
	infrastructure (Global Innovation Index)	7 of 12	45/100 score; 63/126 countries
	business sophistication (Global Innovation Index)	7 of 12	40/100 score; 33/126 countries
universities	*share of top computer sciences universities*	7 of 12	2.3%
	top computer sciences universities relative to GDP	1 of 12	--
	relative emphasis on computer sciences in top universities	10 of 12	-0.2 (-1 to 1)
	share of top engineering and technology universities	4 of 12	3.1%
	top engineering and technology universities relative to GDP	7 of 12	--
	relative emphasis on engineering and technology in top universities	6 of 12	+0.1 (-1 to 1)
collaboration	*share of top international innovation clusters*	6 of 12	1.0%
	state of cluster development (Global Competitiveness Report)	12 of 12	3.5/7 score; 95/140 countries
	university-industry collaboration (Global Competitiveness Report)	10 of 12	3.8/7 score



data not applicable --

data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math
R&D: research and development. VC: venture capital.
GDP: gross domestic product. IP: intelllectual property.
IESE: graduate business school of the University of Navarra.

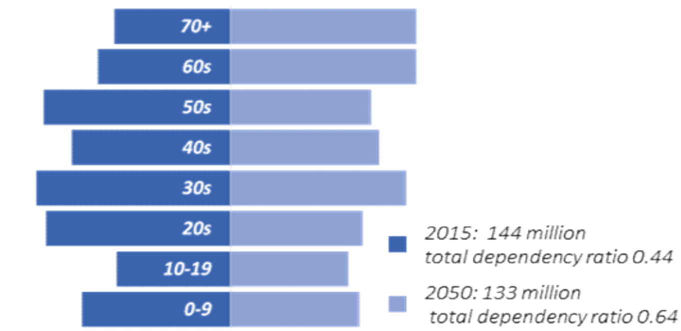
relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

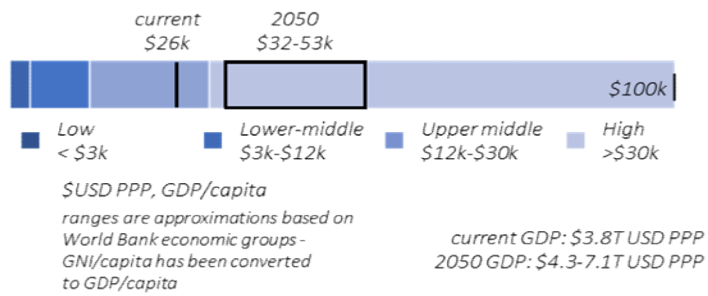
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

RUSSIA

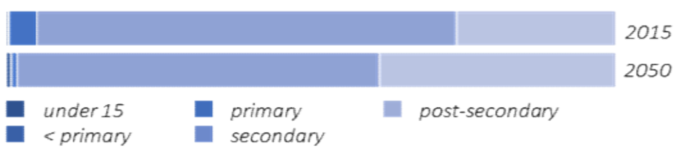
AGE DISTRIBUTION



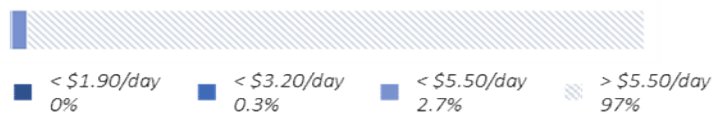
ECONOMY: UPPER-MIDDLE INCOME



EDUCATION DISTRIBUTION



EXTREME POVERTY DISTRIBUTION



General-societal

			low-middle income		high-middle income				high-income				large economy	
sector scores	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	***RUS***	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
general-societal capacity scores	5 of 12	1.1/10 points												
general-societal innovation-driver scores	9 of 12	3.5/10 points												

General-societal: output measures

				low-middle income		high-middle income				high-income				large economy	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	***RUS***	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
economy	*current GDP, PPP*	5 of 12	$3.8T USD PPP, 3.1% of global GDP												
	current GDP per capita	6 of 12	$26k USD PPP												
population	*current population*	6 of 12	143 million 1.8% global pop.												
	current ratio: working age population to young plus elderly population	5 of 12	2.3:1												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

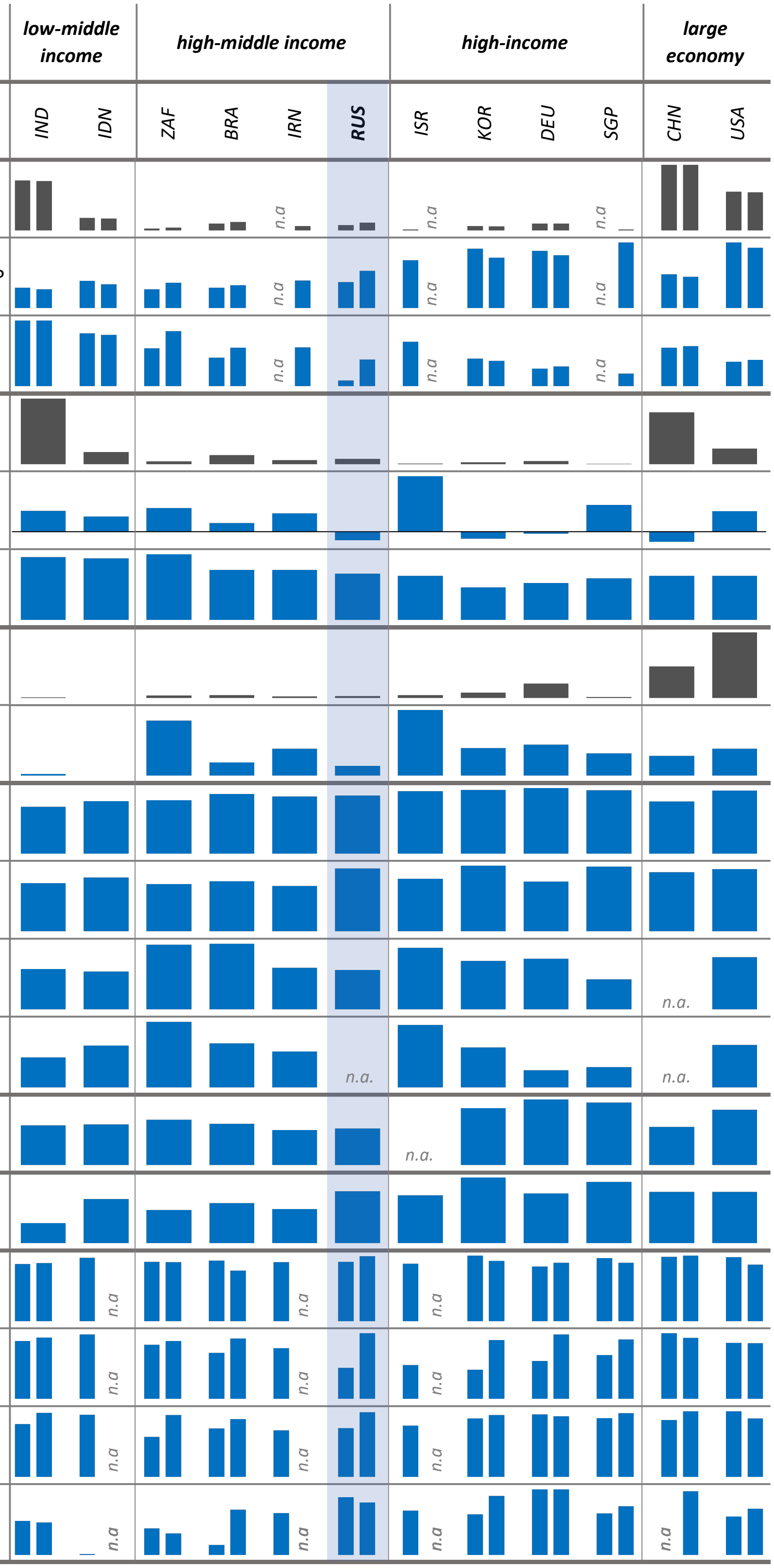
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

RUSSIA

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	7 of 12	$4.3-7.1T USD, 2.0-2.4% of global GDP
	2050 GDP per capita	7 of 12	$32-53k USD PPP
	GDP annual growth rate, 2018 to 2050	11 of 12	0.4-2.4%
population	*2050 population*	6 of 12	133 million, 1.4% of global pop.
	population growth rate, 2018 to 2050	11 of 12	-0.24%
	2050 ratio: working age population to young plus elderly population	6 of 12	1.6:1
universities	*share of top universities*	8 of 12	0.8%
	top universities relative to GDP	10 of 12	--
education	school life expectancy, primary through tertiary	7 of 12	15.0 years
	presence of science education in secondary school	3 of 12	95%
	government expenditure on education as percent of GDP	9 of 11	3.74%
	government expenditure on primary education as percent of GDP	*n.a.*	-
policy	rule of law (World Justice Project)	10 of 11	47/100 score
ICT	ICT adoption (WEF Global Competitiveness)	3 of 12	72/100 score; 25/140 countries
beliefs about science	belief in science as future national benefit	4 of 12	82%
	belief in science as increasing jobs	10 of 12	58%
	belief in science as a personal benefit	8 of 12	71%
	trust in science over religion	3 of 12	60%



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data not available *n.a.*

acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

two bars indicate data from two separate sources

SINGAPORE

Biotech

sector scores	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
			low-middle income		high-middle income				high-income				large economy	
biotech capacity scores	11 of 12	0.2/10 points												
biotech innovation-driver scores	2 of 12	6.3/10 points												

Biotech: output measures

	indicator	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
				low-middle income		high-middle income				high-income				large economy	
publications	*share of top biotech publications*	11 of 12	0.50%												
	top biotech publications relative to GDP	5 of 12	4 of 12 countries												
	relative emphasis on biotech within top publications	7 of 12	-0.2 (-1 to 1)												
	average citation count per biotech publication	5 of 12	5 of 12 countries												
	average citation count per biochemistry, genetics, and molecular biology publications	4 of 12	4 of 12 countries												
patents	*share of world biotech patents, 2014-2019*	7 of 12	1.1%												
	biotech patents relative to GDP	4 of 12	4 of 12 countries												
	relative emphasis on biotech within patents	2 of 12	+0.7 (-1 to 1)												
	proportion of red, green, or white biotech patents	--	61%, 3%, 36%		--										
companies	*share of world biotech companies*	8 of 12	1.5%												
	biotech companies relative to GDP	4 of 12	4 of 12 countries												
	proportion of red, green, white, or R&D service biotech companies	--	23%, 6%, 2%, 69%												

pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

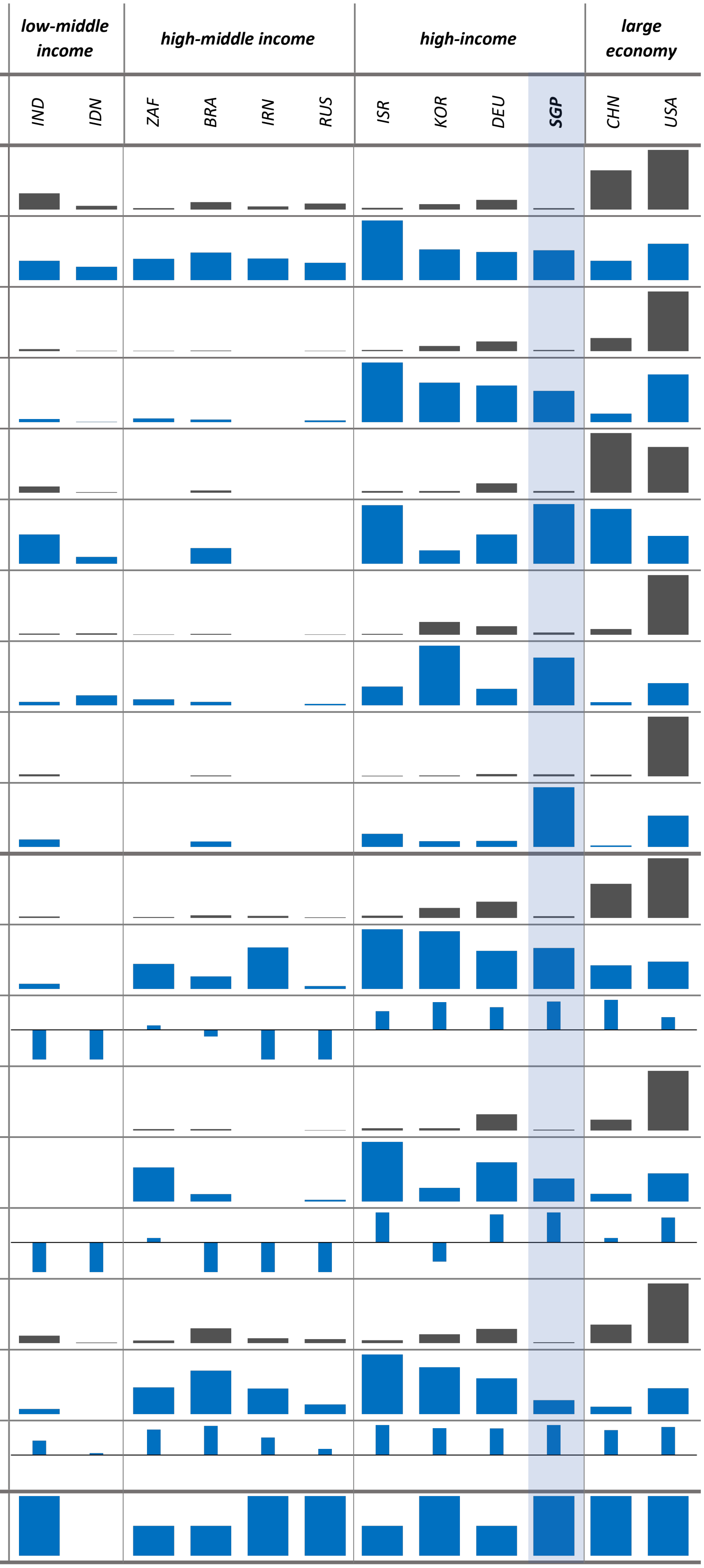
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

SINGAPORE

Biotech : drivers of innovation

	indicator	rank	value
talent	*users of largest genetic sequence database*	11 of 12	0.5% of users
	users of largest genetic sequence database relative to GDP	4 of 12	--
	users of a major genetic engineering tool supplier	7 of 12	603 depositors
	users of a major genetic engineering tool supplier relative to GDP	5 of 12	--
	participation in international genetic engineering competition	6 of 12	0.87% of participants
	participation in international genetic engineering competition relative to GDP	1 of 12	--
	attendance at preeminent synthetic biology conferences	5 of 12	1.0% of attendees
	attendance at preeminent synthetic biology conferences relative to GDP	2 of 12	--
	subscribers to a prominent synthetic biology newsletter	3 of 12	2.1% of subscribers
	subscribers to a prominent synthetic biology newsletter relative to GDP	1 of 12	--
universities	*share of top biotech universities*	8 of 12	0.5%
	top biotech universities relative to GDP	4 of 12	--
	relative emphasis on biotech in top universities	2 of 12	+0.7 (-1 to 1)
	share of top biology universities	8 of 12	0.4%
	top biology universities relative to GDP	5 of 12	--
	relative emphasis on biology in top universities	1 of 12	+0.7 (-1 to 1)
	share of top life sciences universities	11 of 12	0.8%
	top life sciences universities relative to GDP	8 of 12	--
	relative emphasis on life sciences in top universities	1 of 12	+0.9 (-1 to 1)
policy	presence of a national biotechnology plan	1 of 12	1 of 1 pt



SINGAPORE

Biotech : drivers of innovation

	indicator	rank	value	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	***SGP***	*CHN*	*USA*
				low-middle income		***high-middle income***				***high-income***				***large economy***	
industry sector maturity	*share of total global biotech crops*	6 of 12	0%												
	biotech crops relative to total cropland	7 of 12	0.0%												
	share of total global biofuel production	7 of 12	0.8%												
	biotech fuels relative to total liquid fuel production	1 of 12	42.6%												
	average annual growth rate in biofuel production, 2006-2016	2 of 12	80.0%												
	clinical trials of biologics since 2010	10 of 12	1% of trials												
	clinical trials of biologics since 2010 scaled to GDP	7 of 12	--												
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	1 of 11	87/100 score					*n.a.*							
biodiversity	*well-studied animal and plant species*	8 of 12	2.5% of species												
	well-studied animal and plant species scaled to GDP	3 of 12	--												
	non-human sequence entries in largest genetic sequence database	12 of 12	0.1% of entries												
	non-human sequence entries in largest genetic sequence database scaled to GDP	11 of 12	--												
collaboration	*life sciences collaboration (Nature Index)*	5 of 12	3.3% of max score												
	life sciences collaborations relative to GDP	3 of 12	--												

data not applicable --

data not available *n.a.*

acronym: GDP: gross domestic product.

largest genetic sequence database: NIH GenBank.

major genetic engineering tool supplier: AddGene.

international genetic engineering competition: iGEM.

preeminent synthetic biology conference: SBx.0.

prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

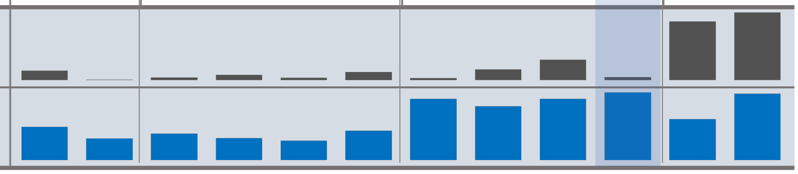
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SINGAPORE

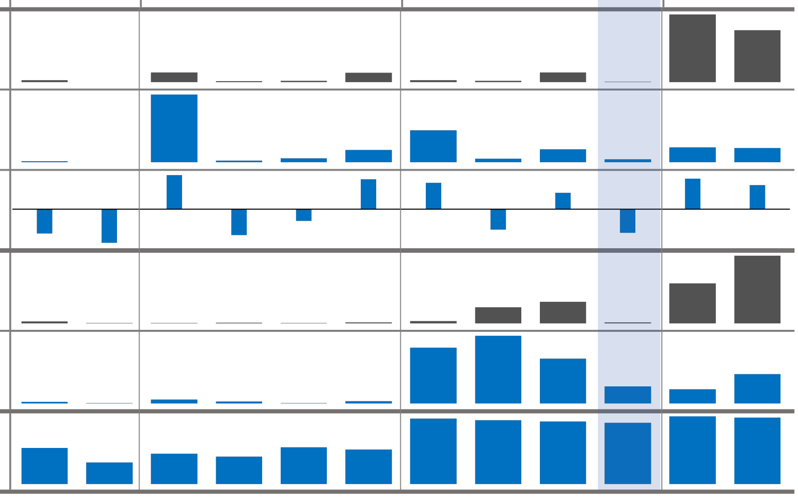
Science and Technology

sector scores	rank	value	*low-middle income*		*high-middle income*				*high-income*				*large economy*	
			IND	*IDN*	*ZAF*	***BRA***	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
science & technology capacity scores	8 of 12	0.4/10 points												
science & technology innovation-driver scores	1 of 12	7.5/10 points												



Science and Technology: output measures

	indicator	rank	value	*low-middle income*		*high-middle income*				*high-income*				*large economy*	
				IND	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	***SGP***	*CHN*	*USA*
publications	*share of top high tech publications*	11 of 12	0.25%												
	top high tech publications relative to GDP	9 of 12	--												
	relative emphasis on high tech within top publications	9 of 12	-0.7 (-1 to 1)												
patents	*share of world patents, 2014-2019*	7 of 12	0.40%												
	patents relative to GDP	5 of 12	--												
STI output	knowledge and technology outputs (Global Innovation Index)	6 of 12	51/100 score; 11/126 countries												



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data not available *n.a.*

acronyms: GDP: gross domestic product

STI: science and technology innovation

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

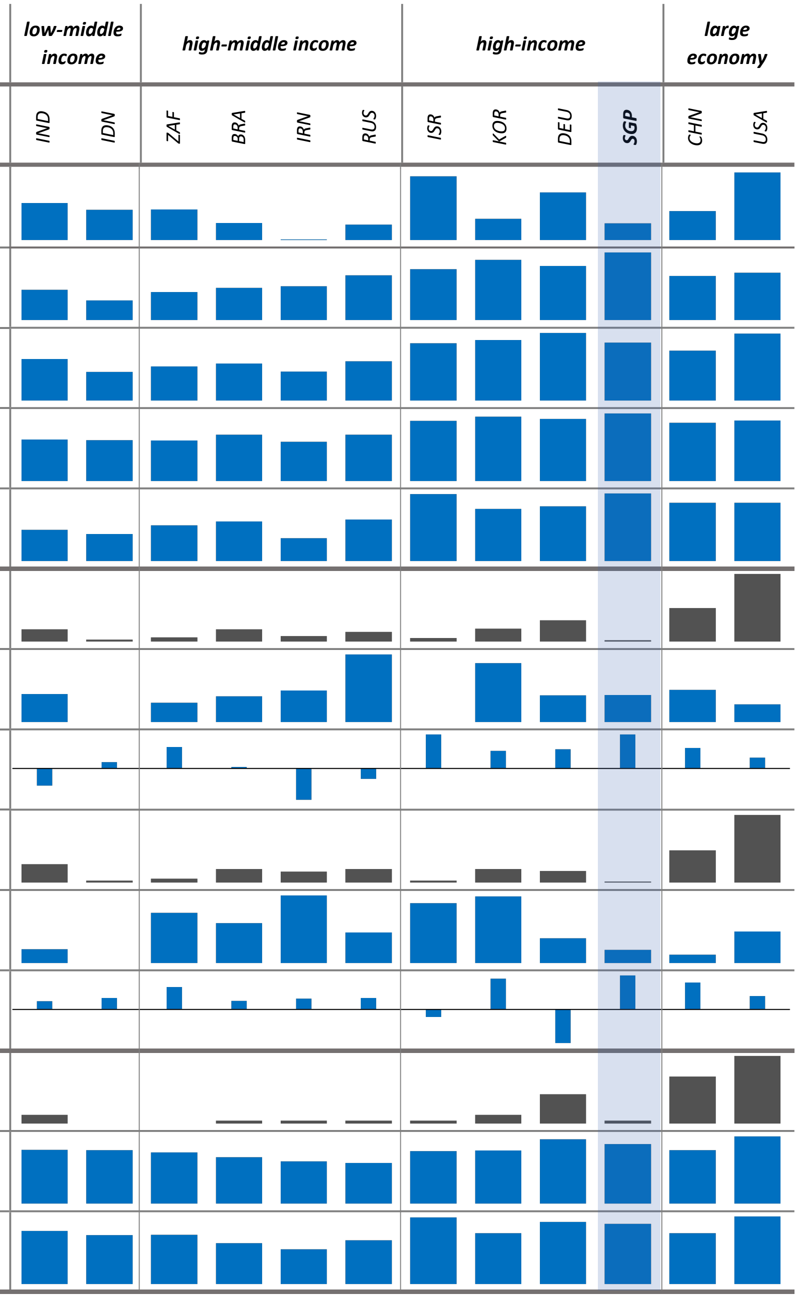
SINGAPORE

Science and Technology : drivers of innovation				*low-middle income*		*high-middle income*				*high-income*				*large economy*	
	indicator	**rank**	**value**	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	***SGP***	*CHN*	*USA*
talent	*share of world STEM graduates*	4 of 10	5.8%					*n.a.*						*n.a.*	
	STEM graduates relative to GDP	1 of 10	--					*n.a.*						*n.a.*	
	retention of foreign-educated PhD students	1 of 10	63.7%			*n.a.*									*n.a.*
	share of world researchers	9 of 12	0.34%												
	researchers relative to GDP	6 of 12	--												
funding: research & development	*total expenditures on R&D*	9 of 12	$10B USD PPP												
	total expenditures on R&D relative to GDP	5 of 12	2.2%												
	R&D expenditures funded by higher ed. relative to GDP	1 of 11	0.63%				*n.a.*								
	R&D expenditures funded by government relative to GDP	8 of 11	0.23%				*n.a.*								
	R&D expenditures funded by business relative to GDP	6 of 11	1.30%				*n.a.*								
funding: venture capital	VC availability (Global Competitiveness Report)	4 of 12	4.7/7 score; 6/140 countries												
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	2 of 11	91/100 score					*n.a.*							
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	1 of 12	5.6/7 score; 1/140 countries												
	ease of technology transfer (US Chamber IP Index)	1 of 11	1/1 score					*n.a.*							
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	1 of 12	6.3/7 score; 3/140 countries												
	patents, related rights, and limitations (US Chamber IP Index)	1 of 11	7/7 score					*n.a.*							
	tax incentives in the creation of IP assets (US Chamber IP Index)	4 of 11	0.7/1 score					*n.a.*							
policy: future	future orientation of government (Global Competitiveness Report)	1 of 12	6.1/7 score; 1/140 countries												

SINGAPORE

Science and Technology : drivers of innovation

	indicator	rank	value
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	10 of 12	56%
	human capital and research (Global Innovation Index)	1 of 12	73/100 score 1/126 countries
	innovation capability (Global Competitiveness Report)	4 of 12	75/100 score 14/140 countries
	infrastructure (Global Innovation Index)	1 of 12	66/100 score 5/126 countries
	business sophistication (Global Innovation Index)	1 of 12	65/100 score 2/126 countries
universities	*share of top computer sciences universities*	12 of 12	0.29%
	top computer sciences universities relative to GDP	6 of 12	--
	relative emphasis on computer sciences in top universities	1 of 12	+0.54 (-1 to 1)
	share of top engineering and technology universities	12 of 12	0.2%
	top engineering and technology universities relative to GDP	10 of 12	--
	relative emphasis on engineering and technology in top universities	1 of 12	+0.32 (-1 to 1)
collaboration	*share of top international innovation clusters*	6 of 12	1.0%
	state of cluster development (Global Competitiveness Report)	3 of 12	5.1/7 score 12/140 countries
	university-industry collaboration (Global Competitiveness Report)	4 of 12	5.2/7 score



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data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math

R&D: research and development. VC: venture capital.

