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Brazil Moving up in the Semiconductor Global Chain

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ABSTRACT: Brazil has implemented policies and incentives for the development of semiconductor chain in the country. In this paper, we described the configuration of semiconductor global chain, identifying the main activities of Brazilian companies, the infrastructures involved and the influence of the industrial policies that are fostering the chain configuration. We carried out a qualitative exploratory study in order to obtain the empirical insights of the current Brazilian operations and strategies to leverage its participation in the semiconductor supply chain. Data was collected by semi-structured interviews and document analysis. Brazilian companies already operate in some value chain activities of the semiconductor chain, especially back-end and Design, but some elements that are constraints to move up in this market were identified: the lack of a national infrastructure, experienced labor, and a proper industrial policy to leverage this economic sector, motivating new ventures, developing national production and attracting foreign companies.

Keywords: global supply chain management; semiconductor; technology

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1. INTRODUCTION

Supply Chain Management (SCM) is an important approach of operations management area, and is at the core of success of most leading companies (Sanders, 2012). Competition is no longer between organizations, but among supply chains that is more complex in nature, involving various work flows across trading partners (Wu et al., 2014). The strategic supply chain management is a phenomenon characterized by broad and complex interactions involving multiple elements such as strategic purchasing orientation for long-term relationships, interfirm communication, interorganizational teams and buyer-supplier integration (Paulraj and Chen, 2004). Considering that nowadays companies source globally, sell globally, or compete with some companies that also do that (Mentzer et al 2007), all these concepts are understood through strategic management theories in order to seek for collaborative advantage in a global environment. Thus, Global Supply Chain Management (GSCM) represents a major focus for many businesses and business schools today (Mentzer et al 2007).

The semiconductor industry fits into this scenario of global production as it has a supply chain network that is spread all over the world (Lee et al, 2006), with the presence of leading technology-based companies which need cost efficiency, mass production and flexibility. The semiconductor industry is a capital intensive industry, with sophisticated processes of R&D, composed of a small number of competitive companies. The management models in this global industry require the implementation of outsourcing/offshoring and supply chain management (Jiang et al, 2010).

Brazil stands out in the global economy as an emerging country and has developed policies and incentives for the development of semiconductor chain. The guidelines are made by public funding for the development of national production and tax incentives aiming to attract foreign companies in order to cooperate and develop the capabilities needed to create competitiveness (BNDES, 2009). Currently, this supply chain involves technological leaders coming from countries such as the United States, Japan, China and South Korea. If compared to these countries, Brazil has a low level of investment in innovation and technology as well as a lack of skilled labor (BNDES, 2004). Brazil already operates in some activities of the semiconductor value chain, such as the back-end and project, and also has some laboratories and design houses. Semiconductor production is one of the priorities of Brazilian economic planning and technological development. The Federal Government aims to move from being a high consumer of microelectronics items to a competitive player in the semiconductor chain. Even considering that the development of microelectronics in Brazil is on the agenda of the Brazilian Ministry of Science and Technology, it is known that the results are still very incipient if compared with leading players.

These considerations compose the basis for the formulation of the research question of this study: "How are Brazilian companies operating in the semiconductor supply chain and what are the main elements to the development of capabilities to move up in this global chain?" In order to answer the research question, we described the configuration of the semiconductor global chain, identifying the participation of Brazilian companies in each activity of the value chain, the infrastructure involved and the influence of the industrial policies that are fostering the composition of this chain. We also emphasize the barrier and opportunities for the growth of Brazilian companies' participation in the global semiconductor chain.

The paper is organized as follow: first, it presents a literature review of Global Supply Chain Management, followed by the description of the method used. Then, we present results showing the structure for semiconductor supply chain and its main value-added activities and the identification of Brazilian companies' operation in this chain. Finally, the presentation of the Brazilian opportunities and challenges are made through three main elements: public policies, infrastructure and human resources.

2. LITERATURE REVIEW

2.1 Global Supply Chain Management

With the complexity of the global market, the need for greater flexibility and lean operations and the necessity to offer more value added for customers, companies must pursue collaborative operations based on interorganizational models. According to Ellram and Cooper (2014) the favorable results achieved by companies, the growth of supply chain management as a major field of study across universities and its popularity among both students and employers supports that SCM works. There are many efforts of practitioners and scholars to understand this research area, its main elements and to develop

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models in order to map and interconnect concepts. Thomas and Griffin (1996), for example, propose a model to reduce operating costs by integrating the activities of procurement, production and distribution, based specially on the advances in communications and information technology, as well as a rapidly growing array of logistics options. Harland (1996) discusses the term supply chain management and how it can be used to represent a variety of different meanings, some related to management processes, others to structural organization of businesses. Cooper, Lambert and Pagh (1997) present a conceptual model identifying the main logistics flows considering different supply chain business processes and components. Mentzer et al (2001), extend the model presenting elements of interfunctional coordination and indicators in a global environment. Chen and Paulraj (2004) propose a model where buyer-supplier relationship is the central operation accomplished in an environment of uncertainties and leveraged by strategic purpose to seek higher performance. Charvet, Cooper and Gardner (2008) focus on the term supply chain management and its use in the academic literature. While definitions of SCM vary significantly, an understanding of the range of its use and the structure of related concepts is worthwhile. These studies help the understanding of the chain configuration and allow practical applications. From these studies we can detach that i) SCM requires strategic operations in a global and uncertain context, ii) the dyad buyer-supplier is an important element to accomplish procurement, production and distribution activities, iii) cooperation, coordination and long term relationship increase the flow of knowledge along the chain and iv) key processes must be managed with adequate infrastructure and technology to achieve higher performance, especially in terms of customer satisfaction, profitability and competitive advantage.

