Statistica & Applicazioni - Vol. IX, n. 2, 2011, pp. 175-187

THE CONFIDENCE ELLIPSES IN MULTIPLE NON-SYMMETRICAL CORRESPONDENCE ANALYSIS FOR THE EVALUATION OF THE INNOVATIVE PERFORMANCE OF THE MANUFACTURING ENTERPRISES IN CAMPANIA

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SUMMARY

Non-Symmetric Correspondence Analysis-NSCA (D'Ambra and Lauro, 1989) is a useful technique for analyzing a two-way contingency table. There are many real-life applications where it is not appropriate to perform classical correspondence analysis because of the obvious asymmetry of the association between the variables. The key difference between the symmetrical and non-symmetrical versions of correspondence analysis rests on the measure of the association used to quantify the relationship between the variables. For a two-way, or multi-way, contingency table, the Pearson chi-squared statistic is commonly used when it can be assumed that the categorical variables are symmetrically related. However, for a two-way table, it may be that one variable can be treated as a predictor variable and the second variable can be considered as a response variable. Yet, for such a variable structure, the Pearson chi-squared statistic is not an appropriate measure of the association. Instead, one may consider the Goodman-Kruskal tau index. In the case that there are more than two cross-classified variables, multivariate versions of the Goodman-Kruskal tau index can be considered. These include Marcotorchino's index (Marcotorchino, 1985) and Gray-Williams' index (Gray and Williams, 1975). In the present paper, the Multiple non- Symmetric Correspondence Analysis- MNSCA (Gray and Williams, J. S,1975), is used for the evaluation of the innovative performance of the manufacturing enterprises in Campania. Innovation represents a very important element for the competition of the enterprises and economic growth. Only the enterprises which are able to innovate regularly can have at their disposal a range of more and more appealing products for the customers. Moreover, only a constant innovation provides the constant efficiency of the processes and the optimization of the production costs. Finally, the use of the ellipse confidence has allowed to identify a category which is statistically significant.

Keywords: *CATANOVA, Confidence Ellipse, Gray-Williams Multiple Tau Index, Multiple Non Symmetrical Correspondence Analysis.*

1. INTRODUCTION

In many situations concerning empirical research, we have to predict a categorical variable (criterion variable) from another (predictor variable). Non- Symmetric Correspondence Analysis (NSCA: D'Ambra and Lauro, 1989) is a useful technique for

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analyzing a two-way contingency table in which rows and columns are assumed to have an asymmetric relationship. In more complex cases, the predictor variables are more than one. In this paper, the Multiple Non- Symmetric Correspondence Analysis- MNSCA, is used for the evaluation of the innovative performance of the manufacturing enterprises in Campania.

We have started from a two-way table contingency with three categorical variables obtained by means of a concatenation of a predictor variable to another. In particular, we have considered the case in which there is an asymmetric relationship between two categorical variables used as predictor variables (column variables- *A* and *B*), which represent the principal sources of innovation, and a response variable (row variable-*Y*), i.e the degree of innovation diffusion.

In particular, the sources of innovation here considered are the costs in Research and Development (R&D) and the other Technological Innovation Costs (TIC), for example the purchase of plants, machinery and equipment designed to the introduction of new products and/or productive processes, acquisition of other technology (patents, non-patent inventions, licenses and know-how) designed to the introduction of new products and/or processes, marketing of innovation products, planning, and so on. Such sources constitute indicators widely used to test the innovative effort of the enterprises and other organizations.

For this purpose, the MNSCA has been carried out, and the index used to evaluate the degree of the relationship between the response variable and the predictors variables is TAU by Gray -Williams. Later, the use of the ellipse confidence has allowed to identify a category which is statistically significant.

The paper is organized as follows: in Section 2, the MNSCA approach is shown. In Section 3, the confidence ellipses are shown and in Section 4 a case study will is shown.

