Brazilian Microelectronics Sector Dynamization: Technology Strengthening and Sustainable Development on Production Chains

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Abstract

The aim of this paper is to assert management mechanisms to support government policies of science technology and innovation, contributing to the identification, planning, and coordination of short, middle and long term integrated actions involving the government, academy and industry in the national ecosystem of microelectronics in Brazil. Given the current context of Brazilian industrial policies, as well as the National Strategy towards Science, Technology and Innovation planned for the 2012-2015 period, this study presents coordinated actions with a triple helix focus towards a greater technologic density and the sustainable development of the value chains of the electronic industry, focusing on microelectronics. Specifically, the paper addresses a public program called National Micro and Nanoelectronic Systems Institute (INCT NAMITEC), a Brazilian multi-institutional research network created in 2008 by the Science, Technology and Innovation Ministry.

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1. Introduction

As widely known, innovative activities have enormous importance among the strategies designed to improve the competitiveness of any industry. According to the triple helix concept, the key for promoting innovation is to put together efforts of academic, government and private companies in a coordinated and systemic way (Etzkowitz, 2010)[1]. The political initiative related in this paper, the National Micro and Nanoelectronic Systems Institute (INCT NAMITEC) is one of the government actions that have been promoting efforts aiming to align Science, Technology and Innovation (S&T&I) Policies with the Industrial Policy.

In Brazil, political initiatives that integrate government, academia and private companies are essential, since a great share of Research and Development (R&D) activities are made by government institutions (public universities and R&D institutes responded by 52.4% of expenditures in R&D in 2010) or laboratories of multinational subsidiaries which investments are decided abroad. According to Fernandes (2010)[2], this scenario reveals some limitations of less-developed economies, due to the reliance on technology imports, rather than domestic production, late industrialization and poor development of institutions. “This led to limitations on collaboration and can be seen as one of the consequences of the underdeveloped nature of countries at the periphery of capitalism (Fernandes et all, 2010) [3]. Thus, research and development networks can benefit local private companies with partnerships for innovation with public institutions, acquiring complementary knowledge, developing applied research, sharing resources and risks and gaining access to funding opportunities and qualified human resources.

Brazilian scenario on (S&T&I) Policies has been redesigned since 2004, with the creation of a new regulatory framework introduced with the Innovation Law. This Law aims to promote incentives for S&T&I in private companies, connecting them with researchers at Public Science and Technology Institutions. Brazilian government also designed tax incentives and created funding lines to (R&D) activities on private companies. However, sectors such as the Brazilian microelectronic industry are not mature and adopt an import strategy to attend internal demand, instead of promoting investments to promote innovation.

Cases like this require additional efforts. This paper describes an ongoing experience on the development of technology management mechanisms in support of the policies mentioned above, that is, the implementation of a formal Coordination of Knowledge Transfer to the Productive Sector within the INCT NAMITEC. The goal is to develop strategies and actions aiming to enhance the transfer of technologies developed in NAMITEC to the productive sector.

One of the coordinated actions developed is the mapping of the microelectronic ecosystem. The methodology was based through collection and analysis of publicly available databases and interviews with specialists in microelectronics. Moreover, the survey and analysis of secondary information databases allowed the development of indicators of technology activities in the microelectronics sector.

This paper is a case study that deals with a real life organization, facing the challenges of interactions between academic institutions and private companies, as well as what has been done in order to promote innovative interactions within INCT NAMITEC. It is organized in three sections, besides this introduction. Section 1 describes the INCT NAMITEC and its organizational features. Section 2 provides a more detailed explanation related to the activities of the coordination for technology transfer, one of the administrative coordination of INCT NAMITEC. Finally, section 3 presents the main conclusions and directions for research, based in the previous items of the paper.

2. INCT NAMITEC’s role on the dynamization of the Microelectronics Ecosystem

The Ministry of Science, Technology and Innovation (MCTI) in Brazil has been using frequently the scientific-technological network model in the application of resources towards fomenting S&T activities. The
National Institutes of Science and Technology Program (INCTs) are based on this concept: according to the MCTI Ordinance n° 429/2008 that established the INCTs, the management model adopted by the members of the program is based on the concept of science and technology network.

