Services sector in the biotechnology firms of South America: a focus in Argentina, Brazil, Chile and Uruguay

Jorge Niosi*

Department of Management and Technology,
Université du Québec à Montréal (UQAM),
P.O. Box 8888 Station Centre-Ville,
Montreal H3C 3P8, Canada
E-mail: niosi.jorge@uqam.ca
*Corresponding author

Tomas Gabriel Bas

Business School and Faculty of Engineering and Sciences,
University Adolfo Ibañez,
Av. Las Torres 2700,
Escuela de Postgrados, Peñalolen, Chile
E-mail: tomas.bas@uai.cl

Abstract: This paper is about a specific type of knowledge intensive business services (KIBS), namely R&D services sector in biotechnology, and their growth in four Latin American countries: Argentina, Brazil, Chile and Uruguay. Like other emerging and developing countries, these countries in the Southern Cone are slowly adopting biotechnology. Many dedicated biotechnology firms (DBFs) are already providing services in the region, from R&D to bioinformatics, to gene identification and stem cell databank storage services. The tendency of DBFs in Latin America is to provide services. The objective of this paper is to identify many of those firms that are dedicated to provide services in biotechnology. The present work that in spite of low public support, biotechnology services in the region are growing, even if this growth is well under the needs and potential of the region.

Keywords: services; biotechnology; international technology diffusion; innovation systems and policies; industry-university linkages; South America; Argentina; Brazil; Chile; Uruguay.

Reference to this paper should be made as follows: Niosi, J. and Bas, T.G. (2014) 'Services sector in the biotechnology firms of South America: a focus in Argentina, Brazil, Chile and Uruguay', *Int. J. Learning and Intellectual Capital*, Vol. 11, No. 4, pp.357–373.

Biographical notes: Jorge Niosi is a Professor at UQAM since 1970 and Canada Research Chair on the Management of Technology since 2001. He is the author, co-author, editor or co-editor of 15 books. He has published over 60 articles in refereed journals. His work is widely cited. He is a Fellow of the Royal Society of Canada (Academy N. 2) since 1994. He has consulted for the Inter-American Development Bank, UNIDO, CIDA, IDRC, Industry Canada, Statistics Canada and other national and international agencies.

Tomas Gabriel Bas is a Professor at University Adolfo Ibañez (Chile) in technology management and innovation since 2005. He is the author, co-author, editor or co-editor of 12 books. He published over 20 articles in refereed journals. He was an advisor to United Nations Economic Commission for Latin America (ECLA) in biotechnology (clusters, public policy, technological innovation policy) and to the World Bank on innovation and clusters in natural resources. He was also an advisor to IDRC and Statistics Canada and many technological firms. He was a co-Founder and Editor of the *Journal of Technology Management and Innovation* (SciELO). He is a member of the Expert Advisory Committee on Assessment of Economics and Management of the National Scientific and Technological Commission of Chile (CONICYT). Distinction: Brilliant Minds – Brains world class 20 most influential researchers in Chile 'El Mercurio', Santiago, Chile.

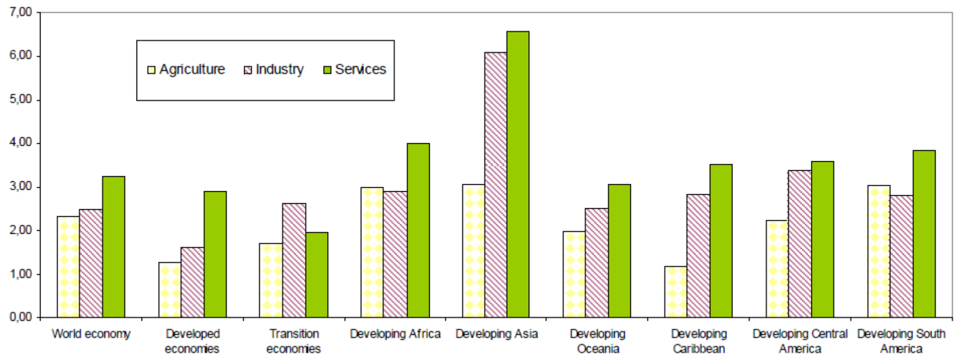
1 Introduction, theory and hypotheses: innovation in KIBS

The services industry has historically been defined as marginal of the productive sectors. Nevertheless, there are different definitions of what is a service. For Jones (2013), the service industries comprise businesses whose principal activity is to provide service products.

The service sector is one of the most important generators of employment and represents a large portion of total GDP in both developed and emerging economies. However, there are only few studies that demonstrate the true impact of the different services in the creation of value on the worldwide economies.

Today, the service sector become more important than manufacturing provides more than half of all employment and value added in most countries (Gallouj and Savona, 2009). Figure 1 shows that services leading the economic evolution in the most worlds regions.

Figure 1 Annual growth rates of value added in main economic sectors in constant price, 1970–2010 (see online version for colours)



Source: UNCTAD Database (2013)

Most studies on innovation have focused on innovation in manufacturing (Gallego et al., 2013). This is particularly so in such innovation-intensive sectors as software, and R&D services like biotechnology, nanotechnology, and clinical research, to name a few.

Not all knowledge intensive business services (KIBS) are innovation intensive. We can see a clear variety in terms of innovativeness. Some, such as accountancy services are at the low side of the spectrum (p-KIBS). R&D services are at the other extreme (Freel, 2005). This paper is about these most innovation-intensive t-KIBS. The objective is to identify some of the dedicated biotechnology firms (DBFs) in Latin America that are dedicated to providing services in biotechnology and further analyse each of the firms interviewed in terms of creativity and knowledge diffusion. In Latin America, the service sector is new, so this study is important to detect if the trend of developed countries persists.