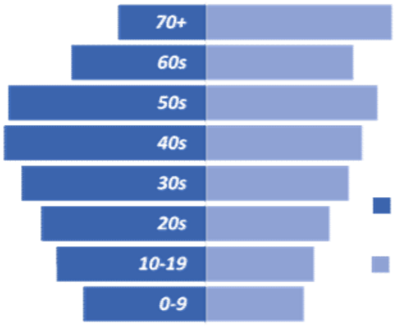
relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SINGAPORE

AGE DISTRIBUTION



ECONOMY: HIGH INCOME

EDUCATION DISTRIBUTION

General-societal

sector scores	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
general-societal capacity scores	12 of 12	0.1/10 points												
general-societal innovation-driver scores	1 of 12	6.5/10 points												

General-societal: output measures

	indicator	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
economy	*current GDP, PPP*	11 of 12	$0.51T USD PPP, 0.42% of global GDP												
	current GDP per capita	1 of 12	$87k USD PPP												
population	*current population*	12 of 12	5.8 million 0.07% global pop.												
	current ratio: working age population to young plus elderly population	1 of 12	2.7:1												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

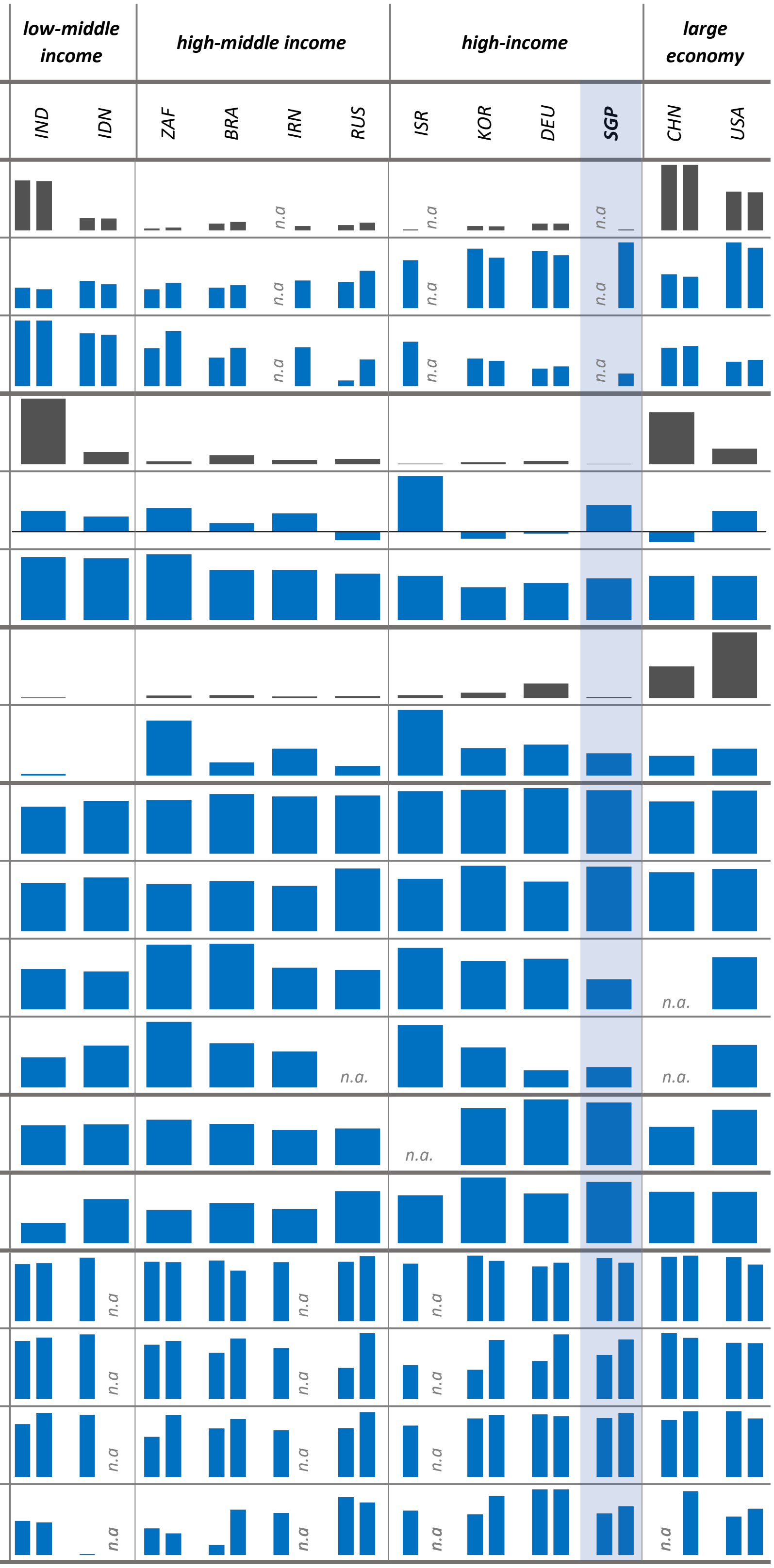
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SINGAPORE

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	12 of 12	$0.69T USD, 0.24% of global GDP
	2050 GDP per capita	1 of 12	$94K USD PPP
	GDP annual growth rate, 2018 to 2050	12 of 12	1%
population	*2050 population*	12 of 12	7.3 million, 0.08% of global pop.
	population growth rate, 2018 to 2050	2 of 12	0.7%
	2050 ratio: working age population to young plus elderly population	10 of 12	1.4:1
universities	*share of top universities*	10 of 12	0.4%
	top universities relative to GDP	7 of 12	--
education	school life expectancy, primary through tertiary	3 of 12	16.4 years
	presence of science education in secondary school	2 of 12	97%
	government expenditure on education as percent of GDP	11 of 11	2.85%
	government expenditure on primary education as percent of GDP	9 of 10	0.74%
policy	rule of law (World Justice Project)	2 of 11	80/100 score
ICT	ICT adoption (WEF Global Competitiveness)	2 of 12	85/100 score; 4/140 countries
beliefs about science	belief in science as future national benefit	5 of 12	80%
	belief in science as increasing jobs	7 of 12	61%
	belief in science as a personal benefit	5 of 12	77%
	trust in science over religion	5 of 12	50%



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data not available *n.a.*

acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

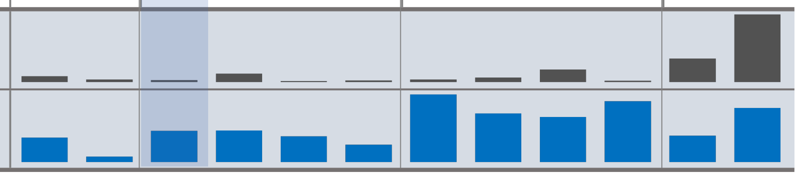
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

two bars indicate data from two separate sources

SOUTH AFRICA

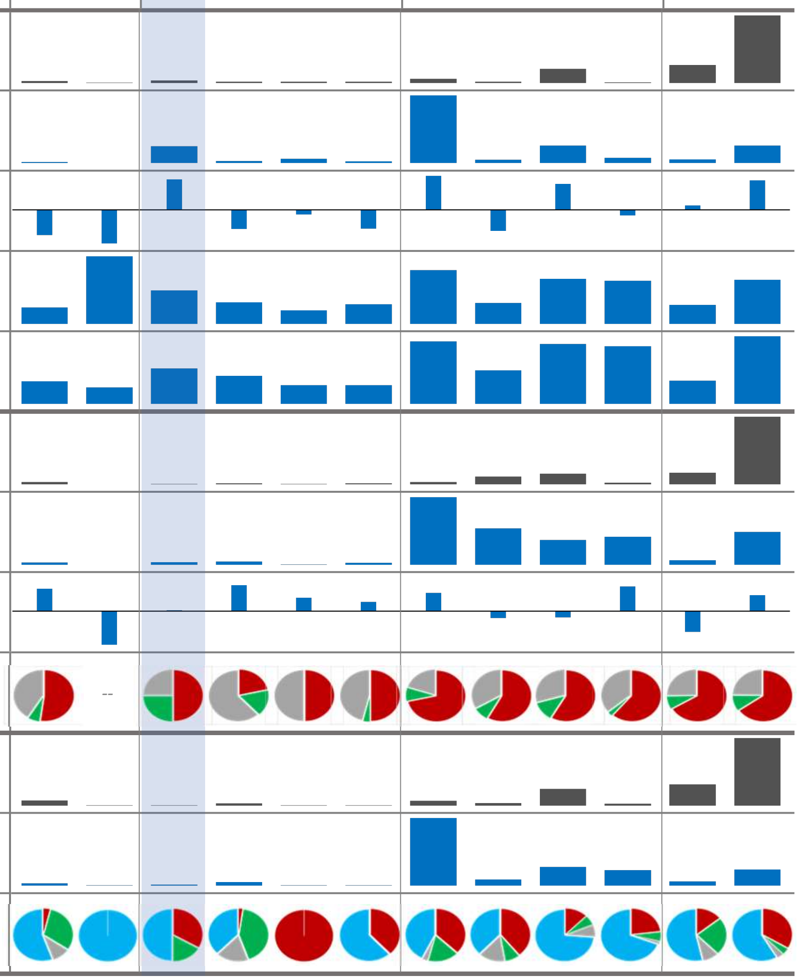
Biotech

sector scores	rank	value	*low-middle income*		*high-middle income*				*high-income*				*large economy*	
			IND	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
biotech capacity scores	9 of 12	0.3/10 points												
biotech innovation-driver scores	7 of 12	3.2/10 points												



Biotech: output measures

	indicator	rank	value	*low-middle income*		*high-middle income*				*high-income*				*large economy*	
				IND	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
publications	*share of top biotech publications*	5 of 12	2.2%												
	top biotech publications relative to GDP	4 of 12	--												
	relative emphasis on biotech within top publications	2 of 12	+0.9 (-1 to 1)												
	average citation count per biotech publication	6 of 12	--												
	average citation count per biochemistry, genetics, and molecular biology publications	5 of 12	--												
patents	*share of world biotech patents, 2014-2019*	10 of 12	0.01%												
	biotech patents relative to GDP	8 of 12	--												
	relative emphasis on biotech within patents	8 of 12	+0.02 (-1 to 1)												
	proportion of red, green, or white biotech patents	--	50%, 25%, 25%		--										
companies	*share of world biotech companies*	10 of 12	0.11%												
	biotech companies relative to GDP	9 of 12	--												
	proportion of red, green, white, or R&D service biotech companies	--	33%, 17%, 0%, 50%												



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

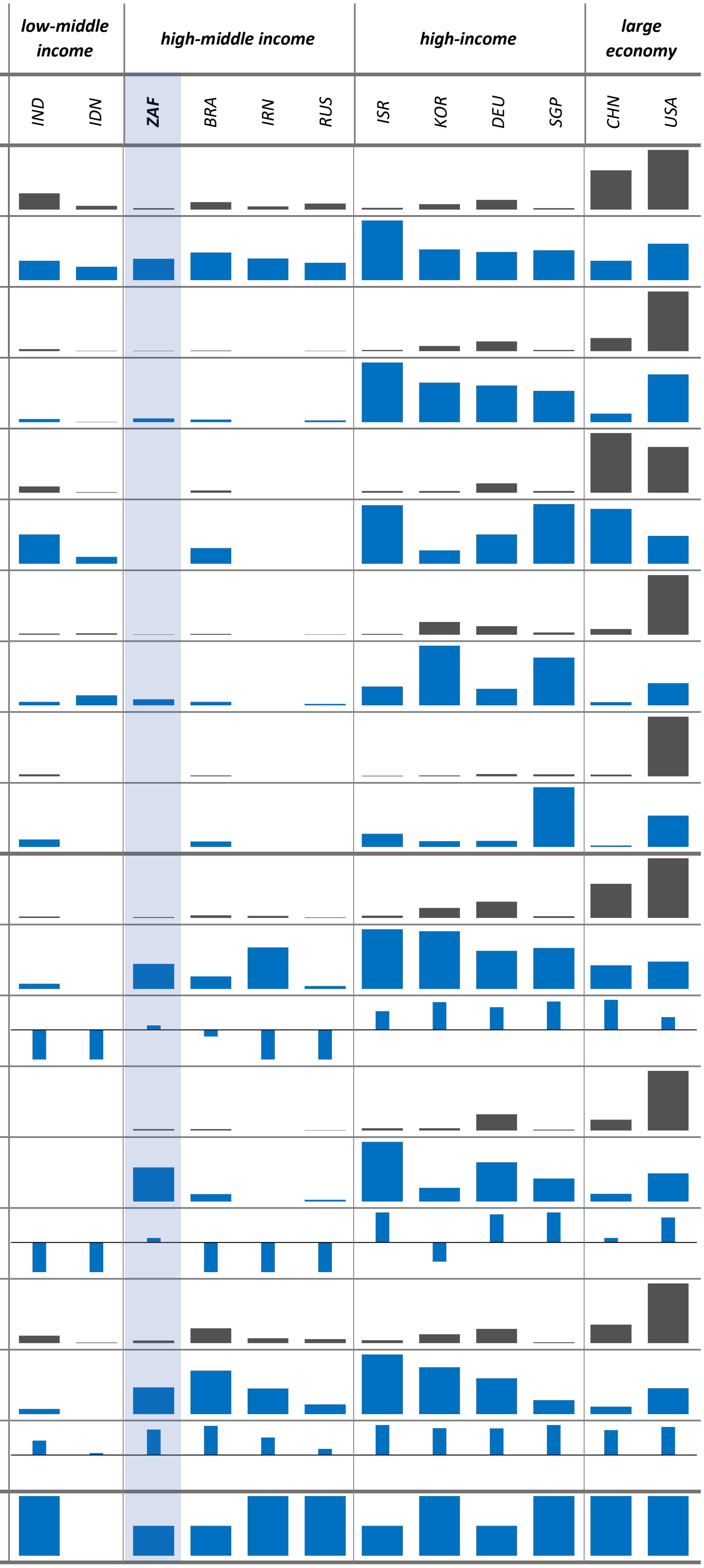
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

SOUTH AFRICA

Biotech : drivers of innovation

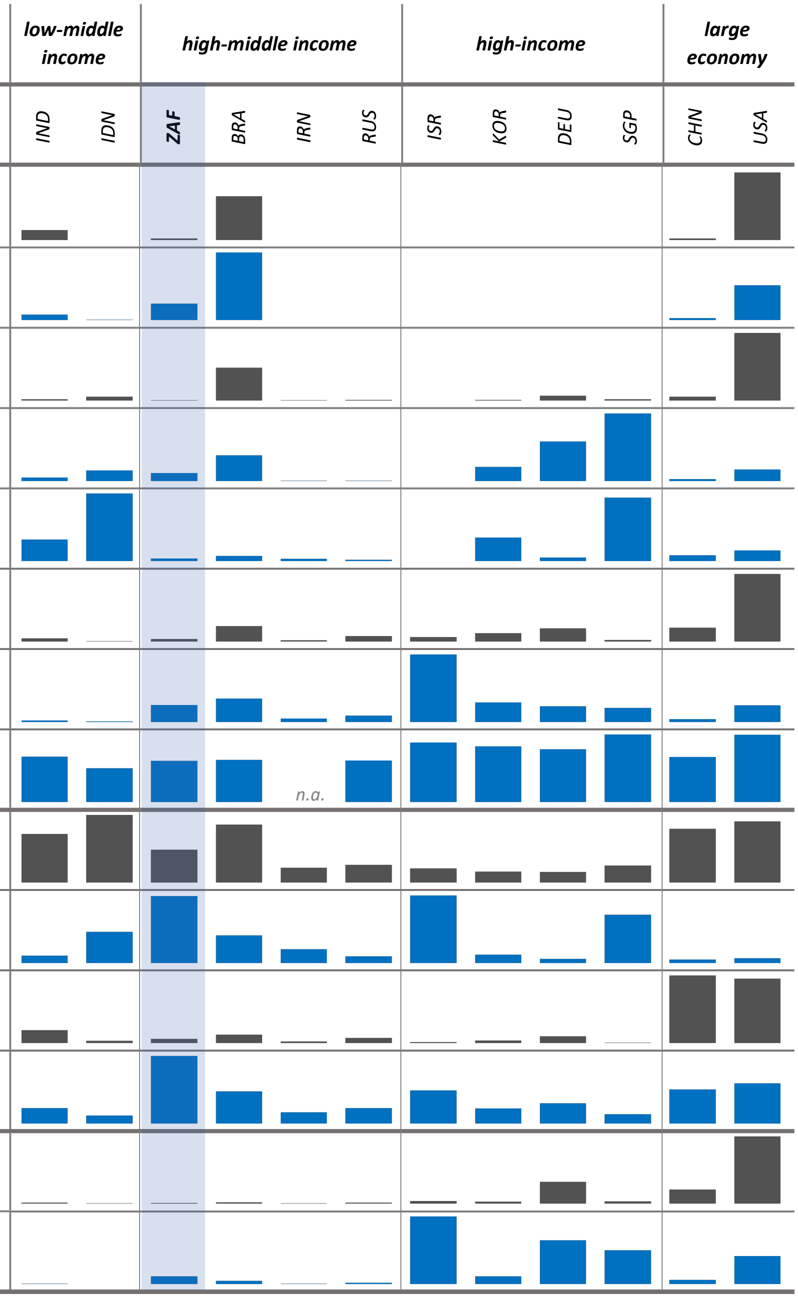
	indicator	rank	value
talent	*users of largest genetic sequence database*	12 of 12	0.5% of users
	users of largest genetic sequence database relative to GDP	8 of 12	--
	users of a major genetic engineering tool supplier	10 of 12	101 depositors
	users of a major genetic engineering tool supplier relative to GDP	7 of 12	--
	participation in international genetic engineering competition	10 of 12	0.0% of participants
	participation in international genetic engineering competition relative to GDP	10 of 12	--
	attendance at preeminent synthetic biology conferences	11 of 12	0.1% of attendees
	attendance at preeminent synthetic biology conferences relative to GDP	7 of 12	--
	subscribers to a prominent synthetic biology newsletter	9 of 12	0.0% of subscribers
	subscribers to a prominent synthetic biology newsletter relative to GDP	9 of 12	--
universities	*share of top biotech universities*	10 of 12	0.3%
	top biotech universities relative to GDP	7 of 12	--
	relative emphasis on biotech in top universities	7 of 12	+0.1 (-1 to 1)
	share of top biology universities	7 of 12	0.7%
	top biology universities relative to GDP	3 of 12	--
	relative emphasis on biology in top universities	5 of 12	+0.1 (-1 to 1)
	share of top life sciences universities	10 of 12	2.1%
	top life sciences universities relative to GDP	5 of 12	--
	relative emphasis on life sciences in top universities	7 of 12	+0.8 (-1 to 1)
policy	presence of a national biotechnology plan	8 of 12	0.5 of 1 pt



SOUTH AFRICA

Biotech : drivers of innovation

	indicator	rank	value
industry sector maturity	*share of total global biotech crops*	4 of 12	1%
	biotech crops relative to total cropland	3 of 12	22.5%
	share of total global biofuel production	10 of 12	0.3%
	biotech fuels relative to total liquid fuel production	7 of 12	5.0%
	average annual growth rate in biofuel production, 2006-2016	9 of 12	3.1%
	clinical trials of biologics since 2010	9 of 12	1% of trials
	clinical trials of biologics since 2010 scaled to GDP	4 of 12	--
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	10 of 11	53/100 score
biodiversity	*well-studied animal and plant species*	6 of 12	4.8% of species
	well-studied animal and plant species scaled to GDP	2 of 12	--
	non-human sequence entries in largest genetic sequence database	7 of 12	1.1% of entries
	non-human sequence entries in largest genetic sequence database scaled to GDP	1 of 12	--
collaboration	*life sciences collaboration (Nature Index)*	10 of 12	1.1% of max score
	life sciences collaborations relative to GDP	5 of 12	--



data not applicable --

data not available *n.a.*

acronym: GDP: gross domestic product.
largest genetic sequence database: NIH GenBank.
major genetic engineering tool supplier: AddGene.
international genetic engineering competition: iGEM.
preeminent synthetic biology conference: SBx.0.
prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

