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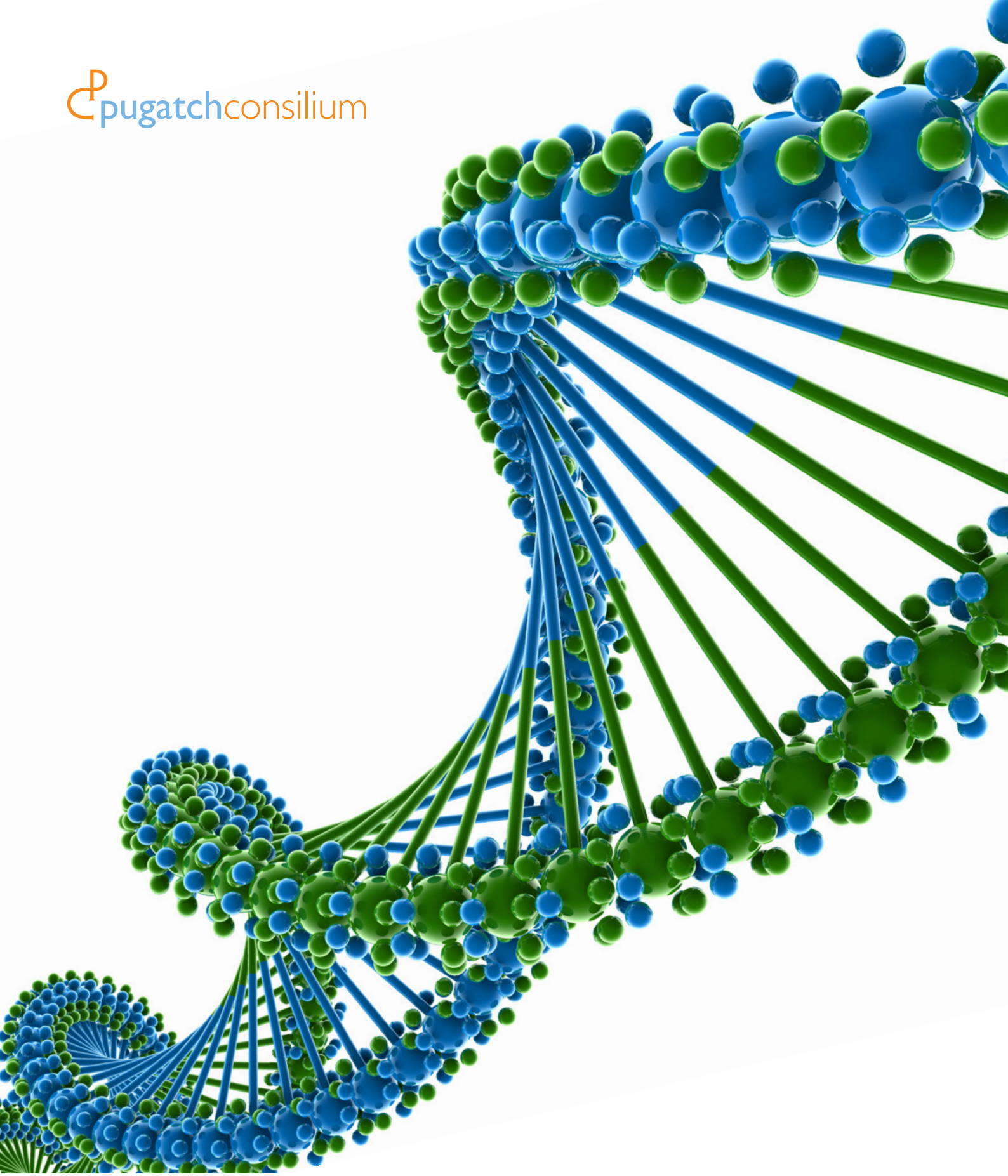

BUILDING THE BIOECONOMY 2015

Examining National Biotechnology Industry Development Strategies Globally

This report was commissioned by the Biotechnology Industry Organization. The views represented here are those of the authors only.

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TABLES AND FIGURES

LIST OF ABBREVIATIONS

ANVISA	Brazilian National Health Surveillance Agency
API	Active Pharmaceutical Ingredient
A*STAR	Agency for Science, Technology and Research (Singapore)
BNDES	Brazilian Development Bank
CDSC	Central Drugs Standard Control (India)
CLs	Compulsory Licenses
CTNBio	Brazilian Biosafety Technical Commission
EMBRAPA	Brazilian Agricultural Research Corporation
EPA	US Environmental Protection Agency
FINEP	Funding Authority for Studies and Projects (Brazil)
FDA	US Food and Drug Administration
FDI	Foreign direct investment
GCP	Good Clinical Practices
GMP	Good Manufacturing Practices
GM	Genetically Modified
GMO	Genetically Modified Organism
ICT	Information and Communications Technologies
INPI	Brazilian Patent Office
IP	Intellectual Property
IPRs	Intellectual Property Rights
IRP	International Reference Pricing
NGO	Non-Governmental Organization
NIH	US National Institutes of Health
OECD	Organisation for Economic Co-operation and Development

LIST OF ABBREVIATIONS (continued)

PE	Private Equity
PCT	Patent Cooperation Treaty
PRO	Public Research Organization
RDP	Regulatory Data Protection
R&D	Research and Development
SFDA	State Food and Drug Administration (China)
SME	Small and Medium Enterprises
TRIPS	Trade-Related Aspects of Intellectual Property Rights
USDA	US Department of Agriculture
USTR	US Trade Representative
VC	Venture Capital
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

EXECUTIVE SUMMARY

Building the Bioeconomy examines and identifies policies and best practices that pave the way for a creating an environment and ecosystem that enables biotech innovation. The 2015 edition focuses on 13 countries: Brazil, China, India, Korea, Malaysia, Mexico, Russia, Singapore, South Africa, Switzerland, Turkey, the UK and the United States. Using a comparative perspective and looking in detail at the country specific-level, the report identifies several important findings as well as lessons learned.

Enabling factors for growing a robust a national biotechnology echo system

Designing an environment that is conducive to the innovation, research, commercialization and marketing of biotechnological products and technologies is not an exact science. There are a myriad of factors that potentially can affect, encourage or discourage rates of biotech innovation. Relevant policies and factors range from those specific to the biotechnology sector and the life sciences to more general ones affecting broader levels of innovation and economic activity. Yet based on the existing empirical literature and the experience of economies that have been successful in building an advanced biotech capacity, it is possible to identify seven enabling factors that together create a national environment conducive to the biotech field.

1. Nurturing human capital
   A basic and fundamental building block for the biotech sector is the availability of high skilled and technically trained human capital.

2. Investing in physical and technological infrastructure for R&D
   R&D infrastructure and capacity is critical to fostering innovation and activity in high tech sectors including biotechnology.

3. Protection of intellectual property rights (IPRs)
   IPRs such as patents and regulatory data protection are historically of real importance to the biotech and biopharmaceutical innovation process as they incentivise the development of new technologies and products.

4. Maintaining a stable, efficient and predictable regulatory environment
   The regulatory and clinical environment in a given country or region plays a significant role in shaping incentives for innovation and establishing levels of quality and safety for biotech products.

5. Introducing technology transfer frameworks and enhancing public-private collaborations
   Technology transfer is an important mechanism for commercializing and transferring research from public and governmental bodies to private entities and private to private entities.

6. Providing for market and commercial incentives
   Market and commercial incentives can come through a number of different forms such as tax incentives and R&D credits for investments in plant, equipment and other R&D infrastructure. For the biopharmaceutical sector pricing and reimbursement systems for medicines and health technologies can have a profound impact on the incentives for biopharmaceutical innovation.

7. The existence of legal certainty and protecting the rule of law
   The general legal environment including as it relates to the rule of law and the rule of law within a business context is crucial to commercialization and business activities.

Together these factors create the policy infrastructure upon which different countries can develop and promote their biotech ecosystems. Still while these factors are fundamental at the systemic macro level, there is also a need to supplement them with policies and actions that are more nuanced and sector-specific.

One size does not fit all – Different biotech sectors have different policy needs

The individual significance of related policies for each biotechnology sector, such as in the fields of biopharmaceutical, ag-bio and industrial biotechnology, may vary, at times significantly, depending on the specific needs of that particular sector. A national strategy or set of policies that are aimed at growing the capacity and productivity of one biotech sector (for example in the field of ag-bio), may not necessarily be suitable for the ability to grow or develop products in other sectors, such as the development of new biopharmaceutical medicines.

Some interesting lessons can be found in the desire and ability of different countries to grow their own biotechnological base in the life sciences. For instance, while Brazil has through EMBRAPA and long-term support for the sugar-cane ethanol industry built a world-leading ag-bio and industrial biotech capacity, so far success has been more elusive in the innovative biopharmaceutical sector. South Africa and India also face a similar situation. A possible explanation for the relatively more limited success these countries have experienced is the fact that there are still a number of grey or incomplete policy areas that are pivotal to the ability to enhance the biopharmaceutical sector, and that are still absent in these countries. Such policy areas include: the need to introduce and protect different forms of IPRs specific to the biopharmaceutical sector; incomplete or ineffective technology transfer policies and frameworks; regulatory delays and inefficiencies in the review and approval of new products; and the absence of satisfactory market incentives.

In contrast other countries have developed and are developing more holistic sector-specific programs that help drive forward their biopharmaceutical sector. For example, Singapore, the US, the UK and Switzerland have built state-of-the-art biopharmaceutical R&D and manufacturing facilities through targeted policies on biopharmaceutical IPRs, high-standard regulations, and commercial and market incentives.

The table on the next page provides a summary overview of some of the major success stories and remaining stumbling blocks for each of the thirteen economies mapped.

The importance of tracking and measuring policy inputs and outputs –the Biotech Policy Performance Measure

Being able to track progress and identify areas of weakness is key to any national policy framework; including in the field of biotechnology. In this respect it is also important not only to focus on the policy inputs but also to try and understand how they may translate into national outputs.

Building the Bioeconomy 2015 includes a new tool: the Biotech Policy Performance Measure. This tool (the "Measure") provides readers a quick overview of a given economy's policy framework and performance in relation to the other economies sampled. The Measure includes some of the most important elements for each of the seven enabling factors used to map a given economy's policy framework including relevant biotechnology policy inputs and outputs. It uses a simple three-tier classification system of policy performance: "Attractive", "Mixed", and "Challenging".

While the purpose of the Measure is not to 'score' or benchmark individual countries to a pre-determined set of criteria it does provide users an idea of how a sample of policies (including inputs and outputs) for each enabling factor compares with the same policy input or output for all economies included in the report. Overall the results show the great variety between economies as well as for each enabling factor for a given economy. For instance, economies can have quite attractive policies and frameworks in place for some enabling factors yet face more significant challenges in other areas. The full results of the Biotech Policy Performance Measure are included in the table on pages 12 and 13.

Country overview - Success stories and Stumbling blocks

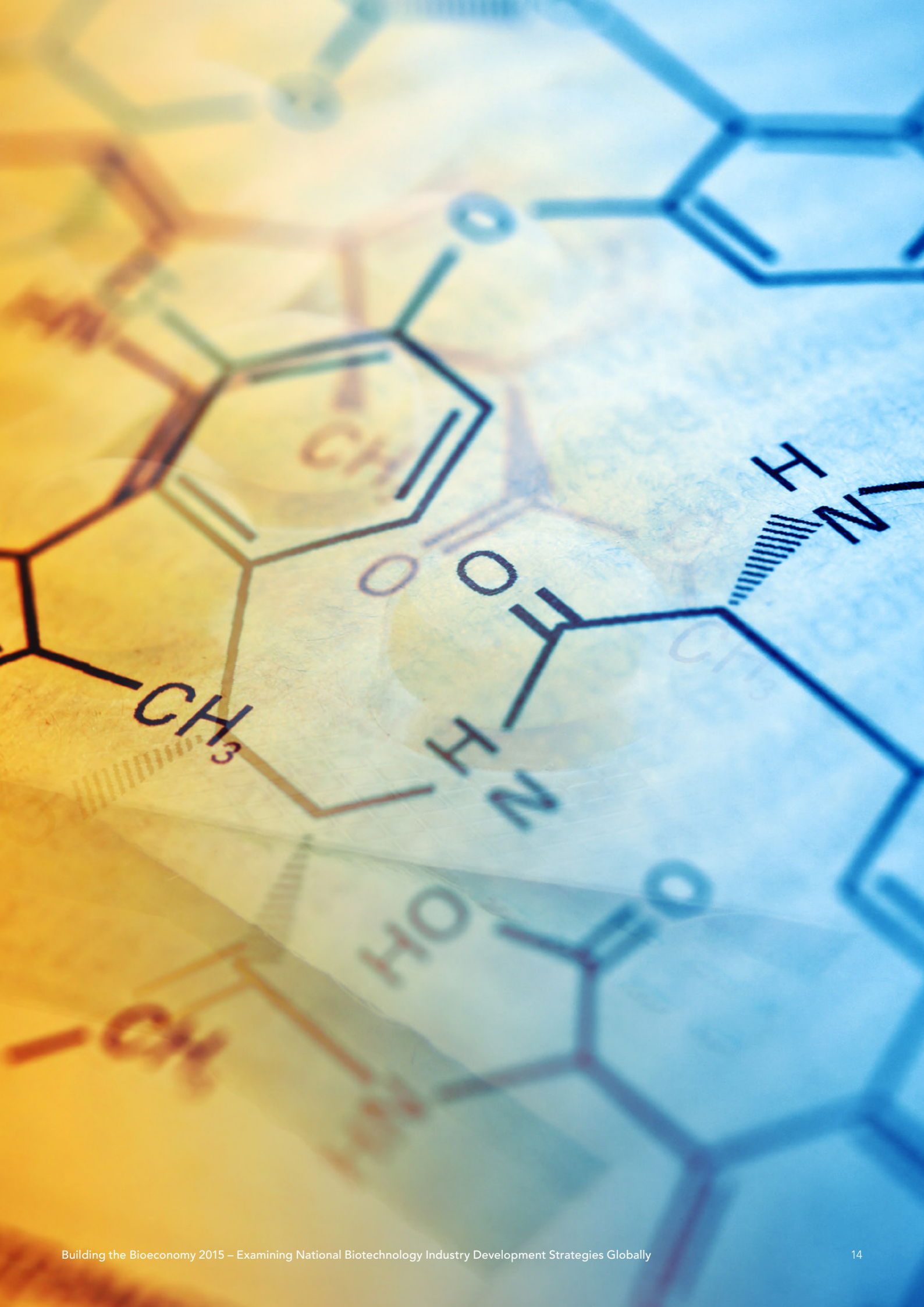
	Success stories	Stumbling blocks
Brazil	• Government support for ag-bio and industrial biotechnology e.g. EMBRAPA and sugar-cane ethanol • Brasil Maior initiative - focus on life sciences and need for improving human capital	• Challenging IP environment • Biopharmaceutical P&R environment challenging - strict pricing policies and local preferencing • Cumbersome tech transfer framework
China	• Significant investor in human capital and R&D infrastructure • High levels of IP creation through patenting (general and biotech	• Challenging regulatory environment for clinical trials and seed registration and commercialization • Strict reimbursement policies have limited the number of biological drugs available • Challenging IP environment
India	• Tradition of strong Government focus on biotech • Potential policy change by Modi Government – focus on innovation, improving IP standards	• No comprehensive national tech transfer framework • Uncertainty over Government support for commercialization and registration of ag-bio products • IP environment: Section 3(d) and patentability requirements; no RDP; use of compulsory licenses and patent revocations for biopharmaceuticals
Korea	• High levels of R&D investment • Comprehensive tech transfer legal framework in place • Strong IP environment	• No commercialized ag-bio products • Data requirements for pharmaceutical patent applications exceed international best practices • Strict pricing policies and limited reimbursement
Malaysia	• Generous high tech and biotech specific credits e.g. BioNexus • Relatively high level of technology transfer and patenting by palm oil PRO (Malaysian Palm Oil Board)	• RDP legally in place but limited in practical availability • Delays in marketing approval of biopharmaceuticals • P&R environment challenging - long formulary delays
Mexico	• Growing biopharmaceutical FDI - circa USD1 billion in 2012 • Cut in market approval processing times by COFEPRIS	• Biopharmaceutical P&R environment challenging • Limited tech transfer framework in place • RDP available but unclear for large molecules
Russia	• High number of natural science PhDs • Generous R&D tax credits available	• Limited commercial use of ag-bio products – regulatory infrastructure not in place • Strict localization and P&R policies
Singapore	• World class biopharmaceutical R&D and manufacturing hub • High levels of clinical trials • Strong IP, regulatory and tech transfer environment • Generous R&D tax credits available	• No commercial cultivation of ag-bio products • Limited industrial biotech
South Africa	• Strong tradition of ag-bio use and production • Generous R&D tax super deduction available • Technology transfer framework in place	• Challenging life sciences IP environment • Limited biopharmaceutical R&D capacity • Long delays for pharmaceutical market authorization
Switzerland	• High levels of human capital • Leading global investor in biopharmaceutical R&D • Strong clinical trials environment	• No commercial production of ag-bio products • GM foods in effect banned
Turkey	• Generous general R&D tax credits available - 150% dedication • Growing number of life sciences graduates - 250% increase since 2000	• Challenging biopharmaceutical IP environment • Ag-bio R&D taking place but no commercialization • Strict P&R policies for biopharmaceuticals
UK	• Top life sciences universities in the world; Cambridge and Oxford ranked 3rd and 4th • High levels of clinical trials - per capita and total • Biopharmaceutical R&D almost 25% of total private sector R&D	• EU regulations on ag-bio not conducive to wide-spread commercialization and use of ag-bio products
US	• Top life sciences universities in the world • World's highest total of clinical trials • High total biopharmaceutical R&D • Biggest producer of ag-bio crops in the world • Leading producer of biofuels in the world	• Uncertainties over patentability of basic biotech inventions e.g. 2013 Molecular Pathology v Myriad Genetics and 2012 Prometheus Laboratories, Inc v Mayo Collaborative Services

The Biotech Policy Performance Measure: Overall results

	Brazil	China	India	Korea	Malaysia	Mexico	Russia
Factor 1: Human capital							
No of researchers per capita (million population)	710	1020	160	5928	1642	386	3096
% of population in tertiary education	0.13	0.04	N/A	0.4	0.05	0.18	0.53
Performance compared to Sample	**Challenging**	**Challenging**	**Challenging**	**Attractive**	**Mixed**	**Mixed**	**Attractive**
Factor 2: Infrastructure for R&D							
R&D spending % of GDP	1.21	1.98	0.76	4.36	1.07	0.43	1.12
Clinical trials per capita	20.08665605	3.9398228	2.009078952	112.4663863	14.27980132	18.21854186	19.21017825
Performance compared to Sample	**Mixed**	**Mixed**	**Challenging**	**Attractive**	**Challenging**	**Challenging**	**Mixed**
Factor 3: Intellectual property protection							
RDP	Challenging	Challenging	Challenging	Attractive	Challenging	Challenging	Challenging
PTE	Challenging	Challenging	Challenging	Attractive	Challenging	Challenging	Attractive
Performance compared to Sample	**Challenging**	**Challenging**	**Challenging**	**Attractive**	**Challenging**	**Challenging**	**Mixed**
Factor 4: The regulatory environment							
Existence of regulatory framework and efficiency	**Challenging**	**Challenging**	**Challenging**	**Attractive**	**Challenging**	**Mixed**	**Challenging**
Factor 5: Technology transfer frameworks							
Frameworks in place	**Mixed**	**Attractive**	**Challenging**	**Attractive**	**Challenging**	**Challenging**	**Challenging**
Factor 6: Market and commercial incentives							
P&R policies	**Challenging**	**Challenging**	**Challenging**	**Challenging**	**Challenging**	**Challenging**	**Challenging**
Factor 7: Legal certainty (including the rule of law)							
RoL index ranking	42	76	66	14	35	79	80
Performance compared to Sample	**Mixed**	**Challenging**	**Challenging**	**Attractive**	**Mixed**	**Challenging**	**Challenging**

The Biotech Policy Performance Measure: Overall results

	South Africa	Singapore	Switzerland	Turkey	UK	US
Factor 1: Human capital						
No of researchers per capita (million population)	363	6437	5500	987	4042	3978
% of population in tertiary education	0.06	N/A	0.35	0.15	0.41	0.42
Performance compared to Sample	**Challenging**	**Attractive**	**Attractive/ Mixed**	**Mixed**	**Attractive/ Mixed**	**Attractive/ Mixed**
Factor 2: Infrastructure for R&D						
R&D spending % of GDP	0.76	2.23	2.87	0.86	1.77	2.79
Clinical trials per capita	36.14435091	245.9623648	445.2940239	21.11706151	149.0663077	251.1714383
Performance compared to Sample	**Challenging**	**Attractive**	**Attractive**	**Mixed**	**Mixed**	**Attractive**
Factor 3: Intellectual property protection						
RDP	Challenging	Attractive	Attractive	Challenging	Attractive	Attractive
PTE	Challenging	Attractive	Attractive	Challenging	Attractive	Attractive
Performance compared to Sample	**Challenging**	**Attractive**	**Attractive**	**Challenging**	**Attractive**	**Attractive**
Factor 4: The regulatory environment						
Existence of regulatory framework and efficiency	**Challenging**	**Attractive**	**Mixed/ Attractive**	**Challenging**	**Attractive**	**Attractive**
Factor 5: Technology transfer frameworks						
Frameworks in place	**Mixed**	**Attractive**	**Attractive**	**Mixed**	**Attractive**	**Attractive**
Factor 6: Market and commercial incentives						
P&R policies	**Challenging**	**Mixed**	**Mixed**	**Challenging**	**Mixed**	**Attractive**
Factor 7: Legal certainty (including the rule of law)						
RoL index ranking	40	10	N/A	59	13	19
Performance compared to Sample	**Mixed**	**Attractive**	**N/A**	**Mixed**	**Attractive**	**Attractive**



1 INTRODUCTION

Last year Pugatch Consilium released *Building the Bioeconomy Examining National Biotechnology Industry Development Strategies*. Commissioned by the Biotechnology Industry Organization the report sought to give an overview of national innovation strategies, policies and best practices that relate to the building of a world-class biotechnology sector.

It identified seven key enabling policy input factors ranging from human capital, protection of intellectual property to infrastructure for research and development. The report looked at the existence and application of these enabling factors in eight of the world's most important economies: Brazil, China, India, Korea, Russia, Singapore, Switzerland and the United States. The report and its findings garnered significant international interest, from governments and policymakers across the world not least in Latin America where the report was first launched.[1]

1.1 *Building the Bioeconomy 2015* – What's new?

More economies covered

This year Pugatch Consilium releases the second edition of *Building the Bioeconomy*. This edition builds on the work of the first edition. By using the enabling factors identified in the first edition it has expanded the sample of economies by five to thirteen economies in total; five new economies and the eight mapped in the previous edition. The new economies included are: Malaysia, Mexico, South Africa, Turkey and the UK. As in last year's edition the sample of economies is geographically and economically diverse with a mix of high-income mature OECD economies and middle income and emerging markets.

The economies included this year are:

1. Brazil
2. China
3. India
4. Korea
5. Malaysia
6. Mexico
7. Russia
8. South Africa
9. Singapore
10. Switzerland
11. Turkey
12. UK
13. US

The sample of economies is intended to reflect a range of key economies in terms of geography and income level. Using the World Bank's classification system,[2] *Building the Bioeconomy 2015* comprises 6 high-income economies (two of which, Singapore and Russia, are not OECD members), 6 upper-middle-income economies and 1 lower-middle-income economy. Table 1 groups the economies sampled according to their World Bank defined income levels.

TABLE 1 *Building the Bioeconomy 2015*, Sampled Economies by World Bank Economy Group

High-income economies	Upper-middle-income economies	Lower-middle-income economies
Korea, Russia, Singapore, Switzerland, UK, US	Brazil, China, Malaysia, Mexico, South Africa, Turkey	India

Source: World Bank (2015)[3]

All economies and biotech policies are mapped using the same enabling factors and methodology. The original economies have been re-mapped and relevant updates to data and each economy's policy framework (general as well as biotechnology specific) have been made.

Examining the policy needs of each biotechnology sector

As a new feature this year's edition includes a dedicated discussion of the distinct needs of individual biotechnology sectors. While all of the seven enabling factors identified and used in *Building the Bioeconomy 2015* are fundamental to promoting innovation in all biotechnology sectors, the individual significance of related policies for each factor may vary depending on the needs of a particular sector. For instance, the policy inputs and requirements for developing a ground-breaking biological treatment for a rare disease or a cancer is not the same as improving the agricultural yields of a strain of soybeans, let alone creating a laundry detergent whose cleaning power is aided by catalytic enzymes. The science and research required to develop new products and technologies in the biopharmaceutical, ag-bio and industrial biotechnology sectors are not the same. Yet in many cases the public policy framework in place and created to enable the development of these sectors and further biotechnology innovation is not targeted at the particular needs of each individual sector.

Not only does this edition of *Building the Bioeconomy* contain a dedicated section on the individual policy needs of the biopharmaceutical, ag-bio and industrial biotechnology sectors (section 4), in addition, for each economy overview a dedicated discussion of the policy framework in place for each biotechnology sector is included. The purpose of this is to, first, highlight how different biotech sectors have different policy needs in a given economy and, second, to point out those areas where sector-specific policies are in place but also where there remains room for further discussion and introduction of new policies.

Measuring performance

In addition to the inclusion of five new economies and a focus on the separate policy needs of the three major biotechnology sectors, *Building the Bioeconomy 2015* also includes a new tool: a Biotech Policy Performance Measure. This tool (the "Measure") provides readers a quick overview of a given economy's policy framework and performance in relation to the other economies sampled. The Measure includes some of the most important elements for each of the seven enabling factors used to map a given economy's policy framework (detailed below in section 3). The design of the Measure, indicators used and methodology is described fully below in section 6, but it is worth briefly noting a few basic facts about what the Measure seeks to achieve.

The overall purpose of the Measure is not to 'score' or benchmark individual countries to a pre-determined set of criteria. Rather, the purpose of this tool is to give readers (and the economies mapped) an idea of how a sample of their policies (including inputs and outputs) for each enabling factor compares with the same policy input or output for the other economies sampled.

Annex

Finally, it is worth noting that this report is accompanied by an Annex. This Annex contains a detailed discussion of each enabling factor included in this report for each of the sampled economies. It is a reference tool and can be read in conjunction with this, the main report.

1.2 Report overview

Building the Bioeconomy 2015 takes into account the specific requirements of the biotechnology sector and how biotech R&D takes place. It identifies key enabling policy input factors ranging from human capital, protection of IP, to infrastructure for R&D. The overall purpose is to provide an overview of some of the best practices in place internationally that support and enhance biotechnology inputs and outputs. The point of reference for this assessment is the development of a globally competitive sector; economies that wish only to develop a sector that is nationally competitive could in principle adopt a more protectionist set of policies. The consequence of such a strategy would however be to limit the ability of local players to succeed in world markets.

In addition to this Introduction the paper contains the following sections.

Section 2 looks at the biotechnology R&D process. In particular it describes the differences between manufacturing products and the more complex R&D process needed to create them.

Section 3 describes the rationale and up-to-date thinking that underpin national biotechnology strategies. It gives an overview and detailed description of each of the seven enabling factors that are of the most importance to making these strategies successful grounding them in empirical research.

Section 4 provides a dedicated discussion of the individual policy needs of the biopharmaceutical, ag-bio and industrial biotechnology sectors.

Section 5 discusses the national innovation and biotechnology strategies in the thirteen sampled economies. For each economy, this section provides:

- An introduction and general economic overview;
- A description of the national innovation strategy and biotechnology strategy;
- A description of the policies in place for three key categories of biotech: biopharmaceuticals, ag-bio and industrial biotechnology; and
- A summary table of policies in place for each biotechnology sector.

(A deeper discussion and analysis of all enabling factors and biotech policies in place for each economy included in this report is provided in the accompanying Annex.)

Section 6 provides an overall measure of the policy framework within each enabling factor for each of the sampled economies. This section describes the building of the Biotech Policy Performance Measure; a metric that provides readers a quick overview of a given economy's policy framework and performance in relation to the other economies sampled.

Section 7 provides concluding thoughts and ties together the data, information and performance review of the preceding sections.

2 BIOTECHNOLOGY INNOVATION

Biotechnologies are today used in a wide variety of sectors and industries to produce everything from advanced biopharmaceutical medicines, genetically modified crops to household goods such as enzyme-based cleaning detergents.

While these products and technologies share the characteristics of having been developed through or are the result of a biotechnology process, the R&D requirements to develop, commercialise, manufacture and maintain a product in the market can vary from one product or technology to another. The regulatory burden is not the same for each industry or sector and neither is the cost of development and length of time required to bring a compound or idea into a commercialised product. For instance, manufacturers of biofuels face a different set of R&D challenges and set of regulations than do companies in the seed industry. As is discussed in section 4 and for each economy overview in section 5 what can be a successful set of policies to encourage growth and innovation in one area of biotechnology may not always translate into a similar level of success in other areas.

Nevertheless, there are some important similarities that are shared across most biotech sectors. Most notable is the cost and complexity of the R&D required to develop a biological product or technology. For instance, research, development and eventual commercialization of new biofuels require considerable time and capital.[4] The estimated cost of a biofuel processing facility is USD350 million per plant and the estimated period of time to move from a pilot phase to full commercialization is 12 years.[5]

Similarly, within the crop protection sector (in which a number of companies increasingly integrate and make use of biotechnologies in their R&D activities) the cost of bringing a new product to market has increased significantly over the past two decades. According to research by the USDA, in 1995 the total cost from the research and discovery phase to registration and market approval was USD162 million.[6] By 2005 this had increased by close to two-thirds to USD254 million.

Looking at other biotech sectors one can see similar trends. For example, for the biopharmaceutical sector the cost of research and development has risen considerably over the last few decades. In 1979, the total cost of developing and approving a new drug stood at USD138 million. Almost 25 years later, in 2003, this figure was estimated to have rocketed to USD802 million.[7] A more recent estimate points to the total cost of drug development being approximately USD1.5 billion.[8] Significantly, different stages of R&D do not contribute equally to the composition of total cost. For biopharmaceuticals it is the clinical component which is the most costly and has increased the most. For example, clinical trials from Phase I to III account for approximately two thirds of the total cost of bringing a medicine to the market, even though they do not represent the longest period of drug development.[9] In addition to cost there is also the challenge of successfully developing new medicines and technologies and the length of time spent on developing a drug. On average, only one to two of every 10,000 synthesized, examined and screened compounds in basic research will successfully pass through all stages of R&D and go on to become a marketable drug. Furthermore, it takes between 10 and 15 years from the filing of a new patent to the day when a new medicine finally becomes available for patients to use.[10]

2.1 R&D vs. manufacturing

Developing high technology processes and/or products such as bio-crops and biopharmaceuticals is not an easy task. As section 3 details this involves highly specialised and expensive R&D infrastructure, trained and skilled human capital as well as a host of other physical and non-physical enabling factors. The R&D required to bring high-tech products to market is the most complex and demanding part of the development cycle. Manufacturing, on the other hand, can in some cases by comparison be less demanding. Often this basic fact and distinction between the demands of developing a national or regional R&D capability for high-tech products versus developing a manufacturing capability is overlooked in policy discussions. The manufacturing process can be confused with the R&D process. Yet it is important to note the distinction between the two.

