INDUSTRIAL COMPLEXES REVISITED

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Victor Prochnik
Master’s Program in Accountancy and
Institute of Economics
Federal University of Rio de Janeiro
E-mail: victor@ie.ufrj.br

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1 INTRODUCTION

This article presents some of the results of a research program on industrial dynamics and sectoral interdependence, developed at the Economics Department of the Universidade Federal do Rio de Janeiro (IE/UFRJ) in the 1980s. The limited disclosure of the work as well as the usefulness of its applications justify this article.\footnote{The record of that professional experience, the first line of research in which this author participated, is another motive. The article thus is also an acknowledgement of the senior lecturers who conducted the various research projects on industrial complexes undertaken at that time and from whom this author has learned considerably: Lia Haguenauer, Fabio S. Erber, Eduardo A. A. Guimarães, Mario L. Possas, José Tavares de Araújo Jr. e Maria da Conceição Tavares. Mention should also be made of Edgardo Lifschitz, who has conducted a similar program in Argentina and three assistant researchers, Marta Xavier Ferreira, Javier Lifschitz and Marcos de Barros Lisboa.}

The research builds on the French concept of Filière to put forth an empirical methodology as well as a theoretical framework. The article describes this methodology, presents the fixed industrial complexes and discusses the alternative theoretical definitions.

One of the features of the methodology herein used is the careful effort to prepare the data for the basic matrix, upon which the delimitation of the industrial complexes is performed; another feature is the application of robust statistical methods instead of the multivariate statistics techniques - the most commonly used method in the specialized literature (Haguenauer et alli, 1984). As a matter of fact, the process of delimitation of industrial complexes uses a simple form of cluster analysis, associated with some arbitrary choices, as more sophisticated mathematical models seem to be insensitive to some qualitative differences among industries.

These are also the features of another method developed independently in Argentina by Edgardo Lifschitz (1989). It is interesting to point out that both Haguenauer and Lifschitz had previously been responsible for the development of the input-output matrixes in their respective countries, and are, thus, used to dealing with micro data.

In the Brazilian research, five major complexes - called macro-complexes hereafter - were singled out: civil construction, machinery and transport equipment, chemicals, textiles and agroindustry. (In addition to these, the paper and printing complex was spotted, since it does not belong to any of the others). In turn, in each of the five macro-complexes mentioned above several micro-complexes were also selected.

There are some subtleties in the study of industrial complexes. For instance, it is important to distinguish the definition of the constitution of a complex (which can be viewed as a dynamic process) from the delimitation (which is done over an inter-sectorial transactions matrix referred to a point in time). Bearing this in mind, the industrial complexes analysis has avoided some common pitfalls as, for instance, measuring the relevance of inter-industrial flows by the amount of
purchases/selling among sectors. Another question refers to the choice of elements that constitute the complexes. Tackling the industrial complexes as an extension of the concept of an industry, considering, thus, only the industries involved, implies giving to the complexes a different interpretation from the one proposed for the national system of innovation, which includes institutions, as well as economic agents.

The industrial complexes analysis was used to study many problems of inter-industrial economics. Technology flows and the diffusion of innovations, the process of industrial diversification, the area of influence of large enterprises, international commerce (an export operation can be viewed as a tie between the productive chain of the exporter country and the productive chain of the importer chain) and industrial and technological policy are some examples. It is also worth mentioning that Brazilian industrial policy has been influenced by the line of research on industrial complexes.

In this context, it is easy to demonstrate the timeliness of the industrial complexes analysis. The interdependence between sectors has been increasing, as the rapid spreading of production re-engineering methods (such as external just-in-time) and information technologies (EDI and Extranets, for instance). Several studies on specific production chains, on cooperation and vertical competition are also found in the literature. In Latin America, for instance, a recent publication by the United Nations Economic Commission for Latin America (UN/ECLAC) is entitled “a development strategy based on natural resource-based production clusters” (ECLAC, 1997). One last example on another issue currently in debate is the process of technological convergence in information technology sectors. All these issues can be best analyzed if there exists a wider set of theoretical tools (concepts, measuring techniques) useful for industrial analysis. The research program on industrial complexes has developed in this direction, and this article critically assesses alternative theoretical definitions of industrial complexes.