Whatever the specific sub-domain, the quantitative analysis of innovation in services – particularly on the side of the outputs – poses several serious problems as Griliches (1992) underlined:

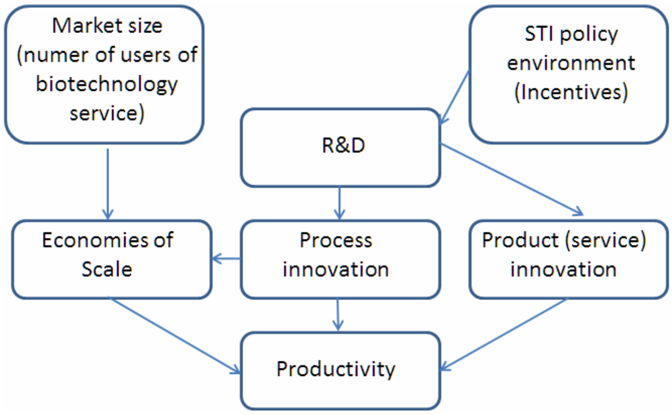
a What is exactly sold? The knowledge produced by the R&D services firm? Is it a prototype in the case of a software program?

b What is the role of the user? Up to a certain degree, the user participates in the definition of the service, thus in the framing of the service innovation itself. When a pharmaceutical firm requests R&D services from a DBF it is clear that the large corporation is participating in the innovation it requests from the smaller service firm.

c The quality of the service is more difficult to measure. This is a problem in the analysis of education or health and R&D services. The client itself may not have a clear understanding of the quality of the services he/she is buying. Other conceptual and measurement problems appear.

The innovation produced by the service firm may have large positive productivity impacts on the users of the innovation, be they agricultural farms using new genetically modified organisms (GMOS), or pharmaceutical corporations using new knowledge produced by a human health R&D services firm. On a second line of users, R&D services can generate positive impacts on the balance of payments through the export of the new products and services, and other even more remote positive effects on the increased life expectancy of the population through better access to food and medicines. Under these conditions, it becomes more difficult to measure the impacts of R&D service innovation. Also, the efficiency and effectiveness of the KIBS firm depend up to a certain point on the size, and the resources it can find in its environment. The issues of open innovation are relevant at this point. Public institutions and policy incentives make a good part of the environment of KIBS. The quantity and quality of policy incentives, public institutions and regulations will affect the nature and quality of the services produced by the KIBS firm. Also, KIBS not only depend on the quality and quantity of public policies and incentives at the national and regional levels; they are a key component of these national and regional innovation systems. Thus, Pilat (2001) suggests that KIBS are a second knowledge infrastructure, one that complements the public one of universities and public laboratories. Several authors have found that in OECD countries, these KIBS experience very rapid growth, and they are among the fastest growing sectors of the economy (OECD, 2007). Yet, drivers of growth in these KIBS are not confined to public policy and incentives. The size and the nature of the market for these services are very important determinants of KIBS innovation (Miles, 2005). In terms of inputs, t-KIBS firms have a high percentage of sales devoted to R&D, while p-KIBS usually do not conduct R&D. Also, t-KIBS often request intellectual property (IP) protection such as patents for their inventions, as well as copyrights, industrial design and trademark protection. p-KIBS firms seldom need this IP. Thus the innovation activities of t-KIBS can be measured. The more the t-KIBS firms are innovative, the more their innovation activities are visible, even if the total impacts of these activities are difficult to gauge. Finally, t-KIBS are concentrated in large metropolitan areas, where they can obtain complementary knowledge from public research institutions, hire skilled professionals and recruit clients and users (Muller and Doloreux, 2009). Figure 2 summarises the main hypotheses.

Figure 2 Innovation and productivity in the KIBS technology-based sector (see online version for colours)



2 Sector context: biotechnology and its international diffusion

Biotechnology is not an industry but a set of general purpose technologies applied to many industries such as agriculture, environmental services, food, mining, pharmaceuticals, and other (OECD, 2008). Modern biotechnology was born in the early 1950s, when Watson, Crick and Wilkins discovered the structure of DNA at Cambridge, UK. Many other scientific and technological developments followed, and biotechnology was used to genetically modify microorganisms, plants and animals to produce GMOs, human proteins as insulin, human growth hormones, interferon and interleukins, as well as MABS.

Biotechnology commercial applications were originally developed in the USA. The first biotechnology firm, Genentech, was established in 1976 in California. In the following years thousands of DBFs were founded in the USA, Western Europe, Canada, Japan and elsewhere. Most products and services invented by these companies require major funding and skills in order to be developed. DBFs specialised in human health products allied with large pharmaceutical corporations to obtain approval and market them. DBF specialised in new seeds often gave licenses to large grain traders such as Monsanto and Syngenta. DBFs cooperated with mineral corporations to produce new genetically modified bacteria. Some types of service firms remained independent for reasons we will examine later.

In biotechnology, the underlying science base evolves very fast and major breakthroughs open new commercial opportunities for small and medium-sized service enterprises (SME). Thus, in 2003 the sequencing of the human genome allowed the creation of a new area of biotechnology (genomics). Using this information and technology, small and medium-sized DBFs could remain independent and offer gene sequencing services to pharmaceutical corporations, farms, governments and individuals. The very large number of genetic information supported the growth of bioinformatics, a service industry that retrieves stores and analyses the millions of pieces of genetic data stemming from the use of increasingly powerful and rapid sequencing equipment. Bioinformatics also analyses information about collateral effects of medicines, information that leads to the discovery of new medicines and the improvement of existing ones. Proteomics followed, the study of thousands of proteins that are produced by organisms, as well as protein purification and mass spectrometry.

