

## Technology and Innovation on Input Sectors of Brazilian Meat Production

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### Abstract

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This paper is an overview of the technological characteristics of meat input sectors. It focuses mainly on the genetic development, animal feed, and animal health. It points out some market economic aspects and technological characteristics in order to demonstrate that: a) these sectors are becoming progressively “science-based sectors” (*à la Pavitt*); and, b) these sectors are more and more ancillary and dependent on more complex and transversal R&D and I, which are generated in the developed countries. This paper points out that, in general, Brazilian R&D and I actors not only have marginal influence in the innovation process of these sectors, but also little force to create autonomous technological “windows of opportunity”. In the long-run, these characteristics also may hamper the cumulative technological learning process and thus not ensure Brazilian competitiveness in the international meat markets.

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**Keywords:** technological innovation, competitiveness, agribusiness, meat industry

**JEL:** Q13; Q16

### 1. Introduction

The literature has been demonstrating that, in the long-run, one of the most important factors of competitiveness of production activities (being analyzed by this analytical approach to supply chains, sectors or industries) is unmistakably related to the persistent and systemic creation of knowledge and its application on the production process in the shape of technological assets.

It is worth saying that the construction of long-term competitiveness is indelibly connected to the ways of generating and disseminating in the social economic fabric and result appropriation from the process called *technological capacitation*, which occurs through the interactive accumulation of technological knowledge and learning by firms, organizations and institutions throughout time (LUNDVALL & ARCHUBUGI, 2002; COSTA, 2003). Creating proper conditions for the development of learning and capacitating processes is a basic pre-condition to the overcome of innovative hiatus and to the construction of dynamic competitiveness of firms and sectors. Competitiveness is then the result of trajetories that are cumulative and built from the interactions and exchanges of different sorts of knowledge.

Through the firm's view, the concept of learning is associated to a permanent process of (re) construction of competences that expresses the bases of knowledge in which companies can access markets.

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Thus, the firm's technological learning and capacitation articulates to different sources of information that can be either internal or external. Internally, the sources are related to specific activities such as production, R&D and marketing; externally, the sources involve articulations with providers, consumers and scientific and technological infrastructure (MALERBA, 1992).

In the case of peripheral economies, the role of multinational companies in the generation of sectorial and technological fluxes and/or in the economy as a whole, can be highlighted according to the logic of learning and capacitation (ARCHIBUGI & IAMMARINO, 2002; LUNDEVALL, 2000; TEECE, 2000). Depending on the function and type of presence of foreign multinationals, development or inhibition can arise upon the production of local knowledge. About this theme, many studies have highlighted that the transfer of technology via production activities from multinationals may not significantly expand the learning and technological capacitation system of peripheral economies. In a variety of cases, multinationals even limit such systems because of the centralization of the nobler technological functions of the companies held in central countries<sup>4</sup>. The learning process will be expanded when activities of greater value, more technological complexity and stronger relations to the local economy occur; the relations are more effective in order to deepen and strengthen the technological capacities of the peripheral country.

The Brazilian agroindustry has been considered one of the most competitive internationally. Other than a (*agro*) sectorial production system that has generated and sustained comparative advantages in the agricultural and processing bases, many studies indicate the positive relation between the agricultural strength with the ever growing incorporation of more complex and transversal technologies in its processing production – not only related strictly to economical aspects, but also in the greater quality of products – (GASQUES *et alii.*, 2010). However, most studies focus on the effects of a univocal relation between 'physical technology' – that is, new technologies incorporated in products and processes (NELSON, 2008) – and its results in terms of productivity and/or *latosensue* economical efficiency. Although that is a valid methodological resource, we understand that it is also paramount to recognize other elements and systemic and institutional circumstances upon the research generation, technological growth and upon the innovation process of agricultural sectors. In the present work, for instance, the identification of the main involved actors (such as companies and private and public institutions), generation and appropriation tools of innovation and in what ways technological transferences and the learning process shape themselves according to different components of production processes. Thus it is possible to detect, with better analytical acuity, some conditions that act upon the process of the technological capacitation of the agricultural sector and, therefore, its competitive potential (or limitations) in the long term.

From this background, the aim of the present work is to analyze the configuration and the main technological and economical elements of one of the most dynamic segments of national agriculture: meat production (beef, pork and chicken). Given the small space of an article, we more specifically aim to focus on elements and trends related to: a) the relative importance of companies and national public institutions in the generation of knowledge and local learning (and/or sectorial); and b) the potential and/or restrictions of the Brazilian reality in order to sustainably construct dynamic and cumulative competitive advantages – especially those advantages based on the use and construction of technological assets<sup>5</sup>.

The analysis herein developed is based upon results of empirical researches about the dynamic and technological competition of meat sector and covers the conditions of Brazilian companies to enter into the creation of R&D and sectorial I.

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<sup>4</sup> Because of their more advanced stages in the process of technological accumulation in a world-wide plan, foreign multinationals subsidiaries have "economies of learning" relatively bigger in comparison to domestic companies (LUNDEVALL, 2000)

<sup>5</sup> The production segments of poultry farming, industrial pig farming and livestock will be analytically prioritized.

The first source of results is from the Private Research Directory (DPP), which made the systematization of information and economical characteristics herein covered possible, either through bibliographical material or structured interviews with many important actors from the P&D and I<sup>6</sup>. The second source is the academic studies of Murakami (2010), Martinelli (2009) and Rohenkohl (2006) that deepened and covered the information and results from the first source.

The article is structured as follows: after this introduction, the notion of competitiveness is discussed and, more specifically, its relation to different perspectives in economical efficiency. Next, the main characteristics of dynamic innovation in the input sectors of meat production are presented, highlighting the genetic, health and nutrition animal input; it aims to emphasize characteristics of the innovation process and the importance related to companies and national public institutions in the creation of knowledge and local learning (and/or sectorial) and thus evidencing the conditions to construct local capacitation and learning – as well as of the construction of dynamic and cumulative competitive advantages of this activity in the long term. In the end, the final considerations will be presented.

## 2. Economical Competitiveness and Efficiency

A variety of authors dedicated to the Industrial Organization point out the heterogeneity of concepts linked to competitiveness. The differences result from theoretical bases, percepts of industrial dynamic and several ideologies thus, the assessment of firms, industries, countries – depending on analytical plan of investigation – and the proposal of formulated policies (HAGUENAUER, 1989; KUPFER, 1991; SIGGEL, 2006).

