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A NON PARAMETRIC APPROACH FOR THE STUDY OF INSPECTIONS IN THE AGRIBUSINESS PRODUCTION

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***Abstract**: The present study concerns the analysis of the inspections (and eventual disputes) during the controls in agribusiness industry, assessed by the ICQ on the entire national territory, during the period 1997-2006. The research was carried out on the available data according year and sector. In particular the examined sectors considered were: dairy production, feed and integrators, eggs, honey and meat. First of all, we have calculated the "dispute rates", dividing the number of disputes to the total number of inspection visits for each sector and year. In this way, we focused our attention both on the temporal variations of the dispute rates occurred in the years and on the comparison of the different production sectors. We used a nonparametric approach, since there is not a guarantee of having asymptotically valid results: in particular we applied the Cox and Stuart test for trend, the NPC test and NPC Ranking.*

***Keywords**: Production sectors, inspection visits, Cox and Stuart test, NPC test, NPC Ranking.*

1. Introduction

In Italy, the prevention and prosecution of agro-food frauds is delegated to many official authorities of control, variously coordinated and differed according the aims of the supervision. The controls can be divided into two types:
1) those directed towards the prevention and suppression of the infringements related to sanitary and fiscal aspects, production, food marketing and agricultural products and technical means of production, 2) and the ones concerning the safeguard of the EC budget, through control of the

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proper usage of the funds granted by the European Community, in many sectors of the agro-food industry [2]; [5]; [6]; [9].
The Central Inspectorate for the Prevention of Fraud (ICRF), today known as the Central Inspectorate for Quality Control of Agro-products (ICQ), established by Law n° 462/1986, is the technical authority of the State, which is responsible for the prevention and prosecution of the offenses in the preparation and commerce of agricultural and food products and is in charge of monitoring and surveillance [8]. This activity is carried out by the means of inspections during the various phases of production [16], processing, storage, marketing and shipping of products in which actual and documentary controls are made, as also in sampling and sample analysis. The number of infringements is detected annually.
The purpose of this study is to develop statistical data on the infringements detected by ICQ during the production, processing, and distribution phases of food products [7]; [11] and feed, in order to render them more applicable in the formulation of legislative considerations.

2. Materials and Methods

The research was carried out on the data available on the site: http://www.politicheagricole.it /Repressione Frodi/default.htm, divided according year and sector [10].
We have examined the following five sectors in detail: milk-cheese, feed and integrators, eggs, honey and meat; these were chosen because they represent the most important sectors in terms of inspection control.
In this study, we analyzed the inspection visits and respective disputes which occurred during the period 1997-2006, within the sectors of production. We have not considered the seriousness of the disputes, because we wanted to examine the relative significant amount of complaints, compared to the number of inspection visits. For this reason, we calculated the "dispute rates", dividing the number of disputes in relation to the total number of inspection visits, for each sector and year. In this way, attention was focused on both the temporal variations of the dispute rates in the considered years and on the comparison of the different sectors of production.
We used a non parametric approach, since there is not a guarantee of asymptotically valid results. In particular, we have applied:

- the non parametric Cox and Stuart test for the trend [15], to evaluate if a possible increase or decrease in the dispute rates have occurred in the totality of the considered years;
- the Non Parametric Combination (NPC) test [14], based on a permutation solution, in order to individualize the existence of possible significant differences among the five considered market sectors. Although the productive sectors are structurally and economically different, we wanted to assess any differences between the number of disputes and / or the number of visits in the five different areas.
- the non parametric procedure “NPC Ranking” [13] in order to achieve a classification of the valid market sectors both in the inspection visits and the disputes, and in reference to the dispute rates for each year of our series.

Firstly, we described the investigated variables; table 1 shows the descriptive statistics for the inspection visits, disputes and dispute rates according market sector.

