Agribusiness Innovation System: Applied Model to R&D Public Organization (Part 2)

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Abstract: This paper deals with the application of a dynamic model, combining Transaction Cost Economics (TCE) and Penrose's theory of the growth of firms, under the New Institutional Economics (NIE) terms, to analyze and manage the "Agribusiness Innovation System" (SIE) coordinated by an agricultural research-development (R&D) organization in Brazil – Embrapa. Considering the changes in S&T paradigms together with broader transformation of domestic and global economic environmental conditions, Embrapa in the nineties sought its own sustainability and internal reorganization as a "firm system", and also that of the Brazilian agribusiness system, as a public "innovation system". To offer R&D, Embrapa's decentralized research centers interact with each other and partners to meet agribusiness R&D demands of the clients, tending to be organized as a complex R&D network. The intended goal is to propose an applied model to subsidize quantitative analysis for the decision-making process in terms of SIE management as a whole and to test key variable relationships when applied to aquaculture, fruit-growing and horticulture business innovation subsystems.

Key words: Agribusiness innovation system, Brazilian agricultural research system, aquaculture innovation subsystem

1.Introduction

Created in 1973, Embrapa is a public R&D (Research & Development) organization, attached to the Brazilian Ministry of Agriculture and Food Supply. It coordinates the Brazilian System of Agricultural Research (SNPA), including research organizations, universities, cooperatives, foundations, NGOs and private corporations. Investments in human resources have projected it as one of the biggest agricultural research agencies in the tropics. Today, from a total of 8,675 employees, about 51% of its 2078 researchers hold M.S. and 44% PhD. degrees. From its headquarters in Brasília, it administrates 40 research centers spread all over Brazil with infra-structure composed of laboratories, germplasm banks, small plants, experimental areas, libraries and herbariums. The 1999-Budget, around US 300 millions, funded about 700 projects, distributed in 18 Research Programs and developed by Embrapa centers or/and in partnership with 1,562 organizations, inside and outside SNPA, through 275 technical cooperation agreements with 160 agencies from 56 countries, involving technologies and information exchanges, advisory, project financing, R&D licensing and joint research projects.

At the end of the 1980's, Embrapa began adjustments in the planning and management of its activities in order to be prepared to face the new challenges for agricultural research at the brink of the 21st century. As summarized in Goedert et al. eds.(1994), Embrapa witnessed the importance of refining its management tools, making strategic decisions in broader external contexts, with information based on: (a) prospective vision of its environment where the R&D beneficiaries are inserted by means of a technique of constructing alternative scenarios, aimed at incorporating the uncertainties and discontinuities of technological and non-technological factors in its long-term strategic plans; (b) studies foreseeing R&D agribusiness demands for a segmented clientele,using a systemic approach to develop a specific methodology of analysis, aimed at giving priorities to R&D programs/projects; (c) monitoring the advances of the frontier of S&T knowledge applied to agribusiness, aimed at keeping pace with them, and expanding collaboration with R&D partners. These transformations attempted to construct an "Agribusiness Innovation System" (SIE) under Embrapa's coordination, characterized by strategic and simultaneous interaction between the "knowing how"(R&D supply side) and "knowing what" (R&D demand side) to innovate within the so-called "agribusiness R&D market". On results obtained by external enviroment analysis mentioned and strategic planning tools, the Second Embrapa Strategic Plan and its Decentralized Research Center Plans were developed in 1991.The Embrapa strategic goal was to promote dynamic competitiveness in the Brazilian agribusiness system through R&D advances, abiding by principles of efficiency, social equity, health/life quality and sustainability of natural resources and environment in benefit of society. Besides, it was also necessary to have in hand the means – internal conditions or governance modes – that allow for the translation of the strategic vision into effective actions and outcomes, considering the links between R&D and support activities. Thus, the Embrapa R&D Planning Model (SEP) and institutional/organizational structures were reformulated and implemented. R&D monitoring and appraisal systems of programs, projects and research units were delineated accordingly and socio-economic impact evaluation of agricultural research outcomes adjusted to provide feedback for strategic and operational plans. As of 1995, these management tools were perfected to obtain incremental gains based on accumulated experience of implementation of changes. In 1997/98, with the completion of the planned-executed-monitored-evaluated-reformulated cycle, a realignment of the Embrapa Strategic Plan was made for the period 1999-2003, now in accordance with the Brazilian Four-Year-Plan (PPA), which allocated resources by projects/activities, oriented by strategically selected national outcomes.

In brief, considering changes of S&T paradigms (especially of biotechnology and information-comunication technologies) together with broader transformation of domestic and global enviromental conditions (institutional, organizational and competitive), Embrapa during the 1990s sought to reorganize itself, fomenting its own sustainability, as a "firm system", and that of the Brazilian agribusiness system, as a public financed "innovation system". Given governance modes located in "agribusiness R&D markets", varying from vertical integration under unified control to hybrid and market solutions, the SIE could be classified as tending to be organized as a complex network of R&D production and exchange applied to the agribusiness sector, approaching an innovation model of fifth generation [1]. To offer R&D, Embrapa's 40 decentralized units - classified as R&D centers of agricultural products, eco-regional/agroforestry and basic thematic areas, besides special support service units - interact with each other and partners (inside and outside SNPA) to meet current and prospective R&D demands of the agribusiness clientele.

2. Justification and Objectives

Having made these adjustments, it was considered important to increase the understanding of the dynamic relationship between agribusiness and the innovation systems that could be translated in terms of more efficient tools capable of identifying and monitoring strategic opportunities to speed up the process of production and exchange of R&D knowledge and also to obtain suitable outcomes in benefit of society's welfare, in general, and the agribusiness clientele, in particular. Therefore, it was considered relevant to establish for Embrapa a similar systemic approach for the analysis of SIE to that for agribusiness system R&D demand studies. Despite the pecularities involved, this framework would offer conditions: (a) to perfect the understanding of SIE; (b) to establish stronger links between the SIE and the agribusiness systems, especially in public research organizations not directly involved in the agribusiness productive activities, such as Embrapa; (c) to take into account connections of agribusiness and S&T enviromental conditions, affecting innovation and agribusiness systems simultaneously .

