\\ 372 \\

Time Series and Data Clustering with Evolutionary Approaches

by

Sandra Paterlini*
Francesco Pattarin**
Tommaso Minerva***

July 2001

Università degli Studi di Modena e Reggio Emilia
Dipartimento di Economia Politica
Viale Berengario, 51
41100 Modena (Italia)
* e-mail: paterlini@unimo.it
** e-mail: pattarin@unino.it
*** e-mail: minerva@unimo.it

Time Series and Data Clustering with Evolutionary Approaches

Sandra Paterlini, Francesco Pattarin, Tommaso Minerva,

Università di Modena e Reggio Emilia
Facoltà di Economia
Viale Berengario 41, 41100 Modena, Italy
paterlini@unimo.it, pattarin@unimo.it, minerva@unimo.it,

Abstract. Clustering methods can extract relevant information from big dataset by determining homogeneous groups. Different evolutionary approaches are proposed as partitional clustering tools both for data and time series. Not only can they converge to the optimal grouping solution but they also give additional information about the characterizing features of each single group and the degree of membership of each object. Moreover, their flexibility has allowed us to validate different aggregating criteria. Results from the analysis of simulated, well known datasets (e.g.: Fisher's Iris) and Italian mutual funds returns series are reported. They support the validity of such evolutionary clustering approaches in defining an alternative way to deal with the classification problem of data and time series.

Key-words. cluster analysis, evolutionary approaches, genetic algorithms, time series and data analysis.

Introduction

Today, the availability of new electronic resources and huge datasets requires the development of new tools capable of extracting the relevant information for supporting decision processes. Data mining can be considered a new broad research field where one of the research aims is to discover patterns and relationships in the data by developing new methodological tools. We propose two new computational algorithms, GAME (*Genetic Algorithms for Medoids Evolution*) and GAPE (*Genetic Algorithms for Parameters Estimation*), to detect similarity among data and to identify the composition of the most homogeneous groups. Cluster analysis principles and evolutionary algorithms are merged together to solve the grouping problem. GAME and GAPE exploit the global convergence and parameter estimation properties of genetic algorithms to determine automatically, through the optimization of clustering criteria, the best number of natural groups, their composition, a relevant point for each group and a measure of the degree of membership of each single observation to a specific group.

GAME uses the genetic encoding to determine a characterizing point, which we call medoid, for each group. Then, the procedure of allocation of each observation to a specific group is inspired to classical k-means partitional algorithm (Forgy 1965). The algorithm works in a deterministic framework where different statistical criteria, directed to minimize the scatter variability *within* the group and/or to maximize the scatter variability *between* the groups, can be used to determine the optimal grouping solution. A measure of the degree of membership of each observation is quantified as inversely proportional to the Euclidean distance with respect to the groups' centroids coordinates.

GAPE exploits genetic algorithms to estimate the parameters of the probabilistic model from which data are supposed to be drawn. The optimal grouping solution is determined in a probabilistic framework through the optimization of the likelihood function. Moreover, GAPE allows to compute membership probabilities for each single observation to a specific group.

The algorithms have been modified to allow an automatic procedure for reducing the dataset size by extracting only the most relevant features for each observation to be considered in solving the grouping problem. Correlated or noise measurements referred to a single object could in fact bias the analysis and the identification of the optimal grouping solution. Furthermore, to consider smaller dataset decreases the computational time required to perform the cluster analysis.

GAME and GAPE have outperformed standard classical partitional algorithms in the analysis of simulated and well-known real datasets (Fisher's Iris dataset). They allow to extract relevant information and to converge to the unique global optimal grouping solution, without falling in local optima as standard cluster algorithms do. The analysis has been extended to consider time series dataset. A sample of 442 Italian mutual funds monthly return series have been considered to show how such approaches could be helpful in extracting significant information both for investors and managers. In fact, the rapid development of the funds industry has shown how an objective, representative and empirically testable classification scheme is highly desired for informative, performance evaluation and forecasting purposes. GAME and GAPE are a possible solution to the mutual fund classification problem. Comparison with the Assogestioni institutional classification shows how a posteriori analysis of the returns series does not always agree with the a priori classification scheme. Return-based style analysis can improve the information offered by the institutional classification scheme.

Genetic Clustering Algorithms

Genetic algorithms are stochastic randomized algorithms driven by the Darwinian evolutionary principle of the survival of the fittest individual of a population. Holland, recognizing the presence of the *building blocks* in the high level structures of objects, proposed in 1975 to look at the evolutionary and innovative processes as an effect of the recombination of objects and schema which characterize the low level structures.

Since then, genetic algorithms have been used successfully in different fields such as biology, finance, statistics, computer science, mathematics. Their capability of exploring the whole search space and their global convergence properties within an elitistic schema (Rudolph 1994) have lead to use them mainly as parameter estimation and optimizing tools.

A genetic algorithm is composed by a population of individuals, where each individual represents the mathematical encoding of a solution of the problem of interest. A single individual is composed by some genes, which can usually assume binary or real allelic values. In order to use them properly and efficiently it is extremely important that the codification adopted is not redundant and could map all the possible solutions. A fitness value, indicating the degree of optimality of the solution mapped by the string, is associated to each individual. The population is then evolved through operators modeled on the biological processes of selection, crossover and mutation to identify the fittest individual of the population. The algorithm stops when the optimality criterion is satisfied. Then, the best individual, that is the one with the highest fitness value, of the last generation identifies the optimal solution.

Different genetic encoding have been already proposed in literature to solve clustering problems. Research has been two-fold: some authors have proposed to use genetic algorithms to tackle directly the clustering problem (Raghavan and Birchand 1979, Bandyopadhyay, Murthy and Pal 1995 1998, Baragona, Calzini and Battaglia 2000) while others have exploit their properties in building hybrid algorithms in order to improve the performance of classical clustering algorithms such as k-means and fuzzy c-means (Babu and Murthy 1994, Khrishna e Murthy 1999, Tseng 2001).

GAME and GAPE use the genetic algorithms to determine some relevant measurements for each single group and then to identify the optimal grouping structure of the data. They differ in the encoding adopted but they use the same evolutionary operators. They assume no a priori information is available. The optimal grouping solution is determined in an unsupervised learning mechanism.

Given a dataset of n objects with p measurements for each object, the aim is to determine the best composition of the g groups in which the dataset could be partitioned.

GAME (*Genetic Algorithms for Medoids Evolution*) chromosome is formed by g groups of p cells, which can assume a real value in the R^p space of measurements. (see Figure 1 Appendix 1). They represent the g medoids coordinates of each single group. The genetic algorithm determines the optimal grouping solution and the coordinates of the medoid of each single group. The first individual of the chromosome is considered. The euclidean distances between each single observation and the g different medoids coordinates, identified by the allelic real values, are computed. Each observation is then attributed to the group whose euclidean distance is minimal among all the g distances computed with respect to the different medoids. Once each observation is allocated to a specific group, a fitness value is computed. The procedure is repeated for each individual. Then, the population is evolved through selection, crossover, mutation and elitist operators, driven by the fitness criteria, until the stopping criterion is satisfied.

Different fitness criteria have been tested. They aim at minimizing a transformation (function) (trace/determinant) of the pooled-*within* groups scatter matrix and/or at maximizing that (trace/determinant) of the *between* group scatter matrix.

If we assume the number of groups is known a priori, the best grouping solution can be determined for each of the fitness criteria reported in the first column of Table 1. The second and the third columns report respectively the admissible data transformations and some properties these criteria have shown.

Fitness Functions	Admissible Transformations	Properties
1. Max tr(B) Min tr(W)	Orthogonal	♦ Work well when there are natural clusters ♦ Tend to create hyper spherical cluster. ♦ Assume implicitly that inside the groups the features have low correlation.
2. Max $tr(BT^{-1})$	Linear not singular	♦ Considers the inter-correlation between the variables
3. Max $tr(BW^{-1})$	Linear not singular	♦ Considers the inter-correlation between the variables.
4. Max |T| / |W|	Linear not singular	♦ Since |T| is constant is equivalent to minimize |W|. ♦ Tends to create groups with strong interconnections between variables. ♦ Assumes implicity that groups have the same covariance structure.

Table 1. Fitness criteria used by GAME algorithm when the number of groups is known a priori (Ricolfi 1992).

