Environmental and socio-economic transformations in developing areas as the effect of globalization

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Regional differences in the development of the biotechnology industry in Latin America, with particular emphasis on Brazil and Mexico

Abstract: The biotechnology industry, now considered a key component of the so-called Third Technological Revolution, is experiencing dynamic growth throughout the world, including many parts of Latin America. This sector has been growing particularly fast since the 1990s in the largest countries of the region – Brazil, Mexico, and Argentina. In the beginning of the 1990s those three countries liberalized their economic policies and policies on foreign trade. They also took active part in the process of globalization by opening up to foreign investment and by ratifying agreements on international exchange of commodities and intellectual property. This clearly accelerated the development of their biotechnology sector. The purpose of this paper is to describe regional differences in the growth of the biotechnology industry in Latin America. The regional distribution of biotechnology companies is also compared. The geographic distribution of biotechnology companies was used in an attempt to identify key regions associated with the biotechnology sector in Latin America, and to determine the factors that impact or are associated with the regional distribution of the biotechnology sector. The research was based on contact data obtained from a Swiss company called Biotechgate, as well as on various Mexican and Brazilian sources.

Key words: biotechnology, Latin America, Mexico, Brazil, business incubators, technology parks

1. Introduction

The biotechnology industry is currently one of the fastest growing sectors of the knowledge-based economy. At the same time, it is one of the main components of the so-called Third Technological Revolution (TTR). The dynamic growth of the biotechnology industry is related to a growing worldwide demand for its products, such as starter cultures in the food industry, genetically modified organisms (GMO) – primarily new varieties of cereals and other cultivated plants in agriculture, new drugs, vaccinations, diagnostic agents in the pharmaceutical industry, detergents and bioremediation agents (used for wastewater treatment) in the chemical industry. Biotechnologies are being used more and more commonly in other branches of industry, often considered traditional, such as the food industry, pulp and paper industry, textile industry, chemical industry, tanning industry, and pharmaceutical industry.

The growing role of biotechnology is also associated with population growth and the desire to eradicate problems such as hunger and malnutrition in economically underdeveloped regions by means of increasing agricultural production. Also pointed out on numerous occasions is the significance of biotechnology for highly developed countries. Advanced economies, facing the aging of societies and the growing expectations of improvement of the quality of life and healthcare, as well as of limiting human impact on the natural environment (for example, in the form of decreasing the use of chemical agents for plant protection), often decide to rely on the development of biotechnology (Kelly, 2004; Otero, 2008; Dorocki, Jastrzębski, 2012; Dorocki, Boguś, Borowiec, 2013).

In spite of rapid progress in the field of biotechnology, which started in the second half of the 20th century, there is still no single precise definition of the term *biotechnology*. One of the broadest definitions is specified in the United Nations's Convention on Biological Diversity. It states that biotechnology is "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use." Therefore, biotechnology is an interdisciplinary science integrating the natural sciences and technology. The definition put forth by the European Federation of Biotechnology states that biotechnology is "the integrated use of biochemistry, microbiology, and engineering sciences in order to achieve technological (industrial) application of the capabilities of micro-organisms, cultured tissue cells, and parts thereof and their molecular analogs in order to provide goods and services" (Dorocki, Jastrzębski, 2012). According to the definition introduced in 1986 by the General Accounting Office (GAO) of the United States Congress, "(…) biotechnology is generally considered to be a component of high technology, and the 'new biotechnologies' are those resulting from recently developed, sophisticated research techniques, including plant cell and protoplast culture, plant regeneration, somatic hybridization, embryo transfer, and recombinant DNA methods" (GAO, 1986: 10; quoted after Otero, 2008: 3).

In Latin America the biotechnology industry began to develop in the second half of the 1980s. It began to grow because the rules governing the economy were liberalized, and barriers that limited foreign investment were eliminated. The growth of the biotechnology industry was also associated with changes in the law introduced by a number of countries in Latin America. Changes in the law now applied also to intellectual property rights (IPR) and patent policies that protect the results of biotechnological research. This is why leading research institutions and well-established universities served as the main driving force in the growth of the Latin American biotechnology industry. On the other hand, starting with the 1990s, large transnational corporations (TNCs) with large research budgets entered the markets of the largest countries in the region and began to play an increasingly important role. In the initial period small companies played an insignificant role, which stemmed from the lack of capital needed for business development. Doing business in this sector requires high expenditures for research and the purchase of patents or licenses (Otero, 2008; Poitras, 2008; Jepson et al., 2008).

Innovation and high rates of growth are important characteristics of the biotechnology sector. This brings an element of high risk to investing in this sector. These characteristics also cause most biotechnology companies to be located in close proximity to other research centers and infrastructure. Such locations also facilitate easy access to centers of technological *know-how* (Zucker et al., 1989; Stuart, Sorenson, 2003).

Biotechnology companies emerge primarily in the neighborhood of world-class universities that provide access to highly qualified personnel and research infrastructure, such as specialized laboratories. These are often the basis for performing scientific research applied to biotechnology (Autant-Bernard et al., 2006). Recent research has also shown that the transfer of knowledge is geographically limited. This is why it is important for companies to be located near the source of innovation (Audretsch 2007; Barker et al., 2007).

In terms of human capital in the biotechnology sector, the transfer of knowledge is nevertheless limited to a job market that is geographically concentrated *(tacit knowledge)* (Saxenian, 1999; Saxenian et al., 2003; Dahl, Sorenson, 2007). In spite of seemingly high employee mobility this is still the case. Moreover, research has shown that R&D employees tend to choose employers locally. This may be related to so-called personal factors (Stryjakiewicz, 2008), or their active pursuit of scientific work (for example, the desire to perform scientific work continuously) (Dahl, Sorenson, 2007). In biotechnology companies, the percentage of employees with a doctoral degree is two or three times higher than at other companies in the R&D sector (van Beuzekom, Arundel, 2009). This proves that biotechnology professionals are characterized by strong ties to centers of scientific research.

The transfer of knowledge is another key factor in the development of biotechnology. A large number of scientific institutions, which is typical of large urban areas, is one source of knowledge. Economies of agglomeration make it possible to form closer ties between business entities and scientific organizations (Domański, 2000; Klasik, 2009; Czyż, Chojnicki, 2008; Markowski, 2008). The positive influence of a regional concentration of industry and institutions in the biotechnology sector is confirmed by examples observed in Canada, Western Europe, and the United States (Corolleur et al., 2003; Aharonson et al., 2008; Sytch, Bubenzer, 2008; Lecocq et al., 2010), as well as those observed in Mexico and Brazil (Casas et al., 2000; Lalkaka, Shaffer, 1999; Dimova et al., 2009; Biominas, 2009).

Financial conditions and cultural issues are an additional factor in the development of the biotechnology industry. The views of society and local authorities are especially important. This takes on special significance in cases where genetic modification is a part of the research process, or when some other "morally sensitive" scientific activities take place (Casper, 2007, 2009). The availability of venture capital is another important element, in developing countries in particular. Access to high-risk capital or funds for investment in high-risk enterprises, which often depends on the views of the members of a given society, also depends on the policies pursued by a given country, with respect to both international money transfers and protection of intellectual property rights including patents (Wagner, 1998, Poitras, 2008; Jepson et al. 2008, Biominas & PwC 2011).

Considering all of the above-mentioned factors, the following resources that affect the growth of the biotechnology industry may be identified (as described by Casper): (1) scientific capital, consisting of scientists along with their unique knowledge and creativity; as well as (2) scientific institutions; (3) human resources, that is scientific and business management personnel including entrepreneurs; and (4) access to technologies and patents, which is especially important in developing countries. The final resource is financial capital along with the investors and financial institutions engaged in making venture capital available to high-risk startup companies. All these resources should additionally be complemented by a rich network of social interconnections that link together scientists, entrepreneurs, managers, and investors. Such networking allows for fast dissemination of information within companies and organizations as well as between them (Casper, Murray 2005; Casper, 2009).

The facts and considerations described above will be a premise in further discussion, as the purpose of this paper is to show regional differences in the development of the biotechnology industry in Latin America. Emphasis is put on Brazil and Mexico, two countries with the best developed biotechnology sector in Latin America. Differences in the region's biotechnology industry will be determined based on the geographic distribution of biotechnology firms and research institutions. The geographic distribution of biotechnology firms will be used to identify key regions associated with the biotechnology sector in Latin America. Finally, the factors that impact, or are associated with, the regional distribution of the biotechnology sector will be investigated. Contact information for biotechnology companies was obtained from the Swiss company Biotechgate and was enhanced by information published by the Fundação Biominas and other institutions that analyze the development of the sector in Latin America.

2. Geographic distribution of biotechnology firms in Latin America

The beginnings of biotechnology are often associated with the development of modern commodity farming in the 1930s in the United States. It was characterized by growing mechanization of agriculture and the increasing use of chemicals used in growing crops. It was also characterized by the introduction of hybrid varieties of corn and modified varieties of other species of cultivated plants. Artificial fertilizers, pesticides, herbicides, and insecticides were used more and more commonly in the commodity farming system. This provided a strong stimulus for the chemical industry and manufacturers of machinery to improve their products and expand their business. Productivity also increased rapidly as a result of these innovations. However, large numbers of farmers were now faced with the necessity to leave the countryside to look for employment elsewhere. This entailed the need to change professions and seek employment most often in cities that were becoming increasingly industrial (Otero, 2008: 7).

