THE GROWTH OF TECHNOLOGICAL INEQUALITIES IN THE FARM SECTOR OF THE BRAZILIAN STATE OF MINAS GERAIS

Leandro Frederico Ferraz Meyer[1]
Marcelo José Braga[2]

ABSTRACT - In this article we intend to analyze the pattern of technological diffusion associated with the process of farm sector modernization in the Brazilian state of Minas Gerais. Therefore, we observed the state's 46 homogeneous micro-regions (MRHs) and applied factorial analysis and cluster analysis techniques to discover the factors that explain this sector's modernization and to group MRHs with similar technological characteristics. Using successive analysis of the groupings formed during every year of the study (1970, 1975, 1980 and 1985), it was possible to describe the dynamic of modern technology's regional diffusion into Minas Gerais' farm sector. The results showed that a great part of state's productive agricultural base was at the margin of the technological modernization process. To test the hypothesis that this result implied an increase in regional inequality, we analyzed the convergence of factors which indicate modernization. From this analysis, we verified the growth of regional technological inequalities in Minas Gerais' farm sector during the 15 year period, 1970 to 1985.

Key words: Agricultural development, Minas Gerais, cluster analysis

[1] Master in Agricultural Economics titled by the Department of Rural Economy, Federal University of Viçosa. 36571-000, Viçosa – MG – Brazil.

[2] Professor and Doctoral student in Agricultural Economics, Department of Rural Economy, Federal University of Viçosa. 36571-000, Viçosa – MG - Brazil. E_mail: mjbraga@mail.ufv.br.

INTRODUCTION

Technological diffusion into the farm sector proceeds with the adaptation of new agricultural techniques to the environment and the existing socioeconomic conditions. According to Hayami and Ruttan (1988, p. 5), "to obtain success and to achieve rapid growth in agricultural productivity, it is necessary to generate ecologically adapted agricultural technologies economically suited to each country or area."

The technological inadequacy of production factors represents an inefficiency in the allocation of resources and exacerbates the distributive conflict. This inadequacy also causes negative environmental effects, results in adverse impacts on the ecosystem, and affect both present and future productivity.

The process of farm sector modernization in developing countries has caused environmental damage. In the wake of the "green revolution" a "package" of technological improvements was developed for use in the developing world that did not take into account the technological readiness nor the environmental conditions found in these countries. Moreover, in the Brazilian case, the change of the farm sector's technological base was begun in the middle of period of accelerated Brazilian industrialization in the mid 1960's, as the country tried reduce its dependence on industrial imports.

The demand for technical change motivated Brazil's national agricultural research centers in a search for applicable new technology. Unfortunately, these early researchers explored technological systems more adapted to the employment of mechanization and chemical input, rather than searching for new technology which could be adapted to the country's differentiated socioeconomic conditions and ecological characteristics. A relatively rigid research mind-set evolved, the results of which can be inferred starting with an investigation of the pattern of regional technological diffusion. Müller (1989) observed that there would not be regional differences in the farm sector but for the dynamics of modernization, its general order, that explains the partial and selective technological penetration into the farm sector.

This object of this article is to analyze the pattern of technological diffusion associated with the process of modernization in the State of Minas Gerais' farm sector. Minas Gerais was chosen for study because of the importance of its farm sector[3], and due to the federal and state programs set up to stimulate this sectors modernization.

This article is divided into three sections and this introduction, first section. Second section is divided into three parts: (1) is an explanation of the process of technological diffusion in agriculture using theoretical models; (2) is a presentation of the general lines of the statistical model employed to define the dimensions of modernization and group the MRHs, and; (3) list the variables and sources of data used in this study. In third section, we discuss the growth of farm sector regional technological differentiation that was found through our analysis of the MRHs. In fourth section, we conclude with a discussion of the significance of new technology's partial and selective penetration into Minas Gerais' various agricultural regions.

METHODOLOGY

Theoretical model

In what is referred to as one of the most significant theoretical contributions on agricultural development, Hayami and Ruttan (1988) distinguish six general approaches to agricultural development: (1) models of resources utilization, (2) models of conservation, (3) models of location, (4) models of diffusion, (5) models of modern input, and (6) models of induced innovation.

We begin with Hayami and Ruttan's location and induced innovation models as they relate to the regional spread of technological innovation in Minas' farm sector. We then add De Janvry's (1977) analytic model of technological and institutional innovations to consider the action of *interest groups* on the direction of technological change. We then make some critical observations to the about the induced innovation model.

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[3] According to data from the Fundação João Pinheiro, the agricultural sector comprised 10.72% of the state GDP in 1995 (Fundação João Pinheiro, 1996).

Location model of urban-industrial impact

The location model was first developed in the works of von Thünen. He attempted to verify, through a generalization of the Ricardian theory of land's income, that the urbanization process interferes with the location of agricultural activities and influences the techniques and the intensity of agricultural production (Hayami and Ruttan, 1988). According to these authors, von Thünen's thesis got the attention of both historians and economists in United States. Historians used von Thünen's ideas to investigate the dynamics of commercial agricultural expansion during the 19th century, investigating the influence of transport cost changes on the production and distribution of goods. Agricultural economists applied von Thünen's theory to the impact of urban-industrial growth rates; this was done to discover if these growth rates could account for the income and productivity variations found in different geographical areas.

The implications of the location model for modern agricultural development were formulated by Schultz (1953). For him, economic development occurs in a specific, primarily urban-industrial, "location matrix." Economic organization is more efficient if set up in the center, or close to the center, of a peculiar matrix of economic development. The factors and products market would work more efficiently in areas of rapid urban-industrial development than in urban areas not yet industrialized.

Schultz was particularly worried about price policies, the failures in agricultural production, and the regional disparities which developed as America's agricultural sector developed. The author highlighted the structural imperfections of the capital and labor markets, and how these imperfections accentuated the role of the urban-industrial complex as the source of new more productive input. Thus, agricultural development would accelerate if located near to the dynamic center because of the proximity of the companies which produced agricultural inputs and transformed agricultural products into consumer goods, as well as because of the higher wages found near this dynamic center.

In a study about the transformation of the Brazilian agriculture, Nicholls (1969) indicated that after 1940, there were clear indications that urban-industrial development in São Paulo was sufficiently large and dynamic enough to begin exercising an independent impact on the productivity of agricultural labor by means of the substitution of that labor for capital. Katzman (1975) in turn used the implication of Schultz's model to explain the disparity in agricultural incomes among areas in the Brazilian State of Goiás. His results indicated that the proximity of product markets and factors was associated with product prices, land values, higher land use rates, and increased investment in machinery per unit of area and per man.