Supply chain management involves multiple firms, multiple business activities and the coordination of those activities across functions and across companies. The literature presents several definitions and categories, what suggests that the term "supply chain management" is still vague (Mentzer et al, 2001; Zacharia et al., 2014). Although definitions of SCM differ across authors, they can be classified into three categories: a) a management philosophy; b) an implementation of a management philosophy; and c) a set of management processes. According to Harland (1996), there are four main uses of the term 'supply chain management':

i. First, the internal supply chain that integrates business functions involved in the flow of materials and information from inbound to outbound towards the end market.

ii. Second, the management of dyadic (two-party) relationships with immediate suppliers.

iii. Third, the management of a chain of businesses including a supplier, a supplier's suppliers, a customer and a customer's customer, and so on.

iv. Four, the management of a network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers.

These perspectives lead us to the definition of a supply chain orientation as the recognition by an organization of the systemic, strategic implications of the tactical activities involved in managing the various flows in a supply chain (Mentzer et al, 2001). Supply chain management is the integration of key business processes from end user through suppliers that provides products, services, and information that add value for customers and other stakeholders (Lambert and Cooper, 2000). Considering that participants in the supply chain may share some common goals and values, collaboration represents an important element for this integration. According to Ramanathan and Gunasekaran (2014) collaborative practices (such as collaborative planning, collaborative decision making and collaborative execution of SC plans) trigger the high level of success in the collaborative supply chains, impacting in higher performance for the whole chain.

The importance of supply chains to the effectiveness of firms in a globally competitive environment has gained acceptance (Rose et al., 2012), what means that the strategy of the supply chain becomes a global issue. As competition becomes increasingly global in nature, the importance of global supply chain management grows (Connelly et al., 2013). Increasing competitive pressures force companies to expand operations beyond national boundaries in order to source materials and components, manufacture products and sell their products (Caniato et al., 2013). Slack and Lewis (2011) pose that global supply means the identification, evaluation, negotiation and configuration across multiple countries. Companies are increasingly looking for suppliers in, sometimes, quite remote locations. According to these authors, many companies have accomplished

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to save from 10 up to 35% in costs by working with suppliers from low-cost countries. Considering this scenario, global supply chain management (GSCM) represents a central area of focus for many businesses and business schools today (Mentzer et al. 2006a). Managers who seek for leverage supply chain processes in order to enhance performance need to understand the relative importance of the various competencies in each particular operating arena. The needs of key customers may vary across international borders, and the means for developing an effective fulfillment and replenishment process may also vary across international locations (Closs and Mollenkopf, 2004). The complexities of cross-border operations are exponentially greater than in a single country, and the ability to compete in the global environment often depends on understanding the specificities that emerge only in a cross border trade - that is, in a GSCM (Mentzer et al.,2006a). The operation in a GSCM is based on the development of capabilities to integrate different companies, from different countries, languages and cultures within distinguished economic and technological level.

Thun (2010) states that the supply chain integration needed to compete in the global market is defined as the improvement of cooperative relationships with customers and suppliers. The challenge is to develop the buyer-supplier cooperation in an environmental uncertainty with multidimensional constructs consisted of dynamism and complexity such as: (1) the dynamism regarding an internationally purchased item which measures the frequency, extent, and unpredictability of changes; (2) the complexity of that purchase item which measures technical complexity; (3) the cultural distance between the buyer's country and the supplier's country which measures informational and communication complexity; and (4) geographic complexity between the two countries which measures the complexity of the flow of goods or logistical complexity (Kaufmann and Carter, 2006). Without going global, companies would be limited to have just goods and services produced within their own borders.

Being global provides opportunities to tap into huge and growing markets, capitalize on new economic trends, and utilize natural resources available in other geographic areas (Sanders, 2012). The larger the portfolio of markets in which the supply chain operates, the greater the opportunities and, simultaneously, the greater the complexities and risks resulting from turbulent environmental conditions (Myers, Borghesi and Russo, 2007). Trading on a global or international market scale is considerably more complicated than on a domestic one. It has implications for the availability of alternatives for sourcing and flexibility in markets, which in turn affects pricing and market power (Parmigiani et al, 2011). There are time costs due to longer transit time. There are also operational costs involved in conducting business in a different part of the world. These include differences in labor productivity and access to labor skills, access to transportation and infrastructural support, as well as availability of technology. There are also significant risks that include political instability, as well as currency fluctuation (Sanders, 2012).

According to Esper et al. (2010), a supply chain orientation is represented by companies operating in a supply chain environment within the global market. Hence, in order to effectively operate in this environment, an appropriate strategy-structure fit is necessary. It is also important a proper evaluation of all the opportunities and barriers, considering the different trade off involved, is what best characterizes the management of a supply chain at a global level.

2.2 Capabilities to go global

The development of strategic capabilities can influence companies' success factors competition directly in their operations in a global supply chain, i.e., capabilities are potential modes of a plant with which it can support and shape corporate strategy and which help it to succeed in the marketplace. The development, nurturing and abandonment of strategic capabilities are major tasks of manufacturing strategy (Größler and Grübner, 2006). In a global chain, it is not just enough to acquire new resources, equipments and to hire specialized people. It is important to develop the necessary capabilities to turn the access to technologies into competitive advantage. Technological capabilities are defined as the specialized resources, i.e., skills, knowledge and experiences, as well as the institutional structures and linkages which are needed to generate and manage technological changes (Bell and Pavitt 1995: 78). Bell (2007) established two subsets of technological capabilities, production capabilities and innovative capabilities.

2.2.1 Production Capabilities

Production capabilities are necessary to use and operate given forms of technology in specific configu-

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rations (Bell, 2007). It is the capability to produce goods at given levels of efficiency and given input requirements. It may be described as technology-using skills, knowledge and organizational arrangements (Figueiredo, 2008).

According to Morrinson et al. (2008), production capabilities include the skills necessary for the efficient operation of a plant with a given technology, and its improvement over time. Process, product and industrial engineering capabilities are part of this subset. They involve activities such as: i) the search for viable alternative technologies; ii) selecting the most appropriate technologies; iii) dominating the technology, iii) adapting the technology to suit the specific production conditions; and iv) the process and product innovations related to basic research activity (Fransman and King, 1987).