Innovations introduced in agriculture in the United States began to make their way into Latin American countries in the late 1940s and early 1950s. This was known as the Green Revolution. It was supposed to help boost food production in the face of high natural population growth. The development of modern agriculture accelerated thanks to the innovations brought about by the Green Revolution, but also triggered severe social and economic consequences in Latin America. A wave of mass migration of agricultural workers and small farmers and their families to cities was one effect of mechanization and intensified agricultural production. However, this migration was not associated with sufficiently rapid industrialization in urban areas. It was quite unlike the situation in the United States in the 1930s. The wave of migration in Latin America resulted in high unemployment among migrants. It also increased the pool of illegal labor and produced excessive employment in the service sector (Bromley, 1998; Bromley, Mackie, 2009; Otero, 2008).

The biotechnology industry in Latin America has been developing since the middle of the 20th century. Mexico and Brazil are the two countries that have contributed the most to this process. Initially, Mexico had the best developed biotechnology sector in Latin America. According to data provided by Biotechgate, six companies of this type already operated in Mexico (Fig. 1).

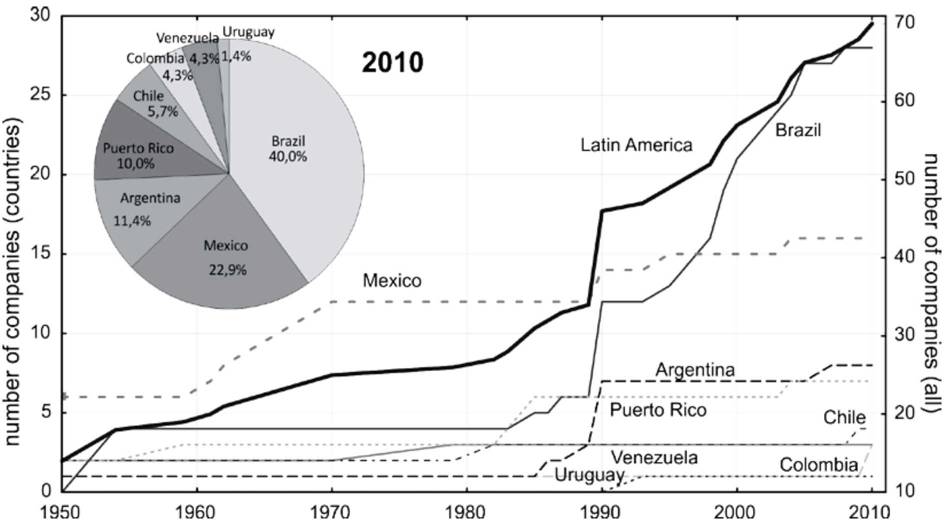

Fig. 1. Number of biotechnology firms in Latin American countries: 1950–2010

Source: own compilation on the basis of: BiotechGate

On the one hand, this should really be linked to the close proximity of the United States, which had traditionally set the standard for the development of new branches of industry and scientific research. This encouraged the government of Mexico to develop an industry engaged in this type of business activity. On the other hand, the close proximity of U.S. biotechnology companies made collaboration easy. This facilitated the diffusion of innovation and fueled the decision process, as Mexican entrepreneurs were willing to get involved in the development of companies in industrial sector on the local market. By pursuing a policy of industrialization, the national government played a key role. The Mexican government implemented this policy by replacing imports with domestic production. The government also introduced measures to protect national industries, which was very important in the emerging branches of industry. By becoming a key investor and by promoting research and development in the biotechnology sector, the state played a major role (Casas et al., 2000; Poitras, 2008).

Further development of this sector in Mexico occurred in the 1960s and 1970s. The number of companies and institutions doing business in this sector doubled from 6 to 12. This happened, to a large extent, as a result of new investments made by the national government. A very important event occurred on the 17th of April, 1961. The Center for Research and Advanced Studies of the National Polytechnic Institute *(Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional - CINVESTAV-IPN)* was established by a decree of Mexico's President Adolfo López Mateos. At present, the Center for Research and Advanced Studies encompasses ten research facilities located in different parts of the country. Three are located in Mexico City (Zacatenco, Coapa, San Borja). These three research centers are involved in molecular biology, biochemistry, biophysics, pharmacology, toxicology, physiology, and neurology. Another important center for the development of biotechnology is the research facility called CINVESTAV-IPN. It was established in 1981 in the city of Irapuato, a city with a population in excess of half a million in the state of Guanajuato. CINVESTAV-IPN is involved in biotechnology, biochemistry, and genetic engineering of plants. Another institution, the National Laboratory of Genomics for Biodiversity – LANGEBIO (*Laboratorio Nacional de Genoma para la Biodivesidad del IPN)*, was established in April of 2005 at the CINVESTAV Department of Genetic Engineering. The establishment of this research center attracted other biotechnology companies to Irapuato, notably DuPont Pioneer (Casas et al., 2000; Possani, 2003).

Another important Mexican center for the development of biotechnology is the Research Center for Genetic Engineering and Biotechnology *(Centro de Investigación sobre Ingeniería Genética y Biotecnología)*. It was established in 1982 by the rector (president) of UNAM *(Universidad Nacional Autónoma de México),* which is the largest university in Mexico. As part of the process of decentralization of research and development organizations in the beginning of the 1980s, it was accepted that such facilities should be located away from the capital city. Hence, the new research center was built in the city of Cuernavaca, which is located 85 kilometers to the south of Mexico City. Nowadays, the Research Center for Genetic Engineering and Biotechnology includes the UNAM Institute of Biotechnology *(Instituto de*

Biotecnología – UNAM) and the Center for Genomic Sciences *(Centro de Ciencias Genómicas - UNAM)* (Possani, 2003; http://www.morelos.unam.mx/).

Today Brazil is the leader in the biotechnology sector in Latin America in terms of the number of biotechnology firms. A sudden increase in the number of biotechnology business entities occurred in Brazil in the late 1980s and in the 1990s. The number grew from six in 1989 to nineteen in 1999. This rapid increase occurred as a result of the introduction of support programs, such as the program for technological development by Brazil's National Scientific and Technological Development Council (CNPq) operating since the mid-1980s. The main aim of the program was to establish technology parks and business incubators that would facilitate and support the formation of companies, help commercialize research results, and make their quick implementation in production possible. Initially, six parks of this type were created. Starting with 1993 the process was accelerated and by 1999 the number of parks increased to 74. In 2011 the number of Brazilian technology parks equaled 384. As technology parks emerged, the number of biotechnology companies increased rapidly. Foreign corporations also became actively interested in doing business here, as they were willing to enter the quickly growing Brazilian market (Lalkaka, Shaffer, 1999; Biominas & PwC, 2011; *Estudo, Análise e Proposições*..., 2012).

The list of Latin American countries with biotechnology companies includes Argentina (8 companies in 2010), Puerto Rico (7 companies), Chile (4 companies), Colombia and Venezuela (3 companies each), and Uruguay (1 company). Argentina experienced the largest increase in the number of biotechnology companies at the end of the 1980s. By 2010, a total of 70 firms were registered in Latin American countries. Forty percent of these firms were registered in Brazil, 23% in Mexico, and 11% in Argentina. Three main types of biotechnology companies may be identified based on data obtained from Biotechgate. The first type consists of biotechnology companies operating in the Diagnostic and Therapeutic (T&D) sector. Their key task is using biotechnologies to discover new therapeutic substances and develop new therapeutic compounds. The next part of this mission is to research the substances to determine their potential use in medicine. To work on innovative drugs, companies of this type must possess their own research and development department, as well as appropriate infrastructure. Their business activity is designed to concentrate on the invention and development of innovative therapeutic substances. Companies that only manufacture or distribute drugs, but do not have their own research and development departments, do not belong in this category. Companies involved in making generic drugs only, and not inventing new therapeutic substances, are also excluded from this category.

The second type consists of service companies operating in the research and development (R&D) sector. Such companies provide support services such as product development, analytical services, screening, production, and research and development services to the biotechnology industry. Some companies may, however, work on drug development, as well as provide services. The principal business activity of a given company determines its classification in such cases. Generally, if the number of employees outside the R&D department is greater than the number of R&D employees, is an indication that it is an R&D service company.

The last type are biotechnology companies classified as “other”. These companies, in order to be put in such category, should satisfy all the requirements for a biotechnology company operating in the therapeutic sector, but they cannot be involved in medical treatment research. They should, however, focus on agriculture, cosmetics, environmental protection, food technology, industrial biotechnology, nutrition pharmaceuticals (i.e. dietary supplements) or veterinary medicine. Furthermore, there are pharmaceutical firms that are trading companies, which are involved in research, production, and sales of drugs and other products. They are usually large enterprises, which generate positive revenues and have their own research and development capability, infrastructure, as well as strong trade linkages. Other types of firms are medical technology companies that perform their own research and development and are involved in the production and sales of medical devices and systems. Additionally, firms that provide services to biotechnology and pharmaceutical companies were identified. This class of firms included investment companies; mass media; professional services and consulting (Professional S&C) companies; and supply & engineering (S&E) companies. Public and non-profit institutions, such as national research institutes, universities, hospitals, technology parks, and foundations, were also identified as a separate class.