Model of induced innovation

The location model's main contribution was that it explicitly considered the effects of non-agricultural development on agricultural development. Before that, the effect of farm location on farm production focused on environmental variation. The formalization of the relationship between rural and urban development led to the creation of the model of modern input; a representative formulation of this model is found in the work of Schultz (1965). Nevertheless, the model of modern input was confined to the marketing of goods and services, never explaining the mechanism by which economic conditions lead to the development and adaptation of a group of efficient technologies for private enterprise. Nor does the model address the relationship of product and factor price differences to private sector investments in specific types of research (Hayami and Ruttan, 1988).

The attempt to include the forms by which variation in the economic system affects the processes of technical and institutional change was refined using the models of induced innovation. Hayami and Ruttan (1988)[4] first formulated a method to apply this model to

[4] The theories of induced innovation were developed, mainly, within of the referencial of the theory of the firm. The works of Fellner (1961, 1962, 1967), Kennedy (1964, 1966, 1967), Samuelson (1966a, 1966b) and Ahmad (1966, 1967) stand out among the group that emphasized the non-neutral character of technological progress induced by changes in the relative shortage of resources, while Griliches (1957) and Schmookler (1962, 1966) focused the influence of the demand growth for products at the speed of the technological change. Finally, Binswanger (1974) incorporated into a model of induced technicoligical change the effect of the relative endowment of factors and the effect of the demand for products on the rate of technological change.

agricultural development. They handled it as an extension of the theory of prices. Hayami and Ruttan tried to explain the dynamic of agricultural development by incorporating the mechanism by which change in product demand and remuneration for use of factors interact to influence the rate and the direction of technological change.

In that sense, the authors advance the hypothesis that technical change is driven along an efficient trajectory by market price signals. They posit that prices efficiently adjust to changes in product and factor supply and demand, and that rural producers interact effectively with research institutions and agricultural companies. Under those conditions, and assuming that scientists administrators are rational, pressure coming from agricultural product producers (farmers) would guide research institutions and agricultural input producers towards socially optimal technical progress.

The model assumes that distortion in the allocation of resources can happen due to the economic resource distribution inequalities and the political power of the elite. It also admits that technology generation and institutional changes often address only the interests of the dominant social group; and these changes can act to reinforce existing inequalities and cause damages to a majority of the population.

As pointed out in the Introduction, the relationship between the process of agricultural technology generation and the diffusion pattern of this new technology can be derived from a study of the adaptability of this new technology to diverse socioeconomic and environmental conditions. In that sense, the technological "package" stemming from the "green revolution" has a difficult time penetrating into those areas where topography, soil quality, agrarian structure, and access to the credit made it hard to employ the newly introduced fertilizers, irrigation techniques, and mechanical devices.

On the other hand, the model of induced innovation presupposes that market forces operate free from distortion. As is known, during the decade of the 70's, Brazilian farm sector, modernization policies were marked by strong, discretionary State intervention on the product and factor markets favoring industrialization. Although, we don't intend to conduct a systematic discussion of the politicians that determined agricultural policy[5], the theoretical skeleton that sustains our following analyses demands that we present a brief model incorporating the actions of *interest groups* into the following explanation of the technical and institutional innovation processes.

Dialectic model of technological and institutional innovation

Hayami and Ruttan's model is According to De Janury (1997), linear and expresses a one directional causal relationship such that technological innovations determine institutional innovations.

On the demand side, Hayami and Ruttan assume that "...displacements in the demand for institutional innovation are induced through changes in the relative readiness of resources due to technical change" (Hayami and Ruttan, 1988, 108) and, on the other hand that "The returns desired by business men or political leaders, generated by the institutional changes that they facilitate to explore new technical opportunities, are one of the largest incentives for the institutional change" (Hayami and Ruttan, 1988, p.6). Therefore, the institutional picture is passive. Institutions, especially public institutions, are unable to block or alter the changes induced by the relative readiness of factors in order to accommodate the dominant group's interests.

The dialectic dimension appears only when it can also explain the form in which institutions act to affect the orientation of technological change. This is done in De Janvry's model. De Janvry' treats the institutional situation as a representation of "the way in which people relate to one another in their respective functions in the production process." (De Janvry, 1977, p. 551). He asserts that the economic structure of a social system it is characterized, essentially, by the production base's level of development and by the institutional situation described above. The productive capacity would be determined by the quantitative and qualitative stock of productive resources.

Admitting the fundamental importance of qualitative attributes, in the form of technologies and skills, in the determination of both

[5] Reference the work of Lamounier and Almeida (1994).

product's and productivity, the author then assumes that the rate and the direction of these qualitative attributes growth are the major determinants of production growth, income levels, and income distribution. As result, it is found that he who controls the production of new technologies and skills determines, in great measure, the rhythm and the nature of economic development.

In this scenario, the social structure would ultimately shape the rate and the direction of technology and skill innovation. On the other hand, such innovations would be a powerful determinant of social change. In this vein, technological (technologies and skills) and institutional changes would be interrelated, and the discussion concerning which induces change first would be akin to egg-chicken dilemma; only a historical study could answer that question (De Janvry, 1977).

In de Janvry's model, those institutions capable of determining property rights and those that define the functions and the purpose of State actions are of utmost importance. On the other hand, the model treats technological and institutional innovations in the context of a general model of supply and demands for public goods because the public sector has been most responsible for stimulating agricultural sector, technological innovation.

The central idea is the *matrix of gains* ("payoff matrix"), which identifies the liquid economic gains or losses expected by *interest groups* in the society due to the offer of a specific group of public goods (technological and institutional innovations). Thus, the supply and demand for public goods is centered in the matrix of gains, conditioned by the socioeconomic structure on one hand and the political-administrative structure on the other.

The relative power a social group exerts on the political-administrative structure determines if a demand made by that social group for a particular private good will be answered. In the case of the demand for specific technological development, that pressure would induce the allocation of human and financial resources to a specific research project.

The **organizational form** of the national system of research would also condition the research organization's response to interest group's demands, in both intensity and direction. In a similar way, the research organization would influence the expectations of the interest group by means of an interaction between dialectic institutions and groups. This interaction would be mediated by the gains generated by attendance to the specific interest group demands, which themselves were generated by new expectations.