If the number of groups is not known a priori, the third and fourth criteria, reported in Table 1 have been modified to include a penalization factor depending on the number of groups. *min(g²det(W)/det(T))* (MC, *Marriott's criterion*, 1982) and *max({tr(B)/(g-1)}/{tr(W)/(n-g)})* (VRC, *Variance Ratio Criterion*, Calinski T., Harabasz J., 1974) have then been used within an iterative approach not only to determine the best grouping solution but also the best number of groups in the dataset. The algorithm stops when the optimal value of the criterion function to be minimized does not decrease when the number of groups increase. Then, the exploration of disjoint solution subspaces where the number of groups is fixed leads to the identification of the optimal number of groups.

GAPE (*Genetic Algorithms for Parameters Estimation*) algorithm introduces the clustering problem in a probabilistic and inferential framework. Data are considered to be realizations of random variables. GAPE codification is directed to estimate the parameters of the fixed-classification model (Bock H.H. 1996) which is supposed to generate the data. This model assumes, for a fixed number of groups g, $(G_1, G_2, .. G_g)$, a known parametric density family $f(.,\theta)$ such that $X_k \sim f(.,\theta_i)$ for all $k \in G_i$, $i=1,..g$ where g is unknown and a parameters vector $\Theta = (\theta_1, \ldots, \theta_g)$. It has been assumed that data are drawn from multivariate normal distributions, which are completely characterized by the vector of the mean values and the covariance matrix. Therefore, GAPE string maps the parameters $\theta_k = (\mu_k, \Sigma_k)$.

The covariance matrix could be factored as $\Sigma_k = \lambda_k D_k A_k D_k^T$, where D_k indicates the orthogonal matrix of the eigenvectors and determines the orientation of the principal components, A_k is a diagonal matrix with elements proportional to the eigenvalues of Σ_k and determines the contours of the density functions and λ_k is a scalar that determines the volume of the ellipsoids (Banfield and Raftery 1993). The genetic codification of the GAPE algorithm allows to estimate the parameters of three different possible structure of the covariance matrix which is assumed to be specified as $\Sigma_{kj} = \lambda_{kj} I$, $k=1,\ldots,g$, $j=1,..p$. In the first case the covariance matrix is constant among the groups and the measurements $(\Sigma = \lambda I)$, in the second case it is constant just among the measurements $(\Sigma_k = \lambda_k I)$ and in the third case each group could have a different variance among the groups and the measurements $(\Sigma_{kj} = \lambda_{kj} I)$ (see Figures 2, 3, 4 Appendix 1).

Each observation is attributed to the group whose respective density value is higher among all the density values computed in correspondence of the different, genetically specified, models underlying each groups. The best grouping solution is then determined by minimizing the following negative form of the log-likelihood of the fixed classification model:

$$F(g,\Theta) = -\sum_{i=1}^{n}\sum_{k=1}^{g} z_{ik} \log(f_{\gamma_i}(x_i \mid \theta_k)) \quad (1)$$

where z_{ik} is equal to one if observation i belongs to group k or zero otherwise and where $\gamma = (\gamma_1, \ldots \gamma_n)$ are labels such that $\gamma_i = k$ if x_i belong to the *k-th* group. After processing each individual, genetic operator are applied to evolve the population to determine the best individual with associated minimum fitness value.

Finally, GAME and GAPE encoding have been modified to select automatically the most relevant $k \le p$ features to be used in determining the optimal grouping solution. p binary cells have been added to each string: if the *i-th* cell $(i=1,\ldots,p)$ contains unitary value the *i-th* feature will be considered in the dataset used in the cluster analysis, otherwise it will be ignored (see Figure 5 Appendix 1). Reducing the size of the dataset allows not only to speed up the convergence of the algorithms but also to consider the possible presence of correlated variables which could mislead the analysis. Hidden structure could also be more easily detected.

Data Evolutionary Clustering

GAME and GAPE algorithms have been tested at first on simulated datasets drawn from multivariate normal distributions with variable location and covariance structure. The analysis has shown that GAME and GAPE are capable of detecting easily and with a high degree of membership the correct belonging of each observation when the dataset has no overlapping clusters. The average error increases when the clusters can overlap. Table 2 shows in the first ten columns the average error on 500 runs of standard partitional algorithms and GAME/GAPE algorithms on ten different dataset generated from multivariate normal with parameters:

$\mu_1=[1,1,1,1]$, $\Sigma_1=I$; $\mu_2=[5,5,5,5]$, $\Sigma_2=2I$; $\mu_3=[9,9,9,9]$, $\Sigma_3=3I$; $\mu_4=[13,13,13,13]$, $\Sigma_4=4I$. Clusters can overlap. The last column reports the average error over the ten datasets. On average, GAME and GAPE algorithms outperform both the classical k-means and the EM algorithm for full and diagonal covariance specification. They have been chosen for comparison since they start, as GAME and GAPE do, with the random choice of groups seeds. It can also be noticed that the average error on some dataset is equal or less than the one determined by the more efficient fuzzy c-means and EM with spherical covariance structure (see for example columns 1, 2 and 3).

	1	2	3	4	5	6	7	8	9	10	Mean Error
GAPE	2.00%	2.50%	1.50%	2.00%	3.50%	2.50%	3.00%	3.50%	2.00%	1.00%	2.35%
GAME MC	1.50%	1.50%	1.50%	7.00%	1.50%	1.50%	1.00%	1.00%	1.50%	1.50%	1.95%
GAME VRC	1.50%	1.50%	1.50%	2.00%	2.50%	0.50%	1.00%	1.00%	2.00%	1.50%	1.50%
K-means	9.41%	10.55%	9.59%	8.86%	2.34%	13.01%	9.88%	9.64%	5.94%	8.46%	4.38%
Fuzzy c-means	2.50%	2.50%	1.50%	4.00%	1.00%	0.50%	1.00%	1.50%	2.00%	1.00%	0.88%
EM-diag	11.17%	11.37%	11.39%	10.00%	1.00%	11.34%	11.32%	8.73%	9.53%	5.14%	4.55%
EM-full	12.22%	13.33%	12.45%	16.74%	1.00%	13.95%	12.44%	10.50%	11.90%	13.93%	5.92%
EM-spherical	2.06%	2.00%	1.50%	2.50%	1.00%	0.55%	1.00%	1.00%	1.50%	1.00%	0.71%

Table 2. Cluster algorithms performance when data are generated from multivariate normal with parameters: $\mu_1=[1,1,1,1]$, $\Sigma_1=I$; $\mu_2=[5,5,5,5]$, $\Sigma_2=2I$; $\mu_3=[9,9,9,9]$, $\Sigma_3=3I$; $\mu_4=[13,13,13,13]$, $\Sigma_4=4I$. The first ten columns report the average errors on 500 runs on 10 different simulated datasets. The last column reports the average errors on the 10 simulated dataset (average on 5000 different runs). Fitness criteria used are reported in italics.

Furthermore, the analysis has shown that parameters estimations determined by the GAPE algorithms are very near to the real values used in generating the data, supporting the validity of the evolutionary approaches not only as optimizing tools but also as estimation tools.

Results from the analysis of real datasets, such as the Fisher's Iris data, common benchmark for validating clustering algorithms, has improved the confidence in such approaches. Table 3 shows a comparison between the GAME and GAPE algorithms for different fitness functions with results reported in the literature and with standard partitional cluster algorithms (k-means, fuzzy c-means, Expectation Maximization). Looking at the first column, it can be noticed that the evolutionary approach correctly identifies all but three items: this is the best result reported up to now. Standard partitional algorithms lead at most to correctly classify all but five items and also, as the second column shows, can easily fall in local minima. Moreover, the number of misclassified items decreases or is equal when automatic data mining is allowed (3rd column). The last two columns report the fitness values associated to the best individual of the genetic algorithms and the ones of the real classification. As it can be noticed comparing the two values, the algorithms determine fitness values smaller than the fitness values associated to the real classification. Therefore, the choice of the fitness function is crucial. Looking at the data, we noticed that the three misclassified

items are more homogeneous with respect to the group they are associated with the GAME algorithms than the real one. Tests about the possible presence of anomalous data or possible errors in collecting the data should be performed to complete the analysis.

Finally, using the MC or the VRC criterions it is also possible to determine the optimal number of groups. The VRC criterion has identified as optimal the number of iris species from which data are collected.

