INNOVATIVE ACTIVITY IN LATIN AMERICA: A COMPARISON BETWEEN INDUSTRIES OF LOW AND HIGH TECHNOLOGICAL INTENSITY

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ABSTRACT

This paper provides an analysis of the innovative activity of three major Latin American countries – Brazil, Argentina, and Mexico – based on the level of technological intensity of their manufacturing sectors. In addition to substantial differences with regard to the technological effort put in by the manufacturing firms of these countries, we also found out that the distinction between innovative activity in the manufacturing sectors of low or medium-low and medium-high or high technological intensity depends on the maturity of the manufacturing framework of these countries. It was observed that the importance in sorting out manufacturing sectors according to their technological intensity varies, both in terms of the probability of bringing innovation into the market and of establishing technological strategies for the various manufacturing sectors. Our study also underscores the importance of interaction of other firm characteristics with the classification of the manufacturing sectors for the determination of such strategies.

Keywords: Technological Innovation; Research and Development, Latin America, Multivariate Analysis

JEL CODE: O30, O54, C10

RESUMO

Esse artigo apresenta uma análise da atividade inovativa nos três principais países latino-americanos, Brasil, Argentina e México, comparando-a segundo o grau de intensidade tecnológica dos setores industriais. Além das diferenças substantivas no nível de esforço tecnológico empreendido pelas empresas industriais do três países, também se verificou que a distinção entre a atividade inovativa nos setores industrias de baixa e média-baixa e alta e média intensidade tecnológica é dependente do grau de amadurecimento da estrutura industrial desses países. Conforme foi observado, a importância da diferenciação dos setores industriais segundo suas intensidades tecnológicas varia, tanto na determinação da probabilidade em inovar para o mercado, quanto na determinação das estratégias tecnológicas pertencentes aos diferentes setores industriais. Nessa análise também é ressalta a importância da interação de outras características observáveis das empresas com as classificações setoriais na definição dessas estratégias.

Palavras-chaves: Inovação tecnológica; Pesquisa e desenvolvimento, América Latina, Análise Multivariada

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Abstract

This paper provides an analysis of the innovative activity of three major Latin American countries – Brazil, Argentina, and Mexico – based on the level of technological intensity of their manufacturing sectors. In addition to substantial differences with regard to the technological effort put in by the manufacturing firms of these countries, we also found out that the distinction between innovative activity in the manufacturing sectors of low or medium-low and medium-high or high technological intensity depends on the maturity of the manufacturing framework of these countries. It was observed that the importance in sorting out manufacturing sectors according to their technological intensity varies, both in terms of the probability of bringing innovation into the market and of establishing technological strategies for the various manufacturing sectors. Our study also underscores the importance of interaction of other firm characteristics with the classification of the manufacturing sectors for the determination of such strategies.

Introduction

Our aim in this paper is to compare the behavior of sectors of low technological intensity with that of sectors of high technological intensity in developing countries in terms of innovative activities. To achieve that, we carry out a comparative analysis between the innovation patterns of sectors of low technological intensity versus high technological intensity in Brazilian, Argentinean, and Mexican manufacturing firms between 1998 and 2001. Note that Argentina, Brazil, and Mexico are Latin America's largest industrialized countries and are responsible for almost the region's overall expenditures on Science and Technology. This attests to the relevance of the present study.

Macroeconomic factors, institutional environments, and some peculiarities of the manufacturing sectors are taken into account in the determination of technological strategies. These sectoral factors impose minimum expenditures on innovative activities without which the survival of a firm would be compromised. In this regard, the literature provides several sectoral classifications that take into account the differences observed in innovative activities carried out by manufacturing firms, as well as the intensity and form of how the relationship between science and technology is established in production processes and in the manufacture of products, basically sorting sectors out in terms of technological intensity. Coupled with these factors, technological strategies are also established based on firm-specific (and somehow unobserved) characteristics that are, at least partially, reflected in observed characteristics such as firm size, export orientation, capital origin, among others, which are related to firms' competitive edge in the market.

Given this web of interconnected factors plus the different industrial frameworks of these countries, the present study aims to show the differences between sectoral patterns regarding innovative activities, conditional on the observed characteristics of firms. The focus is on product innovation, including knowledge sources, expenditures on innovative activities and innovation outcomes.

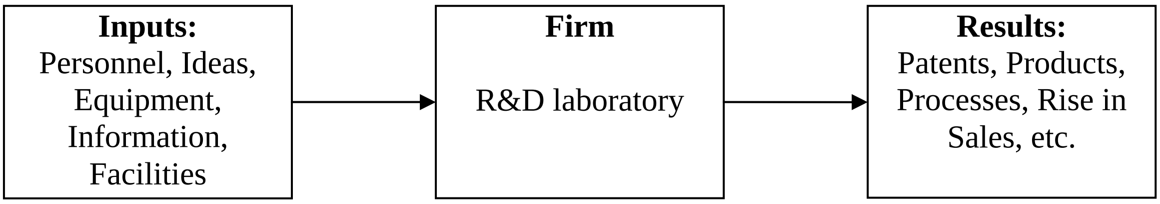
This analysis will be based upon a set of multivariate methods. This is justifiable due to the presence of bias in econometric estimations as a consequence of problems with endogeneity of variables, measurement errors or selection biases. Evidently, these problems are observed when we consider innovation strategies taken by a firm, as can be seen in the models for innovation at the firm level, in the measurement of expenditures on innovative activities; in addition, it is important that innovation surveys assess both categorical and numerical variables. Therefore, the empirical analysis proposed herein is based on the associations between the input flows used for the innovative activity and its respective results, conditional on the observed characteristics of firms.

Following on from this introduction, the paper is organized into four sections. The second section describes the empirical method used. The third one presents the database used; whereas the fourth section shows the results for the three countries under analysis; and the fifth one makes the final remarks and summarizes the results.

2) Methodology

This study is based on the input-output model proposed by Brown and Svenson (1988), fitting into the context of studies conducted by Crépon, Duguet and Mairesse (1998), which assess a similar relationship across French firms in terms of productivity using a different econometric approach. In general, this model evaluates the behavior of firms towards Research and Development (R&D) performance, including different stages (inputs, outputs and outcomes). This model is depicted below.[1]

Figure 1 – Brown and Svenson Model



Here, one assumes the existence of a relationship between observed characteristics of a firm and its technological strategy. Thus, after determining the observed characteristics, one should define the input and output flows, which allow inferring on the technological strategy used. To do that, we split the empirical approach into three stages. First we identify the observed characteristics of innovative firms. Thereafter, we use categories based on the set of variables that represent the input and output flows described in the model above. Finally, we establish associations of these categories regarding the observed characteristics of innovative firms with the categories of the variables that represent the input and output flows. The results are analyzed in the subsequent section, but the complete set of results, usually presented in appendix, for Brazil, Argentina, and Mexico were omitted due to limitation of space.

The observed characteristics of the innovative firm are estimated using classification and regression trees, following Kannebley Jr et alii (2005).[2] The estimation of classification and regression trees allows selecting the subsets of firms represented by terminal nodes. These terminal nodes define the interaction of the characteristics of the firms that make up a given subset.[3] To categorize firms according to their level of technological intensity, it is necessary that the first partition of the matrix node (dependent variable) in the estimation of the regression tree be made by the variable that categorizes the sectors according to their technological intensity, thus allowing us to further expand this tree from this partition.

The variables that represent the observed characteristics are firm size, export orientation, participation of the firm in a corporate group, capital origin, and sectoral effects, defined according to the intensity of factors of production, end-use categories, or technological intensity.[4] The dependent variable should be concerned with whether the firm engaged in product innovation only

[1] The model depicted below is similar to the one used by de Sbragia, Kruglianskas and Arango-Alzate (2002).