For the appropriation of the technologies in order to have an efficient operation of a plant, and its improvement over time, capabilities are leveraged from manufacturing strategy and are related to: i) production with low cost; ii) achieve conformance or higher quality; iii) reliable and fast delivery; and iv) flexibility in production processes and mix and volume of products (Wheelwright, 1984). In operation management, these four dimensions - cost, quality, delivery and flexibility - compose the operational skills that are turned into capabilities that lead companies to higher operational performance. These four capabilities make a rich picture for the development evaluation of operational performance that allows the achievement of higher competitive advantage.

2.2.2 Innovative Capabilities

The innovative capabilities are those needed to create new knowledge or to transform knowledge into new specifications and concrete forms required for operational use (Bell, 2007). It is defined as the capability to create, change or improve products, processes and production organization, or equipment. It may be described as change-generating capability, consisting of technology-changing skills, knowledge, experiences, and organizational arrangements (Figueiredo, 2008). The innovation capability is understood as both the technological learning process from the firm translated into the technology development and operations capabilities, as well as the managerial and transactional routines represented by the management and transaction capabilities (Zawislak et al., 2012).

These capabilities usually involve activities such as: i) development of technology by small innovations; ii) institutionalized search for the most important innovations by the research and development department (R&D); and iii) conducting basic research (Fransman and King, 1987). All of these activities are related to different maturity level of technological development, what Bell (2007) refers to Design and Engineering and R&D capabilities.

Related to these topics, Wang et al. (2008) propose criteria for their evaluation, dismembering into three different capabilities:

- R&D capabilities: Percentage of researchers to overall employees, success rate of R&D products, self-generated innovative products, number of patents and R&D intensity.
- Innovation decision capabilities: The degree of innovativeness of R&D ideas, intensity of collaboration with other firms or R&D centers, R&D knowledge sharing ability, forecasting and evaluating technological innovation and entrepreneurial innovation initiatives.
- Marketing capabilities: Marketing share, degree of new product competitiveness, monitoring the market forces, specialized marketing unit and export percentage.

2.3 Public Policies Leveraging Global Supply Chain Operations

In a global context, the ability of managers to serve specific segments effectively can be limited by regulations and political economies that restrict the ability to standardize the offerings and processes needed to do so. These, often dichotomous, environmental conditions alone account for the often exponentially more difficult management conditions faced by global, rather than single-market supply chain managers. (Mentzer et al., 2007b). Politics and economy can include government regulation, political stability, formation of trade agreements, and currency fluctuations (Sanders, 2012).

Proper assessment of the political economy scenario often facilitates considerable savings in tariffs, as well as market opportunities. It is essential to evaluate political risk, credit risk, social risk and market risk and minimize their effects through awareness of their impact and cost across global supply chains (Mayers et al., 2007).

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According to Mann (2008), trade facilitation must be pursued by policymakers. It is the rubric that covers the research and policy analysis on impediments to global sourcing and multinational supply chains that are not the traditional border barriers such as tariffs or quotas. Trade facilitation offers a macroeconomic perspective on how policymakers should change the environment facing business to promote international trade and economic growth, whereas the microeconomic perspective of supply chain logistics considers how a business should organize its operations given the policy environment. The view is that policies that, for example, increase port efficiency, or use of information technology or adherence to international standards will improve the environment for business to buy, sell and invest across borders and thus drive more efficient and effective trans-border supply chains (Mann, 2012).

Another economic factor that global operations face is the exchange rate fluctuations. Actually, the financial and accounting complexities of foreign exchange rates go beyond the understanding, or responsibility, of global supply chain management. Instead, it is the task of managers to reduce foreign exchange in global supply chain transactions. (Mayers et al., 2007). Small fluctuations are expected and do not have a large impact. However, large fluctuations can have huge implications for global operations. It means that the ability to purchase in the currency you possess is suddenly diminished with no fault of your own. Supply chain managers have to include these fluctuations in their management strategies (Sanders, 2012).

2.4 Semiconductor Supply Chain

A new pattern or structure of the economy, the Information and Communication Technology (ICT) paradigm was established by the end of the twentieth century, having as leading producing players the United States, Europe, Japan, and East and South East Asia (Freeman, 2009). It has caused many transformations in the world, not only by the rapid growth and development of new ICTs, but more importantly by their pervasive application throughout virtually all sectors of the economy (Melody, 2009). The rise of the Internet spawned new forms of transacting business in many of these other industries and services, including retail and wholesale distribution, travel and tourism, financial services, auctioneering and gambling, as well as publishing and information services (Freeman, 2009).

The semiconductor production is an important industries developed within the ICT paradigm. The impact of the chips to the global economy can be realized by the increasing applications of this industry in both social life and professional activities. In today's world, semiconductor has permeated in every part of people's life like nothing did before. From computers, automobiles, office equipment, iPods, iTouch and iPhones, entertainment devices to all home appliances, none can function without the integrated circuit semiconductor devices (Jiang et al., 2010).

Because of its critical position in modern industry, the research on the semiconductor industry is plentiful (Li, Huang and Chen, 2010). The semiconductor industry has a supply chain network that is distributed worldwide, and its manufacturing process has the particular characteristics that should be considered in the supply chain framework (Lee, Lee and Kang, 2006). Global supply chain management strategies have helped the semiconductor companies to gain competitive advantage, with high investments in international operations with successive stages of outsourcing and offshore activities (Jiang, Quan and Zhou, 2010).