	Minimum number of misclassified items	Average number of misclassified items on 500 runs	Misclassified items with Automatic data-mining	Best Fitness Value	Real Fitness Value
GAME *1/tr(B/W)*	3	3	3	0.029	0.0308
GAME *MC*	3	3	3	0.198357	0.210948
GAME *VRC*	16	16	8	0.001805	0.0021
GAME *trW*	16	16	6	7885.144	8.930
GAPE $\Sigma=\lambda I$	16	24.5	6	1635.6	1693.4
GAPE $\Sigma k=\lambda kI$	15	23.7	4	1626.3	9229.3
GAPE $\Sigma k=\lambda kjI$	6	20.2	6	1547.3	2428
K-means	16	25.954	–	–	–
Fuzzy c-means	16	16	–	–	–
EM-spherical	16	16	–	–	–
EM-diag	9	23.68	–	–	–
EM-full	5	17.232	–	–	–
Friedman, Rubin 1967 *trW*	16	–	–	–	–
Friedman, Rubin 1967 *tr(W/B)*	3	–	–	–	–
Baragona,Calzini, Battaglia 2000 *VRC*	16	–	–	0.0018	0.0021
Baragona,Calzini, Battaglia 2000 *MC*	3	–	–	0.1984	0.210948
Fraley-Raftery 1999 EM	5	–	–	–	–

Table 3. Fisher's Iris data (150x4).Comparison among the evolutionary GAME and GAPE algorithms, the standard partitional algorithms (k-means, fuzzy c-means, Expectation Maximization) and results reported in literature. The minimum number of misclassified items with and without automatic data-mining, the average number of misclassified items, the best fitness values and the fitness values in correspondence of the real classification are reported. (the fitness functions used are reported in italics).

Time Series Evolutionary Clustering

The application of GAME and GAPE to benchmark data sets has ascertained their performance advantage with respect to existing clustering algorithms: our genetic algorithms achieve low misclassification rates and provide reliable estimates of the number of groups and the relevant population parameters.

In this section we present some results from the application of GAME and GAPE to a "real world" problem. As a part of an on going research project on quantitative models for portfolio management decisions, we have tested how our genetic algorithms perform in classifying a sample of Italian mutual funds from their returns time series.

As is common practice in most countries, the Italian association of money managers (Assogestioni) classifies mutual funds on the basis of a periodical screening of their portfolio holdings. Assogestioni's scheme is made of five major categories that are defined according to the type of financial assets a fund is most (or totally) invested in. They are: "Azionari" (Equity), "Obbligazionari" (Fixed Income), "Bilanciati" (Balanced, *i.e.* both equity and fixed income), "Liquidità" (Money Market Assets) and "Flessibili" (which have no asset class limit). This scheme, augmented by its finer partitions by currency or geographical exposure and time to maturity, provides investors with a loose picture of the kind of risks they are likely to bear when investing in a particular fund, but suffers from some drawbacks. First of all, fund managers with very different grades of risk tolerance may end up in the same class, irrespectively of how much their strategies are aggressive or conservative, provided that they invest in the same asset classes. Therefore, a different classification based on the risk vs. return profile of funds may give further useful information to investors. This would also serve the purpose of forming meaningful peer groups within which to compare and benchmark the performances achieved by different money managers. Furthermore, although Assogestioni's monitoring is quite careful, it is not possible to exclude that some managers perform windows dressing in order to boost their track record relatively to direct competitors (*i.e.* those managers whose funds belong to the same category).

Statistical classification procedures based on funds' return history are a low cost solution to these issues. Contrary to portfolio holdings, returns time series can be easily and cheaply gathered and updated on daily basis from public sources and cannot be made up. Two main contributions in this direction have been proposed in the existing literature on mutual fund styles. Sharpe (1992) estimates a linear asset class factor model by regressing fund's returns on those of a set of given market or style indices. The fund's investment policy is determined by looking at the combination of those indices with the highest loadings, which are also commonly used to infer risk and to form peer groups (Lucas and Riepe 1996, Cucurachi 2000). As new returns become available, rolling regression results convey a picture of how the investment strategy changes over time. Brown and Goetzmann (1997) propose a second approach based on clustering time series of monthly returns with the k-means algorithm. Their procedure does not rely on the specification of a factor model and therefore the analyst is not committed to the choice of a set of indices as in Sharpe's regression. Funds clusters are ready to use peer groups and their centroid vectors, which are in fact as many returns time series as there are clusters, can be taken as group benchmarks. Taken as it comes, the k-means output does not provide any clue of what groups are, but auxiliary qualitative information on funds' characteristics (*e.g.* their declared investment objectives) or a second step asset class regression on centroids may be exploited to gain insight.

An obvious limitation of Brown and Goetzmann procedure is that, with classical k-means, there is no way to determine the optimal number of groups for a given data set. GAME and GAPE provide a viable solution to this issue. Also, due to their genetic nature, they are known to converge to global optima, whereas k-means does not. We have run both algorithms on a sample of 442 out of 457 mutual italian funds that were active at the end of year 1995, for which complete five year time series of monthly returns are available on the Datastream™ database. The funds' list has been compiled from the Assogestioni archive. Fifteen funds have been excluded because return data were unavailable although they are still active. According to the Assogestioni classification 186 funds were Azionari, 50 Bilanciati, 7 Flessibili, 17 Liquidità and 182 Obbligazionari at the end of year 2000.

Two different approaches have been followed. The first one consists in describing each fund by its average monthly return and standard deviation, which is taken as a measure for risk. Different normality tests have been performed on each funds series. Table 4 shows that, assuming returns are independently and identically distributed in time, normality is rejected at most in 38.9% of cases at the 5% significance level (20.6% at the 1% significance level). This provides some support to our choice of using the mean and the standard deviation to summarize each time series.

Normality Tests Results

Test procedure	*Normality rejected*	*Significance level* 5%	1%
Bowman-Shenton	*Cases*	118	91
	Percentage	26.7	20.6
D'Agostino-Tietjen	*Cases*	172	83
	Percentage	38.9	18.8
Shapiro-Wilks	*Cases*	138	73
	Percentage	31.2	16.5
Lilliefors	*Cases*	94	37
	Percentage	21.3	8.4
Total number of cases		442	

Table 4. Normality Tests Result for the sample of 442 Italian mutual funds monthly returns series. Period: 31/12/1995-31/12/2000.

Then, the data passed to our algorithms are a matrix of 442 objects with 2 measurements for each object. GAME and GAPE algorithms have been run for the different fitness criteria displayed in Table 1. All the criteria have lead to group data in a similar way. The MC and the VRC criterion identify 5 and 4 optimal groups respectively. In Appendix 2 Table I we report summary statistics for the solutions obtained by using each criterion with the number of groups fixed to five. Moreover, tables in correspondence of different numbers of groups for the MC and VRC criterion are reported (see Appendix 2 Table V and VI).

Table 5 below reports a comparison between the groups composition identified by GAME when the MC criterion is used and the Assogestioni classification at the end of year 2000. The scatter matrix shows how Equity funds are split in three different classes (Table 5, 1st, 3rd, 4th rows), which we may define as "medium return, medium risk", "high return, high risk" and "low return, high risk". Fixed Income Funds, characterized by low return and low risk, are almost all grouped in a single class (Table 5: 5th row) together with the Money Market Funds. Finally, the last group is composed mainly by Balanced funds together with some Fixed Income (Table 5: 2nd row). The Flessibili funds, possibly because of their heterogeneous asset allocation, tend to be put in different groups.

Marriott's Criterion					Groups Mean Values	
Value	Count	Percent	scatter matrix	differences	mean return	mean std.dev
1	109	24.66%	93 11 4 0 1	146	1.360%	4.740%
2	56	12.67%	3 37 1 0 15		1.000%	2.970%
3	60	13.57%	58 1 1 0 0		2.110%	6.950%
4	33	7.47%	32 0 0 0 1		0.350%	6.150%
5	184	41.63%	0 1 1 17 165		0.450%	0.770%

Table 5. GAME mutual funds classification (MC criterion) vs Assogestioni Classification. The dataset is composed by the mean monthly returns and the standard deviations. In the first column the group composition is reported, in the second the scatter matrix between GAME and Assogestioni classification, in the third the total number of funds with different classification w.r.t. Assogestioni scheme and in the fourth and fifth the groups mean values of the returns and of the standard deviations.

Figure 6, reported Appendix 1, shows the scatterplot of the grouping solution identified by the GAME algorithm when the MC criterion is used. Groups are clearly shaped by their risk vs. return profiles, thus providing further information which may be usefully exploited together with Assogestioni's institutional classification. Furthermore, the use of the GAPE algorithm not only allows us to estimate the optimal grouping solution and the parameters of the different distributions from which the data are supposed to be drawn, but also supplies group membership probabilities for each single fund.