Established in 2008, the INCT NAMITEC aims to stimulate the development of the Brazilian microelectronic industry, and counts on several educational and research institutes in the fields of physics, chemistry, computer science and electric/electronic engineering. Currently, NAMITEC is constituted of 137 researchers of 27 departments in 23 institutions in 13 Brazilian states (INCT/NAMITEC, 2012)[4].

NAMITEC is aimed at advancing the research and development of intelligent micro- and nano-electromechanical systems for use in sensor networks and embedded and self-adjusted systems, among others. In fact, the network was conceived having as an integrator axis the technologies of wireless sensors networks. The other areas were conceived to subsidize the production of autonomous electronic systems (intelligent sensor networks, embedded systems and self-adjustable systems), and contemplate all the necessary knowledge in research to develop wireless sensor network, ranging from materials and fabrication techniques to integrated circuits projects and intellectual properties libraries. Applications include agriculture, environmental protection, energy, biomedical instrumentation, automotive, aerospace and telecommunications. The main goals of the program are R&D on (a) systems-on-chip and sensor networks, (b) design/test methodology and electronic design automation tools for low-power and fault tolerant analog, radio frequency and digital integrated circuits, (c) micro- and nano-electromechanical, photo- and optoelectronic devices, (d) materials and processes for the fabrication of micro- and nano- integrated devices and circuits.

NAMITEC has as its host and coordination institute the Center for Information Technology Renato Archer (CTI), an Institution subordinated to the MCTI Ministry. It is managed by a committee composed by five members of different institutions. Its research activities are organized in eight coordination areas, being five technological and three administrative ones (Chart 1).

NAMITEC is inserted into the Brazilian industrial policy aimed at developing the semiconductor industry. It provides an interaction between academia and industry, adding to initiatives such as Sibratec (Brazilian Technology System) (1), the Brazil’s Program of Formation of microelectronics designers (2). The alliance between these institutions, the government, universities, C&T institutes and companies is a model of triple helix collaboration Researchers of the NAMITEC group are affiliated with several nationwide education and research institutions, working on a wide spectrum of disciplines with Noticeable is the affiliation of a considerable number of emerging groups from the north and northeast of the country, where microelectronic industry is very weakly represented, contributing to the development of research in these areas, as well as industrial results.

<table>
<thead>
<tr>
<th>Field</th>
<th>Specific Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological</td>
<td>A1 Area – Wireless sensor networks</td>
</tr>
<tr>
<td></td>
<td>A2 Area - Integrated circuits and IP’s design</td>
</tr>
<tr>
<td></td>
<td>A3 Area – Electronic Design Automation - EDA</td>
</tr>
<tr>
<td></td>
<td>A4 Area – Semiconductor devices</td>
</tr>
<tr>
<td></td>
<td>A5 Area – Materials and fabrication techniques</td>
</tr>
<tr>
<td>Administrative</td>
<td>A6 Area – Formation of human resources</td>
</tr>
<tr>
<td></td>
<td>A7 Area – Technology transfer to industrial sector</td>
</tr>
<tr>
<td></td>
<td>A8 Area – Knowledge transfer to society</td>
</tr>
</tbody>
</table>

Source: Adapted from INCT/NAMITEC (2012)

The coordination A7 (Knowledge Transfer to the Productive Sector), has as its objective to develop strategies and actions aiming to enhance the transfers of technologies developed in within NAMITEC to the productive
sector. In order to do so, several strategies are applied, including direct contact with companies, meetings with business associations and participation in events.

The interactions with productive sector occur by agreements between NAMITEC participant institutions and companies, aiming towards technology and knowledge transfer. This is one of the most difficulty areas on INCTs. Nevertheless, it is possible to consider that the results achieved in three years of NAMITEC’s activities have been successful, especially relating to process and equipment transfer to the productive sector (Table 1).