Considering the entire spectrum of types of biotechnology organizations operating in Latin America, the two types that are most common are biotechnology companies and public institutions (Fig. 2).

The most innovative biotechnology firms, or those in the T&D and R&D sectors, comprise 23% of all registered companies in Latin America. This is a proportion that is close to their share in the world (25%). For comparison, their share in the European Union is 30% and in the United States it equals 38%. Non-commercial institutions comprise over 34% of all biotechnology institutions in Latin America. Their share worldwide is about half of that (18%), whereas in the developed countries of the European Union their share is 15%, and in the United States it is just 11%. Biotechnology is the sector of the innovative economy, in which cooperation between industry and research institutions is the strongest. In the biotechnology sector, unlike in the remaining innovative sectors of the economy, most innovations are developed by dedicated research organizations, usually universities (Eliasson 2000). This cooperation, however, has another dimension, both in developed and developing countries. Private institutions stimulate research conducted at public institutions in developed countries. In developing countries, however, research is funded by national governments (research grants, stipends), but the research results are used by private companies or business entities – the so-called spin-off companies (Rothaermel, Deeds, 2004; Ukropcova, Sturdik, 2009; Dawidko, 2012).

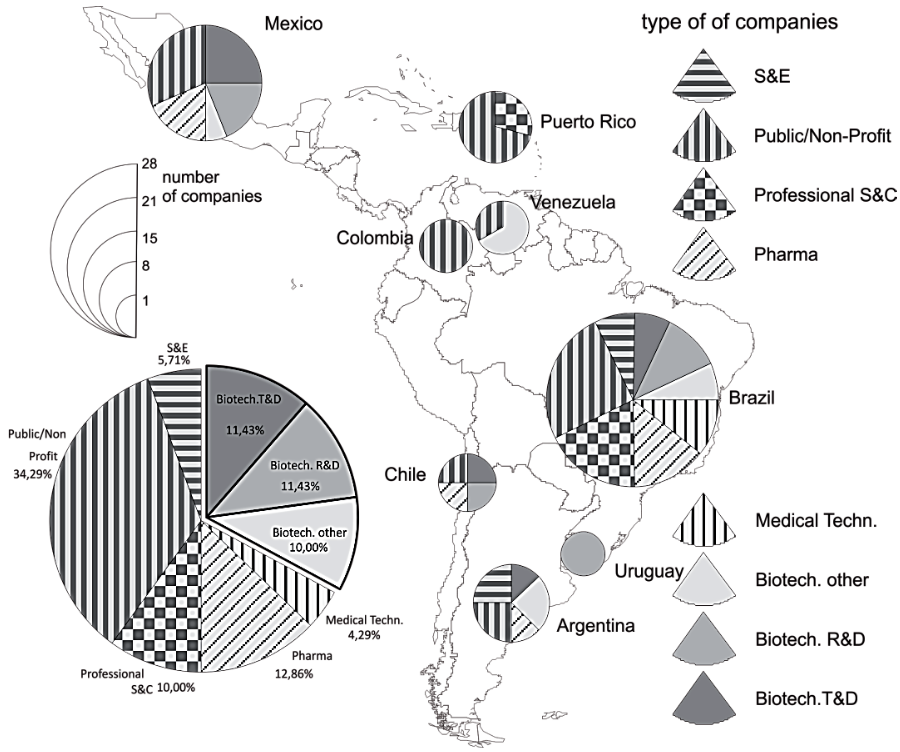

Fig. 2. Number and type of biotechnology firms in Latin America in 2010

Source: own compilation on the basis of: BiotechGate

Universities and international research institutions are the principal noncommercial organizations in Latin America. These institutions significantly stimulate the development of biotechnology. Mexico, with its capital Mexico City, the island of Puerto Rico, and Brazil stand out in terms of the number of such organizations (Fig. 3). The case of Brazil will be discussed in more detail later in this paper (Tab. 3).

The dependence between the share of research institutions and biotechnology companies is especially noticeable in Mexico. Biotechnology companies (T&D, R&D, and others) account for over half of all companies in Mexico, whereas national institutions owned by the state account for 31%. The remaining 19% are pharmaceutical companies. This makes Mexico one of the largest pharmaceutical markets in the world, and the second largest in Latin America, after Brazil. Annual pharmaceutical drug sales in Mexico in 2012 reached nearly 13.7 billion U.S. dollars, whereas the value of pharmaceutical production exceeded 10.7 billion U.S. dollars. Mexico ranks second in Latin America, and is surpassed only by Brazil, whose demographic potential is almost two times greater than Mexico's. For that reason Brazil is a market that is over two times larger than Mexico, both in terms of the dollar value of pharmaceutical production and in terms of consumption (Tab. 1).

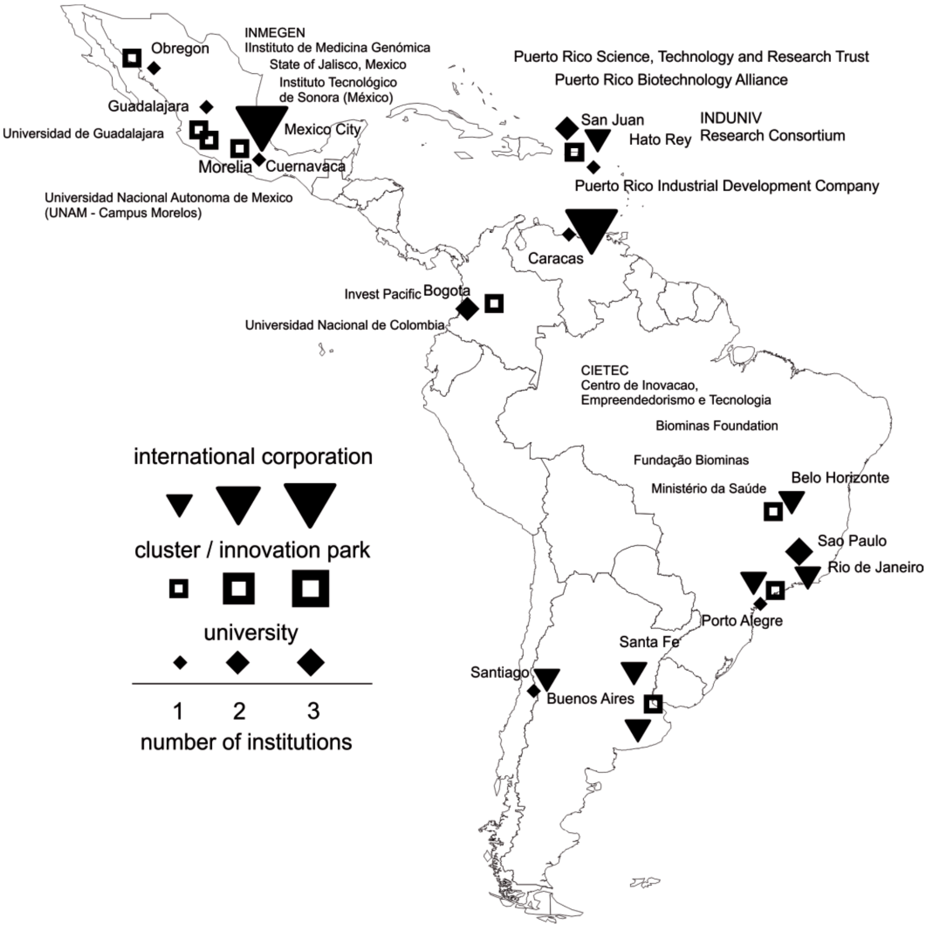

Fig. 3. Noncommercial biotechnology institutions

Source: own compilation on the basis of: BiotechGate

The pharmaceutical sector in Mexico was strongly impacted by the recent worldwide economic recession. In the years 2009–2010, both consumption and production decreased by almost 23.9%, which reflects the negative trend . Faced with a decrease in sales on the domestic market, starting in 2010, companies in this sector fought to export their products to markets in neighboring countries (Fig. 4). The value of exports in 2012 reached nearly 1.9 billion U.S. dollars. The main target markets for these exported goods were the United States (22.1%), Venezuela (17.6%), Panama (11.9%), Brazil (7.5%), and Colombia (5.9%). It should also be noted that the value of pharmaceutical imports in 2012 was 4.985 billion U.S. dollars. This means that the trade balance for this sector was negative, and the resulting trade deficit amounted to 3.111 billion U.S. dollars (*The Pharmaceutical Industry*, 2013).