In fact, the neo-schumpeterian analysis on industrial complexes does represent an important progress in relation to previous studies on industrial clusters, as the former allows for the introduction of the industrial complexes analysis in this expanding theoretical body. In this vein, it is a fertile interaction. Not only are the analytical principles already developed in the neo-schumpeterian literature useful for studies on industrial complexes such as this, but it also permits the advancement of the current theory.

Araujo Jr. (1985) associates the introduction and diffusion of a radical innovation as the basis of the emergence of an industrial complex. The article presents this new interpretation and refines it, by suggesting that the definition of an industrial complex, resulting from the
evolution of a technological system, is more appropriate than understanding it as an unfolding of a primary innovation.

Erber (1985) defines industrial complex based on two basis: the technological trajectory and technological paradigm. Based on the idea of a paradigm, according to Erber (1985), one can arrive at a definition of industrial complexes, since that idea involves “(...) the idea of innovation clustering” (p.3). These clusters develop through the growth and joint and interdependent transformation of the new industries that produce these innovations. According to the author, his concept of industrial complexes is manageable in an inter-industrial technological flows matrix. As it is well known, DeBresson et alli (1993) have demonstrated that clusters are also formed in these matrixes.

This article builds on Erber (1985) and compares it with Araújo Jr. (1985). It claims the two alternative interpretations are not incompatible. Much to the contrary, they complement each other. Comparing the two should lead to contributions to both theoretical and applied analysis, and the article points to future research programs by contrasting (superposing) technological flows and input-output matrixes.

2 INDUSTRIAL COMPLEXES AS SETS OF PRODUCTIVE CHAINS.

This section presents and discusses the concept of industrial complex put forward in the research study - Industrial complexes in the Brazilian economy - published in Haguenauer et alli (1984). It begins with an instinctive definition of industrial complexes and the presentation of the diagrams of industrial complexes delimited in the same study. Afterwards the development of the concept of industrial complex is presented, followed by the proposed formal definition together with the delimitation criteria employed.

The industrial sectors can be grouped into sets or blocs, in such a way that between the industries of one particular bloc there are strong purchase and sale relationships and between industries belonging to different blocs less intense relationships prevail. Sectors in the same bloc tend to move together, as a result of the interdependence between them in terms of purchases and sales. These sets, or blocs, are called industrial complexes.

The study published in Haguenauer et alli (1984) presents a general conceptual view of industrial complexes, indicates some of its possible applications and, finally, delimits industrial complexes in the Brazilian economy. Five major complexes, called macro-complexes were delimited: civil construction, machinery and transport equipment, chemicals, textiles and agro-industry, in each of which various
microcomplexes were defined. Besides these four, the paper and printing complex, which does not belong to any of the others, was also delimited.

The diagrams are arranged as follows. They correspond to industrial complex delimitation on a matrix of intersectoral transactions constructed on the basis of the tables used to form the input-product matrix for 1975. The delimitation for 1980, resorting to the same method, was carried out later - Lisboa and Prochnik (1989). There also exists a delimitation for more recent matrix but these are even smaller than the previous ones, in terms of rows and columns. It is preferred, therefore, to present the result related to 1975, due to the greater detailing of the corresponding input-product matrix.

As can be seen from the annexed figures, the delimiting method employed leads to industrial complex formation by productive chain and/or segments of interlinked productive chains. This characteristic stems from the criteria of association between sectors, which favors purchase and sale relations of greater value. From the sales point of view, each sector is related to client sectors, starting with the main consumer sector of these sales and continuing in order of decreasing importance, until meeting the criteria that the sum of the sales of the related sectors to the sector of origin, reaches at least 50% of the latter’s sales. The method, therefore, seeks to highlight the links between the successive stages of production, recomposing in this way the productive chains - see Hagenauer et alii (1984) and Lisboa and Prochnik (1989).
MICRO-COMPLEXES IN THE MACHINERY AND TRANSPORT EQUIPMENT COMPLEX

STEEL INDUST.