Table 1. Types of interactions: NAMITEC Institutions with the productive sector (2009-2011)

<table>
<thead>
<tr>
<th>Types of Interactions</th>
<th>Expected</th>
<th>Accomplished</th>
</tr>
</thead>
<tbody>
<tr>
<td>Know-how transferred on product fabrication</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Process and equipment transfers to the productive sector</td>
<td>10</td>
<td>31</td>
</tr>
<tr>
<td>Analogical, digital and radio frequency intellectual Property Libraries (IP)</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Companies partnerships</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Adapted from annual report INCT/NAMITEC 2012.

The main difficulty of NAMITEC’s technology transfer activities are on the interactions with the companies, that may be considered peripheral, since these are not institutions that directly integrate the NAMITEC network. Despite the fact that the five technical areas of NAMITEC are integrated in a productive chain, each institution develops interactions with the companies in an isolated manner, usually not involving any of the remaining institutions within NAMITEC.

The network formed by NAMITEC is essentially an academic network, since the majority of the participants are public institutions of education and research, promoting the formation of human resources as well as scientific and technological production (articles, patents and software).

These characteristics indicate that in NAMITEC, as conceptualized by Callon (1992)[5], the emphasis is on the scientific pole (production of knowledge) and technological pole (application of knowledge). It lacks, however, an active participation of the market pole, including the companies and users that materialize the innovation. In the NAMITEC network, the majority of exchanged intermediates (that mediate the interactions of the actors) between the poles are academic documents, lectures and courses aiming human resources formation and bound to events directed to scientific production.

In order for NAMITEC to promote innovative activities, it is necessary that the private companies assume a bigger role, as proposed in the network concept by Castells (1996, apud Corallo e Protopapa, 2007)[6]. Furthermore, joint and coordinated actions by the Government and the Education and Research Institutions are required so that the several organizations that are a part of the Brazilian microelectronic sector’s organizational ecosystem acquire a beneficent convergence to the generation of useful innovations for the society as a whole. Be it in the form of a Horizontal Network of Induced Innovation (Pellegrin et al, 2007)[7] or a Triple Helix (Leydesdorf e Etzkowitz, 1996)[8], a broader interaction between actors is necessary.

In Brazilian’s microelectronic industry, the challenges are even greater, given the fragilities of the companies. The Brazilian industry is not internationally competitive. Its dependence on imports is structural and deep, and is increasing with the expansion of domestic demand (Bampi, 2009)[9]. We also highlight the very low domestic content in higher added value electronic components, which are essential for the functionality of electronic final goods in general.

According to Fernandes (2010)[10] an important reason for that is the country’s orientation to a deeply rooted culture of importing technological packages. From a private company’s point of view, the implementation of technological innovations requires investments and time. The benefits that can be acquired by systematic and formal innovative activities include improvements on competitiveness, access to policy incentives to research and development, growth of market share, creation of barriers to new competitors and leadership on change processes. In order to do so, companies need to combine the use of internal resources with searches for external resources, such as capabilities, equipment and knowledge.
Finally, to create internal demand and new opportunities is important and require to fight firms preference in favour of technology imports, since microelectronics is a high complex global activity, with high levels of competition and mobility assets, that is geographic spread and outsourced in an ever growing rate along the production chain. This means new opportunities to industries which have innovation capabilities and competitiveness.

The management of technologies developed on NAMITEC increased by development, application and transfer of technology to the productive sector, shows that this goal could be achieved, and also includes target technologies (directly related to the Technologies developed) and support Technologies (such as measurement techniques, clean rooms technology, etc), with less visibility but a great potential for utilization by private companies.

3. Technologic management mechanisms to support government policies of S,T&I

Since microelectronics technologies are complex and multidisciplinary, the unfolding of a target technology into the support technologies that make target technologies suitable reveals the knowledge in a wide field of applications necessary to dynamize the Brazilian microelectronics, widening the possibilities of interaction between NAMITEC as well as with private companies. Strengthening the support technologies can also contribute to the consolidation in Brazil of an ecosystem with high technology density.