The literature on biotechnology business models has become fairly abundant (Casper, 2000; Rasmussen, 2010). "A business model is a way to create value for a business and then at least to capture some of that value for the organisation" [Chesbrough, (2011) p.90]. Generally speaking, two major business models are recognised among DBFs: the *product* and the *service* models. In the product business model, the DBF conducts R&D services in order to create a new or improved product such as a medicine, a diagnostic kit, a tool, or a GMO. Its goal is either to sell it directly to the market or, more often, to license out the new technology to a larger corporation that is able to obtain approval for the product, and is able to manufacture it on a large scale and market it internationally. The product business model requires large investments, involves extensive project costs and risks, and is seldom adapted to DBFs in developing countries. The service model, on the other hand, is based on a platform technology that allows the company to deliver services to a variety of different clients. Bioinformatics and gene identification are among two of the most common business service models among DBFs.

Because the underlying science base is highly dynamic and increasingly costly, biotechnology requires strong government incentives and support. It also creates many goods, services and products such as new drugs and seeds, key genetic information and environmental services, that often produce sales and employment.

3 Methodology and analysis

The number and distribution of DBFs in each Latin American country is not exactly known. Estimations vary widely from one author to the next. The reason is that no statistical office in the region studies the R&D services sector, and individual researchers use different methods and definitions to make their estimations. The study was done through the identification of suitable dedicated biotechnology services firms (DBSFs), interviewing company executives and government and incubator officials using proven questionnaires. Several sources publish nominal lists of companies. The most reliable one is BIOTECSUR, the organisation of biotechnology-active companies in the region. Yet, our samples have no pretension represent the (unknown) total population. But the companies we have interviewed are modern DBSFs. However, the number of DBSFs agree to be interviewed in the service sector are very limited since the vast majority among them prefer to keep your confidential data. It is extremely difficult to interview the DBSFs for fear of losing confidentiality related to their data. Despite the circumstances, we were able to identify 22 DBSFs (more 11 governments and incubators actors), which mean a reasonable number. Whatever the source, it was clear that biotechnology companies are located in the largest agglomerations in each Latin American country: Buenos Aires and Rosario in Argentina, Belo Horizonte, Sao Paulo, and Rio de Janeiro in Brazil, Santiago in Chile and Montevideo in Uruguay. As to policymakers, in each of these countries several government departments have a say on the development of biotechnology. They include the Ministries of Agriculture, Education, Environment, Health, and Industry, and independent regulatory agencies such as ANMAT in Argentina and ANVISA in Brazil. Finally, company incubators, usually hosted at the large national universities are a key component of the public incentive toolkit. To interview them all would require months of intensive work in the field. We decided to interview a few of them in each country, selecting the ones that seem among the most active in biotechnology. It is clear that the information they provided was about the existing programs and the resources invested in them. We counted on the executives of the biotechnology firms to give their appraisal of these programs. Our company questionnaire, built on the basis of Statistics Canada one, solves the problem of identifying DBFs from other biology-using firms, as one of the first questions asks what modern biotechnologies the company uses. Thus, the interviewer soon knows whether he/she is visiting a modern biotechnology firm or not. The questionnaire used contains variables on the technologies applied, products and services in the markets, R&D and other innovative activities, skilled personnel, employment and sales. It has 24 questions that are converted into over 100 variables. Table 1 summarises the fieldwork.

Table 1 Fieldwork of interviewed actors

Country	*DBSF*	*Government laboratories*	*Government departments*	*Company incubators*	*Total*
Argentina	7	2	1	1	11
Brazil	9	2	1	1	13
Chile	4	1	1	0	6
Uruguay	2	0	1	0	3
Total	22	5	4	2	33

The majority of the 22 DBSFs interviewed were active in human health (15 or 68%), and three others active in human and animal health. In every country except Chile, human health was the most common application. Less than half of the interviewed firms (10 or 45%) were university or public laboratory spinoffs; the others were start-up firms. The average age was ten years, and the median age was 8.5 years, but the Chilean and Uruguayan firms were much older. In each country there are one or two firms over 100 employees. The average firm had 50 employees and the median number of employees was 22; the average numbers show the impact of some very large firms on the mean sizes. Table 2 shows the main statistics.

Table 2 Summary of descriptive statistics (all figures in US millions)

Variable	*Argentina*	*Brazil*	*Chile*	*Uruguay*	*Total*
Interviewed DBFs	7	9	4	2	22
Active in human health	4	8	1	2	15
Active in human and animal health	1	1	1	0	3
Active in Ag-Bio	2	0	1	0	3
Active in mining, environment	0	0	1	0	1
University/public lab spin-off	3	6	0	1	10
Average R&D expenditure	1.3	1.3	0.11	0.15	0.9
Median R&D expenditure	0.25	1	0.12	c	0.3
Average age	9	9	14	15	10
Median age	6	8	11	15	8.5
Average employment 2011	60	51	54	22	50
Median employment 2011	12	30	15	c	22
Average sales 2011	9	0.2	7	0.2	3.2
Median sales 2011	0.2	0.2	2.5	0.2	0.2
Firms that exported in 2011	1	2	3	2	8
Patenting firms	4	3	2	1	10
Firms with trademarks	4	4	2	2	12
Problems with other regulation	0	4	0	1	5
Firms using public funds	5	8	2	1	16
Firms using private funds	7	9	4	2	22
'Successful' firms*	5	7	3	1	16