For example, traditional "small molecule" pharmaceutical drugs (which are chemical and manufactured through a process known as chemical synthesis) are very difficult and costly to research and develop requiring high levels of technical infrastructure and skilled human capital. By comparison the manufacturing of such pharmaceutical drugs can be much less technically challenging depending on the specific composition of the pharmaceutical drug. Consequently, a small molecule pharmaceutical can be developed in one country yet it, or its key constituent parts (such as the API), can be manufactured in a different location and by a different entity. Indeed, the outsourcing of pharmaceutical manufacturing and the manufacturing of APIs has been a common practice within the pharmaceutical industry for years.[11]

With regards to the development and manufacture of biological technologies and products there is, however, less of a distinction between the requirements of manufacturing and product development. While developing a biological product or technology also requires high levels of expertise and advanced technical infrastructure, given the size, complexity and inherent instability of a biologic, the manufacturing process also requires a considerable level of stability and technical capacity.[12] Specifically, the manufacturing process must be consistent and not changed with new parts or processes introduced. Otherwise there is a risk that the quality and purity of the manufactured product is compromised.[13] These challenges – of maintaining stability and consistency to ensure a high quality product – are unique to the manufacturing of biologics and make the outsourcing of this manufacturing difficult and technically testing.[14]

In this respect developing a sophisticated biotechnology capacity can be considered as providing even more of a technical challenge than other high-tech products. Section 3 examines just how difficult this is and the challenges of making sure that all physical and non-physical enabling factors are in place to successfully build a world-class biotechnology capability and what specific policies are enablers for different biotech sector.


100
75
50

3 NATIONAL STRATEGIES TO ENCOURAGE BIOTECHNOLOGY ACTIVITY

This section describes the rationale and up-to-date thinking that underpin national biotechnology strategies. The section identifies and defines seven enabling input and output factors that are of the most importance to making these strategies successful.

3.1 What is a National Innovation Strategy?

In essence, a national innovation strategy or system refers to the measures that state actors or regions (such as the EU) take in seeking to promote innovation in general or in a particular sector.

National innovation strategies are a set of policies and initiatives aimed at encouraging innovation on or at a macro or micro level. They can be coherent, synergistic plans for interconnected action or a laundry list of disparate initiatives that on their own promote innovation. They can consist of both generic policies (those that generally address factors of innovation) and specific policies (those that address components specific to innovation in the targeted field, say biotechnology). The type of policy pursued and the prospective effect (negative or positive) is largely a result of what type of innovation infrastructure and factors are already in place.[15] For example, it is difficult to produce an effective specific policy encouraging biotech innovation, if the basic educational infrastructure of educating and training scientists and researchers is not in place.

While a national innovation strategy is shaped by various elements and no two national strategies can be identical, there are a number of components or best practices which are necessary for putting in place and successfully executing a national innovation strategy. This report identifies seven such factors.

3.2 Promoting biotech innovation: Seven enabling factors

Designing an environment that is conducive to the innovation, research, commercialisation and marketing of biological products and technologies is not an exact science. There are a myriad of factors that potentially can affect, encourage or discourage rates of biotech innovation. Relevant policies and factors range from those specific to the biotechnology sector and the life sciences to more general ones affecting broader levels of innovation and economic activity. Moreover, every situation, economy or region is different. Depending on the structure of a particular economy and levels of overall socio-economic development, different economies have greater or lesser needs in specific policy areas. But which areas are they?

Based on the existing literature and experience of those economies that have been successful in building an advanced biotech capacity it is possible to piece together a set of principles and factors which, evidence suggests, are enablers of biotechnology innovation. While each factor is mostly described independently in the academic literature and studies by the OECD, WIPO and other international institutions, taken together these enabling factors are likely to create an environment conducive to biotech innovation. They cover areas ranging from basic scientific skills and capabilities to the more complex and biotech specific such as clinical and technical regulations.

The first factor is human capital. A number of general and biotech specific studies have found that without the right human capital it is virtually impossible to create the conditions in which biotech innovation can take place. For example, a 2006 OECD study of biopharmaceutical innovation emphasized the importance of human capital and availability of skilled and trained scientists, researchers and technicians.[16] Similarly, the National Science Foundation's *Science and Engineering Indicators* place a strong emphasis on levels of education, strength of higher education and number and quality of researchers when compiling its indicators.[17] Moreover, in terms of rates of innovation a 2010 study found that sectors which maintain a relatively high share of highly-skilled employees, such as the science-based industries, engage in more innovative activity.[18]

The second factor is infrastructure for R&D; without the necessary laboratories and clinical research facilities biotechnology R&D would be next to impossible. The importance of investing and building adequate infrastructure is highlighted by the OECD in their most recent *Science and Technology Outlook* in which OECD economies were surveyed on their priorities for the coming years and a majority replied they would look to invest in R&D infrastructure.[19]

Third is the protection of IP. Always a controversial field (particularly in relation to biopharmaceutical innovation) yet the economic and empirical evidence built up over the last few decades suggests quite strongly that overall IPRs tend to have a positive impact on economic activity, especially for high-tech industries and for FDI.[20] For example, comparing WTO members (that is, signatories to the TRIPS Agreement) with non-members, a 2003 OECD study found that overall IPRs tend to have a positive impact on FDI with WTO members generally enjoying higher levels of FDI than non-members.[21] The authors found that with the exception of least developed countries, which may not yet have implemented the TRIPS Agreement due to transition period allowances, WTO members have higher levels of FDI than non-members. Léger used regression analysis to determine that IP protection is one of the most influential factors on innovation in both developing and industrialized countries.[22] Similarly, the OECD's Cavazos et al looked at R&D expenditure and technology transfer as well as FDI and found that a 1% change in the strength of a national IP environment (based on a statistical index) is associated with a 2.8% increase in FDI in-flows, a 2% increase in service imports and a 0.7% increase in domestic R&D.[23] Finally, looking at one economy Pham examined the economic contribution of IP-intensive industries to the US economy and found that these industries generated one-third of total US economic output.[24]

The fourth factor is the regulatory environment which creates the conditions for the production and sale of high quality products and technologies.[25] In the biopharmaceutical sectors clinical regulation is of particular importance in attracting investment and clinical trials. A 2012 study by Charles River Associates found that clinical regulations and the regulation of clinical research activities played an important role in determining clinical trial location.[26] Regulatory certainty and transparency is also an important factor affecting rates of general and biotech specific innovation. Long regulatory delays and barriers can stand in the way of translating scientific and academic research into fully commercialized products.

Technology transfer framework constitutes the fifth factor, as it is a critical mechanism for commercialising and transferring knowledge for the purpose of developing usable and commercially available technologies. For example, using fifteen years of data from the annual Association of University Technology Managers (AUTM) survey a 2012 study estimating the economic contribution of licensing activity by academic institutions found that in the US the contribution of academic licensing to gross industry output ranged from USD199-836 billion (2005 USD).[27] Contributions to GDP were equally significant estimated at between USD86-388 billion (2005 USD).[28] The latest figures from the AUTM survey show how licensing revenue and technology transfer is continuing to grow in the US and presents an important income stream for higher education institutions. Results from the latest available survey (2013) show that executed licenses and options grew by 8.2%, the number of new commercial products increased by 20%, and there was an 11% increase in the number of patents issued.[29]

The sixth factor is market and commercial incentives which are provided as a means of enabling access to new technologies such as innovative treatments while also securing future innovation. These range from general R&D incentives to specific policies aimed at biotech sectors such as pricing and reimbursement policies for biopharmaceuticals. Academic research and modelling suggests that for biopharmaceutical products restrictive pricing and reimbursement policies limit and delay new product launches. For example, a 2007 study investigating the impact of price controls on product launches in several OECD and middle-income economies found that price controls (and other supply side controls) have a significant impact on potential product entry, reducing the likelihood of entry by roughly 75% compared with a market having no price controls.[30]

And finally, the seventh enabling factor is legal certainty (including the rule of law), which is crucial to commercialization and business activities.[31] A sound and predictable legal and administrative framework contributes to an environment in which research and ideas can be more successfully commercialized, licensed and marketed.[32] Economies in which administrative and legal justice is harder to attain and in which dispute resolution and enforcement of contracts and rights is a challenge are less likely to encourage general entrepreneurial activity including in the biotech sector.

The following pages provides a more detailed description of each enabling factor, its importance in contributing to an environment that encourages and promotes biotech innovation and research, and the types indicators that can be used to measure and gauge the presence of each factor in a given economy.

Human capital

High skilled and technically trained human capital is one of the most fundamental features that successful biotech innovation is reliant upon. Yet while having sufficient numbers of science and technology graduates is in itself essential, ensuring that the degrees are of a high quality is of equal if not more importance. For example, while a number of emerging markets score relatively highly on the OECD PISA test and have large numbers of research scientists, their skills are not always adequate to the development of innovative and cutting edge technologies.[33] In order to promote innovation, the researchers and scientists that make up the human capital must be set in an environment which provides scientific as well as commercial opportunities.[34] Indeed, as discussed below economies that have invested in developing technology transfer pathways to enable and encourage successful academic-industry transfers have generally succeeded in promoting general rates of high-tech innovation as well as biotechnology innovation.[35]

Human capital refers to and can be measured by a range of indicators including: higher education rankings; life science and medical college rankings; life science graduates; number of life science, biotech/or biomedical professionals and researchers; tertiary education levels; and level of researchers and scientists in the population.

Infrastructure for R&D

Combined with having adequate, educated and technically proficient levels of human capital, R&D infrastructure and capacity is critical to successfully fostering innovation and activity in high tech sectors including biotechnology.[36] For example, countries which allocate more resources into R&D tend to attract more foreign investments into biomedical research and enjoy the benefits of biomedical innovation.[37]

What types of policies are in place to encourage the building and introduction of these types of facilities and initiatives? Governments and countries can on the one hand support the building of R&D infrastructure through direct support and government funded and operated facilities and also through public-private partnership. For example, as outlined below in Section 5, Singapore is now considered a key player in biomedical R&D after the establishment of a cutting edge biomedical science infrastructure, enabled by sustained public sector investment of over $2 billion since 2000.[38] Additionally, the multiple public-private partnerships between the public sector, Boston-based universities and research centres and pharmaceutical companies has led to the development of the Boston technological hub as a national leader in the field of biomedical innovation.[39]

A country's R&D capacity and available infrastructure for R&D is reflected by a number of different indicators including total R&D expenditure; patenting intensity; biotech R&D expenditure; life science investment levels; public-private partnerships; and academic and scientific citations.

Intellectual property protection

Over the last decade a number of empirical studies have been published on the positive and cumulative economic effects of IPRs. In particular, there is a growing body of evidence suggesting a positive link between the strengthening of IPRs and economic growth and development, job creation, technology transfer, and increased rates of investment and innovation. IPRs are historically of real importance to the biotech and biopharmaceutical innovation process. For biopharmaceutical as well as non-pharmaceutical biological products and technologies the evidence suggests that IPRs incentivise and support the research and development of new biological technologies and products.[40] In particular patents and other forms of exclusivity for biopharmaceuticals such as regulatory data protection and special exclusivity incentives for the protection and production of orphan drugs provide research-based companies with an incentive to invest vast sums in R&D and the discovery of new biotech drugs, products and therapies. As noted above, the research process for biopharmaceuticals (and many other biotech products) is unique in its time, cost and high rate of failure. The market exclusivity period provided

by IPRs give firms the protection and incentive needed to recoup R&D investments made. Evidence suggests that many drugs and therapies would not have been discovered had it not been for the incentive and protection provided by these IPRs. For instance, analysis of market exclusivity periods and legislation finds that the combination of market exclusivity and income from patent protection drives private investment in innovation, which contributes to new drug development.[41] Older studies have estimated that between 60-65% of pharmaceutical products would not have been introduced or developed in the absence of patent protection.[42]

For biologics exclusivity periods under RDP are of particular importance as there may be a so-called 'gap' in patent protection between a biosimilar and the innovator, reference product. Because of the inherent characteristics of large molecule biologics a biosimilar can be approved for marketing – based on a comparison to a reference product – yet not directly infringe any existing, in force patents for the reference product due to differences in structure, administration, or mechanism of action. Under this scenario the exclusivity provided by a RDP term is critical to a biotech innovator.

The regulatory environment

The regulatory and clinical environment in a given country or region plays an important role in shaping incentives for innovation and establishing adequate levels of quality and safety for biotech products, particularly biopharmaceuticals. A strong regulatory environment creates the conditions for the production and sale of high quality products and technologies.[43] Procedures, standards and conditions are to a large extent dependent on the regulatory framework and regulations in place. Different biotech sectors have different needs and regulatory structures in place. The regulation of GM crops, for example, may be carried out by a separate entity from that which regulates biopharmaceuticals. This is often the case with other biotech products as well such as biofuels. Depending on the product there may be some regulatory overlap and more than one agency or body may be involved. For example, in the US divisions within the USDA, FDA and other federal agencies, including the EPA, regulate different biological products and technologies.[44]

Overall the most advanced and innovative biotech markets in the world are also those which have the highest levels of clinical and regulatory standards. Looking at biopharmaceuticals this is achieved through setting and imposing high clinical and manufacturing standards through GCPs and GMPs as well as post-marketing surveillance through pharmacovigilance programs.[45] A country which wishes to develop an industry that is competitive in international markets (as opposed to simply dominant in its home market) needs to develop a regulatory system that is aligned with international best practice. This is illustrated by, for example, the growing focus of major drug authorities, such as the FDA and EMA, on ensuring that international manufacturers and non-US manufacturing adheres to their standards, the establishment of foreign offices and increased inspections of foreign manufacturers and suppliers.[46]

While it may impose substantial costs on manufacturers to comply with these standards they also give patients confidence in new biomedical products being safe and effective. There are a number of efforts both at the national and international level to minimise the cost of these high standards through the coordination and harmonisation of clinical and regulatory standards. In the biopharmaceutical sector, for instance, this includes the International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use.

Technology transfer frameworks

Technology transfer is a critical mechanism for commercialising and transferring research from public and governmental bodies to private entities and private to private entities for the purpose of developing usable and commercially available technologies. Technology transfer activities that are based on academic-industry and public-private sector collaborations provide a significant and distinct contribution to the economic strength and well-being of countries in which such activities take place.[47] The process enables public research institutions to obtain access to commercial research funds, state-of-the-art equipment and leading-edge technologies, while allowing industry to benefit from the extensive knowledge and ingenuity of academic

researchers.[48] To better understand the potential impact of technology transfer on innovation and economic development it is worth considering the US which has become regarded as a pioneer and leader in this field.

In the 1980s the US passed two path-breaking pieces of legislation: the Patent and Trademark Law Amendments Act of 1984 and 1986 (the Bayh-Dole Act) and the Stevenson-Wydler Technology Innovation Act, which was later amended by the Federal Technology Transfer Act of 1986 and the Technology Transfer Commercialization Act in 2003. This legislation attempted to supply federal laboratories (e.g. the NIH) and universities using federal funds with the incentives needed to work with industry for the purpose of translating early stage research into usable products in the marketplace for the benefit of the wider public. The legislation sought to secure the above goals through three major changes to the IP system. First, they allowed universities and federally funded bodies to retain ownership of the proprietary knowledge stemming from the research and daily activities of these institutions, including the ability to own patents on their inventions. Second, they encouraged these institutions to become much more proactive and professional in the management and exploitation of their IPRs by creating professional technology transfer offices. Finally, the legislation sought to stimulate the commercial and financial aspects of public-private collaboration, with the intention of creating new businesses (such as spin-off companies) and generating income for the institutions, as well as for the researchers.[49]

The new laws led to a flood of technology transfer activities based on the exploitation and commercialization of IPRs. A decade after the legislation was passed the combined campuses of the University of California became the top recipient in the US of biotechnology patents; a position formally held by the pharmaceutical company Merck.[50] Indeed, *The Economist* called Bayh-Dole "Possibly the most inspired piece of legislation to be enacted in America in the last half-century".[51]

University technology transfer activity has increasingly become recognized by policy-makers in a growing number of countries as a powerful driver of economic growth and innovation. Since the US technology transfer system of public-private partnerships was put in place many other economies have sought to emulate it. Canada (1985), Japan (1998), UK (1998), Germany (1998, 2001), France (1999), Austria (2002), Italy (2001), Belgium (1999), Spain (1986), Denmark (2000), Switzerland (2002), Netherlands (1998) and Korea (1998, 2000 and 2001) have all adopted frameworks aimed at promoting technology transfer between public private partnerships through the exploitation of IPRs.[52] As will be discussed in section 5 the evidence suggests that those economies that have adopted these frameworks, technology transfer activity has steadily increased.

Although primarily considered within a public-private, academic-industry context, it is also worth mentioning that in many countries it is not only the regulatory and legislative framework for technology transfer from public to private entities that can be challenging, but also for transfer activities between private entities.

But developing successful technology transfer platforms is not a simple task, even in mature markets where such activities have long been established. An effective technology transfer platform depends on a wide range of factors, such as the establishment of technology transfer offices which employ IP experts and marketing professionals; industry oriented scientists; entrepreneurs and companies seeking seed technologies to license from a university and then develop; governmental grants to support the process; and a strong national IP system that allows a university/academic institution to protect and license its inventions.[53]

The availability of technology transfer frameworks can be measured by examining the existence of relevant policies, laws and/or frameworks as well as their actual use through university patenting rates, licensing agreements and commercialisation activities in all sectors and between all relevant entities.

Market and commercial incentives

Market and commercial incentives can come through a number of different formats. These include general R&D tax incentives as well as biotech sector specific tax incentives.

For the biopharmaceutical sector market and commercial incentives are primarily determined by the existing pricing and reimbursement systems for medicines and health technologies. Most health care systems have in place either direct or indirect mechanisms for regulating and adjusting the pricing and reimbursement of medicines. In Europe this is frequently done directly through pricing and reimbursement negotiations between health ministries or government agencies and biopharmaceutical manufacturers. Prices are often determined through complicated formulas of internal and external reference pricing that compare the cost of medicines in a number of economies. Many health systems have also adopted advanced systems of pharmaco-economic and cost-effectiveness analysis and comparisons. In other more diversified health systems, such as in the US, the price and cost of medicines is to a greater extent influenced by pure market factors. However, payers – be they public bodies such as Medicare and Medicaid or private health insurers – still set formularies and reimbursement guidelines.

The continued rise of health care costs in mature and emerging markets has put more pressure on health authorities and payers to limit future increases in health spending. The manner and extent to which these policies are put in place can have a profound impact on the commercial and market incentives for innovation more broadly in the health sector as well as for biotechnology R&D.[54]

Legal certainty (including the rule of law)

The general legal environment including as it relates to the rule of law and the rule of law within a business context is crucial to commercialization and business activities.[55] The legal and business environment of a given economy can be mapped through existing international indices such as the World Justice Project's *Rule of Law Index*.

Below Table 2 summarizes the seven enabling factors discussed and described above.

TABLE 2 Enabling factors

High-income economies
• Human capital
• Infrastructure for R&D
• Intellectual property protection
• The regulatory environment
• Technology transfer frameworks
• Market and commercial incentives
• Legal certainty (including the rule of law)

4 THE MICRO LEVEL – UNDERSTANDING SECTOR BY SECTOR NEEDS

While all of the seven enabling factors outlined in the preceding section are fundamental to promoting innovation in all biotechnology sectors, the individual significance of related policies for each factor may vary depending on the needs of a particular sector.

For instance, the policy inputs and requirements for developing a ground-breaking biological treatment for a rare disease or a cancer is not the same as improving the agricultural yields of a strain of soybeans, let alone creating a laundry detergent whose cleaning power is aided by catalytic enzymes. The science and research required to develop new products and technologies in the biopharmaceutical, ag-bio and industrial biotechnology sectors are not the same. Yet in many cases the public policy framework in place and created to enable the development of these sectors and further biotechnology innovation is not targeted at the particular needs of each individual sector.

As was discussed in section 2, the R&D process and needs of each of the three major biotechnology sectors identified are slightly different. Although overall each sector requires fundamental inputs such as a skilled workforce, sophisticated R&D facilities, a stable legal and political environment, intellectual property protection and high-quality regulations, the specific policies needed for each sector can vary significantly. Success can be achieved with a particular policy framework or set of policies for one sector but be less effective for a different sector.

Below some of the specific policies for the three major biotechnology sectors are outlined. The purpose of this discussion is to highlight a few of the key areas where sector-specific policies have proven to be successful in generating innovation and activity in each of the individual biotechnology sectors. (A fuller discussion of sector-specific policies and their presence in each of the sampled economies is provided in section 5. In addition, at the end of each economy overview a summary table of policies in place for each sector is provided.)

4.1 Biopharmaceuticals

In addition to fundamental components – such as the presence of specialised researchers and sophisticated R&D and clinical infrastructure – the protection of intellectual property through an adequate legislative and regulatory framework as well as the ability to enforce such laws and regulations is critical to biopharmaceutical and biomedical innovation.

Given the significant regulatory hurdles and long evaluation times for a new biopharmaceutical product, specific biopharmaceutical IPRs such as patent term restoration, regulatory data protection and other minimum patent periods are essential to encouraging biopharmaceutical and biomedical innovation. As mentioned, it takes between 10 and 15 years from the filing of a new patent to the day when a new medicine finally becomes available for patients to use.[56] This is particularly important in countries where patent backlogs can stretch back years and years. For example, as is discussed below, in Brazil the patent office faces an application backlog of 10-13 years. Due to this long-standing backlog applicants are by law offered a minimum period of patent protection of 10 years. Although significantly shorter than the internationally accepted and TRIPS defined 20 year period, the Brazilian legislation at least offers rights-holders a minimum floor and period of protection for their innovations.

For biologic medicines periods of exclusivity provided through regulatory data protection are of particular significance. Without such legal and regulatory frameworks and effective enforcement mechanisms in place, encouraging innovation and the development of new biologic medicines and technologies is very challenging.

In addition to the protection of intellectual property, a key ingredient for encouraging biopharmaceutical and biomedical research is the regulatory framework. In particular, internationally competitive processing times for clinical trials applications and market authorization applications for new drugs and technologies is critical. For example, two emerging markets with significant potential and high expectations in developing a biomedical and biopharmaceutical capacity, Brazil and Turkey, suffer from long regulatory delays. For example, in Brazil approval for clinical research needs to go through two separate government agencies and approval times can stretch to over one year compared to three months in the US and EU.[57] Similarly, Turkey suffers from long delays in its market authorization process. Although Turkish regulators have stated that a submitted application must be processed within 210 days, surveys of manufacturers suggest that waiting times can exceed 3 years.[58] This can be contrasted with Mexico where regulatory authorities have committed to and implemented reforms that cut the approval time for drugs already approved in the US, Canada, and EU from 360 days to 60 days. As will be discussed below in its economy overview, in part due to these changes Mexico has seen an uptick in international biopharmaceutical investment and activity.

4.2 Ag-bio

Equally, for the ag-bio sector there are a number of sector-specific policies that are essential to encouraging growth and innovation in this sector.

To begin with a regulatory framework that is conducive to developing new forms of agricultural technologies is of the utmost importance. This is a framework that meets international best practice standards of how seed technologies are evaluated and also processes applications within a reasonable timeframe. Overly restrictive regulations on labelling, the types of GM seeds and foods allowed to market and long processing times all contribute to limiting innovation and activity in this sector.

For example, a good contrast between regulatory regimes and the results they yield is that between the US and the EU. As is discussed below in its economy overview, the US has by most measures achieved the most successful ag-bio market in the world. American grown GM crops consistently account for by far the greatest number of hectares under cultivation.[59] In 2014 US farmers cultivated an estimated 73.1 million hectares with biocrops; almost double the second largest cultivator Brazil. Similarly, the US cultivates the greatest range of GM crops with everything from staple crops such as maize and soybeans to alfalfa, cotton and squash.[60] The US has since the mid-1980s and the introduction of the "Coordinated Framework for the Regulation of Biotechnology" been the leader in global ag-biotech R&D and commercialization. At its core the framework (and subsequent revisions) streamlined the regulatory approval process for biotechnology products and technologies and simplified the application and regulatory requirements (i.e. dispensing with lengthy scientific review periods for GM food simply because the production method included genetic engineering once a product had been deemed safe).[61]

In contrast regulations of GM foods and ag-bio technologies in most European countries and through the EU are much stricter. GM foods are either banned or strict regulations are in force on labelling with a concomitant regulatory focus and requirement on growers to carry out environmental risk assessments.[62] The result has been that there are very few GM products on the EU market and only a limited number of countries produce ag-bio crops. For instance, Spain is the only EU country that grows a considerable amount of ag-bio crops but for 2014 this amounted to a paltry 0.1 million hectares under cultivation.[63] This is considerably less than, for example, Burkina Faso and Myanmar at 0.5 and 0.3 million hectares respectively.[64]

4.3 Industrial biotechnology

In addition to the fundamental components exemplified in the seven enabling factors that all biotechnology sectors require, industrial biotechnology also has a need for sector-specific policies. For example, the successful development and commercialization of biofuels has in large part been the result of government and state support through R&D grants as well as a legislative framework that supports the use of environmentally sound technologies. Both in the US and Brazil the uptake of biofuels and development of a significant corn and sugar-cane based ethanol industry has been the result of public policies in place that support these industries and encourage the use of such biofuels. Brazil has since the 1970s had in place the National Alcohol Program (*Proalcool*). This program has contributed to the building of the Brazilian sugar-cane based ethanol industry. As recently as 2006 Brazil was the biggest producer of bioethanol in the world producing 16billion litres or approximately 36% of global production.[65] Although no longer the top producer, 2013 figures for overall biofuels production show that Brazil is the second largest producer of biofuels in the world accounting for approximately 24% of global production.[66]

Likewise in the US the legislative framework has proven to be a significant driver in encouraging the production and use of biofuels, chiefly maize-based ethanol. Main policy drivers include the Renewable Fuel Standards (part of the 2005 Energy Policy Act and Energy Independence and Security Act 2007).[67] In large measure as a result of these policies the US has increased its production of biofuels from just over 5,226 thousand tonnes oil equivalent in 2003 to over 28,000 thousand tonnes oil equivalent in 2013.[68] It is now by far the biggest producer of biofuels in the world accounting for 43.5% of global production in 2013.[69]

5 MAPPING NATIONAL BIOTECHNOLOGY INNOVATION STRATEGIES

The following section maps the national innovation strategies and policies in place for biotech innovation for thirteen mature and emerging economies. The sample is geographically and economically diverse with a mix of high-income mature OECD economies and middle income and emerging markets.

The economies examined are:

1. Brazil
2. China
3. India
4. Korea
5. Malaysia
6. Mexico
7. Russia
8. Singapore
9. South Africa
10. Switzerland
11. Turkey
12. United Kingdom
13. United States

Using the seven enabling factors outlined above in section 3 as reference points this section provides for an economy overview of the NIS as well as a discussion of the policies in place (or not in place) for the three main sectors of biotechnology identified: biopharmaceuticals, ag-bio and industrial biotechnology. The purpose of this is to, first, highlight how different biotech sectors have different policy needs and, second, to point out those areas where sector-specific policies are in place but also where there remains room for further discussion and introduction of new policies.

A more detailed analysis of the key policies and initiatives in place for each of the seven enabling factors is provided for each individual economy in the accompanying Annex.

These economies provide a good sample for a number for reasons.

First, together they make up a substantial share of world economic output with all, bar Singapore and Switzerland, in the top-30 of the world's largest economies measured by purchasing power parity per the latest figures from the World Bank.[70]

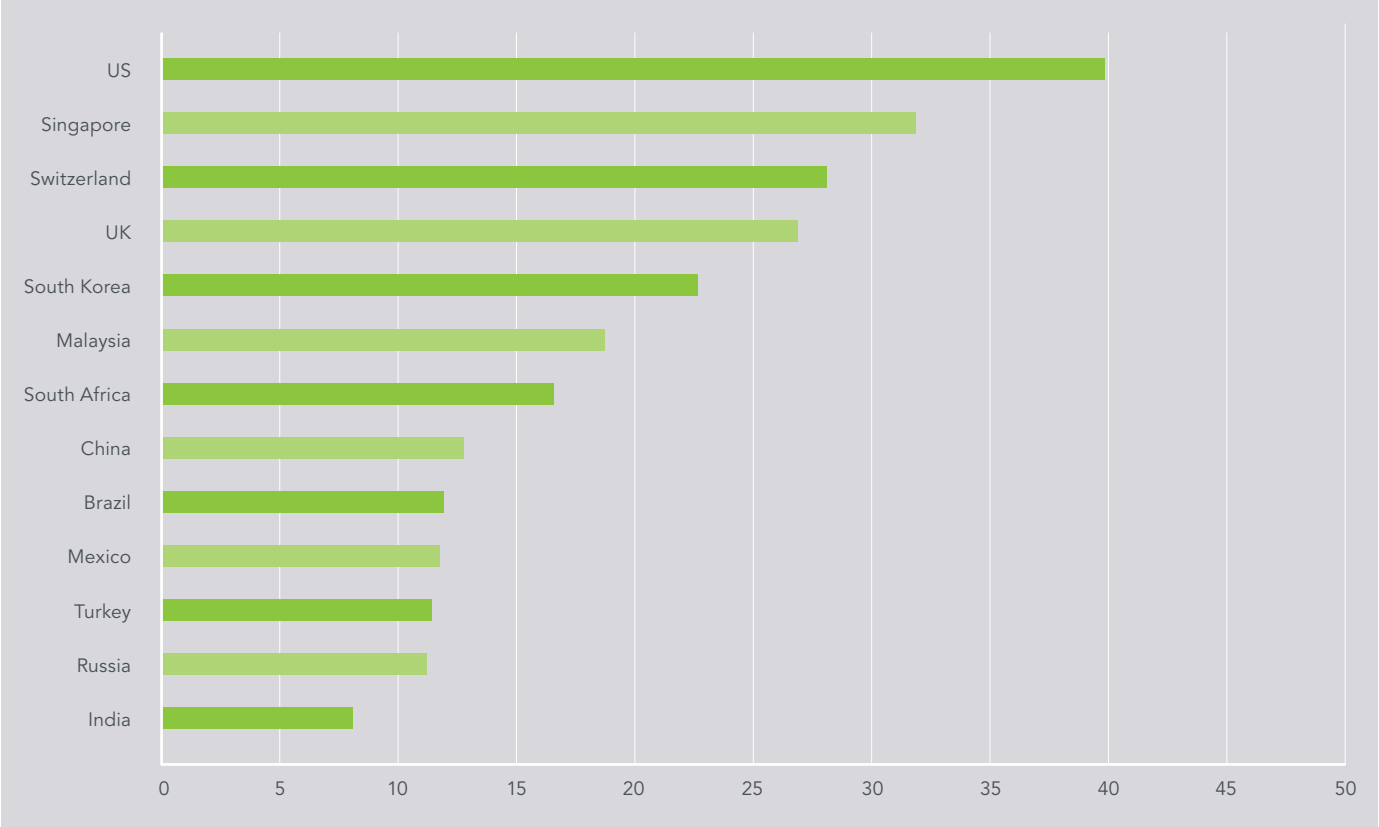
Second, in terms of level of development, they are a good mix of, on the one hand, mature economies that rely on innovation to drive economic growth with, on the other hand, a number of emerging markets that increasingly are looking for innovation and knowledge-based activities to drive their own economic development.

Third, all economies have policies in place and have expressed a desire to develop their respective biotechnology sectors.