[2] A classification and regression tree can be understood as a rule that predicts a dependent variable using the values of their predictor variables, being exhaustively built by partitioning of the sample. The estimation method used is the one proposed by Loh and Shih (1997), the QUEST – *Quick, Unbiased, Efficient, Statistical Tree* – which is a classification algorithm that results in a binary tree, allowing for benefit-cost analyses using pruning rules, whereby the nodes without statistical significance for the dependent variable are removed.

[3] It was established that the trees could not exceed 5 node levels, with at least 100 cases in the parent node and 50 in the child nodes.

[4] The reasons for the inclusion of these variables can be found in Kannebley et alii (2005).

for the firm, or for the market. Chart 1 shows the codes and categories attributed to the dependent and explanatory variables used for estimation of the tree.

Inputs were represented by categorical variables that assessed the degree of importance of eight sources of information on the internal R&D department, other corporate firms, customers and consumers, competitors, consultancy firms, universities and research institutes and fairs and exhibits, and on the ratio between expenditure and revenues regarding internal R&D activities, external R&D acquisitions, other external knowledge sources, machine and equipment, expenditures on training courses and implementation of industrial projects. The variables that represent the outcomes of the innovative activity assessed the effects of innovations in terms of improvement in product quality and diversification, maintenance or expansion of the firm's market share, and patent procurement in the period. Chart 2 describes these variables and presents their corresponding codes.

Chart 1: Variables for Firm Characteristics

Variable	Code	Transformations
Product innovation (dependent)	INOVPROD	0 = Firm-level product innovation 1 = Market-level product innovation
Firm size	LPO	Log of the total employment share
	LRECEITA	Log of overall revenues
Export orientation	EXPORT	0 = Does not export 1 = Exports
Corporate group	GRUPO	Categorical 1 = Independent 2 = Belongs to a corporate group
Origin of holding capital	MULTIS	1 = Domestic 2 = Foreign
Sectoral effects	INTENS_F (intensity of factors of production)	1 = Natural resources 2 = Labor 3 = Capital and technology
	INTENS_T (technological intensity)	1 = Low intensity 2 = Medium-low intensity 3 = Medium-high intensity 4 = High intensity
	CNAE_USO (categories of use)	1 = Capital goods 2 = Nondurable consumer goods 3 = Durable consumer goods 4 = Intermediate goods

Based on this second set of information, we conducted some analyses to define the clusters for two input categories regarding the level of importance attached to the various sources of information (CLFI) and to the relative expenditure on innovative activities (CLDI), and to the impact of the innovation category (CLI1). We opted for the k-median method for the cluster analysis due to its better stability in defining the cluster centroids, and established the number of groups to be estimated as four.

After obtaining two large sets of categorical variables (terminal nodes and input/output clusters), we then performed bivariate correspondence analyses on the observed characteristics (estimated terminal tree nodes) and on the clusters produced for the input/output categorical variables.[5] This analysis allows comparing the profiles of rows (terminal nodes) and columns (input/output clusters) with their respective mean profiles, in addition to enabling the establishment of associations between rows and columns. The latter will be carried out by calculating standardized residuals using the respective contingency tables for the correspondence analysis.[6]

Chart 2: Input and Outcome Variables

Inputs **Sources of information** Internal R&D department (FPEDI) Other firms in the corporate group (FOEG) Suppliers of Machine and Equipment (FFMQ) Customers or Consumers (FCC) Competitors (FCONC) Consultancy firms (FECI) Universities and other research institutes (FUIP) Fairs and exhibits (FFEIRA) Computer-based information systems (FRII) **Percentage Expenditures on Innovative Activities*** Internal R&D department (EPeDI) External R&D (EPeDE) Other external knowledge sources (EPeDOC) Purchase of Machine and Equipment (EAQMEQ) Training (ETREIN) Industrial Projects (EPRJI) * relative to the firm's overall revenues
Outcomes Improvement in Product Quality (QUALI) Product diversification (GAMA) Maintenance of market share (MSHARE) Expansion of market share (ASHARE) Procurement of Patents (Patents)

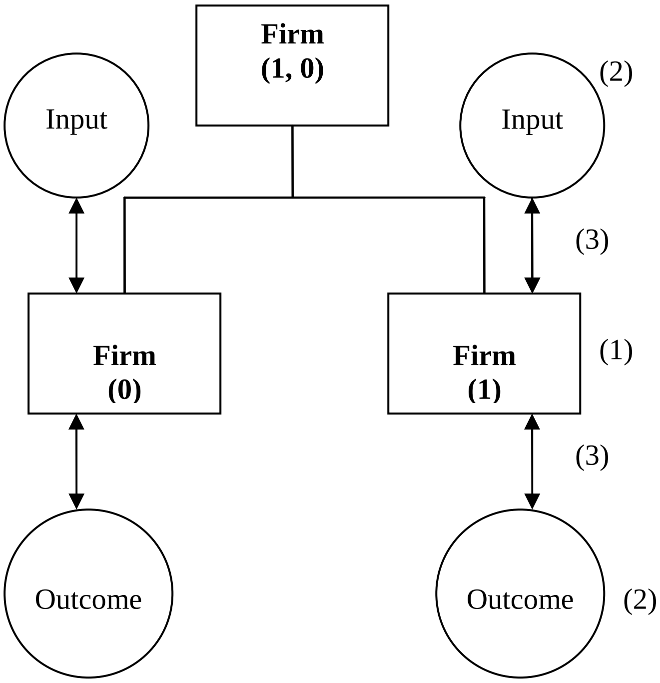
In short, our aim herein can be illustrated by the diagram below. Based on the estimation of the classification and regression tree, represented by (1), we find the categories of innovative firms formed by the terminal nodes. After that, we define the input and outcome categories using the cluster analysis, represented by (2). The association between the observed categories and the input

[5] According to Greenacre and Hastie (1987), the correspondence analysis consists of an exploratory multivariate statistical tool that converts a nonnegative data matrix into a particular type of graphical display where rows and columns are depicted as R^n points. It is an alternative method to the principal components analysis (PCA), as both calculate the distance between variables, but in case of PCA, it includes the Euclidean distance, whereas the correspondence analysis uses the chi-squared distance.

[6] The standardized residuals indicate whether the difference between the observed and expected frequency of each cell in the contingency table is statistically different from zero, using normal distribution for the hypothesis test. For further details, see Pereira (1999).

and output components, depicted in the flowchart below, will be made by the correspondence analysis denoted by (3).

Figure 2 – Empirical Representation



3) Database

The information used in this paper was obtained from research studies on technological innovation conducted in Brazil, Mexico and Argentina. The data on Argentina were provided by the National Institute of Statistics and Census of Argentina (INDEC) for the 1998-2001 period. The Mexican survey was conducted by Mexico’s National Institute of Statistics, Geography and Data Processing (INEGI) for the 1999-2000 period. The Brazilian survey was undertaken by the Brazilian Institute of Geography and Statistics (IBGE) for the 1998-2000 period, and just as any other surveys, the methodology and concepts used were those of Eurostat (third *Community Innovation Survey*, with the inclusion of 15 European Union member states). [7]

Note that the three surveys provide additional information about the employment share, overall revenues, export values, and economic activity fields of the firms, in addition to issues related to their innovative activities. In all surveys, only those firms with at least one innovative activity were allowed to complete the questionnaire. Therefore, the sample used for the comparison across countries was limited to innovative firms. In the Brazilian and Argentinean surveys, the samples included processing firms with 10 or more employees. The Mexican survey was more restrictive, allowing only for the inclusion of firms with at least 50 employees. As our purpose was to compare innovation strategies and the economic performance of firms, the final sample was an intersection of the three surveys. Thus, this study encompassed processing firms with over 50 employees and which were regarded as innovative in

[7] According to the theoretical reference of the Argentinean Survey (EICT), this is based on the Oslo Manual. However, in order to incorporate the peculiarities of the innovation process of Latin American firms, some aspects related to technological innovation were based on the Bogotá Manual, which provides the methodology for innovation surveys in Latin America. The concept of innovation in the EICT is broader than that used by PINTEC. The EICT also prioritizes the innovations related to the organization, management and commercialization, targeting at productivity gains and competitiveness.

product. [8] Given the respective sample weights, the Argentinean survey included 3,502 firms, the Brazilian one surveyed 11,818 firms and the Mexican one, 1,824 firms [9].