Thus, in 1998/99, a postdoctorate program, sponsored by Embrapa, was held at the School of Economics and Business Administration (FEA) of the University of São Paulo (USP). In FEA-USP, the "Program of Studies for Agribusiness Systems " (PENSA) fitted this mentioned need, since it took into account interrelations between economic and business administration science advances, through "New Institutional Economics"- NIE (Williamson,1985; Joskow,1994) to analyze the so-called by PENSA, "Agribusiness Systems" or SAG (Zylbersztajn, 1996; Farina et al.1997). As a result, a SIE managerial and analytical model was constructed (Paez,1999; 2000a; 2000b), especifically applied to the R&D "firm system" (Embrapa/SNPA), related to agribusiness "firm systems" (SAG), and situated in macro-environments (Brazil in domestic and global economic systems in the 21st century), through advances in economic theory under NIE terms. Particularly, the conceptual bases came from the contributions made by Coase (1937), Williamson(1985) in transaction cost economics (TCE) and by Penrose (1959) the growth of the firm. Included were later developments of interest, especially the "Dynamic Capabilities Approach" (Teece et al.1997), complemented by the R&D supply-demand dynamic model proposed by Spiller and Zelner(1997). Under a systemic and interdisciplinary approach by NIE, the SIE model adopted a "bounded determinism", derived from assumptions of bounded rationality/opportunism of human behavior and uncertainties of the external environments, affecting firm production and transaction costs and profits over time. As a consequence, limits of innovative firms tend to be flexible, reaching "sustainable fitter" *equilibria*, *s*trategically designed to "search for profits" over time (as in Penrose), but made up of "remediable efficiency" on transactions ("the fitter" from TCE), foreseen by the economic agents as a discrete, comparative, economizing governance solution at a given moment and place, when confronted with "the fittest" of the marginal *equilibrium.* Additional hypotheses were raised that, independent of the hierarchy of the system under analysis. This logical "process" of unstable and cyclical *equilibria* in the long run repeats itself, but "products" have an extra-logical content, correlated with temporal and spatial contextual environments where located.

Considering this SIE model, the three main objectives of this paper are: (1) to discuss additional evidence in support of the hypothesis raised by the SIE model; (2) describe Embrapa's broad strategic and operational conditions, given changes of R&D management tools during the 1990's, that allow the SIE model constructed to be used; (3) propose a research project applying the SIE model to subsidize quantitative analysis improving Embrapa's decision-making process in terms of SIE management as a whole, and test empirically the relationship of key variables, related to particular innovation subsystems - aquaculture, fruit-growing and horticulture businesses.

3. Theoretical Model:Additional Contributions

Complementary to the conceptual bases of the SIE model in relation to theories of the firm and innovation within the NIE framework, a set of connected articles can also be emphasized. One by Stephan(1996), giving support to the assumption that logical "processes" are repeated independently of the system under analysis, though their "products" have environmental

[1]The fifth generation innovation is a "systems integration and networking model", defined by Rockewell *(apud* Senker, 1995) as a fully integrated parallel R&D model, using expert systems and simulations, with strong linkages to specific customers, strategic integration with primary suppliers for co-development of new products, horizontal linkages with partners; and increased focus on quality and other non-price factors. According to Rockwell, it results from the evolution of R&D models: (a) "technology push", or, a simple linear sequential process, starting from R&D supply side (1st generation); (b) "need pull", or, a simple linear sequential process starting from the demand side (2ndgeneration); (c) "coupling model" or, a sequential process but with feedback loops between supply and demand sides (3rdgeneration); (d) "integrated model", or a parallel development with integrated development teams (4thgeneration).

content. Another by McKelvey(1997), analyzing the effects of biotechnology on the coevolution of "innovation systems" in the various environments wherever they pass, aiming to transform S&T into goods/services of economic value in the market. The last, by Henderson and Clark (1990), refers to the importance of adapting organizational solutions to types of innovation changes, understanding innovation as a "system" composed of S&T core concepts and interrelated components.

In the literature, the "innovation system" within a "firm system" and their correlated governance modes have been usually seen in terms of economic returns for investments made (or, located downstream "innovation system"). This may suggest that when the value is not immediately expressed in monetary terms, the seeking of competitive advantages in the "world of basic science" (or, upstream "innovation system") does not exist. As described by Stephan(1996), even when the objective is that of science for the sake of science, similar mechanisms can be found, encouraging the production of knowledge, even contradicting the assumption of weak appropriability of results when dealing with the public good [2]. Stephan stressed that the equivalent to "property rights" would be the "priority right" to publish in the world of basic science, allowing "the first mover" to absorb all the "social surplus" generated. She further indicated that the world of basic science is not always purely competitive. Concentrated structures occur where few scientists produce much with gains to reputation, accumulative advantages and/or monopoly of research lines. Alternative strategies are also laid down by the scientists in their careers, such as: (a) seeking to move outside the mainstream in an attempt to increase the likelihood of being the first in the "blackwaters" of their area of knowledge; (b) building a portfolio of research projects to balance the uncertainty component, maintaining coherence in the diversification of their works (increasing economies of scope) and collaboration with others to share risks/rewards (reducing bounded rationality); (c) establishing a reputation for obtaining research funding *ex ante*, corresponding to the inherent difficulties of monitoring R&D projects (as proposed by "principal-agent theory" Jensen and Meckling (1976); Fama and Jensen (1983). Stephan argues that it is a stereotypical idea when scientists in non-profit organizations concentrate their efforts on spreading available knowledge, while scientists in industry are dedicated to the development of technologies for purely commercial goals. Despite the undeniable interest of scientists outside the private initiative to get publication "priority rights", the content disclosed may only partially reveal their discoveries. On the other hand, scientists in private initiative are encouraged to publish to enhance the firm's R&D reputation and draw more resources to projects from financial markets. Basic research is developed within firms to monitor scientific advances while using their own "raw material" to ensure the technological development of their products and have bargaining power for R&D transactions with partners. Besides, contents of articles do not differ significantly between the scientists from public and private initiatives with an increasing trend towards co-authorship. Contrary to what has been assumed, numerous Nobel prizes have been won by scientists employed in industry with representation in elitist scientific societies.