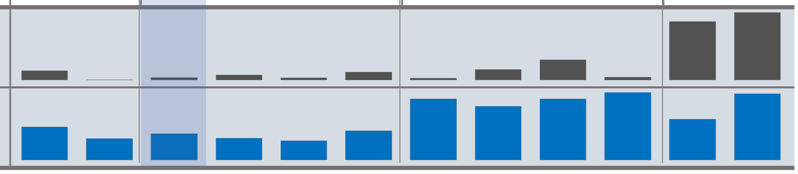
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SOUTH AFRICA

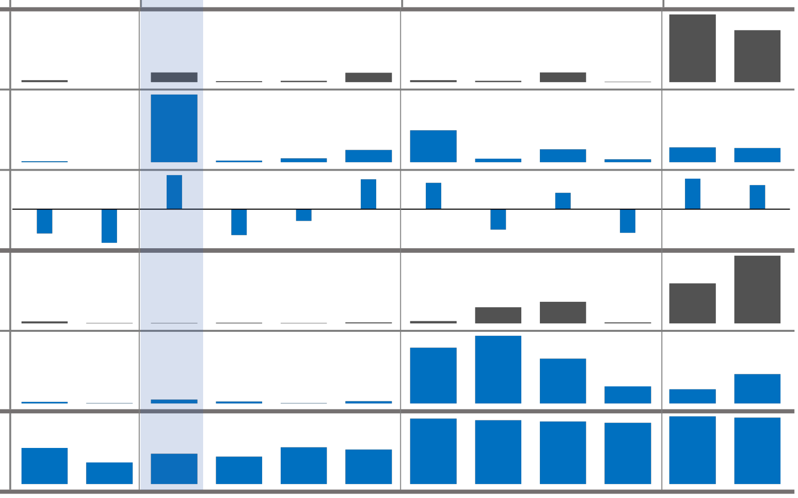
Science and Technology

sector scores	rank	value	*IND* (low-middle income)	*IDN* (low-middle income)	***ZAF*** (high-middle income)	*BRA* (high-middle income)	*IRN* (high-middle income)	*RUS* (high-middle income)	*ISR* (high-income)	*KOR* (high-income)	*DEU* (high-income)	*SGP* (high-income)	*CHN* (large economy)	*USA* (large economy)
science & technology capacity scores	9 of 12	0.4/10 points												
science & technology innovation-driver scores	9 of 12	2.9/10 points												



Science and Technology: output measures

	indicator	rank	value	*IND* (low-middle income)	*IDN* (low-middle income)	***ZAF*** (high-middle income)	*BRA* (high-middle income)	*IRN* (high-middle income)	*RUS* (high-middle income)	*ISR* (high-income)	*KOR* (high-income)	*DEU* (high-income)	*SGP* (high-income)	*CHN* (large economy)	*USA* (large economy)
publications	*share of top high tech publications*	4 of 12	8.0%												
	top high tech publications relative to GDP	1 of 12	--												
	relative emphasis on high tech within top publications	1 of 12	+1 (-1 to 1)												
patents	*share of world patents, 2014-2019*	10 of 12	0.14%												
	patents relative to GDP	7 of 12	--												
STI output	knowledge and technology outputs (Global Innovation Index)	10 of 12	25/100 score; 55/126 countries												



data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product

STI: science and technology innovation

relative strength compared to 12 countries (read across row)

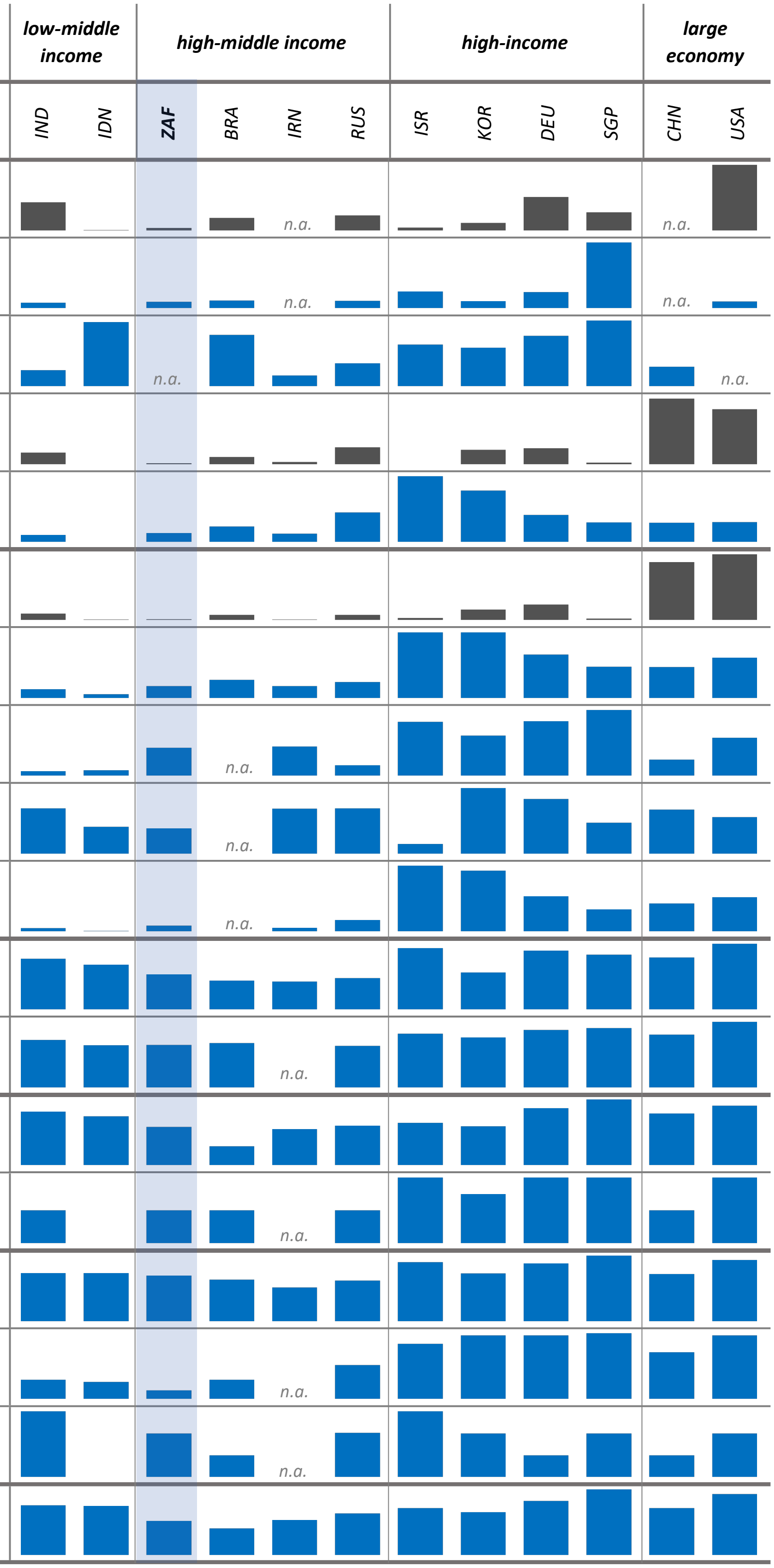
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SOUTH AFRICA

Science and Technology : drivers of innovation

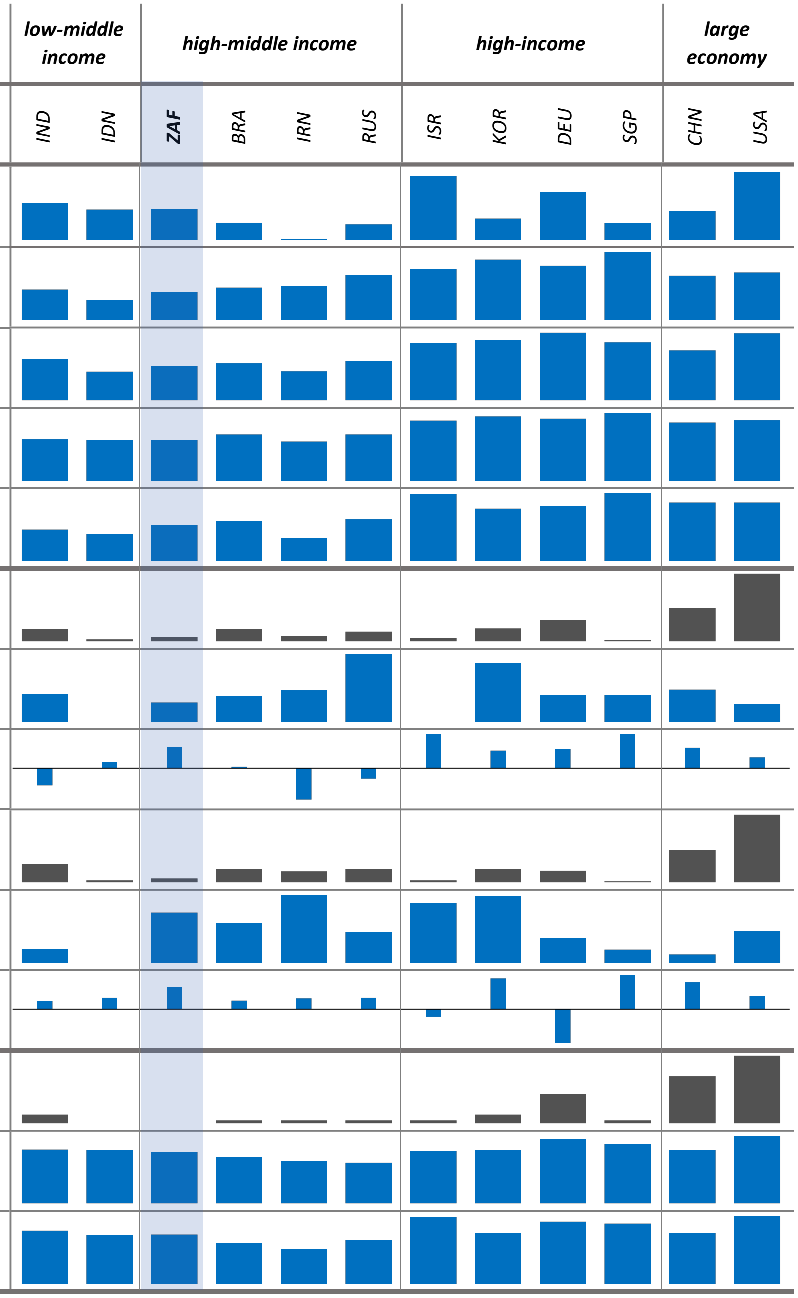
	indicator	rank	value
talent	*share of world STEM graduates*	9 of 10	0.8%
	STEM graduates relative to GDP	8 of 10	--
	retention of foreign-educated PhD students	--	n.a.
	share of world researchers	10 of 12	0.3%
	researchers relative to GDP	9 of 12	--
funding: research & development	*total expenditures on R&D*	10 of 12	5.8B $USD
	total expenditures on R&D relative to GDP	10 of 12	0.8%
	R&D expenditures funded by higher ed. relative to GDP	7 of 11	0.27%
	R&D expenditures funded by government relative to GDP	10 of 11	0.19%
	R&D expenditures funded by business relative to GDP	8 of 11	0.34%
funding: venture capital	VC availability (Global Competitiveness Report)	9 of 12	3/7 score; 63/140 countries
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	9 of 11	65/100 score
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	10 of 12	3.2/7 score; 84/140 countries
	ease of technology transfer (US Chamber IP Index)	6 of 11	0.5/1 score
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	9 of 12	4.4/7 score; 60/140 countries
	patents, related rights, and limitations (US Chamber IP Index)	11 of 11	1/7 score
	tax incentives in the creation of IP assets (US Chamber IP Index)	4 of 11	0.7/1 score
policy: future	future orientation of government (Global Competitiveness Report)	11 of 12	3.2/7 score; 102/140 countries



SOUTH AFRICA

Science and Technology : drivers of innovation

	indicator	rank	value	
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	5 of 12	63%	
	human capital and research (Global Innovation Index)	11 of 12	30/100 score	64/126 countries
	innovation capability (Global Competitiveness Report)	10 of 12	44/100 score	46/140 countries
	infrastructure (Global Innovation Index)	11 of 12	39/100 score	84/126 countries
	business sophistication (Global Innovation Index)	9 of 12	34/100 score	47/126 countries
universities	*share of top computer sciences universities*	9 of 12	1.0%	
	top computer sciences universities relative to GDP	9 of 12	--	
	relative emphasis on computer sciences in top universities	3 of 12	+0.3	(-1 to 1)
	share of top engineering and technology universities	9 of 12	0.9%	
	top engineering and technology universities relative to GDP	4 of 12	--	
	relative emphasis on engineering and technology in top universities	4 of 12	+0.2	(-1 to 1)
collaboration	*share of top international innovation clusters*	11 of 12	0.0%	
	state of cluster development (Global Competitiveness Report)	9 of 12	4.4/7 score	33/140 countries
	university-industry collaboration (Global Competitiveness Report)	8 of 12	4.3/7 score	



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data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math
R&D: research and development. VC: venture capital.
GDP: gross domestic product. IP: intelllectual property.
IESE: graduate business school of the University of Navarra.

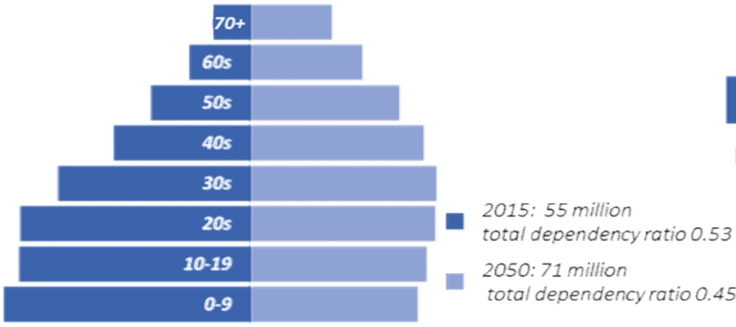
relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

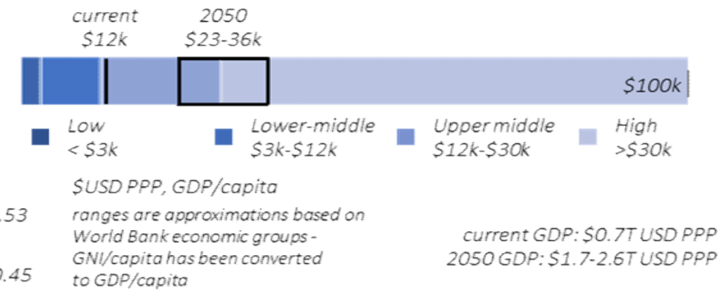
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SOUTH AFRICA

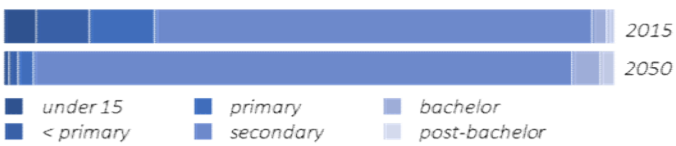
AGE DISTRIBUTION



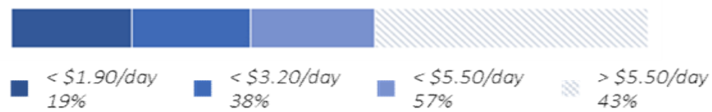
ECONOMY: UPPER-MIDDLE INCOME



EDUCATION DISTRIBUTION



EXTREME POVERTY DISTRIBUTION



General-societal

sector scores	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
			low-middle income		high-middle income				high-income				large economy	
general-societal capacity scores	10 of 12	0.3/10 points												
general-societal innovation-driver scores	6 of 12	4.4/10 points												

General-societal: output measures

	indicator	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
				low-middle income		high-middle income				high-income				large economy	
economy	*current GDP, PPP*	10 of 12	$0.70T USD PPP, 0.58% of global GDP												
economy	current GDP per capita	10 of 12	$12k USD PPP												
population	*current population*	9 of 12	59 million 0.75% global pop.												
population	current ratio: working age population to young plus elderly population	11 of 12	1.9:1												

data not applicable --
data not available *n.a.*
acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SOUTH AFRICA

General-societal : drivers of innovation

	indicator	rank	value	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	*USA*
				low-middle income		*high-middle income*				*high-income*				*large economy*	
economy	*2050 GDP, PPP*	10 of 12	$1.7-2.6T USD, 0.8-0.9% of global GDP					n.a		n.a			n.a		
	2050 GDP per capita	10 of 12	$23-36k USD PPP					n.a		n.a			n.a		
	GDP annual growth rate, 2018 to 2050	3 of 12	2.7-4.1%					n.a		n.a			n.a		
population	*2050 population*	9 of 12	71 million, 0.76% of global pop.												
	population growth rate, 2018 to 2050	3 of 12	0.7%												
	2050 ratio: working age population to young plus elderly population	1 of 12	2.2:1												
universities	*share of top universities*	7 of 12	1.0%												
	top universities relative to GDP	2 of 12	--												
education	school life expectancy, primary through tertiary	9 of 12	13.7 years												
	presence of science education in secondary school	11 of 12	71%												
	government expenditure on education as percent of GDP	2 of 11	6.2%											n.a.	
	government expenditure on primary education as percent of GDP	1 of 10	2.4%						n.a.				n.a.	n.a.	
policy	rule of law (World Justice Project)	5 of 11	58/100 score							n.a.					
ICT	ICT adoption (WEF Global Competitiveness)	11 of 12	46/100 score 85/140 countries												
beliefs about science	belief in science as future national benefit	7 of 12	78%		n.a			n.a		n.a					
	belief in science as increasing jobs	4 of 12	66%		n.a			n.a		n.a					
	belief in science as a personal benefit	11 of 12	63%		n.a			n.a		n.a					
	trust in science over religion	11 of 12	26%		n.a			n.a		n.a				n.a	

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

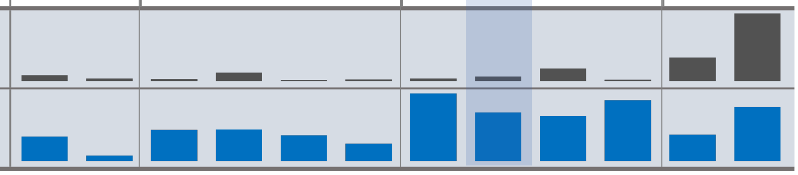
two bars indicate data from two separate sources

SOUTH KOREA

Biotech

sector scores	rank	value
biotech capacity scores	6 of 12	0.7/10 points
biotech innovation-driver scores	4 of 12	5/10 points

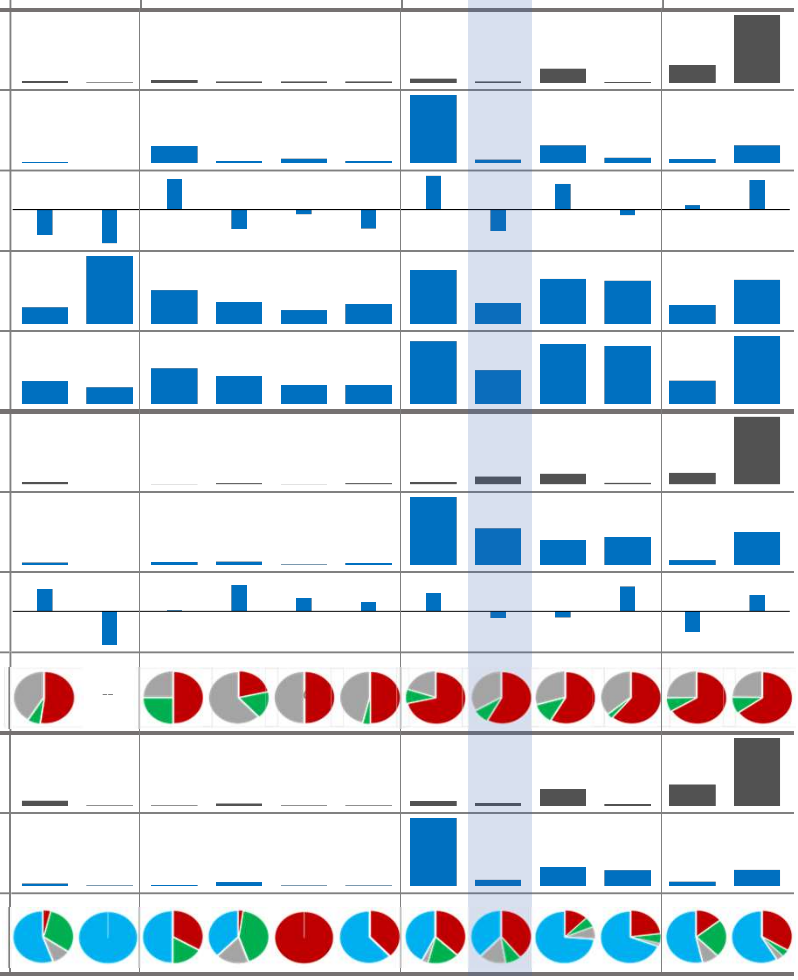
low-middle income: IND, IDN · *high-middle income*: ZAF, BRA, IRN, RUS · *high-income*: ISR, KOR, DEU, SGP · *large economy*: CHN, USA



Biotech : output measures

	indicator	rank	value
publications	*share of top biotech publications*	8 of 12	1.2%
	top biotech publications relative to GDP	8 of 12	--
	relative emphasis on biotech within top publications	10 of 12	-0.6 (-1 to 1)
	average citation count per biotech publication	8 of 12	--
	average citation count per biochemistry, genetics, and molecular biology publications	6 of 12	--
patents	*share of world biotech patents, 2014-2019*	4 of 12	5.2%
	biotech patents relative to GDP	2 of 12	--
	relative emphasis on biotech within patents	10 of 12	-0.21 (-1 to 1)
	proportion of red, green, or white biotech patents	--	58%, 9%, 33%
companies	*share of world biotech companies*	6 of 12	2.2%
	biotech companies relative to GDP	5 of 12	--
	proportion of red, green, white, or R&D service biotech companies	--	39%, 8%, 15%, 38%

low-middle income: IND, IDN · *high-middle income*: ZAF, BRA, IRN, RUS · *high-income*: ISR, KOR, DEU, SGP · *large economy*: CHN, USA