Before analyzing the results for the tree estimates, we are going to present some descriptive statistics about the parameters under analysis in order to get a first impression about the samples. Table 1 presents the percentage of firms that reported some product innovation at the market level and some observed characteristics of the sampled firms. First, the percentage values for the Mexican and Argentinean firms with innovative products at the market level exceed 50%, amounting to 79% in the case of Mexico, whereas for Brazil, these rates are as low as 23%. This discrepancy is not only a consequence of different innovation efforts across these countries, but it is also due to the configuration of sample designs and/or to the different interpretation of the innovation concept by firms. Moreover, the parameter values for Mexican firms are often higher than those for Brazilian and Argentinean firms. The most discrepant values were those for the Total Employment variable, which are twofold higher than those for the Brazilian firms. The characteristics of Brazilian and Argentinean firms are relatively similar, although Brazilian firms are usually larger but less productive. The biggest difference across the samples lies in the percentage of exporting firms. In this case, the percentage for Argentinean firms is almost two times higher than for Brazilian firms.

Table 1 – Observed Firm Characteristics (2000/01)

	Argentina		Mexico		Brazil	
	Mean	Sdev	Mean	Sdev	Mean	Sdev
Market innovation	0.67	0.46	0.79	0.41	0.23	0.42
Exporting firms	0.47	0.49	0.53	0.50	0.25	0.45
Total Employment	103	588	334	733.9	166	643.1
Foreign Capital	0.10	0.30	0.13	0.33	0.07	0.26
Corporate Group	0.13	0.34	0.28	0.45	0.09	0.28

Table 2 displays the descriptive statistics for the intermediate level of importance of information sources, the percentage expenditure and the comparison of qualitative assessments of innovation impacts by Mexican, Argentinean and Brazilian firms considered in this study. As observed for the three countries, the largest level of importance regarding the source of information is attributed to internal R&D departments, followed suppliers of machine and equipment by fairs and exhibits. Other knowledge sources were considered to be less important. The greatest differences concern the larger importance attached by Mexican firms to other firms in the corporate group and to customers and competitors. Argentinean firms apparently underestimate other sources of information in favor of the information provided by the internal R&D departments of the firms.

Note that unlike the statistics for the observed characteristics of firms, expenditures of Brazilian firms slightly outperform the expenditures of Argentinean and Mexican firms. The relative expenditures of Brazilian firms are not outperformed in any of the items by the relative expenditures of Mexican and Argentinean firms, being nearly three times higher than the relative expenditures of Mexican and Argentinean firms on internal R&D activities. The relative expenditures of Argentinean and Mexican firms are quite similar, with expenditures on external R&D activities, purchase of machine and equipment being slightly higher for Argentinean firms, and expenditures on internal R&D activities, industrial projects, and other external knowledge sources being slightly higher for Mexican firms.

[8] Recall that no information set is error-free. For this reason, we use specific criteria in an attempt to reduce possible typing errors or misinformation. Therefore, the total employment and revenue fields designated as zero were excluded from the study. The variables used to assess innovation efforts whose values exceeded 100% were also excluded from the analysis. In this study, we use sample weight (calculated by the specific research institutes) for all estimates.

[9] In the Brazilian case, among 12,569 product innovators (17% of the total number of industrial businesses and 55% of the total number of innovative firms), 9,684 were product innovators only for the firm, whereas 2,975 were product innovators for the market. The INEGI's survey provides information about 8,148 firms assessed during the1999-2000 period, showing that overall product innovation in the Mexican industry amounted to 22.4%, which corresponds to 1,824 firms in the sample.

The comparison of qualitative assessments by Mexican, Argentinean and Brazilian firms indicates that the results obtained by Brazilian firms are on average higher than those for Argentinean firms, but lower than those for Mexican firms. Comparatively, the results for Mexican firms are quite noteworthy, as they demonstrate positive assessments with regard to improvements in product quality, product diversification and market share. In effect, there is a tendency towards an extremely positive assessment of innovation impacts across the three countries. The most modest assessment was that with regard to the improvement in product quality by Argentinean firms, with only 54% of the answers being positive.

Table 2 – Descriptive Statistics of Inputs and Outcomes

	Mexico	Argentina	Brazil
	Mean	**Mean**	**Mean**
Level of Importance of Information Sources			
Internal R&D	0.70	0.77	0.76
Other firms in the corporate group	0.36	0.10	0.09
Suppliers of Machine and Equipment	0.72	0.47	0.62
Customers or Consumers	0.81	0.46	0.70
Competitors	0.57	0.45	0.49
Consultancy firms	0.40	0.08	0.11
Universities and other research institutes	0.23	0.22	0.16
Percentage Expenditure on Innovation Activities (2000/01)			
Internal R&D	0.62	0.55	1.77
External R&D	0.03	0.09	0.18
Other external knowledge sources	0.10	0.04	0.32
Purchase of Machine and Equipment	1.17	1.81	5.44
Training	0.20	0.21	0.41
Industrial Projects	0.09	0.07	1.16
Assessment of Innovation Impacts			
Improvement in Product Quality	0.90	0.84	0.72
Product diversification	0.87	0.67	0.73
Maintenance of market share	0.92	0.76	0.79
Expansion of market share	0.88	0.54	0.74
Patents	0.10	0.09	0.12
Improvement in Product Quality	0.90	0.84	0.72

Thus, what this descriptive analysis shows is that there seems to be no correspondence in the mean for the three components of the figure 1 above. That is, by assuming that Mexican firms are larger, more productive, and more innovative, we may expect a greater technological effort and more significant results for this innovative activity. This is not exactly what we have seen. We perceive that although the observed characteristics of Brazilian firms happen to be more modest, their innovative characteristics are much better distributed, with more favorable results in the different measurement methods used. On average, for this sample of firms with innovative products, Argentinean firms are those which present the weakest indicator of innovation activities.[10]

[10] Note that the same observation is not valid when we consider the total number of innovative firms of the three countries. De Negri (2007) shows that, in this case, the Brazilian firms maintain their leading position in terms of observed characteristics and technological effort, whereas Mexican firms are outperformed by Argentinean firms with regard to these parameters.

4) Empirical Analysis

a) Classification and Regression Tree

The tree estimated for the Argentinean survey has 25 nodes, 13 of which are terminal nodes. In view of the fact that approximately only 33% of sampled firms produce innovative products at the firm level, the estimation of the tree included a threefold higher cost for the misclassification of innovative firms at the firm level for those firms which produced innovations at the market level, implying a sharper loss of adjustment of the latter category. The risk for the tree amounted to 31.8%, slightly lower than the percentage of firms that produce innovations at the firm level, as shown in Table 3.