Examining the descriptive statistics, it is possible to point out that a higher number of inspection visits were detected in the Milk-Cheese sector, followed by the Feeds and Integrators sector; instead the disputes in the Feeds and Integrators sector show a higher mean value in comparison to the remaining sectors. In reference to the dispute rates, higher mean values were also registered for Feeds and Integrators, Honey and Eggs.

Table 1. Descriptive statistics according market sector.

		INSPECTION VISITS		
MARKET SECTOR	***Mean***	***S.D.***	***Min.***	***Max.***
Milk-Cheese	2748.6	1682.1	1167	5767
Feed and Integrators	1661.6	987.7	580	3376
Eggs	890.0	584.9	385	2044
Honey	426.0	393.9	93	1345
Meat	1234.2	1319.4	230	2934
		DISPUTES		
MARKET SECTOR	***Mean***	***S.D.***	***Min.***	***Max.***
Milk-Cheese	201.7	113.3	68	417
Feed and Integrators	213.8	129.2	77	406
Eggs	123.7	75.9	46	270
Honey	43.8	22.6	17	79
Meat	78.4	67.5	6	151
		DISPUTE RATES		
MARKET SECTOR	***Mean***	***S.D.***	***Min.***	***Max.***
Milk-Cheese	0.076	0.019	0.051	0.106
Feed and Integrators	0.217	0.214	0.038	0.594
Eggs	0.144	0.032	0.105	0.210
Honey	0.152	0.088	0.034	0.282
Meat	0.074	0.049	0.019	0.139

As shown in figure 1, higher dispute rates were registered in the Feeds and Integrators sector from 1997 to 2000; followed by a sharp decrease of the rates after 2001 and from the years 2004 to 2006, in reference to this sector, which resulted lower in comparison to the others. The meat sector, which gained significance since 2001, reached its highest point in 2003: in this year its dispute rate resulted higher in comparison to the others. In the last three years of our series, the Eggs sector was characterized by the highest dispute.

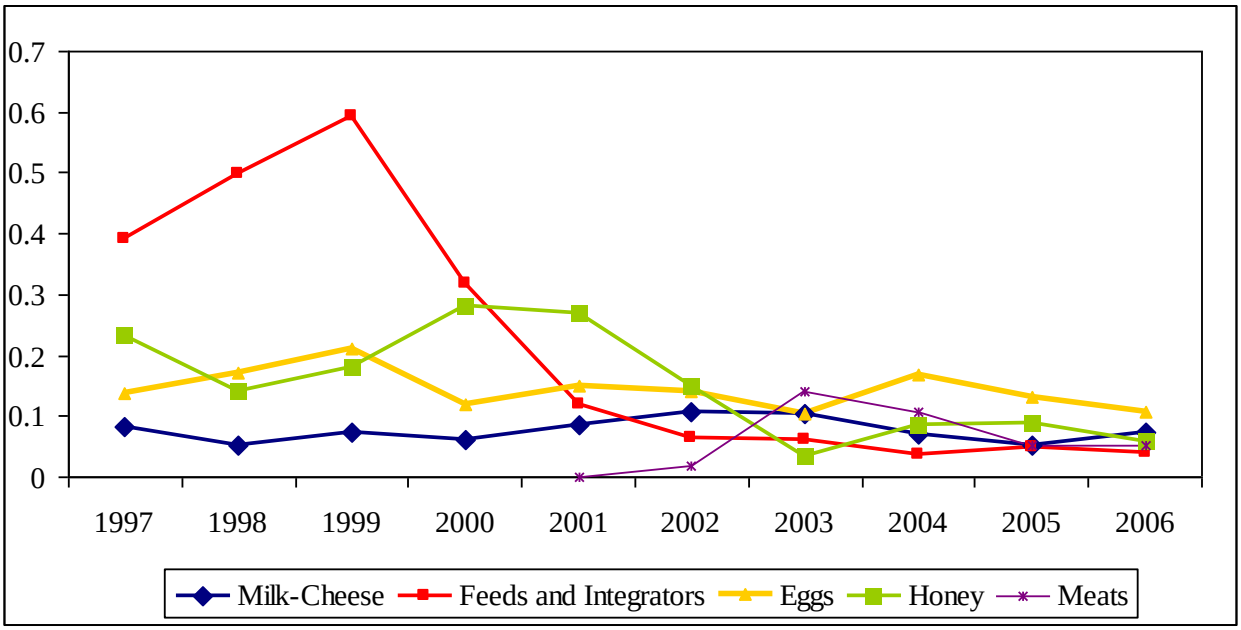

Figure 1. Temporal trend of the dispute rates for market sector.

