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MEASURING THE ECONOMIC FOOTPRINT OF THE BIOTECHNOLOGY INDUSTRY IN EUROPE

Prepared for EuropaBio – The European Association for Bioindustries

Andreas Haaf

Dr. Sandra Hofmann

In collaboration with Dr. Julia Schüler (BIO. ASPEKTE)

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WifOR Institute
Rheinstraße 22
64283 Darmstadt
Germany

Authors
Andreas Haaf
Dr. Sandra Hofmann
Co-author Dr. Julia Schüler (BIO. ASPEKTE)

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Executive Summary

This economic impact study was conducted by WifOR Institute – an independent research institute specialising in impact analysis – on behalf of the European Association of Bioindustries, EuropaBio. It estimates the contribution of the biotechnology industry to the EU economy and labour market in terms of gross value added, employment and trade. The study looks at the economic impact of the biotechnology industry within the 28 European member states. Direct, indirect, and induced effects generated by the biotechnology industry in the EU28 are quantified in accordance with the system of national accounts and using a multiregional input-output model.

GDP CONTRIBUTION OF €34.5 BILLION

The direct contribution of the European biotechnology industry to the EU28 GDP was €34.5 bn in 2018. This accounts for about 1.5% of the industrial sector's GVA. Including spillover effects, the total GVA effect of the EU biotechnology industry amounted to €78.7 bn and equates to the size of the advertising industry in Europe.

SUPPORTING JOBS IN THE EU

The biotechnology industry strengthens the labour market by directly creating 223,000 jobs in the healthcare, industrial and agricultural biotechnology sector, as well as supporting 710,500 jobs in the overall economy through indirect and induced effects.

EXTRA EU TRADE SURPLUS: €22.3 bn

Openness to international trade ensures prosperity in Europe: With a continuously increasing trade surplus of more than €22 bn recently, the European biotechnology industry shows that it makes an above-average contribution by the worldwide distribution of high-quality goods.

DRIVER FOR GROWTH

With an average annual growth rate of 4.1%, the biotechnology industry is growing more than twice as fast as the EU information and communication sector (2.0%) and the overall economy (1.9%), making it one of the fastest growing innovative industries in Europe.

HIGHLY PRODUCTIVE INDUSTRY

With an average labour productivity of €154,500 GVA per employee, the biotechnology industry is a highly efficient and capital-intensive industry and outstrips highly productive industries such as the telecommunications sector and the financial sector.

The purpose of this study is to estimate the economic impact of the production activities of European enterprises applying biotechnology in their research and manufacturing processes. The analysis covers the years between 2008 and 2018 while focusing on contributions to economic growth and employment. Especially estimations of direct as well as indirect and induced effects (so-called spillover effects) are considered, in total tagged as "footprint". The impact is analysed regarding to employment and contribution to gross domestic product (GDP), the latter being measured in terms of gross value added (GVA). Therefore, this economic footprint analysis provides an overall economic picture of the EU biotechnology industry supplemented by trade and R&D figures. It sheds light on the performance of the industry, its direct contribution to Europe's GDP and labour market, as well as on the spillover effects occurring in European supply chains.

The study computes the impact of the biotechnology industry operating in 28 EU member countries.[1] A detailed description of data sources and methodology can be found in Appendix B.

The results show that the biotechnology industry has contributed €34.5 bn GVA to the growth of the European economy in 2018. If indirect and induced effects are considered, this amount increases to €78.7 bn. This simply means that every Euro of GVA directly generated by the biotechnology industry supports additionally €1.3 GVA in the European economy.

Furthermore, the biotechnology industry accomplished to safeguard up to 223,000 jobs directly and supports 710,500 jobs along the value chain, mainly created by the suppliers of goods and services to the biotechnology industry. Or to put it differently, for each job in the biotechnology industry there are 3.2 additional jobs in the overall economy. Detailed figures on the three biotechnology sub-sectors can be found in Chapter 2.

This study was commissioned by *EuropaBio*, the European Association of Bioindustries, with the objective to better quantify the impact of the biotechnology industry on the European Union's economy.

Founded in 1996, EuropaBio is the recognised voice of the EU biotechnology community, championing world-class solutions for society's challenges. EuropaBio and its members are committed to the responsible use of biotechnology to improve quality of life, to prevent, diagnose, treat and cure diseases, to improve the quality and quantity of food and feedstuffs and to move towards a bio-based and zero-waste economy.[2]

[1] Statements concerning the impact of the biotech industry in the EU on the "European economy" and "European labour market" refer to the impact on the EU28 economy and the EU28 labour market, respectively. Neither the impact of firms located in Switzerland nor the impact occurring in Switzerland is included. Comparisons to European industries are based on official data for the EU28 aggregate. Furthermore, no gross output for biotechnological goods is statistically recorded for the following three EU members: Cyprus, Luxembourg, and Malta.

[2] EuropaBio, 'Biotechnology Industry Manifesto 2019. Resetting the Ambition for Biotechnology in the EU'.

1

Biotechnology: definition and impact

Definition of biotechnology and differentiation to related sectors

This study refers basically to the definition of the Organisation for Economic Co-operation and Development (OECD) which is a generally accepted definition of biotechnology (see box 1 for more detail).

Thus, biotechnology is "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services."

BOX 1: OECD Definition of biotechnology

In 2002, the OECD developed both a **single definition** of biotechnology and a **list-based definition** of different types of biotechnology techniques.

"The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services."

This single definition covers all modern biotechnology but also many traditional or borderline activities. Thus, the OECD recommends that the single definition should always be specified by the list-based definition.

DNA/RNA:	Genomics, pharmacogenomics, gene probes, genetic engineering, DNA/RNA sequencing/ synthesis/amplification, gene expression profiling, and use of antisense technology, large-scale DNA synthesis, genome- and gene-editing, gene drive.
Proteins & other molecules:	Sequencing/synthesis/engineering of proteins and peptides (including large molecule hormones); improved delivery methods for large molecule drugs; proteomics, protein isolation and purification, signaling, identification of cell receptors.
Cell & tissue culture & engineering:	Cell/tissue culture, tissue engineering (including tissue scaffolds and biomedical engineering), cellular fusion, vaccine/immune stimulants, embryo manipulation.
Process biotechnology techniques:	Fermentation using bioreactors, bioprocessing, bioleaching, biopulping, biobleaching, biodesulphurisation, bioremediation, biofiltration and phytoremediation.
Gene & RNA vectors:	Gene therapy, viral vectors.
Bioinformatics:	Construction of databases on genomes, protein sequences; modelling complex biological processes, including systems biology.
Nanobiotechnology:	Applies the tools and processes of nano/microfabrication to build devices for studying biosystems and applications in drug delivery, diagnostics etc.

'Revised Proposal for the Revision of the Statistical Definitions of Biotechnology and Nanotechnology'. OECD Science, Technology and Industry Working Papers. Vol. 2018/01. OECD Science, Technology and Industry Working Papers, 18 January 2018. https://doi.org/10.1787/085e0151-en.

A more coherent definition might be, "biotechnology uses structures, functions and processes of living biological organisms or parts of them to provide goods and services". Their smallest entities, the cells, work like a plant or factory as they process materials, energy and information. Hence, biotechnology (or abbreviated biotech) could be considered as an industrial production technology frequently also called fermentation if microorganisms are used.

Often biotechnology is linked to *Life Sciences*. There is no precise and commonly applied definition of Life Sciences, but the term is habitually used to encompass all activities from the biotechnology, medical device and pharmaceutical sector with regard to human or animal health. Thus, besides biotechnology, other technologies are used, such as physical (medtech) and chemical (pharma) technologies.

Also, the term *Bioeconomy* is often linked to biotechnology. In 2012, the European Commission (EC) published its Bioeconomy strategy "Innovating for Sustainable Growth: A Bioeconomy for Europe"[3], which was subsequently updated in 2018.[4] The EC definition is as follows: "The bioeconomy covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services."

Biotechnology is a subset of bioeconomy where biological resources (biomass) could be processed or treated by biological (biotechnology), chemical, or physical means (technologies). This and the context of biotechnology against Life Sciences is schematically illustrated in figure 1.

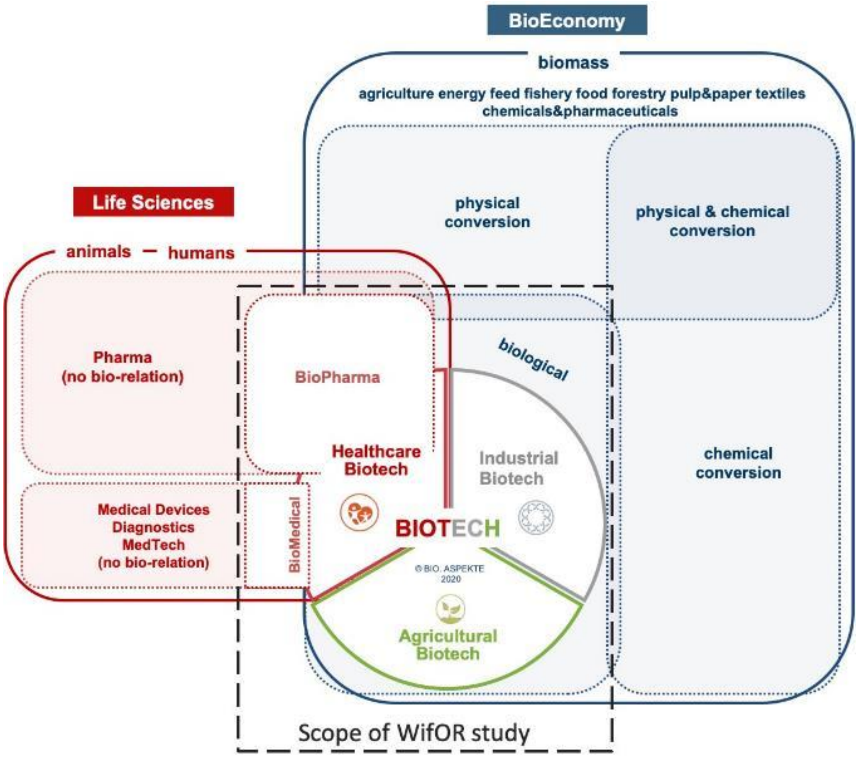


Figure 1: Context of sectors life sciences, biotechnology and bioeconomy.

[3] European Commission, *Innovating for Sustainable Growth*.

[4] European Commission, *A Sustainable Bioeconomy for Europe*.

In this study the scope is on biotechnology as illustrated in figure 1. This means, broader bioeconomy (including physical and chemical conversion of biomass), conventional pharmaceutical technologies and medtech are excluded here. The biotechnology sector itself is divided into healthcare, industrial and agricultural biotechnology.

Biotechnology goes back well before Christ with first applications to produce wine, beer, bread, and cheese. The oldest biotechnology in the world provided safe drinks and food that nurtured civilisations. It is only about 100 years ago that the understanding of the biotechnology mechanisms progressed so that enzymes and microorganisms could be used to produce food, food ingredients or simple chemicals such as ethanol by fermentation. Later, the first pharmaceuticals (antibiotics) were manufactured by using moulds. During World War II, biotechnological production secured the supply of Penicillin. About 50 years ago, bioscientific progressions induced the rise of a new industry that is based on modern biotechnology.

According to the Bio4EU study[5], which assessed the consequences, opportunities and challenges of modern biotechnology for Europe it can be defined as “use of cellular, molecular and genetic processes in production of goods and services. Its beginnings date back to the early 1970s when recombinant DNA technology was first developed. Unlike traditional biotechnology – which includes fermentation and plant and animal hybridisation – modern biotechnology involves a different set of technologies, including industrial use of recombinant DNA, cell fusion and tissue engineering amongst others.” The study published in 2007 presented the first comprehensive picture of the applications of modern biotechnology and their contribution to the European Union’s policy goals. Biotechnology was considered to be one of the key technologies that would enable the EU’s long-term sustainable development.