The simplest notion of competitiveness is related to the performance of exportation; that is, companies that are competitive expand their participation to the worldwide offer of specific products.

Such framework is wide and covers, besides the conditions of production, other factors that inhibit or promote exportation to specific countries, such as commercial policies, the exchange rate, efficiency of commercialization and financial channels, international deals and firm strategies - this is the definition of competitiveness as performance (HAGUENAUER, 1989). Following this perspective, there is no individualization of the effect of each factor but, instead, of the result as a whole. Such measures occur *ex-post*; that is, if there was relative growth in exportation, it could be concluded that there was competitiveness. Preliminarily, it can be inferred that the Brazilian meat sector is competitive, considering growth in exportation.

A second notion considers competitiveness as a structural characteristic, which is able to demonstrate the capacity of a country or of a sector and its firms and offer specific goods at a level that is comparable to that of other economies. Achieving the same level or a higher level of efficiency signifies potential grow in exportation. Such a notion characterizes the concept of competitiveness as efficiency (HAGUENAUER, 1989). It is a definition of competitiveness *ex-ante*, generally restricted to production conditions, which, depending on contextual factors, may not represent better relative performance.

The development of discussions about competitiveness implies a connection to another concept - economical efficiency. In an orthodox approach, given a certain endowment of resources, a country's sector has some comparative advantages. Competitiveness will be reached once it is the right production efficiency or, in other words, the usage of resources, which allow it to take such advantages.

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<sup>6</sup> The research Directory of Private Research (DPP) was financed by the Financer of Studies and Projects (FINEP), and did an ample study about dozens of Brazilian productive sectors, thereby dedicating special attention to aspects related to R&D and Sector I.

Given a certain endowment of resources and production functions of a competitive economy, production efficiency is established at the partial equilibrium point and consists of obtaining a certain level of products at minimum cost. Allocative efficiency, on the other hand, is positioned at the equilibrium point and implies production efficiency in all markets, along with maximum social wellness.

Siguel (2006) highlights the static nature of comparative advantage principles<sup>7</sup>, which limits the ability to explain as well as foresee commercial patterns.

As long as the comparative advantages change throughout time, one must understand the changes of comparative advantages to comprehend commerce patterns.

The comparative advantage contemporary perspective considers the construction of temporary advantages based on technological leadership, accumulated experience and economies of scale (KRUGMAN, 1986, Apud HAGUENAUER, 1989, p. 6).

Siguel's suggestion (2006, p. 145) to use the market share as a dynamic indicator of competitiveness is yet insufficient. It simply grasps alterations in time, in an *ex-post* way, for it is a performance indicator and does not allow the incorporation of competitiveness or uncertainty as theoretical elements or as moderation factors to assess the decisions of companies or the formulation of policies. As Kupfer points out (1991, p.1), the selection of competitive strategies and decision-making processes of companies are not trivial because the information that forms them cannot be wholly obtained through market signs.

Before discussing which notion of efficiency is relevant in a competitive context (or one of comparative advantages), it is paramount to highlight two subsidiary aspects.

Firstly, sectorial interdependency is a current industrial characteristic that makes consistent performance indispensable for the efficient operation of any activity; primarily of those co-participating sectors from the same industrial complex, that is, of those providers and their clients and, complementarily, of the whole industrial fabric – understood as the economic infrastructure and provider of specialized services. The absence or the inefficacy of certain segments could compromise the competitiveness (HAGUENAUER, 1989, p.15). In the meat sector, the discussion of efficiency extrapolates that of the distribution and processing of meats. It covers primary base inputs, characterized as specialized providers, and follows the evolution of consumption patterns.

Secondly, there are sectorial specifications in the analysis of competitiveness. On one hand, there are intensive sectors in technology, whose products and processes suffer continuous modifications and in which the aspects linked to the quality of goods have a major role.

On the other hand, there are mature sectors with widespread technology, standardized goods and important aspects linked to price and cost. However, nowadays, there are sectors, which used to be considered mature, that present asymmetric waves of technology due to the diffusion of new techniques, thereby making the indicators of technological performance as relevant as those of price and cost (HAGUENAUER, 1989, p. 16 e 18).

To Kupfer (1991, p. 4), the decision-making processes of companies that require more or less competitiveness from the firm and from the industry occur within time, based on expectations about the future conditions of competitiveness. A theoretical formulation of competitiveness is necessary, but it must be different from the aforementioned that take into account dynamic competitiveness in uncertain environments. Author (1991, p. 10 e 14) suggests the *standard of competitiveness* concept, which is defined as a particular vector from a set of ways to compete for domination in a competitive space – market or industry, region or nation. The universe of ways of competitiveness would cover price, quality, different products, sales efforts, amongst others. Competitiveness, thus, would be the adequacy of strategies from companies, according to the standard of competition present in the market.

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<sup>7</sup> Limitations of comparative advantages are, according to the author (p. 154), extendable to competitiveness.

There is no certainty of the link between strategy and the standard of competition, considering that the actions of certain firms alter the standard of competition and that this is a non-determining interactive environment. The introduction of innovations constantly agitates the industrial structure and standard of competition.

Although Kupfer's proposition is shaped on the microeconomic plan (firms and industries), one of the interpretations of macroeconomic competitiveness reviewed by Siggel (2006, p. 141) goes accordingly to the aforementioned. Macroeconomic competition may be seen as an aggregation of the microeconomic concept; that is, a national economy is competitive if it has several firms and industries that are internationally competitive. Accepting the standard of competition forged in an open and global economy, the concept of competitiveness, regarding the standard of competitiveness, is in principle, compatible with both analytical levels.

While evolutionary approaches suggest that the notion of competitiveness should be reviewed, it is also considered efficiency.

Allocative efficiency, arising from the distribution of resources according to technological capacities and prices related to a specific time period, may have negative effects due to innovative potential, namely innovative efficiency. The standards of international specializations defined according to allocative efficiency are determined, for each country, by the relative size of discrepancies or by the specific advances in a sector. When technological discrepancies are elevated, allocative efficiency will be in conflict with innovative efficiency (CIMOLI *et al.*, p. 73-74). Thus, when discrepancies are verified in the technological capacities of strategic input sectors, as is the case of the Brazilian meat sector, the current production and allocative efficiency do not imply innovative efficiency.