Table 1. Leading manufacturers and consumers in the pharmaceutical industry in 2012

Region	Production			Consumption		
	Amount (Million USD)	Global Share	Growth 2011–2012	Amount (Million USD)	Global Share	Growth 2011–2012
Asia & Pacific	**477,833**	**46.9**	**13.6**	**488,344**	**46.8**	**13.2**
China	275,508	27.0	18.3	270,010	25.9	18.2
Japan	93,459	9.2	7.2	105,829	10.1	6.2
European Union	**248,748**	**24.4**	**-4.9**	**194,603**	**18.7**	**-4.8**
France	52,233	5.1	-2.8	49,234	4,7	20.1
Germany	50,398	4.9	-10.3	-	-	-
North America	**199,253**	**19.6**	**1.7**	**225,074**	**21.6**	**-3.2**
United States	175,334	17.2	1.2	190,106	18.2	-4.8
Latin America	**35,751**	**3.5**	**-5.2**	**49,234**	**4.7**	**1.8**
Brazil	24,031	2.4	-11.0	29,328	2.8	-6.7
Mexico	10,757	1.1	3.5	13,663	1.3	3.9
Others	**56,947**	**5.6**	**–**	**85,743**	**8.2**	**4.0**
TOTAL	**1,018,532**	**100.0**	**5.0**	**1,042,999**	**100.0**	**4.4**

Source: own compilation on the basis of: *The Pharmaceutical Industry,* 2013

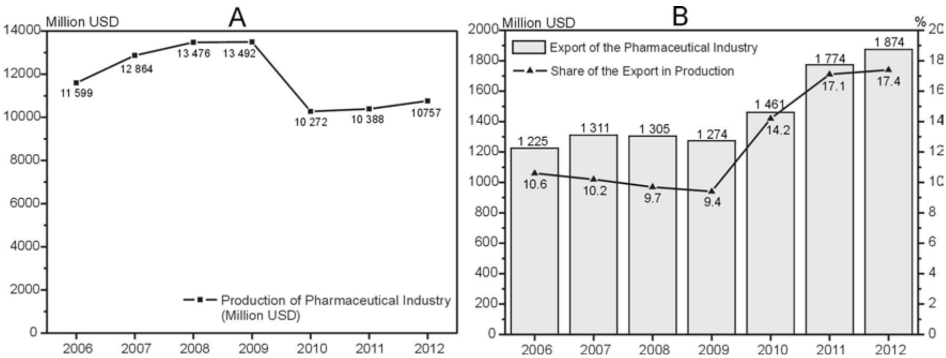

Fig. 4. Production output (A) and exports (B) for the Mexican pharmaceutical industry in the years 2006–2012

Source: own compilation on the basis of: *The Pharmaceutical Industry,* 2013

The influx of foreign direct investment may be viewed as an indication of the dynamic development of the Mexican pharmaceutical sector. In spite of the recent worldwide economic recession, the influx of FDI funds continued, and in the years 2005–2012 their value was 2.866 billion U.S. dollars. The invested capital came, for the most part, from the United States (45.7%), Luxembourg (24.2%), and Ireland (12.6%). FDI projects were characterized by strong geographic concentration. A large share of the investment funds (54.9%) was spent on projects in Mexico City (Federal District). The remaining part was invested in four states: Morelos (25.6%), Mexico (17.5%), Baja California (1.9%), and Aguascalientes (0.2%). The influx of foreign direct investment strongly reflects the geographic distribution of the Mexican pharmaceutical industry. According to data collected by Mexico's National Institute of Statistics and Geography (INEGI), 678 pharmaceutical plants were located in Mexico in 2012. The total number of employees reached 65,200. In terms of geographic distribution, the Federal District had the largest share in the number of pharmaceutical plants, as 216 pharmaceutical plants (31.9% of the total number) were located there. Subsequent places on the list were taken by the following states: Jalisco (123 plants), Mexico (63 plants), Puebla (34 plants), Michoacán and Morelos – 28 plants each (Fig. 5).

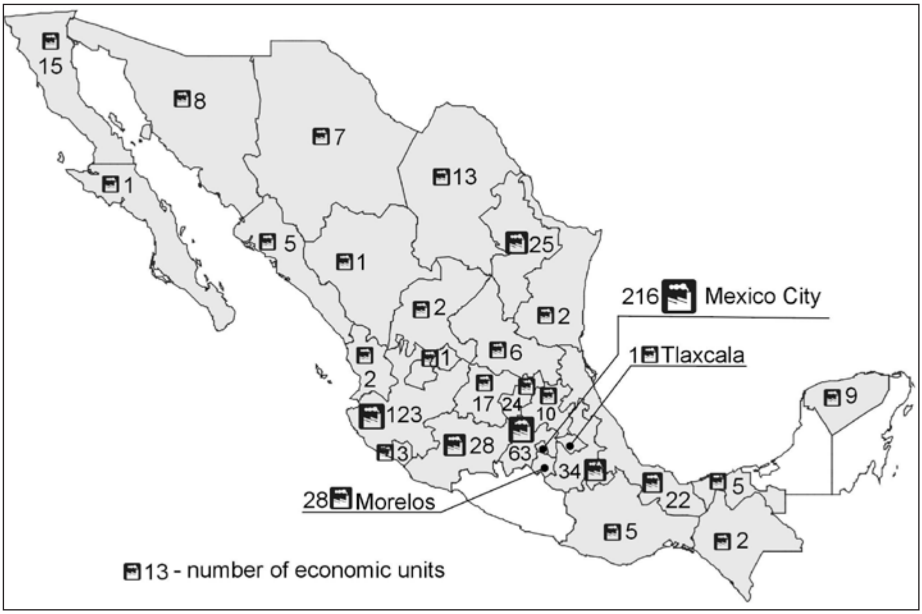

Fig. 5. Regional distribution of the pharmaceutical industry in Mexico in 2012

Source: own compilation on the basis of: *The Pharmaceutical Industry,* 2013

All major pharmaceutical corporations are currently present on the Mexican market. Pharmaceutical corporations not only invest in the creation of networks for pharmaceutical drug distribution, but also develop business clusters concentrating firms involved in clinical trials. Those are located in main metropolitan areas such as Mexico City, Cuernavaca, Guadalajara, and Monterrey. In Mexico, cooperation between pharmaceutical corporations has a long tradition. The Association of Manufacturers and Importers of Medicinal Products (*Productores e Importadores de Artículos Medicinales*) was established in March of 1950. In 1994, the association changed its name to the Mexican Association of Pharmaceutical Research Industries *(Asociación Mexicana de Industrias de Investigación Farmacéutica – AMIIF)*. Currently, it has 31 members, including local branches of the largest pharmaceutical corporations in the world, such as Bayer, New Boehringer Ingelheim de México, Bristol Myers Squibb, Genzyme México, GlaxoSmithKline México, Janssen – Cilag, Merck, Novartis Farmacéutica, Sanofi Aventis, and Roche México (*Biotech round the world* … 2008, *Hoja de Datos* 2012).

The manufacturing of medical devices is an important industrial sector related to biotechnology. In 2009, the value of production in this sector was more than 5.4 billion U.S. dollars, and by 2012 it grew to more than 8 billion U.S. dollars. According to data from the INEGI institute, in 2012 a total of 2,349 manufacturing plants operated in this sector and they employed nearly 135,000 people. Also in 2012, a total of 723 firms reported exporting self-manufactured goods (*The Medical Device Industry in Mexico*, 2013). The value of exports in this sector is steadily growing and in 2010 amounted to 5.798 billion U.S. dollars; by 2012 it was already at 6.343 billion U.S. dollars. A steadily maintained trade surplus was observed for this sector in contrast to the pharmaceutical sector in the study period. The trade surplus exceeded 3.1 billion U.S. dollars in 2012 (Fig. 6).

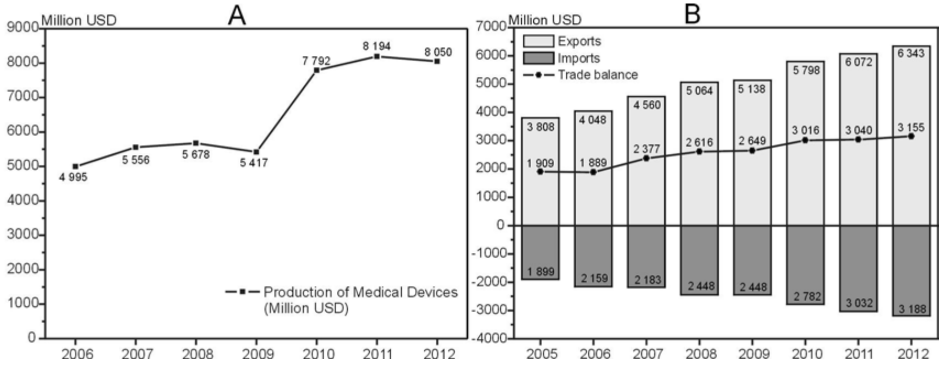

Fig. 6. Production output (A) and trade (B) of the Mexican medical device industry in the years 2005–2012

Source: own compilation on the basis of: *The Medical Device Industry in Mexico,* 2013

Mexico's location and low labor costs make the country a profitable platform for international corporations. Thus, most of the sector's exports (92.1% in 2012) were destined for the U.S. market. Between January of 2000 and March of 2013, foreign companies invested 1.569 billion U.S. dollars in the sector; 86.2% of that money came from the United States, 5.6% from Spain, 4.1% from France, 3.9% from Italy, and 2.4% from Germany. As most exports are headed to the United States and most foreign investors are American companies, the geographic distribution of plants exporting products reflects this – many are located in Mexican states found along the U.S. border. Close to one third of 723 companies exporting products is located in six Mexican states bordering the United States. The largest cluster of companies of this type is located along the border between the state of Baja California in Mexico and the American state of California. More than 148 companies are located in this area, and 81 of them export the goods they manufacture, while the total value of their exports reaches 34.1% of the total value of exports in this sector (*The Medical Device Industry in Mexico*, 2013; *Borderless Innovation…*, 2005).