Impact and value of biotechnology

Biotechnology has the unique advantage to be applicable to a variety of processes in many sectors like healthcare, industrial and agriculture. Gene technology, including gene editing techniques like CrisprCas-9 can be applied across different fields and have a transformative effect in their areas of application. Very few other sectors enhance quality of life, knowledge, innovation, productivity, and environmental protection as biotechnology does.

From new drugs that can address unmet medical needs, fight epidemics and change paradigm in rare diseases, to industrial processes that use renewable feed-stocks instead of crude oil, to drought-resistant crops that allow farmers around the world to better feed more people under increasingly harsher climatic conditions, the applications of biotechnology are multiple and are promising to address key challenges for societies like pandemic preparedness, health and

[5] Zika and Institute for Prospective Technological Studies, *Consequences, Opportunities and Challenges of Modern Biotechnology for Europe*.

well-being, global warming and destruction of biodiversity. Promoting and investing in biotechnology will have economic, societal and environmental impact.

Up to now, the largest impact and value of biotechnology has been seen in the healthcare sector with breakthrough therapies and medicines that are lives saving or improving quality of life for patients and their families. The industrial biotechnology sector itself is on its way to take off with today insufficient detailed economic data to show its continued progress.

In the past fifteen years, the pharmaceutical industry (formerly part of the chemical industry) has transformed itself into a so-called biopharmaceutical industry. With time these companies have become more dependent of new biotechnologies to bring innovative drugs to the market. This critical knowledge was collected through alliances with biotechnology companies or through acquisitions of compounds or whole firms often start-ups originating from the United States.

It was in the US where the biotechnology industry was born in 1976 with the foundation of Genentech (today part of Roche). The first biotechnological produced drug reached the market in 1982 (Lilly/Genentech), a human insulin, developed by means of recombinant DNA technology. It was the first human protein manufactured by engineered bacteria and it replaced the conventional therapy for patients with diabetes. Before this, insulin was extracted from pancreases of animals, usually pigs and cows, with the disadvantage of animal contaminants and limited supply.

Today, biopharmaceuticals (drugs produced on the basis of molecular biotechnology) or biologics (protein drugs) are more and more impacting the pharmaceutical sector complementing its conventional drugs (mainly produced by chemical synthesis). Especially in the subsector of prescription medicines (commonly abbreviated as Rx), biotechnological drugs are predominant with regard to growth in annual worldwide sales as shown in figure 2.

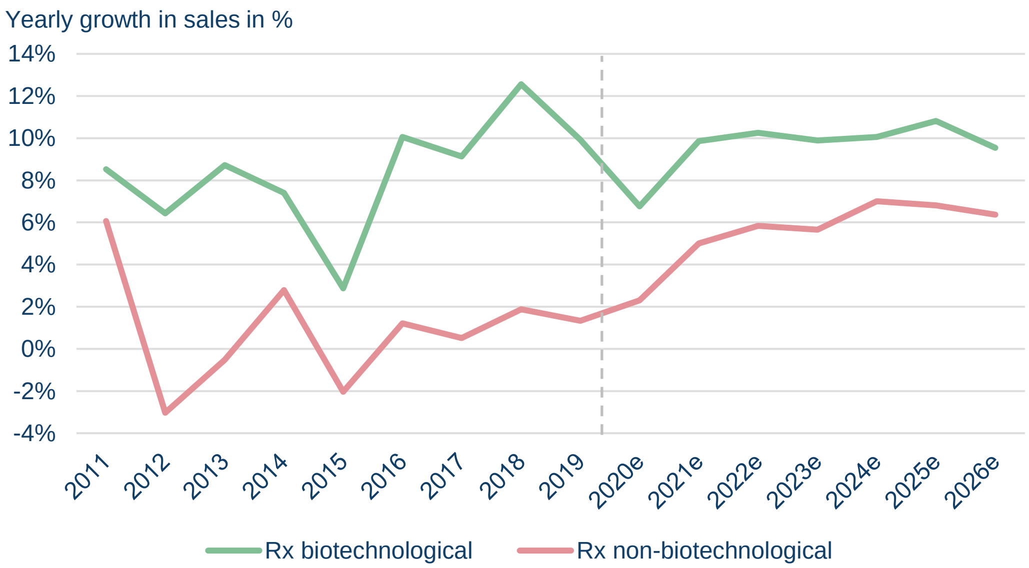


Figure 2: Annual growth in worldwide sales of prescription drugs (Rx) – biotech versus non-biotech

Source: Data from Evaluate Pharma; BIO. ASPEKTE & WifOR analysis.

In some of the past years, prescription drugs produced by conventional, non-biotechnological means have even shown negative development in their worldwide sales figures. However, for the coming years, the data provider EvaluatePharma expects again rising growth rates reaching more than 6% yearly sales growth beyond 2023. In contrast, biologics often have revealed an annual sales growth between 8% and 10% as they frequently are more effective than conventional drugs, eg in the field of inflammatory diseases or in some cancers. This will continue in the near future.

With regard to shares in worldwide prescription drug sales it becomes clear – as shown in figure 3 – that biotechnological medicines or therapies have increased over the years. Ranging from about a fifth in the year 2012, their share was nearly one third in 2019. For 2026 it is expected to reach 36% of all worldwide Rx sales. Focusing on only the best 100 selling products, biotechnological drugs have surpassed the 50% threshold by 2019.

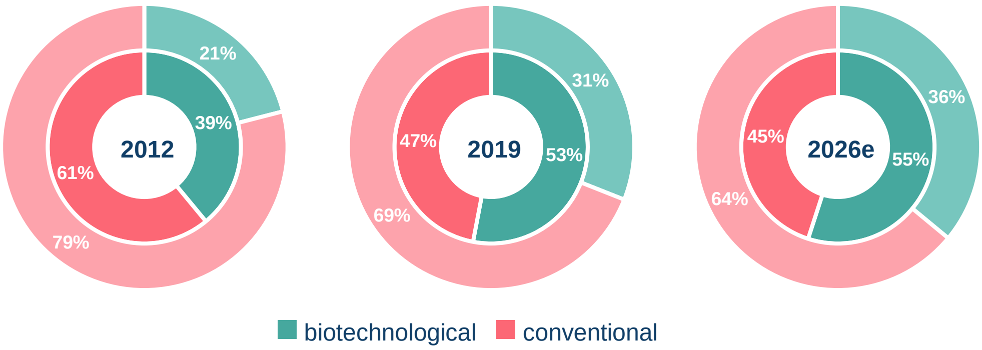


Figure 3: Conventional and biotechnological drugs by shares of worldwide drug sales
Outer circle: all prescription drugs, inner circle: only TOP100 products in sales
Source: Data from Evaluate Pharma; BIO. ASPEKTE & WifOR analysis

Most of the biotechnological drugs were originally developed by US based small and medium sized enterprises (SME). Some are still existing as independent firms; others were acquired by larger pharmaceutical companies. For example, antibodies launched since the 90s by Swiss based pharmaceutical firm Roche, are especially based on the acquisition of the US biotechnology pioneer Genentech in 1990/2009. In 1990 Roche acquired a major stake and in 2009 the whole company was taken over. Genentech started in 1976 to develop the first recombinant drug ever, namely human insulin produced in bacteria which reached the market roughly five years afterwards in 1982. The first antibody developed by Genentech (in collaboration with Biogen), Rituxan/MabThera (brand name in the US/Europe) was launched to the market 20 years after the firm's foundation. In total, the company raised $2 bn in financing before it was completely integrated into the Roche group. Comparable developments are barely to be found in Europe due to a later start of the industry (about 10-15 years) and less favourable financing conditions (see appendix D for more details).

As most of the modern healthcare biotechnology is originating from the US, the US are still today leading when it comes to the number of public companies, the size of the overall market capitalization, the level of R&D investments or the total revenues.

2

European biotechnology industry's economic footprint

The purpose of the study is to examine the biotechnology industry in macroeconomic categories. In contrast to a purely business perspective, the integration of the industry in value chains and its importance for the overall economy can thus also be measured. Through this approach, the results can be compared with national accounts data from statistical offices and thus inform stakeholders and the general public more precisely.

In other words, the focus will not be longer on the companies and their metrics itself but on the goods they are producing. This will include the output of SMEs as well as of larger companies and thus will allow an assesment of the impact of biotechnology with regard to the whole European economy.

Typically, the value of an economy is measured via the gross domestic product (GDP) which sums up the total monetary or market value of all the finished goods and services produced within a country's borders in a specific time period. Related to GDP is gross value added (GVA), what is GDP plus subsidies and minus taxes on products.

In this analysis the focus will be on the following key indicators:

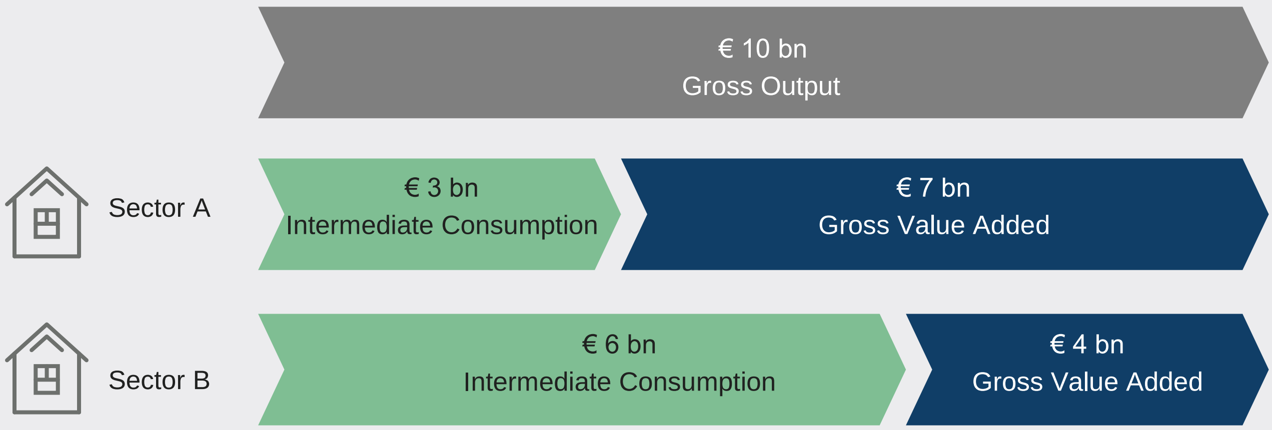
- **Gross value added:** Biotechnology's contribution to GDP
- **Employment:** The number of jobs created, measured on a head-count basis
- **Trade:** The aggregated value of exported or imported biotechnological produced goods from or into the EU
- **Impact of R&D:** Direct GVA of intramural R&D activities in the considered industries

Moreover, the following indicators are computed: **GVA rate** (ratio of direct GVA to output) and **labour productivity** (direct GVA per employed person).

GVA as a key figure to measure the contribution to the economy

A central figure of the economic impact analysis is gross value added (GVA). It is used to assess the economic contribution of companies or industry sectors to a national or regional GDP. In this sense, GVA is the equivalent of GDP on company or industry level. Box 2 illustrates why GVA is better suited to measure economic contributions than, e.g., revenue.

BOX 2: OUTPUT AND GROSS VALUE ADDED



The illustration shows two industry sectors generating the same amount of gross output while their GVAs differ. This difference lies in intermediate consumption: Direct GVA is defined as the difference between output and intermediate consumption such that sector A has a higher GVA and hence its direct GDP contribution is higher than sector B's. Sector B's higher intermediate consumption on the other hand may trigger larger indirect GVA contributions along its supply chains. These may, however, occur outside the economy under consideration. In this way, GVA draws a more detailed and complete picture of the macroeconomic performance of an economic agent than revenue alone.