Observe that the partitioning based on high and medium-high technology and on low and medium-low technology does not make a remarkable distinction concerning the probability of innovation at the market level in the tree branches. Therefore, the definition of the probability of innovation relied chiefly on the expansion of the tree branches as a function of other observed categories. Table 3 shows also the terminal nodes in decreasing probability of their being classified as innovative at the market level. As we may see among the six terminal nodes with the largest probability of classifying a firm as innovative at the market level, only node 17, the one that is most likely to classify firms as innovative at the market level, refers to firms with medium-high and high technological intensity, a peculiar feature of the Argentinean industry. Also noteworthy is the fact that the major explanatory variables selected by the trees are export orientation, sectoral classifications and firm size variables, of which export orientation is positively associated with the likelihood of innovation at the market level.

Table 3: Characteristics of Argentinean firms according to terminal nodes

Node	Description	Total no.	Freq %
17	(INTENS_T = 3 OR 4) AND (CNAE_USO = 3) AND (EXP = 0) AND (LPO <= 3.89)	203	81.8
23	(INTENS_T = 1 OR 2) AND (EXP = 1) AND (INTENS_F = 1 OR 3) AND (LRECEITA <= 16.21)	630	68.1
28	(INTENS_T = 2) AND (EXP = 0) AND (LPO > 3.55) AND (INTENS_F = 1)	59	64.9
25	(INTENS_T = 1) AND (EXP = 0) AND (LPO > 3.55) AND (INTENS_F = 2 OR 3)	278	55.3
20	(INTENS_T = 1 OR 2) AND (EXP = 1) AND (INTENS_F = 1 OR 3) AND (LRECEITA > 17.15)	124	50.0
13	(INTENS_T = 1 OR 2) AND (EXP = 1) AND (INTENS_F = 2)	251	42.5
24	(INTENS_T = 1 OR 2) AND (EXP = 1) AND (INTENS_F = 1 OR 3) AND (16.21 < LRECEITA <= 17.15)	171	41.9
11	(INTENS_T = 3 OR 4) AND (CNAE_USO = 3) AND (EXP = 1)	346	37.7
18	(INTENS_T = 3 OR 4) AND (CNAE_USO = 3) AND (EXP = 0) AND (LPO > 3.89)	90	31.3
26	(INTENS_T = 2) AND (EXP = 0) AND (LPO > 3.55) AND (INTENS_F = 2 OR 3)	218	28.6
15	(INTENS_T = 1 OR 2) AND (EXP = 0) AND (LPO <= 3.55)	733	26.0
7	(INTENS_T = 3 OR 4) AND (CNAE_USO = 4)	227	24.2
27	(INTENS_T = 1) AND (EXP = 0) AND (LPO > 3.55) AND (INTENS_F = 1)	172	22.9

Risk Estimate: 0.317728

The tree estimated for the Brazilian survey only has 13 nodes, 7 of which are terminal nodes. In view of the fact that approximately only 23% of sampled firms produce innovative products at the market level, the estimation of the tree included a twofold higher cost for the misclassification of innovative firms at the market level. Table 4 shows the classification of firms in decreasing order in terms of their probability of being categorized as innovative at the market level and the statistics of the estimation.

The risk for the tree amounted to 28 %, slightly higher than the percentage of firms that produce innovations at the market level. Innovation at the market level is defined by firms that belong to the sectors of high and medium-high technology, whereas innovation at the firm level is defined by firms belonging to sectors of medium-low and low technology. Subsequently, in both branches, the second most important variable for explaining the probability of production of innovative products at the market level concerns export orientation. The remaining predictor variables, in decreasing order of importance, were participation in a corporate group and firm size, expressed by the Neperian logarithm of the revenue or of employment share. As we may see, firms that produce innovative products at the market level (at nodes 4, 10, 7 and 11) account for nearly 32% of the total number of firms and for 63% of the sampled firms which are innovative at the market level.

Table 4 – Characteristics of Brazilian firms according to terminal nodes

Node	Description	Total No.	%
4	(INTENS_T = 3 OR 4) AND (EXP = 1)	1414	67.1
10	(INTENS_T = 1 OR 2) AND (EXP = 1) AND (LRECEITA > 16.92)	571	64.7
7	(INTENS_T = 3 OR 4) AND (EXP = 0) AND (GRUPO = 1)	179	63.4
11	(INTENS_T = 3 OR 4) AND (EXP = 0) AND (GRUPO = 0) AND (LPO <= 3.64)	1636	54.6
12	(INTENS_T = 3 OR 4) AND (EXP = 0) AND (GRUPO = 0) AND (LPO > 3.64)	656	41
9	(INTENS_T = 1 OR 2) AND (EXP = 1) AND (LRECEITA <= 16.92)	894	38.2
5	(INTENS_T = 1 OR 2) AND (EXP = 0)	6468	16.6
	Risk Estimate: 0.279909		

The tree estimated for Mexican firms contains 19 nodes, 10 of which are terminal nodes. In order to take better advantage of the information related to the category with smaller percentage values, the estimation of the tree included a fivefold higher cost for the misclassification of innovative firms at the firm level. This corresponded to a risk of 23%, which is slightly higher than the percentage of innovation at the firm level, as shown in Table 5. For the estimation of this tree, it is necessary that the first partition be made by the sectoral classification according to technological intensity. The sectors of high and medium-high technological intensity defined innovation at the market level, while innovation at the firm level was defined by the classification of sectors of low and medium-low technological intensity.

With regard to innovation at the market level, the only subsequent subdivision is given by the foreign capital origin, according to which domestic firms are those most likely to innovate at the market level. This branch comprises 469 firms, accounting for 25% of the sample. In terms of innovation at the firm level, it amounts to 75% of the sample. In the latter case, the variables positively correlated with the probability of innovation at the market level concern the participation of firms in a corporate group, firm size, and sectoral classification. Table 5 also provides the description of the terminal nodes.

Table 5 – Characteristics of Mexican firms according to terminal nodes

Node	Description	Total No.	%
15	(INTENS_T = 1 OR T = 2) AND (GRUPO = 0) AND (LPO <= 4.67) AND (INTENS_F = 1 OR 3) AND (LRECEITA <= 15.62)	112	100
8	(INTENS_T = 1 OR 2) AND (GRUPO = 0) AND (LPO > 6.28)	65	75.3
6	(INTENS_T = 3 OR 4) AND (MULTIS = 0)	389	73.6
12	(INTENS_T = 1 OR 2) AND (GRUPO = 0) AND (LPO <= 4.67) AND (INTENS_F = 2)	103	70.4
3	(INTENS_T = 1 OR_T = 2) AND (GRUPO = 1)	315	69.9
17	(INTENS_T = 1 OR 2) AND (GRUPO = 0) AND (4.67 < LPO <= 5.21) AND (CNAE_USO = 2)	94	65.4
13	(INTENS_T = 1 OR 2) AND (GRUPO = 0) AND (4.67 < LPO <= 6.28) AND (CNAE_USO = 4)	194	53.2
5	(INTENS_T = 3 OR 4) AND (MULTIS = 1)	80	39.1
18	(INTENS_T = 1 OR 2) AND (GRUPO = 0) AND (5.21 < LPO <= 6.28) and (CNAE_USO = 2)	185	26
16	(INTENS_T = 1 OR T = 2) AND (GRUPO = 0) AND (LPO <= 4.67) AND (INTENS_F = 1 OR 3) AND (LRECEITA > 15.62)	287	8.7

Risk Estimate: 0.232079

b) Cluster analysis

The cluster analysis conducted for input and outcome variables of Argentinean industry is described in Table 6. With regard to the source of information, mean centroid values ranged between 0.24 and 0.61. Cluster 1 was the cluster with the highest mean, whereas cluster 4 was the one with the lowest. The statistics for clusters 2 and 3 exhibit intermediate levels. Also note that cluster 4 has the larger number of observations, which indicates that approximately 38% of sampled firms attach low importance to the different sources of information. On the other hand, nearly 29% of the firms attach a high level of importance to five sources of information, including internal R&D, among the nine sources of information surveyed.