Finally in terms of significance for the increase or decrease of the temporal trends, we have estimated the Cox and Stuart test, for each of the five examined sectors.

3. Theory and results

3.1 Cox and Stuart test

We applied the non-parametric Cox and Stuart test for the trend [4]; [15], in order to evaluate if there was a possible increase or decrease of the dispute rates which have occurred in the totality of the considered years.

3.1.1 The theoretical basis of the test

The Cox and Stuart test can be applied to a sample of data in temporal succession and it verifies whether a monotonous tendency towards an increase or decrease of the central tendency (or of the variability) exists. The methodological formulation is similar to the test of signs for two dependent samples both in the case of small and large samples.

The method allows to attest whether a significant increase or decrease exists in the data on the whole, and among the initial and final values. This happens even if we are in presence of significant casual or cyclical irregularities and considerable distance from linearity.

The test results non significant if the data show an increase phase and prolonging decrease phase. It is significant only if one of the two phases is statistically prevailing. The validation of the hypotheses concerns the existence of a monotonic regression, that is a systematic variation in increase or decrease, not necessarily linear.

3.1.2 Results

In table 2, we registered the Cox and Stuart results for market sector, in reference to inspection visits, disputes and dispute rates.

Examining the results shown in Table 2, it is clear that in reference to the inspection visits, all trends related to the various sectors were characterized by a significant increase, except for the Meat sector which shows a considerable decrease.
For the disputes, in the Feeds and Integrators and Meat sectors, a significant decrease was registered, while an important increase was observed in the Milk-Cheese sector. Finally, analysing the dispute rates, we can note a significant increase for the Meat sector, while significant decrease was observed for Feeds and Integrators, Eggs and Honey.

Table 2. Cox and Stuart results for market sector.

MARKET SECTOR						
			INSPECTION VISITS			
Milk-cheese	+	+	+	+	+	**0.001**
Feeds and Integrators	+	+	+	+	-	**0.011**
Eggs	-	+	+	+	+	**0.011**
Honey	-	+	+	+	+	**0.011**
Meat	-	-	-	-	-	**0.001**
			DISPUTES			
Milk-cheese	+	+	+	+	+	**0.001**
Feeds and Integrators	-	-	-	-	-	**0.001**
Eggs	-	-	+	+	+	0.055
Honey	-	-	+	+	+	0.055
Meat	-	-	-	-	-	**0.055**
			DISPUTE RATES			
Milk-cheese	+	+	-	-	-	0.055
Feeds and Integrators	-	-	-	-	-	**0.001**
Eggs	+	-	-	+	-	**0.011**
Honey	-	-	-	-	-	**0.001**
Meat	+	+	+	+	-	**0.011**

3.2 NPC test

The low sampling number and the non-normality in the distribution of the considered phenomena don't guarantee valid asymptotic results. So, the analysis was achieved through a non parametric approach, using the Non Parametric Combination (NPC) test based on permutation test [14].