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

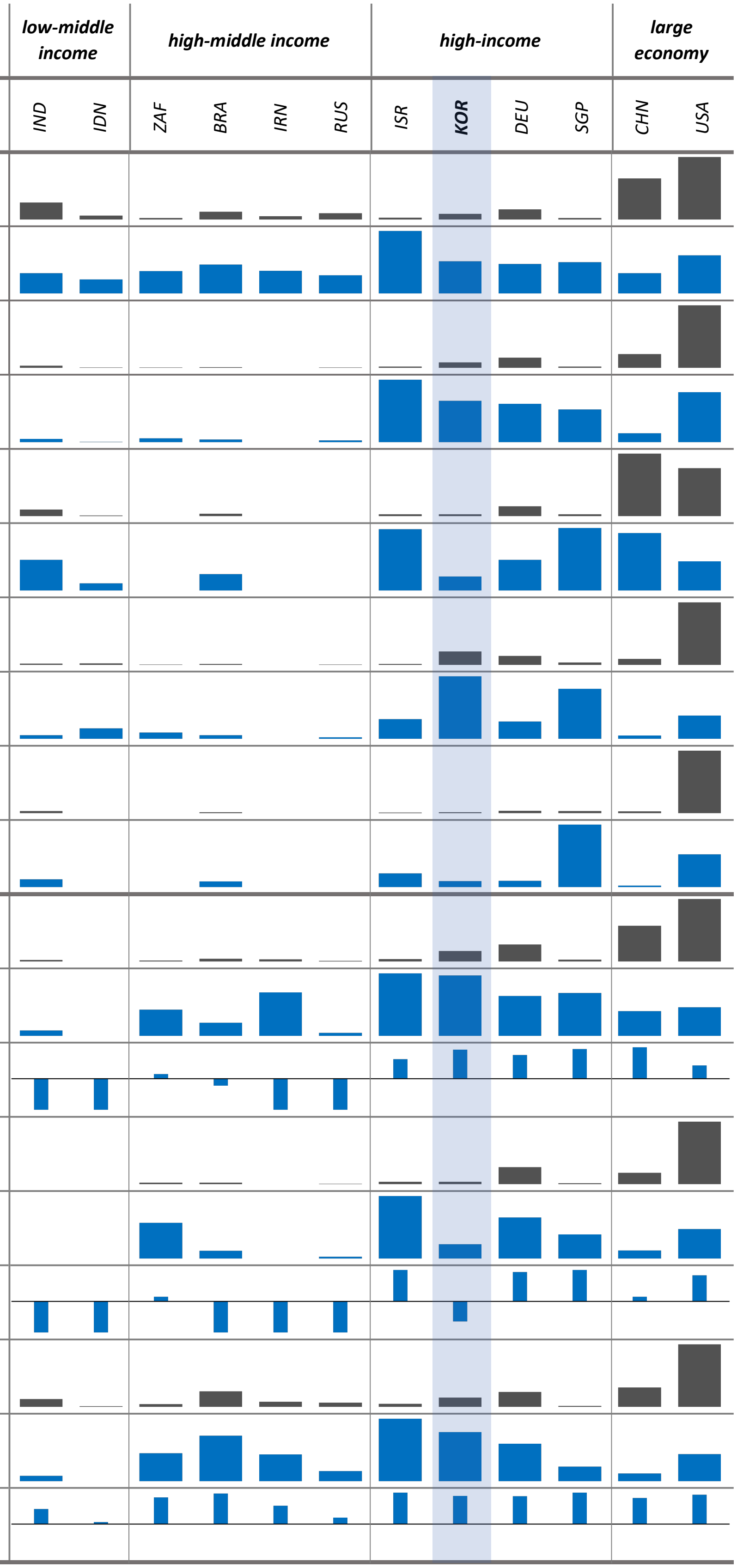
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

SOUTH KOREA

Biotech : drivers of innovation

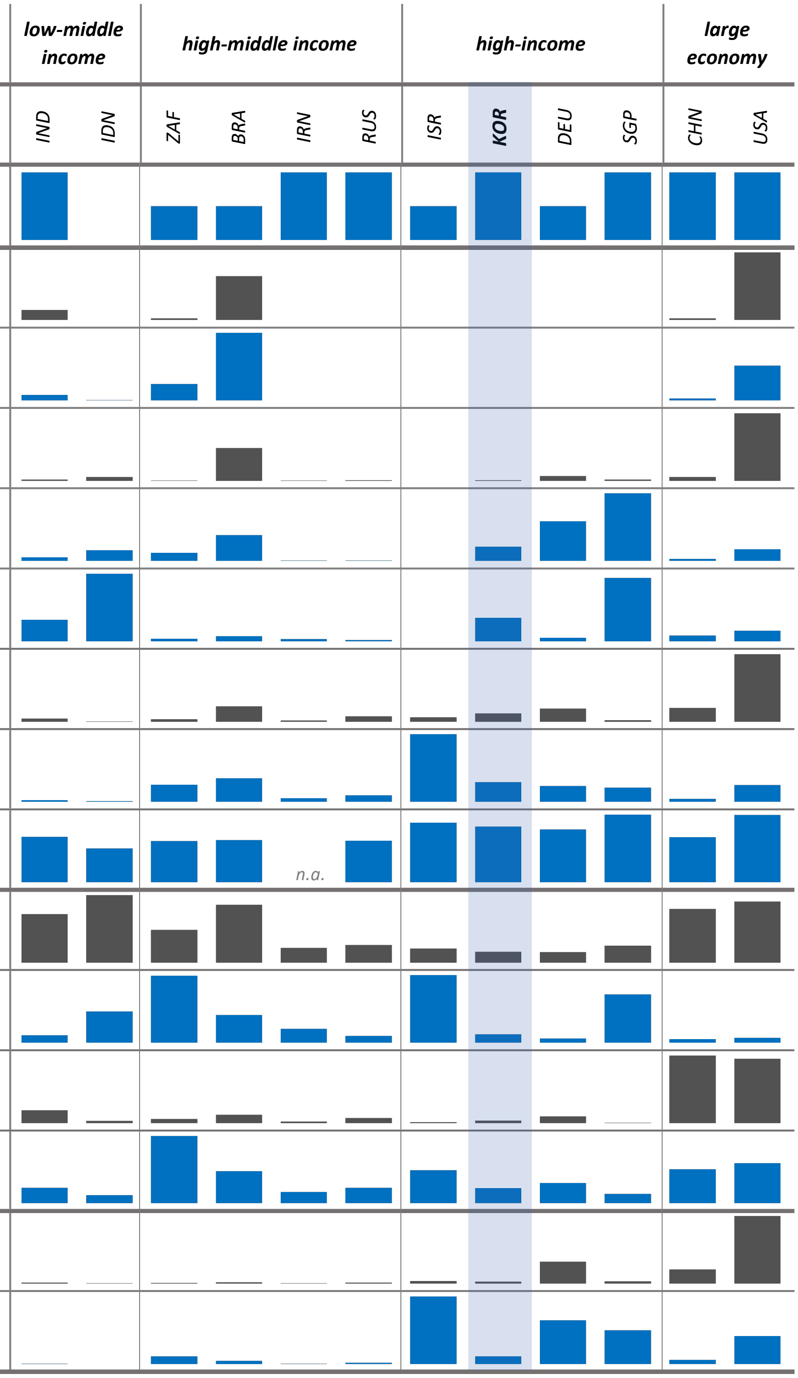
	indicator	rank	value
talent	*users of largest genetic sequence database*	7 of 12	2% of users
	users of largest genetic sequence database relative to GDP	3 of 12	--
	users of a major genetic engineering tool supplier	4 of 12	2849 depositors
	users of a major genetic engineering tool supplier relative to GDP	3 of 12	--
	participation in international genetic engineering competition	6 of 12	0.87% of participants
	participation in international genetic engineering competition relative to GDP	8 of 12	--
	attendance at preeminent synthetic biology conferences	2 of 12	5.5% of attendees
	attendance at preeminent synthetic biology conferences relative to GDP	1 of 12	--
	subscribers to a prominent synthetic biology newsletter	7 of 12	0.9% of subscribers
	subscribers to a prominent synthetic biology newsletter relative to GDP	6 of 12	--
universities	*share of top biotech universities*	4 of 12	3.4%
	top biotech universities relative to GDP	2 of 12	--
	relative emphasis on biotech in top universities	3 of 12	+0.7 (-1 to 1)
	share of top biology universities	4 of 12	1.2%
	top biology universities relative to GDP	6 of 12	--
	relative emphasis on biology in top universities	7 of 12	-0.5 (-1 to 1)
	share of top life sciences universities	5 of 12	7.6%
	top life sciences universities relative to GDP	2 of 12	--
	relative emphasis on life sciences in top universities	5 of 12	+0.8 (-1 to 1)



SOUTH KOREA

Biotech : drivers of innovation

	indicator	rank	value
policy	presence of a national biotechnology plan	1 of 12	1 of 1 pt
industry sector maturity	*share of total global biotech crops*	6 of 12	0.0%
	biotech crops relative to total cropland	7 of 12	0.0%
	share of total global biofuel production	9 of 12	0.4%
	biotech fuels relative to total liquid fuel production	4 of 12	8.8%
	average annual growth rate in biofuel production, 2006-2016	3 of 12	29%
	clinical trials of biologics since 2010	5 of 12	4% of trials
	clinical trials of biologics since 2010 scaled to GDP	3 of 12	--
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	4 of 11	72/100 score
biodiversity	*well-studied animal and plant species*	11 of 12	1.6% of species
	well-studied animal and plant species scaled to GDP	7 of 12	--
	non-human sequence entries in largest genetic sequence database	8 of 12	0.7% of entries
	non-human sequence entries in largest genetic sequence database scaled to GDP	9 of 12	--
collaboration	*life sciences collaboration (Nature Index)*	6 of 12	3.0% of max score
	life sciences collaborations relative to GDP	6 of 12	--



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data not available *n.a.*

acronym: GDP: gross domestic product.

largest genetic sequence database: NIH GenBank.

major genetic engineering tool supplier: AddGene.

international genetic engineering competition: iGEM.

preeminent synthetic biology conference: SBx.0.

prominent synthetic biology newsletter: SynbioBeta.

relative strength compared to 12 countries (read across row)

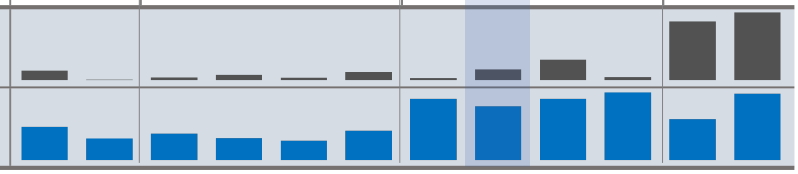
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SOUTH KOREA

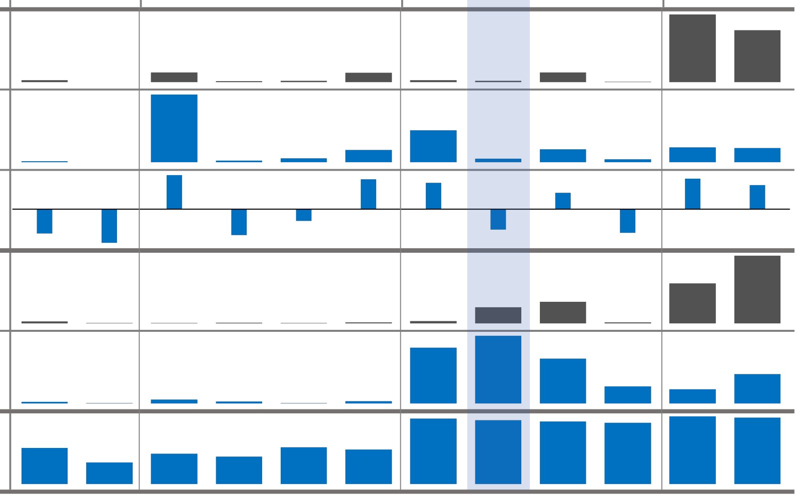
Science and Technology

sector scores	rank	value	*low-middle income*		*high-middle income*				*high-income*				*large economy*	
			IND	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	***KOR***	*DEU*	*SGP*	*CHN*	*USA*
science & technology capacity scores	4 of 12	1.5/10 points												
science & technology innovation-driver scores	5 of 12	6/10 points												



Science and Technology : output measures

	indicator	rank	value		*low-middle income*		*high-middle income*				*high-income*				*large economy*	
					IND	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	***KOR***	*DEU*	*SGP*	*CHN*	*USA*
publications	*share of top high tech publications*	8 of 12	1.2%													
	top high tech publications relative to GDP	8 of 12	--													
	relative emphasis on high tech within top publications	8 of 12	-0.6 (-1 to 1)													
patents	*share of world patents, 2014-2019*	4 of 12	6.5%													
	patents relative to GDP	1 of 12	--													
STI output	knowledge and technology outputs (Global Innovation Index)	4 of 12	53/100 score	9/126 countries												



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data not available *n.a.*

acronyms: GDP: gross domestic product

STI: science and technology innovation

relative strength compared to 12 countries (read across row)

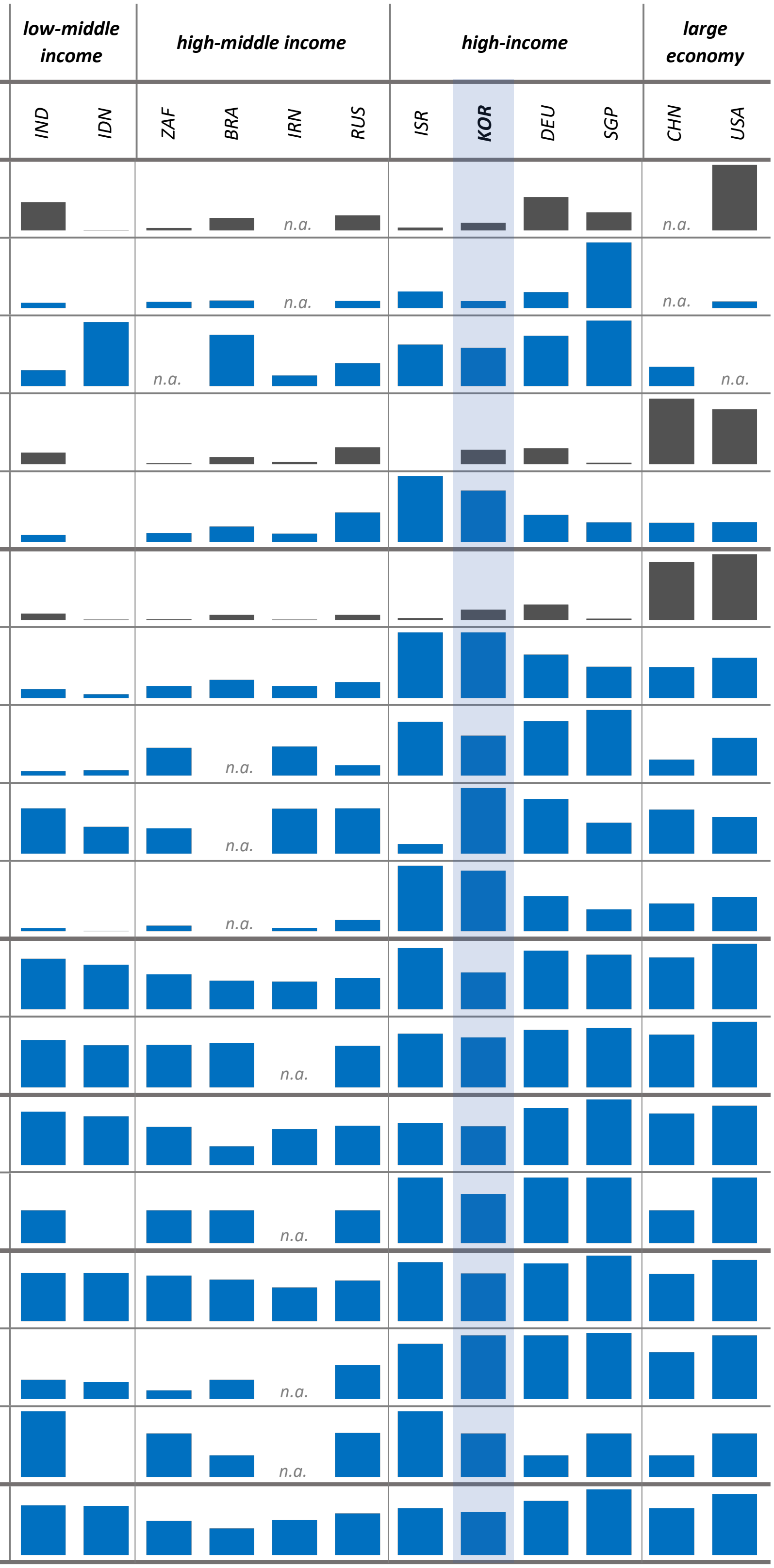
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SOUTH KOREA

Science and Technology : drivers of innovation

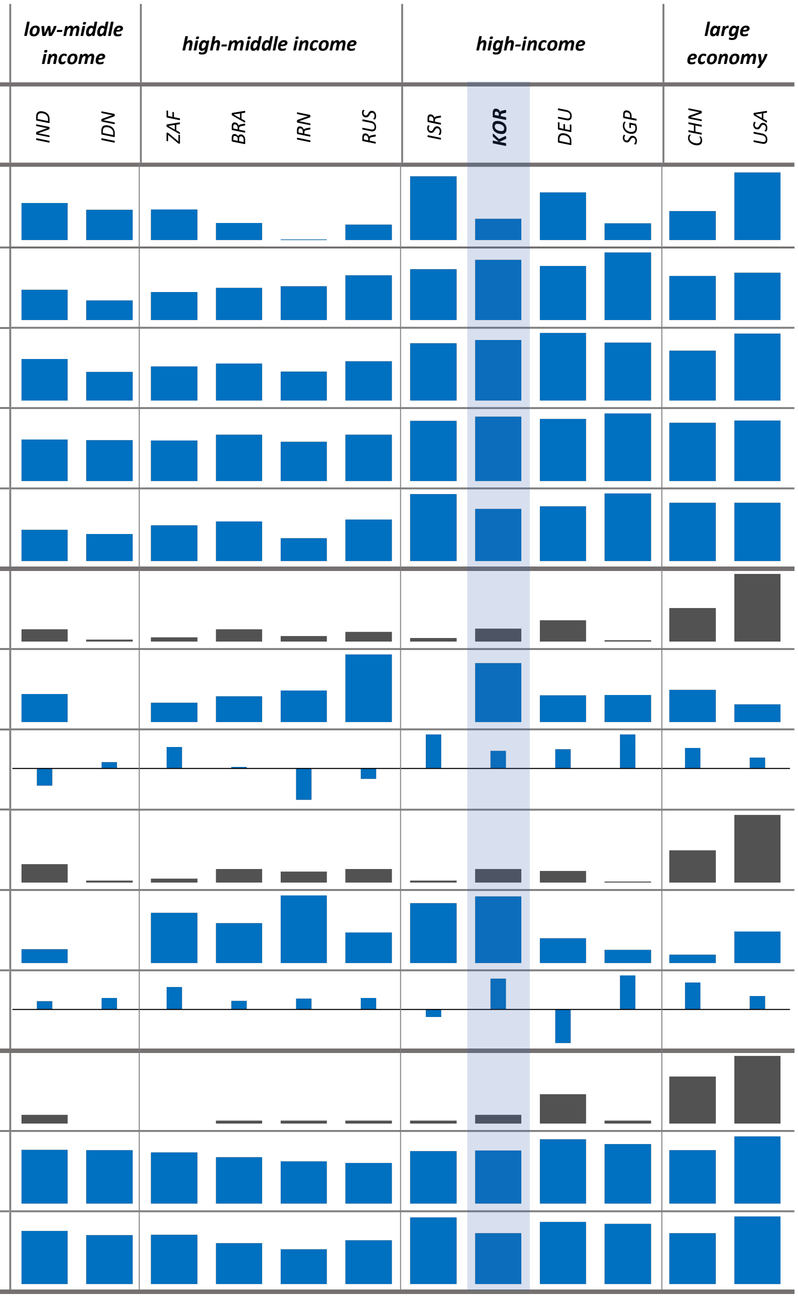
	indicator	rank	value
talent	*share of world STEM graduates*	7 of 10	2.4%
	STEM graduates relative to GDP	6 of 10	--
	retention of foreign-educated PhD students	6 of 10	37.3%
	share of world researchers	5 of 12	3.3%
	researchers relative to GDP	2 of 12	--
funding: research & development	*total expenditures on R&D*	4 of 12	$79B USD PPP
	total expenditures on R&D relative to GDP	1 of 12	4.6%
	R&D expenditures funded by higher ed. relative to GDP	4 of 11	0.39%
	R&D expenditures funded by government relative to GDP	1 of 11	0.49%
	R&D expenditures funded by business relative to GDP	2 of 11	3.62%
funding: venture capital	VC availability (Global Competitiveness Report)	8 of 12	3.2/7 score 53/140 countries
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	6 of 11	76/100 score
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	9 of 12	3.3/7 score 79/140 countries
	ease of technology transfer (US Chamber IP Index)	5 of 11	0.8/1 score
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	7 of 12	4.6/7 score 47/140 countries
	patents, related rights, and limitations (US Chamber IP Index)	2 of 11	7/7 score
	tax incentives in the creation of IP assets (US Chamber IP Index)	4 of 11	0.7/1 score
policy: future	future orientation of government (Global Competitiveness Report)	8 of 12	4.0/7 score 49/140 countries



SOUTH KOREA

Science and Technology : drivers of innovation

	indicator	rank	value	
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	8 of 12	59%	
	human capital and research (Global Innovation Index)	2 of 12	65/100 score	2/126 countries
	innovation capability (Global Competitiveness Report)	3 of 12	78/100 score	8/140 countries
	infrastructure (Global Innovation Index)	2 of 12	63/100 score	13/126 countries
	business sophistication (Global Innovation Index)	6 of 12	50/100 score	20/126 countries
universities	*share of top computer sciences universities*	4 of 12	3.1%	
	top computer sciences universities relative to GDP	2 of 12	--	
	relative emphasis on computer sciences in top universities	6 of 12	+0.3	(-1 to 1)
	share of top engineering and technology universities	4 of 12	3.1%	
	top engineering and technology universities relative to GDP	2 of 12	--	
	relative emphasis on engineering and technology in top universities	2 of 12	+0.3	(-1 to 1)
collaboration	*share of top international innovation clusters*	4 of 12	3.0%	
	state of cluster development (Global Competitiveness Report)	7 of 12	4.6/7 score	30/140 countries
	university-industry collaboration (Global Competitiveness Report)	6 of 12	4.4/7 score	



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acronyms: STEM: science, technology, engineering, and math
R&D: research and development. VC: venture capital.
GDP: gross domestic product. IP: intelllectual property.
IESE: graduate business school of the University of Navarra.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

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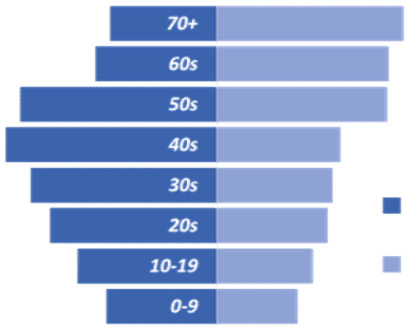
SOUTH KOREA

AGE DISTRIBUTION



2015: 51 million
total dependency ratio 0.37

2050: 48 million
total dependency ratio 0.91

ECONOMY: HIGH INCOME

current
$37k

2050
$72-74k

Low
< $3k

Lower-middle
$3k-$12k

Upper middle
$12k-$30k

High
>$30k

$USD PPP, GDP/capita

ranges are approximations based on World Bank economic groups - GNI/capita has been converted to GDP/capita

current GDP: $1.9T USD PPP
2050 GDP: $3.5-3.6T USD PPP

EDUCATION DISTRIBUTION

2015
2050

under 15
< primary
primary
secondary
bachelor
post-bachelor

EXTREME POVERTY DISTRIBUTION

< $1.90/day
0.2%

< $3.20/day
0.5%

< $5.50/day
1.2%

> $5.50/day
99%

General-societal

sector scores	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
general-societal capacity scores	8 of 12	0.7/10 points												
general-societal innovation-driver scores	4 of 12	5.9/10 points												