Notes: c = confidential
*Successful means growing firms in terms of employment and/or sales

In 2011, average sales were US $3.2 million, but a few large companies biased the averages. Over one third (8/22) of the interviewed firms were exporting products and/or services. Not by chance, the smaller the country the higher the percentage of companies that exports. In Argentina and Brazil, firms can survive without exports, counting on the domestic market, not in Chile or Uruguay, were exports are a condition of survival. Regulatory problems were fairly abundant. In comparative terms, there were more abundant in Brazil, followed by Argentina and Uruguay. The length and quality (or the absence of) regulations were the most frequent grievance. In each country, though, the more the firms were advanced in the product and/or process development, the more they requested authorisations, and the more they found difficulties. Very young firms usually did not complete their products or processes, thus did not request any authorisation. Also, the more complex the product, or the more innovative, the more the authorisations took time and the lack or inadequacy of regulations became evident.

Very often companies used public funds (72% of them), in addition to private funds (100% of them did). As to public funds, companies complained about the scarcity of government loans, venture capital, or and the small amounts of non-reimbursable R&D subsidies. In terms of private funds, in over 50% of the companies, managers had invested personal or family funds, or had obtained capital or loans from private investors.

Over two thirds of the firms (16/22) interviewed were ‘successful’. By success we mean that they grew over the 2007–2012 period, usually both in terms of employment and sales. The other companies were not, including two in Argentina, two in Brazil, one in Chile and one in Uruguay. Of course companies may grow and still be unprofitable, and also some may not grow and yet be profitable. But we did not ask whether the companies had profits or not, a very sensitive question that is not usually responded.

In DBFs, R&D is a routine activity. All the companies we visited were conducting R&D. Yet the amounts they spent were – on average – very low: US $0.9 million. The median amount is even lower: US $300,000 a year. Such amounts show that government incentives were modest, to say the least, and probably highly skewed: a few firms were obtaining large amounts of public support, and most firms obtaining small amounts or no public funds at all (see Table 1).

Open innovation was paramount. Almost all the firms (20/22) collaborated with research universities and over two thirds of them cooperated with public laboratories. Over three quarters of the interviewed firms cooperated with other biotechnology of pharmaceutical firms, and most of them collaborated with foreign private partners[1]. In Latin America there are few new-to-the world innovators, as attested by the reduced number of patents. Only five companies had US, EPO or PCT patents. Yet in a few cases, these companies are conducting breakthrough research and development that may result in radical novelty. Most often than not, however, DBFs in Latin America are service providers linked to agricultural, pharmaceutical and environmental firms. Some of them are entirely or partially controlled by these companies to which they become captive service providers. Trademarks are indicators of some level of innovation. They play a key role in the marketing of innovation, as they allow potential and actual consumers to identify the product or service and its producer. In our sample, over 50% of the firms have requested trademarks, both for their products and their services, and in all the four countries. In addition, there is a strong correlation between having trademarks and patents: basically, almost all the companies with patents had trademarks, but two companies with trademarks had no patents.

4 Biotechnology in Latin America

This study focuses on two of the largest countries in Latin America (Argentina and Brazil), one medium-size country (Chile) and a small country (Uruguay). These are among the countries with the highest human development index and the highest gross expenditure on R&D (GERD) as a percentage of gross domestic product (GDP) in the region. Because biotechnology requires a skilled labour pool and strong expenditures on R&D, we considered that these countries were more likely than others to have nurtured some biotechnology service activity.

4.1 Argentina’s biotechnology

Argentina had a leading start in biotechnology in the region. In the early 1980s, it had a prompt entry in the science, with Dr C. Milstein, future Nobel Prize winner and discoverer of the methods to produce monoclonal antibodies. Argentina also had strong demand for both GMO from its large agricultural sector**,** and for biopharmaceutical drugs produced by a large generic pharmaceutical industry. However, Argentina’s gross expenditure on R&D (GERD) is only 0.61% of GDP in 2010, after staying below 0.5% for decades. Thus the support that public sector institutions (universities and public laboratories) bring to private DBFs is modest. The two main public laboratories working on biotechnology, in agriculture (INTA) and in industrial biotechnology (INTI) conduct little R&D and have no patents. Public funds to DBFs are channelled mainly through FONTAR and FONAPYME suggest that biotechnology receives on average two million dollars a year, and the average subsidy for R&D is between US $50,000 and US $60,000, enough to pay the salary of a graduate researcher and some equipment. Also, in 2007 Argentina approved a National Biotechnology Plan, but the law was not implemented.

The statistical institute does not contribute either, as there is no measurement about the number of firms, the obstacles they face while conducting innovative activities. The private data about the number of DBFs go from 80 firms (Biotecsur, 2010) to 120 (Anlló et al., 2011). All estimations suggest that Buenos Aires (the national capital metropolitan area), Rosario, Córdoba and Santa Fe host the main clusters. Thus our study does not pretend to be based on a representative sample. Five institutions concentrate over 60% of Argentinean publication in biotechnology: they are CONICET, the National University of Buenos Aires, the National University of La Plata, INTA and the National University of Córdoba. Several public universities offer degrees in biotechnology. They include the National University of Buenos Aires, the National Universities of Litoral and Rosario (Province of Santa Fe), the National Universities of La Plata, San Martin, Quilmes (close to the city of Buenos Aires) as well as the National University of Tucumán.