2. MULTIPLE NON SYMMETRICAL CORRESPONDENCE ANALYSIS

Let *N* be a two way contingency table (obtained by means the concatenation of a predictor variable to another) in which we consider the cross classification of n statistical units according to three categorical variables *A*, *B* and Y. Define Y the first (row) variable consisting of *r* categories and *A* the second (column) variable consisting of *c* categories and *B* the third variable (column) consisting of *t* categories. The resulting contingency table is, therefore, of size *r* x (*c* x *t)* with general term n_{ijk}. Let $P = (n_{ijk}/n_{ijk}n)$ be the relative frequency distribution and let $p_{i\bullet\bullet} = \sum_{j=1}^{c}\sum_{k=1}^{t} p_{ijk}$ and $p_{\bullet jk} = \sum_{i=1}^{r} p_{ijk}$ be the marginal row and column frequencies, respectively.

We compute the dependence of row from columns through the Gray-Williams index (Gray and Williams, 1975).

Let $\pi_{ijk} = p_{ijk}/p_{\bullet jk} - p_{i\bullet\bullet}$, for $i = 1, 2, \ldots r$, $j = 1, 2, \ldots c$ and $k = 1, 2, .., t$, be the difference between the unconditional marginal proportion of the *i*th response category, $p_{i\bullet\bullet}$, and the conditional prediction of the ith response given the joint proportion of the two predictor variables, $p_{ijk}/p_{\bullet jk}$.

The Gray-Williams (1975) proposed an extension of the Gudman- Kruskal TAU index for three categorical variables by which the proportional reduction in error (PRE) for the prediction of the response (row) variable can be measured by considering:

$$\tau_{GW} = \frac{\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{t} p_{\bullet jk}\left(\frac{p_{ijk}}{p_{\bullet jk}} - p_{i\bullet\bullet}\right)^2}{\left(1 - \sum_{i=1}^{r} p_{i\bullet\bullet}^2\right)} = \frac{\tau_{GWnum}}{\left(1 - \sum_{i=1}^{r} p_{i\bullet\bullet}^2\right)} \quad (1)$$

The numerator of the Gray-Williams index, τ_{GWnum}, will be the focus of our discussion here, since the denominator is independent of the any of the joint cell proportions of the table N.

To determine the structure of the dependence between three categories variables, one may consider a Generalized Singular Value Decomposition:

$$\pi_{ijk} = \sum_{m=1}^{M} a_{im}\lambda_m b_{jkm} \quad (2)$$

where

$$\sum_{i=1}^{r} a_{im}a_{im'} = \begin{cases} 1, m = m' \\ 0, m \neq m' \end{cases} \qquad \sum_{j=1}^{c}\sum_{k=1}^{t} p_{\bullet jk} b_{jkm} b_{jkm'} = \begin{cases} 1, m = m' \\ 0, m \neq m' \end{cases}$$

where $M = [\min(r,\ c \times t) - 1]$, λ_m are generalized singular values (arranged in descending order such that $1 > \lambda_1 > \lambda_2 > \cdots > \lambda_M > 0$), a_{im} is an element of the singular vector $\mathbf{a}_\mathrm{m}$ and is associated with the ith row response category, b_{jkm} is an element of the joint singular vector $\mathbf{b}_\mathrm{m}$ and is associated with the joint association between the two predictor variables.

This approach is called MNSCA. To graphically view the dependence between the row and column categories, we can plot along mth dimension of the MNSCA plot the row and column profile coordinates:

$$f_{im} = a_{im}\lambda_m \text{ and } g_{jkm} = b_{jkm}\lambda_m \quad (3)$$

Although t is an appropriate measure of the predictability, the statistic cannot be used to test formally for association. By contrast, the C-statistic of Light and Margolin (1971) is used to carry out such tests:

$$C = (n-1)(r-1)\tau_{GW} = (n-1)(r-1)\frac{\sum_{m=1}^{M}\lambda_m^2}{1 - \sum_{i=1}^{r} p_{i\bullet\bullet}^2} \quad (4)$$

Under the zero predictability hypothesis (note that zero predictability also implied no association, i.e independence) $H_0 : \pi_{ijk} = 0$ Light and Margolin (1971) showed that the C-statistic is asymptotically chi-squared distribution with $\{(r-1)[(c \times t) - 1]\}$ degree of freedom. In particular, Light and Margolin (1971), Onukogu (1985 a,b) and Singh (1993,1996), introduced this statistic to obtain a variance analysis procedure for contingency table, commonly referred to as CATANOVA.