Discussing the normative implications of concentration acts, Possas (2004, p. 87-88) points out the difficulty in establishing gains or losses of economical efficiency when changes are expected related to goods, which do not imply a difference in costs. The market delimitation can be altered along with the alteration of the performance of goods. The unpredictability (uncertainty) of this aspect is as big as the potential of technological innovations of the segment at stake.

According to Possas (2004), the main limitation of the allocative efficiency concept is theoretical, as it is connected to the general theory of competitiveness. Such theorization is incompatible with the evolution-like innovative processes, which empirically defy the canons of partial and total equilibrium. Consistent normative alternatives to dynamic economical contexts should be based on alternative theories, as the Neo-Schumpeterian, which is tailored to account for competition with innovation.

When adopting an evolutionary Neo-Schumpeterian perspective of competition, the market can be seen as an environment of innovation selection. The concept of economical efficiency from this theoretical framework must be guided through the presupposition that the market has, as the primary function, the *latosensu* innovation selection (products, processes, routines, strategies). Hence, the normative criterion to assess markets –economical efficiency – must focus on the selective performance of markets; that is, the extent to which markets filter, spread and eliminate new products, processes and strategies. The assessment of economical efficiency (the normative plan) is inaccurate and strongly qualitative (POSSAS, 2004, p.90-91). In a less developed theoretical area, Possas defines selective efficiency as:

“ a hierarchal capacity of the selection process, which reflects the degree in which the filtering of innovations by the market relates to its order, as objective as possible, in terms of progress indicators throughout the innovative trajectory” (POSSAS, 2004, p. 91).

The identification of sectorial technology trajectories is fundamental, as they establish specific variables of that sector for the historic moment whose tradeoffs are characterized as coherent lines of progress with the technological paradigm. The balance of approximation between the relevant variables of the trajectory, such as the gains of physical resistance and the speed of animal growth, establishes the efficiency assessment guides of the selected innovations. That being said, the efficiency of a market can be qualitatively established, such as in the national market of animal genetics; that is, until what point it has promoted the fomentation and diffusion of competitive technology as the landmark of dominant technology.

In the terms discussed in this section, it is impossible to precisely establish *ex-ante* competitiveness. It is possible to identify the current strengths and fragilities, as well as the agents' expectations and, mainly, the variables that characterize the trajectories of important industrial segments. From that, it aims to put sectorial competitiveness against the requirements of the selective environment.

### 3. Input Sectors and the Innovation of the Base of Meat Production

The technological dynamic in meat segments has been presenting three wider characteristics: the first is the *quasi*absence of a successful diffusion of radically new final products, as the standard of food consumption is stable because of the strong intrinsic attributes of the products (such as taste and appearance), thus showing that the innovation in products in such sectors is very incremental. The second characteristic is that there is a progressive connection between the innovation of animal farming input sectors – which we will name the primary base. Hence, innovations in the primary base, seeking greater qualitative differentiation of the primary product (animal), are connected to a greater differentiation and valorization and/or aggregation to the value of the final processed product.

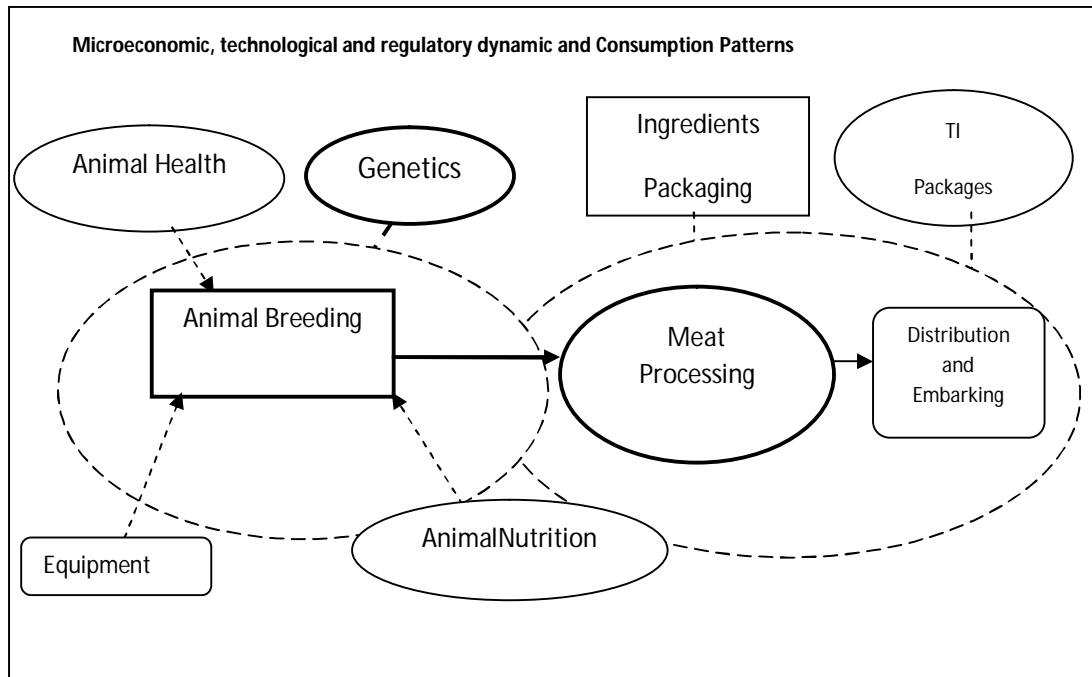
The third characteristic is the ever-growing role of regulatory institutions in the innovation environment, as the regulations on final consumption, as the regulations that affect other dimensions of the production chain, such as the usage of inputs and ingredients.<sup>8</sup>

To expositive ends, one can summarily represent the sectorial system innovation inductors of meat, according to Picture 1. The picture shows the main elements and technological fluxes of this system. The present paper analyzes only the most important characteristics and trends of the primary base innovation – focusing on segments of genetics, of animal health and of feeding/animal food - seeking briefly to place the Brazilian capacitation in each segment. The industrial base, although relevant, requires a complementary effort of investigation.