GVA rate

The gross value added rate (GVA rate) is calculated as the ratio of GVA and output. It shows the integration of the upstream gross value added stages into the economic activities of a company or industry.
A company or industry with a high GVA rate is characterised by strong vertical integration and as a result generates most of its gross value added directly.

In this example, sector A has a 70% and sector B a 40% GVA rate.

Due to its strong link to the GDP, the GVA enables companies and industries to report their performance in a way that ensures comparability with other economic actors as well as political targets. Many political goals are defined in terms of GDP or value added, such as the Europe 2020 target to spend 3% of GDP on research and development.[6]

In the following the key findings from the economic impact on the EU28 economy of the European biotechnology industry are presented. The aggregated economic contributions of the biotechnology industry to the EU28 economy are presented in terms of gross value added, employment and trade.[7].

Gross Value Added Effects

At 44%, the GVA rate of the EU biotechnology industry indicates a substantial share of intermediate consumption in comparison to GVA. This GVA rate indicates relatively high value creation at the biotechnology industry's suppliers and therefore high spillover effects in the European economy.

Biotechnology as we define it, is a cross-sectoral industry. Apart from that, the three subsectors (healthcare, industrial and agricultural biotechnology) mostly reflect the characteristics of their corresponding industry sectors (pharmaceutical and chemical manufacturing, agriculture) in terms of GVA rates and intermediate consumption. However, it must be taken into account that for the purpose of this study few specific goods from the food sector are included[8] in order to comply with the industry definition given in the annex. Thus, their influence on the total biotechnology GVA rate is marginal.

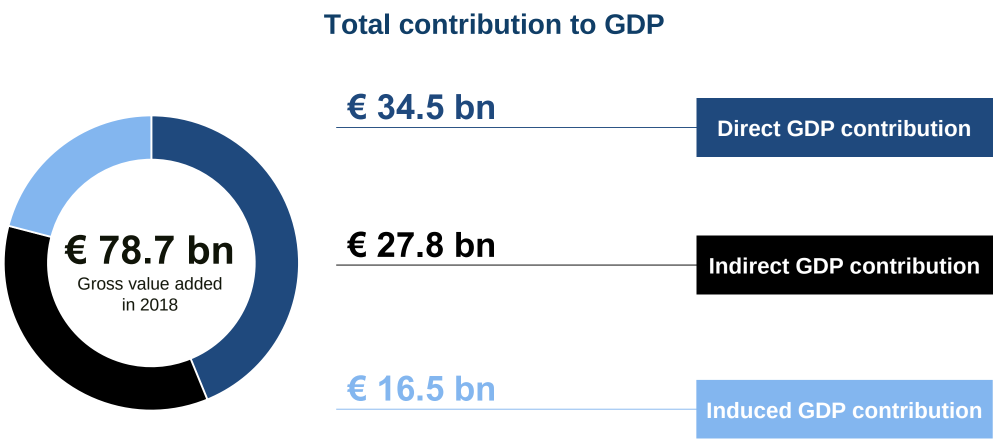


Figure 4: Direct, indirect, and induced GVA effects of Europe's biotechnology industry in 2018.
Source: Eurostat: Prodcom database;WIOD; WifOR analysis.

In terms of direct GVA, the biotechnology industry's contribution of €34.5 bn accounts for about 1.51% of the European industrial sector. In other words, this is approximately one third of the size of the computer, electronic and

[6] European Commission, 'Taking Stock of the Europe 2020 Strategy for Smart, Sustainable and Inclusive Growth'.
[7] Comparisons to European industries are based on official data for the EU28 aggregate.
[8] Included products from the food and feed sector are: yeast, human milk oligosaccharides, food colorants and several preparations for animal feed.

optical products manufacturing sector.[9] The highest direct GVA is created by pharmaceutical biotechnology (€29.9 bn), followed by industrial biotechnology (€4.5 bn) and agricultural biotechnology (€134 m).

The total GVA effects amount to €78.7 bn which is almost the direct GDP contribution of the European media industry.[10] Of these €78.7 bn, direct effects account for 44%. The remaining 56% or €44.3 bn are spillover effects triggered throughout the EU28. These spillover effects consist of €27.8 bn in indirect and €16.5 bn in induced effects (see figure 4). Correspondingly, for each directly generated Euro of GVA, an additional of €1.3 were generated in the EU28 economy.[11]

The highest spillover GVA impact was generated in the industrial biotechnology sector.

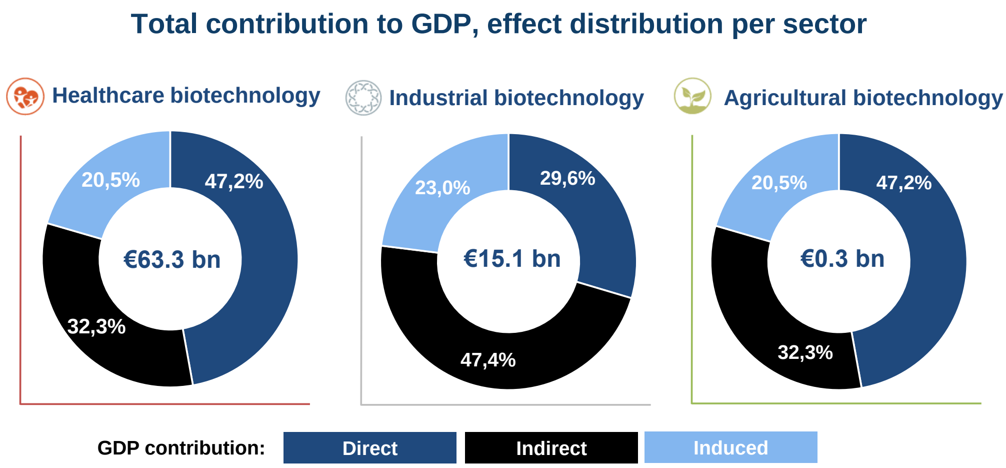


Figure 5: Distribution of direct, indirect and induced GVA effects for the biotechnology sub-sectors.
Source: Eurostat: Prodcom database; WIOD; WifOR analysis.

Broken down by the biotechnology subsectors, the characteristics of these industries can be easily identified. The GVA spillover effects (indirect and induced combined) of the industrial biotechnology are significantly higher than in the pharmaceutical or agricultural subsector as they rely more heavily on intermediate inputs. However in agricultural biotech, induced GVA effects are relatively low (17% of the total effect). This is because consumption along the value chain in this specific sector is not as high as in manufacturing industries (figure 5).

[9] €98.3 bn in 2014, EU28, NACE C26. Eurostat: NAMA 64a: National accounts aggregates by industry.
[10] €79.9 bn in 2017, EU28, NACE J59_J60: Motion picture, video, television programme production; programming and broadcasting activities. Eurostat: NAMA 64a: National accounts aggregates by industry.
[11] The spillover multiplier is the ratio of spillover effects to direct effects.

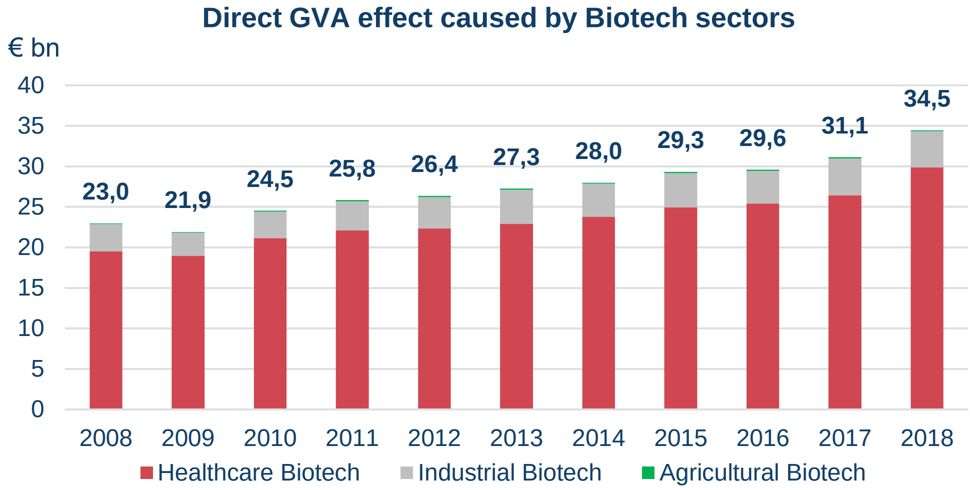


Figure 6: GVA time series for the EU biotechnology industry (EU28, current prices).
Source: Eurostat: Prodcom database; WIOD; WifOR analysis.

A longer-term view shows that the contribution to growth made by the EU biotechnology industry has grown steadily since 2008, except for the year of the financial crisis in 2009. The biotechnology sector is thus a relevant growth driver (figure 6). One reason for this is the expanding adaptation of biotechnological processes, which are increasingly replacing and displacing conventional production methods.

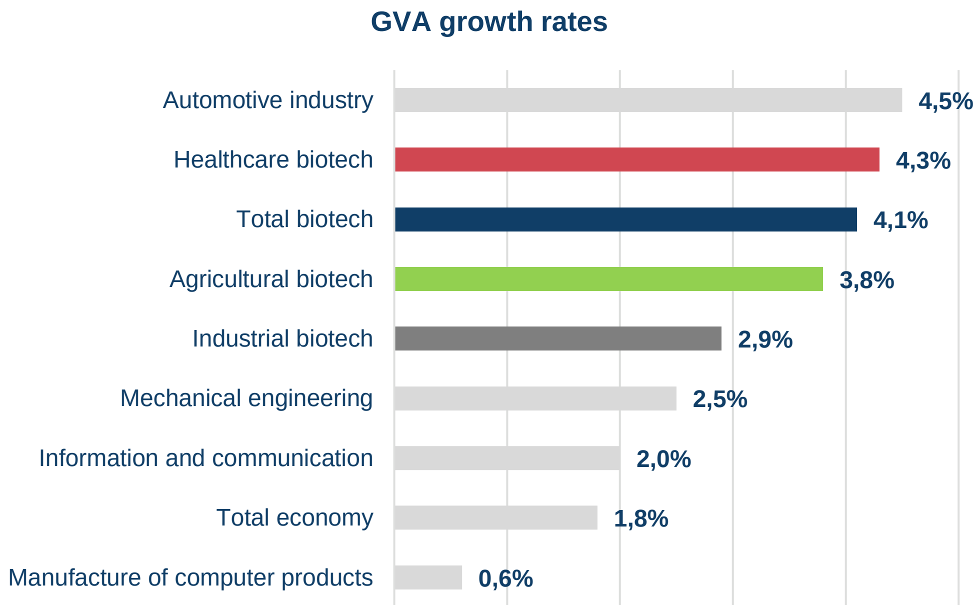


Figure 7: GVA compound average growth rate, (2008-2018).
Source: Eurostat: Prodcom database, NAMA 64a; WIOD; WifOR analysis.

The average growth rates support this interpretation, as each of the three biotechnology sectors has a higher growth rate than the total economy (figure 7). In addition, the biotechnology sector can also exceed the growth of highly innovative industries such as mechanical engineering (2.5%) or manufacturing of computer products (0.6%) in the period from 2008 to 2018. Of the three biotechnology sectors, the pharmaceutical biotechnology sector not only has the highest absolute contribution to GDP (€29.9 bn), but also the highest growth rate (4.3%).

Labour productivity

The labour productivity of the EU biotechnology industry amounted to €154,500 GVA per employee (figure 8). This comparably high labour productivity shows that the EU biotechnology industry is very efficient and capital intensive.