3. THE CONFIDENCE ELLIPSES

This section shows 100 $(1-\alpha)$% confidence ellipses for the predictor categories of a two-way contingency table when the association between the variables is analyzed using the Non-Symmetrical Correspondence Analysis (NSCA) or MNSCA.

Let's consider the property of the element of the *jk*th column singular vector

$$\sum_{h=1}^{H} b_{jkm}^2 = \frac{1}{p_{\bullet jk}} \Rightarrow b_{jk1}^2 + b_{jk2}^2 = \left(\frac{1}{p_{\bullet jk}} - \sum_{h=3}^{H} b_{jkm}^2\right) \tag{5}$$

where H is max between row and column because the relationship (5) is satisfied by considering all singular vectors, even those with eingenvalue equal to zero.

Considering the definition of profile coordinates for *jk*th column category, (5) can be alternatively expressed as follows:

$$\frac{g_{jk1}^2}{\lambda_1^2} + \frac{g_{jk2}^2}{\lambda_2^2} = \left(\frac{1}{p_{\bullet jk}} - \sum_{h=3}^{H} b_{jkm}^2\right) \Rightarrow$$

$$\Rightarrow \frac{g_{jk1}^2}{\lambda_1^2\left(\frac{1}{p_{\bullet jk}} - \sum_{h=3}^{H} b_{jkm}^2\right)} + \frac{g_{jk2}^2}{\lambda_2^2\left(\frac{1}{p_{\bullet jk}} - \sum_{h=3}^{H} b_{jkm}^2\right)} = 1 \tag{6}$$

This equation for an ellipse centered at the point (g_{jk1}, g_{jk2}) in a two-dimensional MNSCA plot with a semi-major and a semi minor axis length of

$$x_{jk} = \lambda_1 \sqrt{\left(\frac{1}{p_{\bullet jk}} - \sum_{h=3}^{H} b_{jkm}^2\right)} \; and \; y_{jk} = \lambda_2 \sqrt{\left(\frac{1}{p_{\bullet jk}} - \sum_{h=3}^{H} b_{jkm}^2\right)} \tag{7}$$

We can observe that $x_{jk} > y_{jk}$ since $\lambda_1 > \lambda_2$. As a result, the elliptical nature of the confidence region will be such that the ellipse will be stretched more along the first principal axis than along the second principal axis. Yet, (7) cannot be used to identify the level of confidence by which a particular column category is consistent with what is expected under complete independence. To deal with this issue, we may consider the following procedure.

To construct a 100 $(1-\alpha)$% ellipse, recall that λ_m^2 accounts for a certain proportion of the total inertia:

$$num(\tau_{GW}) = C\frac{1-\sum_{i=1}^{r} p_{i\bullet\bullet}^2}{(n-1)(r-1)} \tag{8}$$

If the $1-\alpha$ percentile of the chi-squared statistic with $\{(r-1)\times[(c\times t)-1]\}$ degree of freedom is denoted by χ_α^2 and $\left\{[(n-1)(r-1)]\Big/\left(1-\sum_{i=1}^{r} p_{i\bullet\bullet}^2\right)\tilde{\lambda}_{m(\alpha)}^2\right.$ represent a percentage of χ_α^2, such that

$$\frac{\lambda_m^2}{C\left(1-\sum_{i=1}^{r} p_{i\bullet\bullet}^2/(n-1)(r-1)\right)} = \frac{\tilde{\lambda}_{m(\alpha)}^2}{\chi_{(\alpha)}^2\left(1-\sum_{i=1}^{r} p_{i\bullet\bullet}^2/(n-1)(r-1)\right)} \Rightarrow$$

$$\Rightarrow \tilde{\lambda}_{m(\alpha)}^2 = \lambda_m\sqrt{\frac{\chi_{(\alpha)}^2}{C}} \tag{9}$$

Therefore, the 100 $(1-\alpha)$% confidence ellipse for *jk*th column category has a semi-major length and a semi-minor length of

$$x_{jk(\alpha)} = \lambda_1\sqrt{\frac{\chi_{(\alpha)}^2}{C}\left(\frac{1}{p_{\bullet jk}}-\sum_{h=3}^{H} b_{jkm}^2\right)} \text{ and } y_{jk(\alpha)} = \lambda_2\sqrt{\frac{\chi_{(\alpha)}^2}{C}\left(\frac{1}{p_{\bullet jk}}-\sum_{h=3}^{H} b_{jkm}^2\right)} \tag{10}$$

respectively.