In order to overcome the difficulties of creating a microelectronic ecosystem in Brazil, NAMITEC’S coordination for technology transfer was established with a set of objectives, which unfold into three macro-functions with the goal of beaconing management activities of technologic transfer in the NAMITEC network (Chart 2).

In essence, these macro functions have as a final purpose to act on the ecosystem in which public and private institutions of NAMITEC are inserted, creating attractors that stimulate the cooperation towards innovation and mechanisms that allow the planning and efficient management of the organizational ecosystem delimited by the integrating institutions of NAMITEC.

With these efforts, the idea is to induce the diverse actors in the ecosystem to the state desired by the Coordination of Technology Transfer, stimulating collective and interactive learning in the participating institutions (academies and firms) in order to circulate the knowledge that has the potential of generating technologic innovations that strengthen the microelectronics industry.

The organizational ecosystems concept adopted in the model proposed by the Coordination of Technology Transfer does not consider the technologic transfer activity a unilateral relation, in which knowledge flows from the educational and research institutions to the productive sector. This ecosystem approach considers the NAMITEC network as a self-organizing ecosystem (Kay et al, 1999)[11], where changing to a desirable state depends on collective learning processes stimulated by attractors, highlighting the continuous organizational learning of all the components of the ecosystem: network managers, researchers, demanding companies of NAMITEC’s technologies and government institutions.
Chart 2. Macro functions of NAMITEC’s Coordination for Technology Transfer.

<table>
<thead>
<tr>
<th>Macro Function</th>
<th>Actions</th>
</tr>
</thead>
</table>
| Enhance NAMITEC’s cooperation and intern alignment. | 1. Map purposive and supportive knowledge/technology  
2. Identify actual and potential relationships between researchers and technologies  
3. Stimulate cooperation and new projects of common interest  
4. Identify the technologic areas with greatest integration potential  
5. Comprehend the potential synergies existent amongst groups that may facilitate the diffusion of knowledge and organizational learning  
6. Develop means to stimulate greater levels of cooperation between research groups  
7. Enhance comprehension on the complex relationships between organizational learning, technology development and innovation in INCTs  
8. Identify mechanisms to enhance diffusion of knowledge |
| Enhance alignment of NAMITEC’s technologies with company demand | 1. Initial survey on the potential applications of existent technologies  
2. Verify technologic areas with greater potential of application/transfer to companies  
3. Provide conditions so that NAMITEC’s technologies can leverage companies  
4. Identify company demands that mobilize new research in NAMITEC  
5. Identify NAMITEC’s most demanded technologies (purposive and supportive) |
| Develop means to potentiate the assimilation process of NAMITEC’s technologies by the companies | 1. Map company demand  
2. Enhance the comprehension on organizational learning relationships, technologic development and innovation in the cooperation processes with the companies  
3. Develop mechanisms to enhance the organizational learning processes within NAMITEC and in the technologic transfer activities  
4. Make means available to integrate organizational learning processes to labor activities in the target organizations (of the productive sector)  
5. Publicize NAMITEC technologies  
6. Identify mechanisms to enhance diffusion of knowledge outside NAMITEC.  
7. Stimulate university-company cooperation  
8. Contribute to a greater level of cooperation amongst research groups (suppliers) and the productive sector (demand)  
9. Foment complementary projects  
10. Study more effective transfer mechanisms  
11. Study protection of intellectual property mechanisms |

Source: Coordination A7/NAMITEC (2012)

The mapping of the microelectronic ecosystem allowed the identification of critical relationships and priority short-term actions, expanding the knowledge on technologic demands of the productive chains. Most of the technology in microelectronics are complex and multidisciplinary. The evolution of a target technology into support technologies that make the process feasible allows the identification of several areas of knowledge, setting better conditions for management. The identification expands the possibilities of interaction of these technologies with other academic and productive areas, and the strengthening of supporting technologies tends to contribute to make target technologies feasible, allowing a gradual consolidation of a national ecosystem with an elevated technologic density.