General-societal: output measures

	indicator	rank	value	low-middle income: IND	IDN	high-middle income: ZAF	BRA	IRN	RUS	high-income: ISR	KOR	DEU	SGP	large economy: CHN	USA
economy	*current GDP, PPP*	8 of 12	$1.9T USD PPP, 1.6% of global GDP												
	current GDP per capita	4 of 12	$37k USD PPP												
population	*current population*	10 of 12	51 million 0.66% global pop.												
	current ratio: working age population to young plus elderly population	1 of 12	2.7:1												

data not applicable --
data not available *n.a.*
acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

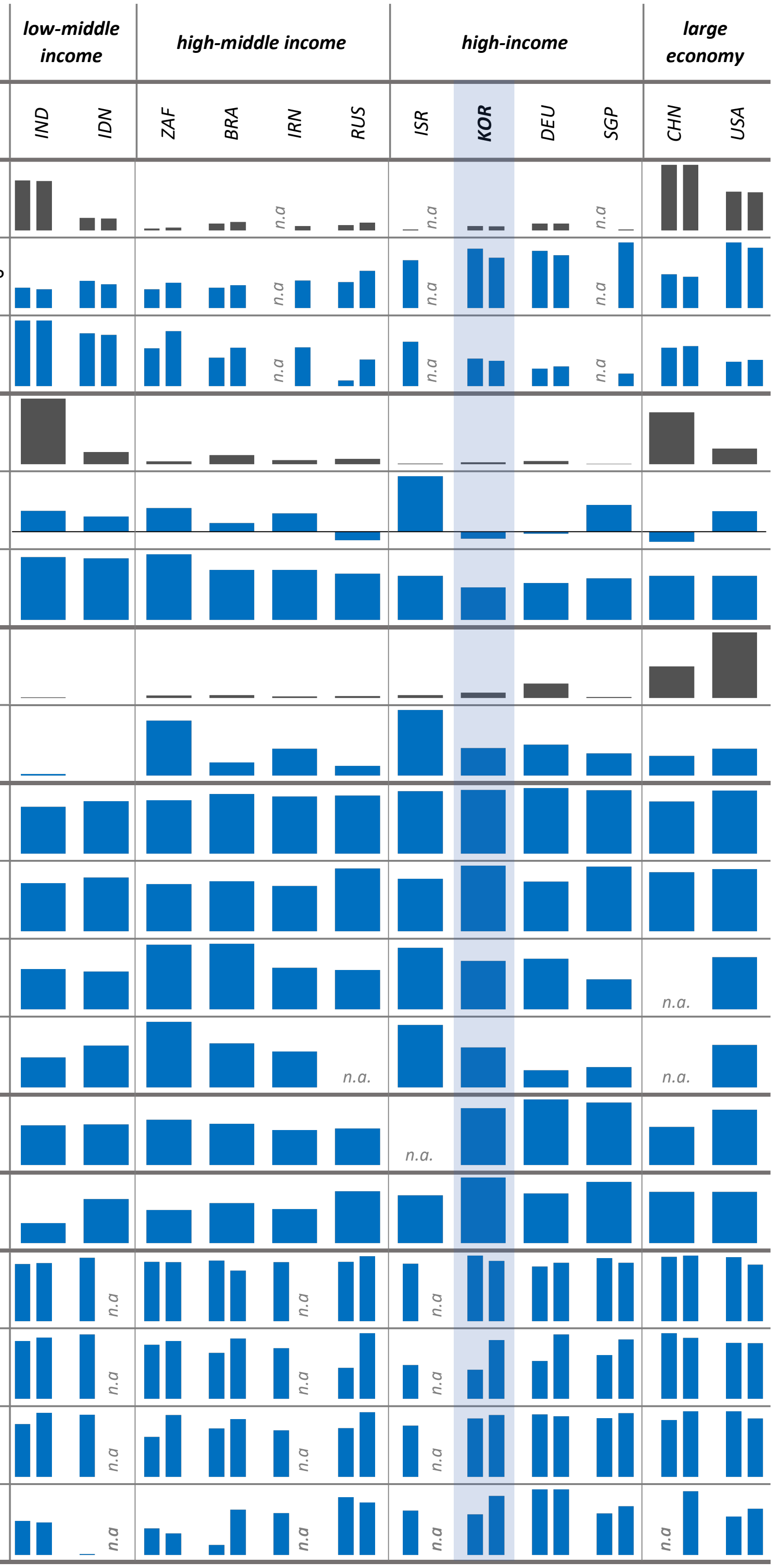
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

SOUTH KOREA

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	9 of 12	$3.5-3.6T USD, 1.2-1.7% of global GDP
	2050 GDP per capita	4 of 12	$72-74k USD PPP
	GDP annual growth rate, 2018 to 2050	8 of 12	1.9-2.0%
population	*2050 population*	10 of 12	48.3 million, 0.52% of global pop.
	population growth rate, 2018 to 2050	10 of 12	-0.20%
	2050 ratio: working age population to young plus elderly population	12 of 12	1.1:1
universities	*share of top universities*	4 of 12	2.2%
	top universities relative to GDP	4 of 12	--
education	school life expectancy, primary through tertiary	2 of 12	16.5 years
	presence of science education in secondary school	1 of 12	99%
	government expenditure on education as percent of GDP	6 of 11	4.6%
	government expenditure on primary education as percent of GDP	6 of 10	1.5%
policy	rule of law (World Justice Project)	3 of 11	73/100 score
ICT	ICT adoption (WEF Global Competitiveness)	1 of 12	91/100 score 1/140 countries
beliefs about science	belief in science as future national benefit	3 of 12	83%
	belief in science as increasing jobs	11 of 12	53%
	belief in science as a personal benefit	6 of 12	76%
	trust in science over religion	4 of 12	56%



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data not available *n.a.*

acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

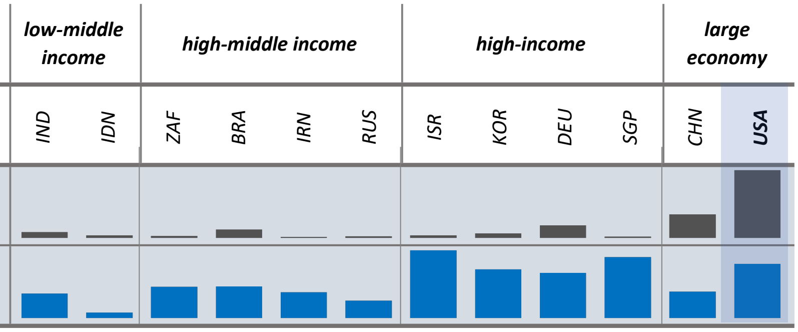
"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

two bars indicate data from two separate sources

UNITED STATES

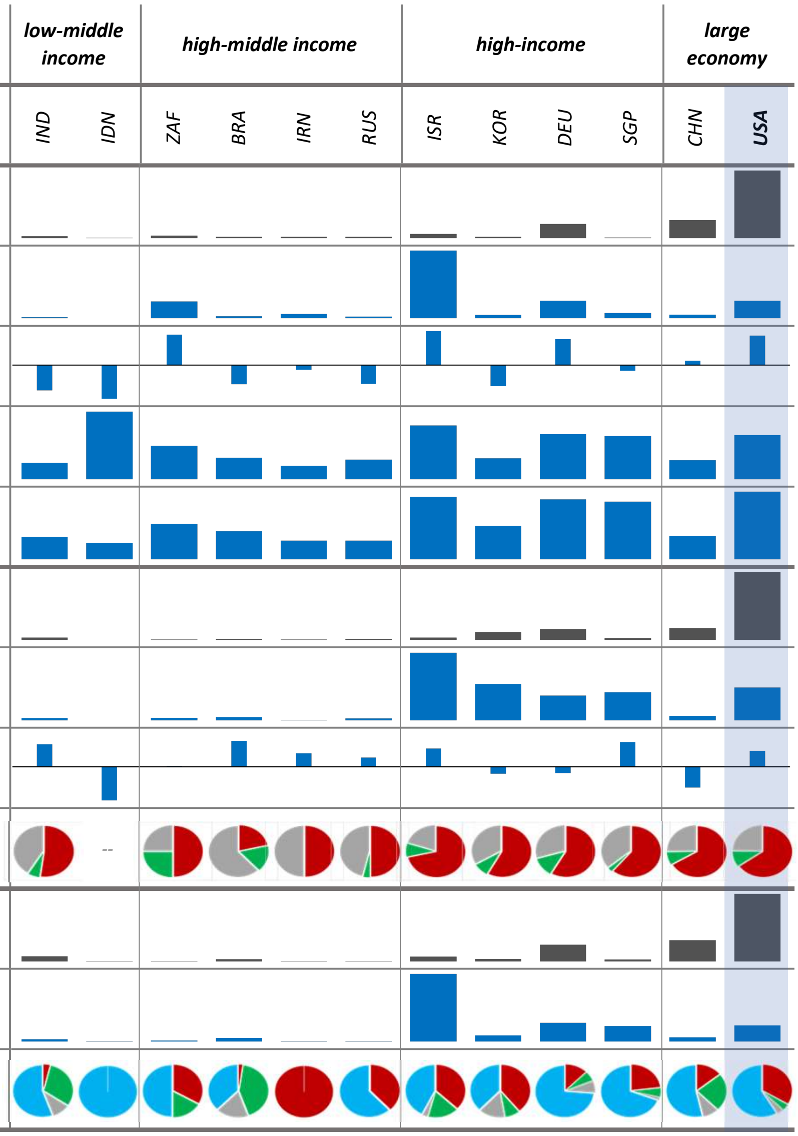
Biotech

sector scores	rank	value
biotech capacity scores	1 of 12	9.8/10 points
biotech innovation-driver scores	3 of 12	5.6/10 points



Biotech: output measures

	indicator	rank	value
publications	*share of top biotech publications*	1 of 12	60%
	top biotech publications relative to GDP	2 of 12	--
	relative emphasis on biotech within top publications	3 of 12	+0.8 (-1 to 1)
	average citation count per biotech publication	4 of 12	--
	average citation count per biochemistry, genetics, and molecular biology publications	1 of 12	--
patents	*share of world biotech patents, 2014-2019*	1 of 12	45%
	biotech patents relative to GDP	3 of 12	--
	relative emphasis on biotech within patents	5 of 12	+0.5 (-1 to 1)
	proportion of red, green, or white biotech patents	--	65%, 10%, 25%
companies	*share of world biotech companies*	1 of 12	55%
	biotech companies relative to GDP	3 of 12	--
	proportion of red, green, white, or R&D service biotech companies	--	34%, 4%, 4%, 59%



pie charts: red biotechnology - biopharma (red), green biotechnology - agricultural biotechnology (green), white biotechnology - industrial biotechnologies, e.g. bioplastics, biofuels, biomaterials (grey), R&D service biotechnology (blue)

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product. R&D: research and development.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

BRA - Brazil. CHN - China. DEU - Germany. IDN - Indonesia. IND - India. IRN - Iran. ISR - Israel. KOR - South Korea. RUS - Russia. SGP - Singapore. USA - United States. ZAF - South Africa.

UNITED STATES

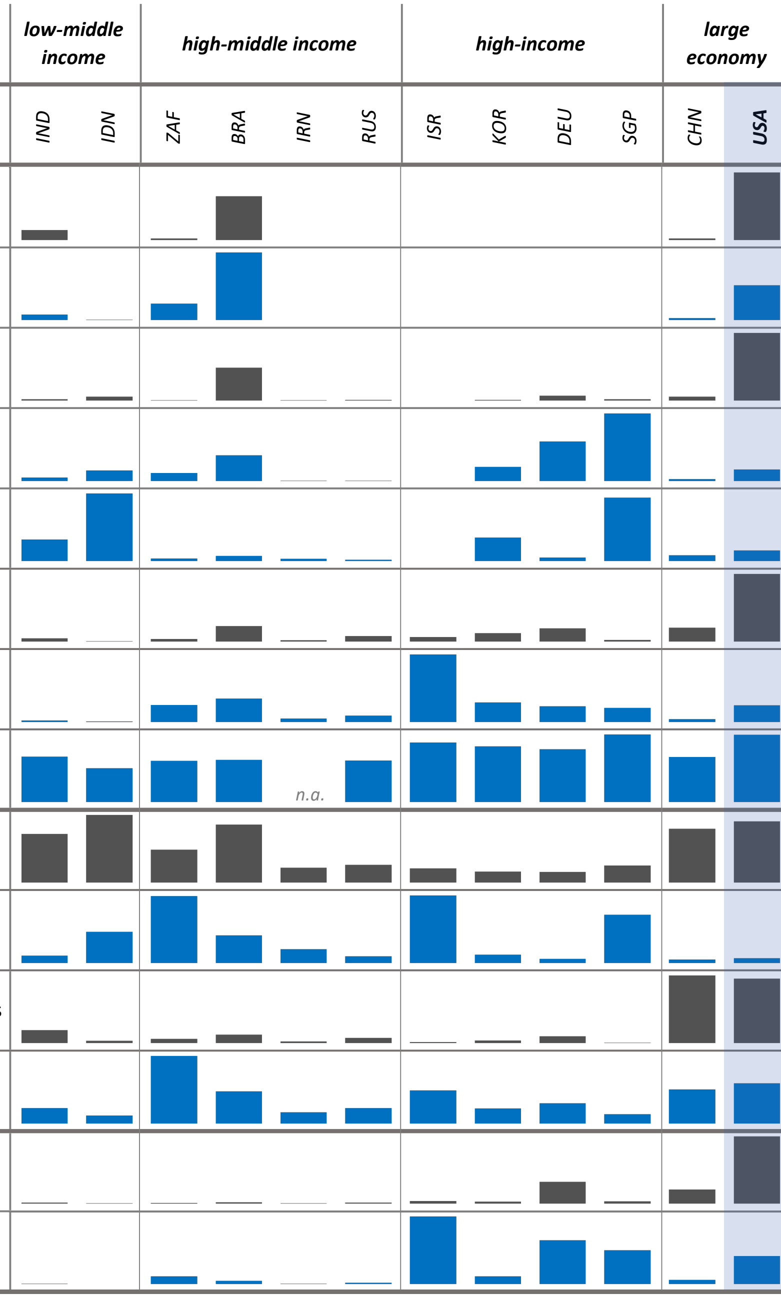
Biotech : drivers of innovation

	indicator	rank	value	*low-middle income*		*high-middle income*				*high-income*				*large economy*	
				IND	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	***USA***
talent	*users of largest genetic sequence database*	1 of 12	22.7% of users												
	users of largest genetic sequence database relative to GDP	2 of 12	--												
	users of a major genetic engineering tool supplier	1 of 12	32918 depositors												
	users of a major genetic engineering tool supplier relative to GDP	2 of 12	--												
	participation in international genetic engineering competition	2 of 12	23% of participants												
	participation in international genetic engineering competition relative to GDP	6 of 12	--												
	attendance at preeminent synthetic biology conferences	1 of 12	26% of attendees												
	attendance at preeminent synthetic biology conferences relative to GDP	3 of 12	--												
	subscribers to a prominent synthetic biology newsletter	1 of 12	62% of subscribers												
	subscribers to a prominent synthetic biology newsletter relative to GDP	2 of 12	--												
universities	*share of top biotech universities*	1 of 12	20.6%												
	top biotech universities relative to GDP	6 of 12	--												
	relative emphasis on biotech in top universities	6 of 12	+0.3 (-1 to 1)												
	share of top biology universities	1 of 12	30.9%												
	top biology universities relative to GDP	4 of 12	--												
	relative emphasis on biology in top universities	4 of 12	+0.6 (-1 to 1)												
	share of top life sciences universities	1 of 12	51.0%												
	top life sciences universities relative to GDP	6 of 12	--												
	relative emphasis on life sciences in top universities	4 of 12	+0.9 (-1 to 1)												
policy	presence of a national biotechnology plan	1 of 12	1 of 1 pt												

UNITED STATES

Biotech : drivers of innovation

	indicator	rank	value
industry sector maturity	*share of total global biotech crops*	1 of 12	40%
	biotech crops relative to total cropland	2 of 12	47.5%
	share of total global biofuel production	1 of 12	46.2%
	biotech fuels relative to total liquid fuel production	5 of 12	7.3%
	average annual growth rate in biofuel production, 2006-2016	5 of 12	13.0%
	clinical trials of biologics since 2010	1 of 12	33% of trials
	clinical trials of biologics since 2010 scaled to GDP	5 of 12	--
	innovation in biopharma (Biopharmaceutical Competitiveness Index)	2 of 11	87/100 score
biodiversity	*well-studied animal and plant species*	2 of 12	9% of species
	well-studied animal and plant species scaled to GDP	10 of 12	--
	non-human sequence entries in largest genetic sequence database	2 of 12	17.3% of entries
	non-human sequence entries in largest genetic sequence database scaled to GDP	2 of 12	--
collaboration	*life sciences collaboration (Nature Index)*	1 of 12	100% of max score
	life sciences collaborations relative to GDP	4 of 12	--



data not applicable --

data not available *n.a.*

acronym: GDP: gross domestic product.
largest genetic sequence database: NIH GenBank.
major genetic engineering tool supplier: AddGene.
international genetic engineering competition: iGEM.
preeminent synthetic biology conference: SBx.0.
prominent synthetic biology newsletter: SynbioBeta.

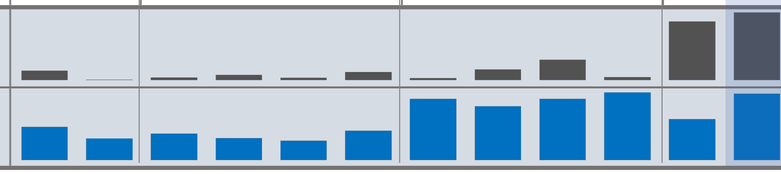
relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

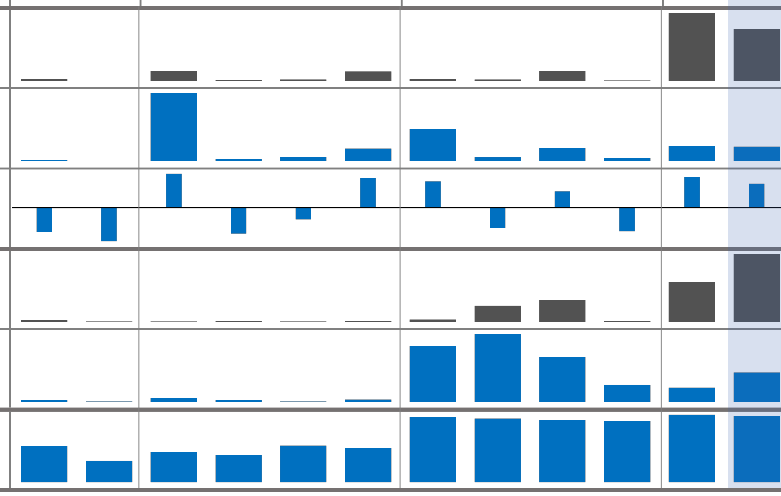
Science and Technology

sector scores	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
			low-middle income		*high-middle income*				*high-income*				*large economy*	
science & technology capacity scores	1 of 12	9.4/10 points												
science & technology innovation-driver scores	2 of 12	7.4/10 points												



Science and Technology: output measures

	indicator	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
				low-middle income		*high-middle income*				*high-income*				*large economy*	
publications	*share of top high tech publications*	2 of 12	44%												
	top high tech publications relative to GDP	4 of 12	--												
	relative emphasis on high tech within top publications	5 of 12	+0.7 (-1 to 1)												
patents	*share of world patents, 2014-2019*	1 of 12	27%												
	patents relative to GDP	4 of 12	--												
STI output	knowledge and technology outputs (Global Innovation Index)	2 of 12	56/100 score 6/126 countries												



data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product

STI: science and technology innovation

relative strength compared to 12 countries (read across row)

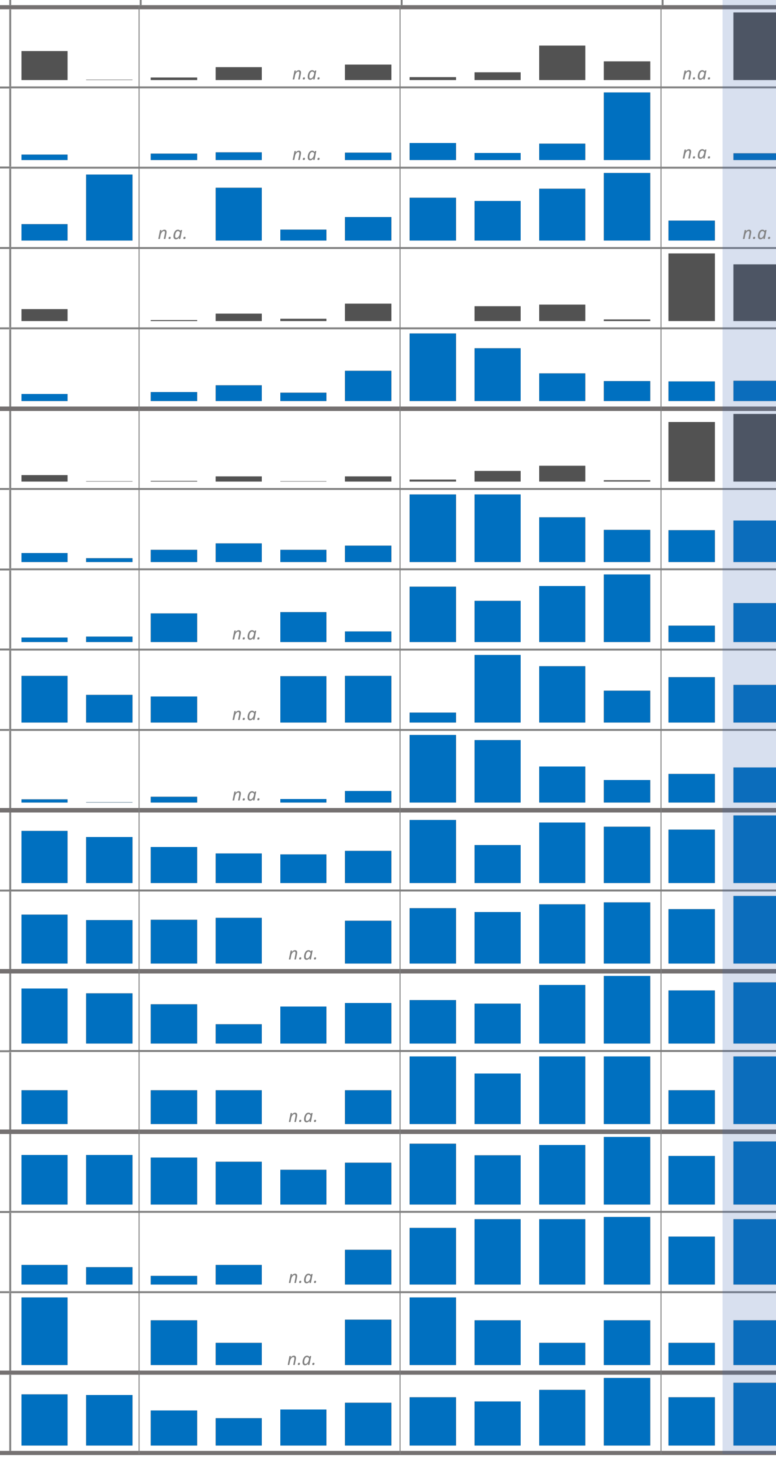
"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