According to Li, Huang and Chen, (2010), the semiconductor supply chain is composed fundamentally of three characteristics: i) design house, IC circuit design and sales (like Qualcomm, Broadcom, and NVIDIA); ii) foundry, providers of contract chip fabrication (like TSMC, UMC, and Global Foundry); and iii) integrated device manufacturers (IDM), for overall semiconductor industry integrators (like Intel, Samsung, and IBM). Traditionally, IDM is regarded as a technology leader and contributor, whereas Foundry is considered only a manufacturing capacity provider. A design house is dedicated to IC circuit design and sales. Lee, Lee and Kang, (2006) pose that semiconductor companies are running a global business through multiple manufacturing sites, warehouses or distribution centers, subcontractors and suppliers. Manufacturing sites may consist of multiple fabrication sites, probe sites, assembly sites, and final test and packaging sites throughout the world. It is necessary for the supply chain model of the semiconductor industry to include the entire network stream starting from suppliers of raw materials to customers of the final products.

Figure 1 presents a map of the semiconductor supply chain, highlighting the main activities and

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characteristics of the companies that operate in each value chain activity (Gutierrez and Mendes, 2009). The whole process is composed of four different phases:

i. The product design: it makes an assessment of market demands and it designs the products.

ii. Manufacturing: it is performed by means of physical-chemical processes to produce the wafer. This phase is called front-end.

iii. Packaging and test of the IC, denominated back-end.

iv. Customers' services.

The producers of CIs operate in different ways in this supply chain and are classified according to their business model:

i. IDM (Integrated Device Manufacturer): they operate in all of the chain activities, from conception to customer services.

ii. Fabless: they accomplish the conception and customer services activities and outsource the front and back-end. They own the brand, the market and the product.

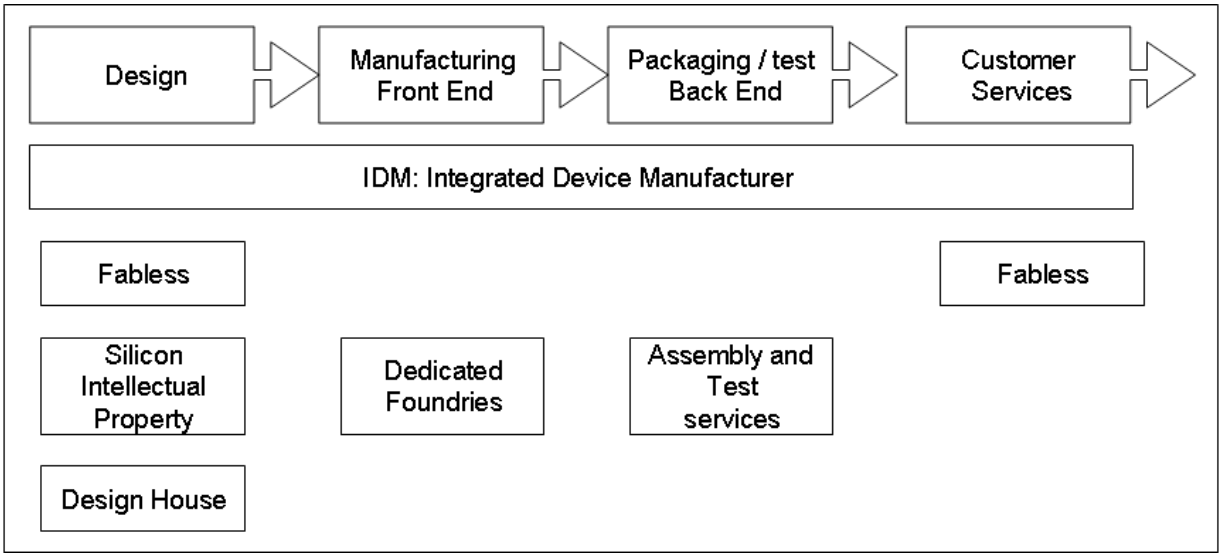
iii. Dedicated foundries: They perform the physical-chemical processes of the components.

iv. Assembly and test services: They are responsible for the back-end activities.

v. Design houses: they are independent and are hired by manufactures, by IDM or by fabless.

vi. Silicon Intellectual Property (SIP): Companies that license their technology to a customer (IDM, fabless or design house) as intellectual property.

Figure 1: Semiconductor Supply Chain



(Source: Adapted from Consórcio A.T.Kearney/Azevedo Sette/IDC, apud Gutierrez and Mendes, 2009)

3. METHOD

Based on the exploratory nature of the study, it was possible to conclude that the use of a qualitative approach was appropriate (Yin, 2008). Qualitative research allows the use of a flexible research design providing a reflexive process during the data analysis (Maxwell, 2013). In this way, a descriptive and exploratory approach can help this research to better understand a social and cultural context within which decisions and action take place (Mayers, 2009) in the Brazilian semiconductor industry scenario. First, it describes the phenomenon following the literature review and it finishes raising new research question.

Data for this paper were gathered from primary and secondary sources.

The secondary sources comprised available documentation, industrial reports and scientific articles.

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These data were used to:

i. Describe the semiconductor global chain and its main characteristics.

ii. Detach the participation of Brazilian companies in the semiconductor chain.

iii. Describe the Brazilian industrial policies created to leverage this industry.

iv. Complement the analysis.

The primary source came from semi-structured questionnaire and interview procedure. The interviews were conducted with six managers who were selected for their knowledge and experience on different stages and activities of Brazilian operation in the semiconductor chain.

i. Interviewed 1 (I1): CEO of a Brazilian semiconductor manufacturer company.

ii. Interviewed 2 (I2): CFO Expert in the Brazilian public policies oriented to the development of the microelectronic industry.

iii. Interviewed 3 (I3): CEO of a technological research institute focused on microelectronics.

iv. Interviewed 4 (I4): CEO that acts in international relationships with foreign companies and research institutes focused on microelectronics.

v. Interviewed 5 (I5): Consultant and Researcher who works for public sector in the development of industrial policies for the semiconductor industry.

vi. Interviewed 6 (I6): Process engineer of a Brazilian semiconductor manufacturer company.

The interview protocols were developed on the basis of the literature review and highlighted elements to understand and analyze the participation of Brazilian companies in the semiconductor global chain and the main gaps and barriers involved. These different narratives brought a rich picture of the current reality.