Finally, there are some notable differences between the economies in terms of their capabilities and specifically their rate of innovativeness. To begin with on a macro basis some are considered as being more proficient in promoting and generating both general rates of innovation as well as biotech innovation. At a more granular level some economies also have strengths in particular areas of biotechnology. For example, Brazil has for many years been a pioneer in using and developing GM crops and developing agricultural biotechnology. In 2013 Brazil had 42.2 million hectares of biotech crops under cultivation growing maize, soybeans and cotton; second in the world only to the US.[71] And the Brazilian Government through EMBRAPA has for decades been closely involved in the R&D and commercialisation of agricultural biotechnologies. Others, such as Switzerland, the UK and Singapore, are considered as having had success in building a biopharmaceutical and biomedical capability.

A good place to start and get a sense of the general state of the biotechnology sector in each economy is the *Scientific American Worldview* Scorecard. Published annually since the late 2000s the Scorecard provides an assessment of economies' relative innovative capabilities

FIGURE 1 *Scientific American Worldview* Scorecard 2014, economies sampled[73]



Source: Scientific American (2014)

and successes as they relate to biotechnology.[72] Above Figure 2 provides the 2014 Scorecard scores for the thirteen economies examined. The maximum available score in the Scorecard is 50 and is calculated on the basis of performance in a range of biotech related categories and factors.

As would be expected the economies with the highest overall scores are relatively mature markets with well-established life sciences and biotech sectors. Indeed, the US, Singapore, Switzerland and UK were all in the top-ten for the entire Scorecard and not just in the comparison of the thirteen countries sampled.

The discussion in the following economy overviews echoes one of the broader findings and points made in Scientific American's research and Scorecard: while the overall level of biotech innovation can grow in emerging markets – including all the BRICS – each economy already has strengths in specific policy areas and specific enabling factors.

5.1 Brazil

Brazil is the seventh largest economy in the world measured on a PPP basis. The latest World Bank national accounts figures from 2013 show total Brazilian GDP at PPP just over USD 3 trillion.[74] Measured on a per capita basis Brazil is a middle income country with an estimated 2013 GDP per capita of USD 11,208 per the World Bank.[75]

Increased Brazilian economic competitiveness is also reflected in its global economic competitiveness ranking. The World Economic Forum's 2014-15 Global Competitiveness rankings ranked Brazil as the 57th most competitive economy in the world.[76]

National innovation and biotechnology policy overview

In 2014 the Brazilian Government introduced new legislation on research relating to biodiversity and biotechnology.[77] The legislation (lei 7.735/2014) is meant to simplify the registration procedure and reduce existing hurdles for researchers and the commercialization of new products and technologies. Under the current legal and regulatory framework (dating back to the early 2000s) there is much uncertainty surrounding what type of research is permitted without an official application and subsequent regulatory approval. The new law was passed by the Brazilian Congress in February 2015 and at the time of research was being considered in the Senate.[78]

The Government also introduced new regulations regarding "Partnerships for Productive Development" (PDPs), public-private partnerships aimed to further R&D particularly in biopharmaceuticals. A new ordinance was issued in 2014 by the Ministry of Health (No. 2.531) which replaces the older ordinance from 2012.[79] The purpose of the new ordinance is to provide greater clarity on how the PDP mechanism works and the rights and responsibilities of the involved parties. Local legal analysis suggests that while some elements of the PDPs have been successfully addressed through the new ordinance, there remain areas that are still to be fully defined to maximize the potential of the PDPs such as pharmacovigilance and surveillance of biologics and biosimilars developed through a PDP.[80]

These new laws and regulations build on Brazil's long-standing public innovation infrastructure and biotech policies. A number of important government institutions and agencies such as BNDES, FINEP and others have been supporting innovation and investment in Brazil since the 1970s.[81] In recent years there have been a number of specific innovation national policies and initiatives introduced. For instance, in 2004 the National Innovation Law was passed. This legislation sought to incentivise innovation within the public sector (particularly at universities) and innovation partnerships between academic institutions and the private sector.[82] In 2011 the Brazilian Government launched the *Brasil Maior* plan a, socio-economic development initiative in response to the financial crisis and global economic downturn. This plan places an emphasis on promoting innovation and focuses on developing a number of high tech sectors including ICT, aerospace, biofuels and health care.[83] The Brazilian Ministry of Science, Technology and Innovation has a long standing and active involvement in guiding national innovation policy as does the Ministry of Development, Industry, and Foreign Trade.

With regards to the use and development of biotechnology this has been a part of Brazilian public policy for many years. EMBRAPA has long supported the use of biotechnology in agricultural production. Brazil has also relied on biofuels (sugar-cane ethanol) as a primary source of transportation energy since 1975 and the introduction of the Brazilian National Alcohol Program (*Proalcool*).[84] Biotechnology was identified as a national strategic priority in 2003 culminating in the 2007 decree No. 6,041 (*Política de Desenvolvimento da Biotecnologia*). This decree focused on building the international competitiveness of Brazilian biotechnology and contains policies relating to direct support for R&D, the building of R&D infrastructure, human capital training and development as well as improvements to the existing regulatory framework and other policies.[85] The decree also established the National Biotechnology Committee (*Comitê Nacional de Biotecnologia*) to coordinate the implementation of the Government's biotechnology policies. The Committee is comprised of 23 federal-level agencies and ministries all devoted to growing Brazil's biotech sectors. Although the Committee

is still in its formative stages and so far results have been limited, in many ways the Committee can be viewed as a model for other countries trying to coordinate biotechnology policy right across government. It provides stakeholders and government officials with a potential central meeting point and body to discuss and coordinate biotechnology policy.

Biotech sector by sector policy overview

Biopharmaceutical

Brazil has a growing biopharmaceutical market which is now the largest market in Latin America worth an estimated USD25billion.[86] Brazilian biopharmaceutical policy has traditionally been committed to non-research based medicines. Historically this was achieved through the promotion of a copied-drugs industry built during the 1980s.[87] These drugs (known as *similares*) have by and large been phased out through important changes to drug approval regulations with Brazil having introduced measures to effectively curtail the use and distribution of these similares, replacing them with bioequivalent tested generic drugs. Regulations introduced in 2003 require all *similares* drugs to submit bioavailability data, pharmaceutical equivalence tests and a copy of GMP certificate issued by ANVISA.[88]

Public/private partnerships are growing in importance in the biopharmaceutical sector. For example, BNDES has provided direct support and grants to the building and development of R&D and biotechnology manufacturing sites with domestic as well as international private sector partners. In 2013 BNDES partnered with Novartis to build a biotechnology plant in the Northeast of Brazil (Pernambuco).[89] Additionally, in March 2014 BNDES agreed to fund the construction of a biopharmaceutical plant for Libbs Pharmaceuticals that will focus on developing cancer medications.[90] Although there are still challenges in translating this support into concrete biopharmaceutical products and fully commercialized technologies (discussed in the accompanying Annex), nevertheless this is an area of increasing prioritization for the Brazilian Government. BNDES provides a significant amount of funding for biomedical and biopharmaceutical research, manufacturing and innovation. For example, under its *Profarma* program (in 2013 the third phase of the program was renewed) a BRL5 billion budget has been allocated to the pharmaceutical health sector till 2017.[91] In 2013 the agency announced the funding of a separate stream specifically for biotechnology, Profarma-Biotechnology, which will target biopharmaceuticals and the furthering of a domestic R&D capacity.[92] FINEP is also a major provider of research grants to biotech companies and has been providing support for the biotech sector since 2001.[93] Through the INOVAR program it also acts as a source of venture capital, seed and private equity capital.[94]

Together, these and other public and private initiatives suggest that the environment in Brazil for biomedical innovation has improved in the last few years. For example, of the registered biotechnology companies in the country 33% are focusing on health related issues.[95]

Still, there remain significant challenges in Brazil in promoting and expanding biopharmaceutical R&D and innovation. As detailed in the accompanying Annex, Brazil faces challenges in the realm of protecting and offering biopharmaceutical IPRs (particularly for biopharmaceuticals which are not offered RDP) as well as offering effective and timely approval of clinical trials applications. This is reflected in the clinical research activity. Despite the market size and general levels of socio-economic development, Brazil does not host a high number of clinical trials measured on an absolute or per capita basis. The latest data suggests that there were currently 4,259 registered trials in Brazil out of a regional total of 6,263 in Latin America.[96] However, a relatively small proportion of Brazil's newer trials are in the realm of riskier, more complex trials (particularly Phase I). Here, Brazil currently has only 27 Phase I trials in operation; significantly less than the OECD average of 90.[97]

Ag-bio

Brazil has a tradition of strength in the agricultural biotech sector. The publicly funded research corporation EMBRAPA carries out the vast majority of agricultural R&D. EMBRAPA's research has contributed to expanding the amount of land under cultivation, ranching and poultry production.[98] It is publicly funded and had a 2013 budget of BRL2.3 billion.[99]

The Agency has also developed and registered an extensive portfolio of IP. Over the years EMBRAPA has accumulated over 200 international patents and developed 350 cultivars.[100] It is also becoming more active in public-private partnerships, including with international industry. For example, EMBRAPA has through a number of private-public partnerships developed and brought to market new ag-biotech products and technologies. In 2010, for instance, the Cultivance-e soybean was approved for market by CTNBio. This herbicide-tolerant soybean was developed jointly by BASF and EMPRAPA in Brazil all the way from the R&D, laboratory stages to a commercial phase.[101]

Industrial biotechnology

The biofuels industry has been supported since the mid-1970s and the domestic Brazilian sugar-cane ethanol industry is one of the biggest in the world. More recent efforts include the 2014 announcement by BNDES and FINEP that BRL1.48 billion would be made available through the PAISS Agriculture Plan to promote innovation in the sugar-cane ethanol industry.[102] The plan follows the PAISS Industry program that awarded BRL2.5 billion to companies focused on innovation in the sugar-based ethanol and chemical sectors.[103] The PAISS Agriculture Plan aims to increase annual gains in sugarcane productivity from 1% to 3%, increasing production of sugarcane based ethanol by nearly 12 billion litres by 2020.[104] In addition to supporting sugar-based ethanol, the Government has also backed soybean based biodiesel companies by instituting a national biodiesel mandate. The mandate went into force in 2008 requiring a 2% biodiesel blend nationally; the blend composition was increased to 5% in 2010 and was further increased to 7% in November 2014.[105]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 3 Brazil: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• University of São Paulo in top 100 life sciences ranking • *Brasil Maior* initiative - focus on life sciences • Still low levels of researchers in population • PDPs growing in importance • Question remains over efficiency and extent to which PDPs promote cutting edge R&D	• EMBRAPA expertise and human capital investment • Public-private investment in ag-bio • Strong tradition of government support	• Industry expertise in sugarcane ethanol sector • PAISS initiative targeting new productivity gains in biofuels
Intellectual property protection	• No RDP available for biopharmaceuticals • ANVISA involvement in evaluating biopharmaceutical patents • Suggestion to eliminate 10-year minimum term	• 10 year RDP term available for agrochemicals and pesticides	• Brazilian patent law and administration of patent rights difficult for all sectors
The regulatory environment and Technology transfer frameworks	• ANVISA provides a relatively high quality regulatory standard • Bioequivalence requirements for generic drugs are in place • Biosimilars pathway in place • National tech transfer framework in place through 2004 Innovation Law • Barriers remain e.g. licensing agreements must be published in the INPI's Official Gazette; are subject to INPI approval; and limitations on fees and payments between the contracting parties	• Agbio regulated through CTNBio; generally well regarded • Ag-bio tech transfer concentrated in EMBRAPA • EMBRAPA has TTO and successful IP policy in place - accumulated over 200 international patents and developed 350 cultivars	• INPI suffers from long delays for all sectors including industrial biotech • Tech transfer, partnership and commercialization of public and private research key part of long term development of sugar-cane
Market and commercial incentives	• Biopharmaceutical P&R environment challenging - strict pricing policies and local preferencing	• Limited availability of R&D tax credits • Support through direct government partnership and investment	• Limited availability of R&D tax credits • Support through direct government partnership and investment

5.2 China

China is the second largest economy in the world with an estimated 2013 total national output of USD16.1 trillion measured on a PPP basis.[106] However, measured on a GDP per head basis China is a middle income country with a per capita income of USD6,807 for 2013 at current USD.[107] China is the world's 28th most competitive economy according to the World Economic Forum 2014-15 Global Competitiveness rankings.[108]

National innovation policy overview

In 2015 Chinese policymakers continued to place a strong emphasis on innovation and investing in innovation. At the annual National People's Congress session in March the 2015 budget was outlined including central government expenditure on R&D. Science and technology spending was announced to increase by 12.3% to CNY275 billion.[109] This builds on the 2014 budget which offered a realignment towards investment in basic research compared with previous years. Basic research was slated to receive a total appropriation of USD6.6 billion, an increase of 12.5% from previous years and roughly 15% of total overall central government science and technology spending.[110] Significant resources were also invested in health and medical research with close to USD500 million allocated for biopharmaceutical development for infectious diseases. At the time of research it remains unclear the extent to which the announced 2015 central government budget will affect these specific projects.

These announcements and budgets build on long-standing policies and initiatives. The main long-standing policy instruments and planning tools include the "Medium- and Long-term Plan for Science and Technology Development 2006-20" launched in 2006 and the more recent Twelfth Five-Year Plan, 2011-2015".[111] Both plans emphasized the need for China to grow its innovation capacity and have set ambitious general targets and sector specific ones, including for biotechnology. For example, the former set as a target the increase of R&D spending as a percentage of GDP to 2% by 2010 and 2.5% at a minimum by 2020.[112] The plan also included economic growth targets linked to technological advances and an emphasis on the need for the development of an indigenous high-tech capability through a policy of "indigenous innovation". A new five-year plan is set to be announced in early 2016. While few details have emerged about the exact content of this plan, reports suggest that the focus will be on innovation, economic development and areas such as green technologies.[113] Within both the Medium- and Long-term Plan for Science and Technology Development and the Twelfth Five-Year Plan biotechnology figures prominently. For example, in the latter the "biological industry" is identified as one of seven strategic industries to be developed and invested in.[114] Specifically, developing an advanced R&D, manufacturing and industrialization capability is outlined as priorities.

Biotech sector by sector policy overview

Biopharmaceutical

Looking at biopharmaceuticals, R&D in China has been expanding rapidly with R&D expenditures in the pharmaceutical industry reaching USD3.249 billion in 2011 compared to just USD162 million in 2000.[115] However, a large proportion of this funding went towards biosimilar products and traditional Chinese herbal medicines. A similar pattern can be found in the distribution of public sector funding with USD26.65 million earmarked for biopharmaceuticals compared to USD105.7 million for chemical medicines and USD41.87million for herbal remedies.[116] As mentioned above, the 2014 budget included earmarked spending for basic research in the biomedical sciences, however there are no details at the time of research for the 2015 budget.

Other Government supported initiatives include the State Biotech Pharmaceutical Industrial Base, housed in the Shanghai Zhangjijan High-Tech Park.[117] The park caters to small and medium sized companies by offering business services and incubator spaces.[118] For larger companies, the Chinese government has undertaken a massive building program, constructing 10 R&D facilities with over 74,000 square meters of space, a foreign offices building offering almost 14,000 square meters of space and a six story hotel for business clients.[119] To date, the pharmaceutical base has attracted over 400 companies from around the world including AstraZeneca, Novartis and Roche.[120] China has also become a global leader

in genome sequencing through, for example, the Beijing Genomics Institute which has developed a significant next-generation sequencing capacity.[121]

2015 saw the release of new, finalised guidelines for the approval of biosimilars. Released in March the "Technical Guideline for the Research, Development and Evaluation of Biosimilars" build on a draft version published for public consultation in late 2014. This is an important step for strengthening the regulatory environment in China and is discussed in full in the accompanying Annex.

Still, there remain significant challenges in China in promoting and expanding biopharmaceutical R&D and innovation. As detailed in the accompanying Annex, China faces challenges in the realm of protecting and offering biopharmaceutical IPRs (particularly for biological products which are not offered RDP). This is reflected in the clinical research activity. Despite the market size and general levels of socio-economic development, China does not host a high number of clinical trials measured on an absolute or per capita basis. China as of 2014 had 5,793 registered trials. Moreover, a relatively small proportion of China's newer trials are in the realm of riskier, more complex trials (particularly Phase I). Here, China currently has only 66 phase I trials in operation; less than the OECD average of 90.[122]

Ag-bio

While it has long been a priority for Chinese policymakers to build a strong biopharmaceutical capacity, with regards to the agricultural biotechnology sector the relationship has been more complicated. On the one hand the central government is on track to spend USD4 billion dollars on GMO seed research by 2020 and has invested in related infrastructure (for example a massive warehouse to store genetically modified seeds).[123] But on the other hand, key decision-makers have expressed caution about full commercialization and use of ag-bio products. In September 2014 a collection of speeches by President Xi were released. These suggest that while supportive of investment in biotechnology and biotech research, the President was cautious about allowing the commercialization of biotech products, particularly in the ag-biotech field.

The President is quoted as saying:

Biotech is a new technology, and a new industry with bright prospect. As a novel issue, biotechnology attracts social disputes and doubts, which is normal. For this issue, I want to emphasize two aspects, one is guaranteeing safety and the second is indigenous innovation. That is, we shall be bold in research, but cautious in commercialization…The research and innovation shall be bold, so we can take the commanding heights in biotechnology, and not let large foreign companies dominate the agricultural biotechnology product market.[124]

Similarly, public fears of GMO food have resulted in very few GMO seed varieties being commercialized. Indeed, the regulatory pathway to commercialization has not been easy to navigate either for international or Chinese innovators. The Ministry of Agriculture has only approved six GMO plants since 1997.[125] Currently, the Ministry allows the growing of GM cotton, peppers, tomatoes and papayas and the importation of GM soybeans and corn.[126] Yet trade in these products is not actively encouraged even for Chinese growers. For example, biosafety certificates for the only Chinese developed rice and corn products were allowed to expire during 2014.[127] Equally, delay in regulatory approval resulted in a number of ag-bio products not being allowed for import and significant losses to industry.[128]

Still, there are indications that the government recognizes that public fears of genetically modified products must be quelled if the country is to successfully feed its population. In February 2015 the Chinese government released its "number one document", an annual report that focuses on the countries agricultural sector. This most recent edition was the first document to acknowledge the debate surrounding genetically modified foods. After the release the Chinese Depute Head of Rural Affairs said that better social understanding of genetically modified foods would be needed moving forward.[129]

Industrial biotechnology

Looking at industrial biotechnology and the biofuels sector, China is not a large producer of biofuels. While significant investment has been made into renewable energies since the early 2000s (particularly in wind and hydropower) biofuels lags behind. China has a commitment to reach specific targets in biofuels production. For bioethanol (from non-food grain) and biodiesel (the two main forms of biofuels) 2020 targets are 10 million and 2 million tonnes, respectively.[130] Yet in 2013 China produced 2.6% of global biofuels. This is far behind countries like the US and Brazil at 43.5% and 24.2% respectively and roughly on par with Indonesia (2.5%) and Argentina (2.9%).[131]

There are some initiatives in place at the local and provincial level. Here some governments are actively involved in industrial biotechnology research. For instance, the Chinese Academy of Sciences and the Tianjin Municipal Government established the Tianjin Institute of Industrial Biotechnology in 2012. The stated long-term strategic goals of the Institute are developing new renewable resources to replace fossil fuels, utilizing green bioprocessing to replace chemical bioprocessing and promoting industrial productivity through biotechnology.[132] To accomplish these goals TIB is divided into four research divisions: the National Engineering Laboratory for Industrial Enzymes, CAS Key Laboratory of Systems Microbial Biotechnology, Tianjin Key laboratory For Industrial Biological Systems and Bioprocessing Engineering and Tianjin Engineering Center for Biocatalytic Technology.[133] The research from these four institutions is available via technology transfer through the Tianjin Industrial Technology Innovation and Incubation Center. As of 2013, eight independent companies had emerged from research conducted at the Institute.

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 4 China: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Over 80,000 Western educated life science PhDs have returned to China • High total number of life science graduates • High levels of researchers in population • Significant investment in biopharmaceutical infrastructure • Leader in genome sequencing through new infrastructure	• Significant investment in ag-bio R&D and seed development • 2008 12 year program of USD3.5 billion special research grants to universities and research institutes • Government backing for ag-bio R&D strong • Limited amount of developed seeds commercialized	• Targeted areas of expertise e.g. Tianjin Institute • Biofuels policies second to other renewables e.g. wind, solar and hydro
Intellectual property protection	• Patent protection for biologics traditionally narrower than international standards • RDP in place but not clear it applies to biologics • High levels of counterfeit and substandard medicines	• High levels of illegal production of seeds and brand infringement despite government enforcement efforts	• Enforcement of IP rights difficult for all sectors
The regulatory environment and Technology transfer frameworks	• New biosimilar pathway introduced • Onerous requirements for clinical trials - delay product registration • National tech transfer framework in place since 2000s • Chinese university patenting rates some of the highest in the world • Technology transfer through start-ups and spin-offs has increased significantly	• Ag-bio products must be registered and approved in the country of export prior to an application for approval can be made in China • Regulatory requirement that import applications include viable seeds • Commercialization of ag-bio products hampered by regulatory barriers including lack of approval for domestically developed rice	• Indigenous innovation policies affect all industries including industrial biotechnology • Quality of patent applications • Universities have limited capacity to fully commercialize innovations
Market and commercial incentives	• Biopharmaceutical P&R environment challenging • Strict reimbursement policies have limited the number of biological drugs available	• General R&D tax credit available and reduced rates of corporation tax and VAT for qualifying high-technology enterprises • Limited direct commercial incentives for ag-bio products	• Subsidies directed towards biofuel producers • Price controls on ethanol in place to create price floor in relation to price of gasoline

5.3 India

India is the third largest economy in the world with an estimated 2013 total national output of USD6.77 trillion measured on a PPP basis.[134] Measured on a GDP per head basis India is a lower middle income country with a per capita income of USD1,498 for 2013 at current USD.[135] India is the 71st most competitive economy in the world according to the World Economic Forum 2014-15 Global Competitiveness rankings.[136] A drop of 11 spots from the 2013-2014 rankings.

National innovation and biotechnology policy overview

The second half of 2014 and first half of 2015 saw a number of new policies and significant initiatives launched by the new Indian government under Prime Minister Modi. There were some policies that were aimed directly at encouraging innovation and growth of the biotechnology sector, and there were other, indirect policies, which nevertheless have the potential to have a significant impact on Indian biotechnology.

First and foremost is the "Make in India" initiative. Presented and viewed as the flagship policy of the Modi Government to encourage foreign investment and increased manufacturing (high-tech included) the policy spans key industries from infrastructure, textiles, automotive to biotechnology and pharmaceuticals.[137] These industries and sectors have all been targeted with subsidies, R&D tax credits (sector specific and more general) and preferential treatment including relaxing long-standing restrictions in FDI and foreign ownership, most notably in the defence and rail industry.[138] For biotechnology and pharmaceuticals the policy has through the 2014-15 Budget established some targeted exemptions from service tax as well as new research and teaching centres through an expansion of the All-India Institute of Medical Sciences.[139]

In addition the new Government has made a number of announcements with regards to the protection of intellectual property. In a draft new National IP Rights Strategy and accompanying documents the Modi administration has highlighted the need for action on enforcement, trade secrets and improved performance of Indian government institutions administering IP rights.[140] The National IP Rights Strategy document states that the "objective of the IPR strategy is to transform Indian into an innovative economy as would reflect in high rankings in appropriate development and innovation indices".[141] In addition, new bilateral dialogue mechanisms between the US and India – including the IP Working Group of the Trade Policy Forum – have been introduced. Most recently the Prime Minister himself stated that India should align its patents law with "international standards".[142]

These new policies and initiatives build on the existing Indian biotechnology and national innovation policy framework. As noted in the previous edition of *Building the Bioeconomy* India is in the midst of an ambitious ten-year plan launched in 2010 as the "Decade of Innovation".[143] In terms of concrete goals the plan set as a target raising total spending on R&D as a percentage of GDP to 2% with the contribution of industry and private sector spending to double.[144] The plan also established a government supported venture capital fund (the India Inclusive Innovation Fund) to provide seed capital and investments in small, medium and micro size businesses that specialise in socially needed innovation.[145]

Looking at biotechnology, the Indian biotechnology sector is by international standards quite well-developed. The sector has grown considerably over the past decade from a total estimated market size of USD1.1 billion in 2005 to USD4.3 billion in 2013.[146] Biopharmaceuticals constituted the largest value share of the Indian biotechnology industry making up just under two-thirds of total 2013 value. But India is also a large producer of GM crops: the country is the fourth largest grower of ag-biotech crops in the world with 11.6million hectares of cotton under cultivation in 2014; a slight increase over 2013.[147]

India has had a national biotechnology plan in place for a number of years with a separate central government Department of Biotechnology since the mid-1980s and biotechnology retains a prominent place in national policymaking. A "National Biotechnology Development Strategy" has been in place since 2007 with a new Strategy published in 2014. Overall the 2014 Strategy shifted the focus to the translational and developmental elements of biotech R&D.

Out of the 10 guiding principles identified in the Strategy, four relate to translating R&D into tangible products and services and the targeting of areas of need in the Indian bioeconomy.[148]

Biotech sector by sector policy overview

Biopharmaceutical

As mentioned, the biopharmaceutical sector is by far the most developed and biggest of India's biotechnology sectors. The Department of Biotechnology runs a "Medical Biotechnology Program" from which support and funding is offered for infectious diseases, chronic diseases, vaccine development, and stem cell research.[149] Tangible outputs from these programs include the development of products (e.g. a rapid test for the diagnosis of celiac disease and a method to detect Neisseria Gonorrhea and Chlamydia Trachomatis as well as the ROTAVAC virus[150]) as well as academic research: the chronic disease biology program has funded over 800 projects that have generated 400 papers with an average impact factor of 4.5.[151] The Department has also established 17 Centers of Excellence with research funding being provided for 69 projects.[152] To promote private sector growth, the government has created four Biotech Park and Incubation Centres located around the country and is in the process of building four more.[153]

Yet there remains significant challenges in India. As detailed in the accompanying Annex, India's intellectual property environment relating to biopharmaceuticals is below international standards. India does not provide RDP for submitted clinical test data; a key provision for encouraging research into biological drugs. Moreover, patentability standards are also outside international norms. Under Section 3(d) of the Indian Patent Act, there is an additional "fourth hurdle" with regards to inventive step and enhanced efficacy that limits patentability for certain types of biopharmaceutical inventions and chemical compounds. This has led to a number of patent revocations in recent years. India has also made use of the threat and actual use of issuing compulsory licenses for biopharmaceutical products.

The results of these policies can be seen in levels of clinical trials as well as availability of new molecular entities. As of 2015 the aggregated number of clinical trials taking place (or having taken place) was 2,612.[154] This is behind all other BRICS as well as more mature economies such as Korea on an absolute and a per capita basis. Moreover, looking at more recent trends in clinical research, most of the trials taking place in India are late-stage. In 2013 out of 117 total new trials taking place over half (60) were the less complex phase III trials.[155]

Similarly, looking at the launch of newly developed molecular entities India is behind other sampled countries. Data from IMS suggests that out of 140 new products launched between 2006-2010 only 39 of these (28%) were introduced on the Indian market.[156] This was the lowest total bar China of the sampled countries. Particularly for innovative products India was behind. For instance, out of a total of 22 new oncology products launched in this time period, only 4 had been made available on the Indian market.[157]

Ag-bio

The Indian government has been increasing funding for the agricultural biotech sector, recognizing that having the second largest population in the world makes this sector a priority area.[158] The 2015 budget allocated resources to various rural development funds and financing for credit mechanisms targeting small and medium farmers.[159] Traditionally government support for ag-bio comes from the Agriculture Biotechnology Programme within the Department of Technology and from the New Millennium Indian Technology Leadership Initiative. The latter was originally launched in 2000 as a public/private research initiative aimed at promoting science and technology innovation.[160] In 2009, the Indian government reaffirmed its support for the program by allocating Rs. 700 crore to the program in the eleventh Five Year Plan.[161] The revamped program also included new funding mechanism including the ability to co-finance projects with venture capital funds.[162] Successes include the release of four GM plant varieties to farmers. These include two new varieties of Mentha Piperite (mint) known as CIM-Indus and Cim-Madhuras and low ligin varieties of Ochlandra Travancorica and Leucaena Leucocephala for use in paper products.[163] The Department of Biotechnology also houses an "Agriculture Biotechnology Programme". This initiative has undertaken in-house projects such

as wheat genome sequencing and the creation of a National Plant Gene Repository in New Delhi for research use.[164] In addition, over the past five years the program has provided funding to over 300 R&D projects[165] with several notable successes including the creation of heat tolerant wheat hybrids and twenty five versions of the banana plant resistant to Banana Bunchy Top Virus.[166]

Yet also for the ag-bio sector India faces a number of hurdles, particularly in the regulatory space. The key body for approving new products for market and imports (the Genetic Engineering Appraisal Committee) was not in session between 2012-2014.[167] Field trials of new seeds and plant varieties suspended by the previous government were allowed in 2014 only to be suspended again.[168] A committee appointed by the Supreme Court of India recommend a moratorium on the commercialization of ag-bio products due to safety and regulatory concerns.[169] Overall the regulatory environment for ag-bio and commercialization of ag-bio products remains highly uncertain.

Industrial biotechnology

In the industrial biotechnology space India also has a well-established framework and a number of policies in place, particularly for biofuels. In 1999 the Indian government charted the National Bioresource Development Board with the mission of developing a countrywide framework for the development of bio-resources. Through the Department of Biotechnology the Bank has assisted in the creation of a biofuel research network comprised of universities, research institutions and private sector companies.[170] The network has invested in bioethanol, biodiesel, bio-butanol and bio-hydrogen research.[171] The Bank has also facilitated the creation of three Bioenergy Centers to assist in the commercialization of biofuels.[172]

Under the 2009 National Policy on Biofuels India has targeted a 20% biofuel blend by 2020.[173] Like China, and in an effort to ensure food security, India is focused on non-agricultural biofuels such as waste products and algae.[174] The Department of Biotechnology has reported that the country is successfully working towards the 2020 deadline. Promising research has been conducted into developing algae based biofuel and in using the Jatropha Curcas plant, a small tree poisonous to humans, to create biofuel.[175]

In 2015 the State Bank of India announced it would invest USD12 billion over the next 5 years in renewable energy.[176] The goal is to develop 15GW of renewable fuels within the next five years. The pledge comes as part of the Modi's government's aim to have biofuels account for 15% of energy consumption over the next decade. Looking at current levels of biofuels production India lags behind and is per 2013 figures responsible for 0.5% of global biofuels production.[177] Still, this is a 42% increase over 2012 levels and an even more impressive doubling since 2010.[178]

Nevertheless there are hurdles here too. India has had in place local content requirements for the wind turbine and solar industry.[179] These requirements range from 50-60% for a given solar or wind project.