UNITED STATES

Science and Technology : drivers of innovation

	indicator	rank	value	*IND*	*IDN*	*ZAF*	*BRA*	*IRN*	*RUS*	*ISR*	*KOR*	*DEU*	*SGP*	*CHN*	***USA***
				low-middle income		***high-middle income***				***high-income***				***large economy***	
talent	*share of world STEM graduates*	1 of 10	21.0%					*n.a.*						*n.a.*	
	STEM graduates relative to GDP	7 of 10	--					*n.a.*						*n.a.*	
	retention of foreign-educated PhD students	--	n.a.			*n.a.*									*n.a.*
	share of world researchers	2 of 12	12.7%												
	researchers relative to GDP	5 of 12	--												
funding: research & development	*total expenditures on R&D*	1 of 12	$511B USD PPP												
	total expenditures on R&D relative to GDP	4 of 12	2.8%												
	R&D expenditures funded by higher ed. relative to GDP	5 of 11	0.36%				*n.a.*								
	R&D expenditures funded by government relative to GDP	7 of 11	0.27%				*n.a.*								
	R&D expenditures funded by business relative to GDP	4 of 11	2.04%				*n.a.*								
funding: venture capital	VC availability (Global Competitiveness Report)	1 of 12	5.6/7 score 1/140 countries												
	VC index (IESE Venture Capital and Private Equity Country Attractiveness Index)	1 of 11	100/100 score					*n.a.*							
policy: regulatory burden	lack of burden of government regulation (Global Competitiveness Report)	2 of 12	5.0/7 score 4/140 countries												
	ease of technology transfer (US Chamber IP Index)	1 of 11	1/1 score					*n.a.*							
policy: intellectual property	intellectual property protection (Global Competitiveness Report)	2 of 12	5.9/7 score 13/140 countries												
	patents, related rights, and limitations (US Chamber IP Index)	2 of 11	7.5/7 score					*n.a.*							
	tax incentives in the creation of IP assets (US Chamber IP Index)	4 of 11	0.7/1 score					*n.a.*							
policy: future	future orientation of government (Global Competitiveness Report)	2 of 12	5.7/7 score 3/140 countries												



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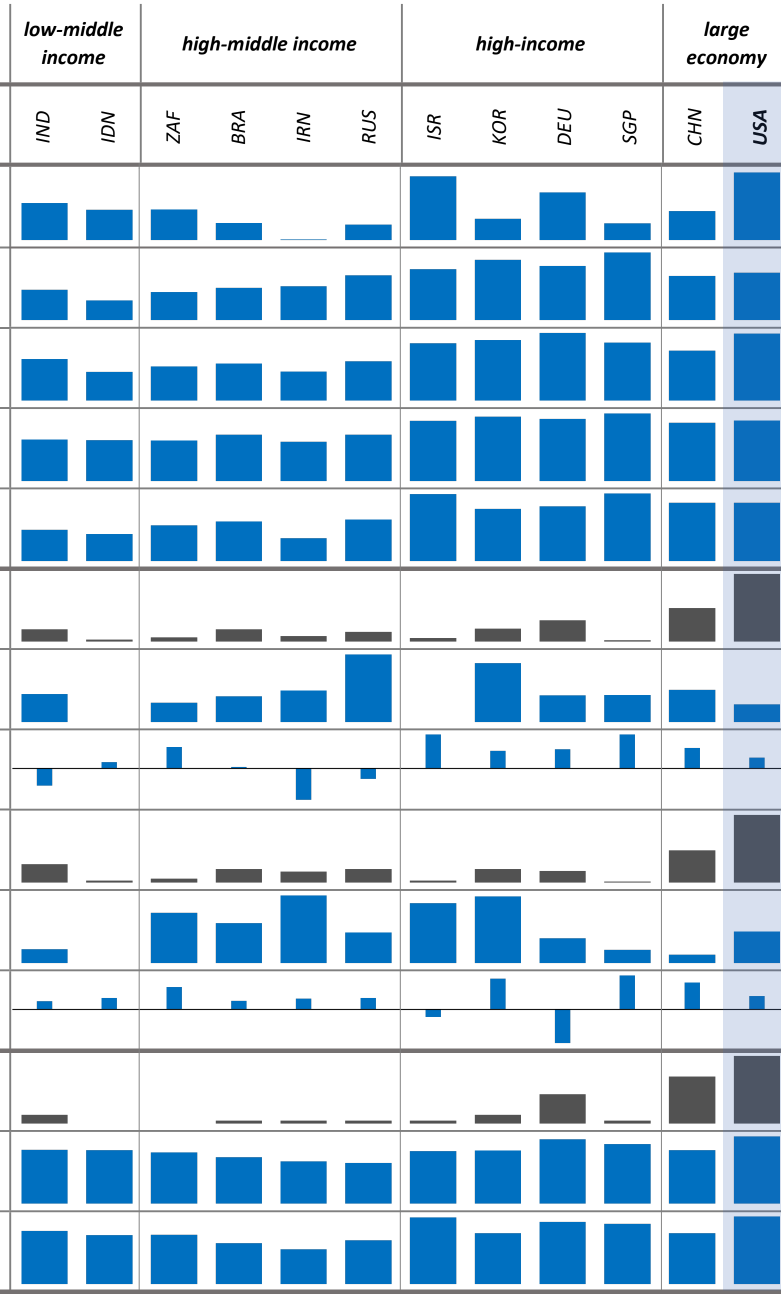
Science and Technology : drivers of innovation



	indicator	rank	value	
innovation	acceptance of risk in entrepreneurship and business (Global Competitiveness Report)	1 of 12	82%	
	human capital and research (Global Innovation Index)	5 of 12	51/100 score	21/126 countries
	innovation capability (Global Competitiveness Report)	2 of 12	87/100 score	2/140 countries
	infrastructure (Global Innovation Index)	4 of 12	59/100 score	24/126 countries
	business sophistication (Global Innovation Index)	3 of 12	56/100 score	8/126 countries
universities	*share of top computer sciences universities*	1 of 12	16.0%	
	top computer sciences universities relative to GDP	10 of 12	--	
	relative emphasis on computer sciences in top universities	7 of 12	+0.2	(-1 to 1)
	share of top engineering and technology universities	1 of 12	16.0%	
	top engineering and technology universities relative to GDP	6 of 12	--	
	relative emphasis on engineering and technology in top universities	5 of 12	+0.1	(-1 to 1)
collaboration	*share of top international innovation clusters*	1 of 12	23.0%	
	state of cluster development (Global Competitiveness Report)	1 of 12	5.8/7 score	1/140 countries
	university-industry collaboration (Global Competitiveness Report)	1 of 12	5.9/7 score	

data not applicable --

data not available *n.a.*

acronyms: STEM: science, technology, engineering, and math
R&D: research and development. VC: venture capital.
GDP: gross domestic product. IP: intelllectual property.
IESE: graduate business school of the University of Navarra.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

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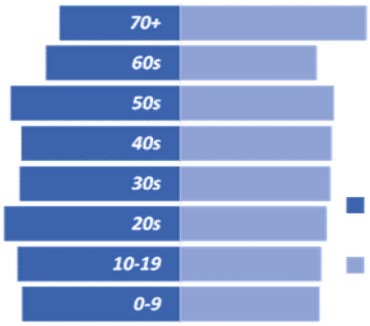
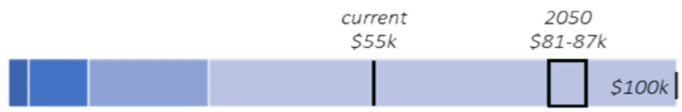
AGE DISTRIBUTION



2015: 320 million
total dependency ratio 0.51

2050: 393 million
total dependency ratio 0.67

ECONOMY: HIGH INCOME



Low
< $3k

Lower-middle
$3k-$12k

Upper middle
$12k-$30k

High
>$30k

$USD PPP, GDP/capita

ranges are approximations based on World Bank economic groups - GNI/capita has been converted to GDP/capita

current GDP: $18T USD PPP
2050 GDP: $32-34T USD PPP

EDUCATION DISTRIBUTION

under 15 · < primary · primary · secondary · bachelor · post-bachelor

EXTREME POVERTY DISTRIBUTION

< $1.90/day 1.2% · < $3.20/day 1.5% · < $5.50/day 2% · > $5.50/day 98%

General-societal

sector scores	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
			low-middle income		*high-middle income*				*high-income*				*large economy*	
general-societal capacity scores	2 of 12	7.5/10 points												
general-societal innovation-driver scores	2 of 12	6.2/10 points												

General-societal: output measures

	indicator	rank	value	IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
				low-middle income		*high-middle income*				*high-income*				*large economy*	
economy	*current GDP, PPP*	2 of 12	$18.2T USD PPP, 15% of global GDP												
	current GDP per capita	2 of 12	$55k USD PPP												
population	*current population*	3 of 12	331 million 4.3% global pop.												
	current ratio: working age population to young plus elderly population	8 of 12	2.0:1												

data not applicable --

data not available *n.a.*

acronyms: GDP: gross domestic product.
PPP: purchasing power parity.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

UNITED STATES

General-societal : drivers of innovation

	indicator	rank	value
economy	*2050 GDP, PPP*	3 of 12	\$32-34T USD, 11.8-15% of global GDP
	2050 GDP per capita	2 of 12	\$81-87t USD PPP
	GDP annual growth rate, 2018 to 2050	9 of 12	1.8-2.0%
population	*2050 population*	3 of 12	393 million, 4.2% of global pop.
	population growth rate, 2018 to 2050	5 of 12	0.57%
	2050 ratio: working age population to young plus elderly population	7 of 12	1.5:1
universities	*share of top universities*	1 of 12	27.4%
	top universities relative to GDP	5 of 12	--
education	school life expectancy, primary through tertiary	4 of 12	16.3 years
	presence of science education in secondary school	4 of 12	94%
	government expenditure on education as percent of GDP	4 of 11	5.0%
	government expenditure on primary education as percent of GDP	4 of 10	1.6%
policy	rule of law (World Justice Project)	4 of 11	71/100 score
ICT	ICT adoption (WEF Global Competitiveness)	5 of 12	71/100 score 27/140 countries
beliefs about science	belief in science as future national benefit	6 of 12	80%
	belief in science as increasing jobs	5 of 12	66%
	belief in science as a personal benefit	2 of 12	79%
	trust in science over religion	7 of 12	47%

data not applicable --
data not available *n.a.*
acronyms: GDP: gross domestic product.
ICT: information and communication technology.
WEF: World Economic Forum.

relative strength compared to 12 countries (read across row)

"absolute" measures: unscaled counts, can be expressed as percent of world totals (e.g., GDP)

"intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

two bars indicate data from two separate sources

Appendix

Appendix A:

Table of 2020 Indicator Scores, including variables for weights, rates of change, and democracy index scores.

section		indicator	weights [B]	rates of change [C]	*relative score for each indicator* [A]											
					IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
biotech	outputs	*share of top biotech publications*	*10*	*0*	0.3	0.0	0.4	0.2	0.2	0.2	0.6	0.2	2.1	0.1	2.6	10.0
		top biotech publications / GDP	7	1	0.1	0.0	2.5	0.3	0.6	0.2	10.0	0.5	2.6	0.8	0.5	2.6
		relative emphasis on biotech within top publications	-	0	1.3	0.0	9.5	2.2	4.3	2.2	10.0	1.9	8.8	4.2	5.6	9.3
		average citation count per biotech publication	2	0	0.5	10.0	3.7	1.5	0.0	1.1	7.4	1.4	5.8	5.5	1.0	5.7
		avg. citation count in biochem, genetics, and mol bio pubs	1	0	1.2	0.0	3.7	2.2	0.4	0.4	9.0	3.3	8.5	8.1	1.3	10.0
		share of world biotech patents, 2014-2019	*10*	*0*	0.4	0.0	0.0	0.2	0.0	0.1	0.3	1.2	1.6	0.2	1.7	10.0
		biotech patents / GDP	10	1	0.3	0.0	0.4	0.5	0.1	0.3	10.0	5.4	3.7	4.2	0.7	4.8
		relative emphasis on biotech within patents	-	0	9.1	6.1	8.4	4.2	-	7.8	8.8	2.0	0.0	10.0	4.4	7.8
		proportion of red, green, or white biotech patents	-	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		share of world biotech companies	*6*	*0*	0.7	0.0	0.0	0.3	0.0	0.1	0.7	0.4	2.5	0.3	3.1	10.0
		biotech companies / GDP	6	1	0.3	0.0	0.1	0.5	0.0	0.0	10.0	0.9	2.8	2.3	0.6	2.4
		% of red, green, white, or R&D service biotech companies	-	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	drivers of innovation	*users of largest genetic sequence database*	*4*	*0*	2.5	0.4	0.0	1.0	0.3	0.8	0.0	0.7	1.4	0.0	6.5	10.0
		users of largest genetic sequence database / GDP	4	3	1.3	0.0	1.7	3.1	1.8	0.9	10.0	3.7	3.2	3.5	1.3	4.9
		users of a major genetic engineering tool supplier	*4*	*0*	0.3	0.0	0.0	0.1	0.0	0.1	0.2	0.9	1.6	0.2	2.2	10.0
		users of a genetic engineering tool supplier / GDP	4	3	2.2	0.0	1.4	0.8	-	0.6	10.0	9.6	7.3	9.1	2.8	8.8
		participation in international genetic engineering competition	*4*	*0*	1.1	0.1	0.0	0.4	0.0	0.0	0.3	0.3	1.6	0.3	10.0	7.7
		participation in int'l genetic engineering competition / GDP	4	3	4.9	1.2	0.0	2.6	0.0	0.0	9.8	2.2	4.9	10.0	9.2	4.7
		attendance at preeminent synthetic biology conferences	*1*	*0*	0.2	0.2	0.0	0.1	0.0	0.1	0.2	2.1	1.4	0.4	0.9	10.0
		attendance at preeminent syn bio conferences / GDP	1	3	0.6	1.7	1.0	0.6	0.0	0.2	3.2	10.0	2.7	8.0	0.5	3.7
		subscribers to a prominent synthetic biology newsletter	*1*	*0*	0.3	0.0	0.0	0.2	0.0	0.0	0.1	0.1	0.4	0.3	0.3	10.0
		subscribers to a prominent syn bio newsletter / GDP	1	3	1.3	0.0	0.0	0.9	0.0	0.0	2.2	1.0	1.0	10.0	0.2	5.3
		share of top biotech universities	*4*	*0*	0.3	0.0	0.2	0.4	0.3	0.1	0.4	1.7	2.7	0.3	5.7	10.0
		top biotech universities / GDP	4	1	0.9	0.0	4.2	2.1	7.0	0.5	10.0	9.7	6.4	6.9	3.9	4.6
		relative emphasis on biotech in top universities	-	0	1.0	0.0	6.3	4.7	1.2	0.1	8.3	9.7	8.9	9.8	10.0	7.5
		share of top biology universities	*3*	*0*	0.0	0.0	0.2	0.2	0.0	0.0	0.4	0.4	2.7	0.1	1.8	10.0
		top biology universities / GDP	3	1	0.0	0.0	5.7	1.2	0.0	0.3	10.0	2.3	6.6	3.9	1.3	4.7
		relative emphasis on biology in top universities	-	0	0.0	0.0	6.4	0.8	0.0	0.1	10.0	3.1	9.7	10.0	6.4	9.3
		share of top life sciences universities	*3*	*0*	1.2	0.0	0.3	2.4	0.7	0.6	0.4	1.4	2.3	0.1	3.1	10.0
		top life sciences universities / GDP	3	1	0.9	0.0	4.5	7.3	4.3	1.6	10.0	7.9	6.0	2.3	1.3	4.3
		relative emphasis on life sciences in top universities	-	0	4.5	0.0	8.4	9.7	5.5	1.5	10.0	8.8	8.8	10.0	8.2	9.3
		presence of a national biotechnology plan	6	4	10.0	0.0	5.0	5.0	10.0	10.0	0.0	10.0	5.0	10.0	5.0	10.0
		share of total global biotech crops	*3*	*0*	1.5	0.0	0.3	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	10.0
		biotech crops relative to total cropland	3	3	0.8	0.0	2.4	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	5.1
		share of total global biofuel production	*2*	*0*	0.2	0.6	0.1	4.9	0.0	0.1	0.0	0.1	0.7	0.2	0.6	10.0
		biotech fuels relative to total liquid fuel production	1	3	0.5	1.6	1.2	3.8	0.0	0.0	0.0	2.1	5.9	10.0	0.3	1.7
		average annual growth rate in biofuel production, 2006-2016	1	3	3.2	10.0	0.4	0.7	0.3	0.2	0.0	3.5	0.5	9.4	0.8	1.6
		clinical trials of biologics since 2010	*5*	*0*	0.4	0.0	0.3	2.3	0.1	0.7	0.6	1.2	1.9	0.2	2.0	10.0
		clinical trials of biologics since 2010 scaled to GDP	2	3	0.2	0.0	2.4	3.4	0.4	0.9	10.0	2.9	2.3	2.0	0.3	2.4
		innovation in biopharma	3	3	3.4	0.0	2.2	2.5	-	2.3	7.6	6.5	7.9	10.0	3.3	9.9
		well-studied animal and plant species	*2*	*0*	6.6	10.0	3.9	8.3	0.7	1.2	0.6	0.0	0.0	1.1	7.5	8.9
		well-studied animal and plant species scaled to GDP	2	3	0.6	4.3	9.9	3.8	1.6	0.5	10.0	0.8	0.1	7.0	0.0	0.2
		non-human sequence entries in largest genetic sequence database	*2*	*0*	1.8	0.3	0.6	1.2	0.2	0.7	0.1	0.3	1.0	0.0	10.0	9.5
		non-human sequence entries in genetic seq. database / GDP	2	3	1.3	0.0	10.0	4.1	0.5	1.2	4.2	1.2	2.1	0.2	4.4	5.4
		life sciences collaboration	*4*	*0*	0.1	0.0	0.1	0.2	0.0	0.1	0.4	0.3	3.2	0.3	2.1	10.0
		life sciences collaborations / GDP	4	2	0.0	0.0	1.1	0.5	0.0	0.2	10.0	1.1	6.5	5.0	0.6	4.1

- indicators in grey, italics are *"absolute" measures: expressed as percent of world totals (e.g., GDP)*
- indicators in white are "intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)
- shading indicates the range of minimum (score 0) to maximum (score 10) values

0	1	2	3	4	5	6	7	8	9	10

[A] - data is transformed to a 0-10 scale, based on the max and min value of each indicator within the 12 countries, in order to generate a country's "score" for each indicator

[B] - weights prioritize the relative influence of each indicator to the health of a country's biotechnology endeavor, and are factored into the aggregated section scores. score 0 = least influential or not applicable for weighting. score 10 = most influential.

[C] - rates of change indicates how quickly an indicator score can be impacted by policy change. These scores are factored into decadal projection modeling for future section and combined scores. Score 0 = policy is unlikely to alter the score within 30 years. Score 4 = policy can change the score within a short time frame.

section		indicator	weights [B]	rates of change [C]	relative score for each indicator [A]											
					IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
science & tech	outputs	top high tech publications / GDP	10	1	0.2	0.0	10.0	0.2	0.6	1.8	4.7	0.5	1.9	0.4	2.2	2.1
		relative emphasis on high tech within top publications	-	0	1.4	0.0	10.0	1.2	3.3	9.4	8.9	2.0	7.4	1.5	9.5	8.5
		share of world patents, 2014-2019	*10*	*0*	0.3	0.0	0.0	0.1	0.0	0.1	0.3	2.4	3.2	0.2	5.9	10.0
		patents relative to GDP	10	1	0.2	0.0	0.6	0.3	0.1	0.3	8.2	10.0	6.6	2.5	2.1	4.4
		knowledge and technology outputs	10	1	3.2	0.0	1.9	1.3	3.3	2.8	9.5	9.2	8.9	8.6	10.0	9.8
	drivers of innovation	*share of world STEM graduates*	*5*	*0*	4.2	0.0	0.3	1.9	-	2.3	0.4	1.1	5.1	2.7	-	10.0
		STEM graduates / GDP	4	3	2.0	0.0	1.3	1.3	-	1.8	1.4	0.9	1.6	10.0	-	0.6
		retention of foreign-educated PhD students	2	3	1.0	9.7	-	7.4	0.0	2.2	5.6	5.1	7.2	10.0	1.6	-
		share of world researchers	*5*	*0*	1.7	0.0	0.2	1.1	0.3	2.6	0.0	2.2	2.4	0.2	10.0	8.4
		researchers / GDP	4	2	4.1	0.0	2.9	3.8	4.7	10.0	0.0	8.7	4.0	4.0	4.8	2.6
		total expenditures on R&D	*10*	*0*	1.1	0.1	0.0	0.7	0.1	0.7	0.2	1.6	2.3	0.1	9.2	10.0
		total expenditures on R&D / GDP	5	3	0.8	0.0	1.3	2.3	1.3	2.0	10.0	10.0	6.4	4.4	4.4	5.9
		R&D expenditures funded by higher ed. / GDP	3	4	0.0	0.2	3.8	-	4.0	1.0	8.1	5.8	8.1	10.0	1.9	5.5
		R&D expenditures funded by government / GDP	1	4	6.4	3.1	2.8	-	6.3	6.4	0.0	10.0	8.0	3.8	6.1	4.8
		R&D expenditures funded by business / GDP	1	2	0.5	0.0	0.8	-	0.5	1.7	10.0	9.2	5.3	3.3	4.2	5.2
		VC availability	3	0	6.0	4.5	1.9	0.2	0.0	0.9	8.9	2.4	8.2	7.1	6.3	10.0
		VC index	3	1	2.4	0.2	0.4	1.1	-	0.0	5.0	3.5	6.6	7.5	4.7	10.0
		lack of burden of government regulation	4	4	7.4	6.4	4.2	0.0	3.7	4.4	5.0	4.2	8.2	10.0	7.0	8.6
		ease of technology transfer	4	4	5.0	0.0	5.0	5.0	-	5.0	10.0	7.5	10.0	10.0	5.0	10.0
		intellectual property protection	2 2/3	4	4.6	4.6	3.8	2.5	0.0	2.1	7.9	4.4	7.6	10.0	4.2	8.7
		patents, related rights, and limitations	4	4	1.9	1.5	0.0	1.9	-	4.4	8.1	9.6	9.6	10.0	6.7	9.6
		tax incentives in the creation of IP assets	1 1/3	4	10.0	0.0	6.6	3.3	-	6.7	10.0	6.6	0.0	6.6	3.3	6.6
		future orientation of government	8	2	5.9	5.8	1.9	0.0	2.1	3.8	5.2	4.2	7.0	10.0	5.2	8.8
		acceptance of risk in entrepreneurship	2 2/3	0	5.4	4.4	4.5	2.4	0.0	2.2	9.4	3.1	7.0	2.4	4.2	10.0
		human capital and research	1 1/3	3	2.2	0.0	1.8	2.6	3.0	5.2	6.5	8.5	7.2	10.0	5.1	5.8
		innovation capability	1 1/3	2	3.3	0.0	1.4	2.1	0.1	2.7	7.3	8.2	10.0	7.5	5.4	9.8
		infrastructure	1 1/3	2	0.8	0.6	0.4	2.5	0.0	2.5	7.4	8.9	8.1	10.0	6.7	7.4
		business sophistication	1 1/3	1	1.9	0.9	2.9	3.8	0.0	4.2	9.9	6.5	7.2	10.0	7.9	7.9
		share of top computer sciences universities	*3*	*0*	1.7	0.1	0.5	1.7	0.6	1.3	0.4	1.7	3.0	0.0	4.9	10.0
		top computer sciences universities relative to GDP	3	1	0.6	0.0	4.7	3.0	2.6	1.7	10.0	5.3	4.3	1.6	0.8	2.7
		relative emphasis on computer sciences in top universities	-	0	2.2	5.8	8.1	5.0	0.0	3.2	10.0	7.5	7.7	10.0	7.9	6.4
		share of top engineering and tech universities	*3*	*0*	2.6	0.1	0.4	1.9	1.5	1.9	0.1	1.9	1.6	0.0	4.7	10.0
		top engineering and tech universities relative to GDP	3	1	2.0	0.0	7.4	5.9	10.0	4.5	8.9	9.9	3.7	1.9	1.2	4.7
		relative emphasis on eng. and tech in top universities	-	0	6.3	6.7	8.3	6.3	6.6	6.7	3.9	9.5	0.0	10.0	9.0	7.0
		share of top international innovation clusters	*6*	*0*	1.3	0.0	0.0	0.4	0.4	0.4	0.4	1.3	4.3	0.4	7.0	10.0
		state of cluster development	3	2	5.0	4.9	3.9	2.2	0.6	0.0	4.5	4.8	8.9	7.1	4.8	10.0
		university-industry collaboration	3	3	5.6	4.3	4.3	1.9	0.0	2.7	9.7	4.8	8.3	7.7	4.8	10.0

- indicators in grey, italics are *"absolute" measures: expressed as percent of world totals (e.g., GDP)*

- indicators in white are "intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

- shading indicates the range of minimum (score 0) to maximum (score 10) values

0	1	2	3	4	5	6	7	8	9	10

[A] - data is transformed to a 0-10 scale, based on the max and min value of each indicator within the 12 countries, in order to generate a country's "score" for each indicator

[B] - weights prioritize the relative influence of each indicator to the health of a country's biotechnology endeavor, and are factored into the aggregated section scores. score 0 = least influential or not applicable for weighting. score 10 = most influential.

