SPATIAL INDUSTRIAL COMPLEXES: SPATIAL ACESSIBILITY MATRIX AND FUZZY LOGIC APPROACH, MINAS GERAIS - BRAZIL

RODRIGO SIMÕES[1]

1 - Introduction

In the beginning of the 1990s, the continuity of the Brazilian fiscal crisis and the emergence of globalization (commercial and financial liberalization, denationalization and privatization of part of the productive structure, etc.) led the public policy-making for mitigation of regional inequalities – at an integrated national level[2] – to disappear even from the policy-makers' imagination, being replaced by the so-called ideology of local power[3]. As highlighted by CANO[4] (2002:282 *et passim*),"(...) the old tools and institutions concerned with such a subject [reduction of regional disparities] have fade away, giving room to new and modern ideas, as those of local power and competitive region (or city)..." Given the economic situation existing after the 1994 trade opening in Brazil, some scholars of the regional issue have admitted that – due to the (so proclaimed) new foreign insertion of the country – the distinct regions would increasingly search for insertions of their own, by partially disconnecting themselves from the rest of the national territory.

Therefore,"(...) it would be necessary to construct a new national policy on regional development adequate to the new era. Such a proposition should attempt (...) to discover, rediscover, or encourage competitive potentials of distinct Brazilian regions (...) which would face regional disparities"(CANO, 2002:284).

This new regional development policy – following the path of the sectorial-typed industrial policies – started to emphasize mainly on promoting and encouraging the so-called local productive agglomerates – the clustering policies – derived from the Marshallian concepts of specialization and industrial district (MARSHALL, 1920).

Thus, the clustering policies were now seen as the new *panacea* for the solution of regional issues and their implementation would guarantee the improvement of regional potentialities, leading to a better insertion in the national and even the international markets. As highlighted by FIEMG (2000:17):

> "(...) due to the scarcity of capital, fiscal incentives, and lack of autonomy for the state to determine the lines of a macroeconomic policy [it is

---

[1] Professor and Researcher of the Centre for Economic and Regional Development (Cedeplar) at the Federal University of Minas Gerais (UFMG), Brazil.

[2] DINIZ (2002) emphasizes that the single regional policy accomplished at the federal level during the President Fernando Henrique Cardoso administration - *Eixos Nacionais de Integração e Desenvolvimento* (national axes of integration and development), of the Ministry of National Integration – if, on the one hand, has advanced in attempting to connect regional potentialities with the foreign market and create synergic effects between the physical/social infrastructure and productive activities, has, on the other hand, brought about contradictory implications as for the idea of reducing regional inequalities. CANO (2002:281) also asserts that the *Axes…* "(...) were vectors linking productive areas to export harbors (...) merely affecting origin-destination points, doing little or nothing in favor of the larger areas in which they were inserted, (...) virtually ignoring the urban and social problems of the bigger cities involved by the axes".

[3] It does not fall to this paper to evaluate or even discuss local power. For this issue, see BENKO & LIPIETZ (1992), CASTELLS (1996), ALBAGLI (1999), GRANOVETER (1985), ZEITLIN (1992), PUTNAN (1993), VAINER (2000), FERNANDES (2001, among others.

[4] This author, as did PACHECO (1998), also highlights this quite possible national fragmentation, derived from such a process.

necessary] to implement a new socioeconomic development model based on the concept of cluster, [so that] the agglomerative power of a cluster be able to contribute to an increased local competitiveness and the resolution of social and regional inequalities"[the underlining is mine].

On the one hand, if this kind of policy brings advantages by privileging an economically sustained development – without endless allotments by the public sector –, it also brings about serious problems from the viewpoint of national productive integration. Given the variety of sectorial/regional specialties and the need to adapt policies to the specificities of each local[5], the actions may cause the break of unity, leading to a fragmentation of the regional policy and to the "(...) break of important links of the productive chains, many of them in the interregional sphere" (CANO, 2002:283). Moreover, the subnational scales in peripheral countries do not possess the needed fiscal mechanisms for mitigating regional imbalances of the magnitude found in Brazil.

MARTIN (1999) also noted that the emphasis on this new regional policy should be understood from the viewpoint of the specific situation in the central countries in which inter and intraregional imbalances are marginal, i. e., they mostly occur in differences between growth rates and unemployment rates. Countries like Brazil, where regional imbalances are strongly represented in the value of the initial aggregate magnitudes (GDP, infrastructure endowment, etc.), need the mediation between the mere abandonment of the traditional "policies of assisted areas" and the adoption of "picking winners strategies", such as those, proclaimed by the clustering policies[6]. As stated by MARTIN (1999:9 *et passim*), "(...) cluster policy focuses on areas of potential and success rather than on 'problem areas' of decline. [It] abandons 'assisted area' approach for one based on 'local growth nodes'". Moreover, he emphasizes that "(...) cluster policy may do nothing for depressed localities and may accentuate uneven development within regions".

Therefore, mediation between traditional regional policies – fiscal incentives, subsidies, etc. – and "modern" policies for the identification and incentive of regional competitive advantages should necessarily undergo that which DAVID (1999) calls "(...) empirical and analytical efforts to discern and quantify the variety and heterogeneity of interdependent processes which conform the geographic dimensions of regional development". As SUZIGAN (2001:37) highlights in his *Agenda de Pesquisa Aplicada* (agenda for applied research) on industrial agglomerations in Brazil, producing empirical evidence on productive agglomerations should be intensified but, more than that, he stresses that cluster policies are not *panacea* and "(…) more general problems of regional economic imbalances should be treated by means of regional and national policies. Industrial agglomeration studies should only aim at empirically understanding and evaluating the industrial organization in the geographic space"

In this sense, when analyzing regional development policies, PARR (1999:1264) underlined that - despite the severe criticism of the so-called growth-pole strategies - "(...) echoes of growth-pole strategies are still be heard (mostly) the arguments in favour of technopolis-based development and, most recently, regional industrial clusters" [the underlining is mine].

Thus, to identify spatially productive chains and their porosities can still be considered a relevant "input of regional policy", as it allows the selection of industrial

---

[5] As MARTIN (1999:11) recalls: "Seeking to imitate or replicate existing clusters elsewhere is unlikely to be successful: policy models do not travel well".

[6] It is not our intent to appraise cluster policies here as an industrial and technological policy. For a careful evaluation of the literature on the theme in Brazil, see SUZIGAN (2001) and CASSIOLATO (2000).

complexes and productive sequences with possible incentives, by taking advantage of their regional potentialities and mainly their linkages with the national economy. As PARR (1999:1250) states, in the regional development policies "(...) there was frequently no attempt at sectorial selectivity (to be) encouraged ".

This paper attempts to contribute to this debate, by means of a discussion of clusters adopting an approach other than the Marshallian one. Recovering Perroux's concepts of economic poles and industrial complexes in space, we propose a multisectorial analysis of industrial location, by mounting a methodological proposal of spatial interpretation of input-output matrices, building up: 1) a matrix of spatial friction coefficients and, using this results, 2) spatial industrial complexes to State of Minas Gerais – Brazil in 1980 and 1996.

2 – Spatial Industrial Complexes: identification methodologies

The major problem of the polarization theory, as a strategy for development and mitigation of regional imbalances – as stated by LEMOS (1988) – is the need to reveal, how interindustrial relations may generate spatial external economies which, in turn, may characterize the leading dynamic industries in the growth process. That amounts to say that there is no guarantee *a priori* that the induced effects of propulsive industry will be rebated and materialized in the very space – either in its immediate hinterland or in the regional or even in the country – and even that, instead of poles, it will bear productive enclaves disconnected from the regional/local situation. As PARR (1999:1210) points out "(...) it becomes more complicated when a propulsive industry is established at a planned pole in the expectation that will make the region locationally attractive to firms which are related to this industry in terms of backward and forward linkages".

This author is even more explicit when analyzing the literature on economic poles:

> "(...) numerous studies were undertaken, involving the structure of input-output linkages of propulsive sectors. But these were either carried out without respect to space or, equally, unrealistically, with the expectation that linkage in economic space would automatically be accompanied by linkage in geographical space, either at the planned pole or else where within the region". (PARR, 1999: 1251).

Therefore, despite stressing the relevance of intersectoral and polarized space relations – which Boudeville changes into a concrete region – the polarization theories do not present mechanisms guaranteeing such a linkage. Furthermore, methodologies assuring local impacts of a propulsive unit are not found in the theory.

Before assessing the possibilities of considering strictly spatial aspects in mounting industrial complexes – so that groups of interrelated industries become growth poles, through their concentration in a complementary economic space – it is worth presenting a brief analysis of some works already considered as classic in the regional literature whose main concern is focused on the relation of space *vs.* intersectoral relations.

The major issue posed is how to identify, within the actual socioeconomic structure, what would be, in Hirschman's words, the efficient and appropriate sequences of incentives and investment – for Perroux, the propulsive industries (sectors) – capable to overcome the economic lag of a given region through its capacity of generating linkage demands. The classic methodology for identifying such propulsive sectors was proposed by RASMUSSEN (1956) and adapted by CHENERY & WATANABE (1958) based Leontief's matrices, and is called the identification methodology of key-sectors.

In the beginning of the 1990s, an approach called "Field of Influence" (FI) was developed by SONIS & HEWINGS (1991), which reinforced the methodologies of identification of major sectors in the economic structure, by allowing identifying what would be the technical coefficients which – once modified – caused a greater impact in the system as a whole. Based on the FI methodology, a technical coefficient hierarchy can be developed with which more sensitive sectorial relations may be identified "(...) meaning that they will be responsible for the greatest induced impacts on the economy as a whole" (HADDAD, 1995). More recently, SONIS *et al.* (1997) developed a methodology for the analysis of interactions and interdependencies between regions, which uses interregional matrices that allow the ranking of existing synergies between economic linkage subsystems previously selected. Therefore, it is possible to structure "(...) the contribution of each interaction to the total production in the productive process of each region" (GUILHOTO, 1999:11)[7]. There is no need to go any further in discussing key sectors and correlated developments. It is only worth mentioning the relevance of determining those sectors with greater linkage and impact power on the economy[8].

As stated by ABLAS & CZAMANSKI (1982:207-9), one of the main issues of concern for regional planners "(...) refers to the choice of an adequate composition of industries liable to be implemented in a certain area", and among the various possible criteria – capital-labor relation, volume of capital, capital-output relation, average wage level, skilled labor, etc. – the most remarkable one is "(...) the magnitude of activity multipliers to be created locally". The importance attributed to investment multipliers and government expenditure

> "(...) comes from the understanding that government resources [direct or indirect, as incentives] can not bear the whole burden of investment to implement a set of activities whose resources should be preferentially channeled to key sectors of the productive structure where secondary effects are significant" (ABLAS & CZAMANSKI,1982:209).

Therefore, sectors or groups of sectors should be identified in the productive structure of each region that may play the role of a Perrouxian growth pole.

Even if we are reproducing here the arguments of all authors on the subject, it should be clear that all of them use the same intuitive notion of industrial complex, which is similar to the definition of cluster as defined by Ablas & Czamanski[9]. Their difference, however, is related to the definition of 1) which are the relevant economic flows; and 2) what is the methodology for mounting such complexes? What we are interested here is to assess more carefully which are precisely the methodologies introducing – explicitly or implicitly – the spatial issue together with intersectorial relations or spatial industrial complexes.

Thus, for the purpose of our study, we judge it more adequate to establish three distinct groups of analysis directly linked to the issue of identification and appraisal of

---

[7] We are not discussing here the Field of Influence and Decomposition methodologies. For further details, see SONIS & HEWINGS (1991) and GUILHOTO (1999).

[8] Based on these original works, several authors have attempted to propose alternative methodologies for identifying key sectors. For a review on the literature and a proposal of identification of downstream key sectors, see BEYERS (1976). For a discussion on sectorial linkages and key sectors in the recent Brazilian economy, see CROCOMO & GUILHOTO (1998), CLEMENTS & ROSSI (1992), GUILHOTO (1992), (1994).

[9] An industrial complex corresponds to "(...) a group of industries in which ties expressed by flows of goods and services between them are stronger than the existing linkages with other sectors in the economy" (PEREIRA, 1985:49-50).

industrial complexes in space: 1) sectorial empirical studies; 2) ex-post or ex-ante spatial analyses; and 3) methodological contributions.

The group of empirical studies include the works of ISARD (1960), PAELINCK (1970), KARASKA (1969), STEED (1970) and HODGE & WONG (not dated) and are related to a specific kind of approach: the sector(s) to be analyzed is (are) defined *a priori* and an attempt is made to produce normative deliberations designed for implementing such a complex in a given space. This is the case of works such as those of Isard (which studies a possible implementation of petrochemical sector in Puerto Rico), Hodge (ores in Canada), Karaska (paper e cardboard in Philadelphia/USA), etc. In Brazil, a pioneer work in this field is that of LEME (1975), which analyzes the optimum location for a paper industrial plant and assesses what would be the sector's purchase and sales linkages in space. The work of GHOSH & CHAKRAVARTI (1970) is similar, the concern of which is more general though. By using techniques of linear programming combined with input-output analysis, it attempts to determine optimum locational choices for industrial complexes whose implementation is under way, whatever the sectors are to be chosen. These works can not be compared to the other works as they aim at different purposes, i. e., they are not concerned with establishing criteria for the definition of sets of interrelated industries/sectors which, by means of a multiplier effect, may cause a push towards regional development.

The second group of studies is broader and internally differentiated. Three distinct approaches can be verified among them. The first, found in the works of KOLOSOVSKIY (1961) and CHADORNET (1965) is uniquely descriptive, drawing conclusions from qualitative analyses of information obtained from spatial industrial agglomerations, i. e., they initially delimit the space and then try and verify whether there are spatial clusters.

The second approach starts from the selection of a specific region and use of matrices with regionalized technical coefficients[10] in order to analyze intersectorial relations and the identification of industrial complexes, being the works of NORCLIFFE & KOTSEFF (1980) and Ó´hULLACHÁIN (1984) the most representative ones.

NORCLIFFE & KOTSEFF (1980) perform an intersectorial analysis by using the graph method for a specific region – Ontario, Canada – in an attempt to identify locational similarity patterns among the sectors with significant technical relations.

The work of Ó´hULLACHÁIN (1984), in turn, recovers the use of the Principal Component Analysis (PCA)[11] for the identification of industrial complexes, by applying an adaptation of this technique to the industrial structure of the state of Washington, USA.

[10] There is an extensive literature on regionalization of national technical coefficients and application of regional multipliers, among them Strout's multiregional model, Leontieff's intranational model, Chenery's model etc; being Isard's interregional model the most known and applied. For a survey of classic models and interregional matrices, see RIEFLER (1973). For a discussion on implementation of multiregional models, see POLENSKE (1972). FLEGG *et al.* (1994) present an excellent review of the use of locational quotients in adapting national technical coefficients for the construction of regional matrices. Several studies use this procedure for the construction of input-output regional matrices in Brazil. See SILVA & LOCATELLI (1990) (1991), HADDAD (1995), FERNANDES (1997), AZZONI *et al* .(2002). RICHARDSON (1978) shows the conditions for the existence of a real regional input-output matrix, i. e., the one which is not an attempt to regionalize national coefficients, but to capture interregional flows, establishing the real intersectorial flows among the different intranational spaces. The regional models of computable general equilibrium are advancing in the solution of this problem. See HADDAD (1999).

[11] There is no use to explicit here the methodology of principal components. Knowing that the method consists in the resolution of $\boldsymbol{a}_p$ in equation $(\boldsymbol{Z}' \boldsymbol{Z} - \lambda_p \boldsymbol{I})\, \boldsymbol{a}_p = 0$, where λ_p´s are the characteristic roots $\boldsymbol{Z}' \boldsymbol{Z}$ and the $\boldsymbol{a}_p$´s their respective autovectors. See MANLY (1986).

According to this author, the literature concerned with identifying methodologies of industrial agglomerations is mainly concentrated in vertical relations, i. e., those which are a result of spatial agglomerations of successive productive stages with little or no attention to the role of intersectorial complementarity that would in turn reflect the locational attraction factors among correlated industries using the same source of raw materials.[12] The methodology proposed by Ó´hULLACHÁIN (1984) shows an estimate of a set of principal components based on two matrices of intermediate and intersectorial purchase and sales coefficients, **K** ($k_{ij} = x_{ij} / X_j$) and **T** ($t_{ij} = x_{ij} / X_i$), respectively. The PCA with matrix **K** (attributes) provokes the clustering of sectors with similar intersectorial purchasing profile; with matrix **T** (individuals), it clusters sectors with analogous intersectorial sales profile. The identification of sectorial combinations – the industrial complexes based on the PCA – is obtained by ranking the clusters found into six categories, which vary from:

> " (…) components that have high loadings on sectors with similar physical inputs (or outputs) obtained from a small number of sectors; […] components that have high loadings on industries with similar physical inputs (or outputs) obtained from a wide variety of sectors […] and components that have no sectors above the threshold level loading on them.(Ó´hULLACHÁIN, 1984:424-425)".

Once industrial clusters are identified, consistency of the methodology is tested, by estimating the indices of intersectorial linkages within the clusters (CHENERY & WATANABE, 1958). The results found identify similar purchase and sales intersectorial patterns in the region in question.

The third approach, found in the works ROEPKE *et al.* (1974), CZAMANSKI (1974), STREIT (1969), BERGSMAN *et al.* (1972) among others, is an attempt to identify intersectorial linkages among industries or industrial groups – clusters – and then infer the configuration of such groups in the real regional space. We shall discuss here the major aspects, which are closer to the subject of this paper.