Based on the insights of the interviews, content analysis was used to emerge the criteria and elements for the analysis. Four elements were highlighted for evaluation:

i. Chain features: how Brazilian companies have been operating in each value chain activity: Project operation; Wafer manufacturing; and Packaging and Test.

ii. Infrastructure: how national infrastructure facilitates and limits the productive flow and support business strategies.

iii. Human resources: how Brazilian labor is prepared to operate and support the operational and managerial needs of this global chain.

iv. Public policies: how public policies are helping to leverage this industry in Brazil and what could be the next steps.

Based on the content of the interviews and secondary data analysis, it is presented a description of the chain and main capabilities needed. This paper is part of a larger ongoing project and it addresses new research questions at the end for further research.

4. RESULTS

4.1 Brazil Operating in the Semiconductor Chain

Semiconductor production is one of the priorities of Brazilian economic planning and technological development. The country aims to move from a strong consumer of microelectronics items to a strong player in the semiconductor chain. The difficulties of creating a microelectronic ecosystem characterize a great challenge that should be developed to reduce the trade deficit in electronics, that between January and October of 2008 was US$ 19.42 billion (US$ 3.62 billion was specifically related to semiconductors) (Gutierrez and Mendes, 2009). Figure 2 shows that this movement has already begun, highlighting Brazilian participation in each main step of the semiconductor chain. All the Brazilian companies are spread throughout the country, without a clear pattern of location for the industry setting. The design houses are located close to universities due to their vocation for researching. Manufacturing activities (front-end and back-end) located their plants looking for government support, tax incentives and availability of investors.

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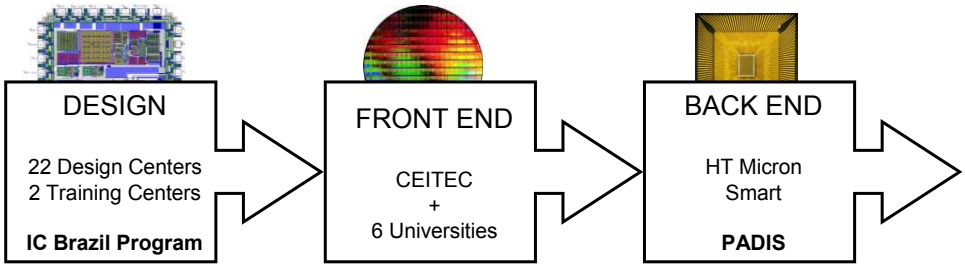
Figure 2: Brazil in the Semiconductor Chain



Source: Adapted from Peter (2011)

4.1.1 Design

This chain activity represents a good opportunity to develop technological capabilities to join the semiconductor global chain. This is a knowledge-based activity that uses logic blocks and electronic elements to develop new integrated circuits with the functionality demanded by customers (Kimura, 2005). The Brazilian Ministry of Science and Technology established a program called "CI Brazil". It is in the scope of Microelectronics National Program and since 2005 it has been inducing the creation and implementation of the microelectronics design in the country. Currently there are 22 design houses distributed throughout the national territory. Partially they are supported by the program and thirteen of these companies are nonprofit organizations. Most of them are spin-offs that have emerged or are connected to universities or public research institutions. (CI Brasil, 2013). Furthermore, the program has actions to fulfill the conditions and demands of this sector, such as infrastructure and human resources (Fink et al., 2010).

4.1.2 Front-End

It is considered the activity with higher value added in the process (Gutierrez and Leal, 2004), but it also requires large investment in infrastructures and equipments (Kimura, 2005). It is very difficult for a developing country to begin an operation in semiconductor chain by the wafer production. Currently in Brazil, the only organization with infrastructure, capacity and expertise to produce wafers is the Center of Excellence in Advanced Electronic Technology - CEITEC SA, supported by technology transferred from Motorola (Fink et al., 2010). It is a Brazilian public company that develops and manufactures applications of semiconductors for three segments: RFID, Wireless and Digital Multimedia. CEITEC is considered an important tool to develop productive and innovative capabilities in all the three main steps of the semiconductor chain.

It is already announced a manufacturing operation in Brazil, the Six Semiconductors, with investments of more than half a billion dollars. The new plant will begin to be built in 2013 and operations are planned to begin in 2015. The two senior partners of the factory will be SIX Intelligent Solutions and the National Bank for Economic and Social Development (BNDES). This plant will generate 300 new direct jobs. Other partners are IBM, BDMG and the groups Matec Investments and Tecnologia Infinita WS-Intecs (Veja, 2012). The goal is to produce 360 wafers per day, with a focus on specific applications for sectors such as medical, industrial, smart cards and documents (Baguete, 2012).

4.1.3 Back-End

As back-end activities demand less investment than foundries, Brazilian government considers them as an opportunity to prepare the necessary supply chain elements for the attraction of new investments (Fink et al., 2010). To promote the back-end operations in Brazil, as public policy we can also highlight the role of the Support Program for Technological Development of the Semiconductor Industry - PADIS, which offers tax incentives to stimulate the sector (Gutierrez and Leal, 2004). It is possible to detach the back-end operations of two companies in Brazil: HT Micron and Smart Modular Technologies.

HT Micron is a joint venture between the South Korea's Hana Micron and a pool of Brazilian companies led by the group Altus (Fink et al., 2010). This joint venture has an initial investment of $ 30 million, with revenues of US$ 300 million by 2012 and US$ 1 billion by 2014. Regard to the participation in

the Brazilian semiconductor market, which is currently US$ 17 billion per year, HT Micron expects a share of 20% of this value by 2014.

Itaucom left the packaging market in 2004 and was readily substituted by The American Company Smart Modular Technologies. This company has already invested US$ 100 millions in the country, operating mainly in the packaging and testing operations. Smart foresees for the next three years an investment of US$ 150 million in advanced technologies for packaging operations. Its intention is to meet the high demand for domestic components used in mobile applications.