4. THE CASE STUDY

In this study, we consider the Multiple Non- Symmetric Correspondence Analysis-MNSCA and the confidence ellipses to evaluate the innovative performance of the manufacturing enterprises in Campania. To evaluate the degree of innovation achieved by enterprises, the survey data UniCredit (2007) concerning Campania have been used. The enterprises under study are those of the first, second and third sectors based on Pavitt classification.

1. **Supplied dominated**: in this macro-category the innovation of the sectors such as textile, shoes, food and non-manufactured sectors (agriculture, services and building sectors) can be found. The size of the firm is medium-small. The principal aim of innovation is the reduction of the costs. The learning by using and by-doing processes are the main strategies of learning.
2. **Scale intensive**: the innovation can be found in the iron metallurgy-car materials, and in the durable used goods. The size of the firm is medium or large. The aim of the innovation is to achieve more efficient production processes. Learning-by-doing plays a major role in the innovative activities of these enterprises.

3. **Specialized supplied**: the innovation belong to sectors such as instrumental mechanics and of machinery. The firms are small and specialized. The sources of innovation are both internal (learning for experience and informal activities) and external (mainly the interaction between producers and users).

TABLE 1. - *Two way contingency table with three categorical variables*

Degree of Innovation Diffusion	**Other Technological Innovation Costs (TIC)**								
	No			Low			High		
	R&D			R&D			R&D		
	No	Low	High	No	Low	High	No	Low	High
No Innovation	14	7	12	6	10	5	7	4	6
Product Innovation	15	4	11	8	10	1	1	6	9
Process Innovation	8	17	14	13	5	6	10	4	7
Proc./Prod.	10	5	3	6	3	3	0	3	7

The response variable (row variable) is the Degree of Innovation characterized by four categories/levels:

1. No Innovation,
2. Product Innovation,
3. Process Innovation,
4. Process/Product Innovation.

The predictor variables (column variables) are R&D (both internal and external) and other Technological Innovation Costs-TIC (i.e. purchase of other technology, patents, marketing of innovative products) characterized by three categories/levels:

1. No (R&D/TIC)
2. Low (R&D/TIC)
3. High (R&D/TIC)

In particular, we have considered the case in which there is an asymmetric relationship between two categorical variables used as predictor variables, R&D and other costs in technology innovation, which represent the principal sources of innovation, and a response variable (row variable-Y), i.e the degree of innovation diffusion. For this purpose, the MNSCA has been carried out, and the index used to evaluate the degree of the relationship between the response variable and the predictors variables is TAU by Gray-Williams. For the Table (1), the numerator of Gray-Williams index is 0.036.

Table 2 shows a significant relationship between the row and column categories (P<0.05).

TABLE 2. - *CATANOVA test to evaluate the significant of the association measure*

	τ_{num}	C- Statistics	DoF	P-value
TOTAL	0.036	38.064	24	0,034**

**significant 5%.

The multiple non-symmetrical correspondence plot of Table 1 (Figure 1) shows that the row categories that mainly contribute to the explanation of the first factorial axis are Product Innovation and Process Innovation, while for the second factorial axis are No Innovation and Process*Product Innovation. The column categories that mainly contribute to the explanation of the first factorial axis are TIC(H)-R&D(No) and TIC(No)-R&D(No), while TIC(L)-R&D(L) for the second factorial axis.

As a result, in the third quadrant of the Figure 1 the enterprises that have not introduced innovation can be found, since the investment in R&S is, on one hand, insufficient to create the organization conditions necessary to carry out innovative products and processes and, on the other hand, to reduce the high degree of failure that