METALLURGICAL PRODUCTS

OTHER TRANSPORT. INDUST.

AUTO INDUSTRY

MACHINERY AND EQUIPMENT

NON-FERROUS METALS

ELECTRIC

ELECTRONIC
In the figures, the rectangles indicate the sectors considered. Inside the rectangles, there are two numbers. The numbers on the right in the rectangles indicates the sales (all the values are expressed in billions of 1975 cruzeiros) for current consumption of the other sectors considered. In the transaction matrix employed to estimate the industrial complexes, certain sectors were excluded, such as various services and products, self-consumption and the sales of the sectors included for the different categories of final demand (export sales, final consumption, government, capital and stock formation). For these reasons, the sales of the sectors closest to the end of the productive chain are very often less than their purchases of current inputs and even equal to zero. One example, is civil construction, whose product is considered wholly to be part of gross fixed capital formation.

The numbers on the left in the rectangles represent the purchases of current inputs coming from agriculture or industry. Inputs such as energy, capital goods acquisitions, wages, etc. are not considered therefore.

The thick lines unite sectors of a single industrial complex. The dotted lines, in turn, unite sectors which although strongly related between each other in terms of purchases and sales, were allocated to different complexes. The figures above the lines indicate the sales of the supplier sectors to the consumer sector.

An important application of industrial complexes is perhaps the simplest one. The visual observation of Brazilian industrial complexes provides an understanding of the industrial structure of the country and the interrelationships between the sectors, which is not possible through any other method. The significance of expressions in current use, such as intermediary goods, final products or basic goods are immediately visible in the diagrams which show the make-up of the complexes.

Having introduced industrial complexes, it is time to discuss the concept, its delimitation and applications. In Haguenuer et al. (1984), the concept of industrial complex is developed on the basis of the definitions of industry and the productive chain. The definition of industry, in turn, can be derived from the idea of market - “an industry is the set of producers that supply the same market” - or the idea of productive process - an industry “is the set of producers that use similar production methods.” The authors opted for the first concept because it means adopting the market as a link between industries. The intensity of the relationship between two industries,
one as a seller and the other as a buyer, is measured by the volume of business done in the market between the two.

The idea of a productive chain, on the other hand, is associated with the idea of a productive process. In the industrial production process, the raw materials are transformed in successive stages. According to the same text “... the designation ‘productive chain’ can be attributed to the sequence of successive stages, to which the different materials in this transformation process are subject: “In the paper and cellulose chain, for example, wood is the main raw material, cellulose and paper are intermediary sectors and the publishing and printing sectors, paper and cardboard and paper products are the final sectors.

Productive chains form a web of complex interconnections. Some chains join together, such as artificial and synthetic textiles, in the production of clothing (figure 4). Other chains subdivide and their branches split into various directions, as exemplified by the steel chain, the basis for many products in the machinery and transport equipment complex and civil construction (figure 2).

One cannot suppose that this web of chains is spread uniformly throughout the economy. On the contrary, one can see the existence of blocs of industries strongly interlinked and which maintain only weak links with other industries. These blocs are the industrial complexes. They arise from the linking up of the segments that make up interconnected productive chains. “In this respect, the linking up of the market defines a new space - wider than the industry, wider even than the productive chain.” The industrial complex is exactly this new space, created out of the linking up of the market” - Haguenauer et alii (1984).

The industrial complex is thus a space formed by a group of strongly interconnected industries. Considering only this characteristic, a definition of industrial complex is put forward, refined later in the same text: a set of industries that are linked, in a direct or mediatized way, through important relationships of buying and selling goods. - Haguenauer at alli (1984, p. 3)

This initial definition is couched so as to emphasize the cohesion between industries which constitute a complex. The industries of widely used products are the first problem to tackle. Many chains are linked through purchases to the same industries of widely used products. Considering all these ties would mean constituting new complexes - ... the scale of which would deprive them of analytical interest - Haguenauer et alli (1984, p. 4).