Even considering that the development of microelectronics in Brazil is on the agenda of the Brazilian Ministry of Science and Technology, and there are operations in the three main stages of the semiconductor chain, it is known that the results are still very incipient if compared with leading countries.

The next section examines the Brazilian participation in the global semiconductor chain, the nature of these operations, highlighting the strengths of these operations as well as the current bottlenecks that still limit growth.

4.2 The Brazilian Companies' Potential, Opportunities and Barriers

As the interviewees have different experiences and responsibilities in the semiconductor chain, it was possible to collect good insights and perceptions about the strengths and weaknesses of Brazilian companies operations in the value chain. It was consensus among all of them that it is very important for the Brazilian economic development the creation of policies and incentives to leverage productive and innovative capabilities in order to turn the country into a competitive player in the semiconductor global chain. It was possible to visualize that the penetration in global supply chain presents great opportunities, but simultaneously great complexities and high risks resulting from turbulent environmental conditions (Myers, Borghesi and Russo, 2007), differences in labor productivity and access to labor skills, access to transportation and infrastructural support (Sanders, 2012). There is also the cultural distance between the buyer's country and the supplier's country which measures informational and communication complexity and geographic complexity between different countries involved in the global chain (Kaufmann and Carter, 2006).

It is a challenge to a traditional producer of commodities like Brazilian companies to move up into a value-added chain led by great technological leaders like Japan, EUA, China and South Korea. All the respondents' perception fits with the three reasons that Macher and Mowery (2003) stand out for how critical is to obtain competitive performance in the semiconductor industry:

i. The introduction of a new semiconductor product typically needs significant changes and innovations in the underlying manufacturing process.

ii. The ability to increase output of a new semiconductor chip rapidly before imitators enter is crucial to profitability.

iii. The high fixed costs associated with semiconductor manufacturing mean that low manufacturing yields and long cycle times reduce profitability and threaten firm survival.

All these factors reinforce the necessity to establish a management and coordination model at a global level that allows a country like Brazil to find its position in supply chain. Looking at the Brazilian companies' potential, opportunities and challenges, we made the content analysis of the interview data and it was possible to identify evidence of 4 elements for evaluation: chain features; infrastructure; human resources; and public policies.

The results founded for the four elements used for the analyses are intrinsically correlated. The figure 3 represents these correlations, composing a map that represents the Brazilian operation in the semiconductor industry and the elements that are necessary for companies to move in this global chain.

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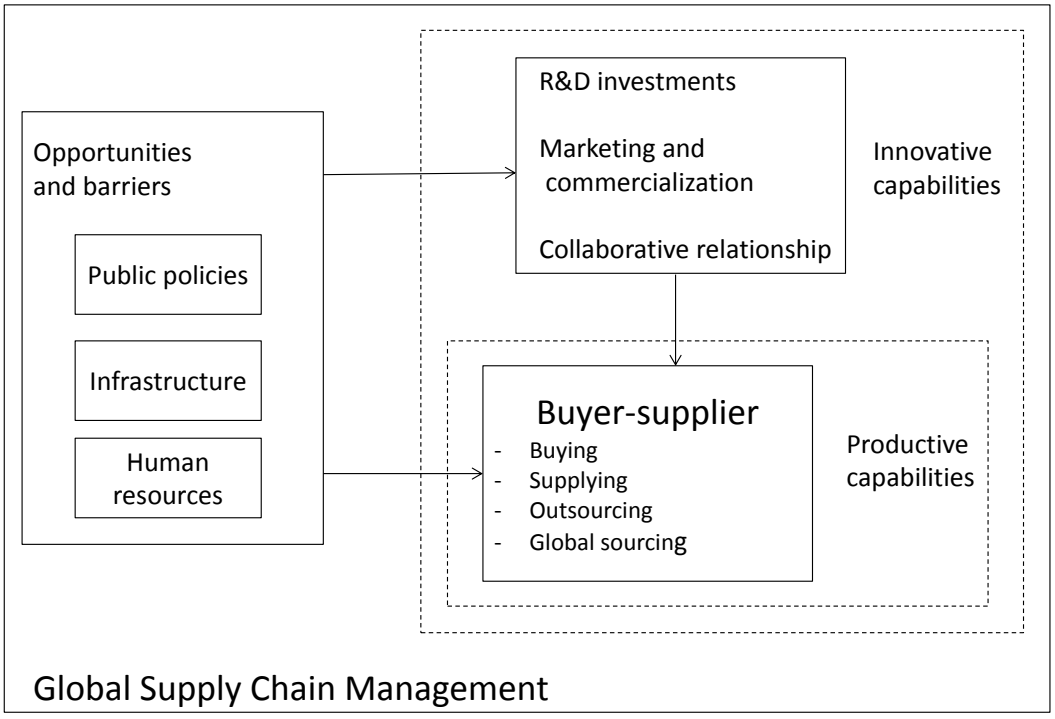
Figure 3: Elements for Brazilian companies to move up in the global chain.



The chain configuration presents that Brazilian companies are basically operating in some specific activity of the semiconductor chain, mainly Design and Back end. The Brazilian operation occurs primarily from dyadic relationships with international companies, which according to Chen and Pauraj (2004) represents the base for the chain operation. The nature of this relationship varies according to the companies' interests and strategies. The Front End operates mainly as buyers, where they have companies such as IBM and Samsung as the suppliers. In the Design Houses activities, it is possible to identify operations as suppliers, offering services as integrated circuit designers, and also global sourcing and outsourcing manufacturing activities for the ones that, beyond the Design, are offering a final product to the market. According to Jiang et al (2010), activities of sourcing, outsourcing and offshoring globally is specifically what characterizes the semiconductor industry as a global chain. Sanders (2010) proposes that been part of a global supply chain represents a mix of risks and opportunities. The three others elements, public policies, human resources and infrastructure, appear in this research both as barriers and opportunities. The actual stage of Brazilian operations is consequence of the opportunities, especially with emphasis on public policies, that from initiatives such as PADIS, CI-Brazil and CEITEC, promoted the leverage of the existing companies. According to Mann (2012) the hole of public policies is not only promote production, but also improve infrastructure and facilitate trade operations to increase a new industry. Compared to the technologically developed countries, and justified by the results of this research, it is possible to induce that the Brazilian companies are already developing production capabilities. They are reaching maturity for what Bell (2007) justifies as capabilities to use and operate given forms of technology in specific configurations. Brazilian companies have capabilities to produce, to develop products and services, to source and outsource activities globally. To really advance in the global semiconductor chain, more opportunities coming from the public policies, improvements in the national infrastructure and proper labor, would allow companies to develop innovative capabilities. This will come with improvements in marketing and commercialization capabilities to search for new market and opportunities, more investment in research and development and by strengthening buyer-supplier operations through long term and collaborative relationships. These can be dethatched as what Mentzer et al. (2001) present as key processes, that in this case must be managed to Brazilian semiconductor industry to move up in the global chain. The four elements highlighted in this research are detailed in the items below