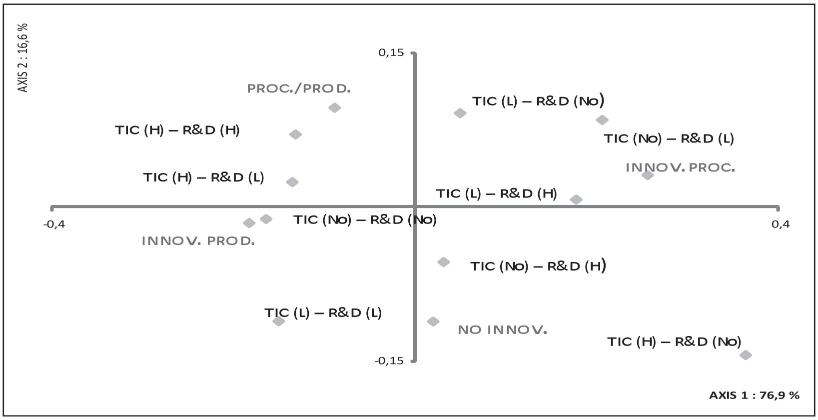

FIGURE 1. - *Multiple Non-Symmetrical Correspondence Plot of Table 1*

does not permit the transformation of the basis research into applied research. Moreover, another weak element of the enterprises located in the south is the incompetence to attract external resources by means of the collaboration with Venture Capital and University and Research Institutes.

In the second and fourth quadrants the enterprises that have introduced innovation of processes and products can be found, although the cost in R&D is low. As the matter of fact, the competitive strategy adopted by the enterprises may be the one based on the imitation of the innovation which already exists. As it is known, the imitation strategy is characterized by a low cost in R&D (or low cost in purchase of non-exclusive technology) and by an advantage which does not imply the exclusive use of the technology.

Finally, in the first quadrant the enterprises that have chosen the contextual use of process and product innovation can be found. For this purpose, it is important to point out that the number of enterprises which has chosen this kind of strategy is insufficient; as a result, this outcome should be read very cautiously or not be considered at all.

Table 3 shows the semi-major (X) and a semi-minor (Y) length for the construction of the 95% confidence ellipses.

The 95% confidence ellipses in Multiple Non-Symmetrical Correspondence Plot of Table 1 show all the categories of other Technological Innovation Costs and R&D are statistically influent in explaining the degree of Innovation diffusion.

TABLE 3. - *Semi-major (X) and a semi minor(Y) length for the construction the 95% confidence ellipses*

Column categories	**X**	**Y**
TIC(No)-R&D(No)	0,069	0,034
TIC(No)- R&D(Low)	0,108	0,054
TIC(No) -R&D(High)	0,055	0,027
TIC(Low)- R&D(No)	0,081	0,040
TIC(Low)- R&D(Low)	0,114	0,057
TIC(Low)- R&D(High)	0,062	0,031
TIC(High)- R&D(No)	0,176	0,087
TIC(High)- R&D(Low)	0,057	0,028
TIC(High)- R&D(High)	0,088	0,043

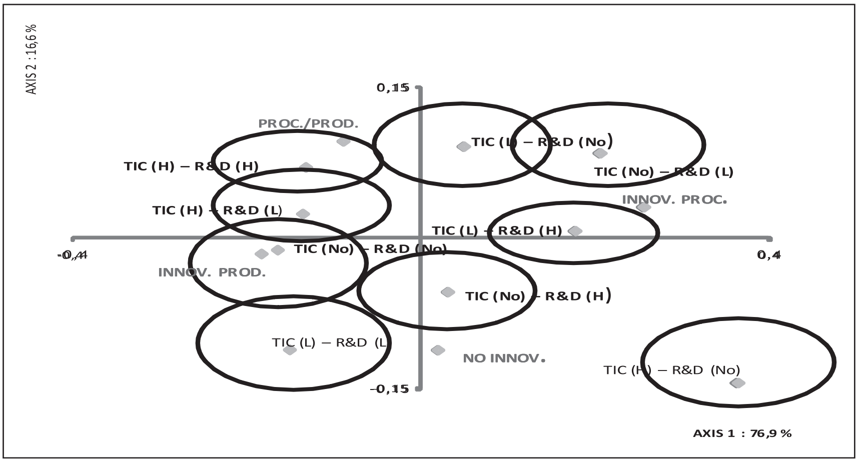

FIGURE 2. - *95% Confidence ellipses in Multiple Non-Symmetrical Correspondence Plot of table*

4.1 *The activity of innovation of the enterprises in the Italian regions*

In this section we illustrate the results of the tenth survey carried out on the small and medium enterprises working in the field of the Research and Strategy function of the UniCredit group (2007), with reference to the variables considered in our study, i.e. the degree of diffusion of the innovation, the cost in technological innovation and the cost in Research and Development.