From these analyses, one can easily conclude that sophisticated incentive/controls were constructed in the world of basic science bringing undeniably greater problems for replication and imitation by "competitors", if compared to those found among innovator and imitator firms in input/output markets. Though Stephan's conclusions refer to countries such as the USA, they confirm close connections between basic and applied science and types of intermediate organizational solutions found in the "innovation system". These R&D hybrid organizational forms have parallels with pure economic environments, fitting also polar cases of monopoly and perfect competition, as discussed by TCE. The appearance of incentive/control differs between basic science and technology worlds, depending on their respective environments, where the entire "innovation system" moves. Although differences do exist, only forms taken by their mechanisms of incentive/control are specific environmental "products". However, they also follow the same logical "process". As proposed by TCE,. they are the most economical organizations possible in relation to external contexts. In comparatively discrete cases, the market solution is adopted for non-specific knowledge asset transactions; or, a vertically integrated solution for highly specific/strategic knowledge assets; or, a hybrid solution for intermediate cases of knowledge specificity. Like economic environments, R&D agents also compete and trade from upstream R&D inputs to intermediate processing phases and downstream product markets, each one with a specific function in the "innovation system". But all aim to satisfy the same strategic goal that joins the parties and divides the tasks of the "innovation system". That is, the search for "benefits" to reward agents who transform S&T knowledge into goods/services to respond to the demands of the final consumer and welfare and security of society, like firms "searching for profits" over time, as proposed by Penrose.

Therefore, from a strictly dynamic dimension, if each phase throughout the "innovation system" has its own environmental characteristics, it is not "economical" to transfer the same incentive/control prevailing in the technology world to the basic science world, since one cannot continue to provide vertical integration governance solutions when assets become non-specific, as hypothesized by TCE. In brief, copying solutions along productive phases of "innovation system" in time as well as transplanting them in space, without considering the environmental peculiarities, is like trying to smoothen communication among agents of the "innovation system", causing the basic scientists to hurry to get "property rights", when their incentives are to obtain publication "priority rights". Each environment has the same logic of functioning to work, but "symbols" used for appropriation of results are different and

[2] This is the same case, discussed by Coase (1974).The argument is that: despite the lighthouses in Great Britain being an example used by economists to represent the typical situation of a public good, in "real life" they were being privately explored and administrated by groups interested in their functioning, under government control.

cannot be transferred from one environment to another without losses in efficiency and efficacy for the "innovation system" to evolve as a whole.

By taking into account both time and space dimensions, specific tools and intermediate channels of communication become necessary to help translate the incentive/control of each environmental condition with reciprocal benefits for the agents by fulfilling their differentiated functions and mitigating their opportunistic behaviors and bounded rationality. Like agribusiness systems, the appearance of private interest associations, as discussed by Farina et al.(1997) emerged to fill gaps left by market and government during the process of the deregulation of the Brazilian economy.

Following this line of reasoning, McKelvey(1997) justified the emergence of NBFs (New Biotechnology Firms) in the USA to fill the gap between basic science and technology environments left by the advance of biotechnology in the 1970s. The argument is that two other intermediate "environments" emerge now with greater visibility, composing four ideal types of S&T environments, coevolving and influencing the generation and selection of new knowledge (Figure 1). The first, the "techno-economic environment", where the incentive is given by the commercial value of the artifacts (or, knowledge) with rewards based on consumer needs in the market. Innovations are incremental, judged and measured by the amount of private entrepreneurial returns. This environment would be equivalent to aquaculture, if compared with the open access exploration of fishery resources.The second, the "basic scientific environment", where the incentive is to advance in basic scientific research with freedom to create and disseminate knowledge in the S&T community. Innovative results are judged by peers, following internal criteria of quality of science itself. Government maintains the flow of resources in fields it considers priorities for society. This environment would be like the discovery and exploitation of new fish stocks within limits of 200 miles, considering only sustainable biological yield criteria.

The third, the "scientific-economic environment", where the incentive is to transform the as yet intangible knowledge into returns can be made private in the longer run. This environment would be like refining fishing equipment and gearing the exploitation of newly discovered fish stocks to the needs of consumers on combined biological and economic yield criteria. The last, the "techno-government environment", where the incentive is to develop technologies to provide flows of public goods to society and be strategic for the nation from military weapons and technological infrastructure to food security. Here, the government plays roles of not only developing technologies and/or ordering them from third parties, but also of regulating their given uses by private economic agents. This environment would be the equivalent of taking the decision to pay the price of sacrificing bio-economic yield in the exploitation of fishing resources in exchange for other strategic priorities of the nation. The key aspect to stress in McKelvey's article is that the analytical treatment of the "innovation system" needs to consider the presence of more than two traditional "environments" (basic and applied S&T) with different incentives/controls, but exercising the same objective of transforming knowledge into results that, in addition to providing benefits (monetary or otherwise) for their creators, fulfills the ultimate goals of society.

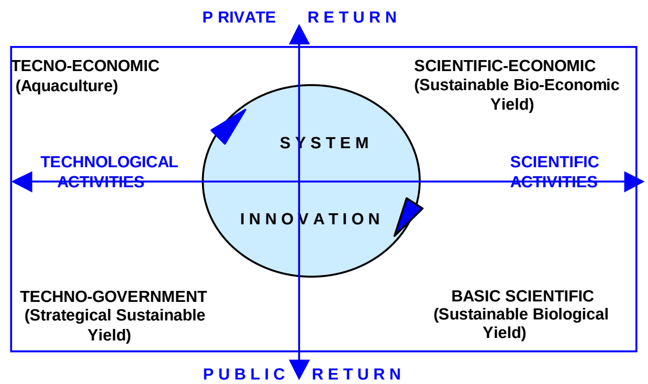

Figure 1 – Ideal Types of S&T environments
Source: Figure prepared based on McKelvey (1997)

But instead of standardization, the selectivity of organizational response in time and space also needs to be respected in each specific case (or, environment) based on the same comparative logical process of the TCE, combined with that of Penrose's dynamic dimension of the growth of the firm.

By the same token, the degree of complexity assumed by the innovation provokes the need for a deeper analysis in order to offer fine-tuned solutions for organizational arrangements. Like Stephan, Henderson and Clark(1990) refined the classification of innovation, taking it as an integrated system. The purpose was to emphasize problems of compatibility of changes generated by the "innovation system" and organizational forms to be adopted. They analyzed four innovation changes due to alterations in the scientific core concept as well as in the interrelations of the core concept with its components (Table 1).