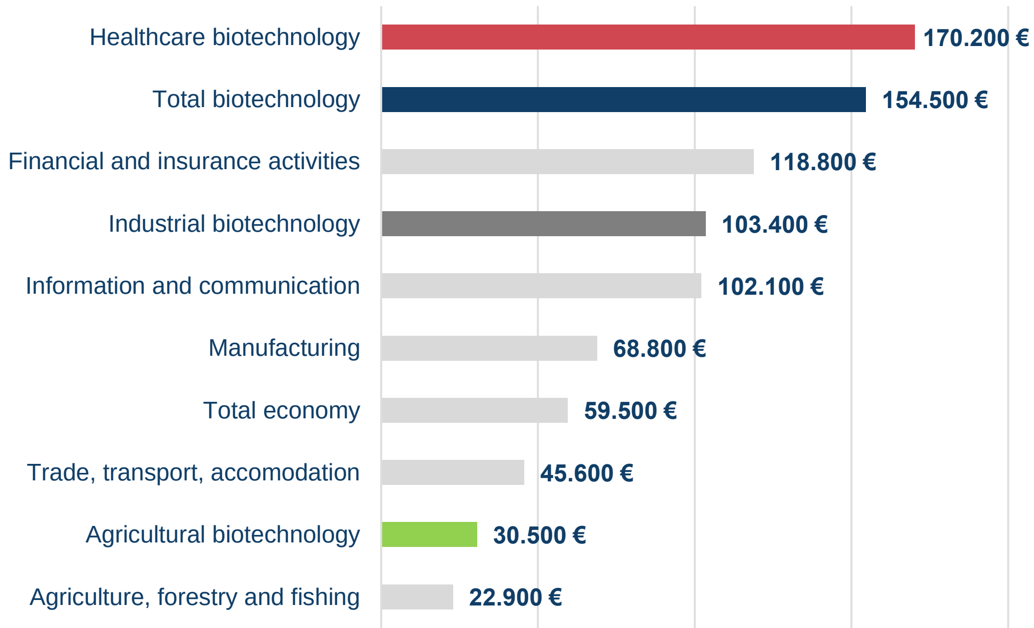


Figure 8: Labour productivity in the EU28, 2018, GVA per person employed.
Source: Eurostat: Prodcom database, NAMA 64a, NAMA 64e; WIOD; WifOR analysis.

The biotechnology industry even outperforms highly productive industries such as information and telecommunication (€102,100) or financial and insurance activities (€118,800) and positions itself well above the manufacturing industry (€68,800), and the total economy (€59,500).[12]

[12] Latest industry data for EU28 from Eurostat.

Employment effects

In addition to their GDP contribution, the EU biotechnology industry also contributes to the EU labour market.

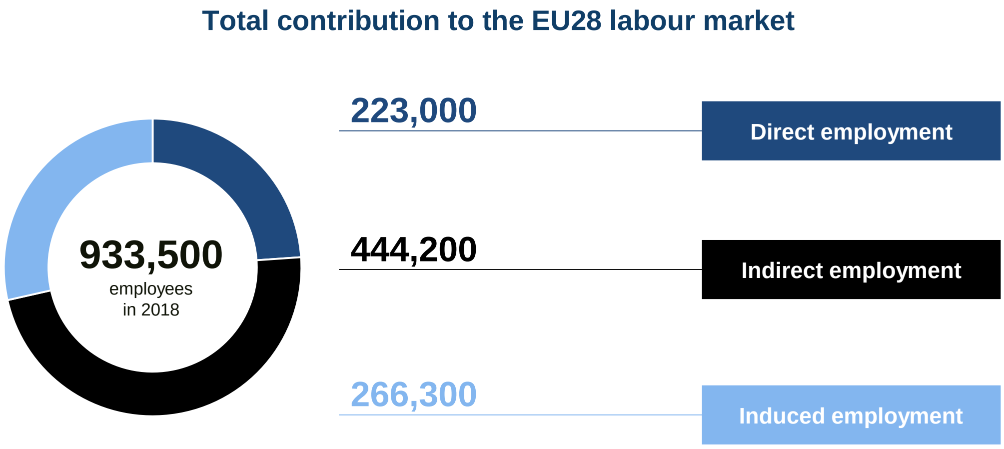


Figure 9: Direct, indirect, and induced employment effects of the EU biotechnology industry.
Source: Eurostat: Prodcom database; WIOD; WifOR analysis.

In 2018, around 223,000 people were directly employed in the EU biotechnology industry, most of them in the healthcare biotechnology sector (175,400; 79%), followed by industrial biotechnology (43,200; 19%) and agricultural biotechnology (4,400; 2%).

In addition to the 223,000 jobs directly created by the biotechnology industry, they also supported almost 710,500 indirect and induced jobs. Consequently, the total employment effects of the EU biotechnology industry amount to 933,500 jobs. The reason for the additional 710,500 jobs on top of the jobs directly created is that the biotechnology industry purchases services and goods from suppliers, which in turn leads to an increase in production and employment in the supplying industries (indirect jobs). Moreover, generated income along this value chain is spent in the overall economy and thus triggers additional job creation. This effect varies depending on the industry and its corresponding supply chain. For the biotechnology industry, this translates into an employment spillover multiplier of 3.2, or in other words, for each direct job, another 3.2 jobs were supported within the overall economy.

This value is in the upper middle range: For example, the spillover multiplier of the automotive industry is ahead with 4.2, meaning that for one job approximately more than four additional jobs are supported along European supply chains. But there are also sectors with a substantial lower employment multiplier, for example in the wholesale trade sector 1.4 and in the agricultural sector only 0.6 additional jobs are supported.[13]

[13] Latest industry data for EU28 from WIOD.

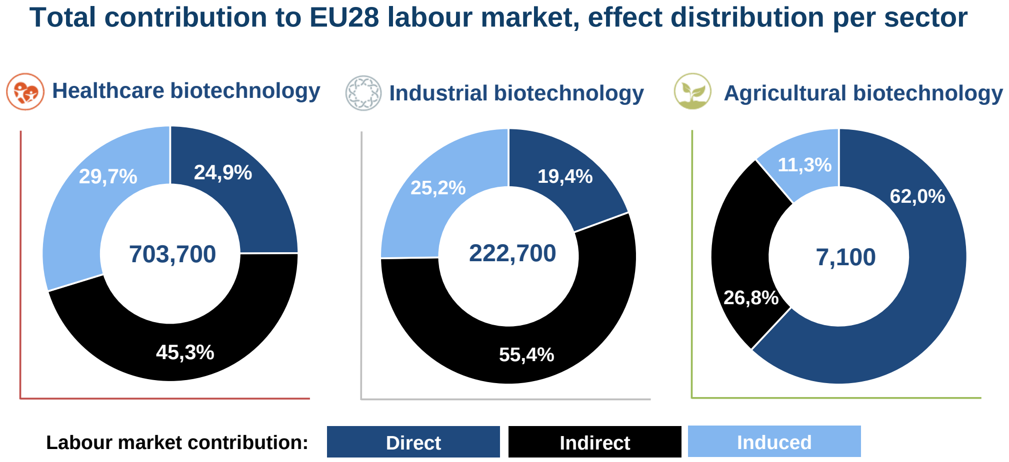


Figure 10: Distribution of direct, indirect and induced employment effects for the biotechnology sub-sectors.
Source: Eurostat: Prodcom database; WIOD; WifOR analysis.

Looking at the three biotechnology sectors, it can be seen that the agricultural biotechnology has the lowest employment spillover effects, as this sector relies least on labour-intensive inputs. Within its value chain, the majority of the workforce (62%) is already tied up in actual production, i.e. as a direct effect. The opposite is true for industrial biotechnology: its intermediate consumtion is so labour-intensive that more than half of the total effect is accounted for by the employees of suppliers (55.4%). Healthcare biotechnology is positioned between these two extremes. These differences may become clearer if only the multipliers are compared as shown in figure 11.

For each direct job in industrial biotechnology, another 4.2 jobs were supported in the overall economy.

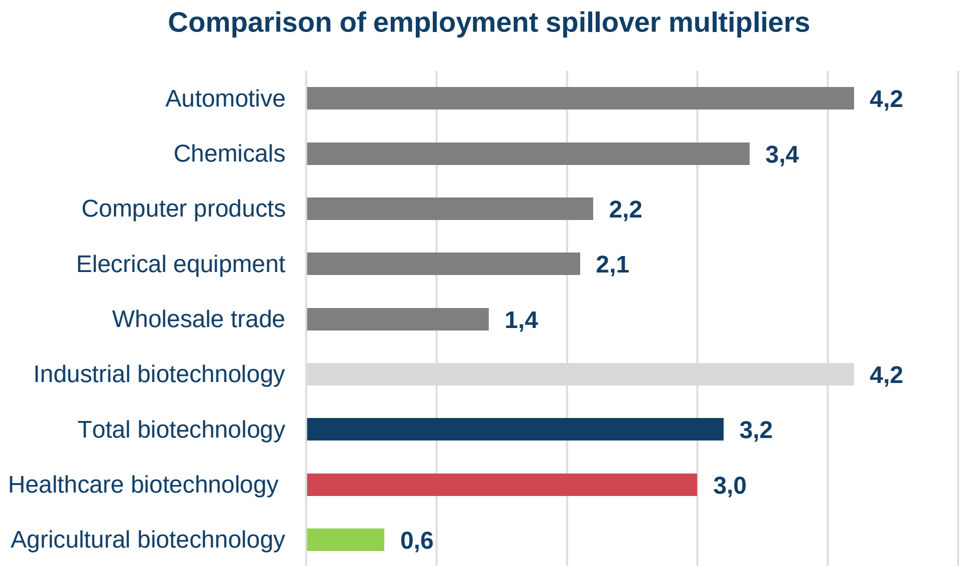


Figure 11: Employment spillover multipliers for the biotechnology sectors and comparable industries
Source: Eurostat: Prodcom database; WIOD; WifOR analysis.

For every job directly generated by healthcare biotech, three additional jobs are supported in the total economy, leading to a spillover effect of more than 528,300 jobs. Industrial biotechnology is at the top of the biotechnology sectors with an employment multiplier of 4.2. The sector is thus responsible for additional 180,000 jobs in the EU28.

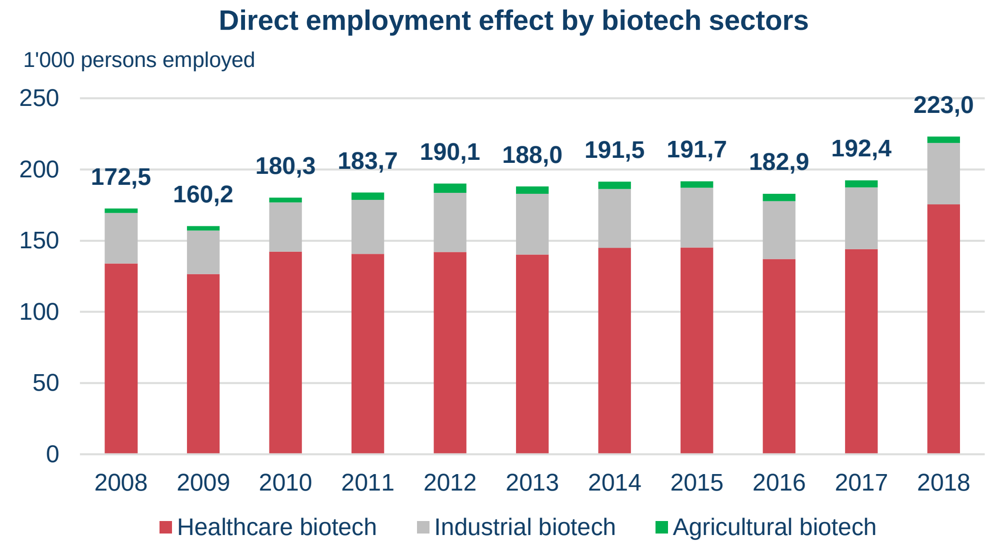


Figure 12: Employment time series for the EU biotechnology industry (EU28).
Source: Eurostat: Prodcom database; WIOD; WifOR analysis.