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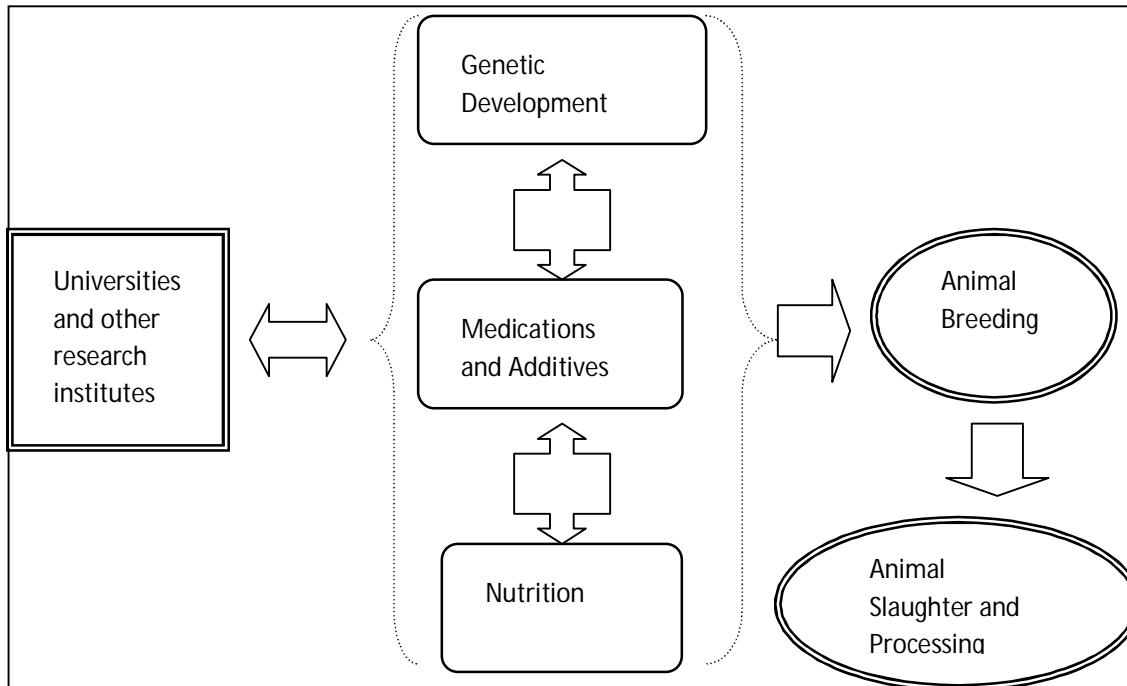
<sup>8</sup> For instance, the production and commercialization of veterinarian medications and of nutrition for animals is authorized and supervised by SDA (Department of Agricultural Defense of the Agricultural and Supply Ministry); or, in the case of veterinarian medications, the Patent Law applies; or, in the case of the defensive animals, it is mandatory to register in the Animal Defense Department.

**Picture 1 – Main technological fluxes in Meat Sectors**



Source: self-created

The innovations that occur in the primary base are the most important in the meat sector, as such innovations more directly affect economical aspects (e.g. the baselines of cost and production), as well as the commercial aspects of processing companies (e.g. affecting the range of product differentiation). The main sources of innovation come from segments of genetics, animal health (veterinarian) and animal nutrition. However, these segments are not isolated in the dynamic of innovative processes because there are constantly interactions of knowledge, information and product fluxes amongst the agents of such segments, thereby raising technological synergies and overflows. The relation between these segments and the most important fluxes of goods and services – which mutually feed on (although with distinctive importance) the sectorial dynamic of technological innovation – are represented in Picture 2. Grasping all the relations and flux characteristics is a complex task, as they are very specific to each technological trajectory and to each type of animal (or even to each type of genetic line of animals). Knowledge implies the sharing of heuristics of problem solving and of cognitive preexisting categories and allows the information that is traded between input firms (amongst them and research institutes) to be interpreted and used in the creation of applied knowledge. The developed solutions are embodied as inputs of animal production- genetic line, semen, embryos, vitamins, whole-grain animal feed, vaccines and medications – that contribute to the rising of productivity and qualitative increments in the meat sector.

**Picture 2 - Innovation System in the Meat Sector Primary Base**

↔ Heuristics of research and problem-solving

↕ Inputs and information amongst providers

→ Inputs and products on meat chains

Source: self-created

### 3.1 Animal Genetic Technology

The innovation in genetics is fundamental in the innovative system of the primary base of meat. In the last few years, this issue has presented important changes in the characteristics of technological dynamics through the most complex usage of biotechnology, as well as through a greater incorporation of information technology. It is characterized as a segment based on science whose sophistication of technological effort is denoted through the naming of genetic developments (replacing the traditional expression, genetic improvement).

Genetic development is an effort made only by specialized firms in animal genetics, involving R&D, to obtain new genetic hybrids and more productive genetic lines and/or that generate qualitative differences in animals. This activity aims to offer new genetic lines and influence the rate of animal growth, quantity and quality of animal carcasses and the resistance attributes and reproducibility of animals. For the development and multiplication of animals of high genetic value, it is necessary to use inputs from other input groups (animal nutrition and health).

Genetic development is an important technological base because it influences the animal capacity to appropriate positive environment characteristics, especially nutrition and hygiene and allows for the incrementation of socially and economically relevant factors. Amongst the factors of social importance, there are animal wellness and the impact of farming upon the environment<sup>9</sup>.

<sup>9</sup> The term "not directly" implies the awareness that the social factors can have economical impacts. For instance, the preoccupation with the environment at any moment influences farming costs through the implementation of waste control systems. However, this happens because there is a former social preoccupation with pollution and its effect on the environment.



Economical factors refer to items that directly affect the cost of farming – feeding conversion and the prolificacy of animals – and others that affect the carcass and meat quality, hence having repercussions in the value regarding processing and commercialization.

The role of genetics is essential to attend the necessities of the industry and contributes to the obtainment of different meat qualities. The increase of possibilities concerning the different qualities of meat, through technological innovations in genetic development, implies the increase in the differentiation of meat products and its by-products<sup>10</sup>. It is worth saying that genetics allow for the emergence of new variants of products, including the *in natura* meat, with different prices, altering the profit per product and/or firms' market participation in regard to the processing of final products.

Picture number 2 shows that the genetic development segment is the receptor of input fluxes and of the innovation segments of health and nutrition. This last segment is the receptor of inputs and innovation in the health animal sector.