In the discussion on the formation of industrial complexes in Argentina, an interesting argument was put forward to explain why it was not necessary to consider the forward linkages of widely used
inputs. Lifschtz (1989) makes a distinction between raw materials and ancillary materials due to the different way they participate in productive processes. Ancillary materials are not mixed with raw materials. They make the productive processes operative, not constituting, therefore, elements capable of indicating the specificities of different industries. For this reason, ancillary raw materials are not included in delimiting industrial complexes.

Another problem is that of capital goods, which are not considered in the matrix of transactions used to delimit industrial complexes. In contrast with industrial inputs, capital goods are not transformed in industrial processing. Acquisitions of capital goods are sporadic and not continuous, as with the other inputs. Many capital goods also are widely used inputs and, as such, come under the previous problem.

Finally, always seeking to constitute complexes made up of sectors with strong links between them, the service sectors, which acquire relatively few industrial inputs, are also not considered. Some service sectors are in the category of suppliers of widely used services (telecommunications, for example). The activities carried out in other service sectors are more related to the use of the goods than with their production (repair services, for example). These are some of the other reasons pointed to for removing services from the matrix used to delimit industrial complexes.

Thus, the definition put forward by Haguenauer et alli (1984) seeks in successive steps, to restrict participation in a complex to industries strongly linked with the other participant industries, while at the same time trying to avoid the occurrence of strong purchase and sale relations between different complexes.

An industrial complex is finally characterized as “a bloc of industries that are interlinked, in a direct or mediated form, through significant relationships of purchase and sale of goods to be later reincorporated and transformed in the production process” - Haguenauer et alli (1984, p.7).

One example which does not fit into the proposed definition is the textile complex and footwear. Despite the similarities between the textile and footwear chains, particularly in terms of the use of the goods, the textile and footwear chains have hardly any links in terms of buying and selling. Haguenauer et alli (1984, p.7) accept the formation of complexes like this: ... the concept should be expanded to include also chains that lead to the same market, which aim at satisfying the same type of economic need.

The conceptualization work in Haguenauer et alli (1984) is directed at reaching an operational definition, based on which it was possible to delimit industrial complexes. The study that will be
discussed in the next section has a different concern, seeking to
anchor theoretically the concept of industrial complex, linking it to
the neo-Schumpeter line of studies.

3 INDUSTRIAL COMPLEXES AS A RESULT OF THE
DEVELOPMENT OF A PRIMARY INNOVATION

In this section, the concept of industrial complex proposed by
Araújo Jr. (1985), which seeks to describe the dynamics of an
industrial complex, is presented. The model is similar, in classifying
the stages and describing some of the characteristics of each stage,
to the product cycle model. The dynamics of a complex comprise
the stages of birth, development, maturity and decline. In the
latter, as will be seen, a possible rejuvenation can restructure the
industrial complex and restart the process.

The model starts from the introduction of a primary innovation.
This innovation, supposing it is commercially successful, marks the
appearance of a new industry or the restructuring on new bases of
an already existing industry.

It is common with a primary innovation for a series of lesser
important secondary innovations to follow, but which taken as a
whole might be of even greater economic importance than the initial
primary innovation. This series of innovations changes the
characteristics of the industry in which it is introduced, leading to
modifications in the productive process and in the quality and
quantity of required inputs as well as the product sold.

The set of changes in the innovating industry extends to
supplier and client industries. For the suppliers of inputs, new
demands are created. From the suppliers of capital goods, new
machinery and equipment are ordered. The client industries, or,
when it is the case, the final consumers, also modify their pattern of
consumption. The industries producing complementary goods and
substitutes are also impacted by the introduction of the primary
innovation.

