STRATEGIES FOR AN INTEGRATED CIRCUIT INDUSTRY IN BRAZIL

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Abstract

Electronics has grown in importance in the life of modern man, either as an economic sector or as a changing element for other productive chains. Furthermore, we have also witnessed a tendency for a larger and larger global market share concentrated on two sectors – microelectronics, and in particular integrated circuits, and software. This has led to the identification and prioritization of these sectors by the government during 2003 and they are the base for the formulation of an industrial, technological and external commerce policy together with the pharmacological and capital goods sectors.

The BNDES has, within the scope of actions promoted by the Electronic Competitiveness Forum sponsored by the Ministry of Industry and Foreign Trade, realized a research study aimed at the implementation of an integrated circuit industry in Brazil. The study, made by a consortium of international consultants and followed by and inter-ministerial group composed of representatives from BNDES, the Ministry of Industry and Foreign Trade and the Ministry of Science and Technology, was finalized at the time of the first national debates on a policy for the microelectronic sector. The basic lines of the policy, including the research results, was presented to the Economic Policy Chamber of the Government Council during January 2004.

The present article resumes the objectives which have guided the execution of the study, deals with the used methodology and presents conclusions, in particular on the evaluation of strategies, products, business models and potential investors. The study also identifies the basic requirements needed for any enterprise working with the manufacturing of microelectronic components as well as making recommendations to Brazilian negotiators.

Introduction [1]

The implementation of a new strategy for economic and social development in Brazil constitutes the next step towards the current macroeconomic stabilization objectives. The ingredients of this new strategy are grouped within two sets of initiatives which, when taken in concert, represent the necessary conditions for an increase of the rate of private investment, the promotion of general economic efficiency and entrepreneurial competitiveness. They are: *a*) the reorganization of regulatory measures, especially in infra-structure, aimed at the creation of a stable and foreseeable investment environment; *b*) a decrease of the credit costs, based on a group of taxation, juridical and fiscal measures with the objective of establishing competitive conditions for private investment in Brazil. To these two initiatives we should add the requirement of tools directed at an increase in the volume of external trade, a condition that is absolutely necessary in order to reduce the external vulnerability of the Brazilian economy.

These horizontal actions will, however, produce even better results if combined with actions focused on sectors, or productive chains, capable to respond to the challenge of foreign trade, technological production, innovation and qualified manpower. Finally, they will also lead to the development of competitive advantages within intensive know-how sectors which demand constant research and development (R & D) and which will, in the long run, guarantee a sustainable Brazilian competitiveness.

The semiconductor industry is the source of innovation and technological progress within the diverse branches of the electronic complex and is, therefore, one of the sectors with great potential for the creation of competitive advantages. It is a market which in 2002 reached global sales in the order of 140 Billion USD and which has reached a average annual global growth rate of around 13,5% during the last 25 years. A stable increase is foreseen for the coming five years, with annual growth rates above 12%.

The electronic complex has an importance which often extrapolates its borders, as electronics are present in almost all modern life activities. It has become the basis of other economic sectors such as the control of productive processes, capital goods, agriculture and livestock, commerce, health services, financial markets, engineering projects and mechanics. Furthermore, a great number of traditional products are being rapidly substituted or technologically modernized through the incorporation of electronics, leading to new possible functions.

The spread of electronics was made possible by phenomena such as miniaturization and the supply of increasingly cheaper electronic products. The engine of this development is the total integration of circuits in one single component, the integrated circuit, or the creation, in one minuscule piece of semiconductor material (silicon), of a component which simulates the complete interaction of a whole circuit with hundreds of other components. The large scale integration of integrated circuits has also

[1] Includes parts of texts reproduced with the authorization of the authors, GUTIERREZ, R.M.V., and ALEXANDRE.P.M.V., Brazilian Electronic Complex and Competitiveness, BNDES Setorial, Rio de Janeiron.18, page 165-192, publ. September 2003.

made possible the inclusion of more complex functions for a single component. The "intelligence" of a product is increasingly integrated within its microelectronic components, and the control over a particular final product is more dependent on the control over this sector than over its production/manufacturing.

Brazil is one of the few large world economies that do not possess the process of manufacturing integrated circuits. Furthermore, the manufacturing of electronic goods in the country is, apart from some exceptions, limited to the simple assembling of imported components *(kits)* which only add a small value to the products. The creation of an integrated circuit industry will allow for a reversion of the present situation and will strengthen the electronic chain as it will diminish the dependency on partnerships with firms abroad and component production. Consequently, it will also foment innovations capable of making the products more competitive, create new and qualified jobs, new goods and component projects and new and complex production processes.

Recent international results have shown that countries that have had success in attracting integrated circuits industries are those that have implemented aggressive incentive policies directed at manufacturers. This is mainly due to the large investments needed for minimum infrastructure requirements and the education of human resources that is required for the manufacturing of electronic components. The positive examples have, in a greater or lesser degree, resulted from the adoption of incentivessuch as subsidies, fiscal exemption and financial incentives during a period of around 10 years.