In the pattern of genetic innovation, the role of the R&D laboratories of multinational corporations is predominant in developing and centralizing important activities of the innovative process. Partnerships with universities are also fundamental in this phase, as access to the advancement in knowledge in fundamental scientific areas of biotechnology, as well as the development of specific software to analyze data related to animals, concerning: a) the prediction of performances by their offspring (quantitative genetics); b) correlation analysis amongst genes and characteristics of low animal heritability, combining the usage of molecular genetics with quantitative genetic software. In this well sophisticated stage, the appropriation of knowledge is related to the obtainment of identification patent methods of genes or genetic segments linked to the heritage transmission of a characteristic<sup>11</sup> and software copyright.

In the development stage of genetic lines, the action of the multinational matrix is also predominant, although exceptions may occur. The competition amongst genetic companies occurs through the differentiation capacity of the product and its different and intrinsic tradeoffs (cost, reproductive performance, feed conversion, physical resistance).

In turn, branches make adaptations according to local conditions and test the performance of new imported lines, in partnership with the laboratories of universities and local research institutes. This is only an incremental improvement (or genetic improvement) of the product. In this less sophisticated phase of innovative effort, the development of the product and process are intertwined. Breeding between different genetic lines - an alteration in the process implies the differentiation of the product (the animal). To retain the possession of animals is a way to protect the innovative process, as well as the appropriation of economic profits derived from innovation (ROHENKOHL, 2006).

The animal genetic market is even more concentrated commercially because of the intense process of merging and the acquisition that occurred recently in the international scope.

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<sup>10</sup> Sadia developed a genetic line specific for the production of Parma ham. With such innovation, the classification of ham being in the refrigerator is dispensable. It is known beforehand about the ham quality, which has quantities of interspersed and lard fatness that are necessary for the prolonged growth of Parma, genetically determined. There are granges specialized in farming animals of such line, with different cost per kilo of the live pig, once these animals present a bad feed conversion and are slaughtered with higher weight than the conventional ones. The innovative technique unleashed organization changes in farming and slaughtering.

<sup>11</sup> Although required, the patent sometimes does not guarantee knowledge appropriation. The usage of brands associated with genetic lines and the rate of innovation (exploring new attributes in animals and lineages) are complementary strategies to obtain and renew extraordinary profits and to create barriers to the entry. For more details, go to Rohenkohl&Martinelli (2009), p. 415-416.

This market is ruled by few companies, notably held in the USA and Europe, which act globally through branches and subsidiaries (Table 1).

**Table 1: Main Companies of Animal Genetics**

Group	Country	Company	Genetics
Tyson	USA	Cobb Vantress	Chicken
Erich Wesjohann	Germany	Aviagen	Chicken
Grimaud	France	Hubbard	Chicken
Genus Plc	United Kingdom	PIC	Pork
Hendrix Genetics	Netherlands	Hypor	Pork
PigtureGroupe	Netherlands	Topigs	Pork
Danish Meat Coop	Denmark	Danbred	Pork
Grimaud	France	Choice Genetics	Pork
JSR	United Kingdom	JSR	Pork
Genus Plc	United Kingdom	ABS	Bovine
Koepon Hold.	Netherlands	Alta Genetics	Bovine
Semex Alliance	Canada	Semex	Bovine
CRV	Netherlands	CRV	Bovine

Source: self-created

The high-end innovation in genetics, although it is central to the competitiveness of agents in a longer term, does not impose as a survival factor of the companies in a short term, once the consumption pattern of meat and its by-products is relatively stable. There is space to who is a step behind from adopting new techniques, that is, to use only the quantitative genetics (software) to guide the genetic development. But in the long term, companies that do not combine quantitative and molecular genetics tend to lose accuracy in the development of the product, compromising the relative performance of their animals the participation in the market.

#### Poultry Genetics

In poultry genetics, the great technological step occurred with the hybrid application, a process that allowed genetic companies to protect their assets<sup>12</sup>. The development of this technique allowed that, even with the most sophisticated genetic tools, it is not possible to fully identify the pure lineages that originated hybrid animals. These two issues have an important implication from the economical point of view: the usage of hybridization generates a “biology blockage” that prevents other agents – that do not have tacit knowledge related to the results of several breeds – from breeding other animals from available animals (GURA, 2007).

In the 60s, the genetic improvement was utilized for weight gain. Afterwards, the development of animal feed associated with genetic improvement enabled greater performance gains and researchers in the nutrition area started to accompany the genetic evolution. Moreover, new demand came, thereby expanding the selection criteria in order to attend the new market needs, such as a) reproduction (production of chicks); b) production (performance of live chicken); c) carcass efficiency (carcass and noble livestock efficiencies); and meat quality (fatness content, pH); d) animal robustness.

The development of poultry genetics is a sequence of several stages (Picture 3). It is initiated with the production of great grandparents (or pure lineages), poultry bred from pure breeds. This activity is done by multinational companies in the area of genetic development (big companies that commercialize pedigrees) in their R&D laboratories that are in their respective countries and/or developing countries. The production of great grandparents originates grandparents that finally breed poultry.

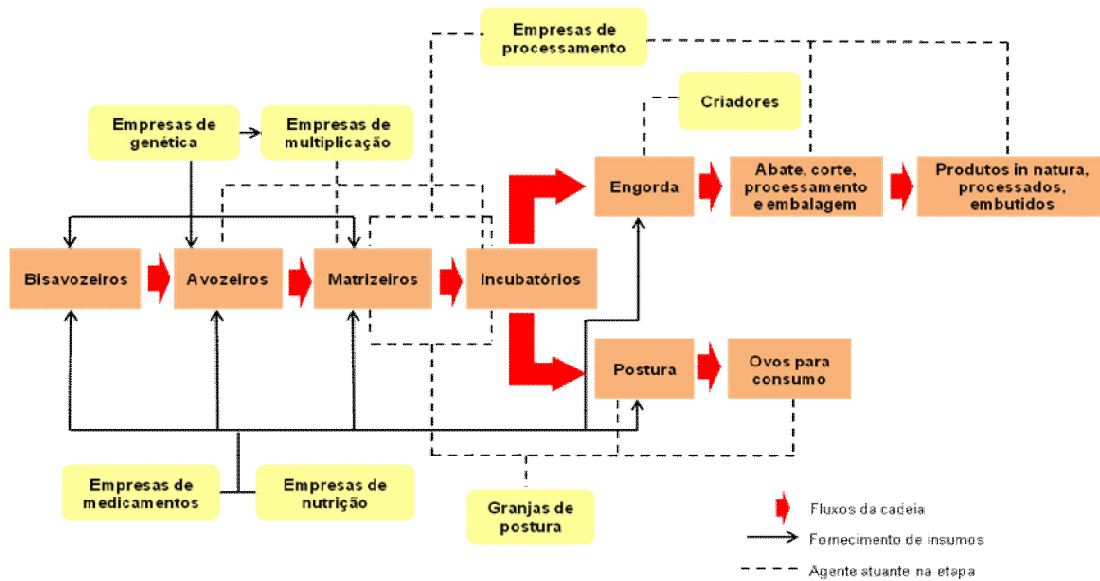
<sup>12</sup> The first hybrid chicken was bred by Henry A. Wallace, founder of Pioneer Hi-bred Co., in 1942. He had already applied the technique in the creating of hybrid corn. The process in itself does not have a proprietary feature, but the results of its application do. If a male and a female, both hybrids, copulate, the following generation will not present the strength of its parents.