Table 1 – Innovation Defined as a System: Framework

Linkages : core concept and components	Core concepts	
	Reinforced	Overturned
Unchanged	*Incremental*	*Modular*
Changed	*Architectural*	*Radical*

Source: Henderson and Clark (1990, p. 12)

Henderson and Clark (1990) stressed that these differences, when not correctly identified, may not be translated into compatible organizational rearrangements and have a significantly negative effect on the performance of the "innovation system", and consequently on the "firm system". An "incremental" innovation would tend to reinforce the competitive position of the established firm that holds the necessary competency, and R&D would be directed to improve particular components of the product. A "radical" type would tend to create clear threats to the competency of the established firm, but changes could be easily identified. However, with na "architectural" type, changes would be subtler because the firm continues to have the competency in the dominant core concept, but organizational forms of communication ordinarily employed between its productive components would need to be altered. The argument is that in these cases, even though the dominant technology is concentrated in established firms, new firms can assume technological leadership, if they are capable of "seeing" organizational changes required in the "innovation system" and established firms are not.

One concludes that small and apparently insignificant changes in the "innovation system" not reflected in its governance can have negative consequences for the survival of the established firm. Thus, organizational forms taken by these four sub-types of innovation can be expanded to cases of the "innovation system" located in the R&D "firm system" whose "production function" aim is exclusively to create, adapt and transfer R&D to such agribusiness sectors as Embrapa/SNPA.

4. Embrapa Overview: An Applied Model Proposal

Similar to agribusiness firms, the Embrapa "innovation system" can be characterized as having: (a) a technical S&T production function, guided by "technological paradigms" (Dosi, 1988) within multidisciplinary branches of science applied to agribusiness with various degrees of maturity and levels of knowledge codification; (b) an institutional model, where Embrapa's decentralized research units and headquarters are transacting among themselves and with external environments, having a techno-organizational form tending to an innovation model of "fifth generation" (Rothwell,. *apud* Senker; 1995); (c) a techno-economic production function, guided by "technological trajectories" (Nelson and Winter,1982), delineated by several types of incentive/control, corresponding to the four environments throughout which the "innovation system" evolves (Mc Kelvey,1997); (d) a common guiding parameter of the dominant "technical-economic meta-paradigm" (Freeman and Perez,1988); (e) an S&T strategy based on the past but ready to take R&D "productive opportunities" (Penrose,1959), strategically outlined by selected agribusiness entrepreneurial priority needs.

This SIE is inserted in a unique R&D "firm system", Embrapa, that coordinates the SNPA and is situated in the "R&D market" instead of agribusiness output/input markets. It possesses a condition different from that addressed in the literature, since it does not join business and R&D units in the same "firm system" for economic profits. Hovever, Embrapa has a structure similar to the so-called M-form (multidivisional of Chandler *apud* Williamson,1985), where SIE low frequency impulses are administrated: (a) at central level, by orientations given by the Embrapa Strategic Plan approved and controlled by an Administrative Council; (b) at research unit level, by orientations given by its Decentralized Research Center Strategic Plans. In turn, comparatively higher frequency impulses of SIE include end-activities – or, R&D programs/projects – and corresponding unit/corporative support and adminstrative activities.

As discussed in McKelvey (Figure 1), it is possible to consider that the changes implemented by Embrapa were channeled to fill the gap within the "scientific-economic environment" of Brazilian agricultural research applied to agribusiness like NBFs for the US pharmaceutical industry. Preserving due proportions, it was a way for Embrapa to reutilize its assets (or, to create "services" for "resources" as in Penrose) to face new opportunities that came with biotechnology and information-communication technologies, and even to alter the Embrapa function already duly exercised in the "techno-government environment". Embrapa has basic conditions for exercising this new role in relation to its own R&D productive resources. With changes in S&T paradigms, it has technical competency, physical infrastructure and human resources, installed in the areas of cellular and molecular biology and has been doing research in genetic resources since its creation in 1973. Embrapa, coordinating SNPA, also has comparative advantages in the intermediate and final evolutive phases of SIE with various levels of asset specificities. Its research units are distributed all over the country with "R&D product centers" (or, R&D economy of scale); "R&D eco-regional/agroforestry centers" (R&D economy of scope); and "R&D thematic area centers" (joint economies of scale and scope in relation to the previous types of units), focused on food processing, environment, soils, precision agriculture, and computer technologies. There are also R&D support service units - technological business and communication – to speed up and intensify links between external and internal environments.

Moreover, Embrapa has accumulated experience in transactional processes - upstream, intermediate, and downstream - from its SIE. In the 1990's, these competitive advantages were expanded qualitatively and quantitatively, considering increasing returns given by the new S&T paradigms (as suggested by Teece,1998). It was also possible to achieve corporative S&T economies of scope, so as to maintain coherence in the diversification of research activities at lower costs in relation to irreversible R&D investments made in the past. Therefore, a "network" of R&D cooperation (inter-institutional and inter-personnel) was reinforced throughout Embrapa/SNPA, speeding up the exchange of S&T knowledge and information. This provided feedback to SIE on newer bases than those restricted to the transfer of financial resources for joint research with partners or simple unilateral technology(process or product) transfer to agribusiness R&D clientele. This can be characterized as an "architectural" innovation system change.

Additionally, with changes in the Brazilian legislation on property rights in the late 1990s, Embrapa also set up a specific central department, aiming to perfect legal aspects of R&D

transactions, refining two basic types of contractual instruments, already available: (a) "contracts of economic performance" including those with R&D clientele for the purpose of financing research with specific private interest goals (near "techno-economic environment"); (b) "contracts of national and international technical cooperation", covering joint research with its R&D partners (near "basic scientific environment"). In turn, to establish a more systematic base to monitor S&T advances, the first "Virtual Laboratory Abroad" (LABEX) was created by Embrapa in 1998, resulting from an agreement with the Agricultural Research Service/USDA. Headquartered in Beltsville/MD, its activities concentrate on technological foresight and on developing institutional strategic alliances focused on Precision Agriculture, Intellectual and Biotechnology Property Rights, and Integrated Pest Control and Diseases in Plants/Animals. The second LABEX is located in France with the same key objectives.