In contrast to gross value added, there is no evidence of a steady increase in employment (figure 12). From 2010 to 2017, the number of employees was relatively constant between 180,000 and 192,000. The rapid increase in employment in 2018 up to 223,000 persons, shows a new dynamic for skilled workers in the biotechnology sector.

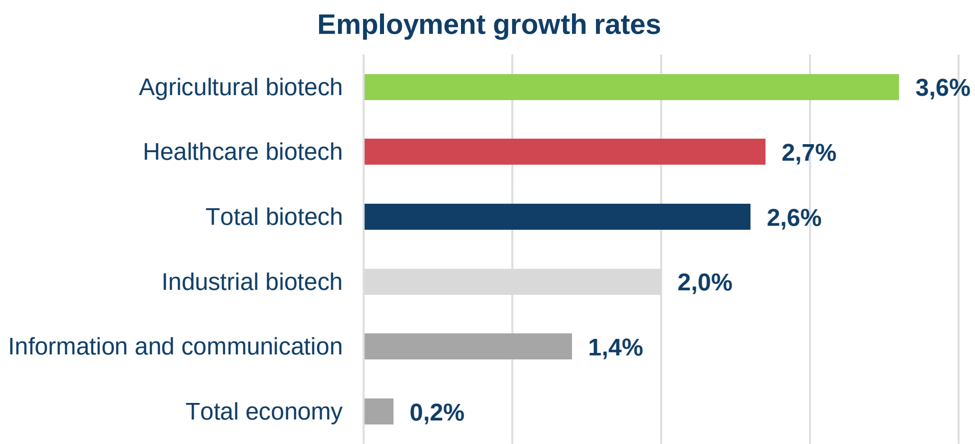


Figure 13: Employment compound average growth rate, 2008-2018.
Source: Eurostat: Prodcom database, NAMA64e; WIOD; WifOR analysis.

Although the absolute employment figures do not allow such a clear interpretation as the value added, when compared to the overall economic employment growth rate (0.2%), it is clear that the biotechnology industry is a positive stimulus for the European labour market (2.6% annual growth). The absolute employment figures for biotechnology are outperforming the overall economy employment growth with a clear acceleration in 2018 due to the technologies introduced in both healthcare and industrial biotechnology like advanced therapies and new biologics for health and new industrial processes.

Trade

In 2018, biotechnology industry exports from the EU28 (extra-EU exports) amounted to €45.0 bn (figure 14). This is a doubling in export volume since the financial crisis of 2009 and thereby an outstanding performance given the relatively youth of the industry. While its share in total economic value added is only 0.2%, biotechnological exports account for 2.3% of all exports from the EU to the rest of the world and shows the tremendous potential of biotechnology exports In addition, between 2008 and 2018, the average annual growth of biotechnology exports (8.4%) has increased more than twice as much as total exports (4.1%).

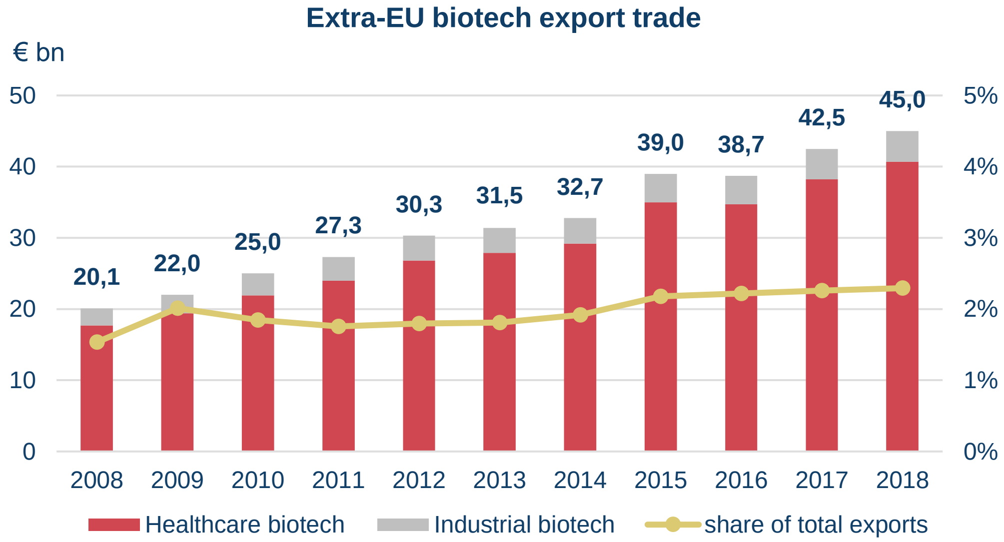


Figure 14: Extra-EU28 exports of the biotechnology industry.
Source: Eurostat: Prodcom database; WifOR analysis.

In addition, between 2008 and 2018, the average annual growth of biotechnology exports (8.4%) has increased more than twice as much as total exports (4.1%).

Biotechnology imports from outside the EU28 (extra-EU imports) almost doubled over the period under review from €11.6 bn to €22.6 bn, despite the high international integration of the biotechnology value chains this is half the level of exports already mentioned (figure 15).

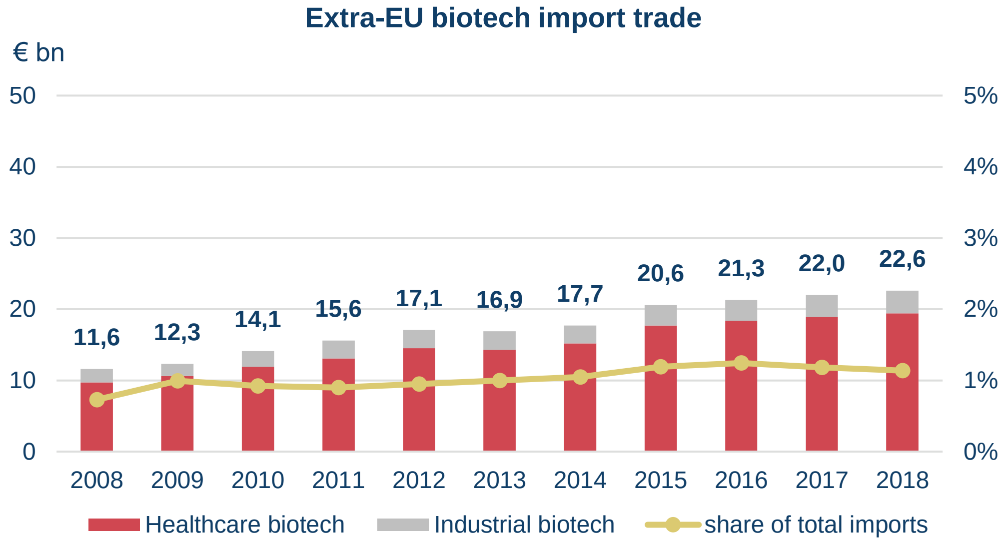


Figure 15: Extra-EU28 imports of the biotechnology industry.
Source: Eurostat: Prodcom database; WifOR analysis.

As a result, biotechnology exports and imports result in a significant trade surplus of €22.3 bn in 2018 as it is shown in figure 16. In fact, the European biotechnology industry's exports are about twice as high as its imports. This is relevant beyond the resulting payment flows into the exporting EU member states, as it is associated with a lower dependence on non-European countries

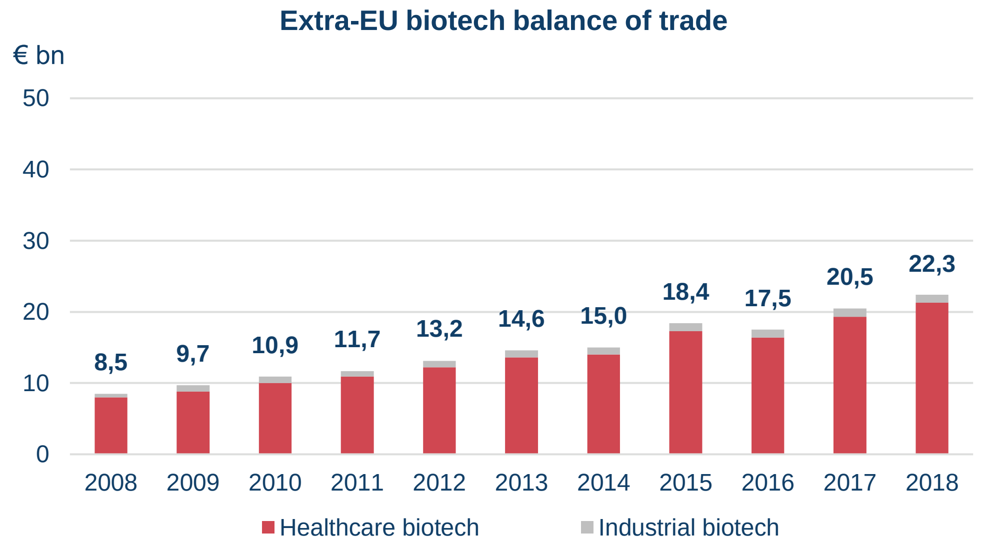


Figure 16: Extra-EU28 trade balance of the EU biotechnology industry.
Source: Eurostat: Prodcom database; WifOR analysis.

However, the international integration of the industry could experience severe setbacks in the event of external shocks, such as the current Covid-19 crisis.

For example, the distribution of life-saving medicines to developing countries via airfreight was severely restricted at the beginning of the pandemic, when first countries imposed lockdowns and international air traffic came to a virtual standstill.[14] Many industries were reviewing their international supply chains in light of the threat of border closures. Especially for pharmaceuticals and medical equipment, there were demand peaks caused by hording behaviour of consumers and increased stockpiling by governments which received significant financial support from the European Commission.[15]

Moreover, several EU member states imposed export bans on numerous drugs which lead to shortages.[16] In this context, it is not surprising that, depending on how supply chains have been disrupted during the crisis, a tendency of re- or near-shoring in some industries and a stronger focus on more sustainable supply chains is expected to happen.[17] But a regionalization of supply chains could potentially increase prices, reduce the diversification of suppliers worldwide and hence especially affect developing countries as they loose access to global value chains and their benefits.[18]

This study shows that the highly internationally integrated biotechnology industry has created a significant trade surplus in the EU in the last 10 years that can certainly be accelerated in the future with the right incentives and an open view to international trade value chains.

[14] UNICEF, 'Impact of COVID-19 on Vaccine Supplies'.
[15] European Commission, 'COVID-19: Commission Creates First Ever RescEU Stockpile'.
[16] Reuters, 'EU Urges States to Lift Export Bans on Drugs That May Lead to Shortages'.
[17] International Labour Organization (ILO), 'The Effects of COVID-19 on Trade and Global Supply Chains'.
[18] Seric et al., 'Managing COVID-19: How the Pandemic Disrupts Global Value Chains'.

Impact of research and development

The direct contribution to GDP made by the biotechnology industry through its internal research activities amounted to around €2.7 bn in 2018. This represents an absolute increase of around €0.9 bn since 2008 and corresponds to an average annual growth rate of 4.5%.

This activity is thus growing faster than the biotechnology industry as a whole (4.1%). In 2018, healthcare biotechnology contributed €2.5 bn and industrial biotechnology €0.2 bn.