In the triple helix model, internal transformation in each helix changes relationships between the others (Etzkowitz e Leydesdorff, 1997)[12], especially in high technology industries, that require the dynamization of all the ecosystem’s levels. To stimulate synergic relationships between industry, academic institutions and government in high technology is an important policy instrument to raise the technology density of productive chains widening the content of local products and services.

The establishment of partnerships for cooperative research and development projects requires the identification of technology supply and demand; planning and negotiation; formalization; execution and follow through the project. A database about microelectronics gathered from primary and secondary data is an important tool to support the mapping of NAMITEC’s technologies, indicating the fields with higher technology demand.

The review of the projects funded by the National Fund on Scientific and Technological Development (Ministry of Science, Technology and Innovation) revealed that, in 237 contracted projects, only 44 (that
consumed 25.3% of all resources) have had the participation of private companies, mostly funded by public calls that required companies’ participation in public-private partnerships.

Chart 3. INCT NAMITEC: Cooperation with private companies

<table>
<thead>
<tr>
<th>Research Institution</th>
<th>Results</th>
</tr>
</thead>
</table>
| Center for semiconductor components/ State University of Campinas                     | Sample study on natural graphite for the production of nano-structured carbon materials (multiple and few graphene layers)  
Microrreactors project to basic studies of hybrid materials such as nano-tubes decorated by nanoparticles;  
Development of silicon sensor matrix applied to mapping and development of electronic circuits of reading matrix of InGaAs sensors-based |
| Center for Information Technology Renato Archer                                      | Manufacture of a Surface Acoustic Wave (SAW) humidity sensor based on nano-structured films with USB interface for the food industry;                                                                   |
| Physics Institute/State University of Campinas                                        | Joint research on graphene materials and exchange researchers                                                                                                                                              |
| Integrated Systems Laboratory/State University of São Paulo                           | Partnership to develop a Monitoring System in real-time of high-tension isolation bushings;  
Ongoing development of acetylene sensor  
Glucose sensor project, manufactured, but it did not work properly  
Strain Gauge project (pressure sensors usage), a few tests have been done.  
Cooperation Project  
Strain gauge project to charge cells;  
NAMITEC’s contribution with a clean room to development project on accelerometer to apply in airplanes;  
Papers on patents breaking and definition of embedded Systems (SOC, SIP, etc) to revenue (IRS – Internal Revenue Service);  
study papers about “clean process” concerning water saving and chemical products in interest of SEMIKRON e SMART companies;  
Project modernization of a polarimeter and refractometer, both functional and are still being produced;  
Measure system and gas flow calibration to anti-fire systems;  
Chip project of failures of transmission lines signals generation |
| Federal University of Rio Grande do Sul                                               | Collaborative project through “sandwich internship” of doctorate students from “sandwich scholarship” in association with the R&D department of the company  
Internship two researchers, in the period from August/2010 to July/2011, including a project (Design) of an integrated circuit (chip) aiming statistics characterization of aging (BTI) in the new IMEC technological knot: 28nm;  
Seminar presentation in November, 2011, invitation received from Cadence company;  
Testing and diagnosing activity of electronic valves, inserted in a cooperation project. |
| Federal University of Rio de Janeiro                                                 | Collaborative project of R&D to manufacture ISC for monitoring systems usage, control and energy generation  
Ongoing cooperation project                                                                                     |
| Federal University of Pará                                                           | Collaborative project of R&D between CEPISA and UFCG, aiming to analyze the technical and economical viability of one-phase transformers, based on one amorphous alloy core, installed in a rural distribution net of electric energy.  
Partnership to develop research in the broadband field using DSL (Digital subscriber line) technology  
Development of innovative telecommunications equipment  
Interaction with companies developing the new DSL standard called G.fast, through the participation as a member in “academy” category |
| Federal University of Paraiba                                                        | Collaborative project of R&D towards the development of a wireless low-cost sensor to monitor carbon monoxide                                                                                                                                                   |

Therefore, chart 3 shows that the mapping of technologies developed on the NAMITEC network has shown an increase in interactions between academic institutions and private companies. Between 2010 and 2011, there have been only seven cooperative agreements; in the 2011-2012, this number raise to thirty cases of public-private cooperation (NAMITEC, 2012)[13]. Between the Five technology areas of NAMITEC, some have a greater interaction with private companies. The Area of semiconductors devices presented the majority of interactions with the productive sector, especially in the specific subarea of integrated optical sensors for chemical analysis.

