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How knowledge flows in university-industry relations: An overview from two economic sectors in Brazil

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How knowledge flows in university-industry relations

An overview from two economic sectors in Brazil

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Abstract

Purpose – The purpose of this paper is to characterize the knowledge flow between companies and universities based on national and sectoral systems of innovation perspective. It is argued here that high-tech sectors can describe a knowledge flow mainly based on scientific research, while sectors with lower technological impact may establish relations based on technical needs.

Design/methodology/approach – A case study research was conducted in the horticulture and aerospace sectors in Brazil. Thirteen interviews were performed with chief executive officer's and academic researchers from both fields.

Findings – Results demonstrated differences in technology development and knowledge infrastructure when comparing both sectors, reflecting the impacts of national and sectoral systems of innovation. The horticulture sector presented technological limitations due to restricted eating habits, logistics, knowledge development at universities and difficulties on the establishment of partnerships between local companies and Embrapa, the main public research centre. Such restrictions limit academic activities while companies look for research partnerships abroad. Space industry also has limited technological development due to international embargoes and lack of research alignment between companies and universities. Companies end up developing research activities internally, usually funded by governmental tenders.

Research limitations/implications – The horticulture sector has limitations, as it is not the main agriculture area in science and technology applications. Future studies may analyse areas like soy beans, sugar cane and coffee, which may present differences specially regarding sectoral systems of innovation.

Originality/value – The finding of this paper may influence the review of sectoral innovation policies, improving the development of local research activities which may be a source of valuable knowledge to companies. It also demonstrates the importance of the knowledge flow to improve sector's technology level.

Keywords Brazil, Knowledge flow, Horticulture sector, Space sector, University-industry relations

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Introduction

University-industry relations are considered one of the main solutions to boost industrial innovation. Universities can be a source of state-of-the-art knowledge, thus generating top-value technology. By its turn, companies may use academic knowledge as a source to new or improved products and processes.

The rising complexity of emerging technologies has evidenced that to stay, competitive companies should develop its R&D activities through partnerships with universities or research centres. The establishment of a knowledge flow from universities to industries and the way back has demonstrated to be necessary in a globalized environment. The knowledge flow can be based on scientific outputs from university like patents or mobility of graduates, or from applied demands from companies as new technological trends or necessities (Østergaard, 2009). This concerns not only companies who employ open innovation practices (Chesbrough, 2006), but also universities who are applying Triple Helix concepts (Etzkowitz, 2008) to improve academic entrepreneurship and the technology transfer processes. Government also has an important role in stimulating such relations by national and sectoral systems of innovation policies (Nelson, 1993; Malerba, 2002; Lundvall, 2007).

Historically, the knowledge flow between companies and universities emerged almost naturally in developed countries. Due to growing competition and market needs, companies have started looking for advanced knowledge solutions which were mainly found at universities (Mowery and Rosenberg, 1989; Freeman, 1992). Nowadays, this debate concerns the complexity of such relations, ways to foster these partnerships and the kind of knowledge being transferred between actors (Giuliani and Arza, 2009).

In emerging economies, governments' intention to stimulate partnerships between academia and business are still incipient. Historical events such as the atomic bomb and the space race have demonstrated the importance of scientific research to technological advances and innovation. However, due to late development of universities and the industrial sector itself, government has become crucial to stimulate partnerships among these two actors through funding of joint projects or the establishment of science and technology policies (Etzkowitz *et al.*, 2005).

Considering the importance of economic and technological development in emerging economies, the university-industry relations theme has been widely discussed lately. The role of actors – university, industry and government – and channels of knowledge transfer – conferences, informal contacts, articles, patents, joint research, etc. – have been guiding researches under different approaches (Cohen *et al.*, 2002; D'Este and Patel, 2007; Bekkers and Freitas, 2008; Spithoven *et al.*, 2010; De Fuentes and Dutrénit, 2012).

However, differences in national policies, academic research and industries' technology level may influence the way actors establish university-industry relations. Each country defines its strategic industrial sector (electronics in Japan, biotechnology and IT in USA) according to geographic characteristics, culture and competences (Tidd and Bessant, 2011). Based on these characteristics, a national plan of industrial development is generated, focusing on specific sectors which are considered promising according to local needs and trends. In this context, it is not clear how national and sectoral systems of innovation may influence the knowledge flow between actors. It is argued here that high-tech sectors can describe a knowledge flow mainly based on scientific research, while sectors with lower technological impact may establish relations based on technical needs.