Brazil is the other Latin American country with the most diversified biotechnology sector, with public institutions and biotechnology companies accounting for 25% each in the total number of companies in the sector. Service companies account for 18%, pharmaceutical companies for 14%, medical device companies for 10%, and delivery companies for 8% (Fig. 2). According to 2011 data from the Brazilian Center for Analysis and Planning (*CEBRAP – Centro Brasileiro de Análise e Planejamento*) and the Brazilian Association of Biotechnology Companies *(BrBiotec Brasil)*, as well as Apex-Brasil *(Brazilian Trade and Investment Promotion Agency)*, which is the Brazilian government agency linked with the Ministry of Development, Industry and Foreign Trade, a total of 237 private companies is part of Brazil's biotechnology sector (Bittar et al., 2011).

Most companies are concentrated in the state of São Paulo (40.6%). The state of Minas Gerais ranks second, with close to 25% of companies. Other Brazilian states with large numbers of biotechnology companies include: Rio de Janeiro (13.1%), Rio Grande do Sul (8.0%), Parana (4.6%), and Pernambuco (4.2%). Close to 40% of these companies work on products associated with human health, and 14.3% work on products associated with animal health. A large percentage of companies also manufacture chemical reagents (13.1%), while 9.7% are associated with the agricultural sector, and another 9.7% with environmental protection. Far fewer companies work on biological energy products (5.1%), which is partially the result of companies producing bioethanol from sugar cane being excluded from this research study (Fig. 7).

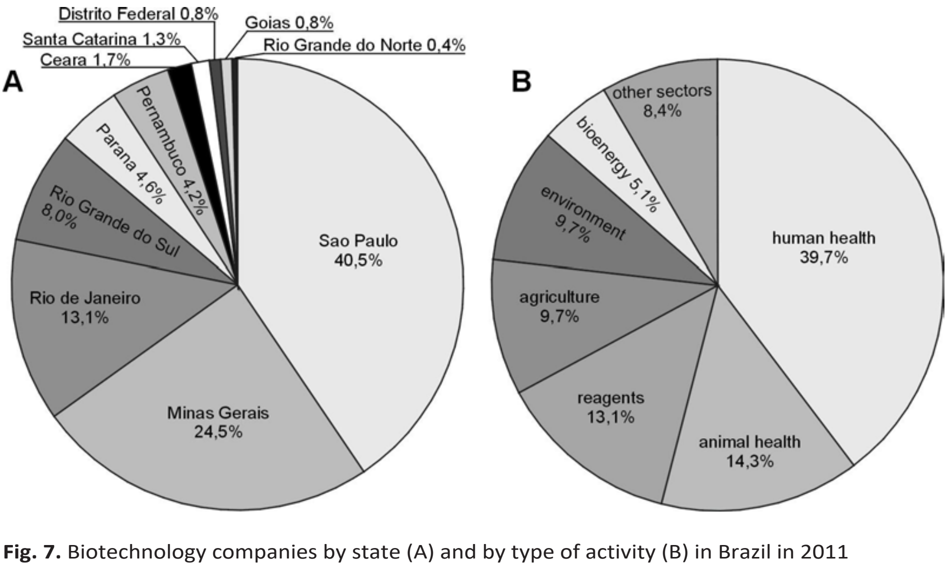

Fig. 7. Biotechnology companies by state (A) and by type of activity (B) in Brazil in 2011

Source: own compilation on the basis of: Bittar et al. (2011: 11–12)

The development of the biotechnology industry in Brazil is significantly aided by an active government policy of supporting new companies and strong collaboration between universities and businesses. The purpose of this approach is to help commercialize research results and accelerate production of novel products. Federal and state authorities in Brazil support the emergence of business incubators and technology parks, which are often built close to key universities and research institutes. In the mid-1980s, Brazil's National Scientific and Technological Development Council (CNPq) initiated the technological progress in Brazil by building six technology parks and business incubators in major cities in the southern and southeastern part of the country. Many more initiatives of this type followed in 1993 and later. By the late 1990s, 74 parks and incubators were operating in Brazil, and by 2011 their number increased to 384. Parks and incubators contributed to the establishment of 2,640 companies hiring a total of almost 16,400 employees. In addition, parks and incubators helped support the development of 2,509 mature companies hiring 29,200 employees (Lalkaka, Shaffer, 1999; *Estudo, Análise e Proposições*..., 2012).

The biotechnology sector owes its rapid development to 13 parks and incubators located in major Brazil cities including Rio de Janeiro, with its oldest technology park in all of Latin America and Bio-Rio business incubator of biotechnology firms. The city of São Paulo also possesses a business incubator, which by 2011 has aided the development of 81 biotechnology companies. Another key biotechnology city is Belo Horizonte, with its Biominas Foundation business incubator and the Minas Gerais Federal University business incubator. Another major center of biotechnology research is the local university in the small city of Viçosa in Minas Gerais state. The university specializes in research on agriculture and animal husbandry. Its business incubator (est. 2001) supports the development of companies associated with agriculture (Tab. 2).

Most technology parks and business incubators are found in the largest cities of several Brazilian states. Exceptions include previously mentioned Viçosa and three cities in the state of São Paulo: Botucatu, Campinas, Ribeirão Preto. Only Campinas possesses a renowned university (Unicamp) that supports biotechnology research (Tab. 2).

Noncommercial entities such as universities and research institutes play an important role in the development of biotechnology in Brazil. Business incubators and technological parks often emerge next to universities and research institutes, which facilitates the transfer of research results and their commercialization. Fifteen Brazilian universities and research institutes are particularly active in the biotechnology sector. The oldest institute – Instituto Butantan – was founded in 1914 in São Paulo and performs biomedical research. Newer research institutes include the Cancer Institute (*Instituto do Câncer*, est. 2008) in São Paulo and the National Laboratory of the Biological Sciences (*Laboratório Nacional de Biociências – LNBIO*) in neighboring Campinas (est. 2009). Another new research institute is the National Laboratory of Science and Bioethanol Technology (*Laboratório Nacional de Ciência e Tecnologia do Bioetanol – CTBE*) in Campinas (est. 2010) (Tab. 3).

Table 2. Main business incubator and technology parks in the biotechnology sector in Brazil

No.	Business incubator or technology park	Area of activity
1.	BIO-RIO Pólo de Biotecnologia do Rio de Janeiro	It was created in 1988 as the first tech-park in Latin America for high technology-based firms. It is connected with more than 40 life sciences firms. The business incubator Fundação BioRio is located inside the tech-park and has in its portfolio 17 graduated firms and 23 incubated, many of which are dedicated to human health and environment areas.
2	CDT Centro de Desenvolvimento Tecnológico (Universidade de Brasília), Brasília	Incubates companies of many areas of activity, 11 of those companies are dedicated to consultancy in human health and nanobiotechnology.
3	CENTEV Incubadora de Empresas de Base Tecnológica (Universidade Federal de Viçosa, Viçosa	Located in a region important for biotech – Minas Gerais – it hosts 45 entreprises concerned with different areas of activirt. Approximately 10 are related to biotechnology, more specifically – working on agriculture and animal health activities.
4	CIETEC Centro de Inovação, Empreendedorismo e Tecnologia, São Paulo	It is a multisetorial business incubator with 149 associated companies. Regarding biotech related areas, there are 18 in biotechnology, 30 in health and medicine, 13 in environment and 20 in chemistry.
5	HABITAT Biominas Brasil, Belo Horizonte	Linked to an important institution for the promotion of biotech sector (Biominas), this business incubator specializes in life sciences: there are 20 companies incubated.
6	IE-Cbiot Incubadora Empresarial do Centro de Biotecnologia (Universidade Federal do Rio Grande do Sul), Porto Alegre	Specialized in biotechnology, it has 7 companies incubated.
7	INCAMP Incubadora de Empresas de Base Tecnológica da Universidae Estadual de Campinas, Campinas	Business incubator associated with one of main universities in Brazil (Unicamp), it has 37 high technology companies, 7 of which deal with life sciences.
8	INOVA Universidade Federal de Minas Gerais (UFMG), Belo Horizonte	Incubates companies of several areas of activty, out of the 50 associated companies, 10 are related to biotechnology.
9	PADETEC Parque de Desenvolvimento Tecnológico da Universidade Federal do Ceará, Fortaleza	Incubates companies of many areas of activity. Its portfolio includes 7 incubated, 5 associated and 32 graduated. Some of the companies focus on biofuels and environment.
10	Technopuc Parque Científico e Tecnológico da PUCRS, Porto Alegre	Tecnopuc houses 66 organizations, out of which 48 are companies, 8 institutions and 10 research units of PUCRS. It has a significant role in production of software, besides housing companies in life sciences areas.
11	POSITIVA Universidade Federal de Pernambuco (UFPE), Recife	Business incubator with companies concerned with different areas of activity. It hosts 5 biotech companies and other 2 are in incubation process.