In the case of agricultural technologies, the gains would be determined by the (1) **physical impacts of the innovation**, in terms of effects on production, the economy, and resource substitution; (2) **distributive effects**, conditioned on the nature of the innovation and the specific status of the different social groups in the structure socioeconomic (decisive factors, in that case, would be the system of land ownership and the degree of access each interest group has to credit institutions, information, and the market); and (3) **economic effect of the new technology**, as determined by the economic value of the physical and distributive effects.

Thus, it can be understood that the interdependence of those three effects determines the *entry* of the matrix of gains as the product of the interaction between the offer of a specific new technology and the socioeconomic structure (De Janvry, 1977). The matrix of gains represents the basic creation and distribution dynamic of technological innovations. An estimate of the economic and social significance of a specific technology would involve the aggregation of several social groups' matrix of gains to obtain the technology's effect on liquidity.

Statistical model

The statistical model employed in this study utilizes extremely varied techniques of analysis—Factorial Analysis proceeded by *Cluster* Analysis. Factorial analysis allows the extraction of the factors that explain the change in Minas Gerais' farm sector's technological base. Using Cluster analysis, the state's homogeneous micro-regions are identified according to similarities in factors of modernization.

a) Factorial analysis

The stages of the factorial analysis can be summarized: (1) determination of the matrix of correlation among all the variables[6]; (2) extraction of the necessary factors to represent the data; (3) transformation (rotation) of the factors to ease interpretation; and (4) determination of the factorial scores. Factorial analysis can also begin with the variance and co-variance matrix. More detailed factorial analysis explanations are found in Kim and Mueller (1978), Schilderinck (1978) and Manly (1986).

The first stage supplies the information to adapt the sample to statistical procedure. Unrelated variables will tend to present low proportional variance "explained" for the *common factors.* The second stage involves the determination of the number of factors needed to represent the group of data and the calculation method used to obtain this number. In the present case, the main components method was used. The first component, or *factor*, is the linear combination that corresponds to the largest proportion of variance presented in the sample. The second component corresponds to the next highest combination that maximizes the proportion "explained" for the remaining variance subject to the non-correlation with the first component restriction (orthogonal). The successive components are extracted in the same way in that they are not correlated with the other variables.

Formally, the ratio between a generic variable and the *factors is* given as:

$$X_i = A_{i1} F_1 + A_{i2} F_2 + \dots + A_{ik} F_k + U_i \tag{1}$$

in that F's are the *common factors* since whole variables they are expressed in function for them. Ui is the *unique factor* that represents the "un-explained" part of the *common factors*, and A's are constants used to combine the k factors or the *factorial loads.*

The sum of the square of the factorial loads results in the proportion of the total variance of each variable that is "explained" for the *common factors,* the *communality.*

The third stage, rotation of the principal axes (components), is used to discover a simple associative structure between the factors and the variables. This procedure is used because factorial analysis is inherently uncertain, as there exist so much solutions and so many ways to gyrate

[6] Factorial analysis also could be used starting from the matrix of variance and co-variance. A more detailed explanation on factorial analysis can be found in Kim and Mueller (1978), Schilderinck (1978) and Manly (1986) [Chapter 8].

the axes. That imposes a need for stability in the found solution; this technique will be described in the following paragraph.

Main axes rotation alters each factors' individual contribution to the "explanation" of the observed variance; but this doesn't affect the *communality* of the variables, nor the proportion "explained" for the total variance. In the present case, a method of orthogonal rotation was used (Varimax) in an attempt to minimize the number of variables strongly related with each factor. This allowed us to obtain more easily interpretable factors.

For each observation, the *factorial score is* obtained by the multiplication of the value (standardized) of the variable *i* by the corresponding *factorial score coefficient.* The general expression, for estimate of the 'nth' *factor*, Fj, is given by:

$$F_j = \sum_{i=1}^{p} W_{ji} X_i = W_{j1} X_1 + W_{j2} X_2 + \ldots + W_{jp} X_p, \qquad (2)$$

in that Wji is the *factorial scores coefficient* and *p* is the number of variables.

b) Cluster analysis

Cluster analysis is a statistical technique employed to classify observations or variables into homogeneous groups when more than one dimension exists and must be considered. A detailed description of cluster analysis can be found in Duran and Odell (1974), Everitt (1977), Kleinbaum and Kuper (1978), Manly (1986), Bussab *et al.* (1990).

To understand cluster analysis procedure, it is necessary to introduce the *distance* concept between the objects being classified. Several methods for measuring that distance exist; the most frequently used is the Euclidian dimension. The general form for calculating the Euclidian distance between points A and B, for a dimension *p*, is given by:

$$d(A, B) = \{ \sum [z_i (A) - z_i (B)]^2 / p \}^{1/2}, \qquad (3)$$

in that z_i indicates the value of variable Zi (standardized) at the suitable point.

In the present context, the distance concept is used to reflect the maximum or minimum *likeness* among the state's micro-regions, in agreement with the region's *factorial scores* .

The groupings formed present the largest internal homogeneity possible, that is, the smallest sum total of distances among their components and the largest heterogeneity among groups.

As there are also several ways of calculating distances between objects, there are also several methods available to combine the objects into groups. These combination methods are classified using *hierarchical* and *non-hierarchical* methods. The hierarchical methods can be *agglomerate* or *divisible.* In any case, however, the distinction between the methods is that by using the *non-hierarchical* methods it is not possible to re-allocate an observation prior to its assignment to a grouping.

Using *agglomerate* methods one creates as many groups as there are units of observation, progressively allocating the observations into groups, then grouping previously formed groups until only one grouping is left that contains all the observations. The opposite occurs when using *divisible* methods.

In the present case, Ward's method was used. This is a hierarchical agglomerate method that demands the use of the square of the Enclidian distance as the measure of observation similarities. The underlying notion of Ward's allocation approach admits the loss of information that results from the allocation of an observation to a data group. This loss can be measured as the sum of the squares of the deviations between the value of the observed characteristic, the medium value of the characteristic in the group to which it was allocated. Thus, each stage of the process, the union of all possible pairs of groupings and the unification of two groups, results in the minimum growth of the sum of the squares of the deviations (Everitt, 1977). There is no one established approach for the definition of the number of considered groups. This is considered a relative definition, determined by the researcher's critical evaluation.

Variables and data sources

To construct the synthetic, farm sector, modernization indicators, the *factors,* thirty one variables were selected. The selection process took into consideration the number of homogeneous micro-regions (MRHs) in the state of Minas Gerais, derived from data supplied by the Agricultural Censuses in the years of 1970, 1975, 1980, and 1985. The variables try to capture the level of technical progress and include: infrastructure indicators, employment of chemical and mechanical inputs, changes in production ratios that accompany the process of technical base change, the level of capitalization of the establishments, and the farming activity.