The work of STREIT (1969)[13] uses a combination of two sets of coefficients in order to mount the complexes. First of all, it establishes the geographic association between pairs of industries, by using a classic index found in the literature of regional economics. Formally, $r_{ij} = \dfrac{\operatorname{cov}(x_{ig}, x_{jg})}{\delta\, x_{ig}, x_{jg}}$, where x is employment; i,j is any pair of industries; and g is a given region. Secondly, it proposes a coefficient of intermediate flow intensity. Formally described as

$$L_{ij} = L_{ji} = \frac{1}{4}\left[O_{ij}\left(\frac{1}{\sum_i O_i} + \frac{1}{\sum_i I_J}\right) + O_{ji}\left(\frac{1}{\sum_i O_j} + \frac{1}{\sum_i I_i}\right)\right]$$

where O_{ij}, O_{ji} are sales from i to j, and from j to i; O_i, O_j are the outputs of i and j; I_i, I_j are total inputs used by i and j.

[12] LATHAN (1976) and HARRIGAN (1982) criticize the use of PCA for the identification of industrial complexes with the argument that this technique is "(...) inappropriate because it fails to include in the grouped industries that industry (or industries) which is the source of complementarity" (Ó´hULLACHÁIN, 1984: 423).

[13] Not only this work but also all of the others in this subset were applied to distinct realities. It is not our intent to show the results of such applications. For further details, see ABLAS & CZAMANSKI (1982:214-229).

From these equations, an industrial complex is defined by the significance of de $L_{ij,ji}$ e $r_{ij,ji}$, i.e., the pairs of industries are considered complex if $r_{ij,ji}$ is higher than a boundary established a priori and if $L_{ij}>(n\sum_j L_{ij})^{-1}$ or $L_{ji}>(n\sum_i L_{ji})^{-1}$.

The works of BERGSMAN *et al.* (1972) and ROEPKE *et al.* (1974) are similar, as they use a combination of multivariate analysis. The work of ROEPKE *et al* (1974) is slightly different as it uses three distinct and complementary factorial analyses: the first based on a matrix symmetrical to that of technical coefficients, $\boldsymbol{B}=\boldsymbol{A}+\boldsymbol{A}'$; the second and the third are accomplished based on the columns and lines of the flow matrix. Thus, an attempt is made to verify whether there are similar purchase and sales patterns and total relations, determining factorial scores, which would define industrial complexes[14].

CZAMANZKI (1974) makes use of an analysis slightly more elaborated, by conjoining multivariate analysis and triangulation of matrices. Firstly, four coefficients are determined that describe the relative importance of flows – backwards and forwards – in each sector. Formally: $a_{ij}=\frac{x_{ij}}{\sum_j x_{ij}}$; $a_{ji}=\frac{x_{ji}}{\sum_i x_{ji}}$; $b_{ij}=\frac{x_{ij}}{\sum_i x_{ij}}$; $b_{ji}=\frac{x_{ji}}{\sum_j x_{ji}}$

where x_{ij} is the flow of goods and services from i to j ; $a_{ij,ji}$ is the backward relative importance and $b_{ij,ji}$ is the forward relative importance.

Based on coefficients a and b it is possible to construct a triangular matrix E, defined as:

$$e_{ij}= \max(a_{ij},a_{ji},b_{ij},b_{ji}) \quad \forall \quad i>j$$

$$e_{ij}= 0 \quad \forall \quad j>i$$

Therefore, the clusters are identified 1) by using a column vector e_i $(i=1,2,...,n)$ $\forall$ n sectors, an already classic procedure of triangulation of matrices[15]; 2) by taking account of all cluster relative linkages – instead of the greatest linkage – defined by i; 3) by using a similarity criterion between total profiles in an attempt to capture the analytically relevant linkages. Formalized as follows, the indexes $\boldsymbol{r(a_{ik}.a_{il}), r(b_{ki}.b_{li}), r(a_{ik}.b_{li}),r(b_{ki}.a_{il})}$ describe the similarity between the purchase and sales structure of two industries. As stated by ABLAS & CZAMANSKI (1982:220):

> "(...) a high coefficient $r(a_{ik}.a_{il})$ suggests that the other industries, k e l, have similar input structures or obtain their supplies from the same producers. A high coefficient $r(b_{ki}.b_{li})$ means that the two industries, k e l, offer their products to a similar set of consumers. A high coefficient $r(a_{ik}.b_{li})$ implies that suppliers of industry k are consumers of products from l".

Then, an intercorrelation matrix is mounted ***(R)*** defining the covariance matrix. Formally stated as $\boldsymbol{r_{lk} = r_{kl} = \max [r(a_{ik}.a_{il}), r(b_{ki}.b_{li}), r(a_{ik}.b_{li}),r(b_{ki}.a_{il})]}$.

Thus, sectorial links were assessed through the characteristic matrices (λ) of ***R***, being the relations between these characteristic matrices and the trace of matrix R an index of association *(i)* which offers an "(...) aggregate measure of the strength of linkages uniting the remaining industries in matrix ***R***, with a large C_i suggesting the existence of an identifiable 'cluster'"(ABLAS & CZAMANSKI, 1982:221).

[14] For a factorial analysis, see ISARD (1960).
[15] See HADDAD *et al.* (1989).

Formalizing, we have $C_i = \frac{\lambda_i}{t_r R}.100$. After identifying the clusters, the authors attempted to find out whether they bear spatial industrial complexes. For this, they propose a regression model whose standardized coefficients would produce a symmetrical matrix defining complexes in space. Formalizing, we have:

$$E_{ik} = a\,p_k + \varepsilon_{ik}$$

$$\varepsilon_{ik} = \beta_o + \beta_i E_{jk}$$

with *i = 1,...,n and k = 1,...,m*; where E_{ik} is employment in industry *i* in region *k*; P_k is a proxy of an index of urban equipment in region *k*; ε_{ik} is the form given to the residue; a, β_o, β_i are parameters.

The work of FINES (1973), introducing the concept of *filières* – nonsignificant differences in the face of the clustering concept – proposes the use of national technical coefficients and the identification of chains of *filières* which, by means of its existence or absence in each region *k*, would make it possible the analysis of the regional industrial structure.

SILVA & LOCATELLI (1990 and 1991) propose a different resolution. In the first place, they present the industrial complexes in the Brazilian economy as a whole[16], by combining it with an analysis attempting to verify the regional pattern of such national industrial complexes through an investigation of the macrolocational determinants of the sectors within the complexes by means of sectorial econometric models. Formally, the model of locational guidance presents the following specification: $VP_{ij} = b_o + b_1 TM_j + b_2 ESP_j + b_3 EEA_j + b_4 Y_{pcj} + b_5 OI_{ij}$ where VP_{ij} is the value of industry *i* output in region *j*; TM_j is the size of market for *i* in *j* ; ESP_j is the degree of regional specialization of *i*, measured by the participation of the output of *i* in total output of *j* ; EEA_j are the agglomeration economies of *j* , measured by the participation of the output of *i* in total output of *j* ; Y_{pcj} is the size of the market effective demand *j*, measured by the domestic income per capita in *j* ; OI_{ij} is the input supply for *i* in *j*, represented by the production of basic raw material of the complex *j*. With such a model, the major regionally locational guidelines of each complex may be verified.

Secondly, they work with the tool of input-output matrices with regional coefficients, estimated based on primary data from economic censuses, i. e., they estimate a regional input-output matrix meaning that the coefficients, flows, etc., represent the internal productive structure of each of these regions and their interconnections. Based on the construction of these matrices, the regional industrial complexes are mounted, by using the methodology proposed by HAGUENAUER *et al.* (1984).

Finally, the two methodologies are confronted so as to infer qualitatively the guidance of sectors with the best potentials for regional development.

The works of the third group – relevant methodological contributions – are characterized by explicitly showing concern with spatial aspects. The work of RICHTER (1969) attempts to explain the geographic association between industries by measuring the flows of goods and services between them. For this, it estimates correlation

[16] Using the methodology of HAGUENAUER *et al.* (1984), which in their opinion "(...) offer the best results in the studies developed for the Brazilian economy" (SILVA & LOCATELLI, 1991:2). SALVATO (1991) uses the same procedure and concludes that the resolutions based on this methodology are convergent.

coefficients among all pairs of industries. Formally stated as $P_{ij} = \frac{x_{ij}}{x_j}$ where P_{ij} is the coefficient of employment, using a regression model; x_{ij} is employment in industry *i* in region *j*; x_j is total industrial employment in *j*.

From the regression, pairs of industries similar in their locational pattern are taken out. From then on, spatial correlation coefficients between each industry and all sectors linked to purchase and sales linkages are estimated, without attempting to identify the cluster and specific complexes. A conclusion is drawn that industrial linkages contribute to the spatial location by means of the generation of agglomerative forces.

KLAASSEN (1967) and VAN WICKEREN (1972) show a model, which permits to estimate the regional multiplier effects of purchases and sales. First of all, they define the power of locational attraction exerted by the market and input sources. Formalizing, we have $\lambda_d = \left(t_d + \sum_l t_l \beta_{kl}\right)^{-td}$; $\lambda_{lk} = \frac{t_l \beta_{kl}}{t_d + \sum_l t_l \beta_{kl}}$ with *l=1,...,n*; where λ_d is the attraction coefficient by the demand side; λ_{lk} is the coefficient of attraction by the supply side; β_{kl} is the technical coefficient of inputs *k* by unit of output *l*; t_d is the cost of space friction (transport, communications, etc.); t_l is cost of space friction by unit of input *l*. Indices λ_d and λ_{lk} represent total space friction costs by unit of operation level of *k*. Assuming that transport costs are irrelevant, λ is derived by means of the following regression: $\psi_{kj} = \lambda_d \delta_{kj} + \sum_l \lambda_{lk} \psi_{lj}$ subject to restriction $\lambda_d + \sum_{l=1}^{n-1} \lambda_{lk} = 1$, where: ψ_{kj} is the participation of region *j* in the national output of *k*; δ_{kj} is the participation of region *j* in the national demand of *k*; ψ_{lj} is the participation of region *j* in the national supply of *l*. Assuming that primary costs of space friction are equal, i. e., $t_d = t_l$ results that $\lambda_d = \left(1 + \beta_{kl}\right)^{-1}$ *and* $\lambda_l = \frac{\beta_{kl}}{1 + \beta_{kl}}$. Based on these results, we are able to compose a table of regional input-output, "(...) weighted by the space friction effects and covering both linkages, forward and backward"(ABLAS & CZAMANSKI, 1982:230). It can be formally written as $g_{kj} = \lambda_d d_{kj} + \sum_l \lambda_l \frac{\alpha_{kl}}{\beta_{kl}} g_{lj}$ where g_{kj} is the output of *k* in *j*; d_{kj} is the total demand for *k* in *j*; g_{lj} is the output of *l* in *j*; α_{kl} is the flow of industry *l* to *k*, by operation unit of *k*; β_{lk} is the flow of industry *k* to *l*, by operation unit of *l*. Based on this equation, we are able to estimate the effects of regional multipliers, taking account of both upstream and downstream linkages in the productive chain.

When analyzing the works presented so far, we can conclude that all authors – in most diverse ways – attempt to establish connections between intersectorial relations and the regional economy since, as stated by ABLAS & CZAMANSKI (1982:207), the linkage effects and the

> "(...) multipliers produced in the regional economy through the introduction of new activities are closely related to the occurrence of

> spillovers [...]. Therefore, [...] it may be preferable to make an effort to introduce a 'cluster' of closely related industries in underdeveloped regions [...], instead of heterogeneous activities with no links between them".

However, we think that all these works, except for those of Klaassen and Van Wickeren, and Silva & Locatelli, which we will treat below, fail for not considering space – and its specific economic properties – in its real magnitude and relevance. That is, those methodologies, as that in Perroux, are mainly concerned with analyzing intersectorial relations, by identifying the productive chains (clusters/complexes) and their linkages. Then, only residually, they apply spatial variables to their models and analogously to a plotting effort, i.e., only then they map such complexes in the concrete geographic reality[17]. As they, with no exception, work with input-output matrix, those authors take for granted that the power of regional impact of an activity is only related to its Keynesian inducing capacity. That is, they do not take into account in its real importance the possibility – and this is increasingly greater in a specialized regional space – of spillovers of such impacts, upstream and downstream, on other localized spaces and regions.

Therefore, if spillover effects, induced by Keynesian linkages, is a real possibility when working in subnational scale[18], it is worth attempting to incorporate strictly spatial categories in the same analytical level to the purely Keynesian analysis (which is a spatial by construction) and not adding, ex post, the space to the conclusions based on key sectors, clusters, *filières,* or industrial complexes. Thus, avoiding a mere juxtaposition of categories is crucial so that: 1) global and sectorial macroeconomic conclusions be transposed to distinct regional realities; and 2) an attempt should be made to guarantee the theoretical and analytical consistency of the results or, in other words, what the results really mean.

The works of KLAASSEN (1967) and VAN WICKEREN (1972) are attempted to overcome these difficulties. As they reconstruct the input-output matrix weighting the technical coefficients by the so-called space friction effects, they propose to give the same analytical status of the Keynesian technical coefficients to the spatial dimension, in addition to providing estimates of multipliers, which are regional by definition. However, these works show what SMOLKA (1982) considers to be a peculiarity of the authors in regional economics, i.e., the incorporation of space in their studies, but disregarding spatial variables.

In the proposed model, the estimation of the attraction coefficients, λ, the basis for regional coefficients, is only possible by means of a regression which assumes space

---

[17] Marginally, some authors attempt to introduce concepts of metropolitan agglomerates (Czamanski), urban networks (Perrin), etc. However, such concepts are always introduced ex-post, which not contradicts our main argument.

[18] This argument is also valid for countries with small internalization of productive structure, usually underdeveloped or developing countries. TAVARES (1972) already drew attention to one of the specific characteristics in industrialization by import substitution, i.e., the derived demand for imports. LESSA (1976) and MELLO (1982) took notice of the relevance of the period elapsing from 1933 to 1955 in Brazil (restricted industrialization) for the feasibility of the heavy industrialization provided by the *Plano de Metas* (a government plan for economic targets conceived in the fifties) which basically consisted in the implementation of a set of base industries (steel, cement, alkalis, etc.) avoiding leaks to abroad – through import of basic inputs – of backward linkage effects of DII nucleus installation in the country. However, the argument is partially valid, as the national spaces count on the nation-state for its insertion in the international division of labor, which does not happen in the same length with federative units in their insertion in the subnational spaces for their interregional division of labor. Recently, due to the growing international productive integration, this argument becomes also valid for nation-states and economic blocs derived from such a process. See LEMOS (1988).

friction costs as nonexistent. In other words, assuming that there is no spatial constraint in moving factors, i.e., that space does not exist or interfere with the locational pattern of sectors, the regional multiplier effects of income are inferred. No further comments on this issue!

The works of SILVA & LOCATELLI (1990 e 1991), however, have a different approach. They assume that industrial complexes based on the national input-output matrix are relevant for regional studies, since national pattern is a reference for subnational scales. However, according to the authors, "(...) one should not labor under the illusion that this pattern can be reproduced in each state [region], since productive activities are oriented to specific locational factors, which are unevenly distributed between regions" (SILVA & LOCATELLI, 1991:3).

Therefore, they admit that subnational spheres possess specificities and attempt to overcome such a difficulty by working with regional input-output tables. Based on such a matrix – localized by definition – they attempt to identify regional industrial complexes by means of a methodology originally formulated for national spaces.

This amounts to say that they implicitly admit a relative self-sufficiency of a subnational space, as their regional matrix obviously includes sectors localized in the region only. Being the tension between national structure and regional structure fundamental if we are to assess the unubiquity of space industrial structures, they conclude the analysis by proposing a subsequent comparison between the complexes mounted based on this matrix and those based on the regression model[19] previously presented, which uses national complexes determined beforehand. Therefore, the major issue we raise here is the relative indetermination either when two distinct methodologies showing opposing properties are combined or when the way by which they should be combined is not proposed[20].

3 - Spatial Accessibility Matrix (SpAM): a methodological proposal

As highlighted by LEMOS (1988) and SIMÕES (2001), the category urban land rent can be taken in its broad shape as a synthesis category of the locational dynamics of productive activities, as it possesses in its scope – once it is dynamised – the two basic dimensions of urban dynamics: agglomeration and disagglomeration4. That is, on the one hand, if the growth of such a rent implies higher efficiency of economic activities and increased differential income of a given localized space, on the other hand, it also suggests the growth limits of any urban scale. We also believe that the determinants of industrial agglomeration may be synthetically described by an urban rent gradient – a spatial surplus gradient. If any activity i is found in any space k, such a favorable localization in localized space implies the existence of a spatial surplus which is changed into the payment of urban land rent. Thus, in the words of LEMOS (1988:225),

> "(...) the localized space for any activity would be that in which global reproduction of the activity [that involves not only the selling of a product, but also the purchase of intermediate inputs and labor force] expressed such an accessibility cost that – even at production cost –

[19] The regression model proposed is that of component decomposition, by means of cross-section analysis. The proposed variables represent the major locational factors discussed in the literature of regional economics. However, the proxies considered show the same problems encountered in all estimations based on insufficient empirical data.

[20] The way proposed by the authors was to compare the results of the two methodologies, which in the case of Minas Gerais present similar results. What is worth mentioning is that nothing can assure that such analogy is valid for the general case, since the results were obtained based on methodologies that do not match either analytically or theoretically.

would allow the presence of a spatial surplus changeable into urban land rent".