Due to the above mentioned considerations and in the light of recent international experiences the Electronic Competitiveness Forum - which is an initiative of the Ministry of Industry and Foreign Trade and which includes representatives from all government entities interested in the sector as well as representatives from industries and workers - has pointed to the need of a research study on how to attract manufacturers of integrated circuits. An agreement between the Ministry of Industry and Foreign Trade and the BNDES resulted in the contracting, through a public bidding process, of a consortium of consultants – A.T. Kearney, International Data Center (IDC) and Azevedo Sette – for the realization of the research study that was closely followed by an inter-ministerial group formed by the BNDES, the Ministry of Industry and Foreign Trade and the Ministry of Science and Technology.

The research opted to concentrate on how to attract international manufacturers of integrated circuits to Brazil as a consequence of finding the existence of large national barriers that hinder investments in the sector and the need to assure a minimum production that is dependent on global sales. Therefore, at least on a short/medium term, only firms that already have access to the international market will be able to overcome such obstacles. Furthermore, as these firms already possess the necessary production technology, directing the strategy to the attraction of international investors will shorten the time, and minimize the risks, associated with the development of a local production capacity of integrated circuits. This does not imply the exclusion of strategies that include the participation of national private firms or even the Brazilian government.

The study has also taken into consideration the costs and benefits related to the entry of Brazil into the community of countries which manufacture integrated

circuits. The evaluated strategies have placed big global firms at the forefront of technology side by side with mid-size companies that have achieved a mature technology but do not possess the same production capacity.

It is, however, of primordial importance to be clear in relation to the benefits forecast by the implementation of an integrated circuit industry. We must always keep in sight the governmental objectives to increase competitiveness, expand the electronic complex in Brazil and strengthen the process of technological innovation ~~in~~ as well as generate qualified jobs in the high technology sector. The qualitative objectives and the foreseen quantitative impact in the sector's commercial balance will be detailed bellow.

Benefits from an integrated circuits industry

The implementation of an integrated circuits industry in Brazil will have as a first benefit the consolidation of the electronics production chain and thereby fill an important gap in the supply of components. Semiconductors possess the characteristic of being able to be used for final products within the diverse sectors that form the electronic complex, such as computer products, telecommunication equipment, consumer products and automatic industrial processes and medical instruments.

The manufacturing of integrated circuits in the country should also allow for a larger number of goods being produced in Brazil and thereby increase the technological content in products and allow for an increased control of the management of productive chains.

The increase in the productive chain of the electronic complex, fomented by the implementation of an integrated circuits industry, has a well defined meaning if we consider that the assembly of imported *kits* is today the main activity within Brazilian electronic production. The use of locally produced integrated circuits will imply an "opening" of some of the *kits and may lead to the production of other types of components* that today face a narrowing market.

On the other hand, the implementation of integrated circuits projects will form the *basis for the developing of differentiation or innovation of the goods to which they are incorporated* and will have a direct effect on the competitiveness of not only electronic products themselves but also on *final goods from other productive chains which use integrated electronic circuits.* Sectors that can potentially benefit include the automobile industry, household products, the aerospace industry and capital goods.

The local development *of projects for the manufacturing of components and goods* will necessarily imply an increase in qualified jobs. We especially expect *significant investments in the education of the work force* parallel to an increase in the use of Brazilian employees in production activities.

The manufacturing of integrated circuits in Brazil will also have a positive impact on the trade balance within the electronic sector. Apart from the substitution of imported components with locally produced ones we expect that part of the production will be exported as the viability of a local semiconductor production should automatically imply their viability in the international market. It is worth reminding that it is within the component sector, and in the group of integrated circuits in particular, that we find the highest and most persistent commercial deficit, as seen in the following Table 1.

Table 1
Brazil: Commercial Balance Within the Electronic Sector – 1996/2003
(In Millions USD)