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 5 India: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Low levels of biopharmaceutical R&D spending • Low levels of researchers in population	• Ag-bio R&D and national expertise in key areas e.g. mustard seeds • R&D hampered by unclear and changing regulations	• Biofuels growing part of India's energy equation
Intellectual property protection	• Section 3(d) and patentability requirements outside international best practice • No RDP • Use of compulsory licenses and patent revocations for biopharmaceuticals	• Limited protection of plant varieties	• Enforcement of IP rights difficult for all sectors
The regulatory environment and Technology transfer frameworks	• High level of counterfeit and substandard medicines • Biopharmaceutical regulations divided between central and regional level • Biosimilar pathway in place • No comprehensive national tech transfer framework in place • 2014 National biotech Guidelines focuses on commercialization	• Freeze on field trials of ag-bio products in place • Uncertainty over Government support for commercialization and registration of ag-bio products • Regulatory uncertainty limits transfer opportunities from universities to private sector • 2015 Government Budget saw decrease of tax on royalties and licensing for technical services	• Long patent backlogs for all industries, particularly, biotechnology
Market and commercial incentives	• Biopharmaceutical P&R environment challenging • 2014 saw extension of price controls to close to 100 essential medicines • 200% R&D biotech deduction available	• R&D tax credits and credits for special economic zones in place • 2015 budget targeted credits and subsidies at small and medium farmers • 200% R&D biotech deduction available	• Subsidies (primarily loans) directed towards ethanol producers • 200% R&D biotech deduction available

5.4 The Republic of Korea

The Republic of Korea (henceforth Korea) is the thirteenth largest economy in the world with an estimated 2013 total national output of USD1,664 trillion measured on a PPP basis.[180] Measured on a GDP per head basis Korea had a per capita income of USD25,977 for 2013 at current USD.[181] Korea is the world's 26th most open and competitive economy according to the World Economic Forum 2014-15 Global Competitiveness rankings.[182]

National innovation and biotechnology policy overview

As noted in the previous edition of *Building the Bioeconomy* Korea is a growing power in the biotech space. Korea has a number of government bodies that oversee and direct national research and innovation policies including the Presidential Advisory Council on Science & Technology and the National Science and Technology Council.[183] Significant resources, time and energy have been expended by the Korean public and private sectors in encouraging biotech innovation and building a strong, viable biotech capacity. The country has mainly focused on the biopharmaceutical sector.

In 2014 the Korean Government made announcements of targeted investment of USD300 million towards biotech and set a goal of developing five new products by the end of 2017.[184] More sweeping targets were set during the summer when a number of government ministries briefed the Korean President on policy plans and initiatives leading to 2020.[185] The plans include increasing the number of Korean global biotech companies to 50 (from 13) and targeting biotech developed climate change mitigating technologies. This includes the development of clean energy, battery and fuel cells, carbon capturing and hybrid vehicles.[186] The Korean Government began promoting biotechnology in the 1980s. After establishing a basic plan for the promotion of biotechnology (Biotech 2000 in 1994) the Government started to coordinate policies and expand its investment in R&D.[187]

Korea has a number of specific biotech policies in place. These range from direct support for R&D activities, to biotech networks, technology transfer and commercialisation bodies. Korea has laid out its biotechnology policy goal through its *Bio-Vision 2016* plan. By 2016, Korea expects to move from 12th place to 7th worldwide in terms of science-technology published papers, and from 15th to 7th with regards to competiveness in patented technology.[188] Further, it seeks to increase its biotech number of R&D manpower from 9,500 to 17,300, and the industrialized market value of the biotechnology market from KRW2.7 trillion to KRW60 trillion.[189]

Government funded biotechnology research in Korea is overseen by the Korea Research Institute of Bioscience and Biotechnology.[190] The Institute functions as an umbrella corporation for a series of research centers focused on different aspects of biotechnology. R&D related to pharmaceutical development is undertaken by the Targeted Medicine Research Center. The Center's main focus is on developing new medications for the treatment of metabolic and inflammatory diseases, chronic disease modulation, the creation of biological products from plants and the creation of a Plant Extract Bank.[191] The Plant Extract Bank currently houses samples from 26,000 thousand different plant varieties found all over the globe. The samples are available to Korean researchers to help facilitate the use of plant-based molecules in novel drug treatments.[192] The Institute has also successfully licensed out two natural drug candidates to Korean pharmaceutical companies for further development, a synthetic drug compound and a nurtaceutical for atherosclerosis.[193] The Institute is also directly involved in the commercialization and exports of new biotech products. In 2015 the Institute announced that Mico Biomed (a joint venture between the Institute and Mico, a private company) had secured contacts worth USD57 million in exports for diagnostic devices and strips developed by the company.[194] The Institute also announced a new partnership with the private sector to further bio-convergence R&D.[195] This partnership involves 45 SMEs who together with the Institute will work to develop new technologies and cross-pollination between biotech silos.

Biotech sector by sector policy overview

Biopharmaceutical

The Korean biopharmaceutical industry is growing rapidly in its capabilities. Pharmaceutical research made up 2.26% of total R&D expenditure at KRW863 million in 2011.[196] The share of biopharmaceutical products as a total percentage of pharmaceuticals went up from 6.5% in 2007 to 9.3% in 2010.[197] In 2009, it was estimated that there were more than 600 biotechnology companies in Korea. Of these, 61% operate in biopharmaceuticals with the remaining being dedicated to areas such as bio-foods, bio-chemicals, bio-environments, bio-energy and resources, bio-process and bio-equipment, and bio-electronics and bio-informatics.[198]

Biotech R&D is receiving a huge boost from the 2010 "Pharma 2020 Vision". Under this program the Korean Government will invest approximately USD8.9 billion over 10 years to build up the countries drug development structure.[199] In addition to spending targets, the 2020 Vision provides investment for the training of 10,000 new researchers; the Government further estimates that projects undertaken by these new researchers will create 58,000 jobs.[200]

There are also a number of concrete private sector initiatives in place. Samsung Biologics is the most prominent example of a company investing and expanding its presence in the biologics space. In 2015 the company announced it would invest USD700million in expanding its main manufacturing facility outside Seoul.[201]

Also indicative of Korea's competitive clinical environment is the high level of clinical trials. Korea currently has 5,974 clinical trials in operation.[202] Moreover, showing the strength and sophistication of its clinical research environment almost half of current (registered in or after 2013) trials were Phase I or Phase II trials.[203]

Ag-bio

High levels of consumer skepticism surrounding the use of GMO products in food have limited the commercialization of agricultural biotechnology products in Korea.[204] Still, despite the public doubts, there is a robust amount of research that takes place in the field. Between 1990 and 2007 experts from the government and academia in Korea published 380 papers on GMO food.[205] Further, in 2013 the Rural Development Administration approved 273 private sector field trials and is in the process of developing 16 types of genetically modified crops.[206] This is in addition to almost sixty varieties of modified crops being developed by the private sector that are currently in the laboratory phase.

Still, despite this impressive roster of crops under development the earliest estimated time frame that any could complete the regulatory review process is five years. Korea's regulatory review is a lengthy, complex process involving input from no less than five different government agencies. At the conclusion of 2014 no products had been approved for commercialization, the product closest to approval is a GM grass variety that has been in and out of the review process since 2008.[207]

Industrial biotechnology

Korea is investing more attention and resources in the industrial biotechnology sector. As part of the Korean Scientific Cooperation Network with the European Research Area the country has developed the PROMOFUEL program to advance the study of next generation biofuels.[208] The Korean Ministry of Science, Education and Technology and the Ministry's counterparts in Germany and Austria jointly fund the program.[209] The project specifically focuses on the development of fuel alternatives from rubber seed oil and fish oil.[210] In addition to PROMOFUEL, the Korea Research Institute of Bioscience and Biotechnology operates the Biorefinery Research Center that focuses on the development on industrial enzyme, biofuel, bio-refining technologies and the creation of industrial microorganisms.[211] The Center has had several successes including the development of a biofuel from agricultural residue, microbial strains that can produce important chemicals used in bio-plastics and microalgal strains that produce a byproduct that can be used in biofuel.[212]

Moreover, recent changes in government policy may jumpstart investment in the country's biofuel sector. Since 2008 the Korean Government has required a 2% biodiesel blend. In December 2014 new regulations were released requiring the biodiesel blend to increase to 2.5% in August 2015 and to 3% by 2018.[213] As of 2013 Korea had a 0.5% share of global biofuels production. While this was an increase over 2012, total output has actually decreased having peaked in 2010.[214]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 6 Korea: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Two universities in top 100 for life sciences • High total number of life science graduates - 126% increase since 2000 • High levels of researchers in population • Significant investment in biopharmaceutical infrastructure and R&D - almost 3% of total industry R&D	• Significant investment in ag-bio R&D and seed development • Growing number of field trials • No seeds commercialized	• Growing interest in biofuels
Intellectual property protection	• Strong biopharmaceutical environment • RDP available • Data requirements for pharmaceutical patent applications exceed international best practices • Uncertainty over patent linkage regulations - e.g. 2014 draft legislation	• No commercialized ag-bio products	• IP rights generally in place and respected
The regulatory environment and Technology transfer frameworks	• Biosimilar guidelines introduced in 2009 • Biopharmaceutical regulators generally highly regarded • KBIRR involved in commercializing new products from development stage - e.g. Mico Biomed	• Burdensome ag-bio regulations • High number of agencies involved in approval of commercial use	• Comprehensive tech transfer legal framework in place
Market and commercial incentives	• Biopharmaceutical P&R environment challenging • Strict pricing policies and limited reimbursement for oncology and rare disease drugs	• High tech investment tax credits available	• High tech investment tax credits availabl

5.5 Malaysia

Malaysia is the twenty-sixth largest economy in the world with an estimated 2013 total national output of USD693 billion measured on a PPP basis.[215] Measured on a GDP per head basis Malaysia has a per capita income of USD10,538 for 2013 at current USD.[216]

Malaysia is the twentieth most open and competitive economy according to the World Economic Forum 2014-15 Global Competitiveness ranking, four positions higher than the country occupied in the 2013-2014 rankings.[217]

National innovation and biotechnology policy overview

The New Economic Model launched in 2010 and the "10th Malaysia Plan 2011-2015" guides national innovation policy in Malaysia. The general goal of the New Economic Model is to lay a foundation for implementing policies that will boost the growth of the domestic economy through structural reforms creating a more decentralized economy, allowing companies the freedom to grow organically.[218] In the 10th five-year plan the Unit *Inovasi Khas* was created as a special innovation unit within the Government reporting directly to the Prime Minister.[219]

In 2005 the Government released the National Biotechnology Policy. The policy identifies three main policy phases to be completed by 2020: Phase I – Capacity Building (2005-2010), Phase II – Science to Business (2011-2015), Phase III Global Presence (2016-2020). Building on the National Biotechnology Policy is the Bioeconomy Transformation Programme. Launched in 2012 the purpose of this program is to focus on the full commercialization and launch of biotechnologies.[220] Recent successes highlighted by the Malaysian Government include the joint partnership between US Verdezyne Inc. and Sime Darby Berhad in industrial biotechnology and the development of palm-oil products and opening of a RM1.5billion commercial facility in Malaysia.[221]

There are a number of biotech specific government agencies grouped into a cluster of organizations and institutions.[222] They include:

- Biotek Malaysia also known as the national Biotechnology division that focuses on the general promotion of biotechnology[223]
- Genom Malaysia is a non-for-profit that focuses on generating new intellectual property that can be used for large scale development in the areas of genetics, structural and synthetic biology, computational systems biology and metabolic engineering[224]
- IPHARM is a research institute that focuses on drug discovery with a particular emphasis on discovering drugs from natural resources found abundantly in Malaysia[225]
- Agro-Biotechnology Institute Malaysia works with universities and industry to develop new ag-bio technology[226]
- Inno Biologics is a government controlled API manufacturer available via contract to domestic companies[227]
- Technology Park Malaysia Corporation provides young companies with affordable access to real estate and technology along with innovation and commercialization support.[228]

Several of these programs have made significant achievements. For example, since its start, the Technology Park Malaysia Corporation has provided business incubator services to 3,000+ different technology companies.[229] Biotech Corp has acquired the rights to several promising technologies that it makes available to companies including DotScan antibody microarray technology that can be used for biomarker discovery[230] and a Marker Assisted Selection technology that can assists ag-bio companies by identifying desirable DNA markers for plant breeding.[231]

Biotech sector by sector policy overview

Biopharmaceutical

Looking at the biopharmaceutical and biomedical sector this is a sector which is receiving more domestic interest. In 2013 close to RM1billion was invested in the biomedical sector.[232] The vast majority of this (over RM700million) was domestic Malay funding. Of this, close to 50% was concentrated in the medical devices field. In 2013 Agila Biotech (a subsidiary of Strides Arcolab) announced a USD35million deal to build a major R&D and manufacturing facility in the Bio-XCell cluster hub on the border to Singapore.[233] The facility is to be co-funded by Bio-XCell. In addition, domestic manufacturers such as CCM Duopharma are diversifying and building a biopharmaceutical capacity.[234] The company announced in 2014 it would be conducting clinical trials of a biosimilar erythopoietinin in Malaysia in partnership with Pangen at an estimated value of RM9million.[235]

Yet challenges remain, particularly with regards to the protection of IP. For example, Malaysia introduced a five-year term of RDP protection in 2011. While this is a positive achievement, challenges remain. Specifically, the full term of protection is not offered to new products introduced in Malaysia. Instead, the term of protection begins whenever a product was introduced globally. This significantly weakens the actual exclusivity and incentive being offered to pharmaceutical innovators through RDP. Moreover, there is a 18-month deadline for registration of a product.[236]

As of 2015 the aggregated number of clinical trials taking place (or having taken place) was 718.[237] Looking at more recent trends in clinical research, most of the trials taking place in Malaysia are late-stage. In 2013 out of 57 total new trials taking place only 3 were the more complex Phase I trials.[238]

Ag-bio and industrial biotechnology

Malaysia traditionally has a strong focus on the industrial biotechnology and ag-bio sectors through the palm-oil industry. Looking at the most recent data, the latest Annual Report by the Biotech Corporation (the agency charged with overseeing the Bioeconomy Transformation Programme) lists 95 projects as being at a "commercially ready" stage.[239] Out of those 95 projects listed the vast majority (81) are either in the ag-bio (50) or industrial biotechnology (31) sectors. The remaining 14 are in the biopharmaceutical/biomedical field.[240] Given the importance of the palm-oil sector the Malaysian government has a number of cross-sector industrial and ag-bio policies in place.

For example, to help promote the domestic industrial and agricultural biotech industries the Malaysian government has implemented the B5 biodiesel programme and the Oil Palm Replanting Incentive Scheme. The initial phase of the B5 program was implemented in 2009 and required all government agency vehicles to run on B5 biodiesel (derived from palm oil), the requirement was subsequently extended to the industrial sector.[241] Once the project is fully implemented monthly usage of biofuel is projected to increase to 41,667 tons from the current 20,833 tons.[242]

Still, there are number of challenges. For instance, there are currently no products actively being tested (papaya has been approved but no active testing in place) or approved for field trials and Malaysia has no ag-bio crops under cultivation.[243] More broadly, the infrastructure for seed registration is currently not in place.[244]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 7 Malaysia: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Relatively high proportion of total graduates studying health and welfare • Relatively high levels of researchers in population • Relatively high levels of clinical trials compared to neighboring countries although few Phase I	• Significant government investment in ag-bio • Limited number of field trials	• Palm-oil industry traditional bastion of biofuels production
Intellectual property protection	• RDP legally in place but limited in practical availability • No patent linkage regulations/ protection mechanisms in place	• No commercialized ag-bio products	• Trade secrets protected under common law - palm oil cases suggest reasonable protection
The regulatory environment and Technology transfer frameworks	• Biosimilar guidelines introduced in 2008 • Reported delays in marketing approval of biopharmaceuticals • Concerns over lack of patent linkage and enforcement mechanisms • Technology transfer and university patenting rates growing	• Ag-bio products not commercialized	• Relatively high level of technology transfer and patenting by palm oil PRO (Malaysian Palm Oil Board)
Market and commercial incentives	• Generous high tech credits and biotech specific credits available e.g. BioNexus program • Biopharmaceutical P&R environment challenging - long delays for inclusion on National Formulary	• Generous high tech credits and biotech specific credits available e.g. BioNexus program	• Generous high tech credits and biotech specific credits available e.g. BioNexus program • Biofuels subsidized through B5 mandates

5.6 Mexico

Mexico is the twelfth largest economy in the world with an estimated 2013 total national output of USD2.014 trillion measured on a PPP basis.[245] Mexico has a per capita income of USD10,307 for 2013 at current USD.[246]

Mexico is the sixty-first most open and competitive economy according to the World Economic Forum 2014-15 Global Competitiveness ranking, six spots lower than the country occupied in the 2013-2014 rankings.[247]

National innovation and biotechnology policy overview

Mexico has four main government bodies that oversee and direct innovation policies. The National Council for Science and Technology is the primary body responsible for supervising financing, coordination and implementation of country innovation policies.[248] The Council works together with the Ministry of Economy, Ministry of Education, and the National Development Bank. In 2013 the Council was recognized as the chief policymaking body within Mexico's national innovation system.[249]

The Ministry of Economy works to promote entrepreneurship in the public and private sector through the National System of Business Incubators.[250] This System is divided into six main categories and offers a focus on biotech: traditional business incubator, medium-technology business incubator, high technology business incubator, biotechnologies and health, advanced food processing, and energy and environmental remediation.[251] In addition, the Ministry of Education has been working with the incubator program to implement successful incubation models at local universities.[252]

The National Development Bank is a public development bank that provides funding for businesses that have advanced beyond the incubator phase. The Bank's primary focus is to provide funding, information resources, and facilitate access to private capital for companies that would not be able to do so on their own.[253]

Mexico has two major national innovation policies in place: the National Development Plan and the Special Programme for Science, Technology and Innovation.[254] The goal of the former is to institute innovation as a basis for economic development and growth with a specific goal of raising R&D spending to 1% of GDP. The latter seeks simply to "transform" Mexico into a knowledge-based economy.

Looking at biotechnology, Mexico has a modestly growing domestic industry. The latest OECD data shows Mexico having some activity with 406 active biotechnology firms as of 2010-11.[255] However, looking at R&D spending and investment Mexican rates are relatively and absolutely quite low. The latest figures from 2011 show dedicated Mexican R&D spending on biotechnology in the business sector at USD88 million at PPP.[256] This made up a total of 3.3% of total business R&D investment.[257] Similarly, looking at value added Mexico's biotech sectors are quite small. OECD estimates of private sector biotechnology R&D as a percentage of total industry value added was quite low at 0.006%.[258] This is in contrast to high performers such as Denmark and the US where value added from the biotech sectors was much more significant at 72.4% and 30% respectively. There is currently no equivalent available data for public sector expenditure.

Biotech sector by sector policy overview

Biopharmaceutical

Biopharmaceutical R&D and innovation is increasing in Mexico with FDI growing steadily in the biopharmaceutical sector. Between 2005-2012 Mexico received a total of USD2.8 billion of biopharmaceutical FDI.[259] In 2012 alone this amounted to USD981 million.[260] Most research-based multinational biopharmaceutical companies are represented in Mexico with a number (including Merck and Boehringer Ingelheim) operating both manufacturing and R&D plants in the country.[261] Mexican biotech R&D has led to the discovery of new drugs including the scorpion antivenom Anascorp.[262] The drug, developed by the Biotechnology Institute of the National Autonomous University of Mexico and manufactured by the Bioclon Institue (a Mexican biotech firm specialising in fabotherapics) is FDA approved and actively used in the treatment of scorpion stings.

Mexico has in place a number of policies targeting biopharmaceutical innovation and has reformed its regulatory environment quite considerably over the last few years. For example, COFEPRIS (the Mexican drug regulator) has introduced a number of reforms and committed to cutting market authorization times. The agency has reduced the approval time for drugs already approved in the United States, Canada, and Europe from 360 days to 60 days.[263] COFERIS approved medications are also approved with less scrutiny in many other South American countries reflecting the agency's strengthening reputation and standards. In 2014 the agency also cut the pre-approval time for clinical trials from 3 months to 1 month reflecting a desire to attract more biopharmaceutical investment and trial activity. In conjunction with the cut in approval times the head of COFEPRIS Mikel Arriola was quoted as saying: "We want pharmaceutical companies to do more research in Mexico on Mexican patients to provide better treatments…[they] should increase R&D investment in Mexico to leverage the high quality local research institutions."[264]

Looking at the level of clinical research, as of 2015 the aggregated number of clinical trials taking place (or having taken place) was 2,340.[265] Looking at more recent trends in clinical research, most of the trials taking place in Mexico are late-stage. In 2013 out of 140 total new trials taking place only 7 were the more complex Phase I trials.[266]

And while challenges remain in its national IP environment, here too Mexico has made significant improvements over the last half-decade. For instance, in 2012, COFEPRIS introduced a five-year regulatory data protection term. While this is a positive step there remains concern over enforcement and, most importantly, biologics were left out from this announcement.

One area where the biopharmaceutical sector faces significant challenges is the P&R environment. Mexico has strict price controls in place with maximum retail prices for patented medicines capped by *Secretaría de Economía* (mainly for private sector). Mexico uses an international reference pricing system calculated on the basis of the average ex-factory price of the previous quarter in the six largest markets for a given product globally. In addition to the pricing system Mexico's public reimbursement of pharmaceuticals is quite strict. All public institutions and insurance schemes are governed by National Formulary (*Cuadro Básico y Catálogo de Medicamientos*) which is set by the *Comisión Interinstitucional del Cuadro Básico de Insumos del Sector Salud* of the Consejo de Salubridad General. This institute sets first, second and third lines of treatment for all publicly reimbursed medicines. Most of the medicines are off-patent and there generally are very few new products added every year.

Ag-bio

In regards to promotion of agricultural biotechnology, Mexico was one of the first countries to adopt the use of biotech crops.[267] In 2005, the government passed the Biosafety Law that clarified regulatory issues relating to the research, production and marketing of biotech foods.[268] One of the positive attributes of the regulatory system is that it allows the Government of Mexico to impute data on biotech crops from other countries as support for their adoption as an approved food substance in Mexico.[269] In order to bring a food product containing GMO material to market a company must conduct a study to determine any potential risks associated with the product, if no risks are found the product may be approved by the Department of Health. If approved, the product must be marketed with a label that identifies it as containing GMO ingredients.[270]

The Inter-Ministerial Commission on Biosecurity and Genetically Modified Organisms and its subsidiary bodies oversees food related biotech activities. The biotechnology regulations enforced by the Commission are not considered burdensome; however, there is some concern among importers that the government has not specified if the general allowance of 2% foreign impurities in seed products extends to GMO seeds products.[271] The Commission has authorized 103 GMO products and the importation of 52 additional GMO products for food and feed uses. In addition to regulating the biotech food industry, the Commission has also provided funding to advance the sector.[272] It has funded research to investigate the drought tolerance of GM maize, the fungal resistance of GM cotton and beans as well as the genetic diversity of corn in the country using use the outcome of this research to support the approval or disapproval of future GE corn strains.[273]

However, despite these initiatives and overall regulatory capacity overall usage and growth of biotech crops is by international measures still limited. In 2014 Mexico was the 16th largest producer of ag-bio crops in the world at 0.2million hectares under cultivation with a focus on cotton.[274] As described by the USDA Mexico has the research infrastructure, regulatory capacity and market size to benefit from wide-spread ag-bio production but has yet to establish broad public acceptance and use of GM products.[275] No product but cotton is commercially available or grown and commercial use and field work on GM corn is currently suspended due to a legal injunction.[276]

Industrial biotechnology

Mexico has been increasing its interest in industrial biotechnology and specifically biofuels and the development of clean energy for some time. In 2008 the Biofuels Promotion and Development Law (*Ley de Promoción y Desarrollo de los Bioenergéticos*) was passed. This law seeks to create an alternative energy market and is based on three pillars: maintaining food security, environmental sustainability and the promotion of energy diversification.[277] While the law has been lauded for its goals and the creation of an alternative energy market, its impact on generating incentives and increased biofuels production has so far been relatively limited. For instance, looking at biofuels production statistics Mexico's share of total global biofuel production in 2013 was 0.1%.[278] And while this figure reflects close to a 300% year-on-year increase in production capacity Mexico's biofuels production capacity is still quite limited. However, 2015 announcements by the national giant Pemex about the sale of gasoline mixed with ethanol may have a significant impact on domestic ethanol production.[279] The new policy (announced in March 2015) means that Pemex will now offer a blend of gasoline with 5.85% ethanol. The ethanol will be sourced entirely from Mexican producers who, as part of the agreement, will invest an approximate USD130 million in improving their production and refining capacity.[280]

There are also other initiatives in place including enzyme technology. A number of internationally industrial biotechnology companies have licensed several innovations developed at the Instituto Technologico de Celaya. AVT Natural Products of India and American Chrysantis both licensed a process developed at the institute that utilizes modified enzymes and bioreactors to extract higher levels of pigment from marigold flowers.[281] Additionally, the National Laboratory of Genomics sequences and analyses many of the plants found in Mexico to help expedite the use of the country's biodiversity in industrial applications.[282]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 8 Mexico: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Increasing number of life science graduates - 500% increase since 2000 • Low levels of researchers in population • Growing biopharmaceutical FDI - circa USD 1billion in 2012	• Tradition of ag-bio R&D • Strengths in corn and phosphorous absorption • Limited amount of commercialized ag-bio products	• Growing interest in biofuels - 2008 Biofuels Law • Pemex will start selling 5.85% ethanol blend
Intellectual property protection	• RDP available but unclear applicability to large molecules • Uncertainty over patent linkage regulations	• Limited commercialized ag-bio products e.g. cotton • Regulatory infrastructure in place	• The protection of trade secrets provided in Industrial Property Law, but rate of prosecution is low
The regulatory environment and Technology transfer frameworks	• Biosimilar guidelines introduced in 2009 • COFEPRIS highly regarded	• Ag-bio regulations • Legal and political environment hamper commercialization	• Limited tech transfer framework in place • Academic regulations focus on publication not patenting
Market and commercial incentives	• Biopharmaceutical P&R environment challenging • Strict pricing policies and limited reimbursement	• R&D tax credits not available only research grants	• R&D tax credits not available only research grants

5.7 Russia

Russia is the 6th largest economy in the world with an estimated 2013 total national output of USD3.460 trillion measured on a PPP basis.[283] Russia has a per capita income of USD14,611 for 2013 at current USD.[284]

Russia placed 53rd according to the World Economic Forum 2014-15 Global Competitiveness rankings. This is an increase of 11 spots from the previous rankings.[285] Recent figures on GDP growth indicate a significant slow-down, dropping from 3.4% in 2012 to 1.3% in 2013.[286] Current circumstances including international sanctions may have a negative short- to mid-term impact on the Russian economy.[287]

National innovation and biotechnology policy overview

As noted in the previous edition of *Building the Bioeconomy* since the financial crisis in 2008-9, the Russian government has targeted innovation and the development of its science and technology capabilities as a main impetus behind diversifying and modernizing the economy. The government's innovation strategy is focused mainly on enhancing and transforming its basic research capabilities into commercial activities, both in traditionally strong fields such as aerospace and nuclear energy as well as new fields such as nanotechnology, medical technologies and alternative fuels.[288] The Strategy for Innovative Development of the Russian Federation 2020 (2020 Strategy), introduced in 2011, is the main document guiding innovation policy in Russia today.[289] The 2020 Strategy sets out several benchmarks and targets in relation to science and technology indicators including the development of human capital and private sector innovation, promoting of a favorable environment in the public sector and building of international science and technology cooperation.[290]

Biotechnology is one of the Russian government's strategic innovation priorities under the 2020 Strategy. The State Coordination Program for the Development of Biotechnology (BIO 2020) and the Strategy of Development of the Pharmaceutical and Medical Industries (Pharma 2020) are among several policy instruments aimed at building a bio-industry in Russia, starting with creating the necessary human and physical capital.[291] The bulk of the funding is aimed at the bioenergy, biopharmaceuticals, agriculture and food biotechnology and industrial biotechnology fields, relying on a mix of government funding and FDI.[292]

In December 2014 Prime Minister Medvedev offered an assessment of what the 2020 strategy had accomplished so far.[293] While pointing to several successes the overall impression the Prime Minister left was that there was more work to be done. Specifically, in his remarks he pointed out how a third of the 45 indicators of progress developed and followed by the Russian Government had not been met.[294]

Biotech sector by sector policy overview

Biopharmaceutical

As mentioned Russia is pushing ahead with plans to develop a world-class biopharmaceutical sector through the implementation of the BIO 2020 plan with plans to devote RUB106 billion to the development of the sector by 2020.[295] The Russian Government plans to focus this funding towards the creation of new vaccines and antibiotics, along with creating the infrastructure to be able to domestically produce a majority of the countries necessary medication.[296] In particular, Russia has set as a goal to construct a series of state-based bio clusters that will act as a 'one-stop-shop' for biopharmaceutical development providing companies with the necessary infrastructure to move from R&D to commercialization.[297]

A significant focus of Russia's biopharmaceutical policies has been on localizing biopharmaceutical research and innovation. Yet in order to achieve these goals, instead of focusing on strengthening local innovative or manufacturing capacity, the Russian government has adopted (or proposed) a range of measures that impose localization. In 2010, the Government passed Federal Law 61-FZ on the Circulation of Medicines stipulating that clinical trials for innovative and generic medicines (bioequivalence studies) must be conducted in Russia if the product is to be submitted for registration.[298] In 2011, the Ministry of Economic Development issued Order No.211 creating a price preference of 15% afforded to locally produced drugs for

state and municipal procurement[299] and the opportunity for local manufacturers (foreign firms excluded) of products on the EDL to adjust product prices annually accounting for inflation rates.[300] Most recently, Russia adopted a stricter definition of "local production" requiring that a pharmaceutical company locally produce the API or final deliverable form of a product in Russia to qualify and put in place a requirement that imported pharmaceutical products could not be considered for state tenders if two or more generic equivalents were produced domestically.[301] And the Ministry of Trade in December 2014 outlined that detailed preferences would be developed and published on what preferences would be available to what phase of development of a given product.[302]

With regards to IP there are significant challenges in Russia. As a WTO member Russia offers a standard 20 year patent protection term. However, while the protection has been available for biotechnological and biopharmaceutical inventions (with the exception of biological processes), the actual protection afforded to biopharmaceutical inventions is at times uncertain.[303] For example, there is no guarantee that the drug regulator will not approve a biosimilar product for market despite an active patent on the reference biopharmaceutical, and remedies through the judicial system are slow and ineffective.[304] Similarly, there remains a lack of progress in implementing Russia's 2010 commitment in developing a fully functioning form of RDP. Under its WTO commitments and the 2010 Federal Law No. 61-FZ "On Circulation of Medicinal Products", Russia has committed to implementing a RDP term of six years. This was a positive step and has significantly strengthened the existing framework and protection mechanisms for pharmaceutical innovation. In 2014 amendments to this law were proposed and subsequently passed. These amendments come into effect on July 1 2015.

While wide-ranging the amendments introduced changes to the law and its application to RDP. Specifically, the amendments did the following:

- The RDP term of protection is limited to and will apply only to cases of "commercial" use.[305]
- Follow-on generic and biosimilar products will be allowed to commence registration with the market authorization authorities four and three years respectively after registration of the reference product.[306]

In addition to the amendments and continued development of applicable regulations 2015 also saw the hearing and verdict on the first court case relating to the application and availability of RDP. In March 2015 Moscow's arbitration court heard and rejected claims made by Novartis that its submitted clinical test data had been relied on to grant approval for a follow-on product.[307] Of note is that in its interpretation of the existing statute the court also appeared to concur with an interpretation put forth by the Ministry of Health that it was not its responsibility (as the market authorization regulator) to confirm and check the exclusivity status of a given product and whether a regulatory data or market exclusivity period was in effect.