Despite the fact that the gradient of the urban land rent is a synthetic element of location, we cannot consider it only under its form of aggregate unity (monetary) rent. Conversely, we should try and consider such a synthetic element of urban land rent under its multidimensional form which allows us to understand: 1) the different sectorial/locational linkages; 2) the spatial ranking of activities through agglomerative advantages in any region; 3) the feasibility of theoretical integration of urban rent with the localization issue; and 4) the analytical interconnection between space and intersectorial relations.

This paper, as those recent works of GOLDNER & SIMÕES (2003), LEMOS & FERREIRA (2001), and LEMOS & DINIZ (2000), is part of a research agenda viewing both the understanding of urban comparative advantages and the possible theoretical and methodological interconnection between intersectorial relations and strictly spatial categories with a view to understand regional development in a multidimensional manner.

A methodological proposal is presented below for the construction of a multisectorial matrix of space friction coefficients, understood as costs of localization and accessibility of an activity i in relation to another activity j in a given region.

The overall objective of such a methodology, which is an alternative to the literature presented here, is to attempt – in the light of the theories of localization and a spatial approach of the economy – to incorporate strictly spatial categories into the purely Keynesian analysis of intersectorial relations, with a view to the understanding of regional development.

It is an alternative not only in the sense of handling sectorial interconnection coefficients of the original input-output matrix, but in the sense of mounting a new matrix with new and different coefficients, which include ex ante spatial categories and not merely transpose general conclusions to a regional analysis. Based on this new matrix, we are able to identify economic-spatial relations not only of trade dependency and interconnection but also those with locational linkage.

According to the aforesaid, we can say that a land rent gradient of spatial surplus can synthetically describe the industrial agglomeration determinants. Parallel to this, we can also state that matrices of intersectorial relations allow us to establish the circulation requirements – intermediate and final purchases and sales and labor as well –and hence permit the understanding of localization in a peculiar way, i.e., in a multidimensional way.

Thus, when assuming a theoretical vector of spatial friction – understood as constraints imposed to the unubiquity of activities – which took account of the multidimensional characteristics of capital in space, we could have an idea of, e.g., what should or could be done in order to localize an activity *i* in a given space *k* based on its locational attributes.

This vector would require the real knowledge of paid/generated urban land rent by each sector, which is not feasible[21]. Nevertheless, it is possible to estimate this sectorial gradient of land rent if the final result of intersectorial relations can be accessed to, which is nothing else than the concrete definition of the productive structure of a given space. The result is the crystallization of purchase and sales

---

[21] It is worth reminding that the income generated by sector *i*, resulting from space monopolization, is spatial land rent and not economic rent that is independent of location. On the other hand, it should also be reminded that all kinds of rent, as interest and industrial profits, are within the sphere of capital in general. See LEMOS (1988).

intersectorial flows of production and wealth, in a space, which is urban by definition[22]. For this, what is needed is to combine two kinds of information: 1) the locational requirements of circulation provided by the input-output matrix through the intermediate flow matrix[23]; and 2) the spatial surplus indicators, sectorial localization structure, provided by the industrial census for the region in question. That is to say, the presence or absence of the activity in a given space *k* implies the existence of spatial surplus, the economic censuses being the source of such data[24].

Formally, if r_i is the rent or unity spatial surplus of sector *i*; X_i is the total output of sector *i*; R_i is the land rent in monetary values of sector *i,* we can state that $r_i = \frac{R_i}{X_i}$ [1]. Based on [1], we can sectorially extrapolate so as to reach a unidimensional vector of the following kind: r_i with $i = 1,...,n$[2] which is the unity gradient of urban land rent, suggesting the existence of a multisectorial hierarchy of spatial friction in a given *k*.

As mentioned before, the spatial surplus generated by a favorable localization – expressed by monopolistic advantages of occupation and use of space – changes into land rent and starts to be characterized as cost. Therefore, "(...) while the presence of spatial surplus is in itself a factor of capital attraction, its conversion into land rent constitutes a repelling factor, representing a [dynamic] contradictory movement" (LEMOS, 1988:245). That is, the generated income stems from benefits received due to he centrality of localization, being partially or totally consumed – in the process of circulation – by the total cost of spatial friction *(CTF)*. As we have worked in relative terms, it follows that $r_i = 1-(CTF_i)$ [3].

This spatial friction, in turn, is linearly related to the direct and indirect requirements of circulation, i.e., it is necessary to include the dimension of intersectorial purchases, intermediate sales, and final demand. Thus, we may reach a theoretical concept of what would be such a spatial friction. Based on the input-output matrix, we are able to construct a new matrix from the intersectorial relations containing specific technical coefficients, which include purchases and intermediate sales requirements, i.e., intersectorial circulation, in addition to final demand.

In this way, we can construct a relation between two sectors configuring the relative output of purchases and intermediate sales and the final demand vector. And this can be formalized as $g_{ij} = \frac{(x_{ij} + x_{ji})}{X_i}$ [4], where g_{ij} is the technical space coefficient of sector *i* at sector *j*; x_{ij} are the sales of sector *i* at sector *j*; x_{ji} are the purchases of sector *j* at sector *i*.

[22] We remind that the urban concept referred to here is not only the 'city'. On the contrary, it is defined by the space where general conditions for a broadened reproduction of capitalism are materialized. See LEFEBVRE (1991), LOJKINE (1981), CASTELLS (1982) etc.

[23] It is Table 2 in the I-O M/BRAzIL/1980 and 1996. The reason for not using the existing the I-O M/MINAS GERAIS/1980 and 1996 as well, was discussed in the previous section and is related to the fact that contrasting national and regional structures in determining locational patterns can only be achieved with the use national coefficients.

[24] In section 4, the necessary mediations for the empirical use of such a theoretical precept will expressed in the application for Minas Gerais.

As total cost of spatial friction *(CTF)* can be defined by the spatial coefficient versus the spatial accessibility of such factors, we can write it as $CTF_{ij} = \left(g_{ij} \cdot v_{ij} \right)$ [5] where v_{ij} is the spatial accessibility cost of circulation *i* and *j* .

Introducing [5] into [3], it comes $r_i = 1 - \left(g_{ij} \cdot v_{ij} \right)$ [6].

As the accessibility cost is related to several markets of both final product and intermediate demand (or even labor force), we can write it in a matrix form, diagonalizing vector r_i. Therefore, from [6], we can write **R = I - G V** [7].

Hence, **V = (I – R) G** $^{-1}$ [8].

As r_i theoretically oscillates between zero and the unity, the worst the location of an activity, the highest the values of **V**, enabling us to determine the circulation bottlenecks from the viewpoint of spatial distribution of activities. Moreover, as we are working in a multidimensional universe, it is possible to establish – preliminarily – the constraints imposed to location, which are related to circulation.

Just as HADDAD (1995), we can present the argument in an easier way, by formulating a hypothetical model of productive structure with only three sectors. Let us take the sectors Steel Industry (s), Petroleum Extraction (p), and Electronic Components (s) in a given region K as examples. The localization of such sectors in region K may be described by estimating vector r_i. Assuming an excellent localization of the steel industry in K ($r_s=1$) and nonexistence of petroleum extraction and electronic components ($r_p=0$ e $r_c=0$), we can present vector r_i, its diagonalized matrix **R,** and matrix **[I-R]** as follows:

$$r_i = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \; ; \mathbf{R} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \text{ and } \mathbf{I\text{-}R} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$

If **V = [I-R] G** $^{-1}$ and each term of the matrix **G** $^{-1}$ is called h_{ij}, we can write that

$$\mathbf{V} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} h_{ss} & h_{sp} & h_{sc} \\ h_{ps} & h_{pp} & h_{pc} \\ h_{cs} & h_{cp} & h_{cc} \end{bmatrix} = \left[\begin{bmatrix} 0 & 0 & 0 \\ h_{ps} & h_{pp} & h_{pc} \\ h_{cs} & h_{cp} & h_{cc} \end{bmatrix} \right]$$

It is worth to say, line 1 of the matrix, referring to the steel industry, can be interpreted as follows: this sector, being well localized in region K, does not impose any constraint to the functioning (intermediate purchases, input supplies) of the remaining sectors in the region. The petroleum extraction sector, however, imposes restriction h_{ps} to the functioning of the steel industry, h_{pp} to the petroleum sector itself, and h_{pc} to the electronic components sector. As the value of g_{pc} – technical relation concerning input selling of petroleum sector to electronic equipment – should be lower than the value of g_{ps} – petroleum in relation to steel – the value of h_{pc} should also be lower than h_{ps}, i.e., the absence of a petroleum sector in the hypothetical region K gives rise to spatial restrictions to the steel industry in an amount higher than that caused by the electronics sector. Nonexistence of an electronics sector also brings about analogous restrictions to those described for the petroleum sector.

If $r_c=1$ is assumed, i.e., good localization of electronics in K, the following matrix can be written:

$$[\mathbf{I\text{-}R}] = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad \text{and} \quad \mathbf{V} = \begin{bmatrix} 0 & 0 & 0 \\ h_{ps} & h_{pp} & h_{pc} \\ 0 & 0 & 0 \end{bmatrix}$$

That is, electronics would not any more impose restrictions to the functioning of the remaining sectors of the economic structure and to itself. As can be noted, the better the sectorial location in K, the smaller the spatial restrictions. In the case of a unity vector r_i, matrix **V** would be null, which means the nonexistence of spatial restrictions to intersectorial circulation, technical relations alone being relevant. Therefore, the less diversified – i.e., the more specialized – a productive structure is, the greater the interregional and intersectorial spatial constraints to the economy.

For the methodology construction, including the components of final demand and labor force is still to be accomplished. Theoretically, we can affirm that the accessibility cost is basically composed of three macro factors: 1) a direct cost of localization, materialized by the concept of land rent, localized space monopoly, i.e., payment for rents or annualized purchase value; 2) direct transport cost which is the cost of several reproductive activities directly paid, i.e., freights for purchases and sales in a multisectorial approach; and 3) indirect costs of localization in which wages and salaries – increased cost of living included – are remarkable[25].

Incorporating the labor force cost in the accessibility cost matrix means taking two joined theoretical aspects into account. The first has to do with the very concept of final demand. As is known, final demand is composed of the total amount of investments, exports, and final consumption – except for the governmental expenditure already incorporated in the other coefficients. A first hypothesis – refuted for its oversimplification – could consider as nonexistent the spatial friction of the final demand vector. A second hypothesis – which is accepted – attempts to endogenize the spatial friction of final consumption in the construction of matrix **V**. For such a final consumption, we may construct a proxy with its salary and wage vector corresponding to the notion of labor force reproduction in the urban center[26].

We can write then $cw_i = \dfrac{vcf_i}{X_i}$ [9] where cw_i is the so-called ‘Castells vector’ of labor force reproduction; vcf_i is the sales for final consumption of sector *i*.

The second theoretical aspect to be highlighted in the incorporation of labor force in the location scope is related to the need for ‘purchasing’ wages or workers by

---

[25] As this includes residential activities (housing, transport, food) that become more expensive and make relative wage to rise in space *k* - cost of ‘spatial’ reproduction of labor force. The theoretical conception allowing such an inference was originally formulated by David Ricardo. From the strictly urban and spatial viewpoint, see the work of GUIGOU (1982). For an application to the Brazilian economy, see LEMOS & CROCCO (2000) and GOLDNER (2002).

[26] We are not concerned here with detaching exports, as we are interested in the domestic market *strictu sensu*. Being the remaining element of the global circuit of capital reproduction, investment can be considered the most expensive component from the spatial viewpoint, since it is a nonsystematic, erratic operation of purchases and sales. The absence of such systematicness – particularly on the demand side – heightens spatial costs. In our case, investment is taken as part of intermediate demand. Due to its strictly global dimension, an investment vector will not be constructed here, as we are only concerned with the spatial reality. However, it is worth mentioning that, when comparing several regional realities, it is necessary to detach this component, being the algebraic-matrix procedures analogous to the labor force vector.

the several economic sectors, i.e., it is up to capitalism to induce workers to be in the locus of production, and this implies spatial costs. A proxy can be formalized as $w_i = \frac{W_i}{X_i}$ [10] where w_i is wage expenditure by output of i ; W_i is total wage mass of sector i.

Since both cw_i[27] and w_i show specificities and assuming that spatial friction in the two components are equivalent, we can formally state that $\left[\sum cw_i + \sum w_i\right] \cdot [v_n] = [WCF_i]$ [11] where V_n is the labor force spatial friction as a proxy of final demand; WCF_i is the spatial cost of consumption for reproducing labor force.

Just as the purchase of final products, the final sale *(F_i)* also has spatial friction and circulation cost. In order to include it in the matrix, we added | F_i | to the principal diagonal of the matrix to be inverted. That is to say, we should rewrite [3] for the principal diagonal. It follows that $g_{ij} = g^*_{ij} = \frac{x_{ij} + x_{ji} + F_i}{X_i}$ $\forall$ $i = j$ [12].

Based on all the identities established, we could write our model and extract the inverted matrix which will provide the multidimensional accessibility costs which are equal to the modified vector r. Then, if $gs'_i = [w_i + cw_i]$ [13], where gs_i' is the wage vector, we can write that

$$\mathbf{I} - \begin{matrix} g^*_{11}v_{11} & g_{12}v_{12} & \cdots & g_{1n}v_{1n} & [gs'_1]v_n \\ g_{21}v_{21} & g^*_{22}v_{22} & \cdots & g_{2n}v_{2n} & [gs'_2]v_n \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ g_{n1}v_{n1} & g_{n2}v_{n2} & \cdots & g^*_{nn}v_{nn} & [gs'_n]v_n \\ [s_1]v_n & [s_2]v_n & \cdots & [s_n]v_n & \left[\sum gs'_i\right]v_n \end{matrix} = \mathbf{R} \quad [14]$$

Being r_{n+1} the productive structure weighted by wages at the national level, i.e., $r_{n+1} = \frac{\sum (r_i \cdot w_i)}{W_i}$ [15] the last element of matrix **R**.

We chose to rewrite [14] in matrix notation as in [7], viewing to avoid proliferation of apostrophes and asterisks, reminding that final demand and labor force, i.e., $\mathbf{G}^{-1}\mathbf{V} = [\mathbf{I} - \mathbf{R}]$ have already been included. Multiplying the inverted matrix of circular requirements $\mathbf{G}^{-1}$ by the matrix resulting from [**I-R]** is the last step for the construction of the spatial accessibility matrix.

Based on the methodology described in this section, we will attempt to define the operational criteria, which would allow us to estimate the spatial accessibility in matrix **V**. While the proposed methodology is purely based on theoretical arguments, the next section will attempt to apply it to a specific regional reality – the State of Minas Gerais, Brazil – and mainly to troublesome database, with an excessive aggregation level and restrained data availability[28]. Therefore, each vector and each matrix,

[27] It is worth noting that, by definition, $cw_i = 0$ for intermediate sectors.

[28] Distinguishing ‘ideal’ methodology x ‘applied’ methodology is justified in our work as an attempt to avoid interpretation and valuation errors in the proposal. While the ‘ideal’ methodology is only concerned with the theoretical mounting of the matrix, the estimation has to take account of the restrictions to its empirical operation. The most clarifying case of the deleterious effects on the understanding and

necessary to the construction of matrix **V,** will be operated in section 4; then the results obtained will be presented and analyzed.

Finally, we can state that, despite the fact that this is an eminently static methodological proposal, its multidimensional characteristic allows us to go beyond a mere ex post spatialization of interesectorial relations. This amounts to say that it allows us to come closer to the very Boudevillean definition of economic space, in which information found in space (transport cost, agglomeration economies, etc.) is synthesized by the presence or absence of economic activities in a given locus, together with the intermediate purchase and sales requirements.

4 – An application for Minas Gerais - Brazil

Before presenting the results of the proposed methodology we should show a brief characterization of the economic insertion of the state of Minas Gerais in Brazilian economy.

The state of Minas Gerais is one of the 27 states comprising The Federative Republic of Brazil. FIG. 4.1 shows the geographical position of Minas Gerais in relation to Brazil. The population of state area was 17,891,494 people in 2000 and it is the second state in the country with 10.54% of its population. The Minas Gerais GDP was about US$ 60 billion in 2000, representing about 8% of the Brazilian GDP. The industry represents about 25% of the Minas Gerais' GDP. The Metropolitan Area of Belo Horizonte (MABH), the capital of Minas Gerais, is 750 km far from the federal capital of The Federative Republic of Brazil – Brasilia – and approximately 580 km from São Paulo and 400 km from Rio de Janeiro, the latter two being the major economic poles in the country.