In terms of government regulations, Argentina has a permissive attitude towards biotechnology, both in its agricultural and health applications. In the 1990s, Argentinean agriculturists were experimenting with transgenic crops. Regulation came at a leisurely pace. New plant varieties can be registered since 1987. New genes in plant varieties can be patented since 1995. In a few years, both locally produced GMOs and imported ones were circulating in the country. Argentina is today (2012) the third country in the world, after the USA and Brazil, in the area planted with transgenic crops.

Finally, Argentina has neither public nor private venture capital to support its fledging DBFs. They thus have to rely on selling R&D services fairly quickly to the private sector. Two cases deserve mention. Rosario, (Santa Fe province) hosts a private firm, founded in 2004 with over 200 shareholders, mostly innovative farmers, as well as some 150 researchers, working mostly on soya, sunflower and wheat seeds. This DBF has obtained 27 patents, granted in Argentina, Australia and the USA, mostly on new or improved organisms. It conducts collaborative R&D with public institutions in Argentina (such as CONICET, INTA, INTI and research universities) and in neighbouring countries. It has also transferred technology to India. Its services include a platform for genomics and bioinformatics, the analysis of environmental impacts on microbial communities, RNA sequencing, and others. Located in Buenos Aires and founded in 2006, another DBF is a successful private R&D product and service firm conducting innovative research on biosimilar drugs (follow-on biologics having lost their patent protection). The firm produces 12 active pharmaceutical ingredients (API) for biopharmaceutical drugs, as well as seven finished products; the same firm is now conducting innovative R&D on five different monoclonal antibodies (MABs) and will build another plant to produce them. These products are exported to unregulated markets in Africa, Asia and Latin America.

In spite of these successful cases, the general picture is not so positive. The median expenditure on R&D of the companies is very low (US$ 250,000 annually as of 2012), as Table 1 shows. Also, a majority of firms are patenting and have trademarks, but only two of them have 'new-to-the world' novelties as attested by US, European or PCT patents. Most firms only have 'new-to-the-country' innovations. Their median sales are just US $200,000 a year, and their median employment is just 12 employees. All of them rely on private funds (mostly generated by sales and private investment).

4.2 Brazilian biotechnology

In the science of biotechnology, Brazil catches up fairly fast. Brazil GERD has increased from 0.85% of GDP in 2000 to 1.19% in 2011. Its public laboratories have a strong presence in agricultural and human health biotechnology. The number of its university graduates, particularly at the master and doctoral levels is growing. Its scientific publication in biotechnology is now in the top 15 in the world. In addition, Brazil has created a dozen technology-based firm incubators in its national universities and is also catching up in the number of biotechnology patents invented in the country.

Like in other Latin American countries, the precise number of biotechnology active firms in Brazil is unknown. The reason for this confusion is that three different types of firms are grouped together[2]:

a DBFs: companies producing R&D services, usually small and medium sized enterprises

b Users of biotechnology products: these are usually large corporations operating in such areas as agriculture, food, pharmaceuticals and other industries.

c Traditional biology services and products firms such as those that improve animal species and plants through hybridisation. Estimates run from 40 to 60 DBFs (Uziel, 2012) to 102 (Fundação Biominas, 2010) to 145 (BRBiotec, 2011). All these private estimates suggest that the cities of Sao Paulo, Rio de Janeiro and Belo Horizonte are the main clusters of Brazilian biotechnology.

In Brazil the two main government laboratories conducting research on biotechnology are large by any type of measurement. Brazilian Enterprise for Agricultural Research (EMBRAPA) was founded in 1973. It hosts 8,275 employees of which 2,113 are researchers with either master's or PhD degrees. EMBRAPA has 38 research centres, three service centres and 13 central divisions. Areas of biotechnology research include biopharmaceuticals, bio-fertilisers, bioinformatics, bio-remediation, cloning, genetic engineering, gene therapy, molecular markers and GMOs. EMBRAPA also produces and distributes transgenic seeds to local peasants at no cost, helping them to increase their productivity and revenues. FIOCRUZ works on many areas of human health. It hosts 7,500 employees, working in 15 institutes across Brazil. Many of them work in biotechnology in one way or another, but Bio-Manguinhos (the Immunobiology Technology Institute) is key. Bio-Manguinhos is the largest producer of vaccines in Latin America.

As to government regulations, Brazil passed from a position of cautious resistance to transgenic crops to a warm approval of them starting in 1997. In a few years, Brazil became the second producer of GMOs in the world. Again, like in Argentina, both local varieties and imported ones are circulating. ANVISA regulates the approval of new drugs and other human health material. Brazil imports most of its biopharmaceutical drugs from the USA and Europe. When it comes to biological follow-on products, Brazil has adopted the same regulations as Europe: companies that want to introduce a biosimilar drug must prove their comparability with the most used drug in the country.

Brazil has developed a very extensive system of public and private universities. The public institutions are considered the best ones particularly the federally funded institutions. All these universities are conducting teaching and research in biotechnology, as attested by their biotechnology incubation and publication activities. These universities are the key knowledge producing institutions behind Brazilian biotechnology clusters. Brazilian universities – together with public laboratories – produce some of the knowledge used by domestic biotechnology firms. Firms also gather knowledge from foreign articles and patents, as well as from scientific collaboration with foreign universities and public laboratories. Most Brazilian DBFs were incubated in universities. Only six institutions concentrate more than 50% of scientific articles in biotechnology. They are located in Sao Paulo, Rio and Belo Horizonte.