[C] - rates of change indicates how quickly an indicator score can be impacted by policy change. These scores are factored into decadal projection modeling for future section and combined scores. Score 0 = policy is unlikely to alter the score within 30 years. Score 4 = policy can change the score within a short time frame.

section		indicator	weights [B]	rates of change [C]	relative score for each indicator [A]											
					IND	IDN	ZAF	BRA	IRN	RUS	ISR	KOR	DEU	SGP	CHN	USA
general societal	outputs	*current GDP, PPP*	*10*	*0*	4.1	1.3	0.2	1.2	0.6	1.6	0.0	0.7	1.6	0.1	10.0	8.1
		current GDP per capita	10	1	0.0	0.6	0.6	0.9	1.4	2.4	3.4	3.8	5.0	10.0	1.1	6.0
		current population	*4*	*0*	9.8	1.9	0.4	1.5	0.6	1.0	0.0	0.3	0.5	0.0	10.0	2.3
		current ratio: working to non-working population	4	0	3.2	4.2	2.8	6.2	8.2	6.2	0.0	10.0	3.2	10.0	9.4	3.5
	drivers of innovation	*2050 GDP, PPP*	*10*	*0*	7.6	1.8	0.3	1.1	0.5	0.9	0.1	0.5	1.0	0.0	10.0	5.8
		2050 GDP per capita	8	0	0.0	1.1	0.6	0.4	2.0	2.4	4.9	6.9	7.0	10.0	2.5	8.5
		GDP annual growth rate, 2018 to 2050	2	1	10.0	7.4	6.4	4.0	5.1	0.7	5.8	2.6	1.1	0.0	5.0	2.4
		2050 population	*4*	*0*	10.0	1.8	0.4	1.4	0.6	0.8	0.0	0.3	0.4	0.0	7.9	2.4
		population growth rate, 2018 to 2050	1	0	4.7	3.9	5.1	2.9	4.4	0.2	10.0	0.5	1.2	5.6	0.0	4.7
		2050 ratio: working to non-working population	3	0	9.2	8.8	10.0	5.3	5.3	4.1	3.5	0.0	1.3	2.8	3.5	3.5
		share of top universities	*6*	*0*	0.1	0.0	0.4	0.4	0.2	0.3	0.4	0.8	2.2	0.1	4.8	10.0
		top universities / GDP	6	1	0.2	0.0	8.4	2.0	4.1	1.5	10.0	4.2	4.7	3.4	3.0	4.1
		school life expectancy, primary through tertiary	2	3	0.0	3.0	3.4	6.8	5.5	6.0	8.3	9.0	10.0	8.9	2.9	8.6
		presence of science education in secondary school	2	4	1.4	4.2	0.9	2.4	0.0	8.6	3.5	10.0	2.2	9.5	6.7	8.2
		government expenditure on education / GDP	1	4	2.9	2.2	9.8	10.0	3.3	2.6	8.8	5.1	5.7	0.0	-	6.2
		government expenditure on primary education / GDP	1	4	2.7	5.1	10.0	5.5	3.9	-	9.4	4.7	0.0	0.7	-	5.3
		rule of law	4	3	1.5	1.8	3.3	2.1	0.0	0.5	-	7.2	10.0	9.0	1.0	6.7
		ICT adoption	4	2	0.0	5.2	2.9	4.4	3.1	7.0	6.1	10.0	6.5	9.0	6.9	6.8
		belief in science as future national benefit	1	0	1.0	10.0	2.2	0.0	6.5	4.1	5.4	5.1	0.1	3.4	6.3	3.3
		belief in science as increasing jobs	1	0	8.9	9.8	7.7	6.8	5.4	5.3	0.0	3.9	6.2	6.2	10.0	7.6
		belief in science as a personal benefit	1	0	4.6	10.0	0.0	1.6	0.2	3.6	3.2	5.9	6.8	6.4	6.4	7.1
		trust in science over religion	1	0	4.6	0.0	3.3	4.1	5.1	7.7	5.5	7.1	9.2	6.4	10.0	6.0
		democracy scores	-	-	*0.78*	*0.84*	*0.72*	*0.78*	*1.48*	*1.37*	*0.63*	*0.61*	*0.50*	*0.91*	*1.50*	*0.61*

- indicators in grey, italics are *"absolute" measures: expressed as percent of world totals (e.g., GDP)*

- indicators in white are "intensity" measures: do not depend on country size or are scaled to population or GDP (e.g., GDP per capita)

- shading indicates the range of minimum (score 0) to maximum (score 10) values

0	1	2	3	4	5	6	7	8	9	10

A - data is transformed to a 0-10 scale, based on the max and min value of each indicator within the 12 countries, in order to generate a country's "score" for each indicator

B - weights prioritize the relative influence of each indicator to the health of a country's biotechnology endeavor, and are factored into the aggregated section scores. score 0 = least influential or not applicable for weighting. score 10 = most influential.

C - rates of change indicates how quickly an indicator score can be impacted by policy change. These scores are factored into decadal projection modeling for future section and combined scores. Score 0 = policy is unlikely to alter the score within 30 years. Score 4 = policy can change the score within a short time frame.

D - democracy scores - developed from the Democracy Index, Economist Intelligence Unit. Denote how rapidly policy changes are likely to occur, given the relative democratic or autocratic rule within a country. These scores are factored into decadal projection modeling for future section and combined scores. score 0.5 = most democratic. score 1.5 = least democratic.

Appendix B:

Bio-enterprise, 2020 scores and 2050 projections

Appendix B-I: Bio-enterprise and section scores and ranks, 2020

2020 scores

absolute capacity:
bio-enterprise and section scores

country	bio-enterprise	biotech	science & tech	general societal
IND	2.3	0.8	1.3	4.0
IDN	0.6	0.4	0.0	1.0
ZAF	0.4	0.3	0.4	0.3
BRA	1.4	1.2	0.7	1.0
IRN	0.3	0.1	0.3	0.5
RUS	1.0	0.3	1.1	1.1
ISR	0.4	0.4	0.3	0.1
KOR	1.3	0.7	1.5	0.7
DEU	2.8	1.8	2.8	1.6
SGP	0.3	0.2	0.4	0.1
CHN	7.9	3.4	8.2	8.4
USA	12.4	9.8	9.4	7.5

innovation driver:
bio-enterprise and section scores

country	bio-enterprise	biotech	science & tech	general societal
IND	3.8	1.8	2.9	1.9
IDN	2.5	0.8	1.7	3.0
ZAF	4.4	2.7	3.3	3.6
BRA	4.0	2.5	1.9	2.8
IRN	3.5	1.7	2.0	3.2
RUS	3.4	1.4	2.7	3.6
ISR	9.0	8.0	7.1	5.0
KOR	7.2	4.1	6.3	5.8
DEU	7.2	3.9	6.5	5.2
SGP	8.9	4.9	6.4	7.4
CHN	4.7	2.1	4.6	4.2
USA	8.3	5.0	6.8	6.0

2020 ranks

absolute capacity:
bio-enterprise and section ranks

country	bio-enterprise	biotech	science & tech	general societal
USA	1	1	1	2
CHN	2	2	2	1
DEU	3	3	3	4
IND	4	5	5	3
BRA	5	4	7	6
KOR	6	6	4	8
RUS	7	10	6	5
IDN	8	8	12	7
ISR	9	7	11	11
ZAF	10	9	9	10
SGP	11	11	8	12
IRN	12	12	10	9

innovation driver:
bio-enterprise and section ranks

country	bio-enterprise	biotech	science & tech	general societal
ISR	1	1	1	5
SGP	2	3	4	1
USA	3	2	2	2
DEU	4	5	3	4
KOR	5	4	5	3
CHN	6	8	6	6
ZAF	7	6	7	7
BRA	8	7	11	11
IND	9	9	8	12
IRN	10	10	10	9
RUS	11	11	9	8
IDN	12	12	12	10

Appendix B-II: Bio-enterprise capacity scores: all growth models

policy status quo

	low growth model A					low growth model B					high growth model B					high growth model C				
country	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**
IND	2.3	4.5	6.8	10.5	8%	2.3	4.5	8.0	14.4	9%	2.3	4.7	9.1	18.2	10%	2.3	6.4	15.6	38.8	13%
IDN	0.6	1.1	1.6	2.3	6%	0.6	1.1	1.7	2.8	7%	0.6	1.1	1.8	3.1	7%	0.6	1.6	3.8	8.7	11%
ZAF	0.4	0.9	1.3	1.8	6%	0.4	0.7	1.1	1.7	6%	0.4	0.8	1.4	2.8	8%	0.4	0.8	1.6	3.3	8%
BRA	1.4	2.5	3.2	4.1	4%	1.4	2.1	3.0	4.4	4%	1.4	2.4	4.1	7.3	6%	1.4	2.6	4.7	8.7	6%
IRN	0.3	0.6	0.9	1.2	7%	0.3	0.5	0.8	1.2	7%	0.3	0.6	0.9	1.5	8%	0.3	0.6	1.1	2.1	9%
RUS	1.0	1.5	1.7	2.0	7%	1.0	1.3	1.6	2.0	7%	1.0	1.4	2.0	2.9	8%	1.0	1.5	2.4	3.7	9%
ISR	0.4	1.1	1.6	2.3	6%	0.4	0.8	1.3	2.4	6%	0.4	1.0	2.5	6.0	9%	0.4	1.1	2.6	6.3	9%
KOR	1.3	2.6	3.1	3.8	6%	1.3	1.9	2.8	4.1	6%	1.3	2.4	4.4	8.4	8%	1.3	2.5	4.9	9.6	9%
DEU	2.8	5.3	6.0	6.9	4%	2.8	3.9	5.3	7.4	5%	2.8	4.9	8.6	15.6	7%	2.8	5.2	9.4	17.4	7%
SGP	0.3	0.7	0.8	0.8	5%	0.3	0.5	0.6	0.8	5%	0.3	0.6	1.1	1.9	7%	0.3	0.6	1.1	2.0	7%
CHN	7.9	15.5	20.4	27.0	7%	7.9	12.6	19.2	29.9	7%	7.9	14.4	25.9	48.6	9%	7.9	15.9	31.0	62.1	10%
USA	12.4	25.2	30.3	36.5	4%	12.4	18.7	27.5	40.9	5%	12.4	23.9	46.0	90.8	7%	12.4	25.7	51.3	103.9	8%

policy push

	low growth model A					low growth model B					high growth model B					high growth model C				
country	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**
IND	2.3	5.1	8.2	13.0	9%	2.3	4.5	8.3	16.0	10%	2.3	4.7	9.8	22.9	11%	2.3	6.4	16.4	44.3	13%
IDN	0.6	1.3	2.1	3.1	7%	0.6	1.1	1.8	3.2	7%	0.6	1.1	2.0	4.4	8%	0.6	1.6	4.3	12.2	12%
ZAF	0.4	1.0	1.6	2.3	7%	0.4	0.7	1.1	2.0	6%	0.4	0.8	1.6	3.9	9%	0.4	0.8	1.8	4.5	9%
BRA	1.4	2.9	4.2	5.4	5%	1.4	2.1	3.2	5.3	5%	1.4	2.4	4.8	10.9	7%	1.4	2.6	5.4	12.6	8%
IRN	0.3	0.8	1.3	1.8	8%	0.3	0.5	0.8	1.5	8%	0.3	0.6	1.1	2.6	10%	0.3	0.6	1.4	3.5	11%
RUS	1.0	1.8	2.3	2.7	8%	1.0	1.3	1.7	2.4	7%	1.0	1.4	2.3	4.4	9%	1.0	1.5	2.8	5.6	10%
ISR	0.4	1.2	1.8	2.6	6%	0.4	0.8	1.4	2.6	6%	0.4	1.0	2.7	7.3	10%	0.4	1.1	2.8	7.7	10%
KOR	1.3	2.8	3.5	4.4	6%	1.3	1.9	2.8	4.4	6%	1.3	2.4	4.7	10.0	9%	1.3	2.5	5.2	11.4	9%
DEU	2.8	5.6	6.7	7.7	5%	2.8	3.9	5.5	8.0	5%	2.8	4.9	9.1	18.1	7%	2.8	5.2	10.0	20.3	8%
SGP	0.3	0.7	0.8	0.9	5%	0.3	0.5	0.6	0.9	5%	0.3	0.6	1.1	2.3	8%	0.3	0.6	1.2	2.3	8%
CHN	7.9	19.2	28.5	39.1	8%	7.9	12.6	20.9	37.4	8%	7.9	14.4	31.3	80.4	10%	7.9	15.9	37.0	99.9	11%
USA	12.4	26.6	33.8	41.1	5%	12.4	18.7	28.3	44.3	5%	12.4	23.9	48.7	107.5	8%	12.4	25.7	54.2	122.3	8%

policy drag

	low growth model A					low growth model B					high growth model B					high growth model C				
country	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**
IND	2.3	4.3	6.2	9.6	8%	2.3	4.5	7.8	13.6	9%	2.3	4.7	8.8	16.6	10%	2.3	6.4	15.2	36.7	13%
IDN	0.6	1.1	1.5	2.1	6%	0.6	1.1	1.7	2.7	7%	0.6	1.1	1.8	2.9	7%	0.6	1.6	3.7	8.3	10%
ZAF	0.4	0.8	1.2	1.7	6%	0.4	0.7	1.1	1.7	6%	0.4	0.8	1.4	2.6	7%	0.4	0.8	1.6	3.0	8%
BRA	1.4	2.4	3.0	3.8	4%	1.4	2.1	3.0	4.2	4%	1.4	2.4	4.0	6.6	5%	1.4	2.6	4.5	7.9	6%
IRN	0.3	0.6	0.7	1.0	6%	0.3	0.5	0.7	1.1	7%	0.3	0.6	0.9	1.3	7%	0.3	0.6	1.1	1.8	8%
RUS	1.0	1.3	1.4	1.6	6%	1.0	1.3	1.5	1.8	6%	1.0	1.4	1.8	2.4	7%	1.0	1.5	2.2	3.1	8%
ISR	0.4	1.1	1.5	2.1	5%	0.4	0.8	1.3	2.3	6%	0.4	1.0	2.4	5.5	9%	0.4	1.1	2.5	5.7	9%
KOR	1.3	2.4	2.9	3.5	5%	1.3	1.9	2.7	3.9	6%	1.3	2.4	4.2	7.6	8%	1.3	2.5	4.7	8.7	8%
DEU	2.8	5.1	5.7	6.5	4%	2.8	3.9	5.3	7.1	4%	2.8	4.9	8.3	14.3	7%	2.8	5.2	9.1	16.1	7%
SGP	0.3	0.6	0.7	0.7	4%	0.3	0.5	0.6	0.8	4%	0.3	0.6	1.0	1.6	7%	0.3	0.6	1.0	1.7	7%
CHN	7.9	13.7	16.8	21.5	6%	7.9	12.6	18.4	26.7	7%	7.9	14.4	23.6	38.5	8%	7.9	15.9	28.5	50.8	9%
USA	12.4	24.0	28.1	33.6	4%	12.4	18.7	27.0	38.8	4%	12.4	23.9	44.1	81.5	7%	12.4	25.7	49.3	93.8	7%

Appendix B-III: Bio-enterprise driver intensity scores: all growth models

policy status quo

	growth model A					growth models B & C				
country	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**
IND	3.8	3.8	3.8	3.8	0%	3.8	4.6	5.4	6.4	2%
IDN	2.5	2.5	2.5	2.5	0%	2.5	3.2	3.9	4.8	2%
ZAF	4.4	4.4	4.4	4.4	0%	4.4	5.1	5.8	6.5	1%
BRA	4.0	4.0	4.0	4.0	0%	4.0	4.5	5.1	5.7	1%
IRN	3.5	3.5	3.5	3.5	0%	3.5	4.1	4.8	5.5	1%
RUS	3.4	3.4	3.4	3.4	0%	3.4	3.9	4.3	4.8	1%
ISR	9.0	9.0	9.0	9.0	0%	9.0	9.7	10.3	10.9	1%
KOR	7.2	7.2	7.2	7.2	0%	7.2	8.1	8.9	9.7	1%
DEU	7.2	7.2	7.2	7.2	0%	7.2	7.9	8.4	9.0	1%
SGP	8.9	8.9	8.9	8.9	0%	8.9	9.0	9.1	9.2	0%
CHN	4.7	4.7	4.7	4.7	0%	4.7	5.6	6.4	7.4	1%
USA	8.3	8.3	8.3	8.3	0%	8.3	8.9	9.5	10.1	1%

policy push

	growth model A					growth models B & C				
country	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**
IND	3.8	6.3	8.4	8.8	3%	3.8	7.0	10.0	11.3	3%
IDN	2.5	5.8	8.4	8.8	4%	2.5	6.6	9.9	11.3	5%
ZAF	4.4	7.0	8.8	9.1	2%	4.4	7.6	10.1	11.2	3%
BRA	4.0	6.8	8.8	9.2	3%	4.0	7.4	9.9	10.9	3%
IRN	3.5	8.6	13.4	14.2	5%	3.5	9.3	14.7	16.2	5%
RUS	3.4	7.9	12.1	12.7	4%	3.4	8.4	13.1	14.2	5%
ISR	9.0	10.6	11.5	11.6	1%	9.0	11.3	12.7	13.5	1%
KOR	7.2	8.7	10.1	10.3	1%	7.2	9.6	11.7	12.9	2%
DEU	7.2	8.6	9.6	9.8	1%	7.2	9.2	10.8	11.6	1%
SGP	8.9	10.2	11.6	11.9	1%	8.9	10.4	11.9	12.3	1%
CHN	4.7	10.1	14.4	15.3	4%	4.7	11.0	16.1	17.9	4%
USA	8.3	9.5	10.6	10.8	1%	8.3	10.1	11.8	12.6	1%

policy drag

	growth model A					growth models B & C				
country	**2020**	**2030**	**2040**	**2050**	**growth**	**2020**	**2030**	**2040**	**2050**	**growth**
IND	3.8	2.9	2.5	2.4	-1%	3.8	3.7	4.1	5.0	1%
IDN	2.5	1.8	1.4	1.3	-2%	2.5	2.5	2.8	3.5	1%
ZAF	4.4	3.7	3.3	3.2	-1%	4.4	4.4	4.6	5.2	0%
BRA	4.0	3.2	2.7	2.6	-1%	4.0	3.8	3.8	4.3	0%
IRN	3.5	2.2	1.8	1.7	-2%	3.5	2.8	3.0	3.5	0%
RUS	3.4	1.9	1.2	1.0	-4%	3.4	2.4	2.2	2.4	-1%
ISR	9.0	8.1	7.5	7.3	-1%	9.0	8.8	8.7	9.2	0%
KOR	7.2	6.3	5.8	5.7	-1%	7.2	7.2	7.5	8.2	0%
DEU	7.2	6.5	6.1	6.0	-1%	7.2	7.1	7.3	7.8	0%
SGP	8.9	7.2	6.3	6.0	-1%	8.9	7.4	6.5	6.4	-1%
CHN	4.7	3.0	2.0	1.7	-3%	4.7	3.8	3.7	4.3	0%
USA	8.3	7.2	6.7	6.5	-1%	8.3	7.9	7.9	8.3	0%

Appendix C:
List of Sources

Sources listed here include databases and comparative reports on general societal, science and technology, and/or biotechnology performance whose findings were included in our analysis. Individual countries' reports and policy documents were also evaluated but are not listed here.

Academic Ranking Of World Universities. ShanghaiRanking Consultancy. Online database.

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Global Agriculture Information Network (GAIN) Reports. US Department of Agricultural Services (FAS). Multiple country reports over multiple years.

Global Innovation Index, 2011-2019 editions. Cornell University, INSEAD (Institut Européen d'Administration des Affaires), and WIPO (World Intellectual Property Organization. (-2019).

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Global Status of Commercialized Biotech/GM Crops: 2018. International Service for the Acquisition of Agri-Biotech Applications. (2018).

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International Genetically Engineered Machine. Primary data. (2019).

Is China Catching Up to the United States in Innovation? Information Technology & Innovation Foundation (ITIF), R. Atkinson, C. Foote. (2019).

IUCN Red List. International Union for Conservation of Nature. Online database.