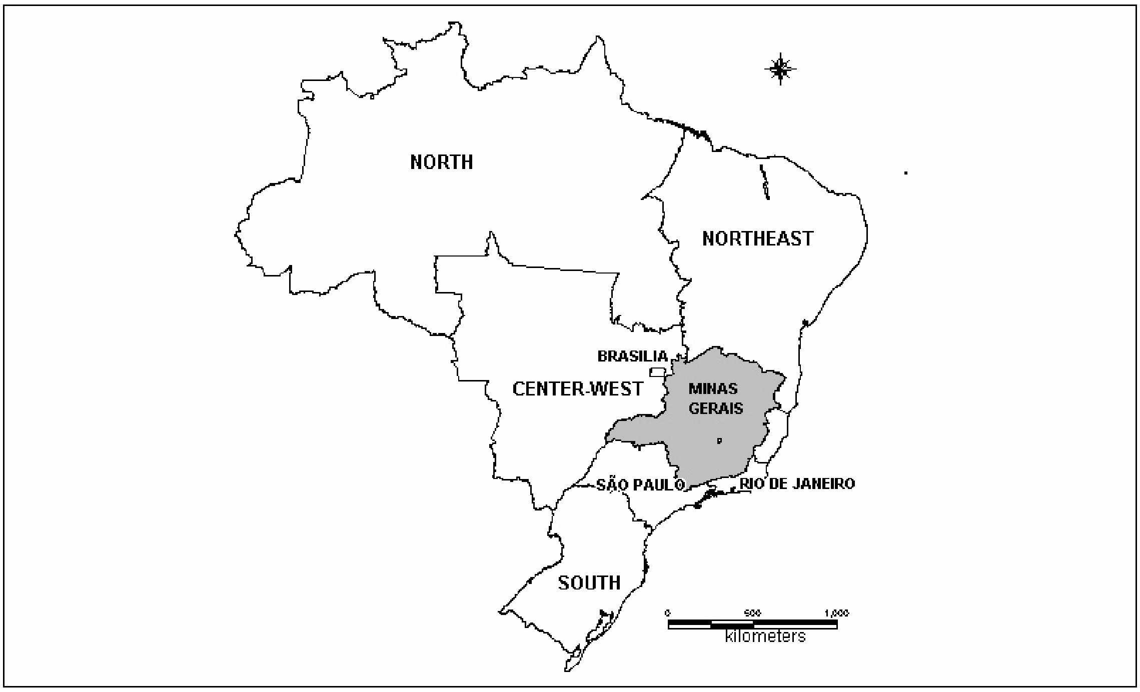

FIG4.1 – The State of Minas Gerais, Brazil

---

valuation of a text which the simultaneous presentation of theoretical model x estimation may provide is found in KALECKI (1954).

As for the politico-administrative aspects, Belo Horizonte is the seat of the state government where the executive, legislative, and judiciary major branches are located. From the economic viewpoint, the region is considered as the third economic pole in the country, placed behind the metropolitan areas of São Paulo and Rio de Janeiro.

The MABH comprises the municipality named after it and 32 other municipalities. The population of the area was about 4.8 million inhabitants in 2000, with a US$ 24 billion GDP in 1996. Approximately 40% of Minas Gerais GDP is concentrated in the MABH, which corresponds to almost 5% of the Brazilian Industrial GDP.

Although, historically, Brazilian industrial activities have been concentrated in South-East, particularly state of São Paulo (DINIZ, 1994) - in order to confirm the empirical evidence in the literature that the recent industrialization was decisive for the new spatial configuration of the Brazilian metropolitan areas - data from TABLE 4.0 show a relative industrial deconcentration in the country between 1970 and 1980, with a loss in the participation of the dominant industrial centers (the states and metropolitan areas of São Paulo and Rio de Janeiro).

TABLE 4.0 – Growth rates, industrial output by metropolitan areas and states, Brazil, 1975, 1980 and 1996

	1975	*1980*	*75-80*	*1996*	*80-96*	75/96
	ρ^1	ρ^1	ψ^2	ρ^1	ψ^2	ψ^3
State of São Paulo	55.01	43.89	3.76	45.03	-1.01	1.23
MA São Paulo	37.14	23.88	1.54	24.68	-0.95	0.23
Interior areas	17.86	20.01	7.34	20.35	-1.10	2.84
State of Minas Gerais	6.60	8.70	9.10	11.47	1.27	4.92
MA Belo Horizonte	2.46	3.21	8.99	4.64	2.13	5.34
Interior areas	4.14	5.49	9.16	6,82	0,73	4,66
State of Rio de Janeiro	12,99	11.76	5.08	10.26	-2.46	1.06
MA Rio de Janeiro	10.40	9.24	4.89	7.96	-2.57	0.91
Interior areas	2.59	2.52	5.82	2.30	-2.05	1.62
Southeast	75.27	65.73	4.70	68.04	-0.93	1.71
South	14.82	15.70	6.74	15.19	-1.54	2.32
Center-West	1.13	2.43	14.62	3.23	1.36	7.47
Northeast	7.37	11.87	11.32	9.74	-3.01	3.57
North	1.31	3.95	18.55	3.49	-2.37	7.09
Brazil	100.00	100.00	6.13	100.00	-1.24	2.20

Source: Prepared by the author.

[1] Participation rate;
[2] Annual average growth rate for each decade;
[3] Annual average growth rate for the period 1975-1996

Such a reversal of the industrial polarization reflected not only the emergence of agglomeration diseconomies in those two poles, but also the emergence of economies of agglomeration in the remaining regions, especially in other metropolitan areas (DINIZ, 1994). On the other hand, the data also show a movement towards a new concentration in the 1990s. Such a trend reversal – as the data on output per capita and participation of the industrial metropolitan production of São Paulo suggest – certainly affects the metropolitan urban dynamics. It means, a possible reproduction of certain agglomerative advantages in both primary poles – modern productive service centers for a supranational market area and the strengthening of chronic agglomerative disadvantages in the emerging metropolitan areas, such as urban infrastructure problems and absolute poverty enclaves.

As seen in TABLE 1, the MABH presented – among all metropolitan areas comprising the development polygon defined by DINIZ (1994) - the higher annual average growth rate for 1975-96. With a growth rate of 4.92% and 5.34% p. a., respectively, the averages of the state of Minas Gerais and MABH have surpassed that for the Rio de Janeiro and São Paulo metropolitan areas, being behind only the Center-West and North Macro regions, which have low initial GDP participation rates.

The next part of this section proceeds an exercise which is designed for the economy of Minas Gerais in two distinct periods – 1980 and 1996 – having, as its empirical base, information from the *Censo Industrial / MG / 1980* (industrial census of Minas Gerais as of 1980); the Input-Output Matrix (M-IP) / Brazil / 1980; the RAIS (an annual listing of labor force information and wages of the Ministry of Labor); and the Input-Output Matrix (M-IP) / Brazil / 1996.

The year of 1980 is used not only because it has the best sectorially/regionally disaggregated database produced by IBGE (the Brazilian census agency), but, as we have seen, mainly because it is a year in which the spillover from the São Paulo industrial activity had already achieved its greatest cycle. And Minas Gerais was one of the major beneficiaries of the industrial investment resulting from what has been usually called "the polarization reversion in Brazil" and "the field of influence of São Paulo industry"(AZZONI, 1986); "the Brazilian development polygon" (DINIZ, 1991), among other names of the same process. The year of 1996 is used because it is the most recent one for which the Input-Output Matrix/ Brazil is available, even though with restricted number of sectors and based on survey, instead of the universe of the Brazilian industry no de 1996. The relatively long period between the two years of analysis will allow us to evaluate the major impacts on the economy of Minas Gerais both from the foreign-trade opening of the 1990s and the new regional design of the Brazilian industry.

The other part of this section is concerned with identifying and analyzing the relation "industrial location *vs* intersectorial relations" in Minas Gerais, by utilizing matrix **V** as a base for a "multivariate analysis of conglomerates with fuzzy logic", i.e., *fuzzy clusters*.

4.1. – Operational Procedures and Matrix V

From the section 3, we can infer that the construction of vector r_i – i.e., the gradient of unit land rents – is the first estimation phase of spatial accessibility matrix **V**. As described previously, we know that the estimation of r_i values first assumes the simplifying hypothesis that any activity i uses a "localized space", as defined in the previous section. The use of such a space generates a spatial surplus, which is transformed into payment of urban land rent. Then, it rests to ascertain the presence of activities in the region in question. Due to database differences, we shall construct **R** in distinct ways for the years under analysis.

4.1.1. – Constructing R and G for 1980

The first procedure is to consult the industrial census[29] - in its highest disaggregation, i.e., the ranking by activity with 6 digits – the variable 'number of

[29] For the years after 1985 and due to the break of periodicity and change of methodology for industrial censuses, several works have used various sources with the aim of providing information for a regionally disaggregated analysis. We chose to work here with the variable "number of establishments by activity" provided by the RAIS just like in LEMOS *et al* (2000).

establishments' Minas Gerais. The existence of a given activity in the state would configure the internal hierarchy of the rent gradient[30].

However, we should have in mind that it is the national input-output matrix that will provide the final and intermediate purchase and sales flows – circulation requirements – and compatibility of aggregation of r_i (digit 6) with aggregation of matrix **G** (level 100) is needed[31]. Such distinct presentations of data provided by IBGE and especially the low disaggregation of some factors leads to a sectorial differentiation in constructing the rent gradient. That is, we should adopt differentiated procedures in constructing r_i in order to satisfy the needed "cleansing" of the I-O M, level 100.

For the industrial sector – our specific goal –, its necessary to reconstruct a vector r_i^*, level 100, from vector r_i with 6 digits. Formally, we can write $r_i^* = r_i \cdot B_r$ where r_i^* is the vector of unit rent gradient in the aggregation at level 100; r_i is the vector of unit rent gradient in the aggregation with 6 digits; B_r is the relative participation, in values, of each activity with 6 digits[32] which composes the matrix sector at level 100[33].

In addition to such a procedure, which is purely formal, we should attempt to capture domestic differences within the state, as for relative spatial concentration of its established industrial park. The mere location of a sector in a given space k disguises different spatial configurations and does not provide exact information on the real sectorial hierarchy in the region, in this way spoiling the consistency of the land rent gradient. In order to minimize the effects of a restrained database – and analogously to that accomplished by FESER&BERGMAN (2000) for the analysis of industrial agglomerates in the USA, specially in North Carolina – we resorted to a relative concentration index which is nothing but a variation of a classic index in regional economics: the location quotient (QL). For the industrial sector as a whole, we can write:

$$QLI_i = \frac{\dfrac{[Nest]_{i,mg}}{[Nest]_{t,mg}}}{\dfrac{[Nest]_{i,br}}{[Nest]_{t,br}}}$$

where QLI_i is the intensity index of the industrial sector regionally in relation to the total for the country; $Nest_i$ is the number of establishments in the industrial subsector; and mg and br are indices for Minas Gerais and Brazil.

In order to make interpretation and analysis easier, an algebraic normalization of the results of vector r_i^* was made, as in LEMOS (1991). Then, we can formally write:

$$[r_i^*] = \frac{e^{QLI} - 1}{e} \qquad \forall \qquad 0 \leq QLI \leq 1$$

$$[r_i^*] = \frac{e^{QLI} - 1}{e^{QLI}} \qquad \forall \qquad QLI \geq 1$$

where e is the Neper number.

---

[30] So far the r_i is an identification scalar with figures 0 or 1which will be modified below.
[31] The sectorial compatibility of Digit 6 x Level 100 may be achieved based on IBGE (1980).
[32] For the issue of disaggregated information in economic census, see SIMÕES (1989).
[33] Such a procedure is justified, as compatibility of disaggregations would lead to that all elements - *grosso modo* - of vector r_i^* were equal to 1. Differentiation is accomplished based on the relative importance of each activity in composing the matrix sector.

The same problem comes up for the agricultural sector, which is squared, however, due to the utmost aggregation in which the data are presented in the I-O M/ Brazil: only sector 0100. The ubiquity of the agricultural sector would obviously imply an element r_i=1.0, which would largely restrict the analysis of the spatial, agroindustrial complex[34]. Therefore, we have constructed a new intensity index *[QLA],* now for the agricultural sector, which is formally written as follows:

$$QLA_i = \frac{\dfrac{VPA_{mg}}{[VPA+VTI]_{mg}}}{\dfrac{VPA_{br}}{[VPA+VTI]_{br}}}$$

in which we adopted the same algebraic normalization procedure formally written as:

$$\left[r_i^*\right]_{primario} = \frac{e^{QLA}-1}{e} \quad \forall \quad 0 \leq QLA \leq 1$$

$$\left[r_i^*\right]_{primario} = \frac{e^{QLA}-1}{e^{QLA}} \quad \forall \quad QLA \geq 1$$

Before going on, it is worth noting that we had to establish a specific geographic base in mounting the rent gradient, due to the data aggregation. That is, the state of Minas Gerais, here represented as the weighted mean of its major regions. That amounts to say that Minas Gerais in itself may be considered as an administrative unit only. There is not - *grosso modo* – such a thing as Minas Gerais economy *stricto sensu*, but several sublocations that are integrated in the larger scope of the Brazilian economy. It was necessary to take the Minas Gerais economy in this study as a mean of its major urban complexes – weighted by the aggregate value of each of them in the economy of the state as a whole – since the value of the rent gradient tends to the unity, without differentiating location intensities and regional specialization if sectorial aggregation is high[35].

Therefore, we used a study by LEMOS (1990) which – based on a methodology privileging the tertiary sector density – identifies six great urban complexes in the state of Minas Gerais: 1) the industrial pole of Belo Horizonte (PIBH); 2) the agricultural pole of Uberlândia(PAUb); 3) the agricultural pole of Juiz de Fora(PAJF); 4) the agricultural pole of Teófilo Otoni(PATOt) ; 5) the agricultural pole of Governador Valadares(PAGV); and 6) the microregions included in the industrial pole of São Paulo(MIPISP). Such a view requires that each of the elements of r_i^* be estimated for each of the regions above and weighted by their participation in the GDP of Minas Gerais. After estimating our rent gradient r_i^*, to be diagonalized in matrix a **R**, we will be able to present its final result (ANNEX).

As can be noted, this vector contains 66 sectors, including the reproduction of the labor force factor (line *w*), which are not correspondent to total sectors of the I-O M for Brazil, 1980. Withdrawing some of the sectors – approximately 40 – is justified because they: 1) do not present economic relevance, as in the case of the dummies variables, which merely provide accounting consistency to the IBGE model; 2) do not present geographic occurrence and are generally used as in the case of some public

[34]The intersectorial disaggregation of sector 0100 of the input-output matrix for Brazil, 1980, may be found in LEMOS (1992). Including such a disaggregation in the construction of accessibility matrix **V** would require a separate study, and the one found here is only a proxy designed to eliminate the undesirable outcomes of the sector's ubiquity in the rent gradient.

[35] See LEMOS (1988).

services and intermediation services; and 3) are in the tertiary sector. Constructing the matrix to be inverted, as indicated in the previous section, must take account of such a restraint. Due to that coefficients of matrix $\mathbf{G}^{-1}$ – the other component necessary for the estimation of the spatial accessibility matrix – do not present any difficulty for their handling, as they can be directly estimated based on the intermediate consumption matrix of activities in the I-O M/Brazil and on the methodology exposed in section 3, the full estimation can be achieved. Inverting matrix **G** was accomplished by using the *S-Plus* and the result of **V** is in ANNEX.

4.1.2 - Constructing R and G for 1996

The procedures used to construct **R** and **G** for 1996 are significantly different from those used for 1980, due to the nonexistence of industrial census with regional disaggregation higher than two digits and the reduced size of the I-O M in 1996.

Constructing vector r_i^* - subsequently diagonalized in matrix **R** – followed the need of compatibility with the I-O M for 1996 at level 80. That is, despite the 80 sectors of disaggregation at the output level, the matrix of intermediate consumption of activities – used for constructing **G –** is reduced to slightly more than 40 sectors. Similarly to the one for 1980, we cleansed the matrix so as to eliminate the variables for statistical adjustment (commercialization margin, financial dummies, etc.), the public utility sector, and the tertiary sector. Thus, we got a 32 x 32 matrix – with the sector constructed for incorporating the labor factor (line w) already included. Undoubtedly, it is necessary to construct a vector r_i^* - to be subsequently diagonalized - with the same size, i.e., 32 x 1.

As a cadastre census with a regional disaggregation compatible to the necessary level for 1996 does not even exist, we used the information concerning the "number of sectorial establishments", provided by the RAIS (the annual listing of social information) in order estimate the 32 elements of vector r_i^*. The compatibility of activities CNAE (217) in the RAIS with the sectors in I-O M 1996 may be found in BRUM (1999).

Information coming from this source is used for constructing vector r_i^* , i.e., each element of r_i^*, similarly to that for 1980, is estimated using an adaptation of the sectorial locational quotient (QL) as in equation [2] in the previous section. The same normalization procedure indicated in [3] and [4] is applied here. For 1996, the procedures applied to the agricultural sector are analogous to those for the industrial sector, using the number of agricultural establishments of the RAIS.

From this point and using the same procedure for 1980, each of the elements of r_i^* was estimated for each of the economic regions in Minas Gerais and weighted by their participation in total employment in the state. However, if the regionalization for 1980 followed the indications by LEMOS (1988), changes in the regional division of labor in Brazil during the almost two decades elapsing the two analysis years require a new regionalization which follows the new configuration of the regional space in Brazil and Minas Gerais. We chose here the regionalization based in a modified gravitational model found in LEMOS *et al.* (2000). In this regionalization, 14 economic mesopoles, mesoregions, which encompass the whole geographic space of Minas Gerais, were proposed[36]. Several microregions in Minas Gerais are part of mesoregions polarized by other states, mainly São Paulo and Rio de Janeiro. Once the weightings are

[36] The homogenous microregions (MRH / IBGE) comprising these poles are found in the ANNEX.

accomplished, similarly to those for 1980, the results of r_i^* for 1996 are shown in the ANNEX.

Once the construction of vector r_i^*, to be diagonalized in **R,** and the information matrix enabling the construction of **G** were concluded, as suggested in the previous section, we estimated $\mathbf{V}=[\mathbf{I}-\mathbf{R}]\,\mathbf{G}^{-1}$. The results of **V** for the two years of analysis are presented in the ANNEX. The values in this matrix – called spatial accessibility matrix – constitute the basis for the construction of spatial agglomerates – clusters – which are based on the properties of each element v_{ij}. As seen before, the value of v_{ij} indicates the constraint to circulation and reproduction each sector impinges to the remaining one from the viewpoint of location and purchase and sales relations (circulation requirements as previously defined).