Based on the importance of systems of innovation on the economic development of emerging countries, our objective is to characterize the knowledge flow between companies and universities based on national and sectoral innovation policies. To observe this phenomenon, this research was conducted in the horticulture and aerospace sectors in Brazil. Horticulture was chosen due to the impact of agriculture in Brazilian exports and economic development and the differences in technology level this sector may present. By its turn, the space sector was chosen due to its high tech activities, adding to the development of Brazilian space activities in the past years. The analysis of these two specific sectors may evidence particularities on the knowledge flow of local university-industry relations, guiding new policies and regulations.

This article is composed of four sections. Initially, the concepts of national and sectoral systems of innovation in Brazil will be discussed, followed by Section 3 which will present the research method used. Section 4 describes the main results and the last section highlights the conclusion of the study, identifying the relation between the knowledge flow and the technological development of the two Brazilian sectors analysed.

University-industry relations from a national and sectoral system of innovation perspective

With the advent of the industrial revolution, companies have optimized their production capacities, expanding markets through the exports of goods and services. Industrial revolution has arisen opportunities to new techniques and technologies, developed trough industries' quality control departments which later became R&D facilities (Mowery and Rosenberg, 1989). At the same period, technology centres were established in countries like Germany, England and USA, supplying specialized technicians and engineers to industry (Freeman, 1992). The work of qualified technicians and engineers has eased the establishment of partnerships between companies and technology centres or universities, shaping the first knowledge networks (Mowery and Rosenberg, 1989; Freeman, 1992).

Based on the observation of this dynamic, the concept of national innovation systems was proposed as an analytical framework which could associate the innovation and learning process with economic development through national policies (Lundvall, 2007). More than the relationship between actors, the *locus* of science, innovation and entrepreneurship has been focused at the national level, where technology priorities were identified and programmes were aimed at stimulating scientific production, university-level training and the diffusion of innovation were implemented (Freeman, 1992; Lundvall, 1992; Nelson, 1993). Key ingredients of national innovation systems are: basic science and technology policy (e.g. pre-commercial R&D programmes), the organization and intensity of R&D, policies for education, learning and training, user-producer interactions, inter-firm connections and networks, entrepreneurship, competition policies, the role of the public sector and the institutional structure of the financial sector (Nelson, 1993; De Jong *et al.*, 2008). The availability of governmental funding is also important to foster innovative activities, as it can provide resources for fundamental research (which may be a knowledge base for future R&D projects) and joint university-industry projects (Cohen *et al.*, 2002; Etzkowitz *et al.*, 2005; Filippetti and Archibugi, 2011). In this sense, public procurements may also be a way to stimulate the benefits of results of technological innovation to society and promote social and economic development (Myoken, 2010).

Adding to this, regional economists have tried to complement existing literature on national systems of innovation by looking at regional and/or sectoral differences in scientific output, in the way innovation is organized and in overall performance (Cooke, 2001). From a national point of view, different industries have specific demands for technologies, knowledge structures and funding, besides the nature of clients and competition. Consequently, countries have distinct approaches to provide support for the development of different industries (Malerba and Nelson, 2011). They have emphasized the importance of geographic proximity and tacit knowledge, the existence of trust-based networks and strong cultures shaping the innovativeness in particular regions and local clusters. According to Malerba (2002), the national systems of innovation approach underestimates the power of private actors, i.e. firms with their different sizes, knowledge bases and corporate strategies, as well as the role of market structure and dynamics within sectors which specifies and shapes particular activities at a local or global level of innovation and production.

In this sense, Iansiti and Levien (2004) bring the concept of business ecosystem. Business ecosystem can be described as cluster or network of companies in which the efficiency of company is connected to the efficiency of the cluster. Here, companies can also benefit from knowledge spillovers of local universities or research centres. Etzkowitz *et al.* (2007) add with the concept of innovation ecosystems, which is an environment composed of entrepreneurs, investors, academic researchers and technology transfer offices, fostering a network of technology development and support.