The considered variables appear, whenever possible, as a ratio of the explored area (AE), or as a ratio of the total occupied personnel (PO). "Explored area" is defined as the sum of the areas of permanently and temporarily tilled land, natural and planted pasture, and natural and planted forest; this is in agreement with Hoffmann (1992). Occupied personnel is defined as the sum of people in the following classification categories: property owners and non-remunerated members of their family, permanent workers, temporary workers and their partners and children (includes women and children less than fourteen years old).

The variables' monetary value was deflated for the IGP-DI (inflation) figures published by Fundação Getúlio Vargas and are expressed in thousand Reais as of December 1996 (1R$=1US$).

The following variable relationships were used in the factorial analysis.

PT 01	Consumption of electric energy (1000 kw/h) / AE
PT 02	Consumption of electric energy (1000 kw/h) / PO
PT 03	Establishment that makes use of chemical fertilizer/ total of establishment
PT 04	Establishment that makes use of organic fertilizer/ total of establishment
PT 05	Establishment that makes use of liming the soil/ total of establishment
PT 06	Establishment that makes use of animal force/ total of establishment
PT 07	Establishment that makes use of mechanical force/ total of establishment
PT 08	Number of tractors / AE
PT 09	Number of tractors / PO
PT 10	Number of animal traction ploughs / AE
PT 11	Number of mechanical traction ploughs / AE
PT 12	Number of animal traction ploughs / PO
PT 13	Number of mechanical traction ploughs/ PO
PT 14	Number of vehicles of animal traction/ AE
PT 15	Number of vehicles of mechanical traction/ AE
PT 16	Number of vehicles of animal traction/ PO
PT 17	Number of vehicles of mechanical traction/ PO
PT 18	Consumption of gas and oil (1000 L) / AE
PT 19	Consumption of gas and oil (1000 L) / PO
PT 20	Capacity of the silos for forage (T)/forage area (natural and planted)
RP 01	Total workers used (PO) / AE
RP 02	Workers in owner's family / PO
RP 03	Permanent workers / PO
RP 04	Temporary workers / PO
RP 05	Establishment that contracted services for contract work/total of establishment
VB 01	Total value of the goods (1000 Reais) / AE
VB 02	Total value of the goods (1000 Reais) / PO
VD 01	Value of the total expenses (1000 Reais) / AE
VD 02	Value of the total expenses (1000 Reais) / PO
VP 01	Value of the total production (1000 Reais) / AE
VP 02	Value of the total production (1000 Reais) / PO

To produce a measure of the speed of transformations, characterized by the *factors*, during the period, the factors must be comparable over several years. That can only be done if the *factors* are extracted from the whole group of observations, including the four years involved in the study. To accomplish that, the matrices with the values of the 31 variables for the 46 observations in every year,(x^{ano}_{46x31}), were combined in way to generate the matrix X_{184x31}, defined below:

$$X_{184x31} = \begin{bmatrix} X^{1970}_{46x31} \\ X^{1975}_{46x31} \\ X^{1980}_{46x31} \\ X^{1985}_{46x31} \end{bmatrix}_{184x31}$$

RESULTS AND DISCUSSION

The factors of farm sector modernization[7]

The factorial analysis resulted in the extraction of four *factors* with a characteristic root larger than one (1). Of these, only the three first will be used to characterize the process of agricultural modernization. The fourth factor was excluded because of its limited descriptive significance. The three selected factors together account for 76.8% of the total data variance (Table 1).

Table 1- Extracted factors for the method of the main components

Factor	Characteristic root	Variance "explained" by the factor (%)	Accumulated variance (%)
1	14,68	47,4	47,4
2	5,85	18,9	66,2
3	3,28	10,6	76,8
4	1,16	3,8	80,6

Table 2 presents the matrix of factorial loads after orthogonal rotation using the Varimax method. The last column to the right gives the

[7] Greater detail on the results of the factorial analysis are found in Meyer (1997

communality value calculated for the three factors in consideration. The interpretation is made through observation of the variables that present higher *factorial loads*[8]. Thus, the boldface values in Table 2 indicate the variables that were considered in the interpretation of their corresponding *factor.*

It is observed that **Factor 1** is strongly and positively related with the variables that indicate employment of modern technology (PT01, PT08, PT11, PT15, PT18) and capital employed per utilized area (VB01, VD01). It is also positively related with the value of production in the area investigated (VP01)and with fodder silo capacity per natural and planted pasture area (PT20). Moreover, it is linked in the same way with other variables that denote technological progress (PT03, PT04 and PT05). Due to limited census information, these variables (PT03, PT04, PT05) are expressed as a percentage of the number of establishments that declared use of the input, not in amount of input per explored area. Thus, the variables pattern of relationship with Factor 1 suggests this factor corresponds with the "intensity of soil utilization." Elevated values for Factor 1 scores are interpreted as high intensity soil utilization.

8 In the extraction of the factors to determine the main components and then followed by orthogonal rotation, the factorial loads corresponds to correlation coefficients between the variable *i* and the factor *j*.

Table 2 - Matrix of the factorial loads after rotation

Variables	*Factor 1*	*Factor 2*	*Factor 3*	*Communalitys*
PT01	**0.79772**	-0.09066	0.10179	0.65494
PT02	0.66838	0.26621	0.11390	0.53057
PT03	**0.72733**	0.33079	0.36698	0.77311
PT04	**0.67057**	0.16091	0.32808	0.58319
PT05	**0.67353**	0.60151	0.00540	0.81549
PT06	0.05674	0.18313	**0.89356**	0.83521
PT07	0.53819	**0.67008**	0.15129	0.76154
PT08	**0.84188**	0.41937	0.03426	0.88581
PT09	0.32739	**0.88620**	0.02095	0.89297
PT10	0.46676	-0.31564	**0.71383**	0.82705
PT11	**0.76850**	0.50399	0.01486	0.84482
PT12	0.01508	0.14978	**0.92605**	0.88023
PT13	0.26899	**0.89561**	0.00301	0.87448
PT14	0.47914	-0.27151	**0.69946**	0.79254
PT15	**0.93649**	0.17974	0.07333	0.91470
PT16	-0.03909	0.31510	**0.84794**	0.81982
PT17	0.37327	**0.87572**	0.13332	0.92399
PT18	**0.79370**	0.47534	-0.01246	0.85606
PT19	0.12699	**0.92193**	0.01104	0.86620
PT20	**0.83118**	0.09624	0.19179	0.73691
RP01	0.53104	**-0.61290**	-0.06769	0.66223
RP02	-0.18864	**-0.57060**	-0.08853	0.36901
RP03	0.30929	**0.70482**	0.15325	0.61592
RP04	-0.00798	0.38031	-0.17385	0.17492
RP05	-0.38245	**0.71682**	0.04972	0.66257
VB01	**0.83900**	0.18222	-0.03539	0.73838
VB02	0.21531	**0.80194**	-0.02663	0.69018
VD01	**0.89285**	0.21093	0.13836	0.86082
VD02	0.22039	**0.89291**	0.15942	0.87127
VP01	**0.89441**	0.13450	0.07421	0.82357
VP02	0.35303	**0.82410**	0.11475	0.81694