Years	1996	1997	1998	1999	2000	2001	2002	2003
Imports	**6.859**	**7.875**	**7.108**	**6.892**	**9.278**	**8.839**	**5.714**	**5.934**
Computers	1.454	1.489	1.529	1.447	1.853	1.715	1.307	1.236
Consumer Electronics	1.037	1.048	623	371	412	361	424	328
Telecommunications	2.087	2.753	2.682	2.711	3.435	3.753	1.511	1.483
Components	2.280	2.585	2.274	2.364	3.578	3.010	2.472	2.888
Integrated Circuits	810	941	867	1.060	1.568	1.445	1.231	1.454
Exports	**1.049**	**1.199**	**1.189**	**1.445**	**2.492**	**2.571**	**2.403**	**2.377**
Computers	281	268	247	337	375	293	164	211
Consumer Electronics	386	411	371	354	434	385	280	254
Telecommunications	154	288	330	494	1.311	1.552	1.547	1.548
Components	229	232	241	261	372	341	412	365
Integrated Circuits	9	8	6	6	42	53	72	32
Balance	**(5.810)**	**(6.676)**	**(5.919)**	**(5.446)**	**(6.786)**	**(6.268)**	**(3.311)**	**(3.557)**
Computers	(1.174)	(1.221)	(1.281)	(1.110)	(1.478)	(1.422)	(1.143)	(1.026)
Consumer Electronics	(651)	(637)	(252)	(17)	22	24	(145)	(74)
Telecommunications	(1.933)	(2.464)	(2.353)	(2.217)	(2.124)	(2.201)	37	66
Components	(2.052)	(2.353)	(2.033)	(2.103)	(3.206)	(2.669)	(2.060)	(2.523)
Integrated Circuits	(801)	(933)	(861)	(1.053)	(1.527)	(1.393)	(1.159)	(1.422)

Source: *Secex (compiled by BNDES*).

It is possible to assert that the figures for foreign trade for the electronic complex *underestimate the real size of the deficit*, even if we include transactions related to integrated circuits in its own column. This is due to the existence of integrated circuits in final goods and in parts and spare parts within computer products as well as integrated modules in imported goods within other sectors, which we have named embedded electronics.

Finally, this set of benefits has the objective of stimulating a medium term *creation of productive activities around new factories of integrated circuits.* The analysis of selected countries has shown that the sustainability of an investment in the manufacturing of integrated circuits is intrinsically linked to the *creation of a microelectronic ecosystem which integrates component manufacturer, suppliers, manufacturers of final goods, project enterprises, education institutions and at least one research center* that will support development activities within the industry and the creation of know-how.

International Experiences

Up to the end of the eighties the majority of the production of integrated circuits came from developed countries such as Japan and the USA. The first half of the following decade was marked by a strong expansion of countries called “Asian Tigers” which started to dominate the production of electronic products. This rapid expansion was the result of long term governmental policies aimed at, among other factors, the increase of the aggregated value of national production. Aggressive policies to attract investments were implemented for that purpose and in order to foment the production of integrated circuits.

Today we find developing countries, with a strong emphasis on exports, amongst the largest producers of integrated circuits. During 2002 we find exports from China (3 Billion USD), Ireland (6 Billion USD), Malaysia (13 Billion USD) and Taiwan (15 billion USD). China, which is also a large importer of integrated circuits, deserves to be praised for the success of its initiatives to attract this industry at such a late date as the nineties.

We can also note that considerable investments have been made in order to keep this industry in the developed countries as for example in the cases of Japan, Germany, the United States and France. One of the identified motives is the classification of the circuit industry by the governments of the named countries a strategic industry. In short , national security reasons have led governments to give incentives to the creation of spearheading technologies that are absorbed by the local industry, and raise the competitiveness of the electronic complex, while fomenting the creation of revenue through *royalties* and exports of goods with high technological content.

It is important to note that all countries that have been able to attract manufacturers of integrated circuits have implemented aggressive programs which have resulted in long term policies that are still in place. Analyzed countries have, in some cases, offered initial incentives in order to attract investments in manufacturing through direct factory investments as shown in Table 2.

The examples in the named Table regarding efforts to attract manufacturers of integrated circuits are not complete, but they do give factual evidence that both developed and developing countries have adopted, or still adopt, active policies in this sector. A detailed research on some of these policies has also been part of the study as it compared different component industry incentives policies in nine different countries. Their experiences demonstrate clearly that if the Brazilian government wants to attract investments to the manufacturing of integrated circuits, aimed at fomenting the competitiveness of the industry, it must put forward an aggressive and competitive policy in relation to competing countries.

Brazil must create and present an aggressive and competitive policy in relation to competing countries, as clearly demonstrated by the other country´s experiences, if it wants to attract investments for the manufacturing of integrated circuits aimed at increasing the competitiveness of the national industry.

Table 2

Examples of Government Incentives to Attract Manufacturers/Firms

Countries	Attracted Manufacturers	Investments (In Billions of USD)	Examples of Government Incentives
Germany (Dresden)	AMD	2,3	Incentives in the order of USD 430 Million (donations and subsidized interest rates)
China	Motorola, NEC STM, Mitsubishi, Phillips	3,1	Joint ventures with Chinese capital (Public and private) of USD 1,5 Billion
South Korea	Hynix Samsung	9,8 9,3	Korean firms financed by Korean government
Ireland	Intel	4,5	Reduction of corporate tax rate to 10%
Israel	Intel	3,5	10 years of tax exemption and donation of up to 30% of initial investment
Taiwan	UMC	n/a	Founded with government participation
Malaysia	Mimos	1,2	Joint venture with Malaysian government (started as a R&D institute)

Source: *Consortium A. T. Kearney/Azevedo Sette/IDC.*

Strategies to Attract the Integrated Circuit Industry

The process of choosing the best options for Brazil's entry into the integrated circuits industry required the mapping of the productive chain and of the existing business models within the semiconductor industry. We also studied the current and future integrated circuits with highest global market demand. As a next step, the study identified the distribution of the industry in several countries and the positioning of the main competitors. This work was necessary in order to guarantee that the proposals for a policy for the integrated circuit industry were in harmony with the investment interests of the main companies/players.