Despite the ambitions of the Russian Government, Russia's clinical research environment remains limited. The number of clinical trials conducted in Russia is still on an absolute and per capita basis fairly small. Looking at the level of clinical research, as of 2015 the aggregated number of clinical trials taking place (or having taken place) was 2,661.[308] Looking at more recent trends in clinical research, most of the trials taking place in Russia are late-stage. In 2013 out of 266 total new trials taking place only 25 were the more complex Phase I trials.[309]

Ag-bio

The Bio 2020 Plan also outlines the goals that the Russian government has set for the agricultural biotechnology sector: namely, the development of novel plant varieties to increase overall crop yields.[310] However, in order to develop a strong agricultural biotechnology sector the Russian government is first working to implement the proper mechanisms for review of genetically engineered food products. In October 2010, the government passed Resolution No.839 that authorized the Ministry of Agriculture and other relevant government agencies to develop guidelines for the registration of GMO seeds.[311] Currently, the country has no such process and as a result there it is not possible for companies to legally commercialize GMO seed products. Originally, the guidelines were scheduled to come into effect in June 2014; however, in April 2014 the government announced that the original target was too optimistic and that a proper set of guidelines would not be prepared until mid-2017.[312]

Despite this delay in producing registration guidelines, Russian scientists are forging ahead with laboratory based GE crop research, although in a limited capacity. Field testing of GE crops requires approval from the Variety Testing Commission at the Ministry of Agriculture.[313] The majority of this research takes place at the Institute of Nutrition and Food Safety Assessment at the Russian Academy of Sciences and the Center of Bioengineering at The Russian Academy of Sciences.[314]

Industrial biotechnology

BIO 2020 sets goals for Russia to develop a world class industrial biotechnology sector that will be able to provide industry with products ranging from industrial enzymes to wood waste based biofuel.[315] There are targets for renewables and biofuels including having a 10% biofuels share in motor oil; a 20% share of the solid biofuels European market; and a 5% share of the world market of motor biofuels.[316]

However, evidence suggests that biofuels are a very small part of Russia's energy mix and an insignificant part of its energy infrastructure. For example, 2013 data on biofuels production lists the countries of the former Soviet Union (Russia included) as producing 0.3% of total global biofuel production.[317] Similarly, estimates suggest that all renewable energies (including biofuels) only account for 1.2% of Russia's total energy production.[318]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 9 Russia: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• High no. of natural science PhDs • Biomedical FDI still relatively low • Low levels of clinical trials • Most clinical research on generics	• R&D taking place but limited regulatory infrastructure hampers overall development	• Growing interest in biofuels - part of 2020 BIO agenda • Insignificant part of energy production and use
Intellectual property protection	• RDP on the books but not being applied • Uncertainty over protection especially in regard to biosimilars • 2014 amendments complicate patent term restoration	• Limited commercial use of ag-bio products • Regulatory infrastructure not in place	• Despite 2014 amendments trade secret protection difficult; high levels of industrial espionage
The regulatory environment and Technology transfer frameworks	• No biosimilar pathway • Tech transfer framework in place and some commercialization taking place	• Ag-bio regulations still being developed • No process for registration of seeds • GMO labelling in effect as part of Eurasian Customs Union	• Joint university-industry general patenting and commercialization taking place
Market and commercial incentives	• Preferential treatment for locally manufactured products in biopharmaceutical pricing and procurement policies	• Generous R&D tax credits available • Targeted credits for Special Economic Zones and Skolkovo	• Generous R&D tax credits available • Targeted credits for Special Economic Zones and Skolkovo

5.8 Singapore

Singapore is the 43nd largest economy in the world with an estimated 2013 total national output of USD425 billion measured on a PPP basis.[319] Measured on a GDP per head basis Singapore is one of the richest countries in the world with a per capita income of USD55,182 for 2013 at current USD.[320] Singapore is the world's second most open and competitive economy according to the World Economic Forum 2014-15 Global Competitiveness rankings and has held this position for years.[321]

National innovation and biotechnology policy overview

As noted in last year's edition of *Building the Bioeconomy* Singapore early on recognized the importance of transitioning to a knowledge-based economy. Through a number of macro- and mico-economic policies Singapore has successfully built an economy recognized as one of the most commerce friendly and innovative in the world. A number of long-term policies have been in effect to develop and expand Singapore's high tech R&D capacity and target specific high-technology niches including biotechnology.

At the Government level a number of departments and agencies are involved in the creation of innovation and biotechnology policies and attracting foreign investment. The Ministry of Trade and Industry is responsible for the coordination of science and technology policies and for the formulation of key economic policies. The Singapore Economic Development Board is the lead government agency that promotes FDI and knowledge-based industries. The board focuses on raising the level of private-sector R&D in Singapore by attracting multinational companies to base their corporate R&D activities there.[322] A*STAR focuses on the development of domestic R&D capabilities, which includes the overseeing of public research institutes. Under the A*STAR, the Bio-Medical Research Council promotes R&D and develops human capital in the life sciences. The Science and Engineering Research Council promotes similar outcomes but targets science and engineering. A*STAR at present oversees 21 research institutes, centers and consortia.[323]

2014 saw Singapore continue to attract significant private sector investment. Total capital investment was SGD12.1 billion (approximately USD10 billion) with a heavy concentration in high-tech business such as electronics (SGD3.3 billion), chemicals (SGD2.5 billion) and biomedical manufacturing (SGD0.8 billion).[324] A number of major biomedical companies invested in Singapore building new manufacturing and R&D facilities. For example, Amgen broke ground on a new manufacturing facility in the Tuas Biomedical Park. The company estimates it will invest USD200 million in this project. Medtronic established its Centre of Excellence for Business Model Innovation, an R&D and business development center.[325]

Biotech sector by sector policy overview

Biopharmaceutical

Looking at the biopharmaceutical and biomedical sector Singapore's overall infrastructure and services are extremely well developed. The Biomedical Sciences Industry Partnership Office serves as a contact point and acts to match companies' R&D needs to expertise that can be found in research hospitals, academic research institutions and public research institutions in Singapore.[326] Singapore has developed world-class R&D and manufacturing capabilities and has seen tremendous growth in the presence and investment by multinational, research-based companies. By and large the efforts by the Singaporean Government to make the country an attractive place for biopharmaceutical development have been very successful. Abbot Laboratories, GlaxoSmithKline, Lonza, Novartis, MSD, Pfizer and Sanofi-Aventis have all set up global manufacturing bases in the country.[327] Today a number of products are manufactured for global markets in Singapore with government estimates of this manufacturing at circa SGD23 billion.[328] Examples of biological products being manufactured in Singapore include Roche's Lucentis, Avastin and Herceptin.[329]

In addition to the policies in place through A*STAR and its affiliates (outlined in the Annex) the Government has several other initiatives in place to promote biopharmaceutical development. These include the Clinician Scientist Award, the Translational & Clinical Research Flagship Programme and The Competitive Research Programme. The Clinician

Scientist Award is an award for clinicians who have a demonstrated track record of producing high quality work. The grant is open to principal investigators who have an advanced degree and are actively employed at an academic institution. Grants range from SGD250,000 to SGD 350,000.[330] The Translational & Clinical Research Flagship Programme provides large grants (up to SGD25million) to bring together the best researchers from different programs to work together to conduct cutting edge research.[331] The Competitive Research Programme is overseen by the National Research Foundation and provides funding to mutli-disciplinary teams on the basis of a merit review process where potential programs are judged in areas such as potential for disruptive innovation and research significance.[332] While the program is not limited to biopharmaceutical research it provides significant funding to the area. Since its launch in 2007 CRP has funded a wide variety of biopharmaceutical projects.[333]

As the above suggests, the clinical research environment is world leading. Per capita Singapore has some of the highest rates of clinical trials in the world. Looking at number of clinical trials to date per million population Singapore has a rate of just under 250 trials, which is on par with the US.[334]

Ag-bio

As a city state Singapore imports 90% of its food supply and has limited investment in the agricultural biotechnology sector.[335] As of 2014 Singapore had no active field trials for GE food products nor does the country have any active GE food products that to commercializes or exports.[336] However, the Government of Singapore does recognize the growing importance of the agricultural biotechnology sector and has established a series of six agro-technology parks to promote research into the sector.[337] Currently, the parks comprise over 1,400 hectares and conduct plant based research with the aim of exporting the research outcomes to other countries in the region.[338]

Industrial biotechnology

Despite the city-state's small size there is a strong tradition in industrial biotechnology and a growing interest in biofuels. For example, chemicals and industrial biotechnology giant DuPont has operated in Singapore since 1975. The company currently has two main manufacturing sites producing engineering plastics and polymers.[339]

Singapore has also ventured into biofuels and specifically biodiesel R&D. In 2007 the Government made clean energy (and bioenergy) a national commitment and identified this sector as a future area of economic growth.[340] SGD350million was committed in government funding and a SGD20 million Innovation for Environmental Sustainability Fund was set up.[341]

Singapore has a number of R&D policies in place to encourage and incentivize development of clean technologies. Since 2011 public sector investment in sustainable energy and clean energy has totaled SGD800million.[342] However, the majority of these projects and policies relate to non-biotechnological initiatives including wind, solar and tidal energy. There is, relatively speaking, limited specific policy infrastructure in place focused on the industrial biotechnology sector in Singapore. Still, the overall strong infrastructure and emphasis on innovation has resulted in a number of biofuel-oriented projects. For instance, Singapore-based Apha Biofuels has partnered with the Westin hotel group in the city to provide 7% blended biodiesel to power the hotels fleet of luxury cars.[343] Singapore is also home to the largest hydrotreated vegetable oil plant in the world operated by Finish based Neste and can produce 800,000 metric tons of HVO a year.[344]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 10 Singapore: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• National University of Singapore ranked as 34th best university in life sciences globally • Strong investment in biopharmaceutical R&D and infrastructure • High levels of biomedical FDI • High levels of clinical trials	• New R&D taking place through ag-bio parks	• Industrial biotech present in Singapore - e.g. Neste Oil
Intellectual property protection	• Strong life sciences IP environment • RDP available • Patent term restoration available	• Plant variety protection in place • 2014 amendments widen scope of coverage	• Strong trade secret protection; ranked highly in OECD Trade Secret Index
The regulatory environment and Technology transfer frameworks	• Biosimilar guidelines introduced in 2009 • Biopharmaceutical regulators generally highly regarded • Innovative biopharma products are generally not approved without prior approval in other jurisdictions	• Regulatory framework in place; GMAC well-respected • No commercial cultivation of ag-bio products	• High rates of general university patenting and commercialization
Market and commercial incentives	• Generous R&D tax credits available	• Generous R&D tax credits available	• Generous R&D tax credits available

5.9 South Africa

South Africa is the 27th largest economy in the world with an estimated 2013 total national output of USD662 billion measured on a PPP basis.[345] South Africa had a per capita income of USD6,618 for 2013 at current USD.[346]

South Africa is the 53rd most open and competitive economy according to the World Economic Forum 2013-14 Global Competitiveness ranking, one position lower than the country occupied in the 2012-2013 rankings.[347]

National innovation and biotechnology policy overview

In 2008 the South African government released the Ten-Year Innovation Plan. The plan was intended to be a high-level look at general areas the country could improve in by 2018 to become one of the world's leading knowledge-based economies. One of the key goals of this plan was for South Africa to host one of the fastest growing biopharmaceutical industries and to be identified as a world leader on climate change research.[348] As is discussed below, while remaining largely unfulfilled this aspiration is still an important part of South Africa's national innovation agenda.

Included in the 2008 document was the creation of The Technology Innovation Agency.[349] The Agency was created to bring all different avenues available for innovation under one roof with the primary objective of generating and utilizing technological innovation to grow the economy and improve the lives of all South Africans.[350] In terms of concrete activities the Agency has created four funds that provide assistance to innovative companies. The largest of these funds is the Industry Matching Fund that provides assistance to companies of all sizes. Businesses are encouraged to partner with universities or public science councils and must match 30-50% of the funding level with loans, royalty payments or shares. The Equity Fund is available to struggling start-up companies that do not have the ability to raise capital from public markets. In return for capital, the Agency acquires equity or convertible shares from the company. Projects undertaken by universities or science councils deemed to be of exceptionally high quality can apply for funding through the Technology Development Fund. Projects receiving assistance through this fund typically are those identified by the Agency as ventures that can succeed without industry partnership. Lastly, very early stage companies have access to the Idea Development Fund that provides entrepreneurs with low-level funding to cover the costs associated with patents and business plan development.[351] The Agency has seen some success through its funding initiatives. It has provided R90 million (USD7.84 million) to develop the Tshwane Animal Health Innovation Cluster to advance research in animal health biotechnology projects.[352] Other projects include the Metagenomics Platform that looks to develop novel products from genetic material found in the South African environment and a clinical trial for a vaginal gel based version of tenofovir that could help prevent the spread of HIV/AIDS.[353]

Looking at the biotechnology sector 2014 saw the Ministry of Science and Technology release a flagship policy document for the biotechnology sectors titled *The Bio-Economy Strategy*. This document builds on past Government initiatives including the 1996 *White Paper on Science and Technology* and 2001 *National Biotechnology Strategy*. The Strategy seeks to further develop South Africa's bioeconomy making all biotechnology sectors into significant contributors to the country's national economic output by 2030.[354] In particular the Strategy focuses on expanding the ag-bio sector in light of its potential broader economic impact in South Africa.[355] The Strategy discusses and highlights a number of critical factors in the generation of biotech innovation discussed in section 3 of this report, including the importance of human capital, R&D infrastructure, technology parks and private-public sector partnerships and contributions.[356] It also includes a number of input and output indicators to measure its performance including patents granted, technology transfer transactions, GMO field trials, approval of new medicines and biomedical products, number of biotech firms, venture capital invested and a host of other important components of measuring biotech innovation.[357] One area where the report does not provide as clear a framework or reference point is the issue of IP rights and providing incentives for the creation of intellectual property assets. Instead, the report focuses on ways in which South Africa could better access existing and developed forms of IP. The Strategy

states that: "South Africa needs to implement a strategy to exploit expired, expiring or unenforceable patents to produce bioproducts locally, at a fraction of the cost of importation."[358] There is no equivalent discussion on the manner in which intellectual property can be created, commercialized and become an industrial asset.

Biotech sector by sector policy overview

Biopharmaceutical

The South African biopharmaceutical market is the biggest market in Africa worth an estimated USD3.61 billion in 2012.[359] A number of international biopharmaceutical manufacturers are present in South Africa with both manufacturing and R&D capabilities. For example, Sanofi has had a manufacturing site in South Africa since the 1970s.[360] The company has also invested in domestic research facilities targeting TB.[361]

In terms of R&D support and investment the 2001 National Biotechnology Strategy allocated USD58 million in public sector support. It also established a system of Regional Innovation Centres set up to identify opportunities across all biotech sectors and regions of South Africa.[362] The Centers include Cape Biotech, Lifelab and BioPad and PlantBio (dedicated to ag-bio).[363] In addition the Government supports the EGoliBio initiative which serves as an incubator for biotechnology companies at various stages of development ranging from companies that have a commercial viable product to those that are still in early stage research.[364] EGoliBio has helped 25 different companies commercialize products. This includes Sliek, a company that provides enzymes to treat lactose intolerance, and AdhocWorks, which has developed a new product to prevent mosquito bites and the transmission of malaria.[365]

Looking at the macro picture the latest available data suggests that South African biotechnology activity is still relatively limited. 2009 figures from the OECD suggest there are 30 active biotechnology firms in South Africa of which 10 are dedicated biotechnology firms. Older survey data suggests that the majority of biotech firms in South Africa are in the biopharmaceutical and biomedical sector.[366] This is significantly less than larger markets such as the UK (with 488 active firms) as well as smaller markets such as Estonia and Poland with 45 and 91 active firms respectively.[367] Similarly, looking at R&D spending and investment South African rates are relatively and absolutely quite low. The latest figures from 2011 show dedicated R&D spending on biotechnology in the business sector at USD69.6million at PPP.[368] This made up a total of 3.0% of total business R&D investment.[369] Similarly, looking at value added South Africa's biotech sectors are still quite small. OECD estimates of private sector biotechnology R&D as a percentage of total industry value added was quite low at 0.02%.[370] There is currently no equivalent available data for public sector expenditure. Nevertheless, there are some international success stories. For example, South Africa's oldest biotech company Bioclones developed and successfully marketed Repotin an EPO used extensively in South Africa.[371]

South Africa's clinical research environment remains limited. The number of clinical trials conducted is still on an absolute and per capita basis fairly small. Looking at the level of clinical research, as of 2015 the aggregated number of clinical trials taking place (or having taken place) was 2,010.[372] Looking at more recent trends in clinical research, most of the trials taking place in South Africa are late-stage. In 2013 out of 144 total new trials taking place only 14 were the more complex Phase I trials.[373]

Ag-bio

South Africa is a major producer of ag-bio crops. In 2013 it was the ninth largest producer of biotech crops in the world with 2.7million hectares under cultivation.[374] Crops under cultivation include corn, soybean and cotton.[375] In the area of agriculture South Africa has long been a user of biotechnologies and the majority of its major crops are planted with genetically engineered seeds.[376] For corn close to 90% of corn plantings are with GE seeds, over 90% percent of soybean plantings and all cotton plantings are grown from GE seeds.[377] All GE seeds used in South Africa are imported, primarily from the US. There is no South African commercial manufacturer of approved GE seeds.

Looking at R&D South Africa has focused primarily on grapevine research with university and government partnering in the development of GE grapevine. Field trials by the Institute for Wine Biotechnology at Stellenbosch University were approved in 2009.[378]

Industrial biotechnology

The South African Government has expressed an increasing interest in industrial biotechnology including biofuels. The 2014 National Strategy lists this sector together with ag-bio and the biopharmaceutical sectors as the focus of the Strategy. While it sees huge opportunity for South Africa in this sector the Strategy does concede that this sector has not been a priority in previous policies.[379]

In terms of biofuels South Africa is currently not a huge producer. Total production for the entire African continent (including South Africa) of biofuels is less than 0.1% of the global 2013 total.[380] However, this amount is likely to increase as a result of the commitments to biofuels made by the South African Government in 2014. In January of that year a Draft Position Paper on the South African Biofuels Regulatory Framework.[381] The Paper follows the 2007 Biofuels Strategy call for a 2% penetration of biofuels in the South African fuels supply.[382] The Draft Position Paper proposes a 20 year general fuel levy to support biofuel manufacturing of between 4.5-6.5 cents per litre of fuel.[383]

In terms of R&D funding mechanisms South Africa offers funding for industrial biotechnology sector through the BioPAD Regional Innovation Centre. BioPAD provides small, medium and micro enterprises access to experts in a wide range of fields to assist in their business development needs.[384] In addition, BioPAD collaborates with outside investors to provide public/private support mechanisms for these companies. This public/private support structure can be accessed in several different ways. The Seed Capital Alliance Platform for Enterprises provides venture capital funding through BioPAD and outside investors to high-technology companies that have developed potential breakthrough technologies in industrial biotechnology.[385] The Microbial Technology Platform supports industrial biotechnology companies looking to discover and find uses for new microorganisms and enzymes.[386]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 11 South Africa: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Highest number of clinical trials in Africa • Most trials are late phase i.e. less innovative • Overall limited biopharmaceutical R&D capacity	• Strong tradition of ag-bio use and production • R&D efforts in grapevine	• Industrial biotech identified as key sector in National Strategy • Biofuels commitment coming into effect in 2015
Intellectual property protection	• Limited life sciences IP environment • No RDP available • Patent term restoration not available • Patent reform package includes s3(D) style fourth hurdle, expansion of CLs	• Plant variety protection in place • Member of UPOV	• Trade secret protection difficult; ranked in bottom third of OECD Trade Secret Index
The regulatory environment and Technology transfer frameworks	• No biosimilar guidelines • Long delays for biopharmaceutical market authorization • Technology transfer framework in place	• Regulatory framework in place; 1997 GMO Act • High level of commercial cultivation of ag-bio products	• High rates of patenting at Stellenbosch University Sugarcane Research Institute
Market and commercial incentives	• Generous R&D tax super deduction available • Pharmaceutical industry one of qualifying/targeted industries	• Generous R&D tax super deduction available	• Generous R&D tax super deduction available • Potential biofuels levy to be introduced in 2015

5.10 Switzerland

Switzerland is the 37th largest economy in the world with an estimated 2013 total national output of USD457 billion measured on a PPP basis.[387] Switzerland is one of the richest countries in the world with a per capita income of USD84,815 for 2013 at current USD.[388] Switzerland is the world's most open and competitive economy according to the World Economic Forum 2014-15 Global Competitiveness rankings and has dominated these rankings for years.[389]

National innovation and biotechnology policy overview

As noted in the previous edition of *Building the Bioeconomy* Switzerland has a well-established policy framework and long-standing success in promoting and incentivizing innovation. Several government agencies and department play roles in the national innovation system. The Federal Department of Home Affairs is responsible for the support of basic research and higher education.[390] The Swiss National Science Foundation is the country's biggest supporter of basic research. The Board of the Federal Institutes of Technology oversees and sets policy for federal institutes of technology. Finally, the national innovation promotion agency KTI is the main public funding source for applied R&D. The KTI is of particular importance as it backs and promotes joint R&D projects between private and public sector institutes. The quadrennial Education, Research and Technology parliamentary bill outlines the Swiss Governments' blueprint and views for innovation policy.[391] This bill is produced through a lengthy consultation and review process involving private and public stakeholders.[392] Indeed, Switzerland has a tradition of close cooperation between industry and private sector institutions with all of the above public bodies in shaping and developing national innovation policy.

In the biotechnology field Switzerland has a number of specific policies in place. These range from direct support for R&D activities, to biotech networks, technology transfer and commercialisation bodies as well as direct help for start-ups from the federal government. Indeed, the building of the Swiss biotechnology industry has benefited immensely from government-backed initiatives through the National Sciences Foundation and its SPP BioTech program launched in 1992. This program sought to promote technology transfer and the commercialisation of biotechnology through start-ups, venture capital partnerships and spin-offs.[393] The success of this initiative and of the Swiss biotechnology sector in general is reflected in the increased number of patents per capita. Since 2001 Switzerland has seen its patents per capita increase by over 300%; far higher than other top biotech countries.[394]

Biotech sector by sector policy overview

Biopharmaceutical

Switzerland has a globally competitive biopharmaceutical sector. The country is home to some of the largest biopharmaceutical manufacturers in the world. Biomedical research makes up a substantial part of overall R&D expenditure. Its two dominant national champions, Roche and Novartis, were the top investors in biopharmaceutical R&D of all multinationals in 2013. Roche spent an estimated USD10 billion on R&D followed closely by Novartis at USD9.8 billion.[395] The majority of R&D spending in Switzerland is by industry. The largest part of this spending came from the Swiss biopharmaceutical industry which in 2012 accounted for 29.6% of all industry R&D at CHF3.8 billion.[396] Biopharmaceutical research represents a large share of the Swiss economy with pharmaceutical exports for 2011 estimated at an excess of USD40 billion.[397] Switzerland's high level of biomedical R&D capability is also illustrated by over 35,000 people with direct employment in the industry and an estimated further 120,000 in related and downstream industries.[398] While there are a number of SMEs and smaller Swiss biomedical manufacturers the industry is dominated by Roche and Novartis. Both companies employ over 10,000 staff each and invest either the majority or a large portion of their R&D expenditure in Switzerland.[399]

Ag-bio

The environment in Switzerland is generally not favorable towards agricultural biotechnology. In 2005 a public referendum was passed banning the use of genetically modified plants and animals in the country. This referendum was extended by the Swiss Parliament for three years in 2010 and for another 4 years in 2013.[400]

Despite the public referendum and lack of public support for GM foods and ag-bio products the Swiss Government does maintain avenues for agricultural biotechnology research. Researchers can apply to the Federal Office for the Environment to receive approval for the experimental release of a GMO product.[401] Currently the authorities are reviewing the application for the experimental release of a blight resistant potato.[402] In addition to granting case-by-case approvals for the field testing of GMO products the Swiss Government has approved EUR600,000 in annual funding to create a three hectare protected field at the Reckenholz Research Station. The first product to be tested at the site will be a GM wheat product with resistance to powdery mildew.[403]

Despite the lack of a domestic market Switzerland is home to one of the largest ag-bio companies in the world, Syngenta. While being a Swiss company Syngenta carries out most of its R&D outside of Switzerland with a strong presence in the US, Brazil, the UK, China and India.[404]

Industrial biotechnology

The industrial biotechnology sector in Switzerland is very small with less than 5% of biotech companies engaging in some sort of biotechnology focusing on the area.[405] However, Swiss industry recognizes the advantages of a strong industrial biotechnology sector and has been lobbying the government to become more involved in the promotion of the sector.[406] In 2014, the Science Industries Switzerland Business Association, Biotechnet, the Federal Institute of Technology and the Swiss Biotech Association launched BiocatCH+, a program to help foster research and technology transfer in the field of biocatalysis. Switzerland is also home to the R&D facilities of some of the largest chemical and industrial biotechnology companies in the world. For example, DuPont has its European Technical Center in Meyrin outside Geneva. This Center is a global R&D facility cutting across most of DuPont's research and products from polymer and advanced materials to blow molding and extrusion.[407] In addition the company also houses its DuPont Geneva Innovation Center in Geneva Switzerland.[408]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 12 Switzerland: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Two universities in top 15 for life sciences globally • Leading global investor in biopharmaceutical R&D • Strong clinical trials environment	• Ag-bio R&D taking place but no commercialization	• Industrial biotech limited compared to biomedical sector • Biofuels targeted with subsidies
Intellectual property protection	• Strong IP environment • RDP available • PTE available	• Plant variety protection in place • Member of UPOV	• Strong trade secret protection
The regulatory environment and Technology transfer frameworks	• Biopharmaceutical regulators highly regarded • High rates of tech transfer • Number of government initiatives and institutes in place to provide help and support e.g. KTI	• No commercial production of ag-bio products	• Successful commercialization and technology transfer rates still behind US
Market and commercial incentives	• Relatively relaxed P&R policies for non-basic list pharmaceuticals • Strict P&R policies for biopharmaceuticals on basic insurance list	• Limited amount of general R&D tax credits	• Tax relief available for biofuels

5.11 Turkey

Turkey is the 17th largest economy in the world with an estimated 2013 total national output of USD1.452 trillion measured on a PPP basis.[409] Measured on a GDP per head basis Turkey has a per capita income of USD10,972 for 2013 at current USD.[410]

Turkey is the 45th most open and competitive economy according to the World Economic Forum 2014-15 Global Competitiveness ranking, one position lower than the country occupied in the 2013-2014 rankings.[411]

National innovation and biotechnology policy overview

The Scientific and Technological Research Council of Turkey is the primary government body tasked with overseeing innovation policies in Turkey.[412] In December 2010, the body approved the National Science, Technology, and Innovation Strategy 2011-2016.[413] This strategy aims to boost innovation and R&D in competitive innovation sectors and other sectors that are identified as areas of strong global demand.[414] In 2011, the government created the Ministry of Science, Industry, and Technology to coordinate with the Council on implementing national innovation policies.[415] To attract high-tech companies Turkey has created three types of special investment zones, 40 currently operational and 19 under construction.[416] Technology Development Zones (also called Technoparks,) were created for companies looking to increase their research and development capabilities in high technology fields. As of 2014, over 2,000 companies, research centres, and universities were operating in the Technoparks. Official estimates suggest companies in the Technoparks have contributed an estimated USD600 million in exports and filed 301 patents.[417] The Technoparks have had some success in housing biotechnology companies with 20% of all firms located in these special economic zones engaged in biotech.[418] Organized Industrial Zones were created as areas with "ready-to-go" infrastructure that include access to roads, water, natural gas, electricity, communications, waste treatment, and other sector specific services.[419] Lastly, Free Zones were created and identified as areas being within the political borders of the country but free from customs requirements. Free Zones are designed to attract export driven companies. 19 such Zones are active and the majority are located near major Turkish ports, providing access to major markets.[420]

However, Turkey also has in place a number of localization policies (primarily targeting the biopharmaceutical sector) which in many ways have counterbalanced some of the positive steps taken in other areas. Localization measures in Turkey include both those that directly target biopharmaceuticals as well as industrial goods more broadly (including pharmaceuticals). Such measures affect companies at various phases in market access – registration, pricing, procurement, etc. One of the principal measures affecting localization is Public Procurement Law No.4734, introduced in 2002 and last amended in 2014. In particular, Article 63 provides up to a 15% price advantage to local goods in government tenders. The goods that qualify for such a preference have up until now been determined annually by the Ministry of Science, Industry and Technology. In September 2014 the threshold for being considered a local product was raised considerably as part of Decree 2014/35. Specifically in order to be included in government tenders, Article 4 requires foreign companies to have made domestic investments of at least 51% of the contract value – and this investment must include major parts of the production process. Under the new measure, imported innovative drugs that do not localize over half of production (in terms of cost) in Turkey will face a significant disadvantage in government tenders, a key point of market access. This measure is particularly likely to affect imported innovative drugs that have been placed in baskets with at least one local generic equivalent. Current estimates value this figure at around TRY2.1 billion (circa USD700-800 million), or 32% of the total market.[421] There are also reports that imported products with existing generic equivalents could become de-listed from reimbursement baskets altogether.[422]

Biotech sector by sector policy overview

Biopharmaceutical

Turkey is a growing biopharmaceutical market and a number of multinationals have dedicated R&D sites in Turkey. For example, in 2014 General Electric announced that it would open the GE Healthcare Life Sciences Technology Laboratory

in Teknopark Istanbul. This R&D facility will focus on "drug discovery, protein science, and bioprocessing".[423]

In terms of clusters and bioparks the major one is Istanbul Health Industry Cluster. This cluster brings together 12 universities, 13 NGOs and 75 companies. The cluster places an emphasis on new companies and provides business incubator programs. The cluster also assists in technology transfer for companies that have developed commercially viable products and works with the Turkish Government to establish industrial parks throughout the country focusing on biopharmaceuticals.[424]

The Turkish Government provides a number of targeted initiatives and programs at the biopharmaceutical sector. This includes the Industry Research and Development program that shifts 60% of R&D costs to the government for projects that provided added value to the Turkish industry[425]; the EUREKA program that covers 50% of the costs of collaboration between R&D centers, companies and universities; and the Project Market Support Program that provides funds to promote collaboration between the private and public sector.[426]

While the Turkish Government has been working to increase biopharmaceutical R&D, several laws are less successful in promoting this end-goal. As mentioned, increasingly restrictive localization policies have been and are limiting potential biopharmaceutical development. Furthermore, the Turkish Government through its P&R policies bluntly restricts spending on biopharmaceutical products.[427] From 2009 to 2010 the government's biopharmaceutical budget was cut by 10%, which was followed by a requirement that the biopharmaceutical industry reduces prices for 2010-2011 to cover spending overruns.[428] Subsequent budgets have also seen significant cuts.[429]

Clinical trial activity in Turkey is quite low with a total of 1,619 aggregated clinical trials. The majority of clinical research is in later phases, with only 3 Phase I trials in operation for recent trials (registered in 2013) out of a total of 151.[430] Early stage trials typically involve the newest health technologies, but are also the most complex and risky to conduct. They are a good proxy for the level of innovation and sophistication of R&D taking place.