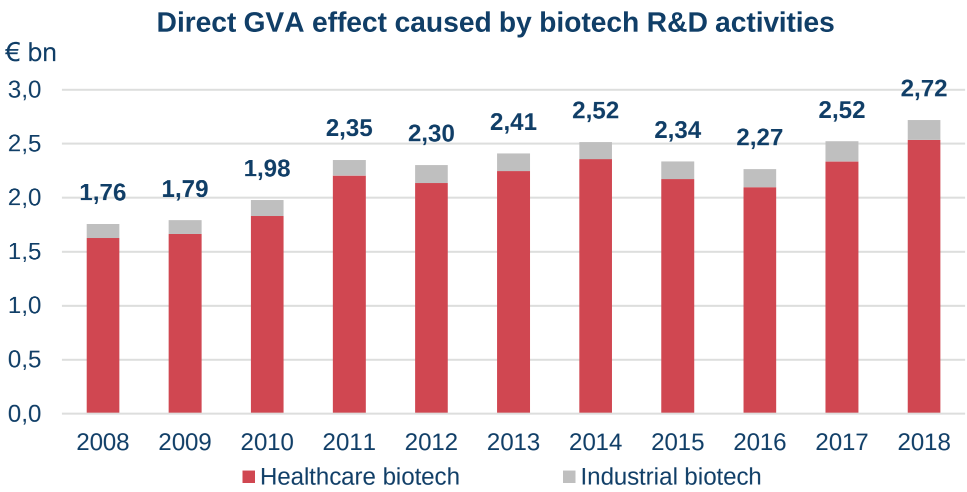


Figure 17: Direct GVA impact of the EU biotechnology industry's R&D activities (EU28, current prices).
Source: Eurostat: Prodcom database, BERD, teina075_r2, WIOD; WifOR analysis.

Rarely before has an event spurred the global research community as much as the Covid-19 pandemic. The time series presented here do not capture this research acceleration, but the literature already anticipates shifts in research resources towards a vaccine or treatments against Covid-19 which could result in significant increase of biotechnological R&D activities analysed here.[19]

[19] Ayati, Saiyarsarai, and Nikfar, 'Short and Long Term Impacts of COVID-19 on the Pharmaceutical Sector'.

3

Conclusion

The EU Biotechnology sector: all the characteristics of a transformative industry for the 21st century

Biotechnology is one of the key enabling technologies of the 21st century[20] that has the transformative potential to change our lives for the better. For urgent global challenges such as climate change, health and well-being, pandemic preparedness, and destruction of biodiversity it can bring exceptional benefits and sustainable value propositions to society.[21]

As our study shows, biotechnology is not only important with regard to enhanced quality of life, knowledge, innovation, and environmental protection, but it has also a significant economic impact with outstanding potential. The European biotechnology industry showed an average GVA (gross value added) growth rate of 4.1% between the years 2008 and 2018. That puts it on a par with other highly innovative sectors

A comparatively high GVA rate of 44% shows that the major value creation takes place within the industry and is not outsourced to suppliers. This is an indicator of an innovative industry that provides high-quality goods. In 2018, it contributed €34.5 bn to the EU28 GDP which represents an increase of €11.5 bn since 2008. Spillover effects, which are due to the purchase of inputs and the expenditure of income, amount to €44.3 bn in 2018 and thus clearly shows the additional economic impact of the industry's intra-European value chains. Each Euro of Gross Value Added generated in the biotechnology industry consequently leads to an additional €1.3 GVA in the overall economy.

The breakthroughs of the biotechnology industry have fully transformed the pharmaceutical supply in the last decade and with new advanced therapies and biotechnology-based treatment options this trend will continue to accelerate. No other industry has been shaped in recent decades by the increasing importance of biotechnology as much as the pharmaceutical market. In Europe, the healthcare biotechnology sector alone accounted for €29.9 bn or 86% of the total biotechnology industry in 2018. In the industrial biotechnology sector this transformation is also in the making. The private and public sectors use industrial biotechnology tools to develop and market a range of novel products. Already today, industrial biotechnology is a central pillar of innovation in Europe and a key enabler in the transition towards a more sustainable and competitive circular bioeconomy.

The insignificance of the agricultural biotechnology in the EU (€134 m GVA in 2018) is the direct consequence of a too complex and rigid policy framework that limits the EU's acreage for GM crops. This greatly reduces the possibility and incentive to invest in this sector, creates a challenging environment for research and limits access to innovation for farmers in most EU member states.[22]

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[20] Organisation for Economic Co-operation and Development, *21st Century Technologies*.

[21] Meyer, 'Sustainability and Biotechnology'.

[22] USDA Foreign Agricultural Service, 'EU-28 - Agricultural Biotechnology Annual'.

The fact that regulation can almost bring an essential sector to a standstill is shown by the low contributions to GDP of agricultural biotech. This sector has moved to other areas of the world and the economic effects are now being achieved outside the EU.

However, the biotechnology industry's dynamism outstrips that of many competing sectors with its high productivity in the sectors where it can flourish. Its ability to safeguard 223,000 jobs directly and 933,500 in total including spill-over effects along the value chain, its doubling of exports since 2008 and its trade surplus of €22.3 bn in 2018 are proof of its competitiveness on the world market.

This study is by definition only a snapshot of the biotechnology sector. The industry benefits from a highly educated workforce, a functioning and barrier-free EU internal market that allows and facilitates cross-border value chains and consistent regulation. As soon as these conditions are questioned, as it became evident from some short-term market interventions during the Corona crisis, it may also affect unfavourably the European biotechnology ecosystem. To develop the biotechnology sector as a whole, stakeholders should not only consider the direct effects of this industry but also its high degree of interconnectivity and integration with the European economy as illustrated by the economic footprint study.

In July 2020, EU leaders agreed on a recovery plan and a multiannual financial framework for 2021-2027. One of the aims of this plan is to help the EU rebuild after the COVID-19 pandemic and promote investment in the environment, digital transformation and citizens health and well-being. Among other things, one approach involves the promotion of stronger supply chains within the EU and the support of key sectors and technologies.[23]

Our study results show that the biotechnology industry has all the characteristics of such a transformative industry: above-average growth, high-value employment for the long run, a constant increase of R&D activities, highly innovative products that extend the lives and increase quality of life of European citizens, creation of a more efficient manufacturing processes, and building the trade surplusses for competitiveness on the global market and new solutions for the global challenges of our planet.

[23] European Commission, 'Recovery Plan for Europe'; European Commission, 'An Enhanced Invest Eu Programme And New Strategic Investment Facility To Help Kick-Start The Economy'.

A

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WIOD: World Input-Output Database, Weblink: http://www.wiod.org/home

B

Data Sources and Methodology

Data sources

For this study on the economic footprint of the biotechnology industry in Europe, several, mostly official, statistics habe been used. Most notable is the Statistics on production of manufactured goods (PRODCOM), the EU production statistics for mining, quarrying and manufacturing. These statistics allow access to production values, exports and imports of about 3,900 industrially manufactured goods (representing section B to C of NACE Rev. 2) for all EU Member States in an annual survey since the early 1990s. This allows a detailed sectoral definition of the biotechnology industry. NACE is the French abbreviation[24] for the Statistical Classification of Economic Activities in the European Community which is used by statistical authorities to distinguish between different industries.

Data restrictions at country level, in particular for pharmaceutical goods, required a data correction, otherwise the production value of the goods concerned would have been massively underestimated. For this purpose, country values have been compared with the EU28 aggregate and allocated to the countries concerned according to the relative share of the parent industry (NACE 2-digit level). This was done using national accounts tables from Eurostat.

As agriculture is not part of the production statistics, a different approach had to be taken here to determine the biotech-relevant production value. Genetically modified insect resistant maize (GM IR maize) is the only biotechnological event approved in the EU[25] and the only genetically modified plant with a significant acreage under cultivation in the EU. A further limitation is that Spain and Portugal are the only EU countries which planted GM IR maize annually between 2008 and 2018.

Thus, in order to determine the relevant production value for the agricultural biotechnology sector, the share of biotechnological maize acreage of Portugal[26] and Spain[27] in the corresponding national total maize acreage[28] is multiplied by the total value of grain maize production[29] and the average yield markup derived from Brooks (2019) to take into account the improved efficiency of GM IR maize.

[24] "nomenclature statistique des activités économiques dans la Communauté européenne"

[25] International Service for the Acquisition of Agri-biotech Applications (ISAAA), 'Global Status of Commercialized Biotech/GM Crops in 2017: Biotech Crop Adoption Surges as Economic Benefits', 92.

[26] State of the environment portal: Areas planted with genetically modified maize in Portugal.

[27] International Service for the Acquisition of Agri-biotech Applications (ISAAA), 'Global Status of Commercialized Biotech/GM Crops in 2017: Biotech Crop Adoption Surges as Economic Benefits', 93.

[28] Eurostat: apro_cpnh1, Crop production in national humidity.

[29] Eurostat: agr_r_accts: Economic accounts for agriculture by NUTS 2 regions.

Industry definition

The definition of the biotechnology sector used in this study is based on a selection of 106 goods from the Prodcom database. These goods are produced in three different industries, namely Manufacture of food products; beverages and tobacco products (NACE C10-C12), Manufacture of chemicals and chemical products (NACE C20), Manufacture of basic pharmaceutical products and pharmaceutical preparations (NACE C21). This selection combines preliminary work by the KET Observatory[30], nova-Institute and IDEA consult. As it is not constructive to include very traditional biotechnology users from the craft sector such as bakeries, breweries or wineries as (modern) biotechnology industry, these were exluded.

It is not the source material, but the biotechnological conversion with the help of living organisms or parts of them, such as microorganisms, cells or enzymes, that is decisive for whether the economic value of a good is taken into account in this study. This focus is especially important to differentiate against the physical and chemical conversion of biological raw material what is mainly in the center of the bioeconomy*.* The economic importance of this broader sector is analyzed by nova-Institute. In their latest study on the bio-economy of the EU28, they assess its turnover in 2017 at €2.4 trillion.[31]

Our data is somehow included in these numbers and reflects the part and importance of biotechnological processing of biomass.

Gross value added and employment

For the calculation of direct, indirect and induced gross value added and employment effects, multiregional Input-Output tables as provided by WIOD[32] were used. At the time of writing, the latest available tables were for the year 2014, which were deflated to estimate corresponding tables for the year 2018. Based on our industry definition, the sector-specific production values for the three biotechnology sub-sectors for each year between 2008 and 2018 and for each EU28 Member State[33], provided by PRODCOM, have been combined with the information provided by WIOD to measure direct GVA and employment.

[30] IDEA Consult et al., 'Key Enabling Technologies (KETs) Observatory. Second Report'.

[31] BIC and nova-Institute, 'European Bioeconomy in Figures 2008–2017'.

[32] Timmer et al., 'An Illustrated User Guide to the World Input-Output Database'.

[33] Although our calculation model takes all 28 EU member states into account, there are only 25 member states that produce goods that meet the biotechnology definition used. Direct effects therefore only arise in the following countries: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and United Kingdom.

Trade

For each combination of country, year and commodity, PRODCOM records not only production value but also imports and exports. Accordingly, the biotechnology industry definition synonymous with a specific selection of goods and the corresponding weighting factors can yield consistent values for (extra-EU) exports and imports.

Spillover effects

Input-Output analysis was originally developed by Leontief (1936, 1941) to describe the industrial structure of an economy. Applying this technique, it is possible to trace the inputs of production along the entire supply chain. While in the traditional model households belong to the final demand sector (are exogenous), their activities are included in the model and thus treated as endogenous by using the "fictitious industrial sector approach".

The basis for the calculation of the effects is formed by the following equilibrium equation:

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{y} \leftrightarrow \boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{y}$$

where **x** is the vector of total gross output and **y** is the vector of final demand. $\boldsymbol{A}$ is either the matrix of intermediate consumption coefficients used to calculate the indirect effects or the matrix of intermediate consumption extended by labour income and corresponding consumption coefficients to calculate spillover effects. The equation relates changes in gross output **x** to changes in demand **d**.