The individual analysis of each sector and its relations may provide the identification of "bottlenecks", which are not only dependent on technical relations of intermediate consumption among sectors – such as those realized by several authors for the whole set of the Brazilian industrial sector and more recently by BRITTO (2002) and NEIT (2003) – but mainly on spatial contingencies each sector may regionally pose to the remaining sectors.

A more careful analysis of the individual values of the elements of matrix **V** could give us more elements for detailing – analytically and multisectorially – the porosities of each productive chain. From these results, we are able to infer which sectorial policy for regional development, with emphasis on industrial sectors, should privilege its action in sectors presenting high values of v – which combines technical relations and location – in the face of the possibility – once resolved those spatial-economic bottlenecks – of heightening interregional integration and lowering interregional leaks of the intermediate purchase and sales structure. For example, the line referring to the sector petroleum extraction is the one presenting the highest values in matrix **V**, as expected. It multisectorially impinges heavy constraints to the petrochemical chain as a whole. On the other hand, the line referring to steel industry – well localized in the state – shows values near to zero even for those sectors keeping strong purchase and sales relations with it.

However, instead of analyzing separately each sector of matrix **V,** which would be extremely self-defeating, we chose to group them into similar classes as for their spatial accessibility, by identifying spatial industrial complexes. That is, using the elements of **V** as the initial data matrix, we applied a multivariate classification method recently disclosed in the literature of regional and urban economics[37], namely the Fuzzy Cluster Analysis, also called Fuzzy-Set Clustering. This analysis may be extremely useful, if we think of strategies for regional development policy, specifically a policy for regional thickening of productive chains and even eligibility of sectors for granting fiscal incentives as suggested by BANDEIRA (2002).

The next section attempts to describe briefly the multivariate classification methods, the logic differences of the classic sets (*crisp sets*) in relation to the nebulous sets (*fuzzy sets*), the fitting of the latter to the object of our analysis, in addition to the definition of the estimate algorithm and its properties.

[37] See HARRIS *et al*. (1993), HARP & FOSDECK (2000), GERMAN *et al.* (1985), GROVE & ROBERTS (1980), ALBRECEHT (1995), HSU *et al.* (2003), BAGNOLI & SMITH (1998), LELLI (2001), DRAESEKE & GILES (1999), COSTA (2002), PHOTIS & MANETOS (2003), DERUDDER *et al.* (2003) among others.

4.2 – Classification Methods and the Fuzzy Cluster Analysis

As found in KAGEYAMA & LEONE (1999:20), the "(...) aim of classification methods is to divide a set of elements (indicators) into subsets (classes) as similar as possible from distances by twos".

In other words, agglomeration (*clustering)* may be characterized as any statistical procedure, which, by using a finite and multidimensional set of data, ranks its elements in internally homogenous, restrained groups, allowing creating significant aggregate structures and developing analytical typologies[38].

The definition of the dissimilarity metrics to be used follows the peculiarities of the data set, statistical characteristics of the variables, and ranking objectives, and it could be based on in one or several individual attributes. The S-PLUS (2000:103) presents five distinct dissimilarity metrics for noncategorical continuous sets and discusses their adequacies. The usual ranking methods – found in the present statistical software – allow the utilization of any of such metrics, the Euclidean distance being the most used one.

Therefore, ranking individuals in homogeneous groups – in which the mean values of each class would represent the individuals located in it, with the least intraclass variability and the utmost interclass variability – allows us to create taxonomies, typologies, in this way reducing the amount of magnitudes to be analyzed and making it possible a more direct understanding of inherent data characteristics[39].

However, as defined by HARRIS et al. (1993:157):

> "Hard cluster analysis suffers from the problem that a given observation, say x, must belong to one and only one cluster, whereas x may in fact possess attributes that partial memberships in several classes".

That amounts to say that the usual classification methods (Hard Cluster Analysis) make use of the concept of classic sets (crisp sets), characterized by the unequivocalness of their pertinence function (or belonging). Intuitively, the theory of sets includes a fundamental dichotomy notion: to belong or not to belong. In other words, defining a classic set implies a binary choice as for pertinence of an individual (object, element) in a given class (group, category): to accept ("= 1") or reject ("= 0") such a proposition. The pertinence function of a set A in relation to X may be described as $A(X) = \begin{Bmatrix} 1, se\, x \in A \\ 0, se\, x \notin A \end{Bmatrix}$.

Thus, each set in relation to which an element may be assigned to is assumed as having unique and distinct coordinates, with all their members identically occupying the same physical spot, and the possibility of internal heterogeneity being written out.

However, if the set of information – either for the peculiarities of the object they represent or the ambiguity of the very data structure – includes a source of imprecision other than the randomness derived from the stochastic processes but derived from the absence of frontiers abruptly defined among the classes[40], we should draw our attention back to the use of the theory of fuzzy sets.

---

[38] For more details see BAROUCHE & SAPORTA (1982), MANLY (1986), KAGEYAMA & LEONE (1999), S-PLUS (2000), among others.

[39] As for our case, agglomerating sectors in clusters with similar locational characteristics and circulation requirements may be interpreted as the configuration of spatial industrial complexes, characterizing sectors with better and worse spatialized economic insertion in the economy of Minas Gerais.

[40] This seems to be our case, in which industrial sectors – mainly those of base industry – keep technical relations of production simultaneously with several productive chains.

According ZADEH (1965), a fuzzy subset of any set *X* is defined as a function *u: X [0,1]*; for each $x \in X$ the value of *u(X)* is the degree of pertinence of *x* to a subset *u*. Thus, if instead of assuming values in the discrete interval *"{0,1}"*, the function of pertinence assumes values of the continuous interval *"[0,1]"*, then set *"A"* is called fuzzy set in which each individual may partially belong to multiple sets. The value of *u(X)* is commonly used so as to represent the degree or extent to which *X* is associated with the semantic description of *u*, though *u(X)* can not be interpreted as the probability that *X* belongs to class *u,* but to what extent it belongs to it. HARRIS *et al.* (1993:157) clearly exemplifies as follows:

> "Therefore, the number $u_{ik} = u_i(x_k)$ specifies the membership that datum x_k has with the i^{th} fuzzy cluster (u_i). In this context, a value such as u_{ik}=0.65 can be interpreted as follows: the numerical features of vector x_k possesses (roughly) 65 percent of the attributes required to be a perfect or prototypical representative of cluster i. Note that u_{ik}=0.65 does not infer that here exists a 65 percent chance that x_k belongs to the i^{th} cluster. The degree of membership of a given datum with a given cluster is unknown using 'hard' clustering algorithms".

WOODBERY *et al.*(1978) also give an example of intuitive pertinence function. If S_1 is the set of whole numbers higher than "*n*", S_2 the set of whole numbers well over "*n*", and *I* and *J* whole numbers such that *I>J>, n,* we can state that *I* is an element of de S_2 in an extent greater than the element *J.*

Based on this introduction of the logic of fuzzy sets, we can return to the classification methods and present the FANNY algorithm [41] (Fuzzy Analysis) for estimating the clusters. According to KAUFMAN & ROUSSEEUW (1990), compared to other fuzzy clusters estimation methods (Fuzzy-C Means, for example, described in BEZDEK, 1981), the FANNY method shows the advantage of accepting dissimilarity matrices by all metrics for the continuous sets, in addition to being more robust than the others.

Thus, for each element *i* and each cluster *v*, there is a pertinence u_{iv} indicating how strongly *i* belongs to *v*, if the conditions below are satisfied

1) $u_{iv} \geq 0 \quad \forall \quad i = 1,\ldots,n \quad e \quad \forall \quad v = 1,\ldots k$

2) $\sum_{v=1}^{k} u_{iv} = 1 \quad \forall \quad i = 1,\ldots,n$

The associations are defined by means of the minimization of the objective function:

$$f = \sum_{v=1}^{k} \frac{\sum_{i,j=1}^{n} u_{iv}^2 u_{jv}^2 d(i,j)}{2 \sum_{j=1}^{n} u_{jv}^2}$$

The metrics of dissimilarity *d(i,j)* – any of those previously described – is estimated based on the information matrix – **V,** in our case – and the minimization of

[41] The software S-PLUS 2000 was used for estimating the fuzzy clusters, by making use of the spatial accessibility matrix **V** as a matrix of basic information for determining the spatial industrial complexes for the economy of Minas Gerais. See KAUFMAN&ROUSSEEUW (1990) for a complete presentation not only of the estimation algorithm for pertinence functions but also the statistical properties and characteristics of the FANNY method.

the objective function, through which estimates of the clusters are generated, is accomplished by means of iterative numerical processes.

The resulting clusters may have their fuzziness assessed by the so-called DUNN coefficient *(F_k)*[42]:

$F_k = \sum_{i=1}^{n}\sum_{v=1}^{k}\frac{u_{iv}^2}{n}$, being $1/k < F_k < 1$. From the instrumental viewpoint, both for 1980 and for 1996, we defined matrix **V** as the original information matrix, the dissimilarity matrix being constructed based on Euclidean distances.

4.3 – Spatial Industrial Complexes (SpIC): identification and fuzzy clusters analysis

Part of the literature on regional economics, specially the works based on the computable general equilibrium (CGE), is again concerned with constructing interregional input-output matrices. These matrices are an attempt to model the economic structure of a given region as far as its intersectorial purchase and sales structure is concerned, describing the existing trade pattern between this region and the rest of the country. Furthermore, they may serve as an auxiliary tool in evaluating the "leaking pattern" of final demand from the analyzed region to "rest of the world" (Minas Gerais in relation to Brazil, for example). They also provide a basis for the estimate of regional multipliers and the identification of key sectors, much in the same way as those of Rasmussen / Chenery & Watanabe.

However, based on these works we will not be able to determine intersectorial regional patterns of leaks, i.e., the effects that the absence or poor location of certain sectors may have on the economic structure as a whole – the basic proposition of our work. Moreover, identifying the set of sectors with similar economic-spatial characteristics allows us to analyze both the faults/porosities in the regional productive chains and their possible opportunities of clustering. Additionally, the value of the respective pertinence degrees of each identified fuzzy cluster would give us the intensity of association and interdependence of each sector in relation to the spatial industrial complex in question. From this point on, we shall identify and analyze the clusters estimated by the FANNY algorithm for Minas Gerais concerning 1980 and 1996.

4.3.1 – Identifying clusters for 1980

As seen in the previous section, we are working with matrix **V** measuring 66 X 66 for 1980. Below, Chart 4.1 describes the sectors and their identification numbers.

It is worth noting that the total results of the pertinence (u_{ik}), which determine the sectorial configuration of fuzzy clusters, are presented in the ANNEX and here we shall only interpret the most significant and economic relevant results[43].

According to MIYAMOTO (1990), the number of fuzzy clusters (k) in hierarchic ranking should the highest possible, since in this way it is possible to identify

---

[42] For normalized data, when the attribute scales of each individual present a wide range of variability – which is not our case - the normalized version of F_k is $F_k^* = (F_k - 1/k)/(1 - 1/k) = kF_k - 1/k-1$, with $0 < F_k^* < 1$.

[43] It is worth mentioning that line 66, concerning the factor labor force, has no economic meaning in estimating the clusters. It is only relevant for interpreting constraints posed intersectorially by the labor market.

linkages for all subclasses. For our case, this will allow us to qualify spatial interdependencies by visualizing the integration intensity of given sectors to given productive chains. Therefore, according to S-PLUS (2000), for estimating the utmost number of fuzzy clusters, the rule *max k = (i/2) –1* should be followed, being *i* the number of individuals in the universe.

Chart 4.1 - Identifying sectors of I-O M for 1980

1	Agriculture and cattle raising	34	Distillation of Alcohol
2	Extraction of metal ores	35	Petroleum refining
3	Extraction of non-metallic minerals	36	Petrochemistry
4	Extraction of petroleum and gas	37	Manufacturing of resins and fibers
5	Extraction of coal	38	Manure and fertilizers manufacturing
6	Cement manufacturing	39	Manufact. of several chemicals
7	Manufacturing of cement structures	40	Pharmaceutical industry
8	Glass manufacturing	41	Perfume industry
9	Manufacturing of non-metallic minerals	42	Manufacturing of plastic sheets
10	Steel industry	43	Manufacturing of plastic products
11	Nonferrous metallurgy	44	Natural fiber spinning mills
12	Manufact. of castings and forged steel	45	Synthetic fiber spinning mills
13	Manufact. of other metallurgic products	46	Other textile industries
14	Manufact.of mach./equip., includ. Parts	47	Manufacturing of clothing
15	Manufact. of tractors and rolling stock	48	Leather and furs
16	Maintenance/repair of mach. and equip.	49	Footwear
17	Manufact. of electric equipment (distrib.)	50	Coffee industry
18	Manufact. of electric equipment (mach.)	51	Rice processing
19	Manufact. of home appliances	52	Wheat grinding
20	Manufact. of electronic equipment	53	Preparation of pickles and juices
21	Manufact. of TV/radio sets and sound syst.	54	Processing of vegetable products
22	Manufact. of motor vehicles	55	Tobacco industry
23	Manufact. of motor vehicle parts	56	Slaughter/prep. of meat products
24	Shipbuilding industry	57	Slaughter/prep. of fowl products
25	Manufact. of railway vehicles	58	Industry of dairy products
26	Manufact. of vehicles of other kinds	59	Sugar industry
27	Lumber industry	60	Manufact. of crude vegetable oils
28	Furniture industry	61	Vegetable oil refining
29	Manufact. of cellulose	62	Manufact. of animal food
30	Manufact. paper and paper articles	63	Other food industries
31	Publishing and printing	64	Beverages
32	Rubber	65	Manufact. miscellaneous products
33	Manufact. of chemical elements	66	Line w

Undoubtedly, many of these fuzzy clusters do not have economic meaning by itself and it is necessary to interpret them jointly with other subgroups. Thirty-two clusters were estimated for 1980[44] and a synoptic view of the so-called closest hard clusters can been seen in Chart 4.2, below.

[44] The Dunn coefficient – which measures the "fuzziness" of the data set composed by **V** for 1980 – is *F = 0,4532.*

Chart 4.2 – The Closest Hard Clusters for 1980

Clusters	Sectors
Agriculture and Cattle-Raising I	38,50,59
Agriculture and Cattle-Raising II	1,51,56,57,58,54
Mining and Metallurgy	2,10,12
Nonmetallic Cluster	3,6,8,9
Paper and Cellulose	29,30,33
Furniture	28,37,43
Clothing/Footwear	44,47,49
Pharmaceutical Cluster	40,41
Nonexistent Cluster	4,5
Sectors in Ill-Defined Cluster	15,17,21,35,55,53,64
Sectors in Ill-Defined Cluster	11,19,23,24,25,39
Individual Clusters	Remaining sectors

Source: prepared by the author.

The first result to be highlighted is the visualization of 9 industrial clusters with relevant spatial-economic characteristics. The linkage of sector (i) to a specific cluster (k) corresponds to the highest value of u_{ik} by sector. As mentioned before, the fuzzy technique allows identifying not only the main linking, but also secondary linkages of each correlated cluster. Henceforth, we shall present the value of pertinence degrees (u_{ik}) higher than 10% of each sector for the analyzed cluster.

The first two clusters encompass the sectors linked to the agroindustrial base, ranked in two major fuzzy clusters.

Table 4.1 – Agroindustrial Cluster I, 1980

Sectors	Pertinence Degrees (u_{ik})
Coffee industry	0.845
Sugar industry	0.657
Manure and fertilizers	0.270
Agriculture and cattle-raising	0.210
Slaughter	0.100

Source: prepared by the author

As we can see from Table 4.1, the first sector involves the agroindustrial base of products that can be taken as tradables, namely, coffee ($u_{ik}= 0.845$) and sugar industries ($u_{ik}=0.657$) and manufacturing of manure and fertilizers ($u_{ik}= 0.270$), the very agricultural and cattle-raising sector ($u_{ik}=0.210$) and to a lesser extent the sector concerning the animal slaughter ($u_{ik}=0.100$). The difference in value of u_{ik} for the last three sectors (manure and fertilizers; agriculture and cattle-raising, and slaughter) is due to that they can also be incorporated in a relevant pertinence degree into another specific cluster, namely, the second agriculture and cattle-raising fuzzy cluster.

Table 4.2 – Agroindustrial Cluster II, 1980

Sectors	**Pertinence Degrees (u_{ik})**
Processing of vegetable products	0.990
Dairy industry	0.766
Rice industry	0.740
Agriculture and cattle-raising	0.580
Fowl slaughter	0.396
Manure and fertilizers	0.236
Cattle slaughter	0.223

Source: prepared by the author.

This cluster is composed of the following sectors: rice processing $u_{ik}= 0.740$), cattle slaughter ($u_{ik}=0.223$), fowl slaughter ($u_{ik}=0.396$); dairy industry ($u_{ik}=0.766$); processing of vegetable products ($u_{ik}= 0.990$), besides agriculture and cattle-raising ($u_{ik}=0.580$) and manure and fertilizers ($u_{ik}=0.236$), which characterize the remaining sectors linked to the agroindustrial complex. The other sectors of this chain can be described as ill-localized and nonintegrated, and considered as isolated sectors in the economy of the state as well. A sector like animal food manufacturing obviously linked to the agriculture and cattle-raising base and the animal slaughter industry was characterized as being a unity cluster with an unequivocal pertinence degree to an isolated cluster ($u_{ik}=0.976$).