Ag-bio

Agricultural biotechnology has become more limited in Turkey as a result of the 2010 Biosafety Law.[431] While the law does allow researchers to study and develop ag-bio products commercialization is limited. The law also requires that the Biosafety Board approve all research prior to its initiation. Researchers in the country have voiced strong disapproval of the law and no GE seeds have been developed in the country since its passage.[432]

Prior to 2010 the majority of biotechnology companies in Turkey and most biotech research was in the area of ag-bio. A 2009 market research study found that over 90% of biotech employees worked in the ag-bio sector.[433]

Industrial biotechnology

Industrial biotechnology has long been an important part of Turkish industrial processes and production. The Turkish yeast industry is of particular importance with a growing share of the world yeast market. Turkish Pakmaya has become a global presence selling its products in over 130 countries.[434] The company has invested in micro-biological R&D since the 1980s with dedicated R&D activities centred on its Pbio Pak Biotechnology Center.[435]

In terms of Government support, companies focused on industrial biotechnology can receive research assistance from the Biotechnology and Bioengineering Application and Research Center. Established in 2009 by the Turkish Department of Planning the Center provides researchers with access to technology and research facilities.[436]

Government mandates for the use of bioethanol and biodiesel were announced in 2011 with ethanol set to be blended at a rate of 2%.[437] At the time of research it was unclear if these measures had been implemented. Looking at biofuels production Turkey is not listed a major producer of biofuels per BP's annual statistical review.[438]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 13 Turkey: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Growing number of life sciences graduates - 250% increase since 2000 • Low levels of clinical trials • Primarily late stage research	• Ag-bio R&D taking place but no commercialization since 2010	• Industrial biotech focused on yeast industry • Biofuels targeted with mandates; unclear over implementation
Intellectual property protection	• Challenging biopharmaceutical IP environment • RDP available in law but limited in practice	• Limited commercialization of ag-bio products since 2010	• Limited legal and practical trade secret protection
The regulatory environment and Technology transfer frameworks	• Long delays for biopharmaceutical market authorization • Tech transfer still at early stages	• No commercial production of ag-bio products	• Low general rates of commercialization and technology transfer
Market and commercial incentives	• Strict P&R policies for biopharmaceuticals • Use of fixed exchange rate and reference pricing	• Generous general R&D tax credits available - 150% dedication • Special deductions apply to Technology Development Zones	• Generous general R&D tax credits available - 150% dedication • Special deductions apply to Technology Development Zones

5.12 UK

The UK is the 9th largest economy in the world with an estimated 2013 total national output of USD2.464 trillion measured on a PPP basis.[439] Measured on a GDP per head basis the UK has a per capita income of USD41,788 for 2013 at current USD.[440] The UK is the 9th most open and competitive economy according to the World Economic Forum 2014-15 Global Competitiveness ranking.[441]

National innovation and biotechnology policy overview

For a number of years, UK government-led initiatives have sought to promote innovation and the development of new technologies. In its first term the Labour Government under Tony Blair emphasised how the British economy should be built and expanded through innovation. The Labour administration published a number of studies on how to improve British innovation and increased public funding in basic science and technology research; built clusters; launched R&D tax credits; increased higher education funding; and encouraged technology transfer.[442] The Coalition government of Conservatives and Liberal Democrats led by the Conservative Prime Minister David Cameron has maintained this commitment to encouraging innovation, but moved policy towards a more market-driven approach.

The UK maintains a strong commitment to innovation coordinated by the country's Department for Business, Innovation and Skills. The Department has 2500+ staff and 10 offices situated around the country.[443] In 2010 the Department published *Blueprint for Technology*. This document outlined how the government would support and create the conditions of technology companies to flourish and continue to expand. The headline policy initiatives were: a reduction of the main rate of corporation tax from 28% to 24% over a 5-year period; maintaining public funding levels for the sciences; reducing regulation; and reviewing the UK's IP framework (including patents).[444] Through this blueprint the emphasis has been on encouraging the private sector to innovate and ultimately create jobs and growth.

Biotech sector by sector policy overview

Biopharmaceutical

Biopharmaceutical research represents a large share of the British economy with pharmaceutical exports accounting for almost 10% of all goods exported in 2014.[445] Figures from 2013 show that 22% of all business R&D expenditures were focused on the pharmaceutical sector; a percentage significantly higher than any other specific sector.[446] The UK is home to some of the most innovative biopharmaceutical manufacturers in the world and houses a globally competitive biotech sub-sector. Many of its universities are ranked among the best in the world for the study of life sciences. Clinical research is thriving and the UK conducts a large number of clinical trials with 9,556 aggregated trials to date.[447] Looking at clinical trial intensity and the number of clinical trials to date per million population the UK has one of the highest levels in the world at 150 trials.[448] Moreover, a high proportion of current trials (registered since 2013) are in the more complex early phase research. Out of a total number of 694 trials with a registered start date in 2013, 187 were Phase I and 202 were Phase II trials.[449]

There were a number of important developments in 2014. In the first half of 2014 Britain was the top destination in Europe for early stage life science investment drawing GBP738 million from January to June.[450] The surge in funding has been attributed to government efforts to support the biopharmaceutical sector and specifically to the creation of a "patent box" tax break.[451] This tax break encourages companies in the UK to commercialize their intellectual property by only being charged a 10% tax rate on any income resulting from that IP.[452] This is a particularly attractive tax incentive to the biopharmaceutical sector given the significant investments required for R&D and product development. In addition to promoting early stage investing, the new tax incentive has also encouraged major industry players to reconsider the UK as a manufacturing destination. Shortly after the tax break was launched GSK announced that it would build a GBP350 million manufacturing facility in the country with the potential for further investment of GBP700 million.[453] In announcing the decision the company specifically cited the UK's commitment to improving the overall environment for innovation.[454]

Ag-bio

The UK has a unique relationship with agricultural biotechnology. While the country as a whole embraces GM food products the current list of genetically modified seeds approved for planting by the EU are not suitable to the UK's growing environment. Despite this, or perhaps due to it, the UK has launched a long-term project to look at the discovery and application of innovative technologies in the agricultural sector.[455] This strategy, known as Agri-Tech, was officially launched in 2013 and aims to improve innovation in the agricultural industry through grants and centers of innovation.[456] To support this project the British Government has created the Agri-Tech Catalyst Fund and provided GBP70 million to provide grants to innovative agricultural projects from early stage development through to commercialization.[457] An additional GBP90 million has been earmarked to create Centers for Agricultural Innovation. These centers are set to concentrate on sustainability with the first center focusing on agricultural informatics to better improve field productivity.[458]

Industrial biotechnology

Industrial biotechnology has for quite some time been viewed as an important component of the UK's future bioeconomy. In 2009 the then Labour Government published *Maximising UK Opportunities from Industrial Biotechnology in a Low Carbon Economy*. The report emphasized the significant future opportunities opening up in the industrial biotechnology sector. Specifically, the report argued that the future value and size of the UK market could be large at GBP4-12 billion.[459] The report identified the UK's strengths in research and technology capacity as well as an already significant chemicals industry presence. The report also identified existing pure industrial biotechnology firms. In 2008 these numbered 42 in total of which the majority were SMEs. Most of the R&D taking place at these firms focused on biopharmaceutical applications of industrial biotechnology including "biocatalysis, biotechnology-based diagnostics/analytics and bio-based molecules".[460]

The focus on promoting industrial biotechnology lives on in the current government. At the beginning of 2015 the Industrial Biotechnology Catalyst Program was launched.[461] The program has been provided with GBP40 million in funding to distribute to companies working on industrial biotechnology projects that will generate biofuels, chemicals, proteins or natural products from biological resources. Companies qualify for funding based on size and type (academic or industry) with small companies having the opportunity to have up to 70% of their industrial research and 45% of their experimental development costs covered.[462]

The UK has also been active when it comes to biofuels. The Renewable Transport Fuel Obligation mandates fuel suppliers that a percentage of their fuels come from renewable sources.[463] The Obligation implements the EU Renewable Energy Directive and EU Fuel Quality Directive. This is the primary tool for incentivizing biofuels production in the UK which is still relatively small-scale. In 2013 the UK accounted for 0.7% of global biofuels production.[464] While this was a 50% increase on 2012, this was still significantly less than smaller comparable countries such as the Netherlands and Belgium.[465]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 14 UK: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Top life sciences universities in the world; Cambridge and Oxford ranked 3rd and 4th • High levels of clinical trials - per capita and total • Biopharmaceutical R&D accounted for almost 25% of total private sector R&D	• Agri-Tech strategy launched in 2013	• Strong academic base • Industrial Biotechnology Catalyst Program launched in 2015
Intellectual property protection	• Strong IP environment • RDP available • PTE available	• Plant variety protection in place • Member of UPOV	• Strong trade secret protection
The regulatory environment and Technology transfer frameworks	• Strong and highly regarded biopharmaceutical environment • High levels of technology transfer and commercialization	• EU Regulations on ag-bio not conducive to wide-spread commercialization and use of ag-bio products • UK R&D in place through Agri-Tech strategy	• Biofuels supported through fuel mandates
Market and commercial incentives	• Indirect P&R policies for biopharmaceuticals through PPRS • Less strict price controls than other EU countries	• Generous general R&D tax credits available • Size of deductions depend on size of company - larger deductions available for SME	• Generous general R&D tax credits available • Size of deductions depend on size of company - larger deductions available for SMEs

5.13 US

The US is the world's largest and most dynamic economy. The latest World Bank national accounts figures from 2013 show total US GDP at PPP USD16.768 trillion.[466] The US is also one of the world's richest economies in terms of per capita income with an estimated 2013 GDP per capita of USD53,042 per the World Bank.[467] The US economy is also one of the world's most open and innovative. The World Economic Forum's 2014-15 Global Competitiveness rankings ranked the US economy as the third most competitive economy in the world.[468]

National innovation and biotechnology policy overview

Promoting innovation has long been at the heart of US economic policymaking. Since the late 1970s and early 1980s the Federal Government has become more heavily involved in innovation policy, passing a number of laws and initiatives ranging from technology transfer to lowering taxes and introducing R&D credits.[469]

The current administration has built and expanded on many of these policies. A number of strategy documents have been released including the 2009 *Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs*, and 2011 follow-up, *A Strategy for American Innovation: Securing our Economic Growth and Prosperity*. Both of these include specific policies on encouraging innovation in the fields of alternative energy, basic research, ICT, health and education. For example, the 2009 stimulus package and budget contained substantial increases in funding for health IT and biomedical research.[470]

In 2014 the Obama administration launched the National Network for Manufacturing Innovation, part of the Revitalize American Manufacturing Act.[471] The purpose of this initiative is (using public and private sector funds) to create synergies between industry, academia and government to "develop advanced manufacturing technologies that will 'lift all ships.'"[472] So far five institutes have been launched each specialising in a different area of advanced manufacturing.[473] Partnering Federal departments are the departments of Defense and Energy.

With regards to biotechnology specific innovation policies the most recent initiative is the *National Bioeconomy Blueprint*. This document outlined a range of Federal policy initiatives aimed at furthering the building and development of the biotech sector in the US. The document was organized around five strategic objectives ranging from: supporting R&D investments; commercialization; improving regulations; updating training programs; and supporting public-private partnerships.[474]

In addition to policies at the Federal level there are also important state level initiatives that, while not formally part of a national innovation strategy, nevertheless contribute to the strengths of the enabling categories and to the overall national capability to perform biotech innovation. In some states, such as California and Massachusetts, these efforts have been real drivers in encouraging biotechnology innovation

Biotech sector by sector policy overview

Biopharmaceutical

The US is the largest biopharmaceutical market in the world and American R&D activities is responsible for the vast majority of global clinical research. As of March 2015 close to 85,000 out of a global total of circa 189,000 clinical trials had been carried out or were taking place in the US.[475] In terms of current trials (trials started after or during 2013) the largest number in the world were taking place in the US at 3,872.[476]

The US is home to the biggest proportion of private sector biopharmaceutical investment. Out of a total of USD50billion in R&D investment by the member companies of PhRMA, USD37billion was invested in the US.[477]

Looking at NMEs developed the vast majority of product development also takes place in the US. A study of drug global development between 1992-2004 showed that that 36.4% of NMEs were developed in the US.[478] The second most prolific developing country was the UK in which 10.4% of NMEs were developed.

Government funding and support for biomedical and biotech R&D comes through both direct support and tax credits. At the Federal level the NIH is one of the main sources of funding for biotech and biomedical research in the United States. The NIH funds over 300,000 researchers at 2,500 universities, medical schools and research institutes in the US and abroad.[479] NIH's current 2015 budget is just over USD30.3 billion.[480] Historically, the NIH has allocated over 50% of its budget to basic fundamental research with translational and advanced research being pursued by biopharmaceutical and biomedical companies. Many commentators have noted that this has, by and large, been a successful combination in creating a steady stream of innovative and new medical products.[481]

The US has a large number of biotech and biomedical clusters. In particular, California and Massachusetts are home to a number of world-leading clusters. In California there are four major clusters that employee more than 20,000 people in biotech and biomedical research: the Bay Area, Los Angeles County, Orange County and San Diego County. More broadly, together these four areas employ over half of the 268,000 (2009 figures) Californians who work in the biomedical industry.[482] The total number of biomedical companies in the state is 2,244 with estimated revenues of USD114 billion.[483]

The Massachusetts biotech cluster, located primarily in the Greater Boston area, is one of the oldest biomedical clusters in the US. The surrounding 122 colleges and universities and top research hospitals, as well as a healthy inflow of public seed money (via federal Small Business Innovation Research grants) and venture capital (it captures just over 18% of all US biotech VC investment) has contributed to the success of this region.[484] This cluster has grown to contain over 430 biotech companies.

Like many American states, both California and Massachusetts offer tax credits to biotech and biomedical companies as an incentive to both start up and run their businesses.[485]

Ag-bio

The US is the world's largest producer of ag-bio crops. In 2014 the US had 73.1 million hectares under cultivation.[486] Crops under cultivation include corn, canola, sugar-beet, alfalfa soybean, cotton, papaya and squash. GM crops are widely used and public support for ag-bio is strong. As recently as 2014 President Obama re-affirmed his support for the ag-bio sector in a letter praising the work of the late Nobel laureate Dr Norman Borlaug. The President stated that "investment in enhanced biotechnology is an essential component of the solution to some of our planet's most pressing agricultural problems."[487]

The US is also home to some of the largest and most innovative ag-bio companies in the world including Monsanto and DuPont.

The ag-bio sector receives support from the National Institute of Food and Agriculture, USDA. The institute maintains three large grant programs to promote the sector including the 1890 Institution Teaching, Research and Extension Capacity Building Grants Program, the Agriculture and Food Research Initiative and Biotechnology Risk Assessment Research Grants Program. The 1890 Institution Program is available to US land grant institutions and concentrates on building up agricultural science programs at universities to train the next generation of scientists.[488] The Agriculture and Food Research Initiative looks to improve food security through the funding of projects that focus on issues such as crop sustainability. Industry, academia and non-profits are eligible to receive funding of up to USD4 million per grant.[489]

Industrial biotechnology

The industrial biotechnology sector is a large contributor to the US economy with revenues of approximately USD100 billion in 2010.[490] A majority of the revenue and research in the area is focused on bioenergy. Since the mid-2000s policies have been in place to promote the use of biofuels. In fact, the legislative framework has proven to be a significant driver in encouraging the production and use of biofuels, chiefly maize based ethanol. Main policy drivers include the Renewable Fuel Standards (part of the 2005 Energy Policy Act and Energy Independence and Security Act 2007).[491] In large measure as a result of these policies the US has increased its production of biofuels from just over 5,226 thousand tonnes oil equivalent in 2003 to over 28,000 thousand tonnes oil equivalent in 2013.[492] It is now by far the biggest producer of biofuels in the world accounting for 43.5% of global production in 2013.[493]

Various departments and agencies within the Federal Government also actively support a number of industrial biotechnology research initiatives. The Bioenergy Technology Office within the Office of Energy Efficiency & Renewable Energy maintains five programs that together make up the research, demonstration and deployment effort. The programs are divided into three groups based on the aspect in the product development cycle they focus on. Together, all five programs provide resources and funding to projects at all stages of development.[494] Additional programs to support industrial biotechnology are available through Advanced Research Projects Agency-Energy in the Department of Energy. This initiative was created in 2007 to conduct energy research that is at too early of a stage to be considered viable for private-sector development.[495] A primary element of the Agency's mission is to transfer its discoveries to the private sector for commercialization and the Agency maintains a Tech-to-Market program that determines the best way for each project to be developed in the private sector.[496] The Department of Energy and the USDA jointly manage the Plant Feedstock Genomics for Bioenergy program. The program supports research that aims to improve biomass feedstocks for bioenergy purposes.[497] In 2014 the program providing funding to ten different projects including USD1.3 million to discover genetic differences that effect bioenergy yields from sorghum and USD1.4 million to further understand how to control the growth of poplar.[498]

The table on the following page provides an overview of the policy strengths and weaknesses for the three major biotechnology sectors (biopharmaceutical, ag-bio and industrial biotechnology) under each enabling factor.

TABLE 15 US: Policy strengths and weaknesses, biotechnology sector by sector and key enabling factors

	Biopharmaceutical	Ag-bio	Industrial biotechnology
Human capital and Infrastructure for R&D	• Top life sciences universities in the world • World's highest total of clinical trials • High total biopharmaceutical R&D	• Biggest producer of ag-bio crops in the world	• Industrial biotech a large part of national output • Bioenergy invested in since mid-2000s
Intellectual property protection	• Strong IP environment • RDP available • PTE available • Uncertainties over patentability of basic biotech inventions e.g. 2013 Molecular Pathology v Myriad Genetics and 2012 Prometheus Laboratories, Inc v Mayo Collaborative Services	• Plant variety protection in place • Member of UPOV	• Strong trade secret protection
The regulatory environment and Technology transfer frameworks	• Strong and highly regarded biopharmaceutical regulatory environment • High levels of technology transfer and commercialization • Life sciences licensing accounts for majority of university licensing income	• Coordinated Framework for Regulation of Biotechnology viewed as successful in promoting biotech sector • Long processing times at USDA	• Biofuels supported through fuel mandates
Market and commercial incentives	• Relatively free market for pricing of pharmaceuticals	• R&D tax credits not permanent; currently expired	• Tax credits available for biofuels at State level

6 COMPARING PERFORMANCE

Creating an environment that promotes creativity, innovation and actual real-life economic gains is not an easy task regardless which sector or industry it is. It requires sustained investment, the right polices and persistence.

This edition of *Building the Bioeconomy* features a new component: a Biotech Policy Performance Measure. This tool (the "Measure") provides readers a quick overview of a given economy's policy framework and performance in relation to the other economies sampled. The Measure includes some of the most important elements for each enabling factor described above in section 3. To recap the seven enabling factors are:

1. Human capital;
2. Infrastructure for R&D;
3. Intellectual property protection;
4. The regulatory environment;
5. Technology transfer frameworks;
6. Market and commercial incentives; and
7. Legal certainty (including the rule of law).

The purpose of the Measure is not to 'score' or benchmark individual economies to a pre-determined set of criteria. Rather, the purpose of this tool is to give readers (and the economies mapped) an idea of how a sample of their policies (including inputs and outputs) for each enabling factor compares with the same policy input or output for the other economies sampled.

The following subsections describes how the Measures is constructed, the methodology behind the Measure, the indicators included and classification system.

6.1 Building a policy performance measure

Measuring and comparing policy performance can be done in several ways with indices and surveys being two of the most commonly used tools for comparing and measuring performance in a given area.

Indices are highly acceptable statistical models that aim to benchmark performance against a predetermined standard; whether it be of an economic, political, legal, scientific, social or other nature. Significantly, an index is predetermined – the creator of the index determines the best practice or standard, and then evaluates performance vis-à-vis this standard and assigns an overall score. As such, an index constitutes a "top-down" approach to benchmarking the performance of a set of variables, whether it is in a country or otherwise. Different indices are based on varying sets of criteria and methodologies. For example, the three most common types of indices used in academic and international benchmarking exercises are: binary; ordinal; and numerical. Binary indices seek to measure or gauge the existence of a particular criteria or indicator. Ordinal indices provide a scale or value such as "good", "average" or "bad". Numerical indices, on the other hand, provide a number and imply a mathematical relationship between scores.

As mentioned, in addition to indices a commonly used method of measuring or gauging performance are surveys. A highly accepted model in statistics and the social sciences, targeted surveys asks experts and professionals about their specific views and experience of the subject matter or situation under analysis. Surveys seek to examine how a particular input or factor works (or does not work) according to the person being surveyed. For example, a survey question might ask what is the experience of person x with regard to factor or criteria y. Together the responses to the survey provide an overview of trends and perceptions of a set of variables.

The two different models can be summarised thus: indices try to have consistent measurement of pre-defined criteria, while surveys are trying to gauge perceptions.

Each methodology has strengths and limitations. For the purposes of the Biotech Policy Performance Measure the methodology used is built on an index model. However, as noted above while some of the methodological aspects of the

TABLE 16 Biotech Policy Performance Measure, indicators used per enabling factor

Factor 1: Human capital
1. No of researchers per capita compared to sample average
2. % of population in tertiary education compared to sample average
Factor 2: Infrastructure for R&D
3. R&D spending % of GDP
4. Clinical trials per capita compared to sample average
Factor 3: Intellectual property protection
5. Availability of RDP
6. Availability of PTE
Factor 4: The regulatory environment
7. Existence of regulatory framework and efficiency
Factor 5: Technology transfer frameworks
8. Frameworks in place
Factor 6: Market and commercial incentives
9. P&R policies
Factor 7: Legal certainty (including the rule of law)
10. World Justice Project 2014 Rule of Law Index ranking

Measure are based on standard index models, the Measure does not benchmark or 'score' economies vis-à-vis a predetermined standard. Instead, economies are compared to each other and their relative policy performance.

6.2 Indicators included

The Measure consists of 10 indicators in total – 5 quantitative and 5 qualitative – from all 7 enabling factors detailed above in section 3. The below table shows the indicators for each of the 7 enabling factors.

The indicators in factors 1, 2 and 7 are quantitative measuring key elements of a given economy's policy framework as it relates to the human capital, R&D infrastructure and its legal environment. Indicators in factors 3, 4, 5 and 6 are more qualitative in nature assessing the policy environment for a given indicator. All indicators (quantitative and qualitative) are based on the information and data collected, analysed and presented in this report and the accompanying Annex.

6.3 Classification system

Each country's performance is classified according to three categories of classification of a given enabling factor and indicator:

1. Attractive
2. Mixed
3. Challenging

Quantitative indicators compare economies to one another based on relative performance. The top third of the economy sample is classified as "Attractive". The middle third of the economy sample "Mixed". And, finally, the lower third of the economy sample is classified as "Challenging". Based on the discussion in section 3 on the desirability and necessity of each of the 7 enabling factors to stimulate innovation in the biotechnology sector economies with higher levels of the measured indicators (for instance, R&D spending) translates into a higher classification. Economies that are in the highest third relative to the economy sample thus receive a classification of "Attractive".

Qualitative indicators are based on a normative assessment of the desirability of the remaining enabling factors. For example, for Enabling Factor 3: Intellectual Property Protection, the availability of such IPRs as regulatory data protection and patent term restoration are viewed as attractive. Similarly, the indicator included in Enabling Factor 4: The Regulatory Environment examines the existence and efficiency of the regulatory structure in a given country. This incudes, for instance, the speed of market authorization for biotechnology products; patent office backlogs; the existence and efficiency of an ag-bio framework; the existence of a biosimilars pathway; and other key regulatory elements discussed in this report and accompanying Annex.

6.4 Calculations

For enabling factors for which there is more than one indicator (enabling factors 1 and 2) the overall classification for this factor is calculated based on the average position of a given economy relative to other economies in the two indicators for each factor. For example, Enabling Factor 1: Human Capital, includes two indicators:

i) number of researchers per capita; and

ii) the percentage of population in tertiary education.

For each indicator economies are grouped according to performance relative to the other sampled economies in the report. Based on their relative performance economies are grouped into thirds. To reach an overall classification for the enabling factor the average grouping/ classification is calculated which equals the final classification of a given economy.

6.5 The Biotech Policy Performance Measure: Overall results

The table on the following two pages shows the overall results.

Overall the results show the great variety between economies as well as for each enabling factor for a given economy. For instance, economies can have quite attractive policies and frameworks in place for some enabling factors yet face more significant challenges in other areas.

The results of the Biotech Policy Performance Measure need to be viewed within the context of the enabling factors outlined in section 3 and the information and data collected for each individual country in section 5 and the accompanying Annex. The following section provides a holistic assessment of all the data and evidence presented in preceding sections and the Annex, tying together all the pieces and sections of this report into an overall set of conclusions and findings about the state of the bioeconomy in 2015.

	Brazil	China	India	Korea	Malaysia	Mexico	Russia
Factor 1: Human capital							
No of researchers per capita (million population)	710	1020	160	5928	1642	386	3096
% of population in tertiary education	0.13	0.04	N/A	0.4	0.05	0.18	0.53
Performance compared to Sample	**Challenging**	**Challenging**	**Challenging**	**Attractive**	**Mixed**	**Mixed**	**Attractive**
Factor 2: Infrastructure for R&D							
R&D spending % of GDP	1.21	1.98	0.76	4.36	1.07	0.43	1.12
Clinical trials per capita	20.08665605	3.9398228	2.009078952	112.4663863	14.27980132	18.21854186	19.21017825
Performance compared to Sample	**Mixed**	**Mixed**	**Challenging**	**Attractive**	**Challenging**	**Challenging**	**Mixed**
Factor 3: Intellectual property protection							
RDP	Challenging	Challenging	Challenging	Attractive	Challenging	Challenging	Challenging
PTE	Challenging	Challenging	Challenging	Attractive	Challenging	Challenging	Attractive
Performance compared to Sample	**Challenging**	**Challenging**	**Challenging**	**Attractive**	**Challenging**	**Challenging**	**Mixed**
Factor 4: The regulatory environment							
Existence of regulatory framework and efficiency	**Challenging**	**Challenging**	**Challenging**	**Attractive**	**Challenging**	**Mixed**	**Challenging**
Factor 5: Technology transfer frameworks							
Frameworks in place	**Mixed**	**Attractive**	**Challenging**	**Attractive**	**Challenging**	**Challenging**	**Challenging**
Factor 6: Market and commercial incentives							
P&R policies	**Challenging**	**Challenging**	**Challenging**	**Challenging**	**Challenging**	**Challenging**	**Challenging**
Factor 7: Legal certainty (including the rule of law)							
RoL index ranking	42	76	66	14	35	79	80
Performance compared to Sample	**Mixed**	**Challenging**	**Challenging**	**Attractive**	**Mixed**	**Challenging**	**Challenging**

	South Africa	Singapore	Switzerland	Turkey	UK	US
Factor 1: Human capital						
No of researchers per capita (million population)	363	6437	5500	987	4042	3978
% of population in tertiary education	0.06	N/A	0.35	0.15	0.41	0.42
Performance compared to Sample	**Challenging**	**Attractive**	**Attractive/ Mixed**	**Mixed**	**Attractive/ Mixed**	**Attractive/ Mixed**
Factor 2: Infrastructure for R&D						
R&D spending % of GDP	0.76	2.23	2.87	0.86	1.77	2.79
Clinical trials per capita	36.14435091	245.9623648	445.2940239	21.11706151	149.0663077	251.1714383
Performance compared to Sample	**Challenging**	**Attractive**	**Attractive**	**Mixed**	**Mixed**	**Attractive**
Factor 3: Intellectual property protection						
RDP	Challenging	Attractive	Attractive	Challenging	Attractive	Attractive
PTE	Challenging	Attractive	Attractive	Challenging	Attractive	Attractive
Performance compared to Sample	**Challenging**	**Attractive**	**Attractive**	**Challenging**	**Attractive**	**Attractive**
Factor 4: The regulatory environment						
Existence of regulatory framework and efficiency	**Challenging**	**Attractive**	**Mixed/ Attractive**	**Challenging**	**Attractive**	**Attractive**
Factor 5: Technology transfer frameworks						
Frameworks in place	**Mixed**	**Attractive**	**Attractive**	**Mixed**	**Attractive**	**Attractive**
Factor 6: Market and commercial incentives						
P&R policies	**Challenging**	**Mixed**	**Mixed**	**Challenging**	**Mixed**	**Attractive**
Factor 7: Legal certainty (including the rule of law)						
RoL index ranking	40	10	N/A	59	13	19
Performance compared to Sample	**Mixed**	**Attractive**	**N/A**	**Mixed**	**Attractive**	**Attractive**

7 THE STATE OF THE GLOBAL BIOECONOMY 2015

The purpose of this report has been to map and assess the state of the bioeconomy in some of the world's biggest and most important economies. Building on the methodology of the first edition of *Building the Bioeconomy* this report used the same seven enabling factors of biotechnology innovation as a guide to map each individual economy's biotech ecosystem.

As was discussed in section 3, while encouraging innovation and building a biotech capacity is not an exact science, and different economies will have different needs, these enabling factors provide a set of principles and areas of public policy governments and officials can take action and expect a positive outcome. Human capital; adequate R&D infrastructure; strong and targeted IP protection; transparent and effective regulations and administration; a technology transfer framework that encourages innovation, the translation of R&D into actual products and full commercialization; and a predictable and stable legal environment – these are all key factors and enablers of general and biotechnology-specific innovation.

Having increased the number of sampled economies by three-quarters from eight to thirteen, *Building the Bioeconomy 2015* now includes coverage of all the BRIC economies as well as some of the most important emerging markets in the world: Malaysia, Turkey, South Africa and Mexico. This is in addition to the developed, high income economies included such as the US, UK and Switzerland.

On top of increasing the number of economies mapped this report introduced a more focused sector specific analysis looking at the three main biotech sectors: biopharmaceuticals; ag-bio; and industrial biotechnology. While all the enabling factors are relevant for the different sectors of biotechnology, each sector also has different, specific policy needs. The evidence gathered from the economies surveyed in this report and the accompanying Annex show just how important it is to have the right policy in place for the right sector.

Finally, this edition of *Building the Bioeconomy* includes a new performance metric: a Biotech Policy Performance Measure. As described, the reason that this metric was designed and included in this edition was not to 'score' or benchmark individual economies to a pre-determined set of criteria. Scores and indices measuring the performance of a given economy to an international benchmark already exist. The annual *Scientific American Worldview Scorecard* provides an excellent benchmark and measure of where a given economy's national biotechnology environment is in relation to international best practices. Rather, the purpose of this tool is to give readers (and the economies sampled) an idea of how a sample of their policies (including inputs and outputs) for each enabling factor compares with the same policy input or output for the other economies sampled.

Together, the mapping of the thirteen sampled economies using the seven enabling factors detailed above in section 5 and the accompanying Annex; the sector-by-sector discussion and focus; and finally the measuring of performance through the Biotech Policy Performance Measure provides a wealth of data and information. The following sub-section synthesizes this data, offers an explanation and some conclusions as to what it all means for biotechnology innovation in 2015.

7.1 Lessons in enabling biotechnology innovation

Having almost doubled the number of economies surveyed from eight to thirteen this edition finds that while challenges abound the proverbial global glass of biotech innovation is more half full than half empty. All economies surveyed in this edition clearly aspire to become global leaders in biotechnology. And while some have been more successful than others, all economies have made progress towards their goals.

The main findings of this report and the accompanying Annex can be grouped around four of the seven enabling factors. Like the first edition of *Building the Bioeconomy* this report finds that while each economy surveyed is different and the state of each economy's biotechnological development is unique, all economies surveyed recognize the prominent place biotechnologies will play in the 21st century. Most recognize the value and necessity of human capital and investing in adequate infrastructure. As mentioned, the recently published biotechnology strategy document by the Government of South Africa referred to and frankly discussed the need for investing in human capital as a fundamental building block for developing a strong biotech capacity. Similarly, many economies are investing in state-of-the art R&D infrastructure facilities through private-public partnerships or through public funding. Brazil's PDPs targeting biopharmaceuticals are an example of this.