In this set of production/transaction, Embrapa's tangible and intangible assets are involved. According to Hall (1993), intangible assets comprise those independent of people (legally protected, such as patents, or not protected, like public information-knowledge) and those dependent on people (such as skills, know-how, ability to innovate). Especially this latter type becomes an important source for generating sustainable competitive advantages, as discussed by Teece(1998). For Embrapa, these transformations had greater multiplying effects than expected, considering the amount of investments, time spent, and risks taken. They altered its intangible assets of competencies and favored the reduction of bounded rationality by participative processes in planning and execution of R&D activities, encouraged internal and external commitment in these processes and facilitated the re-learning. Though the results cannot be measured in strictly quantifiable terms, they constitute new dynamic sources for seeing "productive opportunities" (as in Penrose) and perfecting organizational arrangements of the transactions (as in TCE).

However, these changes were explicitly reflected in the mission/goals of the Embrapa Strategic Plan realignment for the period 1999-2003 (Embrapa,1998). The expression "to make viable" was introduced into the Embrapa mission to connect the goals of increasing "competitiveness/efficiency/productivity" in the Brazilian agribusiness system (situated near "scientific-economic environment) with those of "quality/equity/ sustainability" (situated near the "techno-government environment"). Thus, the SIE is coevolving, searching to make use of scale and scope economies in R&D production and transaction in these "scientific-economic and techno-government environments" – Embrapa's preferential environments of action in connection with other typical environments (Figure 1).

In turn, these first two Embrapa preferential environments are affected respectively by two sets of government policies that condition both the public and private investments in R&D and are counterbalanced: (a) legal guarantees of property rights of innovations, bringing incentives to the economic activity, aiming at elevating competitive advantages and performance of firms in the markets; and (b) regulations for innovations generated by the new paradigms, considering their effects on the resource environment, the food safety/reliability and the health of the population, aiming at increasing the control of public interest over private activities. Thus, for the Brazilian Government, though located in a system hierarchically superior to that of Embrapa/SNPA, there are similar kinds of "transactions" between these "scientific-economic and techno-government environments" to those proposed by the TCE at a transaction micro-analytical level. It does not cease to be a "macro-transaction" between public and private interests of the parties that should selectively find the most efficient governance solution possible, yet still consider the strategic position of the nation. It must economize on bounded rationality and safeguard itself against the opportunism of parties involved. It depends not only on the degree of asset specificity, frequency, and uncertainties of transactions (comparative discrete dimension) but also on the strategic path outlined based on the past activities but aiming to survive and to see new national "productive opportunities" in the future (dynamic dimension).

In the case of Embrapa, the main objective is to make the SIE evolve as efficiently as possible in comparative environmental terms, counterbalancing the pursuit of agribusiness commercial returns with the pursuit of strategic/social returns while searching for Embrapa sustainable *equilibria* in the long run. In "absolute" terms, both the excessive (or low) incentives, and the low (or excessive) controls are equally pernicious for gains to be made over time. The point is not to reach an average solution between these two forces, but to have selective ones, case by case, to be incrementally perfected during the execution of these R&D transactions.

Therefore, apart from the magnitude of the system under analysis, the essence of the logical "process" of decision making repeats itself, as long as the assumptions of opportunism and bounded rationality behaviors are present at any level of complexity-uncertainties of transactions among "parties". The "means" created to control these human characteristics take on different governance modes, affecting and being affected by the environmental conditions in which they are inserted. Partial cyclical and unstable *equilibria* are incrementally obtained in this path, but are strategically oriented in the search for sustainable *equilibria* in the long run.

5. Concluding remarks: Project Proposal

General approach – Given the SIE model and the operational content of "Dynamic Capabilities Approach" (Teece et al.,1997) it was assumed that: (a) Brazilian agricultural research, in general, and Embrapa, in particular, has an accumulated base of productive resources and tangible and intangible assets (or, "situation"); (b) a technical-organizational/ model of R&D production and transactions approaching the "fifth generation" and where means-activities are integrated to the end-activities ("processes"); (c) an institutional mission area and strategic objectives outlined and shared with the external environment ("path"). Then, from a long run perspective, how could Embrapa, coordinating the SNPA, continue to create/recreate dynamic competitive advantages for the Brazilian agribusiness system with increasing returns on the production and transactions in its "innovation system", and, at the same time, reconciling past and present S&T paradigms? The array of possibilities is open, and much greater than a single R&D firm working in isolation would be capable of absorbing. Due to the complexity of factors and increased returns on R&D production and transaction, this fundamental question needs to be specified and inserted in Brazilian and global contexts, with an eye to grasping the multiple facets involved in its answer.

The changes in Brazilian agribusiness and S&T environments at institutional, organizational, and competitive levels were: (a) legislation in effect on property rights (intellectual, patents, breeds, and transgenics), and currently under discussion in biodiversity; (b) regulations in defense of competition and antitrust law; (c) Federal Government administrative reform and Brazilian Four-Year Plan; (d) entry of new multinational enterprises into domestic R&D and agribusiness output/input markets; (e) changes in S&T paradigms; (f) strategic position of Embrapa/SNPA. Taking broad environmental conditions into consideration some key-questions need to be answered:

- What are the relevant factors that influence decisions to "produce" internally, "buy or sell" R&D in the market or to "collaborate"in R&D ? What is the role played by intra- and inter-organizational or even personnel networks (formal or informal) in these decisions?
- Is there a need to differentiate strategic conduct adopted by Embrapa, as a "firm system", in contractual relationships with R&D clientele and partners, with various levels of knowledge and particular competitive market position within SIE typical environments? From the standpoint of the contracting parties, what is the possibility of replacing the R&D "consumer (or R&D "supplier") in cases of contract breach, without causing significant harm to the other party, especially in dealing with confidential information-knowledge, safeguarding quality of R&D products/processes and reputation?
- What are the more economically efficient forms of outlining, making feasible, and monitoring R&D vertical and horizontal transactions of cooperation, according to each case? In which circumstances do patents guarantee the rights of appropriation of the economic benefits of the investments made? Do contracts manage to anticipate *ex ante* all the possible risks and uncertainties in their execution? How to solve the gridlock and make use of credible commitments or threats that can encourage the continuity of R&D transactions, avoiding greater damage to the parties in the future?
- What is Embrapa's strategy to govern transactions as a whole, considering the level of specific investments made in each, their frequency and degrees of external uncertainty conditions, and also Embrapa strategic and R&D priorities, its assets in stock (or to be), and the degree of maturity of the technological knowledge involved in the transaction?
- Would it be necessary to have an evolutionary perspective of links that join the "innovation system", from R&D partnerships in the form of research projects to unilateral contractual relationships for commercialization of products/processes derived from the innovations?