The DBFs interviewed were located in Rio (four), Sao Paulo (three), Belo Horizonte (one) and Porto Alegre (one). In addition, the manager of the Bio-Rio incubator was also interviewed. All these companies are active in R&D for human health biotechnology, including therapeutics, functional additives for food products, health cosmetics, diagnostics and other products. One of these companies is also conducting R&D in animal health. All these companies – except one, which was acquired by a North American firm – are owned and controlled by Brazilian entrepreneurs. A majority of these DBFs were university spin-offs from such universities as the USP, UFRJ and UNICAMP. Some of them were also incubated in other universities.

A group in Rio has adopted a hybrid product/service model, and is active in several lines of biotechnology products and services. The group includes an older pharmaceutical company producing traditional generics, a stem cell databank service company providing stem cell storage and studying regenerative medicine and a recent biopharmaceutical company conducting R&D on biosimilars that are not yet on the market. Another relevant company is based in Sao Paulo, a spin-off from the University of Sao Paulo, founded in 2003, conducting R&D and producing goods and services related to dermatology. This firm is one of the few Brazilian biotechnology companies to have received funds from both domestic angel investors and BNDES. In 2012, the Toronto-based biotechnology company, Valeant, took a minority position in the Brazilian DBF.

Brazilian DBFs are larger than Argentinean ones: the median employment in 2011 was 30, but median sales were similar, and patenting and trademark activity was somewhat lower than in Argentina. Our study found more firms active in human health in Brazil than in Argentina, but the sample is not representative. Also, more firms experienced problems with regulation in Brazil than in any of the three other countries (see Table 1).

4.3 Chilean biotechnology

Chilean biotechnology is fairly different from those of Argentina, Brazil and Uruguay. The main reason is that there are few users from agriculture and pharmaceutical industries. In Chile, other sectors have the potential to fuel the development of biotechnology; they are salmon farming, the fruit and the mining industries. Thus, the profile of Chilean biotechnology shows different specialities than those of Argentina and Brazil. However, the most distinguished biotechnologist in Latin America is Dr Pablo D. T. Valenzuela, former professor at the University of California, and co-founder and VP R&D of Chiron Corporation. In 1997, Dr Valenzuela went back to Chile where he founded Fundación Ciencia para la Vida, and several new DBFs in human and animal health.

According to the association of Chilean biotechnology firms, ASEMBIO, there are 93 manufacturing users of biotechnology in that country, as well as 61 SMEs based in universities and 22 firms producing specialised services. Chile also hosts some 15 incubators prioritising biotechnology, and ten academic technology transfer centres. Like in other countries, it is difficult to assess the accuracy of these estimations. The biotechnology sales of these firms would represent some 100 million USD. Santiago, the national capital is the main location of Chilean biotechnology firms, as well as the host of most research universities in the country.

Chile's biotechnology policy focuses mainly on natural resources: forestry, mining, fruit, aquaculture, small animals and legumes. Issues include quality improvement, resistance to pathogens, biotic stress and gene selection. In mining, companies are interested in the development of bacteria that allow bioleaching, the separation of valuable minerals (mainly copper) from other minerals.

Between 1991 and 2001, the Chilean government supported 408 biotechnology R&D projects, for a total of 73.4 million USD (an average of US $180,000). Since then, public backing has been continuously growing, particularly after the creation of 'Innova Chile' (IC), now the main fund supporting the development of Chilean biotechnology firms. IC was established in 2005 following the merger of two public funding agencies: FDI and FONTEC. Its missions are promoting innovation in private firms, stimulating innovative entrepreneurship and strengthening the national system of innovation. Biotechnology is one of its seven key areas of funding. The mechanisms through which support is provided are seed capital, business incubators, and the establishment of a network of angels. IC supports new technology-based firms with up to USD 190,475 for three years.

Chile forbids the introduction of transgenic crops for both human and animal consumption, but allows their production for exports as seeds. This regulation has made Chile an important producer and exporter of GMO in international markets. Also, Chile forbids the liberation of living transgenic animals in domestic waters. Yet there is some R&D taking place on the genomics of Chilean plants and animals for purposes of finding cures to different plagues and diseases such as those that affect Chilean salmon fisheries. In terms of biopharmaceutical drugs, Chile allows their patenting and imports most of its products from original innovators.

Four Chilean universities dominate the landscape in biotechnology publication: Universidad de Chile, Pontificia Universidad Católica de Chile (PUCC), Universidad de Concepción, and Pontificia Universidad Católica de Valparaíso (PUCV). Three of them are located in Santiago (main Chilean biotechnology cluster) and one in Concepción. Twenty other universities have some publications on biotechnology, as well as several university hospitals and foundations (Niosi et al., 2012). Two main laboratories conduct research on biotechnology and publish their results in refereed journals: the National Agricultural Institute (INIA) and the Milenio Institute of Fundamental and Applied Biology (MIFAB). INIA conducts biotechnology research aiming at the genetic improvement of legumes and fruits. It also aims at preserving the genetic heritage of the country and transmitting its research results to universities, DBFs and other research centres. MIFAB, founded in 1999, focuses its work on human pathology, more precisely on the molecular basis of cell regulation and cell functions. Among its research projects, some focus on cancer, diabetes and obesity. MIFAB also works on the pathogens of salmon.

Four DBFs were interviewed in Chile, all of them in Santiago. Three of them were active in human health and one in mining biotechnology. The mining DBF is the result of a consortium of a large domestic copper company and a foreign multinational corporation; its goal is to develop bioleaching processes for the copper industry. This biotechnology company, founded in 2002, has already been granted seven US patents, since 2009. It sells its services to its two major shareholders and to financial supporters. By far the largest Chilean company, GB operates in human and animal health R&D. It was founded in 2008, and already has 130 employees. It has developed molecules for diagnostics kits for several human and animal diseases. It is now trying to export products (molecules and kits) to the USA. It is offering custom-made MAB services. Its funding initially came from public funds, and now comes from sales. This company has also licensed its molecules to a large multinational pharmaceutical corporation. However, the firm has no patents, either in the country or in other OECD nations. Companies had some comments about regulations in Chile. Speed and cost were not issues. But there is no regulation on biotechnology diagnostics in the country, and this fact represents an obstacle to exports to other countries. These DBFs had experienced productivity growth of over 10% in the last five years, besides increasing total employment by between 14% and 50%. In Chile, supported by a developmental state, growth is taking place, at least for the largest DBFs.