Equipped with the output triggered by a given demand (and labour compensation), the corresponding resulting gross value added is derived using country and sector specific ratios of GVA to output. Employment and labour compensation are calculated analogously.[34]

To calculate the indirect and induced effects, multiregional and sector-specific demand vectors have been created for the biotechnology industry of all EU countries under consideration. In order to calculate the induced effects, the resulting demand vector was supplemented by the net disposable income available to employees for consumption purposes. This vector was used as triggering demand to calculate the indirect and induced effects using the global multiregional Input-Output table provided by WIOD.

[34] A detailed description of the Leontief model and the computation of spillover effects may be found in Miller and Blair, *Input-Output Analysis: Foundations and Extensions*.

C

Brexit: EU27-EU28 comparison

This project was started before the UK's final withdrawal from the European Union on 31 January 2020. Therefore, it covers the EU28. Although the future linkage of the UK to the EU Single Market is uncertain, the new shape of the EU of now 27 Member States has the following impact on the key findings of this study

Figure	EU27	EU28	Impact of UK leaving EU28
Direct GVA, 2018	€ 31.0 bn	€ 34.5 bn	- € 3.5 bn
Spillover GVA, 2018	€ 37.8 bn	€ 44.3 bn	- € 6.5 bn
Total GVA, 2018	€ 68.8 bn	€ 78.7 bn	- € 9.9 bn
Direct employment, 2018	210,700	223,000	- 12,300
Spillover employment, 2018	625,700	710,500	- 84,800
Total employment, 2018	836,400	933,500	- 97,100
Annual average growth rate (2008-2018)			
GVA	4.3 %	4.1 %	+0.2 pp
Employment	2.7 %	2.6%	+0.1 pp

Table 1: Alternative results based on the European Union of 27 Member States.

With the UK's departure from the EU, the EU loses a major contributor to the biotechnology industry. This loss amounts to about € 10 bn total gross value added and 79,000 jobs in the overall economy.

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D

Background information: micro-economic view of the European biotechnology industry and comparison to the US

Key metrics compared

As a result of quite a few positive conditions the US biotechnology industry experienced a constant growth in terms of number of firms, sometimes interrupted by setbacks due to general economic crises.

Mainly in the 1990ies, the European biotechnology industry caught up very fast with regard to the number of biotechnology companies. However, counting the number of public biotechnology firms – which often are better financed – Europe is continuously lagging behind the US. Public companies are the driving force in the US biotechnology industry. They account for about 90% of all revenues and about ¾ of all employees in the industry.

Figure 18 shows selected metrics – number of public companies, revenues, expenses for research and development (R&D), and market capitalization – for the public European and US biotechnology industry. To adjust for the higher number of public biotechnology firms in the US, the analysis includes calculating the metrics per company. Unfortunately, the underlying data for the metrics are only available until the year 2016. Nevertheless, the lagging situation of the European industry becomes clear.

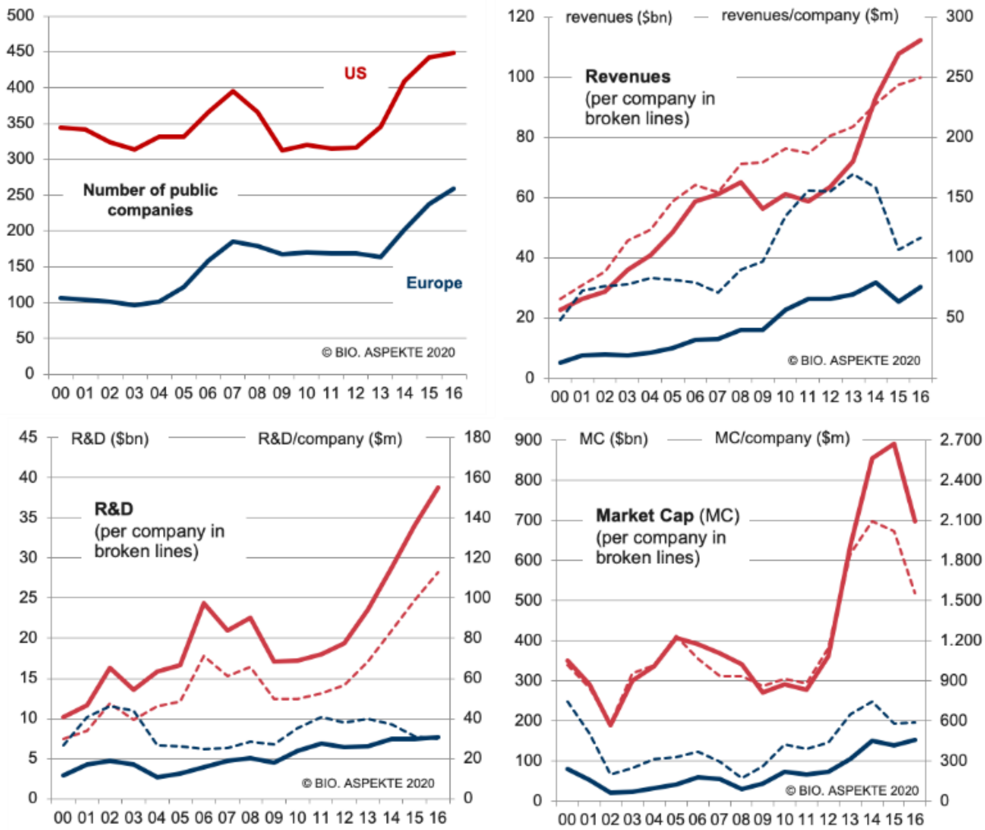

Figure 18: Selected metrics of public biotechnology SMEs, Europe compared to the US, 2000 to 2016.
Source: data from EY Global Biotechnology Reports 2001 to 2017; BIO. ASPEKTE & WifOR analysis.

Financings compared

All the developments of US biotechnology companies and their products were strongly backed by early success stories and favorable financing conditions, eg risk taking and spezialized investors, attractive peer groups at the stock exchanges as well as a supporting regulatory environment. Specially the opportunity to go public and subsequent financings as a publicly listed company with a defined company value supported a flourishing industry.

In Europe there is no comparable financing climate for biotechnology although money is basically available. Less risk-taking combined with almost missing biotechnology success stories is like asking the question "which came first: the chicken or the egg?". In the US a handful of early firms managed to pick the low hanging fruits of the new modern biotechnologies. This resulted in them becoming well financed success stories who were able to grow based on own revenues and new developments. Moreover, venture capital was somehow an invention in the US joint by a prominent equity culture.

The impact of these favorable financing conditions is impressively shown by figure 19: biotechnology financing in the US is about 5 times higher than in Europe. This does not mean that there is better science but better translation into business and innovation supported by an intact financing ecosystem. However, the industry in Europe started about 15 years later which means that a fair comparison actually should include different time frames. With that, the years 2005 in the US and 2019 in Europe have to be compared due to the same amount of financing of about $15 bn.

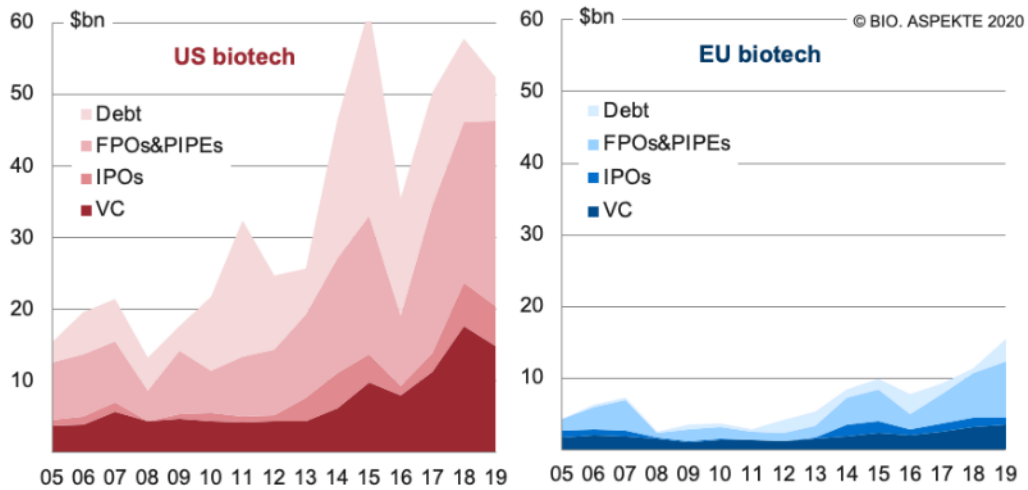

Figure 19: Equity and debt financing in the US and European biotechnology industry 2005 to 2019.
FPO: follow-on offering, IPO: initial public offering, PIPE: private investment in public entity, VC: venture capital.
Source: data from EY German Biotechnology Reports 2011 to 2020, EY Global Biotechnology Reports 2006 to 2017; BIO. ASPEKTE & WifOR analysis.

Lately the biotechnology financing situation in Europe has improved over the past years as is shown in figure 20:

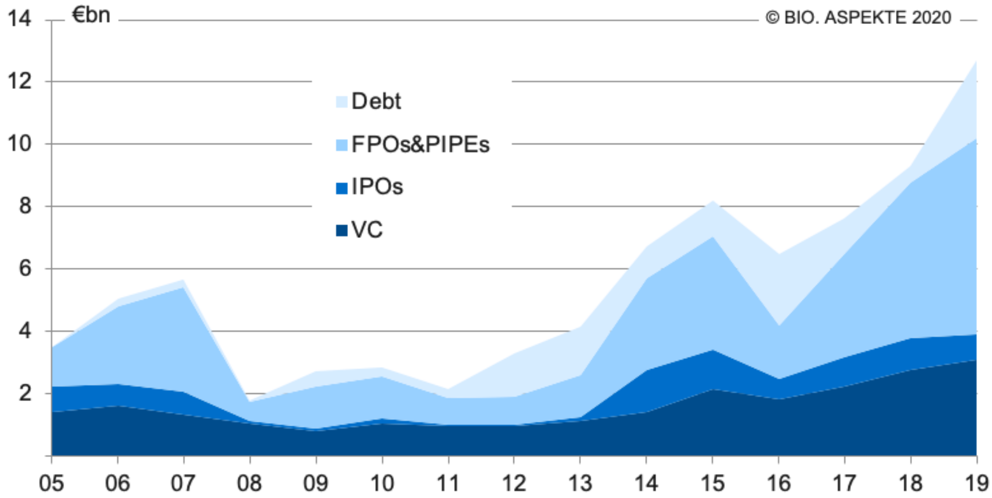

Figure 20: Equity and debt financing in the European biotechnology industry 2005 to 2019.
FPO: follow-on offering, IPO: initial public offering, PIPE: private investment in public entity, VC: venture capital.
Source: data from EY German Biotechnology Reports 2011 to 2020, EY Global Biotechnology Reports 2006 to 2017; BIO. ASPEKTE & WifOR analysis (2016 adjusted for Shire's $12 bn debt financing).

In 2019, venture capital (VC) and follow-on offerings by public companies reached an alltime high and the total volume of equity financings surpassed the benchmark of €10 bn. Although there were 4 VC-rounds larger than €100 m which raised the total VC amount, additionally 9 VC financings reached more than €50 m. This gives hope that the financing situation is stabilizing on a higher level than the years before.

The current COVID-19 pandemie is mobilizing additional public and private money for companies active in the development of vaccines or drugs. On top of Germany based BioNTech's VC and IPO financings in the year 2019 amounting to €290 m and €141 m, the mRNA vaccine pioneer was able to raise €457 m in follow-on financing in July 2020. Another mRNA vaccine pioneer, also based in Germany is CureVac, was already founded in 2000. In 2020, the company raised in total €860 m from investors such as the KfW (Kreditanstalt für Wiederaufbau), European Investment Bank, Qatar Investment Authority, and GlaxoSmithKline. The amount includes proceeds of more than €200 m stemming from an IPO at the US stock exchange NASDAQ in August 2020. These are outstanding amounts of financing, barely never available before by European biotechnology companies.