The cluster analysis for expenditures on innovative activities allows designating cluster 1 as the one whose centroid values are on average higher, followed by clusters 2, 3 and 4, respectively. Note that the high mean obtained for cluster 1 is particularly due to the high value calculated for the centroid of expenditures related to the purchase of machine and equipment, and to the fact that cluster 2 has a high centroid value for this item. Cluster 2 is also the one with the highest centroid value for expenditures involving internal R&D. Approximately 63% of the sampled Argentinean firms were classified by cluster 4, the one with the lowest mean value for centroids.

The clusters estimated for innovation impacts demonstrate that most Argentinean firms assess innovation results positively. That is, virtually 64% of the firms are classified as clusters 1 and 2, respectively the first and second ones in terms of mean centroid values. While cluster 2 contains centroids that are different from zero, but all lower than 1 for all cluster items, cluster 1 contains only centroids with values equal to 1, except for the patents item, which is equal to zero.

Table 6 – Cluster Analysis for Argentinean Inputs

clfi	fpedi	foeg	ffmq	fcc	fconc	feci	fui	ffeira	frii	No. Obs.
1	0.920	0.207	0.633	1.000	1.000	0.148	0.333	0.684	0.414	1003
2	0.920	0.318	0.614	1.000	0.000	0.102	0.330	0.807	0.455	382
3	0.815	0.210	1.000	0.000	0.318	0.121	0.287	0.548	0.280	771
4	0.747	0.224	0.000	0.187	0.232	0.112	0.187	0.290	0.158	1346
cldi	epedi	epede	epedoc	eaqmeq	etrein	eprji				No. Obs.
1	0.448	0.121	0.258	14.250	0.092	0.395				497
2	2.876	0.346	0.183	0.657	0.138	0.474				275
3	0.256	0.092	0.088	3.342	0.106	0.319				533
4	0.081	0.087	0.062	0.200	0.051	0.114				2197
cli1	patents	quali	gama	mshare	ashare					No. Obs.
1	0.000	1.000	1.000	1.000	1.000					1178
2	0.226	0.916	0.741	0.803	0.640					1072
3	0.093	0.884	0.000	0.744	0.000					660
4	0.110	0.305	0.780	0.203	0.085					592

Table 7 displays the statistics for the cluster analysis of input and outcome variables related to innovative activity for the Brazilian survey. These statistics allow ordering the clusters according to the centroid mean values for each analysis, in addition to assessing the dispersion around the mean. As to the sources of information, cluster 1 takes the first place, with the highest mean level and the second lowest dispersion. At the other extreme, we have cluster 4, with the lowest mean level of importance attached to the sources of information, besides the lowest standard deviation. Clusters 2 and 3 differ in terms of dispersion around the mean. Centroid values in cluster 2 are more homogeneous, whereas their values are extremely high in cluster 3 and are restricted to four sources of information only. Clusters 1 and 2 account for approximately 49% of all observations, whereas cluster 4 accounts for the remaining 49% of observations.

With regard to the cluster analysis for relative expenditures the same ordering applies, but some additional comments are necessary. Note that the ordering of cluster 1 was mainly due to the high centroid value for expenditure on machine and equipment, but cluster 2 showed the largest centroid value for expenditures on internal R&D. Cluster 1 accounts for approximately 12% of observations and cluster 4, with low expenditure on innovative activities, for nearly 55% of observations.

In terms of innovation impacts, cluster 1 is the one with the highest mean centroid value, followed by clusters 2, 3 and 4. The centroids in cluster 1 are defined by extreme responses regarding the outcomes obtained. In this cluster, the centroid value for the procurement of patents is zero. Firms in clusters 1 and 2 constitute most of the sampled firms, 83% of the total, indicating that innovation results were extremely positive in the firms' self-assessment.

Table 7 – Cluster Analysis for Brazilian Inputs

clfi	fpedi	foeg	ffmq	fcc	fconc	feci	fui	ffeira	frii	No. Obs.
1	0.931	0.221	0.819	0.900	1.000	0.308	0.385	0.884	1.000	2,446
2	0.849	0.178	0.673	0.763	1.000	0.159	0.174	0.650	0.000	3,306
3	1.000	0.000	1.000	1.000	0.000	0.000	0.000	1.000	0.000	283
4	0.825	0.235	0.586	0.614	0.000	0.149	0.199	0.548	0.367	5,783
cldi	epedi	epede	epedoc	eaqmeq	etrein	eprji				No. Obs.
1	3.309	0.167	0.541	28.366	1.113	3.181				1,444
2	6.151	0.354	0.344	1.212	0.477	1.727				1,407
3	0.882	0.113	0.305	5.739	0.246	1.109				2,430
4	0.371	0.110	0.138	0.464	0.095	0.319				6,537
cli1	patentes	quali	gama	mshare	ashare					No. Obs.
1	0.000	1.000	1.000	1.000	1.000					4,522
2	0.364	0.731	0.732	0.875	0.708					5,347
3	0.129	0.000	0.837	0.000	0.660					620
4	0.307	0.339	0.113	0.245	0.041					1,329

The cluster analyses were performed in a similar fashion for Mexican survey and the results are shown in Table 8. In terms of sources of information, cluster 1 takes the first place, followed by clusters 2, 3 and 4. Note that the largest difference between cluster 1 and 3 concerns the zero value of the centroid for the foeg variable (other firms of the group) in cluster 3, which determines a lower value for its mean. Cluster 2 only contains extreme values, i.e., zero and one, where zero refers to the centroids of the foeg (other firms of the group), feci (consultancy firms) and fuip (universities and other research institutes) variables. In cluster 4, the centroids show a more homogeneous pattern, but much lower in terms of mean. Cluster 3 is the largest, accounting for 45% of the observations, followed by cluster 1 with 25% of the observations.

As to expenditures, cluster 1 takes the first place, followed by clusters 2, 3 and 4. Some additional comments should be made about this ordering. Cluster 1 ranked first due to the high centroid values obtained for the expenditure on machine and equipment and on internal R&D activities. In other words, Mexican firms classified as cluster 1 are those with the highest median values of expenditure on innovative activities, accounting for 3.5% of the observations. Cluster 2 differs from cluster 3 mainly due to the high centroid values for expenditures on machine and equipment observed in cluster 2.

Cluster 4 has the larger number of observations (64%), which explains the low mean values for expenditures on innovative activities obtained by the Mexican industry.

In regard to innovation outcomes, cluster 1 is the one with the highest centroid mean values, followed by clusters 2, 3 and 4. In cluster 1, all centroids are equal to one, except for the procurement of patents, which is equal to zero. Similarly to the Brazilian case, the firms belonging to clusters 1 and 2 account for most of the sample (95%), indicating that innovation outcomes were extremely positive in the self-assessment of firms.