The consultants that were responsible for the research study made direct interviews with manufacturers which enabled them to make a broad inventory regarding their intentions. Their findings were important for the strategic analysis on the most adequate form of entry for Brazil.

The integrated circuits industry is very dynamic and couples the launching of innovative products with progress in the production processes. This allows for constant investment in new factories even in times of weak demand. In Table 3 we present the investments for 2006. As shown, and due to the characteristics of the technological innovation cycle of integrated circuits manufacturing, investments are not limited to firms with a strong brand, product or international presence but are in themselves the precondition for survival in the circuit industry.

An analysis of the value chain of an integrated circuit shows that its production is composed of different stages, such as:

- product conception can be made together with the manufacturer of the final good, if a customized integrated circuit, or by order;
- the integrated circuit project *(design)*
- manufacture including the physical-chemical processing *(stage called front-end);*
- assembly, encapsulating and product testing *(stage called back-end)*; and,
- client service.

Table 3
Planned investments in factories for the manufacturing of integrated circuits up to 2006

	Firms	Countries chosen for new factories	Number F1 [(a)]	Number F2 [(a)]	Number F3 [(a)]	Manufactured Product
1	ACSMC	China		1		Logic Circuits/Other
2	ASMC	China		1		Specialized Wafer Foundry
3	CSMC	China		1		Specialized Wafer Foundry
4	Grace Semi	China		1		Specialized Wafer Foundry
5	Anam	South Korea			1	Specialized Wafer Foundry
6	Dongbu	South Korea			1	Specialized Wafer Foundry
7	Hynix	South Korea	1			Pilot factory
8	Cypress Semi	United States			1	SRAM Memory
9	IBM	United States	1		1	R&D/Logic/Other
10	Infineon	United States			1	DRAM Memory
11	Microchip	United States		1		Microcontrollers (MCU)
12	Micron	United States	1		1	DRAM Memory
13	Atmel	United States and England		1	1	Flash Memory/ Microcontrollers
14	Intel	United States, Israel and Ireland	1		4	Microprocessors (MPU)
15	Elpida	Japan			1	DRAM Memory
16	Fujitsu/AMD	Japan			1	Flash Memory
17	Matsushita	Japan			1	Logic Circuits/Other
18	1st Silicon	Malaysia			1	Specialized Wafer Foundry
19	Angstrem	Russia		1		Integrated Factory (IDM)
20	Au Pte	Singapore			1	Logic Circuits/Other
21	Chartered	Singapore			1	Specialized Wafer Foundry
22	Macronix	Taiwan	1		2	Flash Memory
23	AMD	Germany			1	Microprocessors (MPU)

Source: Consortium A. T. Kearney/Azevedo Sette/IDC.

[(a)] The terms F1, F2 and F3 refer to a terminology which classifies integrated circuit factories according to the National Microelectronics Program and have the following connotation: F1 refers to factories that produce small series of prototypes, has a low end production with investments between 10 Million USD and 100 Million USD; F2 refers to trailing edge technology Factories with investments between 500 Million USD and 1 Billion USD; F3 refers to a leading edge factory with investments above 1 Billion USD.

It is of relevance that the *back-end* memory stage has been produced in Brazil for the last 20 years by Itautec Philco. The *design* has also been made in Brazil during the last five years by Motorola. The *front-end* stage is, however, the stage with the highest value and it does not exist in Brazil.