From a national or sectoral perspective, the business or innovation ecosystem aim to complement specific assets from companies and universities. The fast dynamics of a globalized world brings the necessity of partnerships between companies and knowledge institutes, as companies usually face difficulties in keeping their technology level updated by themselves. When this relation does not happen spontaneously, a third actor responsible for stimulating the partnership emerges: government.

The tripod of university–industry–government relations are mainly described by the Sábato's triangle and the Triple Helix (Sábato and Botana, 1975; Etzkowitz, 2008). Sábato's triangle analyses the involvement of these three actors to drive economic and technological development in Latin America (Sábato and Botana, 1975). Each vertex of the triangle presents the role of one actor, being all connected by a flow of demands. An updated view of Sábato's triangle is detailed by Etzkowitz's Triple Helix (Etzkowitz, 2008). The Triple Helix analyses the integration between science, technology and economic development among the same three actors. Here, each actor may change its role according to the way knowledge relations are established, emphasizing the entrepreneurial university and companies' corporate universities (Etzkowitz, 2008).

On the tripod university–industry–government, knowledge usually flows from university to industry, as university's main role is to develop knowledge, while companies apply knowledge to market needs. Government, by its turn, is responsible for stimulating the approach between them when it does not happens spontaneously. These relationships are driven trough several channels of knowledge transfer according to the actors involved and to their technology level (Cohen *et al.*, 2002; D'Este and Patel, 2007; Bekkers and Freitas, 2008). The main channels described in literature are:

- conferences and workshops;
- informal meetings;

- joint R&D projects;
- hiring university graduates as employees;
- licensing of university patents;
- joint publications;
- lectures/training;
- contract research and consulting; and
- new firm formation by university members.

From national and sectoral systems of innovation to the Triple Helix of relations between actors and channels of knowledge transfer, our discussion is mainly focused on the role of such systems of innovation to the materialization of these relationships. The development of a knowledge connection through research partnerships networks requires a well-structured network of universities, research centres and companies. As mentioned by Lundvall (2007), innovation does not depend solely on firms' technological capability, but also on national innovation systems policies to create a favourable environment of science and technology.

Consequently, some questions about how national and sectoral systems of innovation influence the knowledge flow between companies and universities. What is the difference in university-industry relations in different sectors? What is the influence of academic knowledge to the technological level of companies or the sector itself? How do these companies look for innovative solutions? Which is the knowledge flow? It is argued that in sectors with a structured network of universities, research centres and technology-based companies, the knowledge flow may occur naturally between actors, moving from scientific research to technological demands. On the other hand, in sectors which this network is not well established, the knowledge flow may be limited to technical solutions, impacting on companies and universities' innovation capacity. As described by Tödtling *et al.* (2009), a knowledge flow with high levels of scientific knowledge can make a difference between a simple adaptation of current technology and the development of a disruptive innovation.

Research method

To better understand the influence of national and sectoral systems of innovation on the knowledge flow in university-industry relations, this research was conducted at two specific sectors from Brazil. The horticulture sector was chosen due to the aggregate value of its products and due to the technological diversity. The development and selection of seeds can be performed either by manual handling or by the use of biotechnology. Agriculture is an important sector for the Brazilian international trade, being considered one of the main responsible for its actual economic development. By its turn, the aerospace sector was chosen due to the high tech level of products and processes. In addition, this sector is improving its activities in Brazil by the development of international partnerships for satellite development and launch.

The research was conducted following a multiple-case studies method, as defined by Yin (2008). This method was used because it tries to examine a phenomenon in its real-life context (Yin, 2008) and allows a more flexible analysis of the results (Roesch, 2005). A total of 13interviews were conducted with the companies, technology centres

and universities in Brazil, describing research partnerships characteristics and the knowledge flow from sectoral and national perspectives.

Questionnaires with open-ended questions were used during the interviews, as it provides richness to the topic discussed and insights which were not though initially (Hair *et al.*, 2011). Two questionnaires were designed, one for companies, another for universities and technology centres. Interviews were carried with the director of technology transfer in companies and technology centres. In cases which this position was not available, the interview was conducted with the chief executive officer. At universities, interviews were performed with prominent researchers in their fields of study.

Results

Brazil is among the top ten largest world economies, being agriculture one of the key areas for such fast development. Investments in science and technology have changed the Brazilian agriculture as a whole, from a simple adapter of foreign technology to an international reference in different areas. Other industrial sectors are also following the Brazilian boom, like petroleum and the space sector, mainly based on governmental investments in science and technology.