Another relevant agglomerate for the Minas Gerais economy is the one characterized by the cluster of the mining and metallurgic complex shown in Table 4.3 below.

Table 4.3 – The Mining-Metallurgic Cluster, 1980

Sectors	**Belonging Degrees (u_{ik})**
Castings and steel forged products	0.995
Metal ore extraction	0.956
Steel industry	0.948
Other metallurgic products	0.205

Source: prepared by the author.

This cluster is unequivocally composed of the following sectors: metal ore extraction ($u_{ik}=0.956$); steel industry ($u_{ik}=0.948$) and castings and steel forged products ($u_{ik}=0.995$), and to a lesser extent other metallurgic products ($u_{ik}=0.205$), which constitute the mineral-metallurgic complex characterizing the economy of Minas Gerais until the beginning of the 1980s and was inserted in the interregional division of labor in Brazil. The clear identification of this cluster reinforces not only its importance, but also its integration difficulties with the remaining metal-mechanic complex in Minas Gerais. This can be clearly noticeable, for example, if we assume that the pertinence degree ($u_{ik}=0.205$) of the sector other metallurgic products – obviously a stage ahead in the mineral-metallurgic chain – to the cluster in question may include it in this complex, even if it shows a $u_{ik}= 0.365$ to an isolated cluster. Sectors of more elaborated products, with higher aggregate value, and differentiated position in the metal-mechanic chain do not shown any integration in the industrial economic structure of the state in 1980. Sectors like machines and equipment, automotive parts, maintenance and repair and even the automotive industry are isolated and unity clusters. The establishment of FIAT Automobiles in Betim (Metropolitan Area of Belo Horizonte, the capital of the State of

Minas Gerais) in the mid seventies brought a marginal change in the structural profile of this incipient sectorial integration. However, in 1980, it was not still possible to detect changes in the industrial structure integration, particularly that led by the automotive industry and its suppliers. Such a process, however, is shown in the analysis for 1996, with aggregation problems though.

Another well-defined cluster is described in Table 4.4 below.

Table 4.4 – The Non-metallic Mineral Cluster, 1980

Sectors	**Pertinence Degrees (u_{ik})**
Glass manufacturing	0.997
Cement manufacturing	0.994
Manufacturing of non-metallic minerals	0.151
Extraction of non-metallic minerals	0.107

Source: prepared by the author.

This cluster comprises the sectors of non-metallic mineral extraction ($u_{ik}=0.107$), cement manufacturing ($u_{ik}=0.994$); glass manufacturing ($u_{ik}=0.997$), and manufacturing of non-metallic mineral products ($u_{ik}=0.151$). The sectorial linkage is clear and the relatively low values for extraction and manufacturing of non-metallic minerals are due to the fact that this sector is basic for other sectors in the productive structure, besides having strong links with the industry of civil construction which is not analyzed here. It is worth mentioning that the sector manufacturing of cement structures – a final phase in this productive chain – is not characterized by any specific cluster (all of its u_{ik} are smaller than 5 %) and is ranked as a nonintegrated sector.

Cluster k=4 shows a peculiarity, i.e., it comprises two nonexistent sectors Minas Gerais: Petroleum Extraction and Coal Extraction. Both are fundamental and basic sectors for the whole petrochemical and correlated chains (resins, plastics, rubber, etc.) and steel industry and its developments downstream. The classification of these two sectors in the same group from the application of the FANNY methodology and algorithm may be considered as a guarantee of accuracy for the model. The absence of a petrochemical complex in the state becomes clear as we verify the classification of the sectors linked to such a productive chain. The petrochemical sector – ill-localized in the state – was unequivocally presented as an isolated cluster ($u_{ik}=0.996$) as well as the manufacturing of plastic sheets ($u_{ik}=1.000$), rubber industry ($u_{ik}=1.000$) and to a lesser extent spinning of synthetic fabrics ($u_{ik}=0.490$). The sectors of petroleum refining and plastic articles, in turn, showed an ill-defined ranking; both movements characterized the integration absence of this chain in the region.

Other clusters – less important either from the viewpoint of backwards and forwards linkages the productive chain or the percentage participation in the industrial aggregate value of the state, but with slight spatial linkages – may be identified.

Table 4.5 – The Paper and Cellulose Cluster, 1980

Sectors	**Pertinence Degrees (u_{ik})**
Manufacturing of paper and paper articles	0.998
Manufacturing of cellulose	0.450
Manufact. of noncarbochemical / chemical elements	0.181

Source: prepared by the author.

The first cluster, identified in Table 4.5, is a result of the establishment of CENIBRA (Celulose Nipo-Brasileira S.A.) in Belo Oriente, in the *Vale do Aço* (literally, the Steel Valley, 100 miles northwest of Belo Horizonte) and comprises the sectors manufacturing of cellulose ($u_{ik}=0.450$), manufacturing of paper and paper articles ($u_{ik}=0.998$), and manufacturing of noncarbochemical chemical elements ($u_{ik}=0.181$)[45].

Table 4.6 – The Furniture Cluster, 1980

Sectors	Pertinence Degrees (u_{ik})
Furniture industry	0.992
Manufacturing of resins	0.239
Manufacturing of plastic articles	0.203

Source: prepared by the author.

The second cluster, shown in Table 4.6, encompasses the sectors furniture industry ($u_{ik}=0.992$), resins ($u_{ik}=0.239$), and plastic articles ($u_{ik}=0.203$). It is worth noting that the lumber industry can be characterized in this cluster (it shows a $u_{ik}=0.021$) and in no other else – indicating a slight internal linkage between the raw material base and the rest of the productive chain (the sectors glass manufacturing, with $u_{ik}=0.028$ and other metallurgic products, with $u_{ik}=0.017$, can not be included in this cluster).

Table 4.7 – The Clothing and Footwear Cluster, 1980

Sectors	Pertinence Degrees (u_{ik})
Spinning of natural fiber fabrics	0.859
Clothing manufacturing	0.255
Footwear manufacturing	0.252

Source: prepared by the author.

Table 4.8 – The Pharmaceutical Cluster, 1980

Sectors	Pertinence Degrees (u_{ik})
Pharmaceutical industry	0.227
Perfumery industry	0.172

Source: prepared by the author.

Other two small clusters are shown in 4.7 and 4.8. The first comprises the following sectors: manufacturing of clothing articles ($u_{ik}=0.255$), manufacturing of footwear ($u_{ik}=0.225$), and spinning of natural fiber fabrics ($u_{ik}=0.859$). The second is composed of sectors pharmaceuticals ($u_{ik}=0.227$) and perfumery ($u_{ik}=0.171$). Both clusters are well defined as their values of u_{ik} show, but even though they show pertinence degrees well over those for the remaining clusters. It should be noted that in these two clusters there was a clear, slight integration at the time both with those sectors technically located downstream and those correlated sectors in the productive chain. The nonintegration of the clothing industry with synthetic fibers and that of footwear

[45] The latter is justified by the chlorine bleaching existing at the time of the *Belo Oriente* plant. Nowadays, bleaching is performed by oxygen sprinkling, a cheaper process and less harmful to the environment. See PAULA (1997). The remaining values of u_{ik} for the sector are nonsignificant.

with leather and furs and plastics shows how incipient these sectors were in the state, besides highlighting the spatial constraints that the absence of a petrochemical complex may give rise in the integration of productive chains. The pharmaceutical and perfumery industries, in turn, did not present integration upstream and were slightly important in the state.

Finally, we should focalize two other clusters. The first is not a cluster in itself, but conversely it is a set of sectors – which are important in the industrial structure and relatively well localized in Minas Gerais – that cannot be taken as being integrated in the economy of the state. They are extremely well defined clusters – i.e., with pertinence degrees u_{ik} close to the unity – and characterized as units with only one sector in each ranking. We may list the following sectors as having such a characteristic: manufacturing of machines and equipment ($u_{ik}=0.959$); maintenance and repair of machines and equipment ($u_{ik}=0.976$); electric material ($u_{ik}=0.988$); manufacturing of automotive vehicles ($u_{ik}=0.986$) all of them linked to the chain of mechanic-electric complex, but without the spatial economic interrelations in the state that could characterize them as spatial industrial complexes in Minas Gerais. The relative dissociation between the sectors automobile manufacturing and automotive parts should be emphasized. Other sectors belonging to unity isolated clusters, but not so well localized in Minas Gerais, are manufacturing of other vehicles ($u_{ik}=0.985$), electronic material ($u_{ik}=0.973$), leather and furs ($u_{ik}=0.943$), and distillation of alcohol ($u_{ik}=0.976$).

The last two groups are less clearly defined and have a complex economic explanation. They comprise disconnected sectors from the viewpoint of technical linkages and with slight or no relevance in the industrial structure of the state. Despite being fundamental in structuring some productive chains (manufacturing of electric equipment, petroleum refining, nonferrous metallurgy, various chemicals, automotive parts) and other important final consumption goods (electric home appliances, TV, radio sets and sound systems, and beverages), they cannot be taken as integrated in the state. Those, which are well-localized – nonferrous products and various chemicals – may be considered isolated sectors, with no downstream or upstream integration in the state industrial economic structure. Those ill-localized sectors, in turn, impinge restraints to full interregional sectorial integration in Minas Gerais. None of the sectors listed in these two clusters has pertinence degrees allowing the establishment of clear links with any other ranking and may be taken as being ill defined for 1980.

Now, let us now identify and analyze the clusters in Minas Gerais in 1996.

4.3.2 – Identifying clusters for 1996

As for 1996, as previously pointed out, we worked with a matrix **V** measuring 32 x 32, as a basis for identifying the fuzzy clusters[46].

Before analyzing the results, it is worth emphasizing that the reduced size of the I-O M / 1996 – Brazil, greatly restrains the possibility of identifying slightly diversified spatial industrial complexes. The excessive aggregation level of the matrix disguises certain spatial dynamics; for example, joining the sectors "lumber and furniture" – which were kept apart in 1980 – in only one category makes two locational dynamics,

[46] The same rule suggested by S-PLUS (2000) was applied, i.e., $k = (i/2) - 1$, and 15 fuzzy clusters were found. However, due to the extreme aggregation and reduced number of sectors in the original matrix provided by IBGE, the last two clusters have no statistical and economic significance. The best estimation encountered for 1996 had 13 fuzzy clusters.

absolutely diverse in the case of Minas Gerais, to be mingled with. To consider "textiles" as a single sector is more troublesome from the viewpoint of identifying productive chains in space. That is to say, the spatial-economic logic of "natural fiber manufacturing" and "synthetic fiber manufacturing" – which were disaggregated in the 1980's I-O M – are totally different with their upstream linkages being part of two productive chains with slight association, namely, the agroindustrial and petrochemical complexes. Joining "leather and furs" with "footwear" in a single sector is also troublesome, specially in Minas Gerais, where the most significant footwear production – tennis footwear production in Nova Serrana, 100 miles west of Belo Horizonte – is based on synthetic products[47], not to mention the sector "manure, paints, and other chemicals" which does not deserve any further comments.

Chart 4.3 – Identification of sectors in the I-O M for 1996

	Sectors
1	Agriculture and cattle-raising
2	Mineral extraction
3	Extraction of petroleum and gas
4	Non-metallic minerals
5	Steel industry
6	Nonferrous metallurgy
7	Other metallurgical products
8	Tractors and ground-leveling machines
9	Electric materials
10	Electronic equipment
11	Automobiles, trucks, and buses
12	Other vehicles and parts
13	Lumber and furniture
14	Paper, cellulose, cardboard, and articles
15	Rubber industry
16	Nonpetrochemical, chemical elements and alcohol
17	Petrochemicals
18	Manure, paints and other chemicals
19	Pharmaceutical and perfumery products
20	Plastic articles
21	Textiles
22	Clothing
23	Leather and footwear
24	Coffee industry
25	Processing of vegetable products
26	Slaughter of animals
27	Dairy industry
28	Sugar industry
29	Manufacturing of vegetal oils
30	Beverages
31	Miscellaneous products
32	Line w

Such a high degree of aggregation does not allow that some slightly diversified spatial industrial complexes be identified[48]. Notwithstanding, applying the proposed methodology as an update exercise of the results and mainly of intertemporal

[47] See SANTOS, CROCCO & SIMÕES (2001).

[48] What really surprises us is the nonuniformity of the criteria for agglomerating the sectors to be presented in the matrix for 1996. Some links are accomplished based on upstream homogeneity, as in "manure and paints", others on downstream homogeneity, as in "textiles", and still others – apparently – on residual criteria, as in "other vehicles and automotive parts".

comparison between the identified spatial industrial complexes is justified. Once such remarks have been made, we may start analyzing the fuzzy clusters for 1996. The sectors are found in Chart 4.3.

The total results of the FANNY algorithm estimation from **V** are found in the ANNEX[49]. Chart 4.4 is presented below including the so-called Closest Hard Clusters, i.e., the closest crisp clusters to which each sector will belong in a fuzzy estimation. As those for 1980, tables with clusters identified, based on values u_{ik} higher than 20% for each relevant cluster[50].

Chart 4.4 – The Closest Hard Clusters for 1996

Cluster	**Sectors**
Agricultural cluster	1,24,25,26,27,28,29,30
Mineral-metal-mechanic cluster	2,5,6,7,11
Automotive parts sub-cluster	8, [6],[7]
Ill-defined cluster	9,13,15,17,23
Individual clusters	Remaining sectors

Source: prepared by the author.

As can be noted, most sectors did not present any kind of integration and they may be identified as pure profiles. This is due to both the excessive sectorial aggregation of the matrix and the very industrial structure of the state. The only two spatial complexes clearly identified for the state are related to the two productive chains historically important in Minas Gerais.

Table 4.9 – The Agroindustrial Cluster 1996

Sectors	**Pertinence Degrees (u_{ik})**
Dairy industry	0.780
Agriculture and cattle-raising	0.744
Animal slaughter	0.641
Coffee industry	0.571
Processing of vegetables	0.512
Sugar industry	0.510
Manufacturing of vegetal oils	0.332
Beverages	0.331

Source: prepared by the author.

The agroindustrial complex – identified in the first fuzzy cluster and shown in Table 4.9 – comprises the following sectors: agriculture and cattle-raising ($u_{ik}=0.744$), coffee industry ($u_{ik}=0.571$), processing of vegetal products ($u_{ik}=0.512$), animal slaughter ($u_{ik}=0.641$), dairy products ($u_{ik}=0.780$), sugar industry ($u_{ik}=0.510$), vegetal oils ($u_{ik}=0.332$), and beverages ($u_{ik}=0.331$). This is the most well identified cluster for 1996, which encompasses all sectors in the agricultural productive chain. It is worth noting that, for vegetal oils and beverages, the pertinence degree is clearly lower than that for the sectors more directly related to the agricultural base. The sector vegetal oils has a u_{ik} = 0.153 for an isolated cluster k=5, unequivocally defined by the machines and equipment ($u_{ik}=0.982$).

[49] The value of the Dunn coefficient for 1996 is $F = 0.3515$. This value, lower than that for 1980, was expected, given the lower disaggregation of the matrix.

[50] As the number of sectors – and obviously that of clusters – is approximately half of that for 1980, heightening the lowest limit from 10% to 20% is justified.

As for 1980, an amplified sectorial range of the complex may be noted that encompassed all sectors in a single cluster without differentiating tradable products from domestic market products. However, the undue aggregation of sector 18 (manure, paints, and other chemicals) made – differently from that identified for 1980 – the use of manure and fertilizers were ill-characterized in defining the cluster which showed an only 10% ($u_{ik}=0.100$) linkage to the agroindustrial complex.

The second fuzzy cluster identified, shown in Table 4.10, comprises that what we can call the mineral-metal-mechanic complex in Minas Gerais.

Table 4.10 – The Mineral-Metal-Mechanic Cluster, 1996

Sectors	Pertinence Degrees (u_{ik})
Mineral extraction	0.789
Steel industry	0.650
Automobiles, trucks, and buses	0.499
Nonferrous metallurgy	0.485
Other metallurgic products	0.392
Miscellaneous products	0.364

Source: prepared by the author

The cluster comprises the following sectors: mineral extraction ($u_{ik}=0.789$), steel industry ($u_{ik}=0.650$), nonferrous metallurgy ($u_{ik}=0.485$), other metallurgic products ($u_{ik}=0.392$), automobiles, trucks, and buses ($u_{ik}=0.499$), and miscellaneous products ($u_{ik}=0.364$). In relation to that for 1980, this complex has diversified, presenting now a higher integration degree among its components, i. e., to the mineral-metallurgic base, well identified for 1980. Two very important sectors for describing the integration of the productive structure experienced by the state economy in the last 20 years, i.e., automotive industry and metallurgic products (foundry, industrial boilers, metallic structures, metalworking, among others) were included. Increasing investment and introducing new management process of supplies at FIAT (LEMOS *et al.*, 2003), besides the establishment Mercedes Benz in Juiz de Fora (200 miles at southeast of Belo Horizonte), have contributed to diversifying the economic structure in Minas Gerais after 1990. Despite these developments, we can notice that the sector producing parts and other vehicles – irrespective of its own (in)definition, as it includes the production of aircrafts and railway vehicles, virtually nonexistent in Minas Gerais – is not organically included in this cluster, presenting a small pertinence degree ($u_{ik}=0.129$) as for this complex.

Table 4.11 – The Automotive Parts Subcluster, 1996

Sectors	Pertinence Degrees (u_{ik})
Other vehicles and parts	0.825
Nonferrous metallurgy	0.152
Automobiles, trucks, and buses	0.138

Source: prepared by the author.