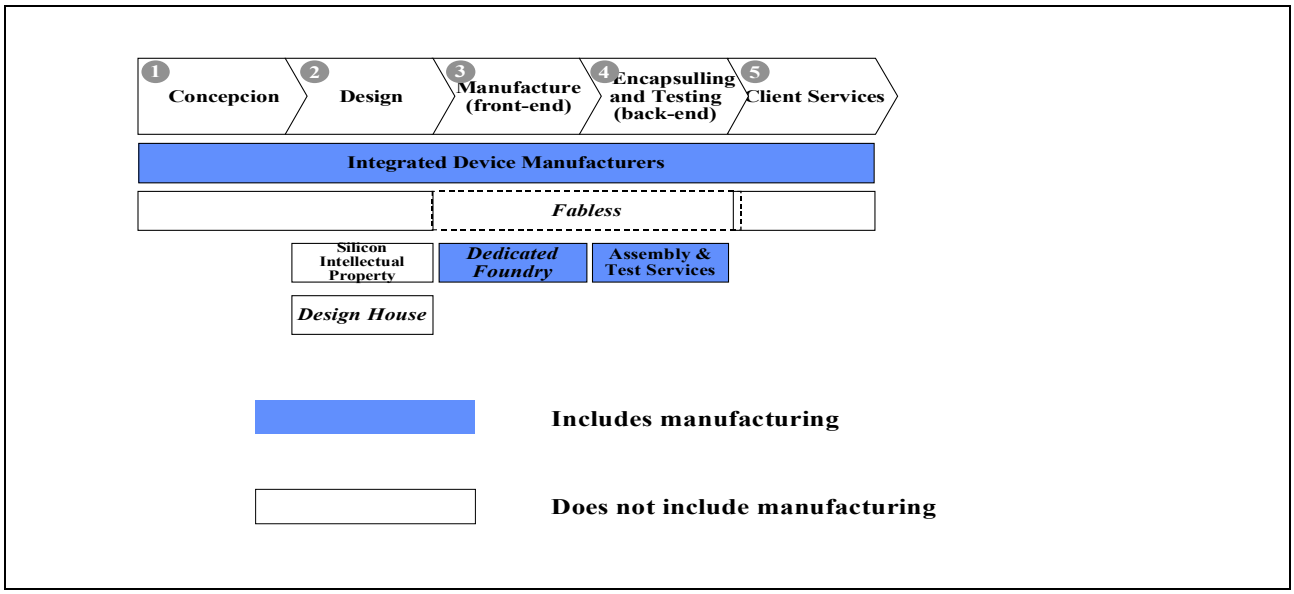
Manufacturers of integrated circuits can be classified according to the type of business or their place in the value chain:

- the integrated manufacturers whose activity stretches from the conception and projecting of the component to the delivery of the product, branded by **the**

manufacturer, to the consumer and which are internationally called integrated device manufacturers;
- firms without factories *(fabless)* which carry out the projecting of the product, label the product and market it to the consumer – manufacturers of final goods -, but outsource the stage of manufacturing to specialized foundries *(dedicated foundries)*;
- the specialized foundries *(dedicated foundries)* which solely perform the product's physical-chemical processing;
- encapsuling firms, which dedicate themselves to the back-end stage;
- independent projecting firms *(design houses)* which are remunerated by the integrated manufacturers;
- intellectual property owners (IP) which develop specific cells and license the project to a third party and are paid through *royalties.*

In the following figure we present an abstract of previously presented information.

Figure 1
Players in the Integrated Circuits Production Chain



Source: ***Consortium A. T. Kearney/Azevedo Sette/IDC.***

There are several types of integrated circuits, each configuring a sub-segment with different dynamic technologies, characteristics and participating markets. The most important current types, in view of their penetration in the international market and their growth perspective, are:

- volatile DRAM memory;
- non-volatile flash memory;
- microprocessors (MPU);
- microcontrollers (MCU);
- customized circuits, including ASIC and SOC;
- traditional analog (SLIC); and
- microelectric mechanical systems (MEMS).

The search for a strategy, or group of strategies, with the objective of maximizing the relation between the benefits and the costs associated to new investments has led to the adoption of a methodology which blended the types of products with the types of businesses, and gave origin to the following list of strategies:

1) leading manufacturers of DRAM memory;
2) 2nd tier manufacturers of DRAM memory;
3) manufacturers of microprocessors (MPU)
4) manufacturers of *flash* memory;
5) manufacturers of microcontrollers (MCU) and customized circuits (ASIC and SOC)
6) leaders of specialized foundries;
7) medium-size specialized foundries;
8) analog manufacturers;
9) MEM manufacturers.

We should note that all the listed strategies refer to the stage of manufacturing of integrated circuits (link 3 in the figure). An analysis of the countries with the strongest circuit industry has shown that countries that have built factories for the manufacturing of chips have gained a mature industry. The study has also shown that, in relation to the other links in the chain, chip manufacturing creates the highest aggregated value as, a) it generates more jobs; b) has the highest rate of invoicing; c) provides better operational margins; and d) attracts the other stages of production.

The nine strategies were evaluated in work-shops composed of government specialists and representatives in order to: *a*) rank strategies in function of the qualitative objectives (strengthening the productive chain, generation of qualified jobs and a strengthening of the competitiveness of the industry and of the technological innovative process) and quantitative (decrease of the trade deficit); and *b*) ponder on the relative importance of the qualitative and quantitative objectives. The evaluated benefits were studied in relation to the costs, technological risks, demand and management and resulted, through the application of a specific method, in two groups of dominating strategies. The first group was related to the quantitative objectives and the second, which was given priority, was related to the qualitative objectives. These two groups can be presented as follows:

- **Manufacturers of Microprocessors/ Leaders amongst specialized foundries (points 3 and 6 respectively of Roster of Strategies)**

This is a sector with only a few companies that produce large quantities and which are at the forefront of the microelectronic frontier. Fixed investments are above 1 billion USD and they need to export more than 70% of the production capacity. This is the reason why this strategy has the biggest impact on the trade balance.