12	PROSPECTA Incubadora de Empresas e Projetos Tecnológicos de Botucatu, Botucatu	Of 38 associated companies, 6 are biotechnology related with activities in environment and agriculture.
13	SUPERA Incubadora de Empresas de Base Tecnológica, Ribeirão Preto	With a focus on human health, it has 32 companies in total, 17 of which deal with life sciences.

Source: Bittar et al. (2011: 20)

Table 3. Main research institutions in the biotechnology sector in Brazil

No.	Name of the institution	Area of activity
1	Biotecnologia da Amazônia (CBA/AM), Manaus	Founded in 2002, this centre is dedicated to the biodiversity of the Amazon region. Administrated by SUFRAMA (the agency responsible for the free tax zone in Manaus), CBA has 25 laboratories that are grouped in the following units: Microbiology; Biochemistry and Molecular Biology; Pharmacology and Toxicology; Natural Products and Extract Production.
2	Centro de Biotecnologia da Universidade Federal do Rio Grande do Sul (CTbiot), Porto Alegre	This center offers courses and training; develops biotech research projects in partnership with private and public institutions. Research areas: genetics and molecular biology of microorganisms; biological control; molecular diagnostic of diseases (humans, animals and plants); animal health and reproduction; plant biotechnology.
3	Centro de Referência em Farmacologia (CRF) – Fundação CERTI, Florianopolis	CRF conducts non-clinical studies, including pharmacodynamics, pharmacokinetics and toxicology. The center provides support to national and international scientific research, contributing to the development of pharmaceutical drugs and cosmetics production.
4	Empresa Brasileira de Pesquisa Agropecuária (Embrapa), units in several cities	Company owned by the Federal government, leader in development of bio and nanotechnology for agribusiness. It has units in many Brazilian States and it is also an incubator for new enterprises in agribusiness. Laboratories for cloning, molecular biology, tissue culture, bioremediation, genetic engineering, nanoparticles and transgenic organisms.
5	Escola Superior de Agricultura "Luiz Queiroz" da Universidade de São Paulo (ESALQ-USP), Piracicaba	It offers undergraduate and graduate courses in bioinformatics, genetics, genetic improvement of plants, and phisiology and biochemistry of plants. It is well-known for R&D in biotechnology for agriculture.
6	Fundação Osvaldo Cruz (Fiocruz), Rio de Janeiro	Federal government research institute with many biotechnology related departments and research projects. In addition to research, it has units that develop and manufacture medicines and vaccines (Bio-Manguinhos and Far-Manguinhos).
7	Instituto Agronômico de Campinas, Campinas	Institute of São Paulo State department of agriculture, it has research centers dedicated to research on coffee, sugarcane and plant genetics. It provides input to the food industry.

8	Instituto Butantan, São Paulo	State Institution created in 1914, it is one of the biggest research centers in biomedicine, responsible for the production of 90% of the serum and vaccines made in Brazil. Develops research on biology and biomedicine, and manufactures products such as anatoxins and hemoderivatives.
9	Instituto de Ciências Biológicas da Universidade Federal de Minas Gerais (ICB - UFMG), Belo Horizonte	ICB has 10 departments with several research laboratories. It offers undergraduate and graduate courses; its laboratories conduct research in areas such as genetics, pharmacology, biochemistry, immunology and microbiology.
10	Instituto de Ciências Biomoleculares da Universidade de São Paulo (ICB - USP), São Paulo	ICB has 7 departments with several research laboratories. It offers undergraduate and graduate courses in biotechnology in partnership with Instituto de Pesquisas Tecnológicas (IPT) and Instituto Butantan. There are several laboratories: anatomy, cell and development biology, pharmacology, physiology, biophysics, immunology, microbiology and parasitology.
11	Instituto de Tecnologia do Paraná (Tecpar), Curitiba	This State-owned company was created in 1940 and is connected to the State Department of Science, Technology and Higher Education. It conducts research and development, manufactures and offers services in immunobiologicals, chemicals and biofuels. Manufactures viral and bacterial-based vaccines and antigens.
12	Instituto do Câncer do Estado de São Paulo (ICESP), São Paulo	Founded in 2008, it is a partnership between the State government of São Paulo and the Fundação Faculdade de Medicina. Focuses on treatment of cancer and develops research in molecular oncology and regenerative medicine applied to oncology. In addition, it conducts clinical trials.
13	Laboratório Nacional de Biociências (LNBIO), Campinas	Founded in 2009, it researches and develops several biotechnology-related areas: structural biology, molecular biology, cell biology, proteomics, genomics, metabolomics and chemical synthesis. Offers the academic community laboratory infrastructure and has its own research projects.
14	Laboratório Nacional de Ciência e Tecnologia do Bioetanol (CTBE), Campinas	Created in 2010, has R&D in sugarcane-derived ethanol. It has different laboratories dedicated to hydrolysis and fermentation; prototypes for agriculture and is implementing two additional ones, for research on physiology and biochemistry.
15	Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro	UFRJ has many departments and research projects related to biotechnology. It integrates several institutes that collaborate and share infra-structure, such as: Medical Biochemistry, Biophysics, Biomedical Sciences, Biology, Microbiology, Macromolecules, Chemistry and the institute of graduate studies and research on engineering (COPPE).

Source: Bittar et al. (2011: 28–29)

Biotechnology companies tend to be concentrated in major urban areas including Mexico City, Rio de Janeiro, Sao Paulo, San Juan, and Buenos Aires, as well as their satellite cities (Fig. 8). Most companies in the sector emerged in major cities prior to the year 2000, followed by new companies in smaller cities such as Campinas, Viçosa, and Ribeirão Preto in Brazil. These trends confirm the initial hypothesis of the paper that innovative companies, especially biotechnology companies, tend to emerge in major urban areas. However, even smaller cities with renowned universities or research institutes are now able to attract innovative companies. Examples of this include Viçosa and Piracicaba in Brazil and Irapuato in Mexico. The emergence of biotechnology companies is less dependent on classic factors of production such as capital and concentration of investment, and more dependent on factors such as proximity to research centers and agriculture. Thanks to recent technological progress and the increasing importance of innovation and knowledge, even small cities have the opportunity to become independent growth centers utilizing their own potential for innovation (*Biotech round the world...*, 2008; Bittar et al., 2011; Brzosko-Sermak, 2012; Siłka, 2012).

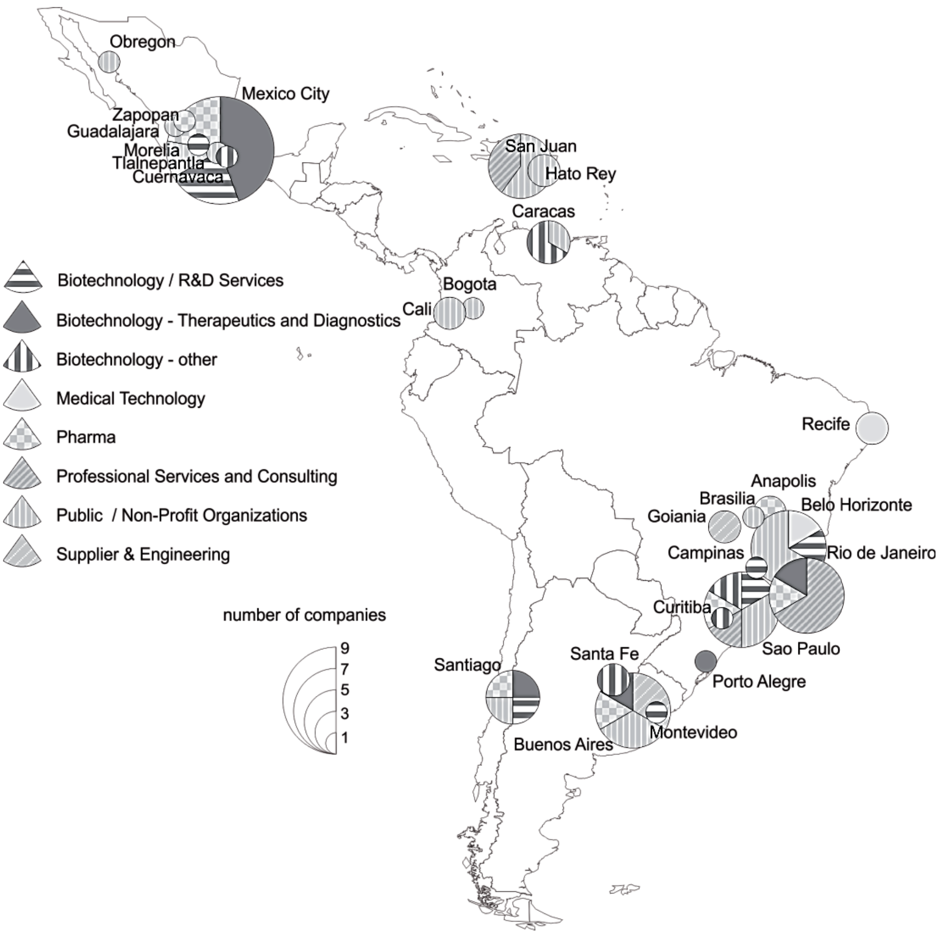

Fig. 8. Main geographic areas where biotechnology firms concentrate in Latin America and the different types of biotechnology firms represented in Latin America

Source: own compilation on the basis of: BiotechGate

Research has shown that biotechnology industry and organizations in Latin America are concentrated primarily in two regions. The first region is the capital city region of Mexico City, along with its neighboring towns. The second is located in southeastern Brazil within a large triangle consisting of the three largest metropolitan areas of São Paulo, Rio de Janeiro, and Belo Horizonte. In all of the remaining cases, large groups of biotechnology companies also concentrate in major cities such as Buenos Aires, Santiago, and Caracas. This, however, primarily depends on the availability of highly qualified personnel, technical infrastructure, and research facilities (Fig. 7).