The second approach we tested does not pre-process data to reduce the size of the dataset, but considers each time series as an object with *p* measurement, much in the spirit of Brown and Goetzmann (1997). Each measurement corresponds to the monthly return on a specific date. We have used GAME but not GAPE because of the larger computational time required to process the whole dataset with the latter. Tables II, VII and VIII in Appendix 2 display the optimal grouping solutions for different fitness criteria. Table 6 below shows the GAME classification when the Marriott's Criterion is used. As before, Obbligazionari and Flessibili funds are allocated to the

same group (5th row). Bilanciati funds tend to be allocated to the same group but, contrary to the previous results, they are not the majority (1st row). Azionari funds tend to be scattered among four out of the five groups (1st, 2nd, 3rd, 4th rows). Looking at the groups mean values reported in the last column, two groups may still be labelled as "average return, average risk", "high return, high risk", but the previous group "low return, high risk" is now split in two classes containing a smaller number Azionari funds only.

Marriott's Criterion					Groups Mean Values	
Value	Count	Percent	scatter matrix	differences	mean return	mean std.dev
1	177	40.05%	122 47 5 0 3	139	1.200%	4.500%
2	51	11.54%	48 2 1 0 0		2.130%	6.980%
3	14	3.17%	14 0 0 0 0		0.490%	7.120%
4	2	0.45%	2 0 0 0 0		2.110%	8.770%
5	198	44.80%	0 1 1 17 179		0.470%	0.890%

Table 6. GAME mutual funds classification (MC criterion) vs Assogestioni Classification. The dataset is composed by the whole time series. Each series is considered as an object with *p* measurements. In the first column the group composition is reported, in the second the scatter matrix between GAME and Assogestioni classification, in the third the total number of funds with different classification w.r.t. Assogestioni scheme and in the fourth and fifth the groups mean values of the returns and of the standard deviations.

Table 7, in the next page, compares the optimal grouping solutions determined by the two approaches through the GAME algorithm with the MC criterion. 92 funds are allocated in a different way. We notice that the second approach, who aims at determining the optimal grouping solution through the analysis of the whole time series data, leads to identify classes which contain more correlated time series. (see Appendix 1, Figures 7 and 8). Table III in Appendix 2 show the comparison between the two approaches optimal grouping solutions when different fitness criteria are used.

Figure 8 in Appendix 1 shows that the return time series of funds which are allocated in the same classes, especially the ones allocated to group 2, 3 and 4, have almost synchronous behaviours and the same turning points over time. Comparison with Figure 7, which shows the time series plot for the GAME solution with the first approach, suggests that within group correlations are higher when the whole time series are clustered, as should be expected. Thus, although more time consuming, the second approach is desirable when one is interested in the diversification benefit that can be achieved by investing in funds from different groups.

GAME optimal grouping using the dataset composed by mean and standard deviation of the monthly returns			Scatter matrix between the optimal grouping solutions determined by using different datasets		GAME optimal grouping using the whole dataset. Consider each serie as an object with T features.		
Marriott Criterion			scatter matrix	differences	Marriott Criterion		
Value	Count	Percent			Value	Count	Percent
1	109	24.66%	105 3 1 0 0	92	1	177	40.05%
2	60	13.57%	10 48 0 2 0		2	51	11.54%
3	33	7.47%	19 0 13 0 1		3	14	3.17%
4	56	12.67%	43 0 0 0 13		4	2	0.45%
5	184	41.63%	0 0 0 0 184		5	198	44.80%

Table 7. Comparison between the optimal grouping solutions identified by the GAME algorithm in correspondence of Marriott's Criterion. The first column shows the optimal grouping composition when the monthly return mean values and standard deviations are used as dataset. The third column shows the group composition when the whole returns time series are used as dataset The second column shows the scatter matrix between the two optimal grouping solutions determined by GAME.

Conclusions

Two evolutionary clustering algorithms have been proposed to extract information from data by determining the presence and the composition of homogeneous groups. The analysis of simulated and real dataset has shown how they can outperform standard classical partitional clustering algorithms by converging to the global optimal grouping solution. The analyses of time series data of a sample of Italian mutual funds supports their usefulness for increasing the information available to investors and managers and supporting their investment decisions. By comparing our results with the institutional classification we show that while for some funds, such as the Obbligazionari and Flessibili, there is substantial agreement, for the Azionari the analysis of the returns time series detects partitions of funds with different characteristics that are pooled together by the latter. Therefore, we believe that our approach can improve the information offered by the institutional classification scheme. Further research aims at characterizing the peer groups identified by the clustering algorithms by asset class models as in Sharpe (1992). Also, other clustering criteria based on correlation coefficients between time series (Bohte, Cepar and Kosmelj 1988) should be tested. Finally, the improvement in computational efficiency that might be achieved by dimensional reduction algorithms for similarity search of time series databases through discrete Fourier transforms and wavelets (Huhtala, Karkkainen, Toivonen 1999, Keogh, Chakrabarti and Pazzani 2000, Povinelli and Feng. 1998) are worth considering.

References

AA.VV., "La classificazione dei Fondi Comuni di Investimento", Assogestioni, *Quaderni di documentazione Ricerca*, n. 19, Roma 1998.

Babu G.P. e Murthy M.N., "Clustering with Evolution Strategies", *Pattern Recognition*, V.27, No2., pp.321-329, 1994.

Bandyopadhyay S., Murthy C.A., Pal S.K., "Pattern classification using genetic algorithm: Determination of H", *Pattern Recognition Letters* 19, pp.1171-1181, 1998.

Bandyopadhyay S., Murthy C.A., Pal S.K., "Pattern classification using genetic algorithm: Determination of H", *Pattern Recognition Letters* 19,1171-1181, 1998.

Banfield J.D:, Raftery A.E., "Model-Based Gaussian and Non-Gaussian Clustering", *Biometrics* 49, 803-821, September 1993.

Baragona R., Calzini C., Battaglia F., "Genetic algorithms and clustering: an application to Fisher's iris data", *Advances in Classification and Data Analysis*, Springer, pp.65-68, 1999.

Bock H.H., Probabilistic models in cluster analysis, *Computational Statistics & Data Analysis* 23, pp.5-28, 1996.

Bohte Z., Cepar D., Kosmelj K., "Clustering of time series", in COMPSTAT, Physica-Verlag, pp.587-593, 1988

Brown S.J., Goetzmann W.N., "Mutual Fund Styles", *Journal of Financial Economics*, pp. 373-399, vol. 43, 1997

Calinski T., Harabasz J., "A dendrite method for cluster analysis", *Communication in Statistics*, 3(1), pp.1-27, 1974.

Cucurachi P.A., "I peer groups nella valutazione della performance dei fondi comuni di investimento azionari", *Economia&Management*, n.1, Gennaio 2000.

Forgy E.W., "Cluster Analysis of Multivariate Data: Efficiency versus Interpretability of classification", *Biometrics*, 21, 768-9, 1965.

Fraley C., Raftery A.E., "MCLUST:software for model-based cluster and discriminant analysis", *Journal of Classification*, 16, 297-306, 1999.

Friedman H.P. and Rubin J., "On some invariant criterion for grouping data", *Journal of the American Statistical Association* 63, 1159-1178, 1967.

Keogh E.J., Chakrabarti K., Pazzani M.J., "Dimensionality Reduction for Fast Similarity Search in Large Time Series Databases", *Knowledge and Information Systems Journal*, vol 1, 2000.

Kim Y. ,Street W.N., and Menczer F. Feature selection in unsupervised learning via evolutionary search, in Proceedings of the Sixth ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD-00), pages 365-369, 2000.

Krishna K. e Murthy M.N., "Genetic k-means algorithm", *IEEE Transactions on System, Man, Cybernetics*, vol.29, No.3, June 1999.

Holland J.H., *Adaptation in Natural and Artificial Systems*, University of Michigan Press, Ann Harbor, 1975.

Huhtala Y., Karkkainen J., Toivonen H., "Mining for similarities in aligned time series using wavelets", in *Proceedings of SPIE*, 1999

Liu G.L., *Introduction to combinatorial mathematics*, McGraw Hill, 1968.