During the period that follows the introduction of the primary
innovation, the firms in the different industries affected seek to
adjust their structures of production, administrative organization and
business strategy to the new requirements. The author highlights
the role of the leading firms - responsible for introducing and
controlling the primary innovation - in this dynamic. The leading
firms are the ones which have, through their control over the
primary innovation, both the capacity to appropriate the financial
returns coming from its introduction and influence supplier and client
industries, modifying their production methods and management (investment) in its own interests.

They try to follow policies which maximize their appropriation of the results of the innovation, ensuring a greater degree of control over the economic returns and greater command over the development of technical progress. The global strategy of the firms and the strategies for the different business functions are redirected towards these goals. The new reality demands adjustments to the organization of the buying, production, sales, marketing operations etc..

One important aspect, influencing all the business functions is the search for juridical means to ensure greater control over the new operations of the leading companies. Different strategic alternatives, which are not excluding, are implemented to achieve the general objective of maintaining control: patents, product fixing - brands, advertising etc. - industrial secrecy and changes in the research and development policy to increase the flow of secondary innovations.

The research and development strategy undergoes an important change, once the commercial success of a primary innovation is proven. The leading companies modify their R & D priorities and concentrate on projects complementary to the recently introduced primary innovation, defining particular specifications of the goods to be produced with the new technology and seeking secondary innovations which can streamline the processes employed and improve the products manufactured.

Decisions concerning vertical integration and control over sources of raw material, formation of join ventures and setting up of networks, distribution and sales agreements also depend partly on the criteria adopted to maintain the control over exploiting the primary innovation. In this way, companies consolidate their market power against pressure from suppliers, clients and substitutes and hamper the activities of potential imitators.

The series of changes in the products, productive processes, forms of administration, organization of the companies and their tie-ups, intersectoral demands and forms of competition leads to a new structure of interindustrial relations, the new industrial complex.

As time passes, the know-how concerning the new technologies and their possibilities grows. The scheme of interindustrial relations, previously unstable because of the transformations in the industries in the complex, tends to consolidate itself. After the formative stage, the complex attains a state of maturity.

Meanwhile in the industry where the primary innovation occurred the monopoly power of the leading companies tends to
decline with the entry of new competitors, as the primary innovation which gave rise to this power becomes disseminated. When this process reaches more advanced stages, in which the differential profit margins start to be threatened, the goals of the research and development programs of the leading companies are switched. These companies then will be prepared to finance projects which, although not having clearly defined reference factors or even a scheduled data for completion, offer the possibility of obtaining a primary innovation which, thus, allows them to recover the efficiency of their instruments of power - Araújo Jr. (1985).

The result is uncertain, perhaps leading to a new primary innovation - as occurred with the glass industry - or after fruitless attempts, to a reduction in the degree of oligopolization of the industry, as in the classic case of the textile industry. In this adjustment stage, other strategies, such as diversification towards more dynamic complexes, or investment abroad, might constitute ways of transferring capital from the companies with fewer prospects in the complex of origin.

There are important variables in the whole process described above: the strategies of the leading companies and their competitors, the nature of the viable market structures and technologies, ways of obtaining correspondents, government action and new developments in the scientific and technological fields.

Having presented the Araújo Jr. (1985) model of industrial complexes, it is worth making two observations, both concerning the conception of technical change implicit in the models. The first comment about the Araújo Jr. (1985) model concerns its taxonomy of innovations. In classifying the innovations in only two groups, primary innovations and secondary innovations, the author limits the possibilities of configurating complexes in the economic space. An examination of the diagrams presented suggests, for example, the predominance of more intricate configurations. This question is taken up again in Section 5, in which the use of a more refined classification of innovations is proposed.

The second observation concerns the economic determinant of the innovations. Among the determinants of the flow of secondary innovations, derived from the primary innovation, the model only registers the demand pressures for innovations (for example, when the major firms shift the goals of their research projects, according to their business strategies).