3.2.1 The theoretical basis of NPC test

The NPC test allows to solve a lot of complex problems related to the validation of multidimensional hypotheses. Considering that two or more (k) variables are observed on a set of *n* statistical units, that are grouped in two or more C groups defined by a classification criterion (treatment). The purpose of this analysis is to verify if there are statistically significant differences among the multivariate profiles of answer-variables of the C compared groups.
We presume that an appropriate k-dimensional P distribution (with $P_j \in F$, j=1,..., C) exists; the null hypothesis establishes the equality in distribution of the k-dimensional distribution among the C groups, against the alternative one, where at least one strict inequality is satisfied:

$$H_0 : [X_1 \overset{d}{=} \ldots \overset{d}{=} X_C] \qquad (1)$$

that can be also expressed as :

$$H_0 : [\bigcap_{i=1}^{k} X_{1i} \overset{d}{=} \ldots \overset{d}{=} X_{ci}] = [\bigcap_{i=1}^{k} H_{0i}] \quad (2)$$

against:

$$H_1 : \bigcup_{i=1}^{k} [X_{1i} \overset{d}{\neq} \ldots \overset{d}{\neq} X_{Ci}] = [\bigcup_{i=1}^{k} H_{1i}] \quad (3)$$

By means of the above-mentioned procedure it is preliminarily possible to define a set of k one-dimensional permutation test, named partial test, through which the marginal contribution of every answer-variable can be examined in the comparison among groups. The partial tests are non-parametrically combined through the CMC (Conditional Monte Carlo) procedure in combined tests, using an opportune combination function (generally Fisher, Tippett or Liptak); these tests generally verify the existence of differences among the multivariate distributions of the groups.
If the analysis is stratified, it is possible to determine through only a test that combines the proposed tests by every stratification; it allows the evaluation of the possible differences among the groups in relationship to all examined variables and to all strata.
If the p-value is significant at a prefixed significance level, the null hypothesis has to be rejected.
This procedure allows to verify directional hypotheses, solving the problems of restricted alternative hypotheses.

3.2.2 Results

By means of the above mentioned permutation solution, we want to investigate the existence of possible significant differences among the five market sectors. The null hypothesis, that estimates the indifference among the variables distribution, and the alternative hypothesis can be expressed through the relationships:

$$H_0 : \left\{ Dispute\_rates_{Milk-Cheese} \overset{d}{=} \ldots \overset{d}{=} Dispute\_rates_{Meats} \right\} \quad (4)$$

against:

$$H_1 : \left\{ Dispute\_rates_{Milk-Cheese} \overset{d}{\neq} \ldots \overset{d}{\neq} Dispute\_rates_{Meats} \right\} \quad (5)$$

The comparison among the five market sectors, obtained by the aforesaid methodology, results statistically significant (p=0.042) at the fixed α level (α=5%); and for this reason we opportunely considered to perform the "two by two" comparisons among the sectors, in order to evaluate the possible significant differences among market sector and the remainders.
So, we performed 10 "two by two" comparisons; their p-values and directionality which are shown on Table 3.

The application of permutation tests allows us to establish that the dispute rates in the *Milk-Cheese* sector are statistically inferior in comparison to those recorded in the *Feeds and Integrators*, *Eggs* and *Honey* sectors; particularly the dispute rates of these last two sectors do not result statistically different.

Table 3. Two by two comparisons between market sectors,

COMPARISON	p-value	Directionality.
Milk-cheese vs Feeds and Integrators	**0.037**	<
Milk-cheese vs Eggs	**0.000**	<
Milk-cheese vs Honey	**0.007**	<
Milk-cheese vs Meat	0.529	
Feeds and Integrators vs Eggs	0.306	
Feeds and Integrators vs Honey	0.386	
Feeds and Integrators vs Meat	0.186	
Eggs vs Honey	0.782	
Eggs vs Meat	**0.007**	>
Honey vs Meat	**0.037**	>

3.3 NPC Ranking

This method is based on permutation solution [12] and it is applied to the combination of ranking [1] ; [13].