Table 8 – Cluster Analysis for Mexican Inputs

clfi	fpedi	foeg	ffmq	fcc	fconc	feci	fui	ffeira	frii	No. Obs.
1	0.777	1.000	0.819	0.902	0.699	0.549	0.249	0.756	0.715	626
2	1.000	0.000	1.000	1.000	1.000	0.000	0.000	1.000	1.000	27
3	0.722	0.000	0.848	0.924	0.557	0.418	0.241	0.804	0.557	825
4	0.392	0.243	0.243	0.270	0.176	0.216	0.108	0.081	0.108	346
cldi	epedi	epede	epedoc	eaqmeq	etrein	eprji				No. Obs.
1	2.271	0.022	0.753	14.232	0.749	0.642				63
2	0.399	0.149	0.384	4.420	0.041	0.227				130
3	0.321	0.019	0.293	1.402	0.142	0.172				455
4	0.256	0.021	0.047	0.121	0.049	0.130				1,176
cli1	patents	quali	gama	mshare	ashare					No. Obs.
1	0.000	1.000	1.000	1.000	1.000					1246
2	0.254	0.739	0.560	0.851	0.828					483
3	0.000	0.000	0.000	0.750	0.750					22
4	0.176	0.294	0.059	0.059	0.059					73

c) Summarized Report

The flowchart 3 presents the inputs and outputs for Argentinean manufacturing firms. By looking at the description of the innovative branch at the firm level, that is, of firms belonging to the sector of low and medium-low technological intensity, we note that most clusters of information with positive associations with the terminal nodes are those with a more restrictive information set and/or with the lowest self-assessment. This is indeed a factor that is peculiar to firms belonging to the sector of low technological intensity. Thus, the distinction between input and output flows at nodes 15, 25, 26, 27 and 28, of non-exporting firms, was chiefly due to the relationship between expenditures on innovative activities and their respective impacts. At these nodes, expenditures on the purchase of machine and equipment were relatively high, but not necessarily correlated with the impacts of innovative activity. What is quite clear in terms of technological strategies is that exporting firms use a broader knowledge base.

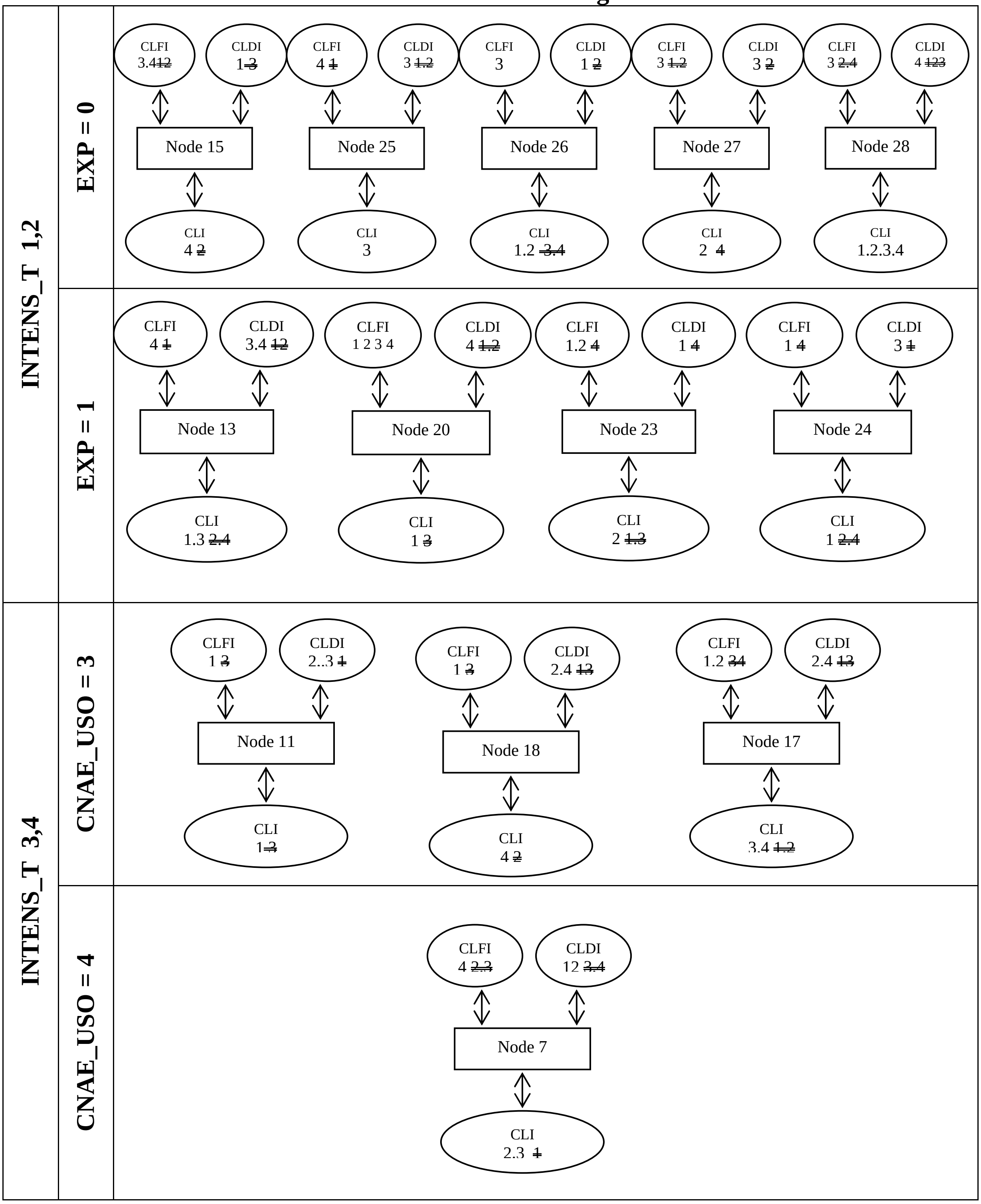
The analysis of innovation at the market level reveals that Argentinean manufacturing firms in the durable consumer goods sector (nodes 11, 17 and 18) use a wider knowledge base, as shown by the associations with the clusters of information sources, where the level and quality of expenditures on innovative activities differ in view of observed characteristics. What we observe in the statistics for standardized residuals (not presented here) is that there is a negative association with cluster 1, which has the highest level of expenditure on machine and equipment. All nodes show a positive association with cluster 2, the one with the highest expenditure on internal R&D. The differences between innovation impacts can be explained by the export orientation at nodes 11, 17 and 18, and by sectoral classification at node 7. Thus, export orientation bears a strong correlation with the technological strategy used by Argentinean manufacturing firms, respecting the differences between the levels of expenditure of the sectors of low and high technological intensity, and being often associated with a higher impact of innovative activities.

Chart 4 summarizes the flow chart shown for the Brazilian case. Due to the smaller complexity of the estimated tree, the flowchart for Brazilian manufacturing firms allows for a more in-depth analysis. Therefore, starting with node 5, firms are non-exporting and belong to sectors of low and medium-low technological intensity, and in this case, the probability of finding firms that produce innovative products only at the firm level is larger. This node is characterized by a technological strategy based on a relatively broader knowledge source, with expenditures on innovative activities strongly oriented towards the purchase of machine and equipment, but also with large expenditures on internal R&D. Since these are firms that operate in the domestic market, the impacts of their innovative activities are limited.

Considering innovation at the firm level only, the comparison between nodes 9 and 10, represented by exporting firms of low and medium-low technological intensity, shows a different pattern of information sources, expenditures and impacts, which is related to firm size. Firms at node 9, which are smaller, show a technological strategy with limited knowledge sources, with non-negligible expenditures on machine and equipment, with an impact proportionately distributed across the three clusters with the highest levels. On the other hand, firms at node 10 show a different strategy from those at node 9, with broader knowledge sources, low relative expenditure, but with a higher impact. These differences can be possibly accounted for by the different forms of insertion of smaller and larger firms into the foreign market, which eventually interfere in their operation in the domestic market.