On the other hand, as can be seen in Table 4.11, this subcluster is well defined ($u_{ik}=0.825$) with a small integration with the very automotive sector ($u_{ik}=0.138$) and nonferrous metallurgy ($u_{ik}=0.152$) only. The internalization in Minas Gerais of parts and components suppliers of the automotive industry during the 1990s (BDMG, 2002; FIEMG, 2000), which should presumably contribute to including this sector in this cluster, is handicapped by the incipiency of the electric-electronic sector in the state.

This subcluster shows a very slight integration with the rest of the productive chain. The electric sector – better localized than the electronic one, mainly the portion concerning electric materials – shows a $u_{ik}=0.101$ to cluster 2. The sector electronic equipment– ill localized in the whole state of Minas Gerais – shows $u_{ik}=0.025$, i.e., only a 2.5% pertinence degree to the metal-mechanic complex, characterizing an isolated cluster ($u_{ik}=0.880$).

A relevant portion of the suppliers of FIAT mounts the components with parts produced in other federative states (mainly São Paulo) the majority of which come from abroad. If it allowed an attempt of integration, the aforementioned modernization of the organizational structure of the assembly industry in relation to its suppliers – the adoption of *just in time* being the principal process – was not followed by the necessary improvement of the productive chain as for the production of components which would permit reduced regional leaks in the productive complex.

The electric sector, in turn, deserves special attention. The work of DUARTE Fº & CHIARI (2002:36), utilizing an interregional input-output matrix for Minas Gerais and the rest of Brazil (AZZONI *et al.*, 2002), shows that this sector started to purchase most of its inputs internally in the state. Such a development, surprising for the authors themselves, was not confirmed by our estimation. It was mostly linked to a cluster which could be defined as ill identified, comprising the following sectors: electric ($u_{ik}=0.344$), lumber and furniture ($u_{ik}=0.365$), rubber industry ($u_{ik}=0.205$), leather and footwear ($u_{ik}=0.298$), and petrochemistry ($u_{ik}=0.384$). Despite the fact that the last three sectors are not part of a specific productive chain, the values of u_{ik} do not allow to identify a relevant integration, even because petrochemistry ($r=0.35$) and rubber industry ($r=0.09$) are ill localized in the state in relation to the country. Moreover, the presence of the electric and lumber and furniture sectors would not characterize the formation of an economically significant productive chain.

The remaining sectors comprise isolated clusters, being high the values of u_{ik}. Cluster 13 shows textiles as the defining sector ($u_{ik}=0.457$) and a slight integration with the Clothing sector ($u_{ik}=0.111$). Clothing, however, unequivocally defines the isolated cluster 12 ($u_{ik}=0.821$), which shows a weak integration between these two sectors in the economy of Minas Gerais.

From the well-defined isolated clusters, we should highlight the group including the nonpetrochemical chemical sector which shows a $u_{ik}=0.997$. This sector experienced a growth higher than the average in the state during the 1990s and became relevant nationally with a participation in the Brazilian employment in the sector of about 7% in 1999 (RAIS, 2000). According to our results, however, such a growth was not followed in the state by a higher integration with the rest of the state economic structure.

Joining paper and cellulose in a single sector has turned that subcomplex defined for 1980 into an isolated sector, with a $u_{ik}=0.968$ in 1996.

Finally, Cluster 4 may also be considered well defined, with sector nonmetallic minerals showing a $u_{ik}=0.900$, and with a slight integration with mineral extraction ($u_{ik}=0.125$). Here, joining sectors extraction of metallic minerals and extraction of nonmetallic minerals in defining the input-output matrix / 1996 turns important sectorial linkages obscure. Due to the relevance of the iron ore extractive industry in the economy of Minas Gerais and its well-defined integration with the metal-mechanic complex, the sector nonmetallic minerals (basically cement, refractories, and glass) is isolated in a single subgroup.

The next, and last, section concludes the paper - an attempt to assess the results consistency - based on a brief analysis of the industrial structure of the state and its development from the 1980s up to now.

5 - Concluding Remarks: Spatial Industrial Complexes in MG

This paper aimed at presenting an identification methodology of industrial complexes in space and performs an application exercise for the economy of Minas Gerais. The methodology is divided into two stages. The first consists of the construction of a spatial accessibility matrix (**V**) that combines – in the same analytical status – the spatial dimension and the dimension of technical relations of production. The values of the elements of such matrix **V** represent the relative magnitude of intersectorial spatial constraints caused by good or poor location of industrial sectors in a given region, taking the intensity of its trades into account. The individual analysis of each element of this matrix may provide the identification of bottlenecks for the internalization, in the region under study, of multiplier effects stemming from a block of investments. It would be like a proxy for the interregional leaking pattern of the intermediate and final purchase and sales relations.

The second stage consists of an attempt to identify groups of sectors having analogous and complementary technical and spatial interrelations, comprising spatial industrial complexes. That is, they would be productive chains – or *filières* – that, besides showing technical linkages of intermediate purchase and sales, would show at the same time locational linkages so as to characterize industrial complexes in space. For this, a statistical method was used with the logic of nebulous sets: *fuzzy cluster.* Applying the FANNY algorithm (*Fuzzy Analysis*), in an exercise for the economy of Minas Gerais, has allowed us to identify intersectorial groupings and analyze their degree of internal integration, showing porosities of the existing productive chains and the isolation of given sectors. Additionally, using the fuzzy logic allowed us to break up the restraints of usual methods, which classify sectors in just one group, i.e., a set may belong to more than one cluster at the same time, a convenient situation in which sectors of basic inputs, for example, can be ranked.

In spite of the interesting results found, the application exercise of the proposed methodology was relatively handicapped by the low degree of disaggregation of input-output matrix disclosed by IBGE, mainly as for the exploration of the methodology potential for identifying industrial complexes and subcomplexes in space, besides the very intertemporal comparability of results. If, in 1980, the I-O M for Brazil showed a disaggregation around 100 sectors, including those with no economic significance – highly aggregated if compared to more than 500 relevant sectors of the input-output matrix disclosed by the US Bureau of Census – the very possibility of using the I-O M 1996 for Brazil is somewhat compromised. Redefining plans for the construction and disclosure of input-output matrices in Brazil is an urgent need, as this is a powerful tool for policy-making both at macroeconomic level and sectorial level and even at the regional level, as we attempt to use in this work.

Based on the aforesaid and on the results previously presented, we are able to conclusively consider about the economic structure of Minas Gerais.

Characterized, until the 1970s, as having an essentially primary economy – heavily concentrated in sectors linked to its natural resources and to its agricultural base – in the last 30 years, Minas Gerais has experienced a relevant diversification of its productive structure. This diversification, extensively explored in the literature (BDMG, 1989, 2002; CHAVES, 1990, 1995; FERREIRA, 1996; FERNANDES, 1997; DINIZ & LEMOS, 1989; DINIZ & CROCCO, 1995, 1996; LEMOS *et al*., 2000; SILVA & LOCATELLI, 1991; HADDAD, 1995, 1999; SIMÕES, 1988; FONTES, 2002; RODRIGUES & SIMÕES, 2003; among others) may be largely explained by the spillover effects from the São Paulo industrial park to its immediate hinterland. If the industrial participation of Minas Gerais expanded by only one percent in the Brazilian industrial GDP during the 1970s, its sectorial change was quite relevant showing a higher aggregate value in the industrial sectorial composition.

However, if such diversification in the seventies – with the establishment of industries of capital goods (POLIHECKEL, KRUPP, CBC, USIMEC, ISOMONTE, among others), fertilizers (ARAFÉRTIL, FOSFÉRTIL), cellulose (CENIBRA), and automobiles (FIAT) – started the modernization of the industrial structure in the state, it only made it partially, without achieving a diversified intersectorial integration. The spatial economic complexes found for 1980 clearly show such an event.

If we remove the two subclusters linked to the agroindustrial complex, the presence of only three semi-integrated productive subchains can be noted. The first of these subchains is the cluster encompassing cellulose, paper and nonpetrochemical or carbochemical, which may be considered relatively linked to the state economic thanks to the CENIBRA's plant in Belo Oriente. Even with this relative integration, the regional impact of this chain is low in the economy as a whole, due to the low forward and backward linkages generated in the productive process.

The second subchain, possessing a more relevant integration, is the cluster comprised by the sectors extraction of nonmetallic minerals, cement, glass, and manufacturing of nonmetallic products. Being important for the industrial structure in the state and maybe the chain best integrated into the state economy in the beginning of the 1980s, this subchain shows a typically Weberian locational orientation (SIMÕES, 1988), mainly linked to its natural resources.

Finally, the mineral metallurgic subcomplex is the most important in the economy of the state and comprises the sectors extraction of metallic minerals, steel, castings, and steel forged products. Here, the absence of integration with the remaining sectors linked to the metal-mechanic chain (machines, equipment, automobiles, motors, and electric equipment) is emblematic. That is, the dynamism of the state economy still shows a direct dependence of its sources of raw materials, namely, mining (metallic and nonmetallic) and arable land, the latter both for the agricultural base and the formation of forests for cellulose production. It is also worth noting the absence of the petrochemical complex, the virtual nonexistence of an integrated electro-electronic chain and even the feeble diversification and linkage of traditional sectors as textiles, clothing, and footwear.

Therefore, we could consider the state economy in the beginning of the 1980s as being characterized, on the one hand, by few semi-integrated industries producing intermediary goods, established in their sources of natural resources and nationally relevant. On the other hand, it is also characterized by a series of isolated sectors with a slight or even nonexistent integration, which are less important and ill-located.

During the decades of 1980 and 1990, this profile was marginally modified. With intensified spillovers from the São Paulo industry and existing locational factors of attraction[51], Minas Gerais furthered the diversification of its industrial structure weakly initiated in the 1970s.

The excessive aggregation of the I-O M / 1996 does not allow to completely evaluate the extent of such a diversification – besides disguising certain specificities of intersectorial integration. However, two dimensions become quite clear when analyzing our results. The first is concerned with the agroindustrial complex, unequivocally

---

[51] Mainly, relatively developed physical infrastructure, proximity to great markets, modern base industries, evolved and relatively skilled labor market, presence of important universities and research centers, urban amenities, among others.

identified in the state, with all sectors in the matrix related to the agricultural food productive chain being part of the same cluster[52].

The second dimension highlighted may be considered as the major structural change in the state economy in the last 20 years and the most relevant result of our work, namely, the thickening of the metal-mechanic productive chain in Minas Gerais, clearly identified by the proposed methodology. Such an integrated diversification – though partial for not having integrally incorporated the correlated electric and electronic subsectors – was led by the automotive industry, showing strong upstream linkages with the sectors steel industry and machines and equipment. Though incipient, this fact reveals a modernization drive in the industrial structure of the state, which makes it possible for the state industrial dynamism to escape from its sole dependence on its basic and intermediary sectors. The regionalization of at least a portion of the electro-electronic chain – particularly the embarked one – could greatly reduce the interregional leaks and improve the industrial structural integration in Minas Gerais, by completely constituting the metal-mechanic spatial industrial complex in the state.

The ill location and low integration of the productive chain linked to petrochemistry and carbochemistry in Minas Gerais may be also considered as one of the major hindrances to a greater industrial dynamism. Such a hindrance poses heavy locational constraints to the industrial structure integration, particularly for the traditional and important sectors for employment generation such as textiles, clothing, and footwear, besides the very automotive sector, increasingly demanding plastic components.

Finally, it should be observed that the methodology proposed here is not incompatible with the works that use interregional input-output matrices. The latter may provide important economic policy suggestions as for example the very updated assessment of the interregional impacts of the change in the Brazilian tax regime, import substitution impacts, etc.

The advantage of the methodology proposed here resides in allowing the analysis of spatial intersectorial restrictions and constraints which in turn allows to identify: 1) regional porosities in specific productive chains; 2) eligible sectors as the focus of regional incentive policies; and 3), not less important, the possibility of regional integration and thickening of productive chains.

REFERENCES

ABLAS, L.A.Q. & CZAMANSKY, S. (1982) Agrupamentos e complexos industriais: uma revisão de métodos e resultados. In: LONGO, C.A., RIZZIERI, J.A.B. (org.). Economia urbana: localização e relações intersetoriais. São Paulo: IPE-USP.

ALBAGLI, S.(1999). Globalização, espacialidade: o novo papel do local. In: CASSIOLATO, J.E. & LASTRES, H.M.M. (eds) Globalização & inovação localizada, Brasília: IBICT/MCT.

ALBRECHT, D.E. (1995) Population trends in resource-dependent counties. Journal of the Community Development Society, 26: 155-168.

AZZONI, C.R. (1986) Indústria e reversão da polarização no Brasil. São Paulo: FIPE/USP.

AZZONI, C.R. *et al.*(2002) Matriz Inter-Regional de Insumo-Produto Minas Gerais / Resto do Brasil, 1996. Belo Horizonte: BDMG, 2002.

[52]Except for manure and fertilizers, for the reasons mentioned before.

BANDEIRA, P. (2000) Construção de Políticas de Integração Nacional e Desenvolvimento Regional. In: MINTER, Reflexões sobre políticas de integração nacional e de desenvolvimento regional, Brasília: MINTER.
BAGNOLLI, C. & SMITH, H.C. (1998). The theory of fuzzy logic and its application to real estate valuation. Journal of Real Estate Research, 16(2).
BDMG (1991). Matriz de insumo-produto do Estado de Minas Gerais – 1980, Belo Horizonte: BDMG, 1991 (mimeo).
BDMG. (1989) Economia Mineira: diagnóstico e perspectivas. Belo Horizonte: BDMG.
BDMG (2002). Minas Gerais do século XXI. Belo Horizonte: BDMG, 10v.
BAROUCHE, J.M. & SAPORTA, G. (1982)Análise de dados, Rio de Janeiro: Zahar.
BENKO, G & LIPIETZ, A.(1992) Les régions qui gagnet: districts et reseaux: les noveaux paradigmes de la geographie economique. Paris: PUF.
BERGSMAN, J., GREENSTON, P., HEALY, R. (1972) The aglomeration process in urban of growth. Urban Studies, 9(3).
BEYERS, W.B. (1976) Empirical identification of key sectors: some further evidence. E&P A, 8: 231-236.
BEZDEK, J.C. (1981) Pattern recognition with fuzzy objective function algorithms, New York: Plenum Press.
BRITTO, G. (2002) Abertura comercial e reestruturação industrial no Brasil: um estudo dos coeficientes de comércio. Campinas: UNICAMP/IE, 2002. (MSc. Thesis).
BRUM, I.D.(2001) Desenvolvimento econômico das regiões metropolitanas de São Paulo e Belo Horizonte: um estudo comparativo do nível de integração industrial. Belo Horizonte: FACE/UFMG.
CANO, W. (2002) Questão regional e política econômica nacional. In: CASTRO, A. C. (org.) Desenvolvimento em debate. Painéis do desenvolvimento brasileiro – II. Rio de Janeiro: MAUAD/ BNDES.
CASSIOLATO, J.E. (2000) De aglomerações a sistemas produtivos e de inovação. Rio de Janeiro: IE/UFRJ. (Nota Técnica 22 – Arranjos Produtivos Locais e as Novas Políticas de desenvolvimento Industrial e Tecnológico).
CASTELLS, M. (1982) A questão urbana. São Paulo: Paz e Terra.
CASTELLS, M. (1996) The rise of the network society. The informational age: economy, society and culture. Cambridge: Basil Blackwell.
CHADORNET, J. (1965) Geographie industrielle. Tome II: L'industrie. Sirey.
CHAVES, M.(1990) Economia mineira: avaliação e perspectivas. V SEMINÁRIO SOBRE ECONOMIA MINEIRA, Anais..., Diamantina: Cedeplar/UFMG.
CHAVES, M. (1995) A heterogeneidade regional em Minas Gerais: como combinar o dinâmico e o estagnado.VII SEMINÁRIO SOBRE ECONOMIA MINEIRA, Anais..., Diamantina: Cedeplar/UFMG..
CHENERY, H. & WATANABE, T. (1958) International comparison of the structure of production. Econometrica, 26: 487-521.
CLEMENTS, B. & ROSSI, J.W. (1992) Ligações interindustriais e setores-chave na economia brasileira. PPE, 22 (1): 101-124.
COSTA, M. (2002) A multidimensional approach to the measurement of poverty. IRISS Working Papers Series, 05.
CROCOMO, F.C. & GUILHOTO, J.M.M. (1998) Interação dos setores econômicos entre as grandes regiões, em 1985: uma aplicação de insumo-produto. XVI ENCONTRO NACIONAL DA ANPEC, Anais..., Vitória: ANPEC.
CZAMANSKI, S.; ABLAS, L.A.Q. (1979) Identification of industrial clusters and complexes: a comparation of methods and findings. Urban Studies, 6 (2).

CZAMANSKY, S. (1974) Study of clustering of industries. Halifax: Institute of Public Affairs, Dalhouse University.

DAVID, P.A. (1999) Comment on ‘The role of geography in development’ by P.Krugman. In: PLESKOVIC, B. & STIGLITZ, J.E. Annual World Bank Conference on Development Economics – 1998. Washington: The World Bank.

DERUDDER, B. *et al.* (2003) Hierarchical tendencies and regional patterns in the world city network: a global urban analysis of 234 cities. Regional Studies, 37 (9): 875-886.

DINIZ, C.C. (1991) Dinâmica regional da indústria no Brasil: início de desconcentração, risco de reconcentração. Belo Horizonte, Cedeplar / FACE / UFMG.