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4.2.1 Chain Features

Currently, Brazil has companies able to operate in the three main activities of the semiconductor supply chain, but at the same time it is not possible to identify business relationship between these companies. The buyer-supplier relationship of each phase is accomplished with international companies. It is clear that it is not possible to discuss this subject as a domestic supply chain. Even leader global companies from countries like Japan, USA and South Korea are sourcing globally, looking for operational efficiency and proximities to potential markets. These elements show that the semiconductor industry really operates as a global chain and are also some of the reasons that make Brazil attractive for this global industry. Brazil is an emerging economy, a large consumer market and has plenty of resources, what represents good elements for Brazilian companies to operate as players in the value chain activities

Project Operation:

There are 22 design houses and 2 training centers in Brazil, what represents good opportunities for researching and development. The barrier here is that few of the design houses are prospecting clients and marketing their services in the international market. Since there is no production scale in Brazil, the only way to expand business is to cooperate with design solutions for international companies. The capability of prospecting international market represents the main barrier to increase the productivity of Brazilian design houses, since infrastructure and humans recourses have been well developed by CEITEC, by public incentives like CI Brazil and by the proximity and relationship of Brazilian design houses with universities and research centers. As an alternative, some Design Houses are operating not only as Designer, but also as Fabless, outsourcing the produtic

Wafer Manufacturing:

The front-end requires high investments and its production is dominated by large companies like Samsung and Hynix. For a new entrant in the semiconductors chain such as Brazil, this value chain activity is not seen as strategic because Brazilian companies will not have the resources, infrastructure and technology needed to become competitive producing wafers. CEITEC has the infrastructure necessary to produce wafers, but uses specific technology and has no prospect of achieving mass scale production needed to boost productivity and competitiveness in the front-end phase. As a public company, CEITEC is doing an important job developing capabilities and represents an important axis of the Brazilian industrial policy towards the semiconductor chain. The private company Six that will start its operation producing wafer with expressive investments and market share strategy may position as an important player in the front-end in the future, as pointed out by Baguete (2012) and Veja (2012). At the moment, the belief is that Brazil should focus on activities of lower risks, lower investments and with higher potential of returns as project and back-end phases.

Packaging and Test:

This important value chain activity, if compared with front-end, requires less investment and represents lower risk for an emerging economy to become competitive in the semiconductor supply chain. Smart and HT Micron are the two companies in Brazil with capacity to operate in the back-end and are focused on selling to the domestic market. This alignment between the great domestic market and the back-end operations represents a potential to develop domestic enterprises and attract foreign capital to move up in the semiconductor chain. The supplier development is critical for these companies, since all raw materials are imported. The back-end companies are subject to the rules imposed by front-end companies like Hinux and Samsung that are the leaders of the semiconductors chain. Collaborative strategies would help these companies to improve buyer-supplier relationship. Considering the lack of maturity of the semiconductor industry in Brazil, these companies still face problems from the limitations of infrastructure and public policies. With a closer attendance to these difficulties and barriers, public institutions may accelerate the improvements to leverage this industry. Another factor in favor of investments in back-end operations is the industry's need for miniaturization of Chips. This will bring more value added, more innovation and new technologies to the back-end activity.

4.2.2 Infrastructure

Infrastructure is detached as great constraint to leverage Brazilian companies in this global chain. Among the traditional problems of infrastructure such as water supply, energy, communication, etc. the most significant ones for the semiconductor chain development in Brazil are related to logistics

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aspects. If we take for example the back-end, for its operations practically 100% of the raw materials and the equipments are imported. The customs clearance in Brazil is slow and can disrupt the efficiency needed by this production chain.

A positive aspect is that as Brazil already has companies operating in this global supply chain and has a clear demand to rethink regulation and import procedures, it is forcing an improvement process in the infrastructure conditions, which may facilitate the future implementation of international sourcing and supplying.

4.2.3 Human Resources

In the short term, Brazil faces a problem with unavailability of engineers and specialized technical labor to operate in the different stages of the semiconductor supply chain. Considering the medium and long term, this situation may be reversed by current initiatives and strategic intentions of the government and private companies. Private companies are seeking to develop labor with support of international institutions and companies. For example, HT Micron has Korean professionals in the implementations of the production plant, Six sent its engineers to be trained in the USA, CEITEC is considered an important training center and a government program called "Science Without Borders" has been sending Brazilian students of technical areas to study and research in recognized international universities.

4.2.4 Public Policies

Considering the risks involved in the semiconductor sector and the need of high investments for the research and production deployment, the support of public policies is a prerequisite to leverage this industry in Brazil. The design houses, for example, that do not have a well-developed commercial area to grow up as a business unit are dependent of CI-Brasil program and its incentives. The Brazilian back-end operation is depended of tax reduction to achieve competitive prices to penetrate in this market. All the Government initiatives, such as PADIS, CI-Brasil and CEITEC that compose the Microelectronics National Program, are suitable for the beginning of the development of the semiconductor industry in Brazil. They have already started to attract companies and investments, developing research and qualifying labor. The barriers faced by the companies that are currently operating in Brazil can help the government guide policies improvements. The opportunities are in encouraging and facilitating trade operations to leverage and enable business transactions. Another point that should be discussed clearly in public policy is the need of having a strategic view of which value chain activities the Brazilian companies should be specialized in.