It is important to note that in both strategies the management of the chain is shared with the project link of the fabricated component, which presently is located outside of the country.

- **Manufacturers of Microcontrollers (MCU) and Customized Circuits (ASIC and SOC)/Medium size Specialized Foundries/Manufacturers of MEM (Points 5, 7 and 9 respectively of the Roster of Strategies).**

This sector represents a large number of producing firms, some of them dedicated to specific sectors or market niches. Production is on a smaller scale and uses mature technologies. Investments reach the hundreds of millions of USD and require the exportation of half of the production capacity, when related to the minimum scale and the internal market demand. When compared with the previous group strategy, this group presents a smaller impact on the Ł trade balance, although the Consortium based its analysis on an investment for a single factory. As this group of strategies implies a smaller investment and a broader form of industrial penetration, we should not discard the hypothesis that Brazil could reverse the trade deficit in this sector during a period of time when the country becomes more attractive to new microelectronic investments.

An analysis of the business chain shows that it is strongly connected to the final product to which produced components are incorporated. Brazil has already a large and varied final products industry, both electronic and other. This industry can absorb the use of integrated circuits and can use them for the development and production of new products and applications.

Prioritization of Strategies and Cost-benefit Analysis

It is important to note that the above mentioned strategies 1, 2, 4 and 8, which were not included in any of the strategy groups, do constitute valid alternatives for the establishment of integrated circuits production in Brazil.

Each of the dominating strategies produces different external effects. The products within the first group are mainly aimed at electronic goods, in particular computers, and will have a strong effect on the trade balance due to the need to export them in order to justify investments. However, the growth in the productive chain caused by the implementation of these strategies is restricted.

The products resulting from the second set of dominant strategies have applications in several sectors, not only within electronics, and are fundamental for the differentiation and innovation of final products. The effects on the trade balance are, due to lower investments and required exportation, more modest than those within the first group of strategies. Their main effects are indirect, as they allow for stronger competitiveness for a large amount of final goods.

The presence in Brazil of a diversified and complex industry will be able to maximize the effects of industrial growth, innovation and differentiation for products that use these integrated circuits. This is due to the fact that demand sets the direction for the productive chain in this group of strategies (i.e. through the definition of the specifications for integrated circuits). It is important to point that a large part of the global demand for this type of products comes from multinationals which are also local producers such as big automobile industries or telecommunications equipment manufacturers. If Brazil succeeds in attracting manufacturers of integrated circuits it could result in the development of other Brazilian projects and products.

The first set of strategies would also have a direct effect on the current account , which not only includes the trade balance but also the effects from royalty payments and dividends. It is also obvious that, due to the lack of a single factory of integrated circuits in Brazil, any of the implemented strategies would have a positive impact.

Factors behind investment decisions

The research on Brazilian competitiveness in relation to the implementation of an integrated circuits industry in Brazil was guided by two main objectives: a) the need to overcome the structural gap; and b) the need for a set of incentives that would make Brazil the object of investments aimed at the implementation of an integrated circuits factory.

The first objective deals with the structural, infrastructure, logistics and human resources requirements which Brazil must address in order to become a contender for the production of integrated circuits by the manufacturers. It is common knowledge that this type of industry requires great effectiveness and speed regarding the entry of imports and exportation of products. It is of great importance to point to the fact that this is an *eliminatory* requirement. If the candidate does not meet the requirements it will be eliminated from the round of negotiations with firms that are potentially interested in Brazil.

The second objective is of a *classificatory* nature and it complements the minimum competitiveness requirements with an offer that makes the country the best alternative in relation to the international business climate. We stress the fact that the simple existence of programs, regions or incentives *does not guarantee* that Brazil will be attractive for a type of production that puts high demands on infrastructure, logistics and human resources. Corrections in the structural gap and the concession of incentives must be seen as equally necessary parts of a single set of integrated initiatives that can lead to a strategy for success.

And finally, even though the study was carried out with the objective of attracting investments for the manufacturing stage of integrated circuits, it does not mean that the propitious conditions to this type of investment in Brazil do not apply to the attraction of industries that produce other electronic components or those that work with other stages of the production, namely projecting, encapsuling and testing.

Recommendations to ensure that Brazil overcomes its gaps

The above mentioned study, based on the evaluation of firms within the sector and on the experiences of countries that have succeeded in attracting manufacturers of integrated circuits, has also identified the main structural conditions for manufacturers and grouped them in the following 10 points:

- quick, efficient and problem free customs procedures;
- efficiency in the structures for imports and exports;
- good airport and harbor infrastructures;
- protection of intellectual properties and patent laws;
- expediency in the registration of the intellectual property of integrated circuits topography;
- efficient payment and collection of royalties;
- continuous work on the education and empowerment of qualified manpower;
- availability and confidence regarding public services such as water/sewage, energy and telecommunications;
- availability of land; and
- concession of working visas to foreigners.