Yet it is also clear that while all economies wish to develop and encourage a vibrant bioeconomy, a number of policy gaps exist. Using the seven enabling factors and the Biotech Policy Performance Measure it is clear that enabling factors 3, 4, 5 and 6 relating to the protection of intellectual property, the regulatory environment, introduction of technology transfer frameworks and presence of market and commercial incentives, were the enabling factors where many economies consistently faced a challenging environment. The policy challenges and gaps for each of these factors is discussed separately below.

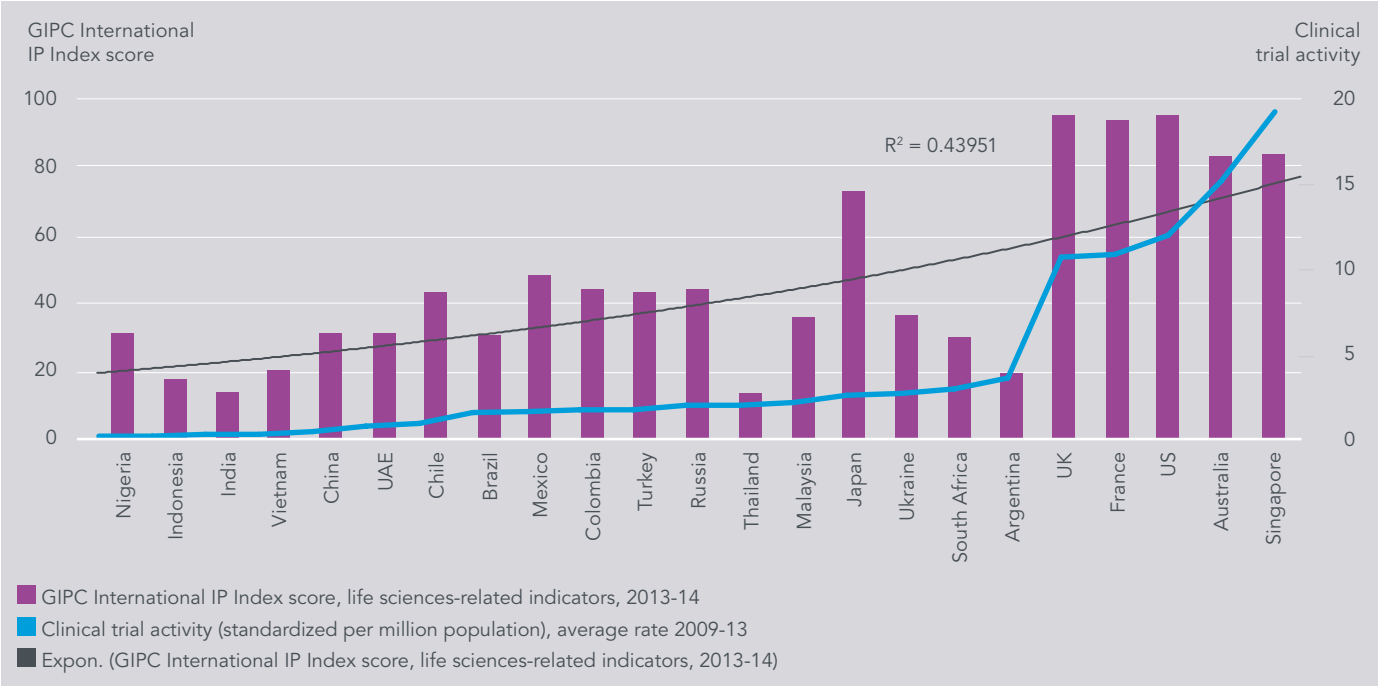
Enabling factor 3: Intellectual property protection

Out of the thirteen countries sampled only the high income economies (the US, UK, Singapore, Switzerland and Korea) were found to have in place strong biopharmaceutical IPRs. In the other economies challenges abound with the IPRs sampled either not being in place at all or, if on the books, significantly weakened by lack of practical availability and/or implementation. The lack of clear and strong policies in some enabling factors is more damaging than others. The protection of IP is perhaps the best examples for this.

As outlined in section 3, offering strong protection for IP and incentives for the creation of IP as an asset tends to produce significant economic gains. Economies in which the creation and commercialization of IP is protected and encouraged tend to see higher levels of FDI, technology transfer and economic activity, particularly in high tech areas such as biopharmaceutical R&D.[499] Both case study and broader analysis supports this assertion.

Statistical modelling on the drivers of biomedical research looking at clinical trial activity in a sample of some of the most important developed and emerging economies in the world suggest that protecting IP correlates more strongly with levels of clinical research than health infrastructure or overall expenditure. Comparing levels of clinical research with strength of the protection of and enforcement of life sciences related IP rights research has found that the clinical trial activity in 25 developed and developing countries is better explained by the level of a given economy's R&D spending and IP protection than by the number of hospital beds or investment in health.[500] The results suggest that the stronger a country's IP environment, the more clinical trial activity it tends to experience. For instance, in countries scoring above 60% of the 2015 GIPC International IP Index's life science-related indicators' total score it was found that 8 times out of 10 they host between 10 and 20 clinical trials per million population, while all countries scoring below 60% of the Index experience 4 trials per million population or fewer. The figure on the following page shows the results of this study for the 25 countries sampled.

FIGURE 2 Association between the level of IP protection and clinical trial activity



While other enabling factors such as the presence of trained and skilled clinicians, relevant hospital and laboratory infrastructure are of critical importance to encouraging clinical research activities, as this evidence strongly suggests, offering relevant protection for biopharmaceutical IP is not to be neglected.

A good, concrete case study example of this is the case of Singapore. In a relatively short space of time the island-state has built a world-class hub of biopharmaceutical and biomedical innovation. As detailed above and in the accompanying Annex, Singapore is now a major international host of cutting edge clinical research with, on a per capita basis, some of the highest rates of clinical trials in the world. Crucially, following the introduction of stronger and targeted biopharmaceutical IPRs in the late 1990s (following the free trade agreement between Singapore and the US) levels of biomedical research and investment into Singapore surged over an eight-year period from less than SGD30 million to close to SGD300 million.[501]

Enabling factor 4: The regulatory environment and Enabling factor 6: Market and commercial incentives

One of the central findings of *Building the Bioeconomy 2015* is that long regulatory delays in processing of market authorization and/or patent applications (for biopharmaceutical as well as ag-bio products) is pervasive not only in emerging markets such as Brazil and Turkey, but also in high-income developed markets such as the US where the FDA and USDA have been criticised for excessive delays.

Similarly, the pricing and reimbursement of biopharmaceuticals presented real challenges in virtually all economies included in the sample. The economies that had the least restrictive environments (the US, UK, Singapore and to some extent Switzerland) are also those economies in which, generally speaking, new medicines are created, clinical research takes place, and new products reach patients the fastest. This final point is of real significance as it shows the tangible benefits to local patients of an improved P&R environment for biopharmaceutical R&D.

For example, 2014 data published by IMS Health shows how economies that have high levels of biopharmaceutical research and less restrictive P&R environments, also tend to see higher numbers of new medicines launched. This is particularly the case for complex disease areas such as oncology.[502] Of the economies included in the IMS data which are also included in this year's edition of *Building the Bioeconomy* the US and UK saw the greatest number of new product launches. Out of a total of 154 new NMEs introduced between 2008-12, 104 were on the US market by 2013 and 78 in the UK. Similarly, for oncology products, 41 new products were launched globally between 2008-12; by 2013 31 of those products were on the US market with the UK seeing 24 launches. Conversely, looking, for instance, at Korea which, on the whole, is a biotechnology success story but has a very challenging biopharmaceutical P&R environment, during the same time period it saw 45 products launched of the total 154 new products introduced and only 10 of the 41 new oncology products. Finally, perhaps the most important take-away with regards to many of the biggest emerging economies (including India, China, Brazil and Russia) is that despite their huge market size and inherent attractiveness because they too tend to see fewer launches of new products in aggregate as well as in complex disease areas.[503] The difficult P&R and regulatory environment are part of this.

Enabling factor 5: Technology transfer frameworks

The availability and functioning of technology transfer frameworks is a critical component of encouraging, on the one hand, the development of IP assets to begin with but then, on the other, the smooth and actual commercialization of these assets. In an encouraging sign more and more economies are recognizing that research that sits on the shelf at a university or a PRO does not contribute to or help develop the next life-saving medicine or seed technology. For example, in the Indian Government's 2014 National Biotechnology Strategy there was a clear focus on the translational and developmental elements of biotech R&D.[504] Out of the 10 guiding principles identified in the Strategy, four related to translating R&D into tangible products and services and the targeting of areas of need in the Indian bioeconomy.[505] Indeed, positive steps have been taken in a number of economies to emulate the success of others in incentivizing public researchers and publicly funded research to focus on commercialization.

Yet challenges remain. A number of economies either do not have a technology transfer framework in place or, if they do, also have in place significant hurdles and barriers to commercialization. Of the thirteen economies included and measured in the Biotech Policy Performance Measure over half, seven, were graded as having a "Mixed" or "Challenging" environment. For example, in Brazil there are regulatory and formal requirements in place that limit the attractiveness of licensing. To become effective and binding on third parties licensing agreements must be published in the INPI's *Official Gazette*.[506] Agreements must also be approved by INPI. There are also limitations on fees and payments between the contracting parties. Exclusive licensing agreements are also subject to more onerous publication requirements than non-exclusive licenses making this process more time-consuming.[507] As described in section 5 and in the Annex, Brazil also has correspondingly low levels of technology transfer and translation of public research into commercial products.[508]

Final thoughts

Building a bioeconomy is not easy. No two economies are exactly the same and promoting innovation is not an exact science. Technological, economic, societal and political variables change and differ from one corner of the world to another. Nevertheless, the evidence and research conducted in this report show that policies that target and work within the seven enabling factors identified (and in particular the four factors discussed above) are likely to lead to positive and sustained results.

NOTES

[1] D Moraes (2014), "Para Meir Pugatch, Brasil terá benefícios econômicos e sociais com a biotecnologia", FIESP, April 28 2014.
[2] World Bank (2015), "Country and Lending Groups", (Accessed March 2015): http://data.worldbank.org/about/country-and-lending-groups
[3] Ibid.
[4] KO Fuglie et al (2011), *Research Investments and Market Structure in the Food Processing, Agricultural Input, and Biofuel Industries Worldwide*. ERR-130. US Dept. of Agriculture, Econ. Res. Serv. December 2011, p 134.
[5] Ibid.
[6] Ibid. p. 58.
[7] JA DiMasi et al (2003). "The price of innovation: new estimates of drug development costs." *Journal of health economics* 22.2 (2003): 151-185.
[8] D Mestre-Ferrandiz et al (2012), "The R&D cost of a new medicine." London: Office of Health Economics p. v.
[9] Ibid.
[10] WHO (2006), "The pharmaceutical industry in Europe, key data", PowerPoint
[11] Thomson Reuters (2012), "The Pharmaceutical Supply Chain", August 2 2012.
[12] BIO (2010), "How do Drugs and Biologics Differ?", November 10 2010.
[13] Ibid.
[14] K Hamer (2010), "Biotech Outsourcing Strategies cmc—Biologics stream", Meeting Report, mAbs 2:5, 461-465; September/October 2010; Landes Bioscience, pp. 462-3.
[15] Innovation infrastructure includes all of the items and policies that, together, encourage or discourage innovation such as regional or national pools of scientists and engineers; excellence in basic research; protection of intellectual property; tax-based incentives; anti-trust enforcement that encourages innovation-based competition; and an economy's relative openness.
[16] OECD (2006), *Innovation in Pharmaceutical Biotechnology: Comparing National Innovation Systems at the Sectoral Level*, Paris: OECD, 2006, p.171
[17] National Science Foundation (2014), *Science and Engineering Indicators 2014*, Washington DC 2014, chapters 2-4.
[18] Schneider, L. et Al. (2010). "Innovation and Skills From a Sectoral Perspective: A Linked Employer-Employee Analysis", *Economics of Innovation and New Technology*, Vol. 19, Issue 2, pp. 185-202.
[19] OECD (2014), pp. 90-1.
[20] W.G. Park and D. Lippoldt (2003) *The Impact of Trade-Related Intellectual Property Rights on Trade and Foreign Direct Investment in Developing Countries*, OECD publishing.
[21] Ibid.
[22] A. Léger (2006), "Intellectual Property Rights and Innovation in Developing Countries: Evidence from Panel Data," Proceedings of the German Development Economics Conference, Berlin.
[23] R. Cavazos et al, (2010), *Policy Complements to the Strengthening of IPRS in Developing Countries*, OECD Trade Policy Working Papers, No. 104, OECD Publishing.
[24] N.D. Pham (2011), *Employment and Gross Output of Intellectual Property Companies in the United States, GIPC*, Washington D.C.
[25] D Torstensson & M Pugatch (2010), *Keeping Medicines Safe – A Study of the Regulations Guiding the Approval of Medicines in Emerging Markets*, Stockholm Network London
[26] T Wilsdon et al (2012), *Policies that encourage innovation in middle-income countries*, CRA, pp. 60-2.
[27] L Pressman et al (2012), *The Economic Contribution of University/Nonprofit Inventions in the United States: 1996-2010: Measures of Economic Impact of Licensed Inventions Commercialized by Licensees of US Respondents to the AUTM Survey 1996-2010*, BIO 2012, p. 3.
[28] Ibid.
[29] AUTM (2014), "Highlights of AUTM's US Licensing Activity Survey FY2013", AUTM 2014, p. 4.
[30] M. Kyle (2007), "Pharmaceutical price controls and entry strategies", *Review of Economics and Statistics*, Vol. 89, No. 1, February 2007, pp. 88-99
[31] Heritage Foundation (2013), *2013 Index of Economic Freedom*, chapters 2 and 6.
[32] M. Brilliant (2013), "Good Business Demands Good Governance", in *Index of Economic Freedom 2013*, Heritage Foundation.
[33] T Wilsdon et al (2012), pp. 51-52
[34] R. C. DeVol et al (2011). "The Global Biomedical Industry: Preserving US Leadership", *Milken Institute*, September 2011, pp. 21-25.
[35] Ibid., p. 22. See also: Jones Lang Lasalle, (2012). *Life Sciences Cluster Report*, http://www.jll.co.il/Documents/life_science_report/pdf/Life-Sciences-Cluster-Report-Global-2012.pdf.
[36] OECD (2006), p. 167.
[37] Pugatch Consilium, (2014). *Scaling Up Global Clinical Trial Activity: Key Trends and Policy Lessons*, October 2014, p. 33.
[38] H. Lim & L. Tai Wei (2010). "Sustainable Development Impacts of Investment Incentives: A Case Study of the Pharmaceutical Industry in Singapore", *International Institute for Sustainable Development*, p. 6.
[39] DeVol et al (2011). p. 22.
[40] M Pugatch et al (2012), *Taking Stock: How Global Biotechnology Benefits from Intellectual Property Rights, The contribution of IPRs to the biotechnology ecosystem and economic growth in developed and emerging economies: examining the literature and evidence*, BIO 2012.
[41] A. Kesselheim, (2010), "Using Market-Exclusivity Incentives to Promote Pharmaceutical Innovation", *New England Journal of Medicine*, Vol.363, No.19 pp.1855-1862
[42] E Mansfield (1986), "Patents and Innovation: An Empirical Study", *Management Science*, (February, 1986), pp. 173-181
[43] Torstensson & Pugatch (2010)
[44] USDA, Plant and Animal Health Inspection Service, Regulations (Accessed March 2014): http://www.aphis.usda.gov/wps/portal/aphis/ourfocus/biotechnology?1dmy&urile=wcm%3apath%3a%2FAPHIS_Content_Library%2FSA_Our_Focus%2FSA_Biotechnology%2FSA_Regulations
[45] World Health Organization. (2002). T*he Importance of Pharmacovigilance: Safety Monitoring of Medicinal Products*, Geneva.
[46] FDA, FDA's International Posts: Improving the Safety of Imported Food and Medical Products, (Accessed March 2015): http://www.fda.gov/forconsumers/consumerupdates/ucm185769.htm
See also the international cooperation agreement and pilot API inspection program between European regulators, the FDA and Australian drug regulatory authorities. EMA et al (2011), "Final report on the International API inspection Pilot Programme", 16 June 2011, EMA/453741/2011.
[47] See for example: OECD, (2004). *Public-Private Partnerships for Research and Innovation: An Evaluation of the Dutch Experience*, Paris.
[48] PriceWaterhouseCoopers, (2005). *Delivering The PPP Promise: A Review of PPP Issues and Activity*, pp. 13-26.
[49] V. Loise & A.J. Stevens (2010). "The Bayh-Dole Act Turns 30", *Les Nouvelles*, December 2010, pp. 185-186, http://www.bu.edu/otd/files/2011/02/The_Bayh-Dole_Act_Turns_30.pdf.
[50] USPTO, (2006), Technology Profile Report: Patenting Examining Technology Center Groups 1630-1660, Biotechnology, Washington, 2006
[51] *The Economist* (2002), "Innovation's Golden Goose", Technology Quarterly Section, p. 3. December 14, 2002
[52] OECD, (2003), *Turning Science into Business – Patenting and Licensing at Public Research Organisations*, Paris.
[53] World Bank Institute, (2012). *Public-Private Partnerships: Reference Guide*, pp. 60-120; See also PriceWaterhouseCoopers, (2005), p. 65.
[54] The Economist (2014), "Fever rising", February 15 2014
[55] Heritage Foundation (2013), *2013 Index of Economic Freedom*, chapters 2 and 6.
[56] WHO (2006)
[57] Folha de S. Paulo (2014), "Grupo lanca iniciativa para fomentar testes clinicos no Brasil", April 10 2014 (Accessed February 2015): http://www1.folha.uol.com.br/ciencia/2014/04/1438426-grupo-lanca-iniciativa-para-fomentar-testes-clinicos-no-brasil.shtml
See also T Wilsdon et al (2012), p. 60.
[58] Pharma Focus.net (2012), "Turkey: East, West and Profits!", special report October 2012, p. S7.
[59] ISSA (2014), "Brief 46-2013: Executive Summary", p. 2.
[60] Ibid.
[61] D Lynch and D Vogel (2001), "The Regulation of GMOs in Europe and the United States: A Case-Study of Contemporary European Regulatory Politics", *Council on Foreign Relations*, April 5 2001.
[62] Ibid.
[63] ISSA (2014), p. 2.
[64] Ibid.
[65] UNCTAD (2014), *The State of the Biofuels Market*, United Nations 2014, p. 9.
[66] BP (2014), *BP Statistical Review of World Energy*, June 2014, p. 39.
[67] UNCTAD (2014), p. 10.
[68] BP (2014), p. 39.
[69] Ibid.
[70] World Bank (2014), "Gross domestic product 2013, PPP", Last updated December 16 2014, (Accessed February 2015): http://data.worldbank.org/data-catalog/GDP-PPP-based-table
[71] ISAAA (2014), p. 2.
[72] *Scientific American Worldview (2014)*, New York, p. 48-9.
[73] Ibid.
[74] World Bank (2014), "Gross domestic product 2013, PPP"
[75] World Bank, Data bank, GDP per capita (current USD), Brazil
[76] World Economic Forum (2014), *The Global Competitiveness Index 2014–2015*, p. 13.
[77] Ministério da Ciência, Tecnologia e Inovação (MCTI) (2014), "Projeto de lei define novas regras para acesso ao patrimônio genético", June 20 2014, (Accessed February 2015): http://www.mct.gov.br/index.php/content/view/355175.html
[78] Câmara Notícias (2015), "Câmara aprova projeto que simplifica pesquisas com biodiversidade", February 10 2015, Brazilian Congress, (Accessed February 2015): http://www2.camara.leg.br/camaranoticias/noticias/POLITICA/481678-CAMARA-APROVA-PROJETO-QUE-SIMPLIFICA-PESQUISAS-COM-BIODIVERSIDADE.html
[79] Ministry of Health, "ORDINANCE No. 2.531, FROM NOVEMBER 12, 2014", Translated into English and published by Licks Attorneys, Rio de Janiero, Brazil. Accessed through "BRIC Wall" legal blog, (Accessed February 2015): https://bricwallblog.wordpress.com/2014/12/22/a-new-list-of-strategic-products-creates-opportunities-for-companies-in-brazil/
[80] L Mueller and R Rodrigues (2014), "Brazil: An Update of the Most Relevant Events for Pharmaceutical Companies in 2014: Part 3 of a 5-Part Series",

BRIC Wall blog, November 28 2014, (Accessed February 2015): https://bricwallblog.wordpress.com/2014/11/28/brazil-an-update-of-the-most-relevant-events-for-pharmaceutical-companies-in-2014-part-3-of-a-5-part-series/

[81] Finep, A Empresa (Accessed February 2015): http://www.finep.gov.br/pagina.asp?pag=institucional_empresa

[82] *Science and Development Network* (2006), "Brazil's innovation law: lessons for Latin America", August 3 2006.

[83] Brasil Maior, Inicio / O Plano / Dimensão Setorial, (Accessed February 2015): http://www.brasilmaior.mdic.gov.br/conteudo/153

[84] C Soccol (2005), "Brazilian biofuel program: an overview", *Journal of Scientific and Industrial Research*, Vol 64, Nov 2005, pp. 897-904.

[85] DECRETO N° 6.041, DE 8 DE FEVEREIRO DE 2007

[86] E Kimball (2014), "Brazil: Opportunities and Challenges in Latin America's Largest Pharmaceutical Market", Thomson Reuters, July 10 2014.

[87] Torstensson and Pugatch (2010), p. 35.

[88] Ibid. pp. 34-5.

[89] thepharmaletter (2013), "BNDES invests 804 million real in Novartis' new Brazil biotechnology unit", December 7 2013.

[90] BNDES, Press Room, News, "BNDES approves R$ 250 million for a factory to produce biopharmaceuticals against cancer", March 19 2014.

[91] BNDES, Press Room, News, "BNDES renews Profarma and expands support to biotechnology", November 4 2011.

[92] Ibid.

[93] R. Rezaie et al (2008), "Brazilian health biotech—fostering crosstalk between public and private sectors", *Nature Biotechnology*, VOLUME 26 NUMBER 6 JUNE 2008

[94] FINEP, Inovar: http://www.finep.gov.br/pagina.asp?pag=inovar

[95] BiotechNOW, (2014), "Biotech Market in Brazil is Booming!", (Accessed February 2015): http://www.biotech-now.org/events/2014/06/biotech-market-in-brazil-is-booming

[96] Clinicaltrials.gov, Home, Find Studies, See Studies on a Map, (Accessed March 2015): http://www.clinicaltrials.gov/ct2/search/map?map=SA

[97] Pugatch Consilium (2014), p. 25.

[98] EMBRAPA, Get to know us, (Accessed April 2015): https://www.embrapa.br/en/quem-somos

[99] Ibid.

[100] P Correa and C Schmidt (2014), "Public Research Organizations and Agricultural Development in Brazil: How Did Embrapa Get It Right?", *Economic Premise*, World Bank June 2014, Number 145, p. 1.

[101] BASF, EMBRAPA (2010), "BASF and Embrapa's Cultivance® soybeans receive approval for commercial cultivation in Brazil", Joint Press Release, February 5, 2010.

[102] BNDES, Press Room, News, "BNDES and FINEP Launch a R$1.48 bn program to encourage innovation in the sugar-based ethanol sector", March 17 2014

[103] Ibid

[104] Ibid

[105] Biodiesel Magazine, Brazil Ups Biodiesel Mandate to 7 percent Starting November, June 2 2014, (Accessed February 2015): http://www.biodieselmagazine.com/articles/95020/brazil-ups-biodiesel-mandate-to-7-percent-starting-november

[106] World Bank (2014)

[107] World Bank, Data bank, GDP per capita (current US$), China

[108] World Economic Forum (2014), p. 13.

[109] Ministry of Finance, "REPORT ON THE IMPLEMENTATION OF THE CENTRAL AND LOCAL BUDGETS FOR 2014 AND ON THE DRAFT CENTRAL AND LOCAL BUDGETS FOR 2015", Third Session of the Twelfth National People's Congress March 5, 20 15, p. 25. Translated copy published via *Wall Street Journal*, "China NPC 2015: The Reports", March 5 2015, (Accessed April 2015): http://blogs.wsj.com/chinarealtime/2015/03/05/china-npc-2015-the-reports/

[110] J Qiu (2014), "China goes back to basics on research funding", *Nature News*, March 11 2014.

[111] OECD (2012), OECD Science, *Technology and Industry Outlook 2012*, OECD Publishing China chapter, p. 264.

[112] M. Schaaper (2009), *Measuring China's Innovation System*, OECD Science, Technology and Industry Working Papers 2009/01, p. 3.

[113] Xinhuanet, "China holds meeting on 13th five-year plan", September 4 2014; Xinhuanet, "China's five-year plan to boost environment protection", April 23 2014; and Z Chun et al, "Green sector will boom during China's 13th Five-Year Plan", March 9 2014, chinadialogue.net.

[114] People's Republic of China, 12th Five Year Plan, English translation, British Chamber China, chapter 10, s 2.

[115] L. Qiu et al (2014). Public funding and private investment for R&D: a survey in China's pharmaceutical industry. *Health Research Policy and Systems*, 12, 27. doi:10.1186/1478-4505-12-27

[116] Ibid.

[117] Ibid

[118] State Biotech & Pharmaceutical Industrial Base (Shanghai), Property & Services – Incubators, (Accessed February 2015): http://www.zjbpb.com/webe/Facilities1.asp?Code=1201&UpperCode=12

[119] Ibid.

[120] Ibid.

[121] R Atkinson et al (2012), *Leadership in Decline, Assessing US International Competitiveness in Biomedical Research*, The Information Technology and Innovation Foundation and United for Medical Research, May 2012, p. 10.

[122] Pugatch Consilium (2014), p. 25.

[123] MIT Technology Review, China's GMO Stockpiles, October 21 2014, (Accessed February 2015): http://www.technologyreview.com/featuredstory/531721/chinas-gmo-stockpile/

[124] USDA Foreign Agricultural Service, Agricultural Biotechnology Annual – China, Report 14032, December 31 2014, President Xi, Central Conference on Rural Work held on December 23, 2013.

[125] Ibid.

[126] Ministry of Agriculture of the People's Republic of China, China Vows Zero Tolerance for GM Rice, July 30 2014, (Accessed February 2015): http://english.agri.gov.cn/hottopics/bt/201409/t20140919_23953.htm

[127] USDA Foreign Agricultural Service, Agricultural Biotechnology Annual – China, Report 14032,

[128] Ibid.

[129] Reuters, "China Underlines Cautious Approach to Biotech Crops", February 3 2015:

[130] R Campbell (2014), *China and the United States—A Comparison of Green Energy Programs and Policies*, Congressional Research Service, April 30 2014, p. 8.

[131] BP (2014), p. 39.

[132] Tianjin Institute of Industrial Biotechnology, Chinese Academy of Sciences, Introduction, (Accessed February 2015): http://english.tib.cas.cn/at/bi/

[133] Ibid.

[134] World Bank (2014)

[135] World Bank, Data bank, GDP per capita (current US$), India

[136] World Economic Forum (2014), p. 13.

[137] Make in India, "Sectors", (Accessed April 2015): http://www.makeinindia.com/sectors/

[138] *Economic Times* (2015), "Make in India: PM Modi vows to double output of defence manufacturing", February 19 2015; *Financial Express* (2015), "Make In India: Green signal for two big-ticket FDI proposals in Railways", March 8 2015; and http://www.makeinindia.com/sectors/

[139] "Make in India", "Sectors", "Pharmaceuticals" and "Biotechnology", (Accessed April 2015): http://www.makeinindia.com/sector/pharmaceuticals/ http://www.makeinindia.com/sector/biotechnology/

[140] NATIONAL IPR POLICY, IPR Think Tank, December 2014, Government of India, pp. 12, 14-16, 20-23

[141] Ibid.

[142] *Economic Times* (2014), "US lauds PM Modi's IPR remarks, but places India on 'priority watch list'", 1 May 2015.

[143] See for example: Office of Adviser to the Prime Minister (2011), "Creating a Roadmap for a 'Decade of Innovation", STRATEGY PAPER MARCH 2011, p. 6.

[144] OECD (2012), p. 312.

[145] National Innovation Council, Government to Launch India Inclusive Innovation Fund - Press Note, January 27 2014, (Accessed February 2015): http://www.innovationcouncil.gov.in/index.php?option=com_content&view=article&id=356:government-to-launch-india-inclusive-innovation-fund-press-note&catid=14:news&Itemid=13

[146] IBEF, Biotechnology Industry in India, Trends, Market Size, Scope of Biotechnology: http://www.ibef.org/industry/biotechnology-india.aspx

[147] ISAAA (2014)

[148] Department of Biotechnology (2014), *National Biotechnology Development Strategy 2014*, Government of India Pp. 4-5.

[149] Department of Biotechnology – Ministry of Science & Technology, Medical Biotechnology, (Accessed February 2015): http://www.dbtindia.nic.in/programmes/program-medical-biotechnology

[150] Ibid.

[151] Ibid.

[152] Ibid.

[153] Ibid.

[154] Clinicaltrials.gov, India, (Accessed April 2015): https://clinicaltrials.gov/ct2/search/map/click?map.x=556&map.y=215

[155] Pugatch Consilium (2014), p. 25.

[156] IMS (2012), *The Global Use of Medicines: Outlook Through 2016*, IMS Institute for Healthcare Informatics July 2012, slide 13.

[157] Ibid.

[158] Department of Biotechnology – Ministry of Science & Technology, Agriculture Biotechnology, (Accessed February 2015): http://www.dbtindia.nic.in/programmes/agriculture-biotechnology

[159] BioSpectrum (2015), "Modi govt's 'Budget 2015' bets big on R&D, skills & tech startups", February 28 2015.

[160] Department of Science and Technology, Press Releases, New Millennium Indian Technology Leadership Initiative (NMITLI) Scheme, February 27 2009, (Accessed March 2015): http://dst.gov.in/whats_new/press-release09/new-millennium-scheme.htm

[161] Council of Scientific and Industrial Research, Press Releases, New Millennium Indian Technology Leadership Initiative Scheme Expanded, February 23 2009, (Accessed February 2015): http://www.csir.res.in/external/Heads/collaborations/nmitli.pdf

[162] Ibid

[163] Ibid.

[164] Department of Biotechnology – Ministry of Science & Technology, Agriculture Biotechnology

[165] Ibid

[166] Ibid.

[167] USDA (2014), GAIN Report India, p. 3.

[168] R. Devraj (2014), "Indian government still 'flip flopping' on GM trials", *SciDevNet*, September 9 2014.