Another issue that should be discussed is the fact that different production companies and research centers are emerging scattered across the country and cannot share infrastructure, suppliers, and distribution networks. Therefore, the public policies also could stimulate the development and growth of Brazilian technology parks. HT Micron, for example, has been implemented in the Technology Park of São Leopoldo - Tecnosinos, with the objective of collaborating with local companies and the local university - Unisinos. Unisinos has been aligning its strategies to develop resources and research that could support HT Micron and the semiconductor industry.

5. CONCLUSION

Globalization has created the means for companies to create vast networks of suppliers and distributors as they search for the efficiency promised by world class supply chains (Parmigiani et al., 2011). So, Global Supply Chain Management appears as an appropriate background for the configuration of the semiconductors value chain, since it is composed by a network distributed all over the world. Connelly et al. (2013) argue that supply chains have been transformed in recent years by the influence of globalization embedded in internationalization issues largely concerned with a wide range of firm characteristics that determine where, when, and why firms expand overseas. This is the case of semiconductor chain, which counts on the participation of a number of companies from different countries that possess distinguished economic and technological levels, with intensive implementation of outsourcing/offshoring to seek global efficiency.

An industrial police composed by government regulation, political stability and trade agreements represent an important element to leverage a new industry e create conditions to national companies to develop capabilities do operate in a global chain. (Sanders, 2012, Mentzer et al., 2007b). Following these guidelines, Brazilian public policies are stim-

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ulating the national microelectronic industry and there is a group of companies already operating in semiconductor global chain that, in order to be competitive, needs cost efficiency, mass production and flexibility. It was possible to identify that Brazilian companies are operating in all the main phases of the semiconductor chain, especially design and back-end. The front-end is incipient compared to the others because it requires large investment in infrastructures and equipments and it is led by great companies like Samsung and Hynix, which are responsible for the governance of the chain. Brazil has as attraction the size of domestic market for microelectronics. It seems strategic what Brazilian government has been doing, developing public policies to attract investments and enterprises to bring more added value to its national production.

Strategies for buyer-supplier relationships are important for each value chain activity. Some elements cited by Chen and Pauraj (2004) as long-term relationship, communication and involvement, can improve the flow of knowledge and technology, strengthening relationships with business partners and allowing the development of capabilities. According to Ramanathan and Gunasekaran (2014) the success of collaboration, by means of supply chain planning, collaborative decision making and execution, indirectly encourage the participating supply chain members to engage in a long-term collaborative arrangement. In Brazilian case, the design houses are looking for international partners and customers for its services and the back-end is sourcing all its raw material abroad. The wafer for packaging is coming from leaders like Samsung and Hynix. It demonstrates how important is the development of relational capabilities to operate as a competitive player in this global chain.

The participation in the semiconductor global chain has started, but some elements that are constraints to move up in this market were identified. The national infrastructure must be improved and there is also a lack of experienced labor to operate in this industry. It seems opportune that Brazilian government improves its public politics focusing also in the trade facilitation to leverage this economic sector. It is in accordance with Mann (2012), when this author affirms that the improvement of infrastructure can change the environment, promoting international trade and economic growth and also change perspective of supply chain logistics of how a business should organize its operations given the policy environment.

This study presents a map of the current Brazilian situation as a player in the semiconductors global chain, highlighting its opportunities and challenges. The evidences presented in this research demonstrate that Brazilian companies in all different value added activities of the semiconductor global supply chain are developing productive capabilities. According to Figueiredo (2008) it demonstrates that the companies present technology-using skills, knowledge and organizational arrangements to operate goods at given levels of efficiency and given input requirements. The study also presents that to move up in this global chain, innovative capabilities needed to be pursued by the companies. Figueiredo (2008) describes this process as change-generating capability, consisting of technology-changing skills, knowledge, experiences, and organizational arrangements. By investments in innovation and developing marketing and sales skills, the national companies will be able to operate as important players in this global industry.

The results of this paper present two different contributions to the field of operations management, with relevance both for academia and for managerial purpose. For the academia, it contributes with a study of supply chain management in a global perspective, identifying the main capabilities needed by companies from an emerging economy to operate as players and move up in a global chain. According to (Connelly et al., 2013) the amount of research devoted to the global dimensions of supply chain management has been small relative to its practical significance. This study can be used as reference for the development of other industries or other emerging economies that are seeking a position in a global chain. For the managerial purpose, the study contributes with two practical issues related to barriers and opportunities that can corroborate to the advances of the Brazilian strategy to leverage the national semiconductor industry. The first can drive the improvement of the actual industrial policies and the second can allow companies in the process of capabilities' development to achieve a proper competitive advantage level to operate as player in this global chain. Casson (2013) poses that a global supply chain approach helps to highlight elements to support initiatives in international market. These elements are important to seek international competitive standards and also to leverage collaborative relationships for sourcing and outsourcing activities with international partner to go global in the semiconductor chain.

The qualitative exploratory approach used in this study focused on the description of the chain in a wide way and it was limited by secondary data and the interviewees' perception. It is suggested to move forward in the research exploring some gaps that were identified:

i. What is the role of public policies to leverage the trade facilitation, attracting new investments and enterprises to stimulate the growth of the national semiconductors industry?

ii. How is national production developing technological and innovative capabilities to advance in semiconductor chain, supplying the national demand and advancing in the future to global markets?

iii. What strategies must lead to develop proper labor to operate in the different phases of 0the chain?

iv. How can buyer-supplier strategy help the different players of the chain to improve their efficiency needed to operate in this industry?

v. Is the stimulus for the development of technological parks a good way to improve the national production?

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