However, again, compared to their main US competitor Moderna Therapeutics the height of invested money is falling short: already in 2015, 2016 and 2018 Moderna raised $450 m, $474 m and $500 m as venture capital financing. In 2018 the IPO brought $604 m and in 2020 two follow-on financings happened with $575 m invested by a consortium of well-known banks such as Goldman Sachs, Morgan Stanley, Barclays or Oddo BHF and $1,338 m additional invested alone by Morgan Stanley.

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Glossary

Debt financing: raising operating capital or other capital by borrowing. Most often, this refers to the issuance of a bond, debenture, or other debt security.

Direct effects: The immediate economic effects directly generated by a company or industry.

Employment: The number of jobs created, measured on a headcount basis.

FPO (follow-on public offering): public issuance of shares to investors by a company listed on a stock exchange.

Gross value added: Describes a company's or industry's contribution to the gross domestic product (GDP).

Gross value added rate (GVA rate): The GVA rate is calculated as the ratio of GVA and output. It shows the integration of the upstream gross value added stages into the economic activities of a company or industry.

Indirect effects: The production activities of a company require purchased materials and services. Such purchased materials and services in turn result in increased production among suppliers also requiring purchased materials and services for their own production process. The resulting cascading effects (e.g., employment, gross value added) are referred to as indirect economic effects.

Induced effects: These originate from the expenditure of directly and indirectly generated incomes. The compensation of employees directly paid by a company or industry and paid by their suppliers in order to be able to satisfy the demand further increases the demand in the economy. This additional demand triggers economic effects (GVA, employment) which are summed up under the term induced economic effects.

Intermediate consumption: Goods and services purchased by a company or industry that are necessary for the production of its own products.

IPO (initial public offering): process of offering shares of a private corporation to the public in a new stock issuance.

Labour compensation: Compensation of employees including gross wages and salaries as well as employers' social contribution.

Labour productivity: Direct GVA per directly employed person.

NACE: The Statistical Classification of Economic Activities in the European Community (NACE) is the industry standard classification system used in the European Union. National accounts data is recorded according to this system. The basic underlying principle is to assign a specific NACE code to each unit recorded in statistical business registers based on their main principal activity. The principal activity is the activity which contributes most to the value added of the unit. If for example one company generates most of its GVA by manufacturing pharmaceutical goods, it is assigned the NACE two-digit code 21 which corresponds to the pharmaceutical industry. The current version of NACE is revision 2 (NACE Rev. 2) and in general is used for statistics referring to economic activities performed as from 1 January 2008 onwards.[35]

PIPE (private investment in public entity): buying of shares of publicly traded stock at a price below the current market value per share by private investors.

[35] Eurostat, *NACE Rev. 2. Statistical Classification of Economic Activities in the European Community*, see also: https://ec.europa.eu/eurostat/web/nace-rev2.

Production value: Measures the amount actually produced by the company or industry, based on sales, including changes in stocks and the resale of goods and services. The production value is defined as turnover, plus or minus the changes in stocks of finished products, work in progress and goods and services purchased for resale, minus the purchases of goods and services for resale, plus capitalised production, plus other operating income (excluding subsidies).

Spillover effects: The combined effects of indirect and induced economic effects.

VC (venture capital): company shares bought by investors to finance startup companies and small businesses that are believed to have long-term growth potential.

Glossary of terms used in the OECD list-based statistical definition of biotechnology

DNA/RNA:

• Genomics/pharmacogenomics: The study of genes and their function. Advances in genomics due to the Human Genome Project and other genome research into plants, animals and micro-organisms are enhancing our understanding of the molecular mechanisms of genomes. Genomics stimulates the discovery of health care products by revealing thousands of new biological targets for the development of drugs and by identifying innovative ways to design new drugs, vaccines and DNA diagnostics. Genomic-based therapeutics includes both protein drugs and small molecule drugs. Genomics is also used in plant and animal breeding programmes.

• Gene probes/DNA markers: A section of DNA of known structure or function which is marked with a radioactive isotope, dye or enzyme so that it can be used to detect the presence of specific sequences of bases in another DNA or RNA molecule.

• Genetic engineering: Altering the genetic material of cells or organisms in order to make them capable of making new substances or performing new functions.

• DNA/RNA sequencing: Determination of the order of nucleotides (i.e. the base sequence) in a DNA or RNA molecule.

• DNA/RNA synthesis: The linking together of nucleotides to form DNA or RNA. In vivo, most synthesis involves DNA replication, but incorporation of precursors also occurs in repair. In the special case of retroviruses, an RNA template directs DNA synthesis.

• DNA/RNA amplification: The process of increasing the number of copies of a particular gene or gene-derived sequence.

• Large-scale DNA synthesis: An automated creation of deoxyribonucleic acid (DNA) molecules.

• Genome- and gene-editing: A type of manipulation of the genome, in which DNA is inserted, deleted or replaced in the genome of a living organism using engineered nucleases, or "molecular scissors."

• Gene drive: A technique that promotes the inheritance of a particular gene to increase its prevalence in a population.

• Other: There are several fields of research on RNA, including RNAi and siRNA, based on the use of recombinant technology to generate RNA sequences to inhibit gene function. Expression profiling analyses expressed genes using microarrays or gene chips.

Proteins and other molecules:

• Peptide/Protein sequencing: Determination of the order of amino acids in a protein or peptide.

• Peptide synthesis: A procedure which links two or more amino acids in a linkage called a peptide bond.

• Protein engineering: The selective, deliberate (re)designing and synthesis of proteins. This is done in order to cause the resultant proteins to carry out desired (new) functions. Protein engineering is accomplished by changing or interchanging individual amino acids in a normal protein. This may be done via chemical synthesis or recombinant DNA technology (i.e. genetic engineering). “Protein engineers” (actually genetic engineers) use recombinant DNA technology to alter a particular nucleotide in the triplet codon of the DNA of a cell. In this way it is hoped that the resulting DNA codes for the different (new) amino acid in the desired location in the protein produced by that cell.

• Proteomics: Analysis of the expression, functions and interactions of all proteins of an organism.

• Signaling: Analysis of signaling molecules such as cytokines, chemokines, transcription factors, cell cycle proteins, and neurotransmitters.

• Cell receptors: Structures (typically proteins) found in the plasma membrane (surface) of cells that tightly bind specific molecules (organic molecules, proteins, viruses etc.). Some (relatively rare) receptors are located inside the cell (e.g. free-floating receptor for Retin-A). Both (membrane and internal) types of receptors are a functional part of information transmission (i.e. signalling) of the cell.

Cell and tissue culture and engineering:

• Cell/tissue/embryo culture and manipulation: Growth of cells, tissues or embryonic cells under laboratory conditions.

• Tissue engineering: Refers to the technologies used to induce:

> (Injected) liver, cartilage, etc., cells to grow (within a recipient organism's body) and form replacement [integral] tissues.
>
> (Extant) cells within the body encouraged to grow and form desired tissues, via precise injection of relevant compounds (e.g. certain growth factors, growth hormones, stem cells, etc.).

• Laboratory grown tissue or organs to replace or support the function of defective or injured body parts (an example is skin tissue culture for grafts).

• Cell fusion: The combining of cell contents of two or more cells to become a single cell. Fertilisation is such a process.

• Vaccines/immune stimulants: A preparation containing an antigen consisting of whole disease-causing organisms (killed or weakened), or parts of such organism is used to confer immunity against the disease that the organisms cause. Vaccine preparations can be natural, synthetic or derived by recombinant DNA technology.

• Marker assister breeding technologies (AKA: marker aided selection (MAS)): A selection process used in plant and animal breeding, where a trait of interest is selected based on a marker (morphological, biochemical or DNA/RNA variation) linked to a trait of interest (e.g. productivity, disease resistance, abiotic stress tolerance, and quality), rather than on the trait itself.

• Metabolic engineering: The practice of optimizing genetic and regulatory processes within cells to increase the cells' production of a certain substance.

Process biotechnology techniques:

• Bioreactor: A vessel in which cells, cell extracts or enzymes carry out a biological reaction. Often refers to a fermentation vessel for cells or micro-organisms.

• Bioprocessing: A process in which living cells or components are used to produce a product, especially a biological product involving genetic engineering for commercial use.

• Bioleaching: The conversion of metals to a soluble form by live organisms such as bacteria or fungi.

• Biopulping: Use of micro-organisms to break down wood fibres for the purpose of producing pulp.

• Biobleaching: Use of micro-organisms to bleach pulp.

• Biodesulphurisation: Use of specific micro-organisms to transform hazardous sulphurs into less hazardous compounds.

• Bioremediation/biofiltration/phytoremediation: The process by which living organisms act to degrade hazardous organic contaminants or transform hazardous inorganic contaminants to environmentally safe levels in soils, subsurface materials, water, sludge, and residues.

• Bioremediation: The use of micro-organisms to remedy environmental problems rendering hazardous wastes non-hazardous.

• Biofiltration: The use of a support containing specific bacteria to capture by filtration hazardous substances from a gas stream.

• Phytoremediation: Refers to the use of specific plants to remove contaminants or pollutants from either soils (e.g. polluted fields) or water resources (e.g. polluted lakes).

• Biorefining: A process, in which biomass is converted to produce fuels, power, heat, and value-added chemicals.

• Biosensing: A detection- or sensing-process based on a sensor, in which a biological component is combined with a physicochemical detector.

• Molecular aquaculture: A biotechnological discipline that is concerned with the structure and function of biological macromolecules essential to the cultivation (or farming) of fish, crustaceans, molluscs, aquatic plants, algae, and other aquatic organisms.

Gene and RNA vectors:

• Gene therapy: Gene delivery, the insertion of genes (e.g. via retroviral vectors) into selected cells in the body in order to:

• Cause those cells to produce specific therapeutic agents.

• Cause those cells to become (more) susceptible to a conventional therapeutic agent that previously was ineffective against that particular condition/disease.

• Cause those cells to become less susceptible to a conventional therapeutic agent.

• Counter the effects of abnormal (damaged) tumour suppressor genes via insertion of normal tumour suppressor genes.

• Cause expression of ribozymes that cleave oncogenes (cancer-causing genes).

• Introduce other therapeutics into cells.

• Viral vectors: Certain (retro-) viruses that are used by genetic engineers to carry new genes into cells.

Bioinformatics:

• The use of computers in solving information problems in the life sciences; mainly, it involves the creation of extensive electronic databases on genomes, protein sequences, etc. Secondarily, it involves techniques such as the three-dimensional modelling of biomolecules.

• The generation/creation, collection, storage (in databases), and efficient utilisation of data/information from genomics (functional genomics, structural genomics, etc.), combinatorial chemistry, high-throughput screening, proteomics, and DNA sequencing research efforts in order to accomplish a (research) objective (e.g. to discover a new pharmaceutical or a new herbicide, etc.). Examples of the data/information that is manipulated and stored include gene sequences, biological activity/function, pharmacological activity, biological structure, molecular structure, protein-protein interactions, and gene expression products/amounts/timing.

Nanobiotechnology:

• Covers the interface between physics, biology, chemistry and the engineering sciences and which, among other things, aims to develop completely new measuring technologies for the biosciences.

• Nanotechnology develops or makes materials that function on a very small scale, typically between 1 and 100 nanometers. Nanobiotechnology uses these particles and materials as tools to improve the performance and sensitivity of several life science technologies e.g. biosensing, medical devices and medical implants.

WifOR Institute is an independent economic research institute that originated from a spin-out of the Department of Public Economics and Economic Policy at the Technical University of Darmstadt, Germany. WifOR's fields of research include Economic, Environmental and Social Impact Analyses as well as Labour Market and Health Economy research.

CONTACT

WifOR Institute
Rheinstraße 22
64283 Darmstadt
www.wifor.com
+49 30 6151 50 15 50
office@wifor.com