Among the cities being considered in the paper, the city with the largest concentration of companies is Mexico City. In short, the most innovative biotechnology firms (T&D and R&D) concentrate in the city. Many companies are also located in neighboring towns: Tlalnepantla, Guadalajara, Zapopan, Cuernavaca, and Morelia. They are usually strictly biotechnology firms or pharmaceutical and biomedical companies. São Paulo, Belo Horizonte, Rio de Janeiro, Recife, and Porto Alegre are the cities in Brazil, in whish such companies tend to concentrate. However, in the case of the first three cities, a large share of companies are trading companies, as well as consulting and service companies (Fig. 8).

3. Summary

The research conducted indicates that rapid development of the biotechnology sector has occurred in recent decades. This is reflected not only by an increase in the number of scientific and research organizations, but also by the dynamic increase in the number of companies in this sector. So far, it has been accepted that companies in the biotechnology sector primarily develop in European countries and the United States. However, the largest countries of Latin America are actively pursuing a policy of supporting the development of biotechnology. This begins with support for the development of research institutions. Latin America's biotechnology policies are also expressed via support for the commercialization of research results through a system of technology parks and business incubators, most often located close to universities and research institutes. Successes achieved by Latin American scientists, as well as the high recognition and quality of research being carried out in the main research centers, also attract foreign investments. A particularly significant influx of foreign direct investment in this sector has been observed in Brazil and Mexico in recent years. Both countries are very attractive to international corporations doing business in the pharmaceutical sector. This is due to the existence of a large and dynamically growing pharmaceutical drug market, which stems from the demographic potential and growing wealth of these societies. Brazil and Mexico are also important producers and exporters of agricultural products such as soy, corn, sugar cane, and beef. This further attracts biotechnology companies making products applicable in the agricultural sector.

According to BiotechGate data, the biotechnology sector grew much faster in Mexico in the initial period. This may have been linked to faster diffusion of innovation from the United States, as well as the migration of scientists and the flow of American corporate investment. However, starting with the 1990s, Brazil began to catch up and became the leader in both the number of companies in business and the number of people employed in the sector. The development of domestic companies is strongly encouraged in Brazil, whereas subsidiaries of foreign companies play a much greater role in Mexico. Nevertheless, the biotechnology industry in these two countries is currently characterized by immense potential and has a chance to develop rather rapidly in the future. In Mexico, international corporations will most likely have much greater impact on further growth in this sector. This is due to the fact that the government pursues a more liberal policy with respect to international companies. In addition, this policy also depends on Mexico's membership in the North American Free Trade Agreement, which puts Mexico in a position where it plays the role of a production platform for the markets of the United States and Canada. On the other hand, the lack of a policy of active support for the creation of domestic companies, similar to Brazil's program of creating business incubators, may result from insufficient capital for investment in this sector. The biotechnology sector is generally characterized by substantial uncertainty in matters of return on investment and of reaching potential profits.

There are two main regions of growth of the biotechnology sector in Latin America, which are affected by different internal and external factors. The first region of growth is Brazil. There, the industry in this sector traditionally concentrates in three main geographic areas – the cities of São Paulo, Rio de Janeiro, and Belo Horizonte. However, in addition to the traditional locations, new growth centers of the biotechnology industry are observed to gain importance. New biotechnology centers are most often associated with newly created research institutions or technological parks and business incubators. The second biotechnology region in Latin America is Mexico. There are four main geographic areas in Mexico, where the biotechnology industry is concentrated: Mexico City – Cuernavaca and its vicinity, Guadalajara – Zapopan, Monterey, and Irapuato. More peripheral industrial centers are emerging outside of main urban areas in both Mexico and Brazil, and they tend to gain importance. This process is clearly more effective in Brazil, as it is more actively supported by the authorities at the federal and state levels.

Research has shown that the sector of agricultural and pharmaceutical biotechnologies is developing especially fast in Latin America. In addition, the importance of research related to medicine and other innovative fields of biotechnology is also currently growing. The two most important countries in the region in terms of the potential of their biotechnology sectors tend to follow different paths in the further development of this industry. Brazil puts more emphasis on independent industrial growth driven by domestic factors and encourages the establishment of domestic companies that possess the ability to compete globally. Meanwhile, Mexico seems much more dependent on the investments of international biotechnology corporations. Local research institutions, universities, and domestic companies mostly play a supportive role for foreign corporations by creating a friendly environment that helps to decrease operating costs and invites further investment.

References

Aharonson, B., Baum, J., Plunket, A. (2008). Inventive and uninventive clusters: The case of Canadian biotechnology. *Research Policy*, *37*(6–7), 1108–1131.

Audretsch, D.B. (2007). Entrepreneurship capital and economic growth. *Oxford Review of Economic Policy*, *23*(1), 63–78.

Autant-Bernard, C., Mangematin, V., Massard, N. (2006). Creation of Biotech SMEs in France. *Small Business Economics, 26*, 173–187.

Barker, S., Youtie, J., Shapira, P. (2007). *Defining a Research Domain in an Emerging Technology: Vaccine Research in the State of Georgia*. Working Paper, Georgia Tech Program in Science, Technology and Innovation Policy. Atlanta: Georgia Institute of Technology.

Biominas, (2009). *Estudo das empresas de biociências do Brasil 2009*, Fundação Biominas. Retrieved Sept. 12, 2013, from http://www.biominas.org.br/download.php.

Biominas & PwC, (2011). *The Brazilian life science industry: pathways for growth*, Fundação Biominas, PricewaterhouseCoopers Brasil. Retrieved Febr. 12, 2013 from http://www.biominas.org.br/download.php.

Biotech round the world: Focus on Mexico, (2008). *Biotechnology Journal, 3*, 1131–1134.

Bittar, A., Torres Freire, C., Golgher, D., Grilli Felizar,do R. (2011). *Brazil Biotech Map 2011*. CEBRAP, BrBiotec Brasil, Apex-Brasil, São Paulo. Retrieved Febr. 12, 2013 from http://www.cebrap.org.br/v2/items/view/419.

Borderless Innovation. Catalyzing the competitiveness of the San Diego – Baja California Region, (2005). UCSD Extension and San Diego Dialogue. Retrieved Febr. 12, 2013 from http://www.sandiegodialogue.org/borderless.htm.

Borderless Biotech and Mexico's Emerging Life Sciences Industry, (2007). UCSD Extension and San Diego Dialogue. Retrieved Febr. 12, 2013 from http://www.sandiegodialogue.org/pdfs/borderlessEng.pdf.

Bromley, R.D.F. (1998). Informal commerce: expansion and exclusion in the historic centre of the Latin American city. *International Journal of Urban and Regional Research, 22*, 245–263.

Bromley, R.D.F., Mackie, P.K. (2009). Displacement and the New Spaces for Informal Trade in the Latin American City Centre. *Urban Studies, 46*(7), 1485–1506.

Brzosko-Sermak, A. (2012). Innowacyjność a endogeniczne zasoby miast wschodniego pogranicza Polski. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego, 19*, 74–92.

Casas, R., de Gortari, R., Santos, Ma., J. (2000). The building of knowledge spaces in Mexico: a regional approach to networking. *Research Policy*, *29*, 225–241.

Casper, S. (2007). How do technology clusters emerge and become sustainable? Social network formation and inter-firm mobility within the San Diego biotechnology cluster. *Research Policy, 36*(4), 438–455.

Casper, S. (2009). *The Marketplace for Ideas: Can Los Angeles Build a Successful Biotechnology Cluster?* A Report to the John Randolph Haynes Foundation, Keck Graduate Institute of Applied Life Sciences.

Casper, S., Murray, F. (2005). Careers and Clusters: Analyzing the Career Network Dynamic of Biotechnology Clusters. *Journal of Engineering and Technology Management, 22*(1), 21–74.

Corolleur, F., Mangematin, V., Torre, A. (2003). French Biotech Start Ups and Biotech Clusters in France: The Importance of Geographic Proximity. In G. Fuchs, B. Luib (eds.), *Biotechnology in Comparative Perspective – Growth and Regional Concentration*. London: Routeledge, 221–257.