Lucas L., Riepe M.W., "The Role of Returns-Based Style Analysis: Understanding, Implementing and Interpreting the technique", Ibbotson Associates, Working Paper, 1996.

Marriott F.H.C., "Optimization methods of cluster analysis", *Biometrics*, 69, 2, pp.417-422, 1982.

Paterlini S:, Favaro S., Minerva T., "Genetic approaches for data clustering", *Book of Short Paper, CLADAG 2001*, Palermo 5-6 Luglio 2001.

Paterlini S., Minerva T., "Evolutionary Cluster Analysis", Quaderno del Dipartimento di Economia Politica n.370, Università di Modena e Reggio Emilia, 2001.
Povinelli R.J. and Feng.X., "Temporal Pattern Identification of Time Series Data using Pattern Wavelets and Genetic Algorithms" in *Artificial Neural Networks in Engineering, Proceedings*, pp.691-696, 1998
Raghavan V.V., Birchand K., " A clustering strategy based on a formalism of the reproductive process in a natural system", *in Proceedings of the Second International Conference on Information Storage and Retrieval*, 10-22, 1979.
Raymer M.L. et AAVV, "Dimensionality Reduction using Genetic Algorithms", *IEEE Transaction on Evolutionary Computation.*
Ricolfi L., HELGA *Nuovi principi di analisi dei gruppi*, FrancoAngeli s.r.l., Milano, Italy,1992.
Rudolph G., "Convergence analysis of canonical genetic algorithm", *IEEE Transactions on Neural Network*, 5(1):96-101,January 1994.
Sharpe W.F., "Asset Allocation: Management Style and Performance measurement", *The Journal of Portfolio Management*, pp.7-19, Winter 1992.
Srikanth R., George R., Warsi N., Prabhu D., Petry F.E., Buckles B.P., "A variable-length genetic algorithm for clustering and classification", *Pattern Recognition Letters* 16, 789-800, 16, 1995.
Tseng Y.L. e Yang S.B., "A genetic approach to the automatic clustering problem" , *Pattern Recognition*, Vol.34 (2), pp.415-424 (2001).

Appendix 1 – Genetic codification

GAME genetic codification

m_{11}	m_{12}	m_{13}	m_{14}	m_{21}	m_{22}	m_{23}	m_{24}	m_{31}	m_{32}	m_{33}	m_{134}
Group 1				**Group 2**				**Group 3**			

Fig. 1. Code of a single individual in GAME algorithm

GAPE genetic codification

μ_{11}	μ_{12}	μ_{13}	μ_{14}	μ_{21}	μ_{22}	μ_{23}	μ_{24}	μ_{31}	μ_{32}	μ_{13}	μ_{34}	λ
Group 1				Group 2				Group 3				Group 1,2,3

Fig. 2. Code of a single individual in GAPE with constant covariance matrix $\Sigma=\lambda I$, when g=3, p=4.

μ_{11}	μ_{12}	μ_{13}	μ_{14}	μ_{21}	μ_{22}	μ_{23}	μ_{24}	μ_{31}	μ_{32}	μ_{13}	μ_{34}	λ_1	λ_2	λ_3
Group 1				**Group 2**				**Group 3**				**Group 1**	**Group 2**	**Group 3**

Fig. 3. Code of a single individual in GAPE with covariance matrix $\Sigma_k=\lambda_k I$ for k=1,…,g. when g=3, p=4.

μ_{11}	μ_{12}	μ_{13}	μ_{14}	μ_{21}	μ_{22}	μ_{23}	μ_{24}	μ_{31}	μ_{32}	μ_{13}	μ_{34}	λ_{11}	λ_{12}	λ_{13}	λ_{14}	λ_{21}	λ_{22}	λ_{23}	λ_{24}	λ_{31}	λ_{32}	λ_{33}	λ_{34}
Group 1				Group 2				Group 3				Group 1				Group 2				Group 3			

Fig. 4. Code of a single individual in GAPE with covariance matrix $\Sigma_{kj}=\lambda_{kj} I$ for k=1,…,g, j=1,..p, when g=3, p=4.

Evolutionary Automatic Data Mining

1	0	1	0	GAME \ GAPEchromosome
1	2	3	4	

Fig. 5. Automatic data-mining when p=4. The first and the third features compose the dataset in correspondence of which to determine the best grouping solution.

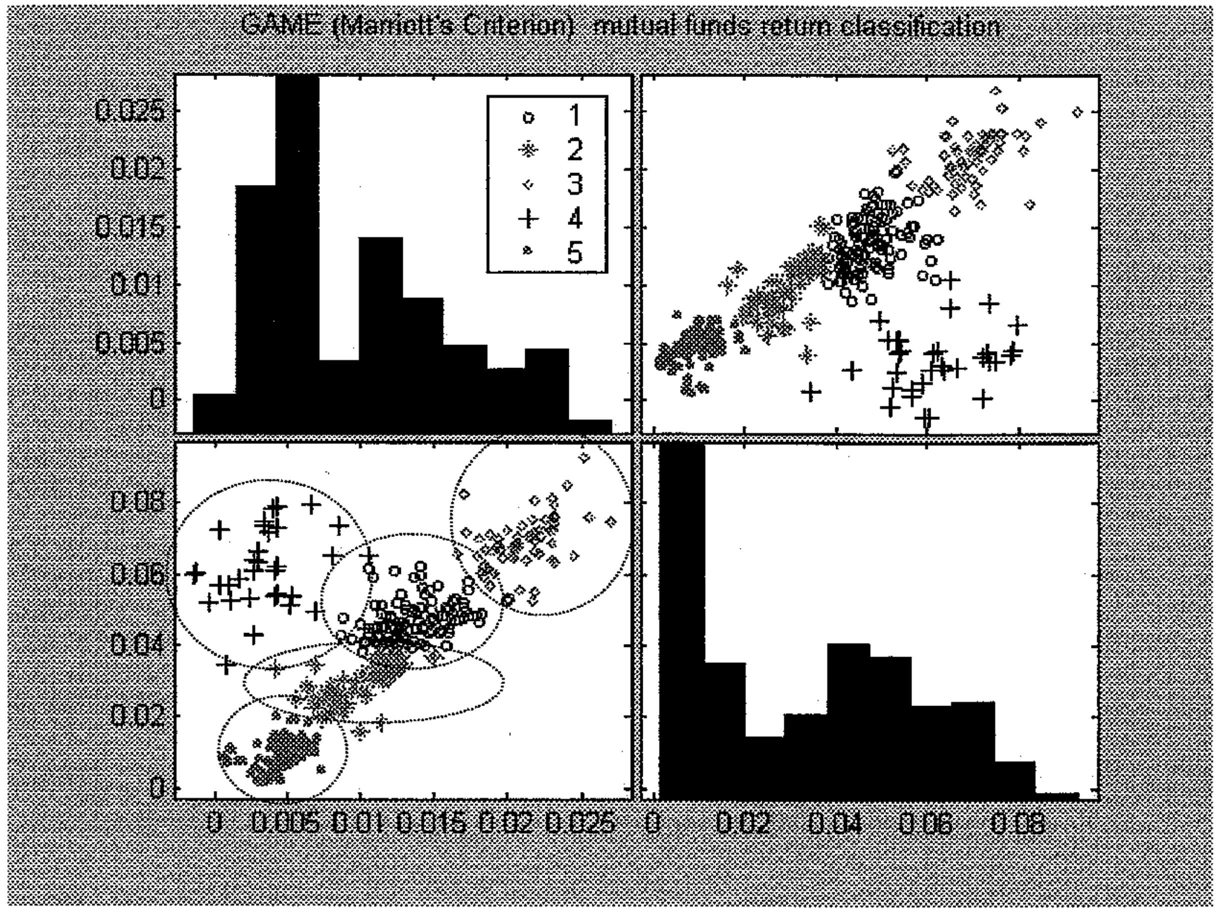

Fig. 6. Scatterplot matrix of the return mean and standard deviation. Different colours identify the different groups composition identified by the GAME algorithm in correspondence of the Marriott's Criterion.