4.4 Biotechnology in Uruguay

Uruguay has a less significant human capital pool, a more reduced internal market, and devotes smaller government funds to support the development of biotechnologies. Yet, the country has managed to introduce biotechnology services and products through several small and medium-sized enterprises. Because its economy and government policy is similar to that of Argentina, there are striking similarities in the applications of biotechnology among DBFs in both countries. In Uruguay, there are no official statistics on the number of DBFs. The BIOTECSUR site publishes a list of 13 Uruguayan DBFs. However, a detailed analysis of this list finds that most of them are either pharmaceutical corporations, producers of recombinant animal health vaccines or companies producing inoculants for edible plants. In fact, the latter are biotechnology users, manufacturing specific lines of products. Once the list was analysed, one is left with only four DBFs producing R&D services.

In 2012, Uruguay published a National Biotechnology Plan, but like in Argentina, no practical implementation or funding followed. In Uruguay, government support for innovation is confined to the National Agency for Research and Innovation (ANII). ANII is a private organisation under government control. Its total annual budget in 2011 was about US $26 million plus US $3 million coming from foreign sources. Even if the funds are modest (US $0.75 per inhabitant) they have grown exponentially from US $8.5 million in 2008, to US $18.5 million (2009), and US $21 million in 2010. Uruguay has no tax credit for R&D, but it has a tax credit for investment, the average amount granted being around US $80,000. The biotechnology companies interviewed have used this investment incentive. None had received other funds. Uruguay has not promoted the development of a venture capital industry; there are no incentives for angel investment either; thus, the country cannot use the more traditional mechanism to support new biotechnology firms. Uruguay has two government laboratories: the National Institute for Agricultural Research (INIA), and the Uruguayan Technology Laboratory (LATU). Neither of them has biotechnology research among its missions.

Uruguay has developed a National System of Researchers (NSR), giving bonuses to the most productive academics. But the NSR has a clear preference for fundamental research and articles, not for applied research and patents. Such a bias is an obstacle to linking university and industry. Two universities in Uruguay teach and conduct research on biotechnology. The largest is the Universidad de la República (UDELAR). Founded in 1949, there is some research and teaching at the Faculties of Sciences, Medicine and Agriculture. Between 1996 and 2011, Uruguayan scholars published a total of 356 biotechnology scientific articles. UDELAR was responsible for 61% of them, followed by the Ministry of Education, the Louis Pasteur Institute (a private non-profit research centre) and INIA. All this scientific activity takes place in Montevideo, the national capital. No other institution had biotechnology publications. Universidad ORT revamped as a university in 1985, created in 2010 the only university degree in biotechnology in the country. The Pasteur Institute in Montevideo was inaugurated in 2007, through an agreement with the French Pasteur Institute. It focuses on three main areas: protein chemistry, molecular biology and structural biology, linked by bioinformatics. The Institute conducts research and trains local and regional human resources in biotechnology. The French government supported the Institute through a €5 million grant and the Uruguayan government contributed €1 million. Its annual budget is US $650,000. In 2007 an international committee selected three competitive research projects, which started their work the same year. Two other research teams were added the following year.

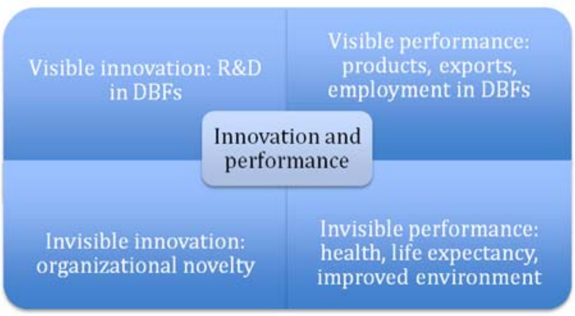
Uruguay allows patenting of both transgenic crops and biopharmaceutical products. The country imports all of these products mostly from original innovating countries. For the purposes of this project, the PI interviewed a total of six firms, but only two of them were DBFs, the others being in fact manufacturers of different products (biotechnology users). One DBF was founded in 2001 as a dedicated R&D services firm. The largest domestically controlled pharmaceutical company in Uruguay acquired it, a spin-off from the UDELAR. This DBF has become a captive R&D service provider of a biotechnology user. Under the umbrella of the larger firm, it is growing, both in terms of employment, revenues, and productivity. A second DBF, established in 1993, is a pure service company. Its specialty is the analysis of DNA. It started conducting service tests for herpes, moved to paternity tests and the creation of DNA banks, and now is focused primarily on gene identification in order to understand the genetic basis of the effectiveness of some drugs marketed by multinational corporations. In addition, it conducts gene identification for security services. Recently, it has diversified into gene identification of large cattle. The company exports services towards different Latin American countries, and conducts R&D in Argentina and Uruguay. Its employment, revenues and its productivity are growing fast. Uruguay invests little on private and academic R&D, and thus it forces companies to rely exclusively on revenues they generate. In a sector where technical change is very fast, and depends on university research, this means serious handicaps for local companies.