DINIZ, C.C. (2000) A nova geografia econômica do Brasil: condicionantes e implicações. In: VELLOSO, J.P.R. (org). Brasil século XXI. Rio de Janeiro: José Olympio.

DINIZ, C.C. (2002) A nova configuração urbano-industrial no Brasil. In: KON, A.(org), Unidade e fragmentação: a questão regional no Brasil. São Paulo: Perspectiva.

DINIZ, C.C. & CROCCO, M.A. (1995) O novo mapa da indústria brasileira: aglomerações industriais relevantes. VII SEMINÁRIO SOBRE ECONOMIA MINEIRA, Anais..., Diamantina: Cedeplar/UFMG.

DINIZ, C.C. e LEMOS, M.B. (1989) Dinâmica regional e suas perspectivas no Brasil. In: PARA a década de 90; prioridades e perspectivas de políticas públicas. Brasília: IPEA-IPLAN, v.3.

DRAESEKE, R. & GILLES, D.E.A. (1999) A fuzzy logic approach to modeling the underground economy. Econometrics Working Papers 9909, Department of Economics, University of Victoria, Australia.

DUARTE Fº, F.C. & CHIARI, J.R.de P.(2002) Características estruturais da economia mineira: uma análise inter-regional de insumo-produto. Cadernos BDMG, 4:11-43.

FINES, J.P. (1973) Analyse spatialisèe des structures de production industrielle: application au cadre règional. Marseille: Faculté de Sciences Economiques. Centre d'Economie Regionale, Université d'Aix en Marseille.

FERNANDES, A. C. (2001) Da reestruturação corporativa à competição entre cidades: lições urbanas sobre os ajustes de interesses globais e locais no capitalismo contemporâneo. Espaço e Debates, 41.

FERNANDES, C.L.L. (1997) A inserção de Minas na economia nacional: uma análise de insumo-produto inter-regional. Nova Economia, Belo Horizonte, X Prêmio Minas de Economia.

FERREIRA, M.S. (1996) Rede de cidades em Minas Gerais a partir da realocação da indústria paulista. Nova Economia, IX Minas Award in Economics.

FESER E.J. & BERGMAN, E.M. (2000). National Industry Cluster Templates a framework for applied regional cluster analysis. Regional Studies, 34 (1): 1-19.

FIEMG (2000). Cresce Minas: um projeto brasileiro. Belo Horizonte: FIEMG.

FLEGG, A.T., WEBBER, C.D. & ELLIOT, M.V. (1995) On the appropriate use of location quotients in generating regional input-output tables. Regional Studies, 29 (6): 547-561.

FONTES, G.G. (2002) Dinâmica espacial da indústria em Minas Gerais: uma análise dos padrões de crescimento das microregiões mineiras no período 1990-2000. Belo Horizonte: FACE/UFMG.

GERMAN, L. *et al.* (1985) Application of cluster analysis for developing a typology of regional economic growth.. SEEA Meeting, Mississipi.

GHOSH, A. & CHAKRAVARTI, A. (1970) The problem of location of an industrial complex. In: CARTER A.P. & BRÓDY, A. (eds). Contributions to input-ouput analysis. Amsterdan: North Holland.

GOLDNER, A. (2002) Estudo comparativo dos fatores aglomerativos e desaglomerativos entre as regiões metropolitanas do Brasil: uma análise multivariada para o período de 1981 a 1999. Belo Horizonte: Cedeplar/UFMG (MSc. Thesis).

GRANOVETER, M. (1985) Economic action and social structure: the problem of embeddedness. American Journal of Sociology, 91 (3).

GROVE, D.M. & ROBERTS, C.A. (1980) Principal components and cluster analysis of 185 large towns in England and Wales. Urban Studies, 17(1): 17-77.

GUIGOU, J.L. (1982) La rente foncière : les théories et leur évolution depuis 1650. Paris: Economica.

GUILHOTO, J.M.M. (1992) Mudanças estruturais e setoriais na economia brasileira, 1960-1990. XIV ENCONTRO NACIONAL DA SOCIEDADE BRASILEIRA DE ECONOMETRIA. (Econometric Brazilian Society). Anais..., Campos do Jordão: SBE.

GUILHOTO, J.M.M. (1994). Índices de ligações e setores-chave na economia brasileira: 1959/80. PPE, 24 (2): 287-314.

GUILHOTO, J.M.M. (1999) Decomposition & sinergy: a study of the interactions and dependence among the 5 Brazilian macro regions. ERSA/RSAI, Conference, Dublin.

HADDAD, E.A. (1995) A estrutura econômica de Minas Gerais: uma análise de insumo-produto. Nova Economia, Belo Horizonte. VIII Minas Award in Economics.

HADDAD, E.A. (1999) Regional inequality and structural changes: lessons from the Brazilian experience. Ashgate: Aldershot.

HADDAD, P.R.; FERREIRA, C.M.C.; BOISIER, S.; ANDRADE, T.A. (1989) Economia regional: teorias e métodos de análise. Fortaleza: ETENE-BNB.

HAGUENAUER, L.; ARAÚJO Jr., J.T.; PROCHINIK, V. (1984) Os complexos industriais da economia brasileira. Rio de Janeiro: IE/UFRJ, 1984 (Working Paper 62).

HALL, P (ed.) (1966). Von Thünen's Isolated State (1826), Glasgow: Pergamon Press.

HARP, A.J. & FOSDECK, D. (2000) A tipology of economic dependency via fuzzy cluster analysis, Idaho, IAESP, Working Papers nº 9711.

HARRIGAN, F.J. (1982) The relationship between industrial and geographical linkages: a case study of the United Kingdom. Journal of Regional Science, 22: 19-31.

HARRIS, T.R. *et al.* (1993) Application of fuzzy-set clustering for regional typologies. Growth and Change, 24(1): 155-163.

HODGE, G.; WONG, C.C. Adapting industrial complex analysis to the realities of regional data (s.l/s.d.). (mimeo). (citado em ABLAS, CZAMANSKI, Op. cit, 1982).

HSU, Y. G. e*t al.* (2003) Fuzzy multiple criteria selection of government-sponsored frontier technology R & D projects. R & D Management, 35(5).

IBGE (1980). Censo industrial: Minas Gerais - censos econômicos, Série Regional, 2 (14). Rio de Janeiro: IBGE.

IBGE (1989) Matriz de Insumo-Produto Brasil – 1980, Rio de Janeiro: IBGE.(Série Relatórios Metodológicos, v.7)

ISARD, W. (1960) Methods of regional analysis. Cambridge: MIT Press.

KAGEYAMA, A. & LEONE, E.T. (1999) Uma tipologia de municípios paulistas com base em indicadores sociodemográficos. Campinas: UNICAMP/IE. (Working Papers 66)

KALECKI, M. (1954) Theory of economic dynamics. London: George Allen & Unwin.

KARASKA, G.J. (1969). Manufacturing linkages in the Philadelphia economy: some evidence of external agglomeration forces. Geographical Analysis, 1(4).

KAUFMAN, L. & ROUSSEEUW, P.J. (1990). Finding groups in data: na introduction to cluster analysis. New York: Wiley.

KLAASSEN, L. (1967). Method of selecting industries for depressed areas. Paris: OCDE.
KOLOSOVSKIY, N.N. (1961). The territorial production combination (complex) in soviet economic geography. Journal of Regional Science, 3(1).
KRUGMAN, P. (1991) Geography and trade. Cambridge: The MIT Press.
LATHAN, W.R. (1976) Needless complexity in the identification of industrial complexes. Journal of Regional Science, 16: 44-55.
LEFÈBVRE, H. (1991) The production of space. Oxford, Basil Blackwell.
LELLI, S. (2001) Factor analysis vs. fuzzy sets theory: assessing the influence of different techniques on sen's functioning approach. Public Economics Working Paper Series / Katholieke Universiteit Leuven, Centrum voor Economische Studiën, Working Group Public Economics.
LEME, R.A.S. (1982) Contribuição à teoria da localização industrial. São Paulo: IPE/USP.
LEME, R.A.S. (1972) Estudo da localização de uma fábrica de papel e celulose. São Paulo: POLI/USP, 1972.
LEMOS, M.B. (1988) Espaço e capital: um estudo sobre a dinâmica centro x periferia. Campinas: IE/UNICAMP (PhD Dissertation).
LEMOS, M.B. & CROCCO, M.A. (2000) Competitividade e dinâmica comparativa das regiões metropolitanas brasileiras. XXVIII ENCONTRO NACIONAL DA ANPEC. Anais..., Campinas: ANPEC.
LEMOS, M.B. (1990) A regionalização para Minas Gerais: uma proposta tendo como referência o circuito espacial do setor agropecuário. In: NABUCO, M.R. (org.). Contradições do desenvolvimento agrícola em Minas Gerais: uma perspectiva regional. Belo Horizonte: Cedeplar (Ensaios Econômicos 4).
LEMOS, Mauro B. (1992) The Brazilian agro-food system. London: University of London, 1992 (PhD Thesis)
LEMOS, Mauro B. & DINIZ, C.C (2000) Vantagens comparativas da área metropolitana de Belo Horizonte no contexto nacional. REN, 31: 530-549.
LEMOS, Mauro *et al.* (2000) Uma proposta de regionalização com base em pólos econômicos e suas áreas de influência. Belo Horizonte: Cedeplar/UFMG.
LEMOS, Mauro B. & FERREIRA, M.F.S (2001) Vantagens comparativas das regiões metropolitanas de Salvador, Recife e Fortaleza no contexto regional. Fortaleza: ANPEC.
LEMOS, Mauro B. *et al.* (2003) Liberalisation and local innovative capabilities: the FIAT supplier network in Minas Gerais. In: CASSIOLATO. J.E. & LASTRES, H.M.M. (eds) Systems of innovation and development: evidence from Brazil. Cheltenham: Edward Elgar.
LESSA, C. (1976) Quinze anos de política econômica. Rio de Janeiro: (mimeo).
LOJKINE, J. (1981) O estado capitalista e a questão urbana. São Paulo: Ed. Martins Fontes.
LÖSCH, A. (1954) The economics of location. New Haven: Yale University Press.
MANLY, B.F.J. (1986) Multivariate statistical methods: a primer. London: Chapman and Hall.
MARSHALL, A. (1920) Principles of economics, London: McMillan.
MARTIN, R. (1999) Drivers: the role of clusters in local economic development. Agenda for the Regional Development Agencies, Cambridge: Robinson College.
MELLO, J.M.C.(1982) O capitalismo tardio. São Paulo: Brasiliense.
MIYAMOTO, S. (1990)Fuzzy sets in information retrieval and cluster analysis, London: Kluwer.

NORCLIFFE, G.B. & KOTSEFF, L.E. (1980). Local industrial complexes in Ontario. ASSOCIATION OF AMERICAN GEOGRAPHERS, Annals..., 70 (1): 68-79.
NEIT (2003) Restrições setoriais ao crescimento econômico: uma avaliação da evolução do grau de utilização da capacidade. Campinas: UNICAMP/IE. (Nota técnica; mimeo)
Ó'hUALLACHÁIN, B. (1984). The identification of industrial complexes. ASSOCIATION OF AMERICAN GEOGRAPHERS, Annals..., 74 (3) : 420-436.
PAELINCK, J. (1970) De quelques aspects operatoires dans l'usage des tecniques d'entrèe et sortie au niveau règional et interregional. Revue Juridique.
PARR, J. (1999) Growth-pole strategies in regional economic planning: a retrospective view. Part 1: origins and advocacy. Urban Studies, 36 (8): 1247-1268.
PARR, J. (1999) Growth-pole strategies in regional economic planning: a retrospective view. Part 2: implementations and outcome. Urban Studies, 36 (8): 1247-1268.
PEREIRA. E.A. (1985) Complexos industrais: discussão metodológica e aplicação à economia brasileira (1970-1975). Campinas: IE/UNICAMP (MSc Thesis).
PHOTIS, Y. N. & MANETOS, P. (2003) Simulation of urban system evolution in a synergetic modelling framework. The case of Attica, Greece. ERSA Conference Papers, 43.
PUTNAN, R. (1993). Making democracy work: civic traditions in modern Italy. New Jersey: Princeton University Press.
RAIS (2000). Relação anual de informações sociais. RAIS TRAB / RAISESTB, 1996. Brasília: Ministério do Trabalho e Emprego. CD-ROM.
RASMUSSEN, P. (1956) Studies in intersectoral relations. Amsterdan: North Holland.
RICHARDSON, H. W. (1978) Insumo-produto e economia regional. Rio de Janeiro: Zahar.
RICHTER, C.E. (1969). The impact of industrial linkages on geographic association. Journal of Regional Science, 9(1).
RIEFLER, R.F. (1973) Interregional input-output: a state of the arts survey. In: JUDGE, G.G. & TAKAYAMA, T. (eds.) Studies in economic planning over space and time. Amsterdan: North Holland.
RODRIGUES, C.G. & SIMÕES, R.F. (2003) Aglomerados industriais e desenvolvimento socioeconômico: uma análise multivariada para Minas Gerais. X ENCONTRO NACIONAL DA ANPUR. Anais..., Belo Horizonte: ANPUR.
ROEPKE, H.; ADAMS, D.; WISEMAN, R. (1974) A new approach to the identification of industrial complexes using input-output data. Journal of Regional Science, 14(1).
S-PLUS (2000) User's manual.
SALVATO, M.A.(1991) Complexos industriais na economia brasileira 1980: uma abordagem metodológica. Belo Horizonte: FACE/UFMG.
SANTOS, F.B.; CROCCO, M.A. & SIMÕES, R.F. (2001) O arranjo produtivo calçadista de Nova Serrana, Minas Gerais. In: TIRONI, L.F. (coord.) Industrialização descentralizada: sistemas industriais locais. Brasília: IPEA.
SILVA, J.A.B.B. da & LOCATELLI, R.L. (1990) Complexos industriais na economia nordestina. Belo Horizonte: ETENE / BNB / Cedeplar / IPEA (mimeo).
SILVA, J.A.B.B. & LOCATELLI, R.L. (1991) Estudos multissetoriais de economia mineira, Relatório III - "Complexos industriais: análise e perspectivas". Belo Horizonte: BDMG / Cedeplar / IPEAD.(mimeo).
SILVA, J.A.B.B. & LOCATELLI, R.L. (1994) Estudos multissetoriais de economia mineira, Relatório II - "Análise e identificação de setores-chave". Belo Horizonte, BDMG / Cedeplar / IPEAD (mimeo).

SIMÕES, R.F. (1988) Padrões de crescimento e dinâmica especial: Minas Gerais, 1970/1980. Belo Horizonte: BDMG / SEMG / CORECON-MG, 1988 (Minas Award in Economics) (Série Monografias Vencedoras).

SIMÕES, R.F. (1989) Uma proposta de metodologia para a abertura de dados fechados dos censos econômicos: o problema da desagregação para a análise regional. IX ENCONTRO NACIONAL DA SOCIEDADE BRASILEIRA DE ECONOMETRIA (Econometric Brazilian Society). Anais..., Fortaleza: SBE.

SIMÕES, R.F. (2001) Localização e renda fundiária urbana: conceitos em busca de uma síntese. I ENCONTRO NACIONAL DA ASSOCIAÇÃO BRASILEIRA DE ESTUDOS REGIONAIS (Brazilian Regional Science Association) , Anais..., São Paulo: ABER.

SLATER, P.B. (1974). A hierarquical clustering of 75 united states industry as based upon interindustry transactions. PRI: West Virginia University.

SMOLKA, M. (1982) O espaço do espaço na teoria econômica. Rio de Janeiro(mimeo).

SONIS, M. & HEWINGS, G.J.D. (1991) Fields of influence and extended input-output analysis: a theoretical account. In DEWHURST, J. *et al* (eds.) Regional input-output modelling: new developments and interpretations. Avebury.

SONIS, M.; HEWINGS, J.D. & LEE, J.K. (1994) Interpreting spatial economic structure and spatial multipliers: three perspectives. Geographical Analysis, 26 (2): 124-151.

SOUZA, M.(1989) O método de dígrafos: uma aplicação para a matriz de relações interindustriais do Brasil de 1975. PPE, 19(3).

STEED, G.P.I. (1970). Changing linkages and interval multipliers of an industrial complex. Canadian Geographer, 14(1).

STREIT, M.E. (1969) Spatial association and economic linkages between industries. Journal of Regional Science, 9(2).

SUZIGAN, W. (2001) Aglomerações industriais como focos de políticas. REP, 21, 3 (83): 27-39.

SUZIGAN, W *et al*. (2000). Aglomerações industriais no Estado de São Paulo. XXVIII ENCONTRO NACIONAL DA ANPEC, Anais..., Campinas: ANPEC.

TAVARES, M.C. (1972) Da substituição de importações ao capitalismo financeiro. Rio de Janeiro: Zahar.

VAINER, C. (2000) Pátria, empresa e mercadoria. Notas sobre a estratégia discursiva do planejamento. In: ARANTES, O. *et al.* A cidade do pensamento único. Desmanchando consensos. Petrópolis: Vozes.

WICKEREN, A. Van. (1972) An attration analysis for the asturian economy. Regional and Urban Economy, 2(3).

WOODBERY, M. *et al.* (1978) Mathematical typology: a grade of membership technique for obtaining disease definition. Computer and Biomedical Research, 11: 277-298.

ZADEH, L.A. (1965) Fuzzy sets. Informational Control, 8:338-351.

ZEITLIN, J. (1992) Industrial districts and local economic regeneration: overview and comment. In: PIKE, F. *et al.* Industrial districts and local economic regeneration. Geneve, IILS.