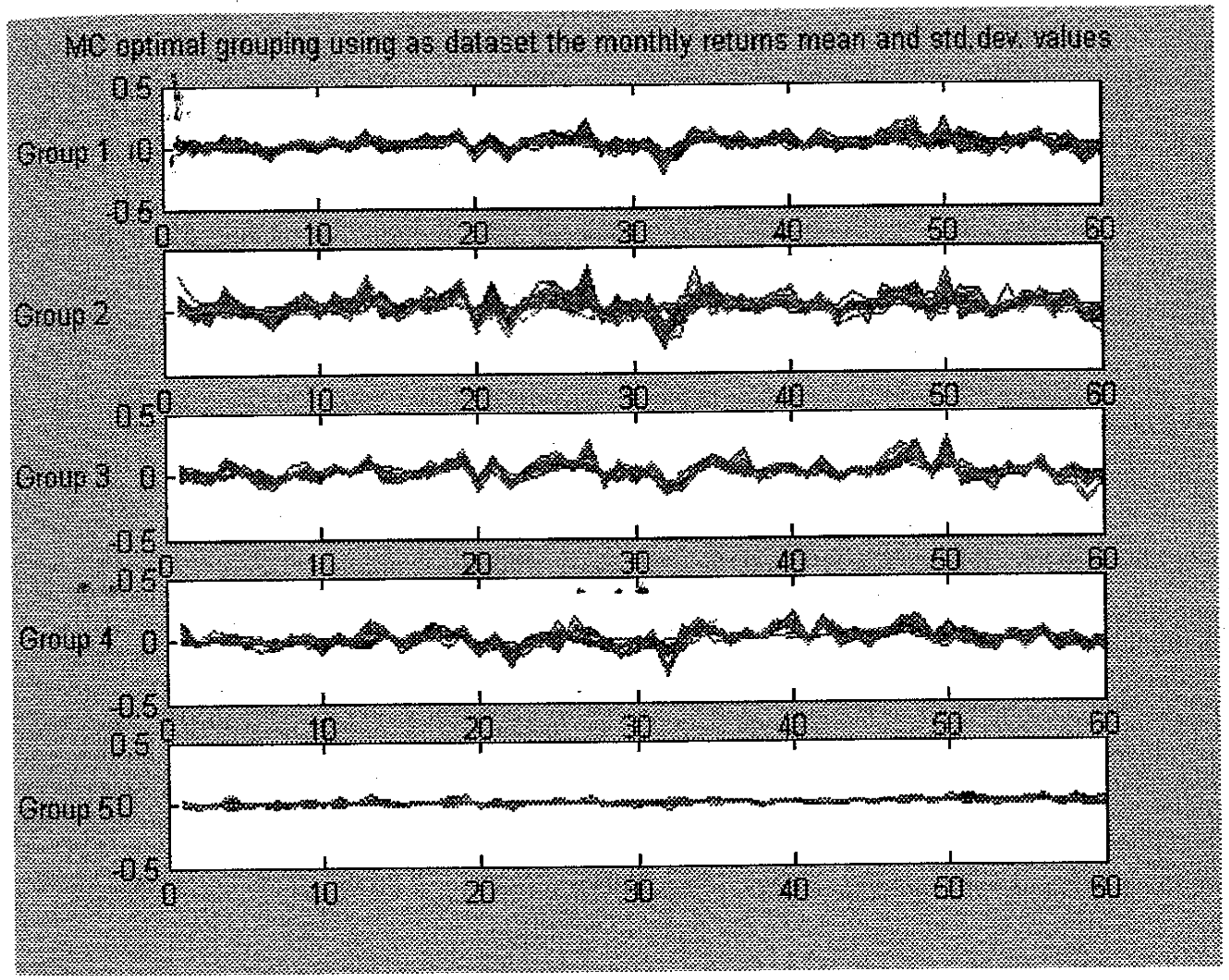

Fig. 7. Monthly return series from 31/12/95 to 31/12/00. Series are grouped by the GAME algorithm (MC criterion). The dataset used in determining the optimal grouping solution is composed by the monthly return mean and standard deviation values on the whole period.

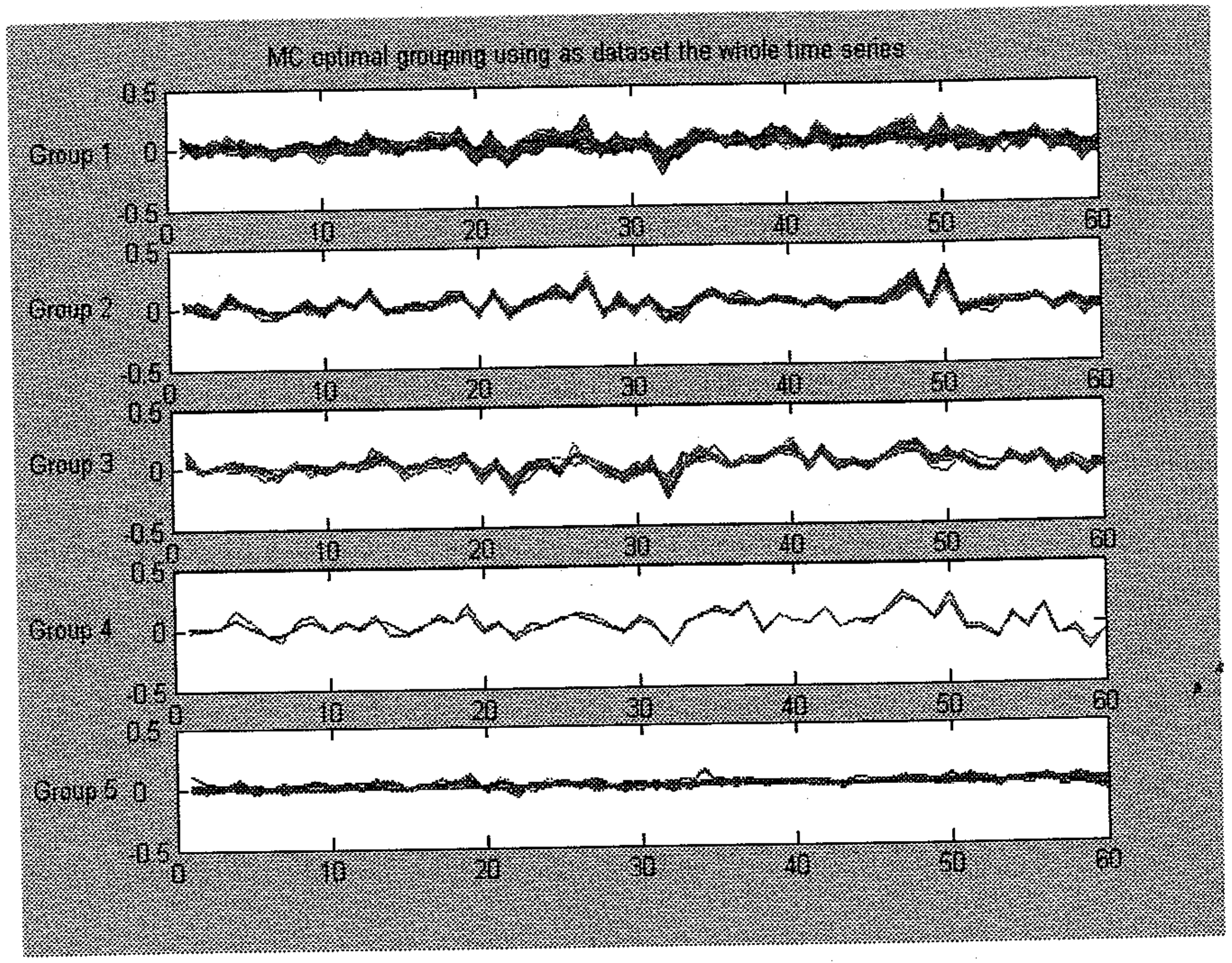

Fig. 8. Monthly return series from 31/12/95 to 31/12/00. Series are grouped by the GAME algorithm (MC criterion). The dataset used in determining the optimal grouping solution is composed by the whole time series dataset. Each series is considered as on object with p measurements, corresponding to the monthly return for each data.

APPENDIX 2

The sample is composed by the monthly returns time series of 442 Italian mutual funds from 12/95 up to 12/00. Comparison between Assogestioni Classification and Evolutionary algorithms classification are proposed.

Assogestioni Classification of the sample (31/12/2000)					Groups Mean Values	
Value	Count	Percent	Tipologia Fondi	Sigla	mean return	mean std.dev
AZ	186	42.08%	AZIONARI	AZ	1.420%	5.660%
BI	50	11.31%	BILANCIATI	BI	1.170%	3.530%
FL	7	1.58%	FLESSIBILI	FL	1.250%	4.470%
LI	17	3.85%	LIQUIDITA'	LI	0.350%	0.290%
OB	182	41.18%	OBBLIGAZIONARI	OB	0.490%	0.980%

Results from GAME algorithm in correspondence of the different fitness criteria reported in Table 1
The dataset is composed by the mean and the standard deviation of the mutual funds time series returns
The number of groups has been fixed equal to 5.