These points are considered as critical for investment, since they were obtained through interviews with executives of leading international firms within the sector and reflect both the perception of entrepreneurs and the experiences of several countries that possess factories for the production of integrated circuits. Brazil has a good position in relation to some of the above mentioned points but still has to work on closing the gap in some. The study has also made a detailed analysis of the country in relation to each of the above requirements, together with a set of solutions, and has been delivered to the government which should give priority to the examination of the referred solutions.

Recommendations to make Brazil be the best available alternative

The requirements to make Brazil the best alternative are strongly coupled with the incentives to manufacturers. Just as the recommendations regarding the overcoming of structural gaps, incentives are “built-in” in the international process of attracting manufacturers of closed circuits. Brazil does already possess a few but diverse incentive tools and can, within specific sectors, unite and organize these incentives in order to reinforce its negotiation credibility.

It is important that “packages” of incentives are graded according to the degree and characteristics of the investment and that external spillover effects are included in the equation, such as the strengthening of productive chains, the education of human resources, the creation of qualified jobs, the generation of associated taxes and levies, the possibilities to attract other industries, research and development applications, etc. The extent of the incentives should be directly related to the manufacturer’s willingness to compromise.

The creation of a consistent strategy aimed at overcoming the structural gaps which will allow Brazil to enter into investment negotiations under conditions that are similar to other international examples. They must, however, be preceded by the implementation of an action plan that integrates different approaches that will equally address the needs of the potential investors as well as give clarity and credibility to government policies. However, as proved by the analysis of successful countries, it is

indispensable that all the approaches are placed under one single management agency , responsible for the communication between investors and all spheres of the government.

Conclusion

The conclusions of the study regarding the possible attraction of integrated circuits manufacturers represent an unprecedented effort by the Brazilian government. The work was carried out for eight months, having benefited from an intense participation and interaction of different ministries. The final stage coincided with the selection of the semiconductor industry as a prioritized sector for Federal industry, technology and foreign trade policies. This should imply that Brazil's determination to recreate its industrial map is closely linked to State policy and should therefore be able to count on stable commitments and on a professional implementation.

Brazil is one of the few great economies without a single factory for the production of integrated circuits. The entry into Brazil of an integrated circuits production industry will constitute an important step forward as it will guarantee the real establishment of an electronics industry. The lack of this industry, coupled with a weak local production of other components, reinforces the idea of Brazil as a simple assembler of final goods which has a huge impact on the commercial balance, on industrial innovation in general, on the growth of the productive chain of the electronic complex, on the competitiveness of other sectors and on the country's ability to educate and retain qualified human resources within the fundamental electronic know-how sector.

International experience shows that countries that today possess integrated circuits factories did in fact achieve this through active and aggressive attraction government programs and through diverse fiscal benefits and financial incentives. The reason behind these efforts is the fact that governments, apart from economic factors related to the control of the electronic chain, consider the industry a strategic sector.

The economic analysis of investments in the production of integrated circuits shows that Brazilian fiscal restrictions, coupled with the need for huge investments, require that the attraction program for this industry is broadly based on the assessment of the created benefits. The present study has evaluated the quantitative and qualitative benefits for each of the nine strategies considered as viable and propitious for the entry of Brazil into the group of countries with an integrated circuits industry.

All nine strategies have shown possible positive results related to currency balance, if only for the fact that Brazil does not currently produce any integrated circuits. If, on the one hand, the strategy to attract leading global microprocessor producers and foundries creates the biggest possible positive impact on the trade balance, on the other hand strategies turned towards medium manufacturers such as foundries, producers of microcontrollers, integrated circuits and MEM, imply much lower fiscal costs.

The study has also brought clarity to the fact that qualitative benefits will be maximised through the attraction of a factory of integrated circuits. The most important effect is the growth in the productive chain of the electronic complex, incentives for innovation and the incorporation of technological innovations to final goods in the diverse

sectors with a demand for integrated circuits. Such an effect will increase the international competitiveness of final products, either electronic or not, and will contribute to the creation of qualified jobs in the country. Strategies turned towards medium manufacturers and MEM maximize qualitative benefits, even though all nine studied strategies can create qualitative benefits.