The enterprises observed in this study are not only those of the South of Italy but also those of the North and Centre of Italy. Obviously, we will pay more attention to the enterprise of the South.

In particular, the survey carried out by Unit Credit Corporate Banking has pointed out that the quota of the innovative companies of the Centre (66.7%) is higher than both the quota of the North (60,6%) and the South one (56%).

The South, specifically, gathers little more than 11% of the companies that have introduced innovation, and shows a very high variability among the regions. Calabria and Abruzzo show shares of innovation diffusion higher that the average, while Basilicata and Molise show very modest shares.

As concerns the cost in innovation, more than 76% of such a cost is concentrated in the North, and, in particular, in four regions: Lombardia (33,8%), Emilia Romagna(13,2%), Piemonte (11,8%) and Veneto (11,5%). The Central regions concentrate about 16% of the total cost for innovation, while the Southern regions concentrate just 7,1% of the cost.

The commitment that the companies dedicate to the innovation activity in each region can be measured by the relations existing between the innovation cost and the turnover of the enterprises that have invested in innovation. In particular, the regions with a higher cost for innovation on the turnover are Marche (3,0%), Trentino Alto Adige (2,9%) and Emilia Romagna (2,8%); Veneto, Piemonte and Lombardia, also present values that are higher than the national average.

With reference to the South regions, good performances of Sardegna (3,3%) and of Campania (2,8%) have emerged, while more modest performances have emerged in Sicilia (1,6%) and in Molise.

In Basilicata the high value of the indicator (4,2%) is due to the presence of plants.

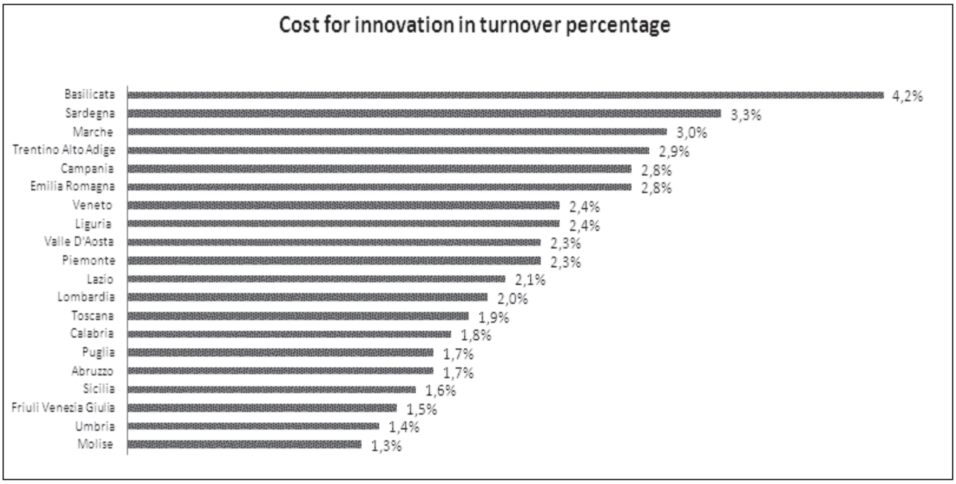

FIGURE 3. - *Cost for innovation in turnover percentage (Source UniCredit, 2007)*

The cost for innovation includes the cost in R&D, the purchase of machinery and innovative plants, patents licenses, the project designed to the introduction of new products and /or productive processes, and marketing of the innovative products.

The innovation is, indeed, a complex phenomenon: technological and organizational factors are involved. The cost in R&D turns out to be strongly concentrated in the Northern regions. Trentino Alto Adige and Piemonte prove to be the regions with a higher percentage in R&D (1,6% and 1,8%, respectively), followed by Veneto, a region with a strong Manufacturing activity (1,5%). In the Centre, Lazio is the most active region in R&D (2,7%), probably thanks to the presence of most public corporations of research, finally we find Marche and Toscana (1,9% and 1,6%). In the South, by contrast, all the regions show low levels of cost in R&D.