4. Conclusions, policy implications and directions for further research

Five assumptions fundament and justify the technology management of technological transfer in the microelectronic ecosystem: i) the ecosystem management must be based on the principle of triple helix in a continuous manner, as an instrument of national policy; ii) an emerging field like microelectronics requires good dynamics in several levels of the ecosystem, both in the scope of technologies (target and support) and in the integration of several industrial sectors (within and outside the electronic industry); iii) the complexity of the national microelectronic ecosystem requires the integrated management and transversal actions during a timeframe; iv) the creation of synergetic relationships between industry and academy is an important factor to both a broader technologic density of productive chains and for the development of science, technology and innovation; v) the prioritization and sequencing of actions must occur within a cost-benefit analysis based on objective criteria, among which the alignment with national priorities, technologic maturity and predisposition of the agents in promoting cooperative actions.

The results of such initiative are limited by both the technical and financial capacity of the Government and microelectronic industry. Despite all difficulties to “transplant” the management model, the paper shows the positives results achieved, although they are incipient compared with international rates. Brazil has achieved the improvement of industrial technological capabilities, joint R&D projects with firms and has formed a large group of Human Resources within the NAMITEC program. The long term tendency of the global electronics industries a sustained growth on the next years, based on two macro-tendencies: i) the digital inclusion of a large amount of world population nowadays with no access to information technologies ii) the tendency towards the incorporation of electronics devices by all other industrial goods, with the objective of creating new functionalities. Furthermore, national economy can benefit from the diffusion of global investments due to the globalization of sophisticated steps of the production chain linked to design and products projects development. This is a key factor that makes viable the insertion on the microelectronics chain (Bampi, 2009)[14]. Thus, it is indispensable efforts to rapidly build partnerships between universities and private companies, and NAMITEC is a tool of industrial and technology policy that aims at this convergence.

Considering the concepts related to the Triple Helix model, the coordination of the technological transfer of the national microelectronic ecosystem in support of governmental policies of ST&I contributes to: i) increasing the dynamics of this ecosystem through mobilization of industry-academy-government interactions; ii) enhancing technologic and innovative productivity in the fields of interest; iii) stimulus towards the alignment between technology demand and supply; iv) creating better environment for greater density in the value chain; v) contemplating technologic entrepreneurship, management culture and collaborative actions; vi) validation and dissemination of methodologies applicable to the management of organizational ecosystems, technologic management and diffusion of innovation towards sustainability; vii) contributing to a sustainable social economic development, such as a diminishment of trade imbalances, the generation of qualified work and the diminishment of environmental impacts; viii) subsidize the continuity of actions that promote higher technologic density and the sustainable development of chains of value.
Future research could seek to deepen studies on target and support technologies; the knowledge of interactions between several industrial sectors; the identification of potential interactions between academy-industry, industry-industry and academy-academy. These further studies will allow the elaboration of an integrated action plan towards elevating the dynamics of the national microelectronic ecosystem, subsidized by the benchmarking of successful international experiences, identifying the required actions and potential attractors; validation of these actions with multiple public and private agents and; creation of conditions to potentiate mobilizations (cooperation foment, network creation, actions with several industrial sectors).

References


Notes

(1) The Brazilian Technology System (SIBRATEC) is a political instrument to articulate and approximate scientific community to firms. The aim is to support industry technological investment on innovation and consequently increase profitability, productivity and competitiveness on internal and external markets. (Decree 6.259) SIBRATEC includes three types of networks: Innovation centers, Technological Services and Technological Extension Programs.

(2) IC Program is based on three main action which aims to: (a) stimulate economic activity on ICs projects; (b) expand the formation of IC designers; and (c) promote the creation of a new national semiconductor industry.