Bearing in mind that technical change constitutes the principal feature of modern economic growth, it is important to try and incorporate better the determinants of technical progress in a model of industrial complexes. A model of industrial complexes, therefore,
should seek to capture both the impact of technical progress on the industrial structure and also take into account the inverse direction of this causality, that is to say, the forms through which the economic organization generates and disseminates new technologies. The model of industrial complexes which comes closest to this question is that of Erber (1985) which, for this reason, is presented in the next subsection.

4 INDUSTRIAL COMPLEXES AS AN EXPRESSION OF A TECHNOLOGICAL PARADIGM

Erber tries to specify the idea of industrial complex based on the technological trajectory and technological paradigm concepts. Based on the idea of a paradigm, according to Erber (1985), one can arrive at a definition of industrial complexes, since that idea involves "... the idea of innovation clustering" (p.3). These clusters develop through the growth and joint and interdependent transformation of the new industries that produce these innovations.

The interdependence between the industries that put into effect the innovations resulting from the development of the new technological paradigm comes from the similarities between their technical bases. The most recent example is that of microelectronics and the expansion of digital technology industries.

In the industries where technical progress is intense the rate and direction of the growth has much more to do with the incorporation and dissemination of technical progress than a change in demand. The investment in technology is also an important factor in defining the pattern of competition. Thus, the groups of industries with a similar technical basis, in which the flow of technology between industries results in an interdependent dynamic, can be classified as industrial complexes.

"There seems to exist, therefore, a link between the idea of 'technological paradigm,' with its implications in terms of innovation clustering and cumulative and synergetic processes of learning and the idea of industrial complex defined by its technical basis. In effect, one could go as far as to say that a new technological paradigm is expressed on the productive plane by the formation of an industrial complex" Erber (1985, p.5).

Erber’s proposal (1985) moves towards a greater incorporation of the determinants of the innovations in a model of industrial complexes: "... The analytical framework proposed by Araújo Jr. (1985) could be widened in the light of the questions raised by the idea of a technological paradigm. This, as we have seen, goes back
to the question of the origin of the primary innovation, which the Schumpeter inspired literature frequently omits.” - Erber (1985 p.7) and “... Another question raised by the paradigm idea is that of the role of institutional factors in the development of the paradigm ... - Erber (1985, p.8).

In the continuing study on the concept of industrial complex, Erber’s proposal (1985) seems to offer a new direction to explore, that of incorporating the debate on the intersectoral transfer of technology. In this respect, two questions stand out, the first concerning how these transfers are distributed throughout the economy and what types of complexes are liable to be formed, and the second concerning the relationship between these complexes and the complexes formed by the flow of intersectoral purchases and sales. These questions are discussed in the next sections.

5 CONSIDERATIONS ABOUT THE ARAUJO JR. (1985) MODEL

Araujo Jr.’s (1985) definition restricts the creation of a new industrial complex to the case in which an industry introduces a primary innovation and subordinates other interconnected industries to its growth strategy. Such, however, does not seem to be more often the case.

An example is that of the electronic complex, which graphs do not show, due to the small bearing had at the time of the primary data assessment of industries from which information technologies originate. Sectors such as semiconductors, telecommunications, consumer electronics, computer production, software etc. belong to this complex. In it, a possible attempt of aplying that model would lead to an election of the semiconductors sector as a leading industry, due to the importance its development had for the other sectors - Freeman and Perez (1988).

In spite of the relevance for the electronic complex as a whole, of radical innovations in the semiconductors industry, it may be argued that (i) radical complementary innovations also took place in other industries of the electronic complex, with strong bi-directional interactions with the semiconductors industry; (ii) there are leading enterprises in several sectors of the electronic complex and it would be difficult to hold that the leading enterprises of the semiconductors sector exercise over the rest of them the degree of influence surmised in Araujo Jr. (1985) model and (iii) finally, there are not, in Araujo Jr.’s (1985) model considerations on how different complexes interconnect, which seems to be, observing different studies
developed on this theme, many of which mentioned in the bibliography, a relevant aspect to be discussed in the study of the movement towards the constitution of an industrial complex.