In search of answers, a research project is proposed to improve the management and analysis of Embrapa's SIE as a whole and specifically for particular "innovation subsystems" (subSIE) - fruit-growing, horticulture and aquaculture businesses – aiming to subsidize the adoption of more efficient decision-making on governance modes of R&D production and transaction without losing track of the strategic direction of Embrapa and Brazilian governmental priorities. These agribusiness sectors selected still do not constitute a significant source of generation of exchange values or income for rural family properties on entrepreneurial bases, despite the growing demand in the domestic/international product markets and possibilities of broadening the supply in the face of Brazilian comparative advantages of natural resources and labor availability . The increase of efficiency and efficacy of these subSIEs has an important role to play, not only in making use of the Brazilian comparative advantages of production but also in dynamizing the competitive advantage of coordination among components of these agribusiness subSIEs.

Embrapa, after changes made, offers the common basis to meet the present and prospective Brazilian R&D agribusiness needs, with information accumulated on these particular subSIEs, allowing for a broader view of technological and non-technological factors, affecting their competitiveness, efficiency, equity and sustainability. Among other published agribusiness studies related to aquaculture, horticulture and fruit-growing, there are projects developed under Embrapa's coordination (Paez,1982; Paez,1988;Castro et al. eds.,1997; Castro et al. eds.1998; Haddad, org.1999). Sources of information are also available, based on some analyses of contractual production and exchange relationships, specifically applied to commercial fisheries from the NIE approach, done by the Brazilian Economic and Social Development Bank – BNDES – (Siffert Filho and Favaret Fillho, 1998; Faveret Filho and Siqueira, 1997). In aquaculture production, extensive work has been carried out under the coordination of the Brazilian Ministry of theNatural Environment (MMA, 1997).

Furthermore, there are possibilities of transferring the experience already acquired by Embrapa in R&D transactions from other "innovation subsystems", such as those for producing seeds of oleaginous and cereal plants. These contractual relationships were established not only with R&D partners but also with holders of R&D complementary assets (as defined by Teece,1986) from private and public organizations. Included were all production and transfer phases of this subSIE: (a) research in improvement of genetic seeds; (b) multiplication of genetic seeds into basic seeds; (c) multiplication of basic seeds into commercial seeds bought by primary producers, as described by Almeida(1997). Subsidizing this kind of transaction in Embrapa traditional collaborative R&D associations, empirical studies were done by PENSA, using the NIE theoretical approach (Pinheiro Machado Filho and Matias,1995; Zylbersztajn and Lazzarini,1997; Nassar et al.1998, Zylbersztajn et al.1999). In addition, other related studies were developed, including benefit/cost estimates of investments made in seed production (Almeida et al.,1999) and the role of R&D in the development of soybean in Brazil, utilizing the sociological approach of "the actor's network theory" (Sousa and Busch, 1998).

Nevertheless, the present stages of subSIE development in aquaculture, fruit-growing and horticulture agribusinesses in Embrapa are different and still under-analyzed. While Embrapa already coordinates of research programs of fruit-growing and horticulture with data on contractual relationships accumulated, that of aquaculture is as yet in its initial phase.

In 1999, the task of coordinating the National Research Program in Aquaculture was attributed to Embrapa, aiming to structure and strategically reposition this subSIE. A work group made up of representatives from Embrapa and SNPA research units, state and federal universities, and the National Center of Tropical Fish Research (CEPTA), linked to the Brazilian Institute of the Environment and Natural Resources (IBAMA) was formed to concentrate information on R&D supply and demand, draw up priority lines of action and, monitor efforts, still scattered, of other aquaculture research group, located in different regions of Brazil and abroad. The R&D activities applied to aquaculture business should concentrate on a reduced number of species, taking into account integrated criteria of available R&D knowledge, Brazil's national or regional strategic priorities, environmental sustainability of production and possibilities to meet market consumer demands (domestic and abroad). The techno-organizational structure of Embrapa will support the aquaculture inter- and intra-institutional R&D actions, based on previous experiences and governance arrangements adopted by other R&D programs.

Besides Embrapa, Federal Government support for fisheries is now institutionally provided by the Brazilian Ministry of Agriculture and Food Supply (MAA) **-** Department of Fisheries and Aquaculture **-** created in 1998, whose activities are strategically oriented by a Plan of Action for the Development of Fisheries and Aquaculture and supporting resources allocated by the Brazilian Four-Year Plan (PPA). In this Strategic Plan of Action, fishing include three major areas: (a) Development Program for Tuna Fishing; (b)Program for Modernizing the Production and Competitiveness of Shrimp Fishing on the North Coast of Brazil; (c) Program for Recovering the Sustainability and Competitiveness in Lobster Production. Aquaculture activities are focused in three selected areas: (a) Development Program for the Production Chain of Tilapia; (b) Development Program for Sea Shrimp; (c) Program for the Development and Sustainability of the Production Chain of Bivalde Molluscs.

From this, it is clear that strategic decisions made by the Brazilian Government signal an incresase of comparative and competitive advantages of both exploratory fishing and aquaculture. In particular, aquaculture as a system constitutes an alternative form of reducing the pressure of overfishing on stocks available along the Brazilian coast and means to lower costs of controlling catches and idleness of the fishing fleet and industrial processing plants. Keeping in mind that the growth rate in consumption of fishery products has been comparatively greater than the supply in global markets, this trend is now also true for Brazil, passing from the position of net exporter to net importer, as anticipated in Paez (1993). In addition, the development of aquaculture on a commercial scale allows for new contractual relationships among producers and industry to emerge, similar to that observed in Brazilian swine and poultry agribusinesses, as strictly coordinated systems. Other advantages can be pointed out to justify the development of an aquaculture subSIE to speed up the production of edible fish products. It can be produced on family properties with the intensive use of labor, and in *consortium* with other crops and livestock in the same productive unit with more efficient legal-technological controls over ecossystem sustainability than exploratory fishing. Besides being a source of exports, aquaculture offers indispensable protein for the elevation of nutritional standards of the Brazilian population at comparatively lower costs than other animal proteins. The emergence of new aquaculture product/input demands, originating from recreational fishing, also constitutes an activity in rapid expansion, especially in Southeastern Brazil.