Legatum Prosperity Index. Legatum Institute. (-2019)

Monthly Biodiesel Production Report. U.S. Energy Information Administration. Online database.

National Science Foundation Science & Engineering Indicators. National Science Board. (2018).

OECD Data. Organisation for Economic Co-operation and Development. Online database.

PATENTSCOPE - WIPO patent database. World Intellectual Property Organization. Online database.

Report on statistics and indicators of biotechnology. OECD Science, Technology and Industry Working Papers - Organisation for Economic Co-operation and Development. (2018).

SBX.0 Conferences. BioBricks Foundation. Primary data. (2019).

Science, Technology, and Innovation Policy (STIP) Compass. European Commission, Organisation for Economic Co-operation and Development. Online database.

Science, Technology,and Innovation Outlook. OECD Science, Technology and Industry Working Papers - Organisation for Economic Co-operation and Development. (2018).

Scientific American Worldview: A Global Biotechnology Perspective. Scientific American. (-2016)

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The Global Competitiveness Report. World Economic Forum. (2018-2019).

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The World Factbook. Central Intelligence Agency. Online database.

The World in 2050: The Long View How will the global economic order change by 2050? PricewaterhouseCoopers. (2017).

THE World University Rankings. Times Higher Education. Online Database.

Trend-Analysis of Science, Technology and Innovation Policies for Biotechnology, Nanotechnology and Converging Technologies (BNCT). OECD Science, Technology and Industry Working Papers - Organisation for Economic Co-operation and Development. (2018).

U.S. Chamber International IP Index, 7th Edition. U.S. Chamber of Commerce's Global Innovation Policy Center, Pugatch Consilium. (2019).

UNESCO Science Report, Towards 2030. United Nations Educational, Scientific and Cultural Organization. (2015)

Web of Science. Clarivate. Online database.

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Wittgenstein Centre Human Capital Data Explorer. Wittgenstein Centre for Demography and Global Human Capital. Online database.

World Bank Open Data. The World Bank. Online database.

World Justice Project Rule of Law Index 2019. World Justice Project. (2019).

World Values Survey Wave 6. World Values Survey Association. (2011-2014).

Appendix D:
List of Interviews, and Interview Questionnaire

Appendix D-I: List of interviewees

All interviews were conducted “off the record”, i.e., expert opinions were included in our analysis and report, but are not attributed directly. In any publication of this document, interviewees should be called “biotechnology expert in (name of country)” and not named. For accuracy, interviews were recorded or notes of the interview were taken, according to the interviewee’s preference. Each interview required approximately one hour.

Interviews with synthetic biology researchers
Drew Endy, Stanford, 12/3/2019
Edward Holmes, Sanford Consortium for Regenerative Medicine (US) and Singapore A*STAR; 12/9/2019
Suresh Subramani, Tata Institute for Genetics and Society, 12/11/2019
Elibio Rech, Embrapa (Brazilian Agricultural Research Corporation), 12/17/2019
Paul Freemont, Imperial College, UK, 12/23/2019
Pam Silver, Harvard Medical School; 1/8/2020

Interviews with biotechnology experts within USDA Foreign Agricultural Service
Ali Abdi; USDA FAS, Israel; 11/13/19
Garret McDonald, USDA FAS, Indonesia, 11/19/2019
Michael Ward and Bobby Richey, USDA FAS; China; 11/20/2019
Peter Olson, USDA FAS, Republic of Korea; 11/21/2019
Ira Sugita; USDA FAS, Singapore; 11/21/2019
Deanna Ayala; USDA FAS, Russia; 11/27/2019
Kyle Bonsu and Dirk Esterhuizen; USDA FAS, South Africa; 12/3/2019
Santosh Singh; USDA FAS, India; 12/9/2019
Leif Rehder, USDA FAS, Germany; 1/9/2020
Oliver Flake, USDA FAS, Brazil; 1/15/2020

Interviews with biotechnology experts within US State Department
Pablo Valdez, US State Department, Brazil; 3/11/2020

Appendix D-II: Interview materials for synthetic biology researchers

Project Summary for interviewees - synthetic biology researchers

Biotechnology by Mid-Century: Anticipating the growth of synthetic biology and genome engineering around the world.

Background on our project:

The esteemed physicist Freeman Dyson, in an essay in the New York Review of Books in 2007, wrote: "It has become part of the accepted wisdom to say that the twentieth century was the century of physics and the twenty-first century will be the century of biology. Two facts about the coming century are agreed on by almost everyone. Biology is now bigger than physics, as measured by the size of budgets, by the size of the workforce, or by the output of major discoveries… Biology is also more important than physics, as measured by its economic consequences, by its ethical implications, or by its effects on human welfare."

Over the next few decades, advances in biotechnology hold great potential for contributing to many societal goals: improved human health and availability of new medicines, better foods and more productive agriculture, cleaner energy supplies, new approaches to protecting our environment, and a wide array of new bio-based industrial products.

But what will it take to turn that potential to reality? And to what extent will both developed and developing nations advance, participate in, and benefit from those scientific and technical advancements? We are hoping that you are willing to help a small team of policy researchers at the J. Craig Venter Institute (JCVI) answer those questions.

Today, the world's biotechnological expertise and innovation is concentrated in just a few countries around the world. The distribution of expertise and innovation by mid-century, and the ability to utilize those skills, depends on the enabling environment for biotechnological advancement, i.e., the drivers of innovation, present in each country. JCVI has a project underway to **understand, describe, and semi-quantitatively characterize** the factors that may impact the capacity for and rate of biotechnology innovation in a selection of the world's nations.

We are focusing on 12 countries: the world's two largest economies, the United States and China; four high-income countries (World Bank classification): Germany, South Korea, Singapore, and Israel; four high-middle income countries: Russia, Brazil, Iran, and South Africa; and two populous and rapidly growing low-middle income economies, India and Indonesia.

Within each country, we are examining indicators and drivers of innovation in several categories, including: 1) indicators of **current state**, i.e., nation-level characterizations of the state of biotechnology innovation and the larger science and technology environment today, 2) **scientific and technological drivers of innovation** that will affect the growth of biotechnology over the next several decades, and 3) **societal and policy drivers** that enable the development of science and technology innovation today and in the future.

The indicators of current state and drivers of future success that we have identified (and have more or less quantified) are listed in a box on the following page.

Indicators of current state and drivers of future success:

Within the biotechnology sector itself:

1. Current research success, as evidenced by well-cited scientific journal publications in biotechnology, molecular biology, and related fields;
2. biotechnology-related patenting activity;
3. significant number of biotechnology companies;
4. regulatory environment conducive to development of new biotechnology products;
5. production of genetically modified crops and biofuels;
6. top universities for training in basic biology, life sciences, and biotechnology;
7. synthetic biology talent, both students and professionals; and
8. international collaboration within the life sciences, as measured by journal articles with multi-national authors.
9. Others?

Within the larger science and technology environment:

1. Current research success in a broad range of advanced technology fields (e.g., nanotechnology, AI, and robotics), as evidenced by journal publications in these areas;
2. total patents (all fields);
3. overall scientific talent, both recent STEM graduates and current researchers;
4. R&D expenditures by universities, businesses, and government;
5. availability of venture capital funding;
6. top computer science and engineering universities;
7. product regulatory policy;
8. intellectual property policies; and
9. presence of university/industry regional clusters.
10. Others?

And finally, general societal trends and drivers of science and technology:

1. GDP, GDP per capita, and population growth rate projections to 2050;
2. population demographics, e.g., aging of the population;
3. overall education of the population and spending on education by government;
4. general "rule of law";
5. adoption of internet and communication technologies; and
6. general population beliefs about the benefits from science, as shown in public opinion surveys.
7. Others?

Interview questions for synthetic biology researchers

Interview Questions

We hope that you will take a few minutes to read the separate two-page introduction to our project. We will open our interview with a brief overview of the project and answer any questions you might have.

If you wish, the interview can be "off the record" with comments attributed to a "scientific expert." With your permission, we would like to record our conversation, solely for internal use to verify the accuracy of our notes.

The goal of our project is to better understand the underlying drivers of innovation that can help a country develop a successful biotechnology research environment and sector. Conversely, what hampers a country from developing such a research environment and sector? We are interested in both developed and developing countries.

To that end, we would like to first discuss with you (1) how you see your field advancing over the coming years to decades and (2) what you think it will take to make your vision a reality. We would like you to consider not only your particular research area, but synthetic biology, genome engineering, and biotechnology, in general.

Next, we would like to discuss the "drivers of innovation" important for the success of a vibrant biotechnology program within a country, for example, education, funding, supportive public policy, and scientific talent. The drivers and indicators that we have identified are listed in the box at the end this document. We would like your opinions about how these and other drivers affect the growth of a biotechnology sector over the longer-term, i.e., the next 10 to 30 years, rather than within any specific funding or political cycle.

Interview thread one:

1. Please tell us a bit about your vision for your particular research area and the larger fields of synthetic biology and biotechnology over the next few decades.
2. What supporting fields or technologies do you see as necessary for these breakthroughs? In particular, we would like your thoughts about the relative importance of future breakthroughs in each of four broad areas:
    a. **Biotechnologies**, i.e., the "wet" tools and technologies, e.g., sequencing, synthesis, and such editing tools as CRISPR. Which of these (or other) categories of wet-lab tools are most important to continued progress?
    b. **Biological data**, i.e., sequence data as well as other associated "omics". The biodiversity of the planet is immense. Do "mega-diverse" nations such as Brazil and Indonesia thereby have a special advantage?
    c. **Bioinformatics**, computational tools, modeling, and emerging approaches employing machine learning. Will next-generation biotechnology require advanced computational hardware or a cutting-edge artificial intelligence research community?
    d. Understanding of **basic biology**. Technological breakthroughs often stem from basic research (with CRISPR as a prominent example). For a country to be a leader in biotechnology, must it also maintain a strong program in basic biological research?
3. How important are advancements in other areas of science and technology (e.g., microfluidics, robotics, and nanotechnology) for achieving breakthroughs in biotechnology?

Interview thread two:

1. Of the drivers of innovation listed at the end of the separate Project Summary document, which do you believe are particularly important for long-term development of:
    a. your particular research area?
    b. synthetic biology and biotechnology, in general?
2. Are there important drivers of future progress that are not listed here?
3. How do you think the drivers that you have identified have allowed your country to be more or less competitive in science and technology?
4. Do you believe that the importance of your identified drivers is different when considering another country that is:
    a. at a different stage of economic development?
    b. at a different stage of technological development?
    c. governed under a different political system?
5. What do you think are the major scientific or social hurdles to future technological development?
6. Overall, are you optimistic about the future of biotechnologies in the world? Why or why not?

Appendix D-III: Interview materials for USDA FAS biotechnology experts

Project Summary for interviewees - USDA FAS biotechnology experts

Biotechnology by Mid-Century: Anticipating the growth of synthetic biology and genome engineering around the world.

Background on our project:

The esteemed physicist Freeman Dyson, in an essay in the New York Review of Books in 2007, wrote: "It has become part of the accepted wisdom to say that the twentieth century was the century of physics and the twenty-first century will be the century of biology. Two facts about the coming century are agreed on by almost everyone. Biology is now bigger than physics, as measured by the size of budgets, by the size of the workforce, or by the output of major discoveries… Biology is also more important than physics, as measured by its economic consequences, by its ethical implications, or by its effects on human welfare."

Over the next few decades, advances in biotechnology hold great potential for contributing to many societal goals: improved human health and availability of new medicines, better foods and more productive agriculture, cleaner energy supplies, new approaches to protecting our environment, and a wide array of new bio-based industrial products.

But what will it take to turn that potential to reality? And to what extent will both developed and developing nations advance, participate in, and benefit from those scientific and technical advancements? We are hoping that you are willing to help a small team of policy researchers at the J. Craig Venter Institute (JCVI) answer those questions.

Today, the world's biotechnological expertise and innovation is concentrated in just a few countries around the world. The distribution of expertise and innovation by mid-century, and the ability to utilize those skills, depends on the enabling environment for biotechnological advancement, i.e., the drivers of innovation, present in each country. JCVI has a project underway to **understand, describe, and semi-quantitatively characterize** the factors that may impact the capacity for and rate of biotechnology innovation in a selection of the world's nations.

We are focusing on 12 countries: the world's two largest economies, the United States and China; four high-income countries (World Bank classification): Germany, South Korea, Singapore, and Israel; four high-middle income countries: Russia, Brazil, Iran, and South Africa; and two populous and rapidly growing low-middle income economies, India and Indonesia.

Within each country, we are examining indicators and drivers of innovation in several categories, including: 1) indicators of **current state**, i.e., nation-level characterizations of the state of biotechnology innovation and the larger science and technology environment today, 2) **scientific and technological drivers of innovation** that will affect the growth of biotechnology over the next several decades, and 3) **societal and policy drivers** that enable the development of science and technology innovation today and in the future.

The indicators of current state and drivers of future success that we have identified (and have more or less quantified) are listed in a box on the following page.

Indicators of current state and drivers of future success:

Within the biotechnology sector itself:

10. Current research success, as evidenced by well-cited scientific journal publications in biotechnology, molecular biology, and related fields;
11. biotechnology-related patenting activity;
12. significant number of biotechnology companies;
13. regulatory environment conducive to development of new biotechnology products;
14. production of genetically modified crops and biofuels;
15. top universities for training in basic biology, life sciences, and biotechnology;
16. synthetic biology talent, both students and professionals; and
17. international collaboration within the life sciences, as measured by journal articles with multi-national authors.
18. Others?

Within the larger science and technology environment:

11. Current research success in a broad range of advanced technology fields (e.g., nanotechnology, AI, and robotics), as evidenced by journal publications in these areas;
12. total patents (all fields);
13. overall scientific talent, both recent STEM graduates and current researchers;
14. R&D expenditures by universities, businesses, and government;
15. availability of venture capital funding;
16. top computer science and engineering universities;
17. product regulatory policy;
18. intellectual property policies; and
19. presence of university/industry regional clusters.
20. Others?

And finally, general societal trends and drivers of science and technology:

8. GDP, GDP per capita, and population growth rate projections to 2050;
9. population demographics, e.g., aging of the population;
10. overall education of the population and spending on education by government;
11. general "rule of law";
12. adoption of internet and communication technologies; and
13. general population beliefs about the benefits from science, as shown in public opinion surveys.
14. Others?

Interview questions for USDA FAS biotechnology experts

Interview Questions

We hope that you will take a few minutes to read the separate two-page introduction to our project. We will open our interview with a brief overview of the project and answer any questions you might have. If you wish, the interview can be "off the record" with comments attributed to an "in-country expert."

1. Questions regarding the most recent Agricultural Biotechnology Report in your country:
    a. Has there been, or do you anticipate, any significant change with regard to plant biotechnology, since your last report, including:
        i. In-country development of GE crops (number, traits, trends, industry vs. government/academic funded)?
        ii. Field testing of GE crops?
        iii. Planting of GE crops?
        iv. Regulation: position with regard to either transgenics, innovative technologies, labeling, other?
    b. Has there been, or do you anticipate, any significant change with regard to animal biotechnology (either in-country development or regulatory review)?
    c. Has there been, or do you anticipate, any significant change with regard to other product categories (which may or may not have been mentioned in your particular country report), such as:
        i. Microbial products for use in the environment (e.g., root zone)? Any development activity that you know about? Is a regulatory pathway clear?
        ii. Advanced biofuels such as algal biofuel or cellulosic ethanol (which may be covered in a separate report?
        iii. Industrial biotechnology, including products of synthetic biology?
    d. Biotechnology policy
        i. Any other significant changes in biotechnology regulatory policy not discussed above?
        ii. Any recent legislation, policy statements, government roadmaps, government R&D priorities, etc. related to biotechnology that would be helpful for us to know about?
2. In general, how do decisionmakers in your country feel about the development of biotechnology? Would you say that it is a priority?
3. In general, is the development of a bioeconomy an important priority to decisionmakers in your country? Is "next-generation" biotechnology, e.g., synthetic biology, on the policy radar?
4. What deterrents or roadblocks do you see that might slow the progress of biotechnology within your country?
    a. What do you see as the biggest hurdles for your country to overcome in its pursuit of biotechnology?
    b. What difficulties do you see for general advancement of science and technology in your country?
5. How do you rank your country internationally with regard to status/success in biotechnology related areas? Do you see this status/success continuing, increasing, or declining in the long-term? Why?

6. We have identified a series of "drivers", such as education, funding, supportive policy, and scientific talent, that help advance a biotechnology program within a country. These are listed in the box at the end of the separate Project Summary document. We would like to better understand how these and other drivers impact the long-term (i.e., decade or longer) potential for biotechnology development on a country level.
    a. Do any indicators strike you as particularly important for long-term development of biotechnology in your country?
    b. Are there important drivers of future progress that are not listed here?
    c. How do you think the drivers that you have identified have allowed your country to be more or less competitive in biotechnology?

Appendix D-IV: Interview materials for US State Department biotechnology experts

Project Summary and Questions for Interviewees – US State Department biotechnology experts

Biotechnology by Mid-Century: Anticipating the growth of synthetic biology and genome engineering around the world.

Background on our project:

Over the next few decades, advances in biotechnology hold great potential for contributing to many societal goals: improved human health and availability of new medicines, better foods and more productive agriculture, cleaner energy supplies, new approaches to protecting our environment, and a wide array of new bio-based industrial products. As the esteemed physicist Freeman Dyson, in an essay in the New York Review of Books in 2007, wrote: "It has become part of the accepted wisdom to say that the twentieth century was the century of physics and the twenty-first century will be the century of biology."

But what will it take to turn that potential to reality? And to what extent will both developed and developing nations advance, participate in, and benefit from those scientific and technical advancements? We are hoping that you are willing to help a small team of policy researchers at the J. Craig Venter Institute (JCVI) answer those questions.

Today, the world's biotechnological expertise and innovation is concentrated in just a few countries around the world. The distribution of expertise and innovation by mid-century, and the ability to utilize those skills, depends on the enabling environment for biotechnological advancement, i.e., the drivers of innovation, present in each country. JCVI has a project underway to **understand, describe, and semi-quantitatively characterize** the factors that may impact the capacity for and rate of biotechnology innovation in a selection of the world's nations.

We are focusing on 12 countries: the world's two largest economies, the United States and China; four high-income countries (World Bank classification): Germany, South Korea, Singapore, and Israel; four high-middle income countries: Russia, Brazil, Iran, and South Africa; and two populous and rapidly growing low-middle income economies, India and Indonesia.

Within each country, we are examining indicators and drivers of innovation in several categories, including: 1) indicators of **current state**, i.e., nation-level characterizations of the state of biotechnology innovation and the larger science and technology environment today, 2) **scientific and technological drivers of innovation** that will affect the growth of biotechnology over the next several decades, and 3) **societal and policy drivers** that enable the development of science and technology innovation today and in the future.

The indicators of current state and drivers of future success that we have identified (and have more or less quantified) are listed in a box at the end of this document.

What we hope to accomplish from interviews with science attaches such as yourself with expertise in biotechnology-related policy:

The rate of biotechnological progress will be influenced, to greater or lesser degree, by each of the scientific, technological, and societal drivers listed in the box below. Country policies can influence many, if not most of the drivers of future technological success. ***We would appreciate your insights on the biotechnology policy landscape in the countr(ies) among those listed above with which you have greatest familiarity.*** Through interviews with USDA Foreign Agricultural Service employees, we have a good understanding of the research and policy landscape for agricultural biotechnology in each country. We are hoping that you will be able to give insights into other biotechnology sectors, e.g., sector-specific policies that either encourage or discourage biologics, industrial biotechnology, biofuels, etc. More broadly, we are interested in your thoughts on related government policies, such as support for STEM education, R&D funding, development of university/industry regional clusters, etc. To the extent that you are able, we would appreciate your directing us to other key reports and/or independent review articles (in English) that you believe would be helpful to our research.

In addition, ***we would like your thoughts on which of the drivers of future success in the box below you consider to be relative strengths or weaknesses in the countr(ies) for which you have expertise.***

Interview questions:

We will open our interview with a brief overview of the project and answer any questions you might have. The interview will be "off the record" with comments attributed to an "in-country expert." With your permission, we would like to record the interview to be able to check the accuracy of our notes.

7. Overall, would you consider the broad policy stance of your country conducive to future growth in biotechnology research and applications?
8. In general, how do decisionmakers in your country feel about the development of biotechnology? Would you say that it is a priority?
9. Are there any recent policy statements, government roadmaps, government R&D priorities, etc. related to biotechnology that would be helpful for us to know about?
10. In general, is the development of a "bioeconomy" an important priority to decisionmakers in your country? Is "next-generation" biotechnology, e.g., synthetic biology, on the policy radar?
11. What deterrents or roadblocks do you see that might slow the progress of biotechnology within your country?
    a. What do you see as the biggest hurdles for your country to overcome in its pursuit of biotechnology?
    b. What difficulties do you see for advancement of science and technology in general?
12. How do you rank your country internationally with regard to status/success in biotechnology-related areas? Do you see this status/success continuing, increasing, or declining in the long-term? Why?
13. What is your opinion of the environment for scientific and technical innovation in general in your country, both today and looking forward to the future?
14. We have identified a series of "drivers", such as education, funding, supportive policy, and scientific talent, that help advance a biotechnology program within a country. These are listed in the box below. We would like to better understand how these, and other, drivers impact the long-term (i.e., decade or longer) potential for biotechnology development on a country level.
    a. Which of the drivers of future success in the box below do you consider to be relative strengths or weaknesses in your country?
    b. Do any drivers strike you as particularly important for long-term development of biotechnology in your country?
    c. Have we missed any important factors that should be considered?

Indicators of current state and drivers of future success:

A. Within the biotechnology sector itself:
   1. Current research success, as evidenced by well-cited scientific journal publications in biotechnology, molecular biology, and related fields;
   2. biotechnology-related patenting activity;
   3. significant number of biotechnology companies;
   4. regulatory environment conducive to development of new biotechnology products;
   5. production of genetically modified crops and biofuels;
   6. top universities for training in basic biology, life sciences, and biotechnology;
   7. synthetic biology talent, both students and professionals; and
   8. international collaboration within the life sciences, as measured by journal articles with multi-national authors.
   9. Others?

B. Within the larger science and technology environment:
   1. Current research success in a broad range of advanced technology fields (e.g., nanotechnology, AI, and robotics), as evidenced by journal publications in these areas;
   2. total patents (all fields);
   3. overall scientific talent, both recent STEM graduates and current researchers;
   4. R&D expenditures by universities, businesses, and government;
   5. availability of venture capital funding;
   6. top computer science and engineering universities;
   7. product regulatory policy;
   8. intellectual property policies; and
   9. presence of university/industry regional clusters.
   10. Others?

C. And finally, general societal trends and drivers of science and technology:
   1. GDP, GDP per capita, and population growth rate projections to 2050;
   2. population demographics, e.g., aging of the population;
   3. overall education of the population and spending on education by government;
   4. general "rule of law";
   5. adoption of internet and communication technologies; and
   6. general population beliefs about the benefits from science, as shown in public opinion surveys.
   7. Others?

Biotechnology by Mid-Century:

Assessing current capabilities. Anticipating tomorrow's leaders.