Another instance refers to metal-mechanical technology diffusion of the last century as studied by Rosenberg (1976). In terms of complexes, the study developed by Rosenberg (1976), may be understood as an analysis, although partial, of the metal-mechanic complex formation.

Thus, the present case of the electronic complex, as well as the evolution of the metal-mechanical complex as described by Rosenberg (1976), imply in the introduction and diffusion of complementary innovations in different sectors whose dynamics go beyond the description of Araujo Jr. (1985). In the chemical complex, innovations also arose in clusters, encompassing sets of interrelated sectors. In order to include cases as those mentioned, an alternative is to reach for a generalization of the model described in the same study.

The innovation taxonomy proposed by Freeman and Perez (1988) fulfills such a need. Its authors discriminate four innovation categories, according to the degree of change which they impart into economic systems: incremental innovations, radical innovations, technological systems and technological systems constellations.

Of special interest is the notion of technological system. The mentioned authors affirm that relevant transformations in economic systems arise from the interrelations between innovations. Technological systems are defined as “...constellations of technically and economically interrelated innovations which affect several branches of the productive apparatus.” They comprise several radical innovations and the secondary consequent innovations.

One of the examples pointed out by the authors is that of technological convergence proposed by Rosenberg (1976). As seen, the technological convergence process resulted in the constitution of the metal-mechanical industries complex. Another instance, mentioned in Perez and Freeman (1988) is the cluster of synthetic materials, innovations in petrochemistry and in the corresponding capital goods, introduced between the 1920s & 1950s.

In this taxonomy, technological systems are generated within wider structures, constellations of technological systems. Among technological systems, a few exercised a pervasive impact over the economic structure as a whole, leading to a complete reorganization of the productive system. Such innovations are the foundations for new long term cycles and “... changes involved....affect the cost and
input structure and the production and distribution conditions through the system.‘”- Freeman and Perez (1988, p. 47).

Technological systems constellations constitute new technical economic paradigms. Five paradigms in time between the first industrial revolution and the present days were circumscribed by the authors, each one corresponding to a long term cycle. The organizing principle of these paradigms is the “dynamics of the costs relative structure of all possible production inputs”. Among them, in each paradigm the key input stood out. Steel is the key input of the third long cycle and energy (petroleum in particular) is the key input of the fourth cycle (1930 & 1940’s until 1980 & 1990s).

The pervasive effect of the key inputs tends to reinforce inter-complex links. The distribution of diesel oil or electricity throughout the economy, for instance, decreases the autonomy of the existing complexes. If one seeks to delimit complexes in which the intensity of relationships among component industries are maximized and links with industries from other complexes are minimized, the inputs with a widespread presence should not be considered.

Thus, in the basic matrix used for delimiting the industrial complexes, the lines relative to sales of widely used inputs are zeroed. The Argentinian method, which has been independently conceived, does the same.

Two of the excluded widely used inputs, electric energy and oil, are identified by Freeman and Perez (1988) as key inputs. It can also be noticed that the pervasive effect of key inputs from previous cycles is relatively less strong. Steel still has a strong presence in the machinery and transport equipment and the civil construction complexes. Cotton, a key input in the previous cycle is more restricted, being used almost only in the textile complex today.

Wood, the basic material prior to the industrial revolution has an even more reduced participation in the make-up of industrial products.

At the other extreme, among complexes which are rapidly developing, the electronics complex is pre-eminent. In the year when primary data was first collected, this sector still had a very timid presence in the industrial structure, and was included in the machinery and transport equipment complex. A new delimitation, with a matrix based on more recent data, may change the configuration of this complex significantly.