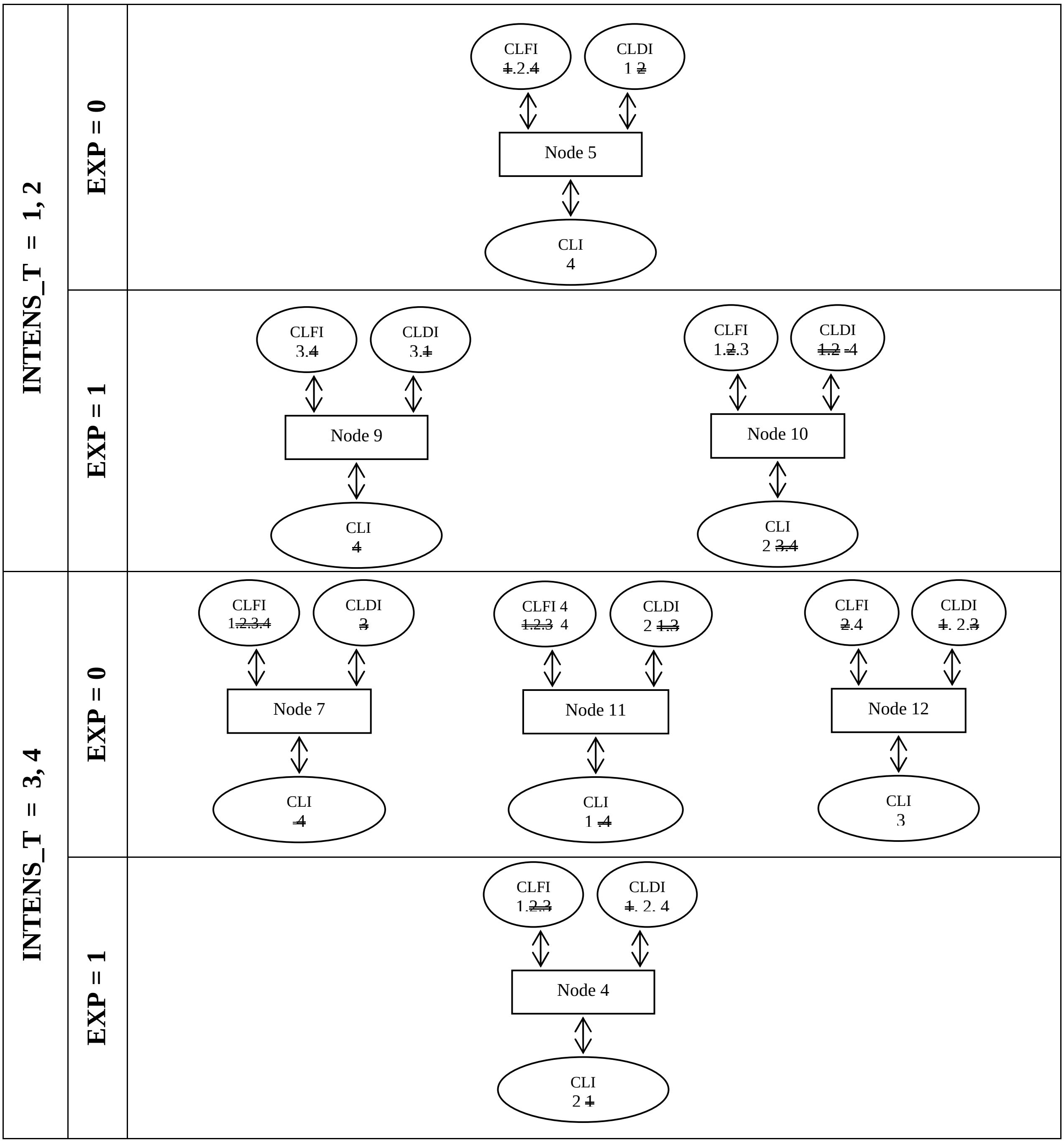
In terms of innovation at the market level, the tree contains 4 terminal nodes, three of them representing non-exporting firms (7, 11 and 12) and one representing an exporting firm (4). The difference between node 7 and nodes 11 and 12 is due to the fact that firms at node 7 belong to a corporate group, unlike those at nodes 11 and 12. This indicates some differences in terms of knowledge sources, since node 7 is positively associated with cluster 1, with the highest mean value for the sources of information, whereas nodes 11 and 12 are strongly associated with cluster 4, which attaches the lowest importance to the sources of information. The expenditures of firms at node 7 are higher, but specifically targeted at the purchase of machine and equipment, with relatively higher impact. That is, the insertion of firms into corporate groups seems to be a determining factor for a broader technological strategy, even if these firms operate only in the domestic market. In terms of input and output, node 4, which represents exporting firms, has a wide knowledge source. However, their expenditures on innovative activities are distributed across clusters with high and low levels of expenditure on R&D; the same applies to innovation outcomes, with concomitant levels of high and low impact.

Chart 3 – Flow Chart - Argentina



~~C XX~~ refers to negative association with, at least, 5 percent level of statistical significance

Chart 4 – Flowchart for Brazil

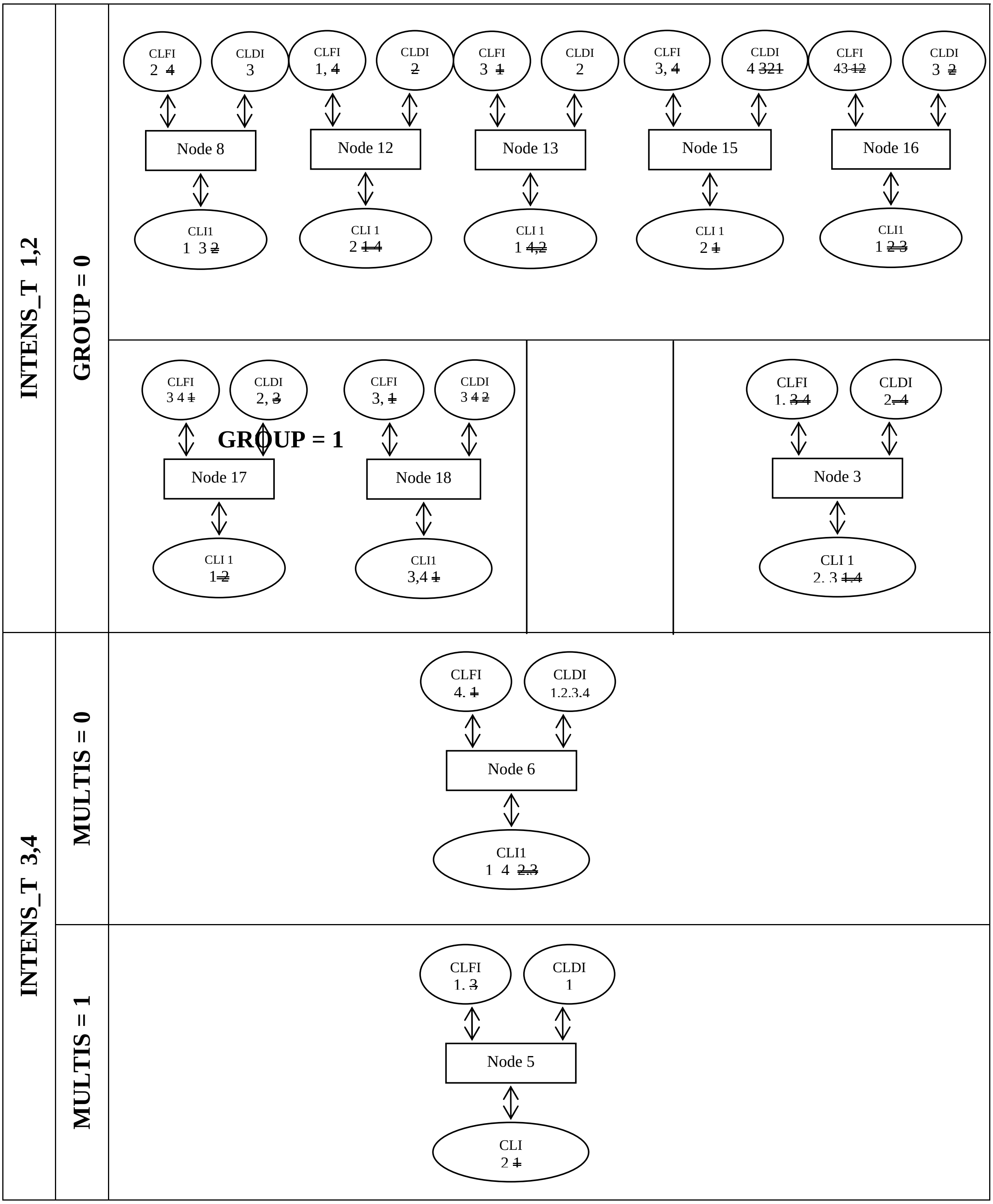


~~C XX~~ refers to negative association with, at least, 5 percent level of statistical significance