Factor 2 is strongly and positively related with the variables that represent employment of modern technology, especially mechanization (PT07, PT09, PT13, PT17, PT19) and capital employed per occupied worker (VB02, VD20). It also is strongly and positively correlated with the value of production per occupied personal (VP02) and with variables that represent the relationship between capital use and production (RP03 and RP05). The negative correlation between variables that express total employment per utilized area (RP01) and use of family labor (RP02) reinforces the interpretation that Factor 2 is an indicator of the intensity of labor use—the capital/work ratio.

The higher the scores for the Factor 2, the higher the micro-regions capital/work ratio.

As opposed to the Factors 1 and 2, **Factor 3** correlates positively with variables that represent the employment of traditional technology, most notably the use of the animal power, and the ratio of utilized area to occupied personal(PT06, PT10, PT12, PT14 and PT16). Although Factor 3 acts mostly as complement to the other two Factors, its inclusion when the homogeneous groups are being defined will allow for a more refined and precise analysis. Micro-regions with high Factor 3 scores will be understood to be areas in which traditional agriculture practices are important. The regions which have low Factor 1,2 & 3 scores will be seen as regions in which agricultural activity is of little economic significance.

The Homogeneous Groups Formed in 1985 and Their Characteristics.

The three factors of modernization were used to form homogeneous regional groupings, MRHs, using the procedure described in an previous section. MRHs were formed for the years 1970, 1975, 1980 and 1985. Before describing the spatial dynamics of farm sector technological diffusion, it is necessary to characterize 1985's homogeneous regional groupings. Table 3 shows the regional composition of eight groups considered in 1985 for a level of likeness inferior to 10.3% of the distance measures'[9] total variation width.

To the characterization of the homogeneous groups was considered a linear regression model, in that the modernization factors were alternated as dependent variables. Applied to the groupings formed in 1985, they were used as independent variables, *dummies,* that expressed the interaction of the groupings and every year of study. Thus, the model is in the following form:

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[9] The consideration of a more rigorous level of likeness, inferior at 8.0%, would result in the formation of 11 groupings. Group G 09 would isolate MRHs Chapadões de Paracatu and Alto Médio São Francisco; Group G 10 would separate MRHs Belo Horizonte and Vertente Ocidental do Caparaó, and Group G 11 MRHs Mata de Ubá and Mata de Cataguases

$$F_{ij} = \beta_{tg} D_t D_g + e_j \qquad (4)$$

in that
Fij is the factorial score obtained by MRH *j* (*j* = 1, 2,..., 184) for the factor *i* (*i* = 1, 2 and 3);
Dt are the *dummies* for the years of the study (*t* = 70, 75, 80 and 85);
Dg are the *dummies* for the homogeneous groups formed for 1985 (*g* = 1, 2,..., 8);
β_{tg} are the partial correlation coefficients for interaction among the *dummies* Dt and Dg;
ej is the term of statistical error.

Table 3 - Homogeneous groups formed in 1985[10]

GROUPS	MRHs
G 01	Pontal do Triângulo Mineiro (TR), Uberlândia (UB), Uberaba (UBR), Alto Paranaíba (AP) e Planalto de Araxá (AX)
G 02	Mata da Corda (MCO), Alto São Francisco (ASF); Três Marias (TM), Rio das Velhas (RV), Chapadões do Paracatu (CH) e Alto Médio São Francisco (AMS)
G 03	Mogiana Mineira (MM), Furnas (FU), Planalto de Poços de Caldas (PC) e Planalto Mineiro (PM), Belo Horizonte (BH) e Vertente Ocidental do Caparaó (VC)
G 04	Formiga (FO), Divinópolis (DI), Espinhaço Meridional (EM), Campos de Mantiqueira (CM), Mata de Ponte Nova (PN), Mata de Muriaé (MU) e Mata de Viçosa (VI)
G 05	Alta Mantiqueira (AM), Alto Rio Grande (RG), Siderúrgica (SI), Mata de Caratinga (CA) e Mantena (MA)
G 06	Juiz de Fora (JF), Mata de Ubá (UBA), Mata de Cataguases (CT), Calcário de Sete Lagoas (SL) e Serra Geral (SG)
G 07	Bacia do Suaçuí (BS), Governador Valadares (GV), Bacia do Manhuaçú (BM), Montes Claros (MC), Sanfranciscana da Januária (SJ), Mineiradora Jequitinhonha (MJ) e Alto Rio Pardo (RP)
G 08	Mineiradora Diamantina (MD), Pastoril de Pedra Azul (PA), Pastoril de Almenara (AL), Pastoril de Nanuque (NA) e Teófilo Otoni (TO)

Source: Data of the research

In order to facilitate characterization of the homogeneous groups, the estimated coefficients of each group's Factor 1, 2 and, 3 were plotted in a histogram derived using the expression above (4) for the year

[10] When utilizing regression models in the characterization of groups we chose to unite Belo Horizonte and Vertente Ocidental do Caparaó MRHs with Group 3 MRHs located in the Sul de Minas. This caused a discontinuance in the agglomeration plan that led to an underestimation of Group 3's partial regression coefficients, especially in Factor 2.

1985. Illustration 1 presents the values of those coefficients in the vertical axis. In the horizontal axis, each of the eight homogeneous groups' three modernization Factors appear side by side.

Analyzing Illustration 1, we can see that agriculture practices in regions making up Group 1 in 1985 had a high capital/work ratio (Factor 2). The same trend was found in Group 2 areas, although of lesser intensity. In Group 2, extensive soil utilization (low coefficient for Factor 1) and the high employment of animal power (Factor 3) indicate that this was still an area in farm sector technological expansion.