As mentioned before, our attention is mainly paid to the regions of South of Italy. In fact, the South is a territory that illustrates a typical Italian problem on its whole. A major reason of Italian holding back and, in particular, of the South, in terms of productivity, innovation, economic growth is to be identified in the severe deficiencies of the education system. Education and training are very important factors for

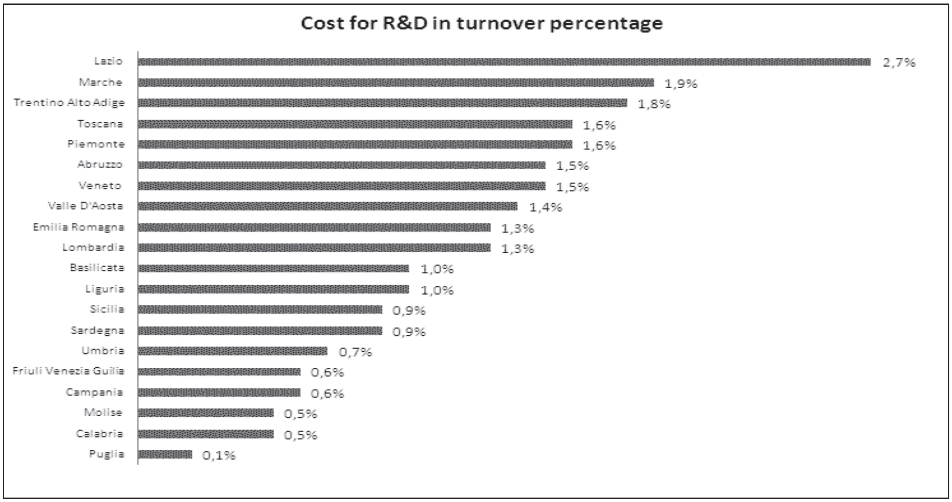

FIGURE 4. - *Cost for R&D in turnover percentage (Source UniCredit, 2007)*

development and growth and they both are necessary for the economic growth and social mobility.

High schooling levels and spread expertise represent essential conditions for work, innovation and growth of companies, to promote development and attract investments.

A further weak element of the Southern companies is the lack of resources to give to the research and development activity, and, in particular, the capacity of attracting external resources through the collaboration of private (Venture Capital) or public corporates (research centres, universities and so on).

As it is well-known, even if one of the main objectives of universities is education, they can provide important contribution to the local economy through research activities that, if applied to the real world, lead to the patenting of inventions and moving. The success of the Silicon Valley, for example, is based on a flexible university system, not a hierarchic one but open to the collaboration with enterprise. In addition , it plays an important role in the economic evaluation of innovation and in the creation of more employment. We think that all these reasons may explain the holding back of Italy and in particular of the South of it in promoting the innovation diffusion processes compared to other European countries.

5. CONCLUSIONS

In this paper, the Multiple Non- Symmetric Correspondence Analysis- MNSCA is carried out for the evaluation of the innovative performance of the manufacturing enterprises in Campania. We have considered the case in which there is an asymmetric relationship between two categorical variables used as predictor variables (column variables- *A* and *B*), which represent the principal sources of innovation, and a response variable (row variable-*Y*), i.e the degree of innovation diffusion. The index used to evaluate the degree of the relationship between the response variable and the predictors variables is TAU by Gray-Williams. Later, starting from the construction of the confidence ellipses suggested by Beh (2010) for the correspondence analysis we have extended this approach to the MNSCA. As Figure 2 shows, the construction of the confidence ellipses has allowed us to identify the column categories that mostly affect the degree of innovation diffusion.

From an applied method point of view, we have pointed out the low innovative performance of the manufacturing enterprises of Campania and, as shown by the survey carried out by UniCredit Corporate Banking, this performance is low in the other Southern regions, too. As the matter of fact, even if Campania has shown levels of cost for Research and Development >1% of GDP-Gross Domestic Product (all the other Southern regions present, by contrast, values of cost for Research and Development < 1% of GDP-Source Eurostat 2007) such a level of investment is still inadequate for the creation of innovative products and processes. It is necessary to favour the joint adoption of innovation of both products and processes and, therefore, we should turn from the innovative models spread in countries characterized by full-grown industrialization which tends to favour product innovation.

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