However, differences in technology development and knowledge infrastructure were observed when comparing both sectors, reflecting the impacts of national and sectoral systems of innovation. Consequently, results were divided in two parts, discussing similarities and discussing differences among sectors on the following section.

Horticulture sector

It was observed that the greater part of the Brazilian horticulture production is directed to domestic consumption, representing only 4.5 per cent of national exports in agriculture. One of the reasons is the lack of investments in logistics, as mentioned by one of the interviewees:

> Differently from soya and corn, Brazil does not have capacity for exporting horticulture products. Vegetables are much more sensitive to temperature, so logistics are much more complicated than soya for example.

Adding to this, horticulture production is mostly conducted by family farms, some of them through organic farming activities. As mentioned by the interviewee from one of the universities: "We work primarily with family farmers. The technology used in this area is very small". The national eating habit of horticulture products is also an issue, as it is three times lower than international standards, contributing to the reduced demand of these products.

Lower national demand and limited logistics end up influencing the production and consequent technological development of horticulture products. Interviewees have mentioned that the horticulture sector has received limited investments from the Brazilian government when compared to other agriculture sectors. One of the interviewed professors has mentioned: "We only see investments on field crops. Federal resources for soya and corn production have increased substantially on the last ten years".

However, the main Brazilian research institute in agriculture technology (Embrapa) faces a different perspective. Embrapa is a governmental research centre that develops agriculture technologies – from seeds to equipments and processes. Embrapa's activities are mostly funded by governmental agencies, developing its research

activities based on national demands and on local farmers' needs. Driven by land reform policies, Embrapa works close to families and local farmer's association demands, as the interviewee from Embrapa has mentioned: "We usually participate in local fairs and events to attend to farmer's demands. They say what they need, and we try to organize it into our research agenda". Consequently, research outputs from Embrapa aims to improve land reform activities, as mentioned by one of the companies' interviewee: "In recent years, horticulture production by family farmers was further encouraged, aiming a self-sustaining seed production".

Trying to have an access to Embrapa results, some Brazilian companies complain about the difficulty in establishing a research partnership. One interviewee has stated that:

> We tried to establish a partnership with Embrapa for technology transfer in seed development. But we could observe that public agencies are not ready to establish this kind of agreement. It has been two years since we started negotiating, and the document has not been signed yet.

However, Embrapa's technology level is not competitive when compared to international seed companies, as the interviewee from a multinational company has said:

> The difference between seeds produced by Embrapa and our seeds is the technology of the seed which impacts in quality of the final product. Professional farmers need products with longer life cycle and better quality in colour and taste, demanding a better quality seed. Our customers are mostly small farmers, but small professional farmers.

Universities, who should be an alternative knowledge source, play a smaller role on the scientific development of the horticulture sector. The interviewee from one of the universities has mentioned that:

> In general universities still don't consider horticulture as an important activity to wealth and food generator, which is also important for national sustainability and sovereignty. It seems that horticulture has not received attention from both university and federal government in matters of research and resources devoted to this area.

Interviewees have also mentioned that government has not provided funding for horticulture research in the past 10 years, compelling researchers to adapt their projects to be included in other areas. Academic researchers end up restricting their activities to applied research or seeds evaluation for companies.

In this scenario, it could be observed that a knowledge flow is mainly based on technical demands, instead of new technologies. Interviewees from both universities have mentioned that:

> We test some varieties provided by companies and analyse their results to specific soil conservation techniques. As we do the evaluations we returned to the company with the responses we had here.

They have also mentioned that: "The focus of Brazilian research is mostly in the adoption of materials to cropping system (including pest control or organic cultivation) and plants resistance to diseases".

With limited knowledge relations with universities, companies look for technology transfer partnerships with institutes abroad. As mentioned by the interviewee from one of the companies:

> We go to this Spanish research institute, talk to the researchers, and explain the local conditions of Brazil, exchange ideas/concepts with him. We are studying the whole scenario with the researcher in order to develop a variety which will reproduce in Brazil.

Another company has also mentioned the existence of partnerships with German universities in which undergraduate students come for an internship period. According to him, this is favourable for establishing a network of relations between his company and German researchers and professionals.