Group 3, contrarily, incorporated agricultural areas in which a considerable amount of modern technology was employed and which realized high production per utilized area (Factor 1). It should be noted that the coefficients for Factor 2 in Group 3 are underestimated due to the inclusion of the MRHs Belo Horizonte (BH) and Vertente Ocidental do Caparaó (VC) (see: note 9).

In 1985, the farm sectors of regional Groups 4, 5, and 6 were dependent on traditional productive factors. This is expressed by the combination of low Factor 2 coefficients, and by often higher coefficients for Factor 3 (Groups 4 and 6).

The regions which make up Group 7 and 8 occupy a large area of the Sweet River (Rio Doce) and Jequitinhonha State Planning Regions and include nearly half of the MRHs found in Minas' Noroeate. Both Groups employed an agricultural system that combined subsistence farming with extensive cattle ranching. This is indicated by the low coefficients for the all three modernization Factors. The higher indicators for Factor 3 in Group 8 is due to the use of rivers for subsistence farming and the extensive employment of human and animal muscle power.

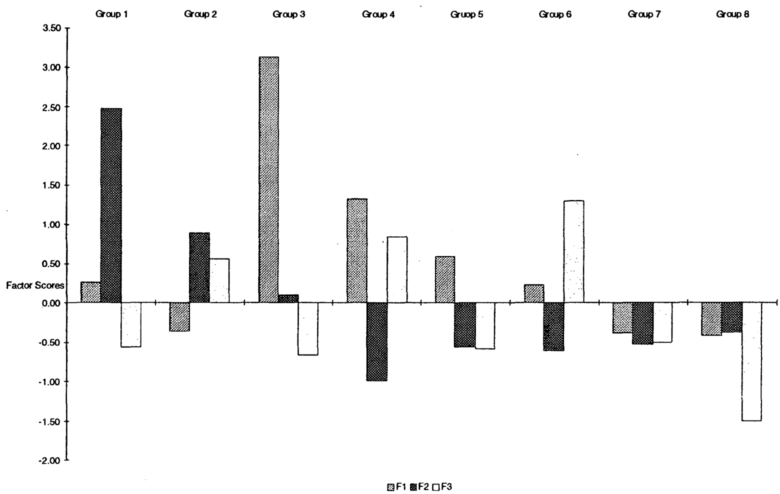


Illustration 1 - Characterization of the homogeneous groups formed in 1985.

In summary, the eight Groups considered in Table 3 could be gathered into four Great Groupings with a smaller degree of internal homogeneity, yet representative of the different systems of agricultural activity found in Minas Gerais in 1985 (Illustration 2).

United, Groups 1 and 2 define the area where the agricultural system's technological base is in expansion. Agricultural practices were employed that substituted human and animal labor for technology, prior to increasing the amount of acreage in productive use. Group 3 is a region employing modern agriculture techniques and now earns high revenues per productive acre.

In the Great Grouping formed by Groups 4, 5, and 6, there continues to be dependence on traditional productive factors because of the area's uneven topography and the inflexibility of the technology developed for Brazil's farm sector. For that Great Group, the coefficient for intensive use of the soil was variable, with high coefficients for Group 4 and low coefficients in Group 6. However, we recognize the influence of special programs to assist in use of the humid tilled plain, and, in great measure, the association between reduced farm size, owners needs, and the topography.

Finally, regional Groups 7 and 8, are defined as "problem areas" in the State of Minas Gerais, lacking water, infrastructure, and a large agrarian population.

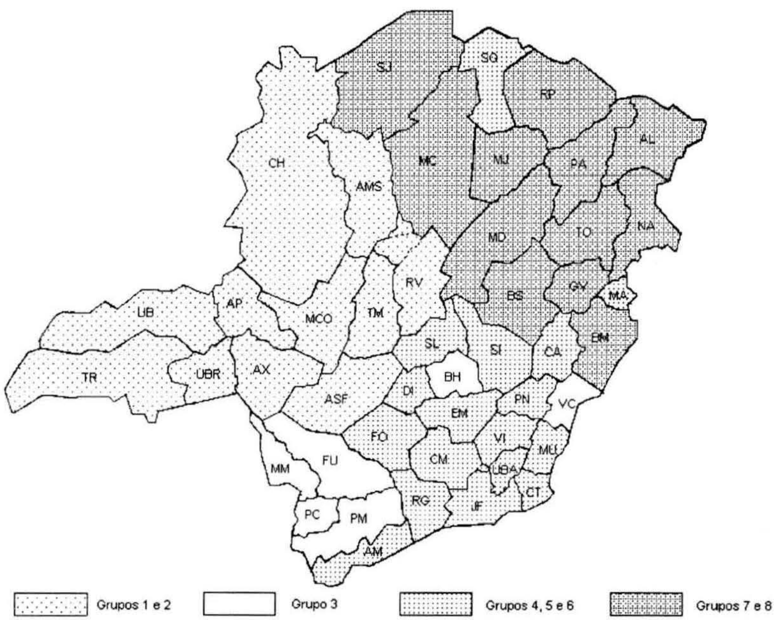


Illustration 2- Homogeneous micro-regions and their modernization *Factors* groups, 1985

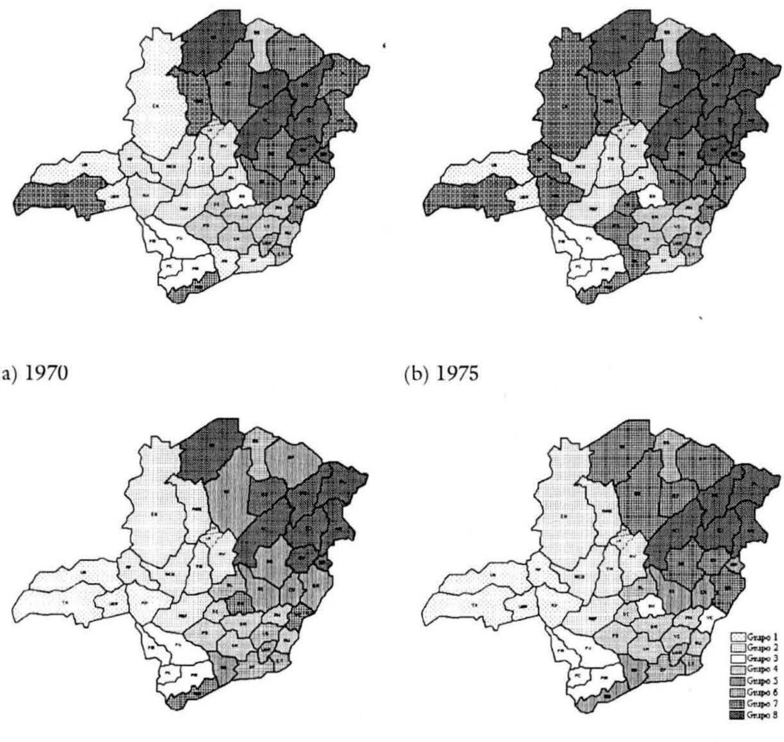
Spatial Diffusion of Agricultural Modernization in Minas Gerais