These two final stages (grandparents poultries and poultries) are produced the company branches of genetic development located in Brazil or by national multiplier companies. These last companies provide services to genetic development companies in the sense of sheltering grandparent poultry and poultry (and in some cases, grand grandparent poultry), in their facilities. They also multiply the reproduction of these poultries to be distributed to processing companies, integrated breeding facilities and granges.

Processing companies and granges acquire the poultries in fertile egg phase and/or chicks in order to breed and produce poultry (in the case of cut segment) and laying hen (in the case of the reproduction/breeding segment). There is the option of acquiring these animals from providers in the fertile egg phase and chucks (incubatory stage) and then breed (fattening stage or breeding stage). In the cut segment, chicks are distributed to integrated breeding facilities to processing companies (RIZZI, 1993; ALVES, 2003; SANTINI *et alii.*, 2004).

Poultry is thus the most important result of the technological package developed by the aviculture genetic sector and functions as the “machine”, with all its components in order to produce the final product: the chick. The chick is then transformed by the aviculturist (fattening stage) into the chicken that the processing industry will slaughter. As Picutre 3 shows, the aviculture sequence -> poultry breeding -> commercial breeder can be constituted by one or several companies and such sequence is differentiated regarding egg or chicken production. To the production of poultry, as make as the female are used and to the use of eggs, only the females are considered. The time period of poultry breeding lasts, approximately, 11 months and the fattening stage, 41 days (JESUS jr., 2007).

**Picture 3: Development Stages of Aviculture Genetics**



Source: Murakami (2010)

The international market of aviculture genetics has been through an intense process of concentration, becoming strongly oligopolistic and run by few multinational companies. The aviculture genetic segment is dominated by three major companies: Cobb-Vantress, run by Tyson Foods, Aviagen, from the German group Erich Wesjohann and Hubbard, controlled by the French group Grimaud. In breeding aviculture, only two companies run the market: Aviagen and Hendrix Genetics. This market is difficult to entry because of the accumulation of scientific and technological knowledge held by such companies – specially the genetic data patrimony – as well as the great investment required to maintain R&D activities.

Brazil is not technologically able to produce a great amount of genetic material in order to have an industrial aviculture. The market is run the international groups that import pure poultry (genetically improved) and put obstacle to the identification of pure breed genes for it is necessary to identify prior generation of great grandparents (SOUZA ALVES, 2003). Until recently, Brazil only imported great grandparent poultries; that is, chicken with a major genetic potential. The importation of great grandparents allows a more qualified participation of branch in concern of great grandparents and final poultry improvements. There is no evidence that such qualification results in competition with the matrix. Still today, pure genetic material is imported by Brazil. However, some companies have already, directly or through partnerships, developed genetic material originated from pure lineages, as it is de case of the Brazilian company Agroceres, incorporated by Aviagen (Aviagen Brasil), or the breeding of grand grandparents, as it is the case of Cobb-Vantress with its own grange and in partnership with big integrating companies. Moreover, it slowly began the exportation of grandparents, improved poultry and incubated eggs in Latin America, Middle East, Africa and Asia.

In concern of public capacitation, the main institution is Poultry and Pig Embrapa that has developed a genetic improvement program upon the acquisition of geoplasma database from the extinct Granjas Guanabara, using two fatherly lineages and two motherly linages of poultry. The commercial result is small and the offer is only to attend the demands of small and medium producers. In a complementary way, since 1999, Embrapa's capacitation has also occurred through research programs on genomics, especially in genetic marketers to the identification of quantitative attributes and animal resistance.

#### Swine Genetics

In the swine genetic segment, there is a clear work division and a hierarchy in the R&D activities, consolidated in the 80s. In the genetic development, it can be highlighted the R&D specialized firms that obtain productive new genetic lines and/or qualitative differences in carcass and meat of its descendants. One can highlight herein the main multinational genetic companies, such as PIC, JSR, NPD, Dalland, Choice Genetics, Dan Bred, amongst others.

Concomitantly, there is the effort of genetic improvement through the adaptation of high-end genetic lines to the necessities or specific perceptions of a slaughter market system and independent breeders, which imply the copulation of "pure" genetic lines in order to obtain a first bred "mongrel". The improvement is only by the increment of the already developed lineages and can be done by genetic forms, by integration/slaughtering companies or by independent producers. The improved characteristic is not fixed (hybridization), its transmission to the next generation is not guaranteed and the animal from genetic improvement are hardly resold in the "pure genetic market"

Such process results in a genetic material multiplication. Animals and its relatives – held in several granges – are multiplied. Data of productive performance collect in the granges, stored and analyzed with specific software, serve to the genetic development firms to do inferences upon the performance of new generations, guiding the selections and breeding amongst animals. To the collection of information about the meat and fatness in carcasses, some companies use the computerized tomography. The set of these practices constitute the genetic improvement, based on the usage of "quantitative genetics". Three main tasks of international branches of big genetic companies, in this stage, must be highlighted and they seek to animal adequacy to the conditions of local climate. This occurs through tests of new lineage performances, imported as "great grandparent animals". In general, such tests are done in partnership with universities and local research institutes.