Chart 5 provides a flow chart of inputs and outputs of the terminal nodes estimated by the classification and regression tree for Mexico. This chart is divided according to the configuration of the tree branches, i.e., sectors of low and medium-low technological intensity and high and medium-high intensity, and their respective predictors, i.e., participation of firms in a corporate group and foreign capital origin. With regard to firms belonging to sectors of low technological intensity, we note that none of the terminal nodes shows a positive association with cluster 1, (CLDI 1). This, in line with the theoretical prediction, indicates that expenditures on innovative activities are low compared to the sectors of high technological intensity. It is also possible to observe the prevalence of the type of impact represented by cluster 1 (CLI1 1), which does not include patent procurement, either denoting low effectiveness of patent protection in these sectors, or low technological innovation impact, thus not requiring this type of protection. The only nodes that are positively associated with cluster 2 (CLI1 2) are nodes 3, 12 and 15. With regard to technological strategies, node 8 (large independent firms) apparently uses a limited strategy in terms of source of information (CLFI2) and has a relatively low expenditure (CLDI3), with the major aim of preserving or expanding its market share. The opposite occurs at node 3, firms that belong to corporate groups, which have a broader strategy, attach more importance to the sources of information, show a relatively high expenditure on innovative activities and outcomes that involve the procurement of patents, although there are some firms at this node with low innovation impact. The diversity of inputs and outputs is noteworthy when compared to nodes 17 and 18. The difference between these nodes is given by firm size: node 17 has 105 to 181 employees, and node 18 contains firms with 181 to 533 employees. The probability of innovation at the market level is greater at node 17 and this finding is corroborated by the input-output flow, with higher expenditure on innovative activities, yielding a higher impact, as seen in the positive association of node 17 with cluster 1 (CLI1 1) and in its negative association with cluster 2 (CLI1 2), and of node 18 with clusters 3 and 4 (CLI1 3 and CLI1 4) and its negative association with cluster 1 (CLI1 1). This summarized report shows that the technological strategies of nodes 13 and 17 are quite similar, and this similarity is associated with the probability of both nodes being innovative for the market.

In the other branch of the tree, which includes firms belonging to sectors of high technological intensity, the difference between national and multinational firms is quite clear. Even though national firms are more likely to innovate at the market level, their input-output flows denote a smaller technological effort, with narrower knowledge sources, having also a smaller impact for innovative activities. Foreign companies were the only ones that showed a positive association with cluster 1, which represents the highest level of technological effort in Mexico, use and attach a lot of importance to the sources of information and have a high impact, including patent procurement.

Chart 5 – Flow Chart for Mexico



~~C XX~~ refers to negative association with, at least, 5 percent level of statistical significance

Final Remarks

This paper provided an analysis of the innovative activity for the three major Latin American countries – Brazil, Argentina, and Mexico – seeking to compare it by using technological intensity as a parameter. We initially demonstrated that there were remarkable differences in terms of technological effort across the firms of these countries. Comparatively, we found out that Brazilian firms are more mature, with a better distribution of innovative strategies and with a higher relative expenditure. Argentinean and Mexican firms share similarities in terms of technological effort. This comparison is clearer in the cluster analyses, which demonstrate that both countries have the lowest expenditure vis-à-vis their revenues, with practically the same number of firms.

The greater maturity of the Brazilian industry is also reflected on the predictive power of the sectoral classification variable according to technological intensity. This variable was automatically selected by the algorithm only in the tree estimated for the Brazilian firms. In the tree for Argentinean firms, this variable could not make any distinction as to the probability of innovation at the market level. Both in the case of the trees for Argentina and for Brazil, export orientation is positively associated with the probability of innovation. In the Mexican case, the fact that a firm belongs to a corporate group, or is a multinational, is strongly correlated with the probability of innovation at the market level. The selection of these different explanatory variables for the estimation of the trees shows the different developmental pattern of these industries and also the way they are inserted into the world economy, given the insertion of the Brazilian and Argentinean economies into Mercosur and of the Mexican economy into the NAFTA.

All analyses revealed differences between quality and level of expenditures on innovative activities across sectors of low and high technological intensity. The results corroborate theoretical predictions. However, as shown by the analyses of the three samples, the heterogeneity of firms is a key factor for the choice of their technological strategies, and there is no regular pattern in the results obtained for these three countries. Nevertheless, the comparisons of information sources related to innovation allowed us to conclude that the conceptual adequacy of industrial sectors according to their technological intensity is directly related to the developmental level of the industries of these three developing countries.

The export orientation of Argentinean firms was crucial for the distinction of technological strategies of firms belonging to sectors of low and high technological intensity. These firms often had wider knowledge sources, as shown by the associations with the information clusters, and in most cases, high level of relative expenditures and of innovation impact.

For Brazil, the analyses demonstrated a clear association between technological effort, firm characteristics, and economic performance in Brazilian firms that produced innovative products. We could note that the association of firm characteristics with the clusters of information source and of impact was more closely related to the probability of innovation at the market level, determined mainly by the technological intensity of the sector and by the export orientation of the firm. In terms of relative expenditures, the association was more strongly determined by the technological intensity of the manufacturing sector.

For Brazilian firms belonging to sectors of low and medium-low technological intensity, non-exporting firms have broader knowledge sources and higher expenditures on innovative activities, and more modest results in terms of market share and with restricted scientific impact. The strategies of exporting firms are based on lower expenditures, whose focus is often placed on the purchase of machine and equipment, and yield significant results at the market level. Apparently, the search for stronger competition through the increase in productivity and reduction in costs makes firms target their technological strategies at the adoption of technology involving machine and equipment more often than non-exporting firms do. In spite of that, the expenditures of the second category of firms on machine and equipment is higher, but counterbalanced by relatively high expenditures on R&D, denoting larger heterogeneity of technological strategies of non-exporting vis-à-vis exporting firms.

Nevertheless, for firms belonging to sectors of medium-high and high technological intensity, export orientation is more weakly correlated with a wider variety of technological strategies. For this subset of firms, their insertion into corporate groups seems to be a key factor for the adoption of a broader technological strategy.

In the case of Mexican firms, we could observe that firms belonging to sectors of low and medium-low technological intensity, especially independent ones, use a limited source of knowledge. There was a relatively low level of expenditure on innovative activities and the outcomes were more geared towards the domestic market, with low technological impact. The variations relative to this intermediate pattern were shown, at a lower rate, by large independent domestic firms, and at a higher rate, by independent firms with 105 to 183 employees, and by firms belonging to corporate groups.

In the case of firms belonging to sectors of high and medium-high technological intensity, we perceived a significant difference in favor of technological strategies of multinational firms. Therefore, the technological strategies of Mexican firms are apparently less due to sectoral differences brought about technological intensity, but mainly to their ownership structure.

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