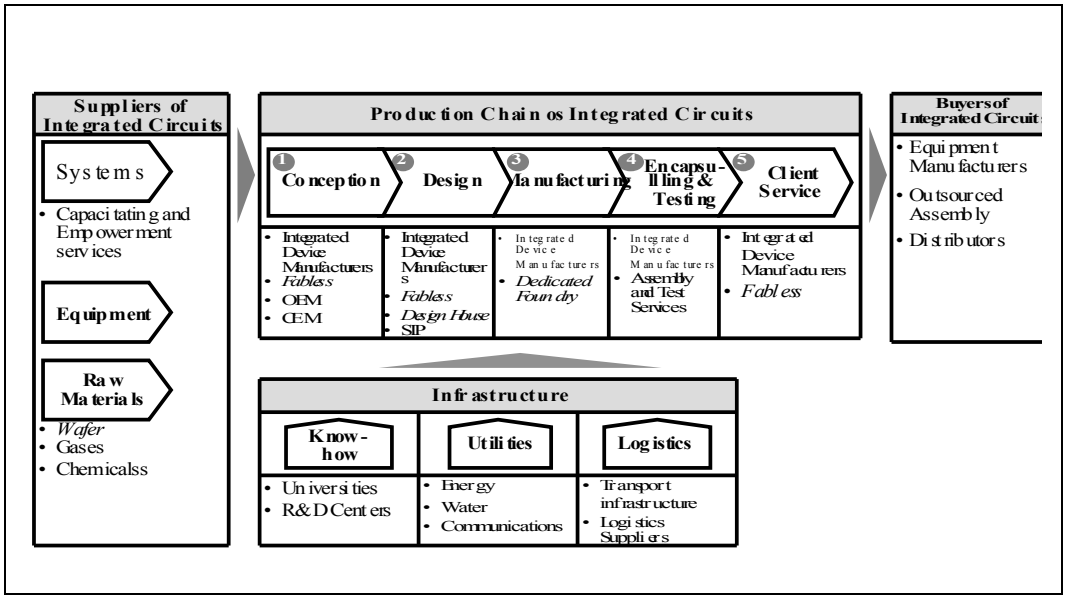
The final evaluation, which will naturally lead to the prioritization of strategies and manufacturers for the process of attracting international investors, cannot be limited by a single effort. The study has also concluded that any strategy for a sustainable process that establishes an electronic chain in Brazil must be directed towards the implementation of not only one but several initiatives within the industry.

It is therefore clear, in spite of the study's specific objectives of attracting investors for the implementation of a factory of integrated circuits, that the long term objective should be the creation of an ecosystem in the country that will integrate the whole electronic chain and its suppliers. We must therefore plan for the existence of a complex composed by firms that represent all the production links within integrated circuits production – projecting, manufacturing including encapsuling and tests – as well as other electronic components such as discrete components. The final goods industry should also be closely linked to the component industry, an industry that uses integrated circuits and which creates new demand for products created by its own projecting activities. And finally, it is necessary to create infrastructures and a network of specific suppliers for the manufacturing of semiconductors and other components.

The study has concluded that the integrated circuits industry, that means ~~and~~ the production of the more sophisticated and important electronic components, puts a strong emphasis on the existence of qualified and quantified infrastructures. It is important to note the importance of water supplies, electricity, transportation and harbors and airports.

Furthermore, the main requirement by a manufacturer of integrated circuits, irrespective of its form of activity or business model, is the availability of qualified manpower with specific qualifications. This will allow for the necessary integration with the specific microelectronic ecosystem structure.

Figure 2
Microelectronic Infrastructure



It is therefore necessary to develop a long term R & D policy which will involve various sectors of the government and to ensure stable resources and adequate management tools. A model that is truly integrated with the business environment must take into account Brazil's comparative advantages and information on R & D initiatives for the qualification of human resources in the area of microelectronics.

Even though the study has the objective of attracting investors for the manufacturing of integrated circuits *(front-end)*, favorable conditions created in Brazil will be equally favorable for the attraction of investments by other types of firms turned towards other stages of production such as projecting and encapsuling and testing.

The presence, in Brazil, of a well known international manufacturer for the production of integrated circuits is paramount if the country is to achieve a presence within the global market. It is also an important step in technological transfer - related to integrated circuits manufacturing – that currently does not exist in Brazil. In order to realize such a project, it is indispensable to create at least one research center that is integrated with the ecosystem and which is a center of reference in relation to know-how and assistance to the named industry.

In short, the implementation of an integrated circuits factory in Brazil must be seen as the first stage of a policy for the electronic complex that combines and maximizes the synergies between industrial and technological policies. An evaluation of the Brazilian situation shows the existence in Brazil of some initiatives related to integrated circuits and prototypes. These initiatives have been taken by Motorola and MCT, the last through its National Microelectronics Program (PNM) that also includes assistance to the Advanced Electronics Technology Center of Excellence (CEITEC). We have also found some other industrial entrepreneurs which deserve to be named such as Itautec Philco and its

encapsuling memory factory and the discrete semiconductor units of Aegis and Semikron. These initiatives can be seen as complementing the current study as they represent important parts of the ecosystem.

We must therefore involve a large number of players in the implementation of a process which will lead to investments and production in the area of integrated circuits. The Federal government as well as state and municipal organs, private initiatives and the academic world have important and relevant roles to play but they need to be coordinated and protected by a decision by the Brazilian State consubstantiated through proper legislation.