Space sector

Brazil has an established space agency since 1994, but it is the national space research institute (Instituto Nacional de Pesquisas Espaciais (INPE)) that is responsible for conducting space research activities since 1971. Nowadays, the INPE is responsible for contracting local companies to develop satellite subparts, while satellites assembling and testing are performed internally. The main project being currently conducted is the Satélite Sino-Brasileiro de Recursos Terrestres (CBERS), a satellite used to control slash-and-burn activities in the Amazon forest, monitor water resources, among others. This project is being developed through a partnership between Brazil and China. The first phase included two satellites (CBERS I and II), but during its execution, three other satellites (CBERS IIb, III and IV) were added to the project.

Brazilian space companies develop most of the research being conducted in the space sector, adapting foreign technology to local needs. As mentioned by the companies interviewed, they must be technologically prepared to attend to the INPE demands:

> We can't plan ahead in projects from the aerospace and defence sector. This demands come from INPE and the space agency. We are really dependent on the definition of the government strategic plan.

However, such demands do not require a significant technological upgrade from previous projects, as mentioned by the interviewee from one of the companies:

> Technological demands of CBERS III and IV are based on a replication with minimal improvement from CBERS I and II. […] Overall, INPE does not want to move much further because CBERS I and II have worked well. […] INPE prefers to stay on the safe side – you know the risk in space is something taken very carefully.

Regarding the technology demanded by new satellite projects, the interviewee from one of the technology centres has mentions that:

> INPE is aware of the technology level Brazilian companies have, so demands are not typically big challenges. In some cases a bigger leap is required, but in general INPE demands take into account local technological level, adding to a second limitation which is the technological embargoes.

Technology development in the Brazilian space industry is also limited by technology embargoes. These embargoes are imposed because the development of space technology is close to military applications. Consequently, technology embargoes narrow the sector's possibilities of reaching the state-of-the-art level in space technology, limiting companies to import outdated products for national space products.

Due to technology embargoes, governmental research centres and universities are the main responsible for the development of national technologies as alternative to foreign ones. Regarding the research conducted in universities, interviewee from one of the technology centres has mentioned that:

> There are some competences within the area of space research like astrophysics, semiconductors, sensors, orbital mechanics, etc. However, these competences are, in most cases, scientific, far away from a final product.

Besides that, the interviewee from another technology centre has mentioned the difficulty in establishing partnerships with companies:

> It is difficult for companies to accept a new technology, whether in product or process, even in cases where technology is used by similar companies internationally. We have been trying to transfer a technology for 20 years, but it has little acceptance from industry.

In this scenario, it was observed that the role of government in stimulating technology development is mainly by direct funding of basic research at universities and technology centres and funding of applied research at companies, but not oriented to stimulate partnerships among actors. The interviewee from one of the companies has mentioned that:

> These basic research projects are not necessarily what will be used in a satellite. It's a conception of an idea which it begins to be transformed into something. If at some point INPE thinks it can be used, they get involved.

However, there are some initiatives from technology centres to establish research partnerships with companies promoting a knowledge flow by joint research activities. As mentioned by the researcher from one of the technology centres:

> We look for companies to carry out projects in partnership. However, there are few cases of joint projects, mainly based on creation of a technology which already exists internationally but has high costs or market barriers kind of project.

He has also added that:

> In general, when a partnership happens, one of our researchers seeks, through 'a friend of a friend', companies which may have a particular need or may have interest in establishing a partnership. But the initiative tends to happen from our researchers.

The lack of funding for joint research projects ends up putting apart companies and universities. As mentioned by interviewees, there are projects being conducted in companies and also in universities, but the approach between institutions is still limited to a few initiatives from governmental research centres. In the end, a high tech sector which should have an intensive knowledge flow limits its interactions by differences in research perspectives and initiatives.

Final remarks

University-industry relations have the objective of improving technological development through innovative activities. National and sectoral systems of innovation may strength the integration between these two actors, easing the knowledge flow and consequential technological breakthroughs. In Brazil, partnerships on the space and horticulture sector have demonstrated similarities regarding the knowledge flow, but differences on the knowledge infrastructure and governmental investments (Table I).