3.3.1 The theoretical basis of NPC Ranking

Given $X = [X_1, X_2, .., X_k]$, observed on N statistical units, (dataset N×k), we can calculate k partial rankings $R_1, R_2,\ldots, R_k$ [3]. In this context, we assume to formulate a global combined ranking Y, expressed as:

$$Y=\psi(X_1, X_2,\ldots,X_k; w_1, w_2, \ldots, w_k) \qquad (6)$$

It is based on three conditions:

- the functional relationships between variables has to be monotonous;
- for all variables in a single criterion of partial ordering must be established;
- the marginal distribution of each variable must be non-degenerate

The methodology implies the following phases:

1) the transformations of rank Rji (ie, partial lists) are estimated $\{R_{ji}= R(X_{ji}) = \#\ (X_{ji} \geq X_{hi}),\ i= 1,\ldots,k,\ j,h=1,\ldots,N\}$;
2) then the scores are computed by means of $\lambda_{ji} = \frac{R_{ij} + 0.5}{N+1}, i=1,\ldots,k;\ j=1,\ldots,N$;
3) the transformation is calculated $\psi:\{Y_j= \psi\ (\lambda_{j1},\ldots\ \lambda_{jk};w_1,\ldots\ w_k),\ j=1,\ldots,N\}$ based on a real combination function;
4) finally, the global combined ranking is obtained Y: $Y_j=R(Y_j)=\#\ (Y_{ji} \geq Y_h),\ j,h=1,\ldots,N\}$.

3.3.2 Results

The application of the non parametric procedure NPC Ranking has allowed to express a number of partial classifications equal to the number of considered variables (the years) and, also, to obtain a global classification that synthesizes all partial classifications. The Tables 4-6 show the results of NPC Ranking application.

Table 4. Results of classification analysis results through NPC Ranking - Inspection visits.

MARKET SECTORS	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Glob
Milk- Cheese	1	1	1	1	2	1	1	1	1	1	**1**
Feeds and Integr.	3	2	2	2	1	2	2	2	3	3	**2**
Eggs	2	3	3	3	4	3	3	3	4	4	**3**
Honey	4	4	4	4	5	5	4	5	5	5	**5**
Meat	5	5	5	5	3	4	5	4	2	2	**4**

Table 5. Results of classification analysis results through NPC Ranking – Disputes.

MARKET SECTORS	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Glob
Milk- Cheese	2	3	2	2	2	1	1	1	1	1	**1**
Feeds and Integr.	1	1	1	1	1	2	2	3	4	4	**2**
Eggs	3	2	3	4	3	3	3	2	2	2	**3**
Honey	4	4	4	3	4	4	5	5	5	5	**4**
Meat	5	5	5	5	5	5	4	4	3	3	**5**

Table 6. Results of classification analysis results through NPC Ranking – Disputes rates.

MARKET SECTORS	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Glob
Milk-Cheese	4	4	4	4	4	3	3	4	3	2	**4**
Feeds and Integr.	1	1	1	1	3	4	4	5	5	5	**3**
Eggs	3	2	2	3	2	2	2	1	1	1	**1**
Honey	2	3	3	2	1	1	5	3	2	3	**2**
Meat	5	5	5	5	5	5	1	2	4	4	**5**

Examining the global classifications, with reference to inspection visits and disputes, it can be noticed that the Milk-Cheese sector occupies the first place in classification, counting more elevated values; followed by Feeds and Integrators and then, Eggs. The Honey and Meat sectors, that respectively represent for the inspection visits the 4° and the 5° places, exchange their own positions reciprocally in the global classification of the disputes. Examining the dispute rates, a different situation appears: the first place is occupied, in fact, from the Eggs sector, in which the

ratio between disputes and inspection visits globally results more elevated; it is followed by Honey and, then by Feeds and Integrators; the last two places are respectively occupied by the Milk-Cheese and Meat sectors.