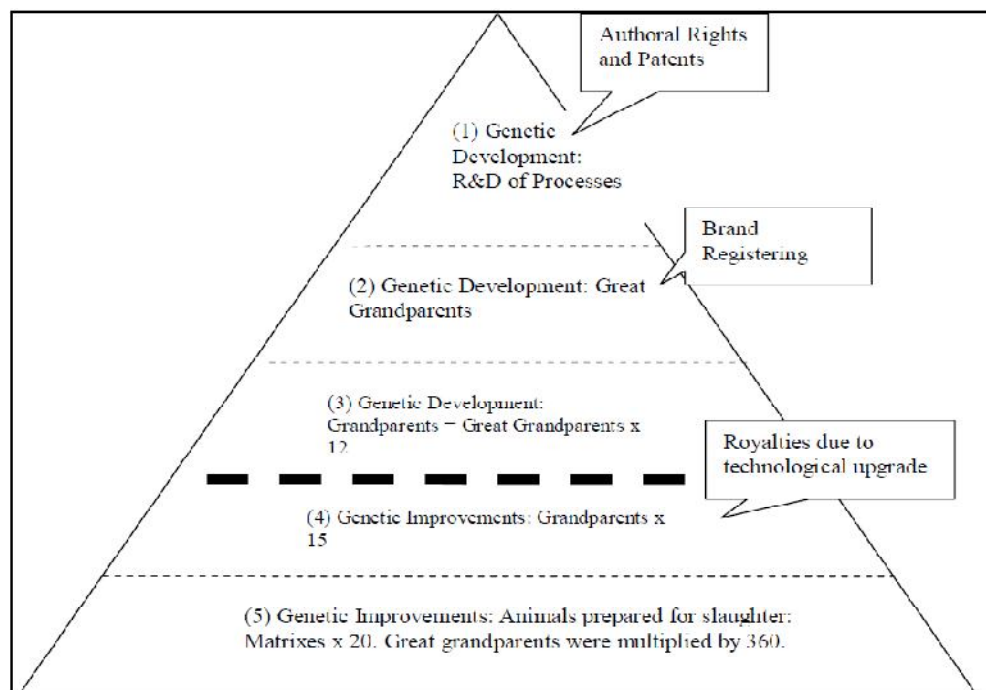
The technological development is combined with new ways of commercialization and interactions amongst agents of the productive chain.

Genetic firms can give grandparents to producers that want specific lineages, charging a selection tax (royalty) to each animal covering.

As the genetic firms' pure lineages have, besides the genetic value, registered brands, it is also about the identified genetic license by the brand. To each productive increment of the lineage defined by the brand, the grandparent is traded by another from the current version. This results, benefiting the genetic firm, in a loyalty from the breeder and the multiplier, a continuous flux of the recipe and consolidation of property upon the intangible asset – the knowledge of genetics – of the fragile protection upon the industrial patent. To the swine producer and multiplier, it implies in a continuous transference of technology without the need to move resources in a capital asset (the grandparents)

Picture 4 shows the sequence and sums the main characteristics of the innovative process in swine genetics. It is evident that the gains obtained in the pure lineages have repercussions in the hybrid porker through the expansion of a scale that dilutes the R&D costs, providing economical sustainability to innovation.

**Picture 4: Innovation Phases in Swine Genetics**



Source: self-created

In Brazil, the beginning of genetic improvement occurred in the 60s with the importation of several breeds, replacing the native genetic material. Large White, Landrace, Duroc and Pietrain breeds were imported. However, national research effort did not accompany international development.

Concerning multinational genetic branches in Brazil, it can be said that generally they repeat the global strategy of genetic development of synthetic lineages, developed and concentrated in R&D laboratories of matrixes. Through the importation of great grandparents, there was an increase of producers and the matrix of grandparents that would sell to integration companies, as well as the making of complementary meat quality tests and animal performance in institutions connected to the local research. Therefore, the overflow of scientific nuclear knowledge of activities to genetic innovation does not occur in a systemic way - stages (1), (2) and (3) in Picture 4 – to local companies. The capacitation of local companies occurs more often in peripheral activities, that is, in techniques of genetic improvement (stages (4) and (5)).

However, some efforts have been made in regards of local agents in more complex technological activities (ROHENKOHL, 2006).

The following cases can be mentioned:

- Empraba-CNPISA that develops genetic material for small and medium producers;
- PIC Agroceres, the knowledge is obtained through joint-venture with the Genus group. Some lineages are completely developed in Brazil with the usage of genetic markers. In these cases, the genetic material developed in the country is exported to England. Amongst others, the genetic material is imported from PIC to technological usage. Therefore, there is information and genetic material exchange amongst several units, seeking the rationalization of costs and better results;
- Sadia<sup>13</sup> has a genetic program that aims independency and diversity in terms of genetic material and quality of raw material used in their products. As a food company and developer of swine genetics, it aimed to obtain knowledge, guarantee "traceability" of production since the swine genetics, and have a specific genetic package to their productions.

### Bovine Genetics

The genetic improvement in bovines is based on several biotechnological techniques that aim the upgrading of the animal to reproductive ends and improvements on meat and milk. The first technique, and also the most used, is artificial insemination (AI), the second is the embryo transference. The third one is embryo sexage with *in vitro* fertilization and animal cloning. The last one is the production of transgenic animals (SIMÃO, 2008).

The AI is the oldest technique in Brazilian agriculture. In 1964, it began the National Plan for Artificial Insemination and in 1968, the Agriculture Ministry created the Department of Physiopathology of Reproduction and Artificial Insemination (DFRIA) and was responsible to guide and supervise the methods used, more than just fomenting its use in all States. In 1974, the first Brazilian Artificial Insemination Association (ASBIA) with the primary objective of fomenting and spreading such practice in bovine producers. In the 60s, the first great official impulse of Brazilian production with the creation of the National Program of Livestock Development was registered, when the country developed its refrigerator cycle (frigorífico) and started to invest in production technologies for the improvement of hygiene of slaughter facilities. Ten years later, classic research of applied quantitative genetics began, implemented by universities, research institutes and breeders' associations, for the improvement of livestock. These programs had the objective of producing animals with high commercial features; that is, with fast growth, premature reproduction and high quality meat.

The Brazilian capacitation is based exclusively on AI. There are two basic types of AI: the first is of those activities which use more advanced technologies and specialized breeders regarding the selection of high breed animals and creation of matrixes of high economical value because of their reproductive values. In this category, there are mainly the branches of big global companies, such as ABS Global, Alta Genetics, CRV Lagoa, that count on the support of R&D research labs. These companies have laboratories in Brazil, with equipment and instruments of research and more precise selection, but basically, of quantitative genetics. These labs follow sanitary protocols required in Mercosul, European Union and Epizootic Global Organization (OIE), thus allowing the conquest of international markets.