Considering the knowledge flow between actors, it could be observed that relations were limited to some specific projects, which were mainly based on technical solutions. The gap between actors was explained by some interviewees as a consequence to the lack of alignment on projects and limited research activities from universities. On the horticulture sector, universities are only able to conduct research based on technical needs, as there are

	Horticulture sector	Space sector
Knowledge flow	Mainly based on technical solutions. Companies also look for partnerships with foreign institutions	Limited partnerships. In general, companies develop research independently from universities
Government investments	Mainly directed to governmental research centres	Funding for companies or universities, but not on joint activities
Sectoral particularities	Differences in investments for horticulture and field crop	Government prefers to keep technological developments for satellites stable instead of demanding upgrades
National limitations	Universities and local companies have limited technological capacities, while multinationals dominate innovations on this sector	Technological embargoes are the main difficulty companies and universities face on R&D activities

Table I. Comparison of space and horticulture sectors

limited funds for fundamental or joint research. As described by Filippetti and Archibugi (2011), the financial sector is important to foster innovative activities, while Etzkowitz *et al.* (2005) mentions the importance of joint projects funded by the government to narrow the gap between companies and universities. Horticulture companies have also described an effort to establish relations with Embrapa (the governmental research centre), the main research centre in this field. However, due to administrative issues or knowledge limitations, these kinds of partnerships were not established. As a consequence, companies interviewed described partnerships with foreign research centres as a solution to develop the technological level of their products and processes. This demonstrates that local knowledge institutions are not prepared to attend to companies' demands, limiting their innovative activities. As mentioned by Lundvall (2007), innovation does not depend only on companies' efforts, but also on a favourable science and technology environment.

On the space sector, it could be observed that university-industry relations are also rare. Interviewees mentioned that they prefer to conduct research without academic involvement, as objectives are different. Companies and universities have developed internal assets to conduct high-tech research, but their activities are conducted separately. Few exceptions in partnerships among public technologic centres and companies were observed. Here, it is visible that there is an effort from government to develop the technological level of the sector, overcoming difficulties given by international embargoes. But the sector still lacks a stronger alignment between companies and universities activities, which could be fostered by public funds focusing on joint research or meetings and commissions which could stimulate informal contacts.

Analysing both sectors, it could be observed that in general the knowledge transfer between companies and universities were similar, mostly based on technical solutions. As mentioned by Bekkers and Freitas (2008), different industrial sectors may use the same channels of knowledge transfer according to the type of knowledge and environmental characteristics, among others. Interviewees from both sectors have described that relations between companies and universities are limited, as academic research is misaligned from industry needs. Adding to this, reduced governmental investments, especially those which demand joint activities, end up sustaining the gap between actors (as mentioned by Etzkowitz *et al.*, 2005).

This is a common issue from emergent countries which have developed their industrial and knowledge structure separately. However, it still can be improved by governmental funds for joint research and a proper alignment of activities between academia and industry. A governmental effort to develop a proper sectoral and national system of innovation could be observed. Regulatory laws like intellectual property rights, tax reduction for companies that innovate and the establishment of technology transfer offices in universities are recent (most of them were signed less than 10 years ago), demanding some time to be efficiently used by companies and universities. As mentioned by Tidd and Bessant (2011), investments in specific sectors are defined according to a national strategy for science and technology development.

Regarding research limitations, governmental effort to stimulate science and technology development on particular sectors may explain the limitations on the horticulture sector. According to interviewees, research funds and investments are mainly focused on field crops. Adding to this, the main agricultural exports are soya, sugarcane and coffee, which are areas that have received more research investments and consequently have improved relations between companies and universities. Considering the differences between agricultural sectors, further research may be conducted on field crops like soya and sugarcane to observe how companies and universities are establishing partnerships, and how is technology development being conducted.

In conclusion, it could be observed that the national and sectoral system of innovation still needs investments, alignment of activities and a proper knowledge flow which may stimulate innovative activities. Even though companies from both sectors face difficulties to establish technology development partnerships with local universities, in the horticulture sector, they go abroad to look for technologies, while in the space sector companies are developing their competences internally to attend to governmental demands. In the end, lower investments in basic and joint research are considered as the main reasons for difficulties in developing sectoral competences. As mentioned by one of the interviewees:

> Why are these areas more developed in Europe? Because horticulture research is funded by the government. In Brazil this does not happens […]. Even in Europe, countries that stand out are those which have invested in research. The group that has not invested in technology is lagging behind.

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