1st column: groups composition

2nd column: Scatter matrix between GAME and Assogestioni classifications

3rd column: total number of funds with different classification w.r.t.Assogestioni scheme

4th-5th columns: group mean value of the returns and of the standard deviation

MC									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	109	24.66%	93	11	4	0	1	146	1.360%	4.740%
2	56	12.67%	3	37	1	0	15		1.000%	2.970%
3	60	13.57%	58	1	1	0	0		2.110%	6.950%
4	33	7.47%	32	0	0	0	1		0.350%	6.150%
5	184	41.63%	0	1	1	17	165		0.450%	0.770%

VRC									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	108	24.43%	94	10	3	0	1	142	1.370%	4.710%
2	59	13.35%	3	39	2	0	15		0.980%	3.020%
3	56	12.67%	54	1	1	0	0		2.120%	7.060%
4	35	7.92%	35	0	0	0	0		0.500%	6.320%
5	184	41.63%	0	0	1	17	166		0.450%	0.770%

trW									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	108	24.43%	94	10	3	0	1	142	1.370%	4.710%
2	59	13.35%	3	39	2	0	15		0.980%	3.020%
3	56	12.67%	54	1	1	0	0		2.120%	7.060%
4	35	7.92%	35	0	0	0	0		0.500%	6.320%
5	184	41.63%	0	0	1	17	166		0.450%	0.770%

trBonW									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	77	17.42%	69	5	2	0	1	188	1.250%	5.420%
2	80	18.10%	56	22	2	0	0		1.200%	4.180%
3	43	9.73%	1	22	1	0	19		0.840%	2.640%
4	62	14.03%	60	1	1	0	0		1.880%	7.170%
5	180	40.72%	0	0	1	17	162		0.440%	0.750%

trBonT									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	61	13.80%	58	2	1	0	0	170	2.120%	6.840%
2	84	19.00%	48	33	2	0	1		1.370%	4.130%
3	58	13.12%	50	3	3	0	2		1.190%	4.980%
4	31	7.01%	30	0	0	0	1		0.310%	6.180%
5	208	47.06%	0	12	1	17	178		0.490%	0.960%

Appendix 2 - TABLE I

Results from GAME algorithm using as dataset the whole mutual funds time series returns
Each time serie has been considered as a single object with T features.
T=number of dates from 12/95 up to 12/00.

The number of groups has been fixed equal to 5.
1st column: groups composition
2nd column: Scatter matrix between GAME and Assogestioni classifications
3rd column: total number of funds with different classification w.r.t.Assogestioni scheme
4th-5th columns: group mean value of the returns and of the standard deviation

MC									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	177	40.05%	122	47	5	0	3	139	1.200%	4.500%
2	51	11.54%	48	2	1	0	0		2.130%	6.980%
3	14	3.17%	14	0	0	0	0		0.490%	7.120%
4	2	0.45%	2	0	0	0	0		2.110%	8.770%
5	198	44.80%	0	1	1	17	179		0.470%	0.890%

VRC									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	140	31.67%	92	41	4	0	3	163	1.280%	4.210%
2	66	14.93%	56	8	2	0	0		2.010%	6.650%
3	18	4.07%	18	0	0	0	0		0.810%	7.090%
4	20	4.52%	20	0	0	0	0		0.320%	5.680%
5	198	44.80%	0	1	1	17	179		0.470%	0.890%

trW									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	146	33.03%	97	42	4	0	3	159	1.290%	4.270%
2	63	14.25%	54	7	2	0	0		2.020%	6.700%
3	21	4.75%	21	0	0	0	0		0.490%	5.920%
4	14	3.17%	14	0	0	0	0		0.490%	7.120%
5	198	44.80%	0	1	1	17	179		0.470%	0.890%

trBonW									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	146	33.03%	92	47	4	0	3	168	1.280%	4.230%
2	62	14.03%	57	3	2	0	0		2.060%	6.890%
3	12	2.71%	12	0	0	0	0		0.640%	7.020%
4	22	4.98%	22	0	0	0	0		0.320%	5.780%
5	200	45.25%	3	0	1	17	179		0.480%	0.940%

trBonT									Groups Mean Values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev
1	120	27.15%	107	10	1	0	2	126	1.170%	4.710%
2	92	20.81%	59	29	4	0	0		1.790%	5.800%
3	14	3.17%	14	0	0	0	0		0.430%	7.120%
4	2	0.45%	2	0	0	0	0		2.110%	8.770%
5	214	48.42%	4	11	2	17	180		0.510%	1.070%

Appendix 2 - TABLE II

GAME optimal grouping using the dataset composed by mean and standard deviation of the monthly returns

MC			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	109	24.66%	1.360%	4.740%
2	60	13.57%	2.110%	6.950%
3	33	7.47%	0.350%	6.150%
4	56	12.67%	1.000%	2.970%
5	184	41.63%	0.450%	0.770%

VRC			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	108	24.43%	1.370%	4.710%
2	56	12.67%	2.120%	7.060%
3	59	13.35%	0.980%	3.020%
4	35	7.92%	0.500%	6.320%
5	184	41.63%	0.450%	0.770%

trW			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	108	24.43%	1.370%	4.710%
2	56	12.67%	2.120%	7.060%
3	59	13.35%	0.980%	3.020%
4	35	7.92%	0.500%	6.320%
5	184	41.63%	0.450%	0.770%

trBonW			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	80	18.10%	1.200%	4.180%
2	77	17.42%	1.250%	5.420%
3	43	9.73%	0.840%	2.640%
4	62	14.03%	1.880%	7.170%
5	180	40.72%	0.440%	0.750%

trBonT			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	84	19.00%	1.370%	4.130%
2	61	13.80%	2.120%	6.840%
3	31	7.01%	0.310%	6.180%
4	58	13.12%	1.190%	4.980%
5	208	47.06%	0.490%	0.960%

Scatter matrix between the optimal grouping solutions determined by using different datasets

scatter matrix					differences
105	3	1	0	0	92
10	48	0	2	0	
19	0	13	0	1	
43	0	0	0	13	
0	0	0	0	184	

scatter matrix					differences
93	12	1	2	0	94
1	53	2	0	0	
45	0	0	0	14	
1	1	15	18	0	
0	0	0	0	184	

scatter matrix					differences
96	10	2	0	0	92
1	53	2	0	0	
4	0	17	14	0	
45	0	0	0	14	
0	0	0	0	184	

scatter matrix					differences
73	1	0	3	3	118
0	53	8	1	0	
27	0	0	0	16	
46	8	4	18	1	
0	0	0	0	180	

scatter matrix					differences
47	30	0	0	7	124
6	54	0	1	0	
17	0	13	0	1	
45	8	1	1	3	
5	0	0	0	203	

GAME optimal grouping using the whole dataset. Consider each serie as an object with T features.

MC			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	177	40.05%	1.200%	4.500%
2	51	11.54%	2.130%	6.980%
3	14	3.17%	0.490%	7.120%
4	2	0.45%	2.110%	8.770%
5	198	44.80%	0.470%	0.890%

VRC			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	140	31.67%	1.280%	4.210%
2	66	14.93%	2.010%	6.650%
3	18	4.07%	0.810%	7.090%
4	20	4.52%	0.320%	5.680%
5	198	44.80%	0.470%	0.890%

trW			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	146	33.03%	1.290%	4.270%
2	63	14.25%	2.020%	6.700%
3	21	4.75%	0.490%	5.920%
4	14	3.17%	0.490%	7.120%
5	198	44.80%	0.470%	0.890%

trBonW			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	146	33.03%	1.280%	4.230%
2	62	14.03%	2.060%	6.890%
3	12	2.71%	0.640%	7.020%
4	22	4.98%	0.320%	5.780%
5	200	45.25%	0.480%	0.940%

trBonT			Groups Mean Values	
Value	Count	Percent	mean return	mean std.dev
1	120	27.15%	1.170%	4.710%
2	92	20.81%	1.790%	5.800%
3	14	3.17%	0.430%	7.120%
4	2	0.45%	2.110%	8.770%
5	214	48.42%	0.510%	1.070%