However, initiatives in aquaculture business are still modest in Brazil, if compared to physical resources and climatic potentialities of production. There is still room to increase comparative advantages with other regions abroad and competitive advantages in terms of coordination among their components. As for commercial fishing (Paez,1982), in the Northeast/North regions, there are more favorable natural conditions for aquaculture production than in the Southeast/South, but it is possible to identify specific and intensive interregional exchanges, based on studies done on aquaculture business in the Northeast region (Universidade Federal Rural de Pernambuco/Sudene, 1996) and Southeast region (Governo do Estado de São Paulo/SAA, 1996), and also on data surveyed by Embrapa R&D demand projects (Castro et al. eds.1997; Castro et al, eds., 1998).The Northeastern states export fry and edible fish to concentrated consumer markets of higher income in the Southeastern states. They supply feed and other inputs to the Northeastern aquaculture producers. The same type of complementarity can be established at the R&D resource base for this subSIE. The Southeast region has greater investments in S&T applied to aquaculture, including human, physical, and financial capacity, than the Northeast region, based on specific data of the Brazilian Ministry of Science and Technology (MCT/CNPq, 1996).

Objectives - In terms of the SIE model constructed, the general objectives of a project to be developed, aiming to analyze and

manage these subSIEs - fruit-growing, horticulture and aquaculture businesses – under Embrapa's coordination, are:
(1) to characterize these subSIEs, inserted in their corresponding S&T environments (as defined in Figure 1) and utilizing a similar system analysis methodology to identify agribusiness R&D demands, as adopted by Embrapa; (2) to update, gather, and broaden the available information base on monitoring S&T supply foresight and R&D demand prospection on these subSIEs; (3) to establish the connections (current and prospective) between these subSIEs and their respective agribusiness systems within the "R&D markets", mapping governance modes adopted by Embrapa/SNPA, including both internal and external relationships in production/transaction; (4) to typify S&T knowledge involving these relationships and to establish their interfaces within Embrapa/SNPA strategic "path" and asset "position" in the R&D markets and its internal corporative "processes"; (5) to analyze and evaluate the set of governance solutions adopted and their performances to improve parameters of decision-making.

Methodology - Apart from a normative approach, the usual treatment given to discrete variable empirical tests of TCE hypotheses has been of qualitative and quantitative (probit and logit), as summarized by Shelansky (1991). Recently, Lazzarini (1999) proposed a dynamic model of transaction analysis - the "generalized urn process" (Arthur, 1989;1991) to operationalize increasing returns both from the perspective of transactions between the same firms or individuals (dyad) and transactions between multiple firms or individuals (network). On the other hand, the influence of Penrose is felt in a large number of current approaches to the theory of the firm, such as the resource-based theory, evolutionary theory, theory of resource learning (Pitelis and Wahl, 1998). According to Slater (1980), Baumol (1962) was the first to construct a mathematical model of steady-state growth of the firm, using Penrose's framework, followed by Marris (1964) who paid more attention to financial aspects.

However, these analytical tools in use do not exclude the possibility that additional paths be tried, such as a simulation model, based on the theory of chaos to allow the handling of the complexity of effects of human behavior and uncertainties of external environments. Oriented by the SIE proposed model, synthesizing theoretical contributions of Coase-Williamson and Penrose and correlated proposals within the integrated framework of the NIE, a qualitative/quantitative analysis and applied model could be developed for the Embrapa "innovation system" as a whole and the "innovation subsystems" of fruit-growing, horticulture and aquaculture businesses in Brazil - the national R&D programs under the coordination of Embrapa.

6. References

Almeida, F.A..*Melhoramento vegetal e a produção de sementes na Embrapa:* desafio do futuro. Brasília: Embrapa-SPI, 1997.

Almeida, F.A.; Wetzel, C.T.; Avila, A..F.D. *Impacto das cultivares de soja da Embrapa e a rentabilidade dos investimentos em melhoramento.* Brasília: Embrapa. CTT, 1999 (Textos para Discussão, 3).

Coase, R. The nature of the firm. *Economica,* 4:386-405, 1937.

Coase, R. The lighthouse in economics. (1974). In: Ronald Coase ed. *The firm, the market and the law.* Chicago: The University of Chicago Press, Chapter, 7, 1990.

Castro, A.M.G.; Freitas Filho, A.; Campos, F.A.; Vasconcelos, J.R.; Paez, M.L.D´A.; Lima, S.V.; Goedert, W. eds. *Anais do Seminário Nacional Sobre Prospecção Tecnológica.* Brasília: Embrapa/CNPq, 1997.

Castro, A.M.G.; Lima, S.M.V.; Goedert, W. J.; Freitas Filho, A.; Vasconcelos, J.R. eds. *Cadeias produtivas e sistemas naturais:* prospecção tecnológica. Brasília: Embrapa-SPI, 1998.

Dosi, G. Sources, procedures, and microeconomic effects of innovation. *Journal of Economic Literature,.* XXVI (Sept.):1120-1171, 1988.

Embrapa. Secretaria de Administração Estratégica (Brasília, DF). *III Plano Diretor da Embrapa:* realinhamento estratégico; 1999-2003. Brasília: Embrapa-SPI, 1998.

Favaret Filho, P.; Siqueira, S. Panorama da pesca marítima no mundo e no Brasil. *BNDES Setorial,* 5, Rio de Janeiro: BNDES, 1997.

Fama, F.E.: Jensen, M.C. Separation of ownership and control. *Journal of Law and Economics,* 26(jun.):301-326, 1983.

Farina, E.M.M.Q.; Azevedo, P.F.; Saes, M.S.N. *Competitividade;* mercado, estado e organizações. São Paulo: Singular, 1997.

Freeman, C.; Perez, C. Structural crises of adjustment: business cycles and investment behavior. In:: Giovanni Dosi, ed. *Technical change and economic theory*. London: Pinter Publisher, 38-66, 1988.

Goedert, W.J.; Paez, M.L.D´A.; Castro, A.M.G., eds. *Gestão em C&T:* pesquisa agropecuária.Brasília: Embrapa-SPI, 1994.

Governo do Estado de São Paulo. Secretaria de Agricultura e Abastecimento . (São Paulo-SP), *Cadeia produtiva do pescado.* São Paulo:Governo de São Paulo/SAA, 1996.

Haddad, P.R. org. *A competitividade do agronegócio e o desenvolvimento regional no Brasil:* estudo de clusters. Brasília: Embrapa-CNPq, 1999.