The graphics thus present a picture of the industrial complexes in 1975. In this picture, technological mature and economically more developed complexes clearly stand out. Complexes in decline or at the beginning of their expansion phases have less weight. Emerging complexes, like electronics, have still not made an appearance.
The conclusion, therefore, is that the 'technological system' category is the most appropriate to describe the evolution of an industrial complex. Radical innovation also forms complexes, although with a more restricted scope. The constellations of technological systems, in turn, tend to cause an opposite effect, the dilution of a complex's autonomy through the widespread use of the key input.

6 INTERINDUSTRIAL ANALYSIS AND TECHNOLOGICAL CHANGE

Finally, it is now the time to discuss the questions raised by Erber's model, preliminarily enunciated in the end of the preceding section. Erber's (1985) proposition of marking the limits of complexes based in a technology flows matrix was not operationalized, "...as much for analytical reasons as for the easiness which input-output matrix offer to empirically delimit the different complexes". Erber (1989, p. 121).

In fact, measurement problems involved in the construction of technology transfer matrix are considerable. In the measurement unit choice there is the option between expenditures in P&D, patents and innovations. The first option is a measurement of innovation process input, and not one of output. The two last options require the construction of weighting systems, since the units do not sum up. In all of these three cases it is difficult to discriminate which are the use sectors and in which proportion are these sectors benefited.

Another class of questions arises from the possible existence of external economies in the R&D processes, hindering measurements of the innovation output. Finally, unlike the purchases and sales flows, technology transations, once accomplished, do not recur - the statistical difficulties of the technological flows matrix building are discussed in greater detail in DeBresson (1990).

Besides several international studies, however, whose evidence allowed Prof. Erber to accomplish the above mentioned propositions, such as Scherer (1982) and Soete (1986), a more comprehensive study offers more conclusive data. DeBresson et alli (1993) estimated a innovation matrix for Italy, using a research undertaken by the censitary agency of that country.

In this research, enterprises were questioned as to having introduced innovations in the preceding three years and, if so, which was the main innovation and the more important use sector for it. Answers obtained allowed the construction of an innovation input-output square matrix, for which a weighting was used in order to allow a comparison between different innovations.
Authors have reached several results, two of which are particularly useful for the discussion of industrial complexes, since they refer to the two questions mentioned in the end of section 4 (these questions were: what type of complexes constitute a technology transfer matrix and how they relate to the complexes formed by a purchase and sales flow matrix).

The first was that the authors were able to form clusters in the innovation matrix. The second refers to the similarity verified between the Italian innovation matrix and the technical coefficients matrix.

DeBresson et alli (1993) showed that the structure of the innovation coefficient matrix has many similar aspects to the Leontief matrix. They have thus shown that there is some relation between innovation patterns and economic exchanges. Such relations may be peculiar to Italy or may be also present in other countries.

The DeBresson et alli study (1993) offers new directions. It is of interest to analyse the relation between clusters formed in the innovations matrix and those formed in the complexes matrix. Research in this direction, one of the objectives of the line of research in industrial complexes, is confluent with the discussion in the previous sub-section on the possible generalization of Araujo Jr's (1985) model. In the case of Erber's (1985) model, the work starts out with an investigation of technological flows and moves on to purchase/sales relationships. In the case of Araujo Jr. (1985), the generalization effort follows a symmetric direction.

7 CONCLUSIONS

The aim of this article is to pose the question of industrial complexes which for many years in Brazil remained stagnant. Besides describing complexes, it was considered relevant to resume the theoretical discussion.

It was suggested the use of a wider innovation taxonomy than the one used by Araujo Jr.(1985). We tried to show that the concept of technological system and of constellations of technological systems is more adequate to describe industrial complexes dynamics.

Another possibility raised by Erber proposition refers to the incorporation of the debate on intersectorial technology transfer. In this direction, the paper of Prof. DeBresson et alli (1993) is of great interest. The existence of a relation between innovation patterns and those of economic exchange, made evident by this author, opens new paths for advancements in the industrial complex concept.
However, it must be noticed that such relations are not direct once further intervenient variables are involved. This discussion is still beginning. Studies along these lines, or in similar ones as those undertaken by Andersen (1994), suggest its feasibility.

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