Czyż, T., Chojnicki, Z. (2008). Gospodarka oparta na wiedzy w regionach metropolitalnych i aglomeracjach miejskich w Polsce. *Studia KPZK PAN*, *120*, Komitet Przestrzennego Zagospodarowania Kraju PAN, Warszawa, 74–95.

Dal, M.S., Sorenson O. (2007). Home sweet home: Social capital and location choice, *Social Science,* 1–22. Retrieved Sept. 2, 2013, from www.druid.dk.

Dawidko, P. (2012). Biotechnologiczne spółki spin-off Uniwersytetu Jagiellońskiego jako mechanizm transferu technologii. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego, 20*, 95–107.

Delerue, H., Lejeune, A. (2008). Internationalization of biotechnology start-ups: the role of geographical location. Retrieved Sept. 2, 2013, from http://uqam.academia.edu/ALejeune/Papers/456543/Internationalization_of_Biotechnology_Start-ps_the_Role_of_Geographical_Location.

Dimova, M., Mitnik, A., Suarez-Buitron, P., Siqueira, M. (2009). Brazil Biotech Cluster: Minas Gerais A Cluster Analysis, *Microeconomics of Competitiveness*. Retrieved Sept. 2, 2013, from http://www.isc.hbs.edu/pdf/Student_Projects/Brazil_Biotech_2009.pdf.

Domański, B. (2000). Some aspects of the development of Polish manufacturing in the perspective of knowledge-based economy. In A. Kukliński (ed.), *The knowledge-based economy. The European challenges of the 21st century*. Warsaw: State Committee for Scientific Research, 281–287.

Dorocki, S., Jastrzębski, P.J. (2012). Regionalne zróżnicowanie rozwoju biotechnologii w Europie. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego*, *20,* 67–94.

Dorocki, S., Boguś,M., Borowiec, M. (2013). Przestrzenne zróżnicowanie rozwoju przemysłu biotechnologicznego. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego, 21*, 94–120.

Eliasson, G. (2000). Industrial policy, competence blocs and the role of science in economic development. *Journal of Evolutionary Economics, 10*, 217–241.

Estudo, Análise e Proposições sobre as Incubadoras de Empresas no Brasil – relatório técnico, (2012). Associação Nacional de Entidades Promotoras de Empreendimentos Inovadores – ANPROTEC, Ministério da Cięncia, Tecnologia e Inovação, Brasília.

GAO (General Accounting Office, U.S. Congress). (1986). Biotechnology: Agriculture's Regulatory System Needs Clarification. (Report to the Chairman, Committee on Science and Technology, U.S. House of Representatives),GAO/RCED 86–59, March.

Goldberg, I., Goddard, G., Kuriakose, S. (2008). Building Knowledge-Based Economy and Absorptive Capacity to Enhance Growth: The Role of Cross-Border Knowledge Flows in Europe and Central Asia (ECA). In M. Runiewicz-Wardyn, L. Koźmiński (eds.), *Knowled-*

ge-Based Economy as Factor of Competitiveness and Economy Growth, Warsaw: Academy of Entrepreneurship and Management.

Hoja de Datos, (2012). Asociación Mexicana de Industrias de Investigación Farmacéutica-AMIIF. Retrieved Sept. 2, 2013, from http://www.amiif.org/system/resources/BAhbBlsHOgZmSSI3MjAxMi8wNi8yMS8wMC8zMS80Ny80MTIvSG9qYV9kZV9EYXRvc19BTUlJRl9BQy5wZGYGOgZFVA/Hoja%20de%20Datos%20AMIIF%20AC.pdf.

Jepson, W.E., Brannstrom, Ch., Stancato de Souza, R. (2008). Brazilian Biotechnology Governance: Consensus and Confl ict over Genetically Modifi ed Crops. In G. Otero (ed.), *Food for the Few. Neoliberal Globalism and Biotechnology in Latin America.* Austin: University of Texas Press, 217–242.

Kelly, M. (2004). Biotech Clusters in Europe - Biotech Clusters get a Shot in the Arm. Retrieved Dec. 2, 2012, from http://www.woodsbagot.com/en/Documents/Public_Research/04_biocluster_Europe_M_Kelly.pdf.

Klasik, A. (2009). *Kreatywne miasta i aglomeracje – studia przypadków.* Katowice: Wydawnictwo Akademii Ekonomicznej.

Lalkarka, R., Shaffer, D. (1999). Nurturing Entrepreneurs, Creating Enterprises: Technology Business Incubation in Brazil, International Conference on Effective Business Development Services, Rio de Janeiro, 2–3.03.1999. Retrieved June 20, 2013, from http://egateg.usaidallnet.gov/sites/default/files/Nurturing%20Entrepreneurs%20Creating%20Enterprises.pdf

Lecocq, C., Leten, B., Kusters, J., Van Looy, B. (2010). *Do Firms Benefit from Being Present in Multiple Technology Clusters? An Assessment of the Technological Performance of Biopharmaceutical Firms,* Section of Economic Geography, series Papers in Evolutionary Economic Geography (PEEG), number 10.19. Utrecht University.

Markowski, T. (2008). Gospodarka bazująca na wiedzy (GOW) a wyzwania wobec zagospodarowania przestrzennego – konceptualizacja problemu. In T. Marszał (ed.), *Rola polskich aglomeracji wobec wyzwań Strategii Lizbońskiej*, Studia, t. CXX. Warszawa: Komitet Przestrzennego Zagospodarowania Kraju Polska Akademia Nauk.

Otero, G. (2008). Neoliberal Globalism and the Biotechnology Revolution: Economic and Historical Context. In G. Otero (ed.), *Food for the Few. Neoliberal Globalism and Biotechnology in Latin America.* Austin: University of Texas Press, 1–29.

Poitras, M. (2008). Unnatural Growth: The Political Economy of Biotechnology in Mexico. In G. Otero (ed.), *Food for the Few. Neoliberal Globalism and Biotechnology in Latin America.* Austin: University of Texas Press, 115–134.

Possani, D.L. (2003). The past, present, and future of biotechnology in Mexico. *Nature Biotechnology*, 21, 582–583. Retrieved Sept. 10, 2013, from http://www.nature.com/nbt/journal/v21/n5/pdf/nbt0503-582.pdf.

Rothaermel, F.T., Deeds, D.L. (2004). Exploration and exploitation alliances in biotechnology: a system of new product development. *Strategic Management Journal*, *25*, 201–221.

Saxenian, A. (1999). *Silicon Valley's New Immigrant Entrepreneurs.* San Francisco: Public Policy Institute of California.

Saxenian, A., Motoyama, Y., Xiaohong, Q. (2003). *Local and Global Networks of Immigrant Professionals in Silicon Valley*, San Francisco: Public Policy Institute of California.

Siłka, P. (2012). Typologia miast ze względu na potencjał innowacyjny. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego, 19*, 61–73.

Stryjakiewicz, T. (2008). Sektor kreatywny jako czynnik kształtujący nową jakość przestrzeni europejskiej. In D. Ilnicki, K. Janc (eds.), *Przekształcenia regionalnych struktur funkcjo-*

nalno–przestrzennych „Europa bez granic–nowe wyzwania". Rozprawy Naukowe Instytutu Geografii i Rozwoju Regionalnego Uniwersytetu Wrocławskiego 3, Wrocław: Instytut Geografii i Rozwoju Uniwersytetu Wrocławskiego, 11–18.

Stuart, T., Sorenson, O. (2003). The geography of opportunity: spatial heterogeneity in founding rates and the performance of biotechnology firms. *Research Policy, 32*, 229–253.

Sytch, M., Bubenzer P. (2008). Research on Strategic Alliances in Biotechnology: An Assessment and Review. In H. Patzelt, T. Brenner (eds.), *Handbook of Bioentrepreneurship*. New York: Springer, 105–131.

The Medical Device Industry in Mexico, (2013). Ministry of Economy, ProMéxico Trade and Investment, Business Intelligence Unit, Mexico D.F. Retrieved Sept. 15, 2013 from http://mim.promexico.gob.mx/work/sites/mim/resources/LocalContent/84/2/130815_DS_Dispositivos_Medicos_EN.pdf.

The Pharmaceutical Industry, (2013). Ministry of Economy, ProMéxico Trade and Investment, Business Intelligence Unit, Mexico D.F. Retrieved Sept. 2, 2013 from http://mim.promexico.gob.mx/work/sites/mim/resources/LocalContent/369/2/130820_DS_Farmaceutica_ENG.pdf.

Ukropcova, D., Sturdik, E. (2009). Biotechnology commercialization in Europe, *Nova Biotechnologica, 9*(3), 255–264.

van Beuzekom, B., Arundel, A. (2009). *OECD Biotechnology Statistics 2009*, Paris: OECD.

Wagner, K.C. (1998). Biotechnology in Mexico: placing science in the service of business. *Technology in Society, 20*, 61–73.

Zucker, L.G., Darby, M.R., Armstrong, J. (1989). Geographically localized knowledge: spillovers or markets? *Economic Inquiry*, *36*, 65–86.