5 Conclusions and policy implications

In biotechnology, innovation is essentially R&D. All the 22 companies interviewed were conducting R&D. Almost of all them were practising ‘open innovation’, collaborating with domestic research universities and public laboratories, and most often with foreign biotechnology and pharmaceutical firms in order to gain complementary knowledge. Over one third of the companies had patents, and five of them had been granted US, European and/or PCT patents, showing that some new-to-the world innovation is taking place in the region. The use of trademarks in the largest of these biotechnology service firms and biotechnology users shows that some level of novelty takes place. However, imitative innovation of products invented elsewhere is the norm in Latin America’s biotechnology. In two of our selected countries, Argentina and Brazil, domestic generic pharmaceutical companies and public government laboratories are aiming at the production of biological copies of existing biopharmaceuticals that are losing patent protection in the USA and Europe. In Chile, one DBF is moving in the same direction: imitative innovation of biopharmaceutical drugs. In the area of organisational innovation, imitation is also the rule: open, collaborative innovation and the creation of captive biotechnology firms is not a new to the world organisational innovation; it is the way many large pharmaceutical companies based in Europe, Japan and North America are incorporating biotechnology.

Biotechnology services companies are being created in all the four countries, and some of them show increasing employment, revenues and productivity, despite reduced government support for advanced academic and public-sector R&D, limited domestic markets and small human capital pools. Pure service biotechnology companies are more easily established in the region than product companies. These service companies require less start-up capital, smaller investments in R&D, and are often able to develop a stream of revenues fairly rapidly. In Argentina and Uruguay, several large pharmaceutical corporations have acquired biotechnology R&D service companies; in Argentina, a group of agricultural firms has also followed this path to internalise biotechnology R&D services. In Chile, mining companies have established their own captive R&D service provider. But the R&D service model is not the only one existing in the region. Other biotechnology services, such as bioinformatics, gene identification and others, even more specialised, such as stem cell bank services, are also part of the biotechnology landscape in the region. Figure 3 summarises the innovation activities of the firms and their impacts, both visible and invisible.

Figure 3 Innovation activities and performance of DBFs (see online version for colours)



In each country, interviews with policymakers have helped to understand the rationale and figures of the public programs. User surveys are one important method of assessing the quality of public innovation policy incentives and regulations (Georghiou and Roessner, 2000). Our survey of biotechnology companies, even if not statistically representative, points to some deficiencies in regulation and innovation policy of Latin American biotechnology.

References

Anlló, G., Bisang, R. and Stubrin, L. (2011) *Las Empresas de Biotecnología en Argentina*, CEPAL, Santiago.

Biotecsur (2010) *Catalogo de empresas y centros de investigación 2010* [online] http://www.biotecsur.org (accessed December 2011).

BRBiotec (2011) *Brazil Biotech Map 2011*, Belo Horisonte.

Casper, S. (2000) 'Institutional adaptiveness, technology policy and the diffusion of new business models: the case of German biotechnology', *Org. Studies*, Vol. 21, No. 5, pp.887–914.

Chesbrough, H. (2011) *Open Service Innovation*, Jossey Bass, San Francisco.

Freel, M. (2005) 'Patterns of technological innovation in KIBS', *Industry and Innovation*, Vol. 13, No. 3, pp.335–358.

Fundação Biominas (2010) *A Study of Brazilian Biotechnology Companies*, Belo Horizonte.

Gallego, J., Rubalcaba, L. and Hipp, Ch. (2013) 'Services and organizational innovation', *The Right Mix for Value Creation*, Vol. 51, No. 6, pp.1117–1134.

Gallouj, F. and Savona, M. (2009) Innovation in services: a review of the debate and a research agenda', *Journal of Evolutionary Economics*, Vol. 19, No. 2, pp.149–172.

Georghiou, L. and Roessner, D. (2000) 'Evaluating technology programs: tools and methods', *Research Policy*, No. 29, pp.657–678.

Griliches, Z. (1992) *Output Measures in the Service Sector*, University of Chicago Press, Chicago.

Jones, J. (2013) *UK Service Industries: Definition, Classification and Evolution*, Office for National Statistics [online] http://www.ons.gov.uk (accessed December 2013).

Miles, I. (2005) 'KIBS: prospects and policies', *Foresight*, Vol. 7, No. 6, pp.39–63.

Muller, E. and Doloreux, D. (2009) 'What we should know about KIBS?', *Technology in Society*, Vol. 31, No. 1, pp.64–72.

Niosi, J., Hanel, P. and Reid, S.E. (2012) 'The international diffusion of biotechnology: the arrival of developing countries', *Journal of Evolutionary Economics*, Vol. 24, No. 4, pp.767–783.

OECD (2007) *Summary Report of the Study on Globalisation and Innovation in the Business Service Sector*, Paris.

OECD (2008) *OECD Reviews of Innovation Policy China*, Paris.

Pilat, D. (2001) 'Innovation and productivity in services: state of the art', *Innovation and Productivity in Services*, pp.17–56, OECD, Paris.

Rasmussen, B. (2010) *Innovation and Commercialization in the Biopharmaceutical Industry*, Elgar, Cheltenham.

UNCTAD Database (2013) *Global Investment Trends Monitor*, No. 11 [online] http://www.slideshare.net (accessed September 2013).

Uziel, D. (2012) *Biotecnologia no Brasil*, EDUERJ, Rio de Janeiro.

Notes

1 The names of the companies and the interviewees are kept confidential as agreed upon with the interviewees.

2 The North American Industrial Classification System (NAICS) and the MERCOSUR one have different codes for these industries.