4. Final considerations

Our statistical analysis, carried out by the means of a non-parametrical approach, allowed us to reach a global vision of the inspection visits (and of the relative disputes) in order to check the preparation of agribusiness products, controlled by the ICQ on the entire national territory.
The application of the Cox and Stuart test allowed us to assess that for the inspection visits, a significant increase was verified for all trends related to the different sectors, except for the Meat sector that is characterized by a significant decrease.
In reference to the disputes, in the Feeds and Integrators and Meat sectors, a strong decrease has occurred, while a significant increase can be noticed for the Milk-Cheese sector.
Focusing our attention on the dispute rates, we assessed the existence of a significant increase for the Meat sector and a meaningful decrease for Feeds and Integrators, Eggs and Honey.
Comparing the five market sectors, the application of the NPC test allowed us to characterize the existence of some significant differences.
In particular, the dispute rates in the Milk-Cheese sector are statistically lesser than the ones observed in the Feeds and Integrators, Eggs and Honey sectors; the dispute rates of these two last sectors do not result statistically different.
The NPC Ranking allowed us to obtain only a global classification of the production sectors, with reference to inspection visits and disputes: examining the positions of each sector we can notice that the Milk-Cheese sector occupies the first place in classification, because it counts elevated values; on the second place stands the Feeds and Integrators and on the third, the Eggs sector.
The Honey and Meat sectors, that respectively occupy in the inspection visits the fourth and the fifth places, reciprocally exchange their positions in the global classification of the disputes.
Focusing on the dispute rates, a different position can be observed: the Eggs sector is positioned on the first place, followed by Honey and then by Feeds and Integrators; finally, Milk-Cheese and Meat sectors respectively hold the last two places.
The same methodology could be used also when considering other market sectors as a possible future development of the present article. Moreover, the analysis can also be extended to a larger number of years following 2006.

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References

[1]. Arboretti Giancristofaro R., Corain L., (2009). The NPC ranking method with application to the evaluation of educational services and quality of products, in *Multivariate Methods and Models for Evaluating Public Services*. Rimini, 25-26 May 2009, 46 - 47.

[2]. Commissione Europea (2008), *Libro verde sulla qualità dei prodotti agricoli: norme di prodotto, requisiti di produzione e sistemi di qualità*, COM 641, Bruxelles.

[3]. Corain L., Salmaso L., (2007). A nonparametric method for defining a global preference ranking of industrial products. *Journal of Applied Statistics*, 34, 2, 203-216.

[4]. Cox DR, Stuart A. (1955). Some quick tests for trend and dispersion. *Biometrika*, 42, 80-95.

[5]. De Giovanni G. (2004). *Le etichette dei prodotti alimentari*. Edagricole, Bologna

[6]. De Giovanni G. (2010). *Etichettatura degli alimenti*. Tecniche Nuove, Milano.

[7]. Garber L.L.Jr, Hyatt E.M., Starr R.G.Jr. (2003). Measuring consumer response to food products. *Food Quality and Preference*, 14, 3-15.

[8]. Idda L., Furesi R., Pulina P. (2003). Il settore agro-alimentare e le nuove regole della competizione, Quaderni di Economia e Politica Agraria, 1, Sassari, Gallizzi

[9]. ISMEA (2007). *Sistemi di tracciabilità dei prodotti agroalimentari*. ISMEA, Roma.

[10]. Passantino A, Alibrandi A., Coluccio P, Cubeddu G.M, Conte F. (2008). Controllo dei prodotti di origine animale. *Obiettivi e documenti veterinari*. 6, 23-30.

[11]. Peri, C. (2006). The universe of food quality. *Food Quality and Preference*, 17, 3-8.

[12]. Pesarin F., Salmaso L. (2006). Permutation Tests for Univariate and Multivariate Ordered Categorical Data. *Austrian Journal of Statistics*. 35, 2, 315–324.

[13]. Pesarin, F., Lago, A., (1998). Non parametric combination of dependent rankings with application to the quality assessment of industrial products. *Metron*, LVIII, 1-2

[14]. Pesarin, F., (2001). *Multivariate Permutation Test, with application in biostatistics*. Chichester, John Wiley & Sons.

[15]. Soliani L. (2008). *Statistica applicata*. UniNova. Casa Editrice Universitaria, Parma

[16]. Stabird S.S., (2000). Designing food safety regulations: the effect of inspection policy and penalties for non-compliance on food processor behaviour. *Journal of Agricultural and Resource Economics*, 25, 2, 616-635.