[169] S. Kumar et al (2014), "The legal battle over field trials of GM crops", *Nature India*, 31 January 2014.
[170] National Bioresource Development Board – Overview Document, (Accessed February 2015): http://www.dbtindia.nic.in/wp-content/uploads/NBDB-inputs.pdf
[171] Ibid
[172] Ibid
[173] Department of Biotechnology – Ministry of Science & Technology, Bioenergy Programme: A Paradigm Shift, (Accessed February 2015): http://www.dbtindia.nic.in/programmes/bioresources-environment-and-bioenergy/bioenergy-programme
[174] Ibid
[175] Ibid
[176] A Lee (2015), "State Bank of India pledges $12bn for renewables", *Recharge* February 16 2015; and S Mittal (2015), "India's Largest Bank Commits $12.5 Billion For Renewable Energy Funding", *Clean Technica* February 19 2015.
[177] BP (2014), p. 39.
[178] Ibid.
[179] S Ezell et al (2013), *Localization Barriers to Trade: Threat to the Global Innovation Economy*, THE INFORMATION TECHNOLOGY & INNOVATION FOUNDATION, SEPTEMBER 2013, p. 23.
[180] World Bank (2014)
[181] World Bank, Data bank, GDP per capita (current US$), Korea, Rep.
[182] World Economic Forum (2014), p. 13.
[183] OECD (2009), *OECD Reviews of Innovation Policy: Korea*, pp. 179-80.
[184] C Mu-hyun (2015), "South Korea to invest $300m in biotech", March 17 2015 ZDNet.
[185] Business Korea (2014), "Blue Chip" Industry Korean Government to Develop 50 Innovative Biotech Companies by 2020", July 18 2014, Business Korea.
[186] Ibid.
[187] OSEC Business Network Switzerland (2011), *South Korea: Bio Technology Industry in Korea*
[188] OSEC (2011)
[189] Ibid.
[190] Korea Research Institute of Bioscience and Biotechnology (KRIBB), About Us, (Accessed February 2015): http://www.kribb.re.kr/eng/
[191] Ibid.
[192] Ibid
[193] Ibid
[194] KRIBB, News, "KRIBB Company Posted an Export of 57 Mil. USD", March 5 2015, (Accessed April 2015): http://www.kribb.re.kr/eng/
[195] Ibid. "It's the Convergence! KRIBB to Join Forces with the Industry", September 29 2014, (Accessed April 2015)
[196] OECD.Stat, Research and Development Statistics, Business enterprise R-D expenditure by industry and by source of funds
[197] Ministry of Food and Drug Safety, Bio Information, (Accessed April 2015): http://www.mfds.go.kr/eng/index.do?nMenuCode=45
[198] OECD (2009)
[199] Pharmabiz, "Korea to accelerate "Pharma 2020 Vision", August 21 2014, (Accessed April 2015): http://www.pharmabiz.com/PrintArticle.aspx?aid=84405&sid=21
[200] Ibid
[201] E Palmer (2015), "Samsung BioLogics to expand new Songdo plant", February 17, 2015, FiercePharma Manufacturing.
[202] US National Institute of Health, clinicaltrials.gov
[203] Pugatch Consilium (2014), p. 25.
[204] USDA Foreign Agricultural Service, Republic of Korea – Agricultural Biotechnology Annual, July 15 2014, Report Number KS1431
[205] Ibid
[206] Ibid
[207] Ibid
[208] Korean Scientific Cooperation Network with the European Research Area (KORANET), (Accessed April 2015): http://www.koranet.eu/
[209] KORANET, PROMOFUEL: Promotion of Advanced Biofuels: Preparation, Fuel Properties and Engine Emissions, 2012, (Accessed April 2015): http://www.koranet.eu/_media/JC_KORANET_factsheet_PROMOFUEL_final_version.pdf
[210] Ibid
[211] KRIBB – Biorefinery Research Center, Objectives, (Accessed April 2015): http://www.kribb.re.kr/eng/sub02/sub02_09_01.jsp
[212] Ibid
[213] Korea IT Times, "Oil Refiners Face Challenges Due to Biodiesel Regulation", December 22 2014
[214] BP (2014), p. 39.
[215] World Bank (2014)
[216] World Bank, Data bank, GDP per capita (current US$), global average is US$13,716
[217] World Economic Forum (2014), p. 13
[218] World Bank, (2010), What is New in Malaysia's New Economic Model?"
[219] OECD, (2013), *Innovation In Southeast Asia*, Paris, p. 197
[220] Biotechcorp (2014), *Annual Report 2014*, p. 1.
[221] Ibid.
[222] MOSTI, Biotechnology Cluster, (Accessed April 2015): http://www.mosti.gov.my/en/cluster/bioteknologi/
[223] MOSTI, National Biotechnology Division (BIOTEK), (Accessed April 2015): http://www.mosti.gov.my/en/about-us/divisions-departments/national-biotechnology-division-biotek/
[224] MOSTI, Genome Malaysia, (Accessed April 2015): http://www.genomemalaysia.gov.my/v3/
[225] Malaysian Institute of Pharmaceutical and Nutraceuticals, About IPHARM, (Accessed April 2015): http://www.ipharm.gov.my/2014/index.php/about-ipharm.html
[226] Agro-Biotechnology Institute, About Us, (Accessed April 2015): http://www.abi-nibm.my/index.php/about
[227] InnoBio, About Us, (Accessed April 2015): http://www.innobiologics.com/?page_id=5
[228] MOSTI, About TPM, (Accessed April 2015): http://www.tpm.com.my/about/ab.php
[229] Ibid
[230] BioTechCorp, Products and Technology, (Accessed April 2015): http://www.biotechcorp.com.my/products-technology/
[231] Ibid
[232] Biotech Corp (2014), pp. 46-7.
[233] S Las Marias (2013), "Agila Biotech to Set Up Biotech Facility at Malaysia's Bio-XCell Ecosystem", March 21 2013, *Pharma Asia*.
[234] J Chin (2014), "Biologics to raise CCM Duopharma's profile", 22 February 2014, *The Star Online*.
[235] Ibid.
[236] PhRMA (2015), pp. 137-8.
[237] Clinicaltrials.gov, India, (Accessed April 2015): https://clinicaltrials.gov/ct2/search/map/click?map.x=556&map.y=215
[238] Pugatch Consilium (2014), p. 25.
[239] Ibid. p. 8.
[240] Ibid.
[241] BioTechCorp, (2009), *The Malaysian Industrial Biotechnology Sector – A Frost and Sullivan Whitepaper*, Frost & Sullivan, p. 20.
[242] Bloomberg Business, (2014), "Malaysia Delays Full Implementation of B5 Biodiesel Mandate" (Accessed April 2015): http://www.bloomberg.com/news/2014-08-06/malaysia-says-full-implementation-of-biodiesel-mandate-delayed.html
[243] USDA (2014), Malaysia Agricultural Biotechnology Annual, pp. 4-6.
[244] Ibid.
[245] World Bank (2014)
[246] World Bank, Data bank, GDP per capita (current US$), Mexico
[247] World Economic Forum (2014), p. 13.
[248] L. R. Leon (2012), *Erawatch country reports 2012: Mexico*. (Country Report), Belgium: Erawatch Network - Technopolis Group Belgium, p. 11.
[249] OECD (2014), *STI Outlook…*, p. 385.
[250] OECD (2013), p. 41
[251] Ibid
[252] Ibid, 42
[253] Ibid, 47
[254] OECD (2014), *STI Outlook…*, p. 118.
[255] OECD.Stat, Key Biotech Indicators, Number of firms active in biotechnology, 2011 or latest available year, 2014.
[256] OECD.Stat, Key Biotech Indicators, Biotechnology R&D expenditures in the business sector, 2011 or latest available year, Millions of USD PPP
[257] Ibid.
[258] OECD.Stat, Biotechnology R&D intensity in the business sector, 2011 or latest available year, Biotechnology R&D in the business enterprise sector as a percentage of industry value added.
[259] Ministry of Economy (2013), "The Pharmaceutical Industry", *ProMexico, Trade and Investment*, p. 15.
[260] Ibid.
[261] Ibid.
[262] Flinn Foundation, "FDA grants approval to scorpion antivenom tested by UA team", Arizona Biosciences News, August 12 2011; Instituto Bioclon, "Who we are", (Accessed April 2014): http://www.bioclon.com.mx/bioclon/html/quienes_en.html
Mexico business blog, "Recent developments in biotechnology in Mexico", November 18 2011, (Accessed April 2014): http://bdp-americas.com/blog/2011/11/18/recent-developments-in-biotechnology-in-mexico/
[263] WireNews (2013), "Mexico pharmaceuticals & healthcare report Q2 2013",(Accessed April 2014): http://www.wirenews.co.uk/mexico/healthcare/9185/mexico-pharmaceuticals-healthcare-report-q2-2013-now-available-at-fast-market-research
[264] BMI Research (2014), "COFEPRIS Shortens Pre-Approval Time For Clinical Trials", March 17 2014, (Accessed April 2014): http://www.bmiresearch.com/news-and-views/cofepris-shortens-pre-approval-time-for-clinical-trials#sthash.rCBlOe4S.dpuf
[265] Clinicaltrials.gov, (Accessed April 2015): https://clinicaltrials.gov/ct2/search/map/click?map.x=556&map.y=215
[266] Pugatch Consilium (2014), p. 25.
[267] USDA (2014), "Agricultural Biotechnology Annual, Mexico", p. 6.
[268] Ibid
[269] Ibid
[270] G Guerra (2014), "Restrictions on genetically modified organisms: Mexico", Law library of US Congress, March 2014, (Accessed April 2015): http://www.loc.gov/law/help/restrictions-on-gmos/mexico.php
[271] USDA (2012), "Agricultural Biotechnology Annual, Mexico"
[272] Ibid

[273] CIBIOGEM, Results of Projects Funded by background CIBIOGEM (unofficial translation), (Accessed April 2015): http://www.conacyt.gob.mx/cibiogem/index.php/resultados-proyectos-financiados-fondo-cibiogem
[274] ISAA (2014), p. 2.
[275] USDA (2014), "Agricultural Biotechnology Annual, Mexico", p. 2.
[276] Ibid.
[277] USDA (2009), "GAIN Mexico Biofuels Annual", p. 2.
[278] BP (2014), p. 39.
[279] Reuters (2015), "Mexico's Pemex launches ethanol biofuel program to cut Emissions", March 20, 2015
[280] Pemex, Press Release, "Pemex signs contracts for the acquisition of anhydrous ethanol", April 8 2015.
[281] UCSD Extension School, (2007), *Borderless Biotech & Mexico's Emerging Life Sciences Industry*, p. 9.
[282] Langebio, What is langebio?, (Accessed January 2015): http://www.langebio.cinvestav.mx/?pag=50
[283] World Bank (2014)
[284] World Bank, Data bank, GDP per capita (current US$), Russia
[285] World Economic Forum (2014), p. 13.
[286] World Bank, Data bank, GDP annual growth, Russia
[287] Bloomberg, "Russia Facing Recession as Sanctions Likely to Intensify", March 24 2014
[288] Ministry of Economic Development (2011), *Strategy for Innovative Development of the Russian Federation 2020*, 12/8/2011
[289] Ministry of Economic Development (2011), *Strategy for Innovative Development…*
[290] ERAWATCH, "Russian Federation: Policy Documents", (Accessed January 2014): http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/ru/policydocument/policydoc_0007
[291] Embassy of Switzerland in Russia, "Pharma 2020: The Strategy of Development of the Pharmaceutical Industry of the Russian Federation – Analytical Summary", http://www.s-ge.com/de/filefield-private/files/25703/field_blog_public_files/5244; Russian Government, *State Coordination Program for the Development of Biotechnology in the Russian Federation until 2020: Summary*, http://owwz.de/fileadmin/Biotechnologie/Information_Biotech/BIO_Booklet_Block_A4_CS4.pdf
[292] Ibid., p.12
[293] D Medvedev (2014), "Progress report on Russia's Innovative Development Strategy to 2020", Meeting of the presidium of the Presidential Council for Economic Modernisation and Innovative Development, December 19 2014.
[294] Ibid.
[295] Government of the Russian Federation, Summary – State Coordination Program for the Development of Biotechnology in the Russian Federation Until 2020 (BIO 2020), 2012, p. 12.
[296] Ibid, p.16
[297] Embassy of Switzerland in Russia, p. 7.
[298] Consult Pharma, (2010), Russian Federation law No. 61, (Accessed March 2014): http://www.consultpharma.ru/index.php/en/documents/drugs/152-61fz?showall=1
[299] Dubevoise & Plimpton LLP, (2013), "Recent Developments in the Russian Pharmaceutical", Lexology.
[300] V. Omelyanovskiy. (2013), *Pricing of Pharmaceuticals in Emerging Countries of the Central & Eastern European Region: The Case of Russia*, ISPOR.
[301] Deloitte, (2013), *Trends and Practical Aspects of Development of the Russian Pharmaceutical Market*, p. 6.
[302] KPMG (2014), *Pharma bulletin*, Issue #12, 2014 (December)
[303] WIPO (2011), "Federal Service for Intellectual Property, Patents and Trademarks (ROSPATENT) Russian Federation: Exceptions and Limitations", http://www.wipo.int/scp/en/exceptions/replies/russia.html
[304] The Pharma Letter, "Novartis criticizes system of public procurement tenders in Russia", 9/28/2012, (Accessed March 2014): http://www.thepharmaletter.com/article/novartis-criticizes-system-of-public-procurement-tenders-in-russia
[305] See: Baker & McKenzie (2015), "Significant Changes to the Law on Circulation of Medicines Will Come into Force in 2015", Legal Alert, January 2015; and A Gorodissky & Partners (2015), "Overview of Changes to Laws Governing Circulation of Medicinal Products", April 2015
[306] Ibid.
[307] See: BMI Research (2015), "Novartis IP Infringement Case To Test Multinationals' Resolve", March 31 2015; Marchmontnews (2015), "Court rules in favor of Russian drug registration, dismisses Novartis' rights infringement complaint", April 16 2015; and Vegas Lex (2015), "Russian court considered its first data exclusivity case: implications for pharmaceutical manufacturers", April 2015.
[308] US National Institute of Health, www.clinicaltrials.gov
[309] Pugatch Consilium (2014), p. 25.
[310] Government of the Russian Federation (2012), "State Coordination Program for the Development of Biotechnology in the Russian Federation", 2012, Report Number: VP-P8 322, p. 27.
[311] USDA (2014), "The Russian Federation – Agricultural Biotechnology Annual 2014", Report Number: RS1444
[312] RT.com (2014), "Russia Postpones Planting of GMOs by 3 Years", April 23 2014, (Accessed April 2014): http://rt.com/news/154032-russia-gmo-food-ban/
[313] USDA (2014), "The Russian Federation…"
[314] Ibid.
[315] Government of the Russian Federation, Summary – State Coordination Program, p. 16.
[316] USDA (2014), "Biofuels Annual, Russian Federation", p. 7.
[317] BP (2014), p. 39.
[318] USDA (2014), "Biofuels Annual, Russian Federation", p. 1.
[319] World Bank (2014)
[320] World Bank, Data bank, GDP per capita (current US$), Singapore
[321] World Economic Forum (2014), p. 13.
[322] OECD (2013), "Singapore: innovation profile", in *Innovation in Southeast Asia*, OECD Publishing, pp. 237-8.
[323] Ibid.
[324] EDB (2014), Annual Report, Singapore EDB, p. 4.
[325] Ibid.
[326] EDB (2014), *Biomedical Sciences Singapore The Biopolis of Asia*, EDB Singapore.
[327] EDB, Industries, (Accessed April 2014):https://www.edb.gov.sg/content/edb/en/industries/industries/pharma-biotech.html
[328] EDB (2013), *Singapore Biotech Guide 2012/2013*, p. 15.
[329] Ibid.
[330] Singapore Ministry of Health, Research Grant – Clinician Scientist Award, (Accessed April 2015): http://www.nmrc.gov.sg/content/nmrc_internet/home/grant/talentdev/csa.html
[331] Singapore Ministry of Health, our Research – TCR Flagship Programme, (Accessed April 2015): http://www.nmrc.gov.sg/content/nmrc_internet/home/our_research/tcr_flagship_programme.html
[332] National Research Foundation, Competitive Research Programme, (Accessed April 2014): http://www.nrf.gov.sg/about-nrf/programmes/competitive-research-programme
[333] National Research Foundation, Competitive Research Programme List of Awarded CRP Projects, (Accessed April 2014): http://www.nrf.gov.sg/docs/default-source/default-document-library/list-of-projects-that-have-been-awarded.pdf?sfvrsn=0
[334] Pugatch Consilium (2014), p. 24.
[335] USDA (2014), "Singapore – Agricultural Biotechnology Annual", Report Number: SN4006
[336] Ibid
[337] Agri-Food & Veterinary Authority of Singapore, Agrotechnology Parks Map, (Accessed April 2014): http://www.ava.gov.sg/explore-by-sections/farms/land-farms/farming-in-singapore/agrotechnology-parks-map
[338] Agriculture Extension and Advisory Service Worldwide, Singapore – Public Sector Advisory Services, (Accessed April 2014): http://www.worldwide-extension.org/asia/singapore
[339] DuPont Singapore (2009), "DuPont Singapore Factsheet", pp. 1-2.
[340] Singapore Environment Council (2007), *Elements*, Issue 2 of 2007, p. 3.
[341] Ibid.
[342] EDB, Clean Energy, In Brief, (Accessed April 2015): https://www.edb.gov.sg/content/edb/en/industries/industries/clean-energy.html
[343] Eco-Business (2014), "Singapore's First Biodiesel-powered Luxury Fleet to be powered by Cooking Oil, January 21 2014
[344] Energy Trends Insider (2014), "Global Biofuels Status Update", 28 August 2014, (Accessed April 2014) http://www.energytrendsinsider.com/2014/08/28/global-biofuels-status-update/
[345] World Bank (2014)
[346] World Bank, Data bank, GDP per capita (current US$), Switzerland
[347] World Economic Forum (2013), p. 15.
[348] South African Department of Science and Technology, (2008), *Ten-Year Innovation Plan*
[349] The Technology Innovation Agency, (2015), About Us, (Accessed April 2014): http://www.tia.org.za/about-us
[350] Ibid.
[351] Ibid., Funding Application General Guidelines, pages 6-7
[352] Ibid. Tshwane Animal Health Innovation Cluster Initiative
[353] Ibid., Our Projects
[354] Ministry of Science and Technology (2014), *The Bio-Economy Strategy*, pp. 3-4.
[355] Ibid. pp. 23-4.
[356] Ibid. pp. 18-22.
[357] Ibid. p. 38.
[358] Ibid. p. 21.
[359] Espicom (2015), "The Pharmaceutical Market: South Africa", p. 15.
[360] Sanofi South Africa, Manufacturing Facility, (Accessed April 2015): http://www.sanofi.co.za/l/za/en/layout.jsp?scat=2235DDE7-03E4-4F71-9FEF-ACFC65034618
[361] Ibid.
[362] I Parker et al (2001), A NATIONAL BIOTECHNOLOGY STRATEGY FOR SOUTH AFRICA, June 2001, p. 62.
[363] S. Al-Badr (2009), "Small but tenacious: South Africa's health biotech sector", *Nature Biotechnology*, volume 27, number 5, May 2009.
[364] eGoLiBio, About Us, (Accessed April 2014): http://www.egolibio.co.za/aboutus.htm
[365] Ibid.
[366] S Al-Badr (2009)
[367] OECD.Stat, Number of firms active in biotechnology, 2011 or latest available year, 2014.
[368] OECD.Stat, Key Biotech Indicators, Biotechnology R&D expenditures in the business sector, 2011 or latest available year, Millions of USD PPP
[369] Ibid.

[370] OECD.Stat, Biotechnology R&D intensity in the business sector, 2011 or latest available year, Biotechnology R&D in the business enterprise sector as a percentage of industry value added.
[371] Ibid.
[372] US National Institute of Health, www.clinicaltrials.gov
[373] Pugatch Consilium (2014), p. 25.
[374] ISAA (2014), p. 2.
[375] Ibid.
[376] USDA (2014), "Biotechnology in South Africa Annual", July 14 2014, p. 2.
[377] Ibid.
[378] Ibid.
[379] Ministry of Science, (2014), p. 32.
[380] BP (2014), p. 39.
[381] South African Government (2014), "Position Paper on the South African Biofuels Regulatory Framework: Draft".
[382] A Gilder & M Mamkeli (2014), "Biofuels in South Africa", ENSafrica.
[383] Ibid.
[384] BioPAD, Investment Options, Received from http://www.speer.co.za/test/biopad/invest.htm
[385] BioPAD, Project Information, (Accessed April 2015): http://www.speer.co.za/test/biopad/bioscape.htm
[386] Ibid.
[387] World Bank (2014)
[388] World Bank, Data bank, GDP per capita (current US$), Switzerland
[389] World Economic Forum (2014), p. 13.
[390] Proneos GmbH, in collaboration with IKU Innovation Research Centre, Corvinus University of Budapest; Institute of International Relations and Approximation of Law, Comenius University, Bratislava; Observatoire des Sciences et des Techniques, Paris, (2010a), "Private Sector Interaction in the Decision-making Process of Public research Policies", Switzerland, 2010
[391] Ibid.
[392] Ibid.
[393] Swiss Biotech (2010), Report 2010. p. 6.
[394] Ibid. p. 10.
[395] K. Pickering (2014) "Roche leads pharma R&D spend for 2013", PMLIVE, December 19 2014.
[396] Interpharma (2014), "Swiss Healthcare and Pharmaceutical Market", p. 81.
[397] Pharmtech.com, "Swiss Pharma Strength" , July 1 2011
[398] Ibid.
[399] Ibid.
[400] GMO-free Europe, Switzerland Updates + Overviews, http://www.gmo-free-regions.org/gmo-free-regions/switzerland.html
[401] Federal Office for the Environment (FOEN), Experimental Release of Genetically Modified Organisms (GMOs), (Accessed April 2015): http://www.bafu.admin.ch/biotechnologie/01756/08902/index.html?lang=en
[402] Ibid., Application to Release Genetically Modified Potato Strains with Improved Potato Late Blight Resistance for Experimental Purposes
[403] ScienceInsider (2013), "Switzerland Creates Secure Test Site for GM Crops", 28 March 2013
[404] Syngenta, Crops & Innovation, R&D Overview, (Accessed April 2015): http://www.syngenta.com/global/corporate/en/products-and-innovation/research-development/Pages/rd-overview.aspx
[405] Swiss Biotech (2014), *Swiss Biotech Report 2014*, p. 15
[406] Ibid
[407] DuPont, Global R&D Centers, Meyrin, Switzerland, (Accessed April 2015): http://www.dupont.com/corporate-functions/our-approach/science/dupont-research-development-centers-worldwide/meyrin-switzerland-the-european-technical-center.html
[408] Ibid. http://www.dupont.com/corporate-functions/our-approach/science/innovation-centers/innovation-center-geneva.html
[409] World Bank (2014)
[410] World Bank, Data bank, GDP per capita (current US$), Switzerland
[411] World Economic Forum (2014), p. 13.
[412] The Scientific and Technological Research Council of Turkey, Who we are? (Accessed April 2015): http://www.tubitak.gov.tr/en/about-us/content-who-we-are
[413] Ibid. National STI strategy 2011-2016.
[414] OECD (2012), STI Outlook: Turkey.
[415] Ibid
[416] Turkey special investment zones, (Accessed April 2015): http://www.invest.gov.tr/en-US/investmentguide/investorsguide/Pages/SpecialInvestmentZones.aspx
[417] Today's Zaman (2014), "R&D has a way to go in Turkey", January 26 2014
[418] D. Cetindamar & A. Rickne (2013). *Turkish Biotech*, from 35th DRUID Celebration Conference
[419] Ibid
[420] Ibid
[421] IMS (2014), *IMS Dataview*, September 2014.
[422] AIFD (2014)
[423] Invest in Turkey, "GE to launch a biotech lab in Turkey by mid-2015", November 17 2014.
[424] Istanbul Health Industry Cluster, "Health Industry joining Forces in Istanbul", Accessed April 2015): https://inovita.org/uploads/1404998946_ISEK_BROCHURE.pdf
[425] Deloitte, (2014), *The Pharmaceutical Industry in Turkey*, p. 56.
[426] Ibid
[427] PhRMA (2014), *Special 301 Submission 2014*. p. 38.
[428] Ibid
[429] Ibid
[430] Pugatch Consilium (2014), p. 25.
[431] USDA, (2014), "Turkey Agricultural Biotechnology Annual"
[432] Ibid.
[433] EUROPABIO (2009), *Biotechnology Report, Turkey*, EUROPABIO AND VENTURE VALUATION, 2009, p. 2.
[434] Pakmaya, About Us, Pakmaya Worldwide, (Accessed April 2015): http://www.pakmaya.com.tr/en/Hakkimizda/Index/8
[435] Ibid.
[436] BIOMER, About Us (unofficial translation), (Accessed April 2015): http://biyomer.iyte.edu.tr/en/hakkimizda/
[437] G Bölük & A Koc (2013), "The Implications of Biofuel Policy in Turkey", International Journal of Energy Economics and Policy Vol. 3, Special Issue, 2013, pp.14-22.
[438] BP (2014), p. 39.
[439] World Bank (2013)
[440] World Bank, Data bank, GDP per capita (current US$), Mexico
[441] World Economic Forum (2014), p. 13.
[442] W. Straw (2009), "British Innovation Policy", *Science Progress*, January 2009
[443] Department for Business Innovation and Skills, About Us, (Accessed April 2015): https://www.gov.uk/government/organisations/department-for-business-innovation-skills/about
[444] The Department for Business, Innovation and Skills (BIS), *Blueprint for Technology*, November 2010
[445] HSBC Global Connections, United Kingdom Trade Forecast, (Accessed April 2015): https://globalconnections.hsbc.com/singapore/en/tools-data/trade-forecasts/gb
[446] The Association of the British Pharmaceutical Industry, Research and Development, (Accessed April 2015): http://www.abpi.org.uk/industry-info/knowledge-hub/randd/Pages/expenditure.aspx#6
[447] US National Institute of Health, clinicaltrials.gov
[448] Pugatch Consilium (2014), p. 24.
[449] Ibid.
[450] Reuters (2014), "Britain Leads Europe in Biotech Fundraising", July 10 2014
[451] Ibid
[452] Financial Times (2014), "UK Agrees deal on 'patent box' tax break", February 12 2014
[453] IHS (2012), "Business Environment for Big Pharma Improving?", HIS Blog March 23 2012
[454] Ibid.
[455] USDA, (2014), "UK Agricultural Biotechnology Annual"
[456] AgriTech Blog, About the Agri-Tech Strategy, (Accessed April 2015): https://agritech.blog.gov.uk/about/
[457] Department for Business Innovation and Skills, Department for Environment Food and Rural Affairs, Department for International Development, 24/12/2013, Strategy for Agricultural Technologies Summary, (Accessed April 2015): https://www.gov.uk/government/publications/uk-agricultural-technologies-strategy/uk-agricultural-technologies-strategy-executive-summary#what-we-will-do
[458] Ibid.
[459] Department for Business, Enterprise & Regulatory Reform (2009), *IB 2025 Maximising UK Opportunities from Industrial Biotechnology in a Low Carbon Economy*, p. 7.
[460] Ibid. p. 26.
[461] Deloitte (2015), "Grants & Incentives Program Updates, The Latest Legislative Developments from Around the World"
[462] Ibid.
[463] Department for Transport (2012), "Renewable Transport Fuels Obligation", November 5 2012, (Accessed April 2015): https://www.gov.uk/renewable-transport-fuels-obligation
[464] BP (2014), p. 39.
[465] Ibid.
[466] World Bank (2014)
[467] World Bank, Data bank, GDP per capita (current US$), United States
[468] World Economic Forum (2014), p. 13.
[469] RD Atkinson (2014), "Understanding the US National Innovation System", THE INFORMATION TECHNOLOGY & INNOVATION FOUNDATION, June 2014, p. 5
[470] Executive Office of the President, National Economic Council, Office of Science and Technology Policy, (2009), *A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs*, September 2009, p. 9. R. Steinbrook (2009), "Health Care and the American Recovery and Reinvestment Act", N Engl J Med 2009; 360:1057-1060, p. 1057.
[471] Advanced Manufacturing National Program Office, Advanced Manufacturing Portal, NNMI, (Accessed April 2015): http://manufacturing.gov/nnmi.html
[472] Ibid.
[473] Ibid.
[474] For a detailed breakdown of the Strategic Objectives and accompanying policies see Pugatch Consilium (2014), *Building the Bioeconomy Examining National Biotechnology Industry Development Strategies*, p. 41.
[475] Ibid.
[476] Pugatch Consilium (2014), p. 25.
[477] PhRMA (2014), *2014 Profile*, p. 72.

[478] S Keyhani (2010), "US Pharmaceutical Innovation in an International Context", *American Journal of Public Health*, June 2010, Vol 100, No. 6.
[479] NIH, About NIH, http://www.nih.gov/about/budget.htm (Accessed March 2015)
[480] Ibid.
[481] J Loscalzo (2006) "The NIH Budget and the Future of Biomedical Research", *New England Journal of Medicine*, 2006; 354: pp. 1665-1667.
[482] California Healthcare Institute, BayBio and PwC, (2011), California Biomedical Industry 2011 Report, p. 8
[483] Ibid. p. 4.
[484] Massachusetts Biotechnology Council, "Massachusetts by the numbers", 2009, http://www.massbio.org/economic_development/the_massachusetts_supercluster/massachusetts_by_the_numbers (Accessed September 2011)
[485] California Healthcare Institute et al, (2011), p. 17.
[486] ISSA (2014), p. 2.
[487] S. Wyant (2014) "President Obama provides clear endorsement of agricultural biotechnology", *Agri-Pulse*, April 15 2014.
[488] National Institute of Food and Agriculture, Grants – 1890 Institution Teaching, Research and Extension Capacity Building Grants (CBG) Program, (Accessed April 2015): http://www.csrees.usda.gov/fo/1890capacity.cfm
[489] National Institute of Food and Agriculture, Grants – Agriculture and Food Research Initiative – Food Security, (Accessed April 2015): http://www.csrees.usda.gov/fo/foodsecurityafri.cfm
[490] White House (2012), *National Bioeconomy Blueprint*, Washington DC, p. 1.
[491] UNCTAD (2014), p. 10.
[492] BP (2014), p. 39.
[493] Ibid.
[494] Office of Energy Efficiency & Renewable Energy, Research, Development, Demonstration, and Deployment, (Accessed April 2015): http://www.energy.gov/eere/bioenergy/research-development-demonstration-and-deployment
[495] ARPA-E, Frequently Asked Questions, (Accessed April 2015): http://arpa-e.energy.gov/?q=faq
[496] ARPA-E, Tech-To-Market (T2M), (Accessed April 2015): http://arpa-e.energy.gov/?q=arpa-e-site-page/tech-market-t2m
[497] Genomic Science Program, Planet Feedstock Genomics for Bioenergy, (Accessed April 2015): http://genomicscience.energy.gov/research/DOEUSDA/
[498] Ibid. 2014 Awards
[499] See section 3, sub-section *Intellectual Property* for a detailed discussion and full references.
[500] Pugatch Consilium (2014)
[501] M Pugatch & R Chu (2011), "The strength of pharmaceutical IPRs vis- à -vis foreign direct investment in clinical research: Preliminary findings", *Journal of Commercial Biotechnology*, 16 August 2011.
[502] IMS (2014), *Global Outlook for Medicines Through 2018*, IMS Institute for Healthcare Informatics, p. 24.
[503] Ibid.
[504] Department of Biotechnology (2014), *National Biotechnology Development Strategy 2014*, Government of India Pp. 4-5.
[505] Ibid. pp. 5-16
[506] See: AH Oikawa (2013), "IP licensing in Brazil: what you need to know", *World Intellectual Property Review*, 1 June 2011; and F Oliveira do Prado et al (2010), "Technology transfer in a public Brazilian university", *Triple Helix in the Development of Cities of Knowledge, Expanding Communities and Connecting Regions*, conference proceedings, 20-22 October 2010.
[507] Ibid.
[508] F Oliveira do Prado et al (2010), p. 12.

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