The second activity is about the companies that basically use simpler and inexpensive genetic technology, which is economically accessible to commercial breeding, mainly those that practice the full cycle (breeding, rebreeding and fattening) of livestock.

### 3.2 Technological Development in Animal Health and Animal Nutrition

Animal health is a pharmaceutical industry branch, whose competitiveness is rooted in intensive R&D, operating in an interactive model driven by public regulatory system and the patent system. The central innovations (vaccines, organic minerals, amino acids and vitamins) are made outside Brazil.

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<sup>13</sup>Obtained in the BR Foods Company constitution.

Oftenthere is the use of the development of a production process to human health in veterinary medicine.

The animal food industry in Brazil can be divided in market segments. The first is the vertically integrated producers, which acquire the premix and mix it in their own property; the second is the market composed of big processing-integrating companies (especially poultry and swine), which produce and provide animal feed to their branches; and the third segment is the companies that act directly in the market. Our analysis is only about the third segment. The animal food industry can be characterized in two types of activities. The first is the combination of grains and cereals processed with basic ingredients whose technology is basic and fully widespread. The second activity is about the production and formulation of premixes which require more technological complexity and it are in the head of the innovative dynamic of animal food section. The production of micro ingredients of premix is a segment based on science, whose main suppliers are companies of pharmaceutical and fine chemistry industries. Brazil does not internally produce the main constitutive elements of the premix, such as mineral supplements, amino acids, antibiotics and the vitamins, which are mostly imported (with the exception of vitamin K, iron, magnesium and copper). In Brazil, one can say that the "assembly" of the premix occurs mainly through the importation of the main ingredients – the companies do the so called premix formulation product according to the biochemical and pharmaceutical criteria of each specific client (poultry, swine and livestock). The premix formulation process is not trivial because it demands laboratorial tests of ingredient quality control or even "traceability" criteria, especially to exportation meat sectors that must follow the requirements from international deals upon the usage of productive ingredients.

Hence, there are, in the animal food industry, two types of companies: foreign companies acting in the global markets of ingredients; and small Brazilian companies acting in local/regional markets that acquire technical capacity in order to produce the premix but that depend on vitamins offered by multinationals.

These multinationals are technologically trained companies in the development and innovation of the premix, once they have advanced R&D laboratories in the matrixes that elaborate mixtures of technologically improved ingredients and/or with distinctive attributes for each animal segment. Furthermore, they themselves produce a great deal of sophisticated micronutrients in central countries or they can have access, in conditions of economically relative advantages, to the global markets of these products because of their organizational abilities and their advantages in terms of production scales and scopes.

Differently, national companies, which develop specific formulations and attend the needs of local markets, are subordinated to the importation of ingredients and to the innovative dynamic of foreign companies. Quality tests and sometimes the development of new formulations are usually hired along with universities and research institutes.

In the case of livestock segment, the animal nutrition is through the ingestion of pasture. In this area, Brazil is technologically capacitated, especially with the support of Embrapa (livestock sector) that has been leading researches on pasture composition development since the beginning of the 70s when it first introduced signal grass pasture (with better nutritive qualities). Since then, Embrapa's organization and research system, together with universities and seed industry, have developed new nutrition technologies to cultivate pasture seeds that: a) are more adaptable to several biomes in Brazil; b) foods with higher contents of fibers and protein; c) allow the easing of intertwined cultivation systems with several vegetables species (such as pigeon peas and stylosanthes - plants that recuperate degraded areas), e d) allow the incorporation of silage technoques and the usage of industrial waste (bagasse of cane, cotton lump and citric pulp, etc) as livestock nutrition. The propagation of these new technologies have been allowing, on one hand the farming of more animals in smaller spaces (bigger supporting infrastructure) and on the other hand, expanding the geographical amplitude of farming livestock systems.

Moreover, in the economical plan, there is a drop in production costs because of the possibility of the productive incorporation of less valuable lands.

#### 4. Final Considerations

This article analyzed the main characteristics of the innovative and technological dynamic of input sectors of livestock, swine and poultry primary base. One can see that the most important tendency in these sectors is concerned with the ever-growing technological complexity, especially in genetic and animal health areas. In these sectors, the innovation on products and processes progressively becomes based on more advanced and sophisticated scientific knowledge, generated in solid research networks and yet dependent of more generic technology such as molecular biotechnology, biological nanotechnology and information technology. The dynamic poles of innovation are multinational companies' branches that determine a clear work division in the innovation system; that is, these companies run the way of generating and appropriating knowledge and technology and, therefore, Schumpeterian profit. In general, R&D and I domestic agents are supporting agents in the process of sectorial innovation and have little strength for the autonomous creation of sectorial opportunities. To these domestic agents, the most common role is to create product adaptation according to the local production conditions. This process is done via partnership with companies, research institutes, Embrapa, cooperatives and local universities, which generate low spillover effect regarding knowledge and autonomous learning to local production agents. In this sense, the aptitudes and knowledge are limited and with low pervasive sectorial and systemic effect, given its incremental and adaptive character in comparison to other countries' knowledge production.

According to the perspective of technological capacitation of Brazilian firms, one can say these are still far away from doing the technical catching-up, given their limited R&D and learning efforts. According to Kim and Nelson (2000), one can say that the innovation baseline of local firms is basically in a duplicative imitation, that is, it is the simple copy of developed technology by external agents to the firm. Only in the swine genetic segment, one can think of a creative imitation stage, that is, there is a capacitation to copy innovation, yet with some original contribution from the copied firm to adapt and improve the technology adopted.

This degree of knowledge generation and sectorial technology dependency and/or systemic sectors is preoccupying because it cannot allow the maintenance of competitiveness levels, thus, the own economical and commercial gains in the long term of the Brazilian meat sector. This preoccupation becomes bigger for two reasons: a) on the offer side, recent studies show that the technology generation and innovation is even more characterized not only by this scientific input complexity, but also by the organizational structuration, that is, the technology is generated by systemic complementarities amongst agents, sources of innovation and institutions; b) on the demand side, there is a greater differentiation of products and a greater market selectivity, especially on quality (*latusensu*) of products and on the concomitant practices of decommunitization of markets. Hence, in a long term perspective, the dynamic competitiveness of the Brazilian meat sector must be related to the implementation of technological and industrial policies so that they can generate a greater systemic and organizational capacitation and learning to its local agents.

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