Hall, R. A Framework linking intangible resources and capabilities to sustainable competitive advantage. *Strategic Management Journal*, 14, 607-618, 1993.

Henderson, R.M.; Clark, K..B. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly* , 35(1): 9-30, 1990.

Jensen, M.C; Mecking, W. Theory of the firm:managerial behavior, agency costs, and ownership structrure. *Journal of Finnancial Economics*, 3, 305-360, 1976.

Joskow, P. The new institutional economics: alternative approaches. *Journal of Institutional & Theoretical Economics.* 151(1):248-259, 1995.

Lazzarini, S. G. *Self-reinforcing governance:* the analysis of transactional increasing returns. St. Louis: John M. O. School of Business, Washington University, MO:[s.n.], 1999.

Marris, R.L. *The economic theory of managerial capitalism.* London: Macmillan, 1964.

McKelvey, M. Coevolution in commercial genetic engineering. *Industrial and Corporate Change*, 6(3): 503-532, 1997.

MCT/CNPq, *Aquicultura para o ano 2000.* Brasília: Ministério da Ciência e Tecnologia. Conselho Nacional de Desenvolvimento Científico e Tecnológico. 1996.

MMA *Diretrizes Ambientais para setor pesqueiro:* diagnóstico e diretrizes para aquicultura. Brasilia: MMA, 1997

Nassar, A.M.; Kikudome, K.; Zylbersztajn, D. Fundação MT: um caso de ação coletiva no agribusiness. In: *Seminário Internacional Pensa*, 8., Águas de São Pedro. Anais... São Paulo: USP-PENSA, 1998.

Nelson R; Winter, S. *An evolutionary theory of economic change.* Cambridge: Harvard University Press, 1982.

Paez, M.L.D´A. An overview of Brazilian foreign trade in seafood products. In: *International Seafood Trade Conference*. Anchorage, Alaska: University of Alaska, 1982, 381-403. (Alaska Sea Grant Report, n. 83-2).

Paez, M.L.D´A. An analysis of factors affecting international trade of seafood products: the Brazilian case. *Biennial Conference of the International Institute of Fisheries Economics and Trade*, 4., 1988, Eisberg, Denmark. Proceedings... Eisberg, Denmark: IIFET, .425-454, 1988.

Paez, M.L..D´A. Exploração de recursos pesqueiros no Brasil. *Revista de Administração*, vol. 28, n.4, p.51-61, 1993.

Paez, M.L.D´A. Sistemas de inovação em organizações públicas de P&D do agronegócio:nova economia institucional, equilíbrios sustentáveis e teoria do caos. In: *II Workshop Brasileiro de Gestão de Sistemas Agroalimentares.* Ribeirão Preto: PENSA/FUNDACE/FEARP-USP. Anais... Ribeirão Preto, 254-265,1999a

Paez, M.L.D´A. *Análise e gestão de sistemas de inovação em organizações públicas de P&D* Brasília: Embrapa-CTT, 2000a (Textos para Discussão, 4).

Paez, M.L.D´A. Innovation system in agribusiness: new institutional economics, sustainable equilibria, and chaos theory. In: *10th Biennial Conference of the International Institute of Fisheries Economics and Trade.* Corvallis, Oregon: IIFET-Oregon State University. Proceedings... Corvallis, Oregon, 2000b.

Penrose, E.T. *The theory of the growth of the firm* (1959). Oxford:Oxford University Press (2nd edition). 1980.

Pinheiro Machado Filho, C.A.; Matias, A. B. Embrapa/Unimilho: franquia em genética vegetal. *Revista de Administração*, 30(4): 51-64, 1995.

Pitelis, C.N.; Wahl, M.W. Edith Penrose: pioneer of stakeholder theory. *Long Range Planning*, 31(2): 252-261, 1998.

Senker, J. Tacit knowledge and models of innovation. *Industrial and Corporate Change*, 4(2): 425-444, 1995.

Shelansky, H. *Empirical research in transaction cost economics:* a survey and assessment. Berkeley: Department of Economics, U.C. Berkeley, 1991.

Slater, M. Foreword. In: E.T. Penrose. *The theory of the growth of the firm.* (1959) Oxford: Oxford: University Press (2° ed.), vii-xxxii, 1980.

Siffert Filho, N.; Favaret Filho, P. Agribusiness e competitividade. In: *Seminário Sobre Competitividade na Indústria de Alimentos.* Campinas: Instituto de Tecnologia de Alimentos (ITAL), 1998.

Spiller, P.T.; Zelner, B. Product complementarities, capabilities and governance: a dynamic transaction cost prespective. *Industrial and Corporate Change*, 6(3): 561-594, 1997.

Sousa, I.S.F. de; Busch, L. Networks and agricultural development: the case of soybean production and consumption in Brazil. *Rural Sociology*, 63(3):349-371, 1998.

Stephan, P. The economics of science. *Journal of Economic Literature*, 34(Sept.):1199-1235, 1996.

Teece, D.J. Capturing value from knowledge assets: the new economy, markets from know-how, and intangible assets. *California Management Review*, 40(3): 55-78, 1998.

Teece, D.J. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy*, 15, 285-305, 1986.

Teece, D.J. The firm organization, industrial structure, and technological innovation. *Journal of Economic Behavior & Organization*, 31, 193-224, 1996.

Teece, D.J.; Pisano, G.; Shuen, A. Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7): 509-533, 1997.

Superintendência do Desenvolvimento do Nordeste. (Recife-PE). *Complexo agroindustrial do pescado no Nordeste do Brasil*. Recife:UFRPe-SUDENE, 1996.

Williamson, O. *The economic institutions of capitalism*: firms, markets and antitrust implications. N.Y: Free Press, 1985.

Zylbersztajn, D. Governance structures and agribusiness coordination: a transaction cost economics approach. *Research in Domestic and International Agribusiness Management*. 12, 245-310, 1996.

Zylbersztajn, D.; Lazzarini, S.G. On the continuity of contracts: a study of the Brazilian seed industry. In: *Inaugural Conference for the International Society for New Institutional Economics*. St . Louis, MI: Washington University Press, 1997.

Zylbersztajn, D.; Lazzarini, S.; Pinheiro Machado Filho, C.A. Avaliação dos impactos de variedades transgênicas no sistema agroindustrial da soja. *Revista de Administração*, 34(3): 21-31, 1999.