In an previous section we discuss the spatial diffusion of new farm technologies in Minas Gerais and its dynamic. Illustration 3 locates the MRHs and identifies them with their Group in each one of the four years of the study, graphically illustrating the our results.

In 1970, (a), we see that the MRHs that form Group 1 in 1985, (d), were members of three different groupings. In 1985, the nucleus of Group 1 is made up of the MRHs Uberlândia (UB) and Uberaba (UBR) that in 1970, were characterized by agricultural activity similar to that found in the MRHs: Chapadões de Paracatu (CH), the Noroeste, and Alto Rio Grande (RG) in the Sul de Minas. After 1970, technical progress accelerated in UB and UBR, isolating them in a single grouping in 1975 (b). In 1980 (c), new technology diffused into the neighboring MRHs of Pontal do Triângulo Mineiro (TR) and Planalto de Araxá (AX); and they joined UB and URN in Group 1. In 1985 (d), technological progress reached the MRH of Alto Paranaíba (AP); and it also entered Group 1. In 1985, the composition of Group 1, UB, UBR, TR, AX, and AP, coincided with the State Planning Region known as Triângulo Mineiro/Alto Paranaíba (Illustration 4 shows the eight macro-regions used by State planners).

Group 2 can be characterized as a group of regions into which new agricultural technology is expanding. In 1970, it included MRHs in Planning Region V (Alto São Francisco), the MRHs Planalto de Araxá (AX) and Alto Paranaíba (AP) in Planning Region IV (Triângulo / Alto Paranaíba), Calcário de Sete Lagoas (SL) in Planning Region I (Metalúrgica/Campo das Vertentes); and Juiz de Fora (JF) in the Zona da Mata (a). The MRHs in Planning Region IV, AX & AP, eventually gathered into Group 1 by virtue of the more rapid growth in their capital/work ratio (Factor 2). The last two MRHs, SL & JF left the group in 1980 (c) when the intensification in agricultural capital use Group 2 extended to the MRHs of Chapadões do Paracatu (CH) and Alto Médio São Francisco (AMS); parts (c) and (d).

The extensive use of modern agricultural technology, as defined in the previous section, remained focused in the Sul de Minas, in the MRHs Planalto de Poços de Caldas (PC), Planalto Mineiro (PM), Furnas (FU), and Mogiana Mineira (MM). In 1970 (a) and 1975 (b), MRH Belo Horizonte was grouped with the three more southern MRHs without discontinuity in the grouping's outline (note 9). Large scale agricultural activities of great commercial value characterize Minas' south, where coffee, orange, sugar-cane and corn are grown. Several factors, unlike those that characterize agricultural practices employed in the Minas' south have caused the high intensity of soil utilization in the area immediately surrounding Minas' Capital, Belo Horizonte,. Nearer the State Capital, small agricultural establishments farm the available land intensely to provision the great urban center.



(a) 1970 (b) 1975

(c) 1980 (d) 1985

Illustration 3 - Groupings formed in 1970, 1975, 1980 and 1985.

In 1980, MRHs Belo Horizonte (BH) and Vertente Ocidental do

Caparaó (VC) in the Zona da Mata, formed a differentiated grouping (c) by virtue their having the least employment (on farms) and the smallest revenues per occupied personal (Factor 2). In 1985, although remaining an isolated group, those two MRHs were gathered into Group 3 to facilitate the statistical analyses.

The area occupied by Groups 4, 5, and 6, a great portion of the state of Minas Gerais, for reasons soil type, climate, or topography, is not adapted to the use of the available new technology. These general technological composition of these Groups was little altered during the period studied. In 1980, only the MRHs Montes Claros (MC) in the Noroeste, Alto Rio Pardo (RP) in the Jequitinhonha Region, and Bacia do Suaçuí (BS) and Bacia do Manhuaçú (BM) in the Rio Doce Region left Group 4 and were incorporated into Group 7. Because of intensified soil use in relation to its neighbors around the Doce River, MRH Mantena (MA) left Group 7 in 1985 (d) and joined Group 5.

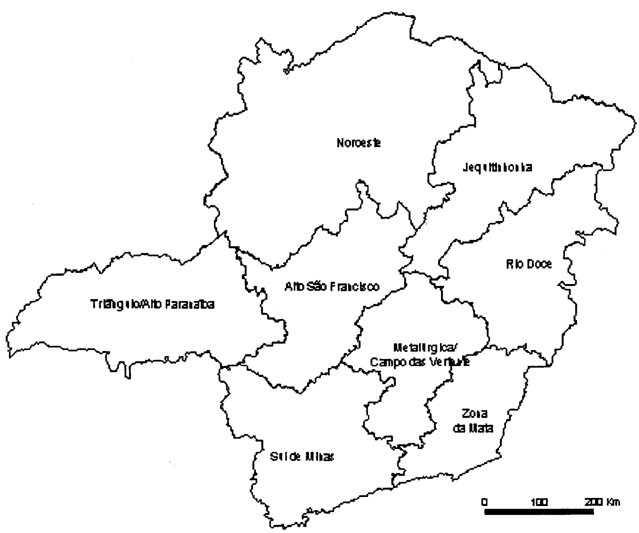


Illustration 4 - State Planning Department Macro-regions in Minas Gerais (IGA/CETEC, 1994)

Lastly, the MRHs in Groups 7 and 8 still employ traditional agricultural productive techniques. These MRHs evidence the technological inequality growing between Minas Gerais' regions due to the partial and selective regional penetration of modern agricultural techniques. In 1970, Group 7 (a) was composed of just the MRHs San Franciscana da Januária (SJ) in the Noroeste Region; Mineiradora Jequitinhonha (MJ), Mineiradora Diamantina (MD), and Pastoril de Pedra Azul (PA) in the Jequitinhonha Region; and MRHs Teófilo Otoni (TO), Governador Valadares (GV), and Mantena (MA) in the Rio Doce Region. In 1970, only these MRHs presented technological indicators inferior to those found in the remainder of the state. By 1985, MRH Mantena was the only Group 7 MRH that showed enough intensification of soil use to move into Group 5. Moreover, the relative delay in technological improvement, already observed in the four MRHs that slipped down the technological ladder, caused MRHs Mineiradora Diamantina (MD), Pastoril de Pedra Azul (PA), Pastoril de Almenara (AL), Teófilo Otoni (TO), and Pastoril de Nanuque to become still more technologically distanced and, in 1985, fell into Group 8 (d).

One of the results of this selective diffusion of technical progress in Minas Gerais' farm sector between 1970 and 1985 was the growth of regional inequalities, as it can be seen Illustrations 5 and 6.

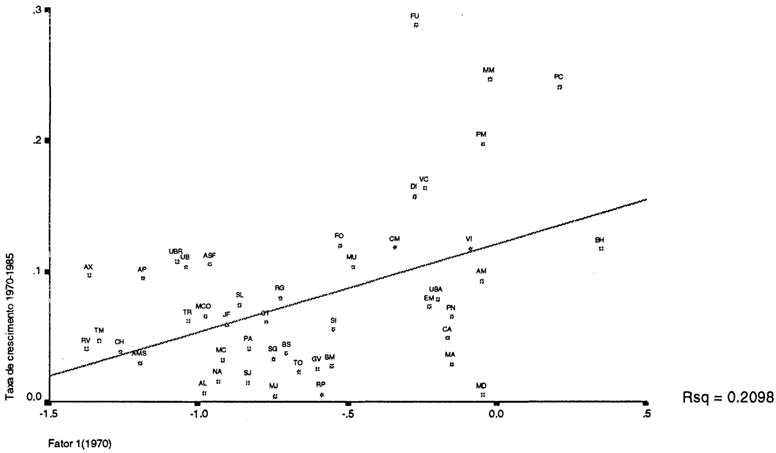


Illustration 5 - Technological divergence among the homogeneous micro-regions in relation to the intensity of soil utilization (Factor 1): 1970 to 1985

The axis of abscissas of the graph presented in Illustration 5 shows the value of each MRH's factorial score for Factor 1 in 1970. The axis of the ordinate shows the linear growth rate of Factor 1 between 1970 and 1985. In situation of technological convergence, the line formed by the coordinates of the points in the Cartesian axes would be adjusted with a negative inclination. This would indicate that the MRHs with the highest scores for Factor 1 in 1970, had the smallest growth rates during the period; and the smallest scores for Factor 1 in 1970 indicate the MRHs which had the highest growth rates.

As it can be observed in the Illustration 5, the positive inclination of the adjusted regression line reflects the growth of technological inequalities among Minas Gerais' micro-regions between 1970 and 1985. In 1970, MRHs in Group 03 (MM, FU, PC, PM, BH, and VC), had the highest intensity soil utilization and were the ones that had the highest growth rates. This is contrary to the stagnant growth rates found in Group 7 MRHs (BS, GV, BM, MC, SJ, MJ and RP) and Group 8 MRHs (MD, PA, AL, NA and TO).

The same thing happened in the evolution of the capital/work ratio (Factor 2). In this case, the process was caused by the expansion of technical agriculture into Minas Gerais' savanna areas. Notice how the MRHs in Groups 01 (TR, UB, UBR, AP, and AX) and 02 (MCO, ASF, TM, RV, CH, and AMS) are positioned toward the upper right corner of Illustration 6.

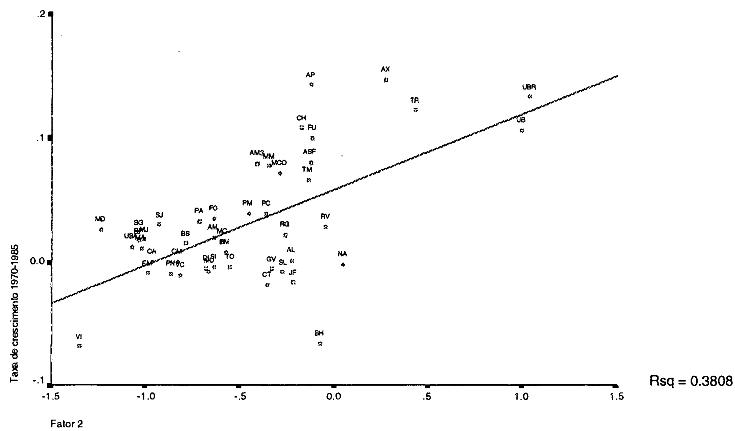


Illustration 6 - Technological divergence among the homogeneous micro-regions correlated with the capital/work ratio (Factor 2), 1970 to 1985

CONCLUSIONS

In a sense, the forces which determined the road taken by farm sector development in Minas Gerais respected the theoretical presuppositions assumed by the model of urban-industrial impact. Thus, the influence of the great urban center São Paulo, near the areas of the Triângulo Mineiro and in the Sul de Minas, helps to explain the more rapid agricultural development in those areas. The opening of the Belo Horizonte to Brasília highway assisted agricultural development in the state's Northeast, in the MRHs of Rio das Velhas, Três Marias, Chapadões de Paracatu, and Alto Médio São Francisco.

On the other hand, the model defends that theory that variables in the political order were largely responsible for the growth of regional disparities in Minas Gerais' farm sector. Politicians determined the adoption of a relatively inflexible technological "package" which restricted technological development in many farming regions. Moreover, the different rates of technological progress found among the state's regions are strongly associated to distribution policies and rural credit resources.[11]

In this sense, we found that the theoretical model proposed by De Janvry (1977) explains the process and results of technological diffusion in Minas Gerais' farm sector most appropriately. This is so because the action of *interest groups*, in the context of forced industrialization policies ordered by a military regime, directed national agricultural research to adapt a "package" of imported technology rather than generate a new technology adapted to the socioeconomic and environmental diversity of the country.

As result, the technical diffusion that occurred was directed toward Minas Gerais' savanna lands. Unfortunately, most of the state was at the margin of this technological change in agricultural practices and that caused the growth of regional differences.

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[11] This relationship is formalized in Meyer (1997). In this article also treated in detail the association between the direction of the technical progress according to the factors of modernization and the different agrarian structures in the various state regions.

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