Appendix 2 - TABLE III

Results from GAPE algorithm
The dataset is composed by the mean and the standard deviation of the mutual funds time series returns

The number of groups has been fixed equal to 5.
1st column: groups composition
2nd column: Scatter matrix between GAME and Assogestioni classifications
3rd column: total number of funds with different classification w.r.t.Assogestioni scheme
4th-5th columns: group mean value of the returns and of the standard deviation
6th-7th columns: estimated group mean value of the returns and of the standard deviation by GAPE

sigma=lambda*I									Groups Mean Values		GAPE Estimated values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev	mean return	mean std.dev
1	109	24.66%	94	10	4	0	1	144	1.370%	4.700%	1.270%	4.690%
2	60	13.57%	3	39	1	0	17		0.960%	2.970%	0.910%	2.960%
3	57	12.90%	55	1	1	0	0		2.090%	7.070%	1.980%	7.050%
4	34	7.69%	34	0	0	0	0		0.490%	6.280%	0.480%	6.270%
5	182	41.18%	0	0	1	17	164		0.450%	0.760%	0.440%	0.740%

sigma(k)=lambda(k)*I,k=1,...,n.groups									Groups Mean Values		GAPE Estimated values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev	mean return	mean std.dev
1	116	26.24%	101	10	4	0	1	137	1.310%	4.740%	1.270%	4.760%
2	60	13.57%	3	39	1	0	17		0.960%	2.970%	0.890%	2.960%
3	56	12.67%	54	1	1	0	0		2.120%	7.060%	1.980%	6.980%
4	28	6.33%	28	0	0	0	0		0.540%	6.570%	0.570%	6.620%
5	182	41.18%	0	0	1	17	164		0.450%	0.760%	0.440%	0.740%

sigma(k)=lamda(kj)*I, k=1,...,n.groups, j=1,...n.features									Groups Mean Values		GAPE Estimated values	
Value	Count	Percent	scatter matrix					differences	mean return	mean std.dev	mean return	mean std.dev
1	61	13.80%	104	10	3	0	1	134	1.310%	4.780%	1.270%	4.760%
2	57	12.90%	3	39	2	0	17		0.970%	2.980%	0.910%	3.040%
3	182	41.18%	55	1	1	0	0		2.100%	7.040%	2.090%	7.050%
4	24	5.43%	24	0	0	0	0		0.420%	6.670%	0.420%	7.050%
5	118	26.70%	0	0	1	17	164		0.450%	0.760%	0.440%	0.740%

Appendix 2 - TABLE IV

Results from GAME algorithm in correspondence of the Marriott's criterion
The dataset is composed by the mean and the standard deviation of the mutual funds time series returns
The iterative procedure has determined the optimal number of groups equal to 5.

	Marriott's Criterion								
Number of Groups	2	3	4	5	6	7	8	9	10
Best Fitness Value	0.8004	0.4126	0.2985	0.2792	0.3398	0.34	0.3316	0.3308	0.3241

1st column: Number of groups
2nd column: Groups composition
3rd-4th columns: group mean value of the monthly returns and of the standard deviation of the monthly returns

Number of Groups				Groups Mean Values	
2	Value	Count	Percent	mean return	mean std.dev
	1	226	51.13%	1.400%	5.400%
	2	216	48.87%	0.500%	1.040%
				Groups Mean Values	
3	Value	Count	Percent	mean return	mean std.dev
	1	194	43.89%	1.570%	5.240%
	2	214	48.42%	0.500%	1.020%
	3	34	7.69%	0.370%	6.150%
				Groups Mean Values	
4	Value	Count	Percent	mean return	mean std.dev
	1	143	32.35%	1.290%	4.290%
	2	63	14.25%	2.070%	6.920%
	3	35	7.92%	0.390%	6.140%
	4	201	45.48%	0.480%	0.900%
				Groups Mean Values	
5	Value	Count	Percent	mean return	mean std.dev
	1	109	24.66%	1.360%	4.740%
	2	56	12.67%	1.000%	2.970%
	3	60	13.57%	2.110%	6.950%
	4	33	7.47%	0.350%	6.150%
	5	184	41.63%	0.450%	0.770%
				Groups Mean Values	
6	Value	Count	Percent	mean return	mean std.dev
	1	109	24.66%	1.390%	4.710%
	2	58	13.12%	0.980%	2.940%
	3	57	12.90%	2.100%	7.040%
	4	16	3.62%	0.450%	5.290%
	5	182	41.18%	0.450%	0.760%
	6	20	4.52%	0.380%	6.820%
				Groups Mean Values	
7	Value	Count	Percent	mean return	mean std.dev
	1	83	18.78%	1.260%	4.180%
	2	42	9.50%	0.830%	2.620%
	3	53	11.99%	1.580%	5.340%
	4	23	5.20%	0.360%	5.710%
	5	180	40.72%	0.440%	0.750%
	6	51	11.54%	2.140%	7.150%
	7	10	2.26%	0.410%	7.430%
				Groups Mean Values	
8	Value	Count	Percent	mean return	mean std.dev
	1	64	14.48%	1.540%	5.260%
	2	75	16.97%	1.250%	4.080%
	3	51	11.54%	2.140%	7.150%
	4	97	21.95%	0.380%	0.440%
	5	88	19.91%	0.530%	1.160%
	6	20	4.52%	0.270%	5.610%
	7	35	7.92%	0.840%	2.690%
	8	12	2.71%	0.500%	7.280%
				Groups Mean Values	
9	Value	Count	Percent	mean return	mean std.dev
	1	56	12.67%	1.500%	4.870%
	2	60	13.57%	1.200%	4.040%
	3	38	8.60%	0.870%	2.740%
	4	98	22.17%	0.380%	0.440%
	5	87	19.68%	0.530%	1.160%
	6	17	3.85%	0.260%	5.480%
	7	14	3.17%	0.420%	7.130%
	8	23	5.20%	1.600%	5.960%
	9	49	11.09%	2.160%	7.180%
				Groups Mean Values	
10	Value	Count	Percent	mean return	mean std.dev
	1	54	12.22%	1.210%	4.570%
	2	40	9.05%	1.220%	3.610%
	3	20	4.52%	1.520%	6.010%
	4	86	19.46%	0.400%	0.390%
	5	95	21.49%	0.490%	1.080%
	6	35	7.92%	1.690%	4.940%
	7	18	4.07%	0.350%	6.890%
	8	14	3.17%	0.290%	5.170%
	9	31	7.01%	0.780%	2.460%
	10	49	11.09%	2.160%	7.180%

Appendix 2 - TABLE V

Results from GAME algorithm in correspondence of the Marriott's criterion
The dataset is composed by the mean and the standard deviation of the mutual funds time series returns
The iterative procedure has determined the optimal number of groups equal to 4.

Variance Ratio Criterion									
Number of Groups	2	3	4	5	6	7	8	9	10
Best Fitness Value	0.00064	0.000514	**0.0005054**	0.000507	0.000515	0.000494	0.000483	0.000448	0.000426

1st column: Number of groups
2nd column: Groups composition
3rd-4th columns: group mean value of the monthly returns and of the standard deviation of the monthly returns

Number of groups				Groups Mean Values	
2	Value	Count	Percent	mean return	mean std.dev
	1	228	51.58%	1.390%	5.380%
	2	214	48.42%	0.500%	1.020%
				Groups Mean Values	
3	Value	Count	Percent	mean return	mean std.dev
	1	153	34.62%	1.190%	4.270%
	2	198	44.80%	0.470%	0.880%
	3	91	20.59%	1.640%	6.800%
				Groups Mean Values	
4	Value	Count	Percent	mean return	mean std.dev
	1	124	28.05%	1.240%	4.830%
	2	59	13.35%	0.980%	3.020%
	3	75	16.97%	1.740%	7.010%
	4	184	41.63%	0.450%	0.770%
				Groups Mean Values	
5	Value	Count	Percent	mean return	mean std.dev
	1	108	24.43%	1.370%	4.710%
	2	59	13.35%	0.980%	3.020%
	3	56	12.67%	2.120%	7.060%
	4	35	7.92%	0.500%	6.320%
	5	184	41.63%	0.450%	0.770%
				Groups Mean Values	
6	Value	Count	Percent	mean return	mean std.dev
	1	70	15.84%	1.390%	5.220%
	2	73	16.52%	1.240%	4.110%
	3	53	11.99%	2.130%	7.120%
	4	23	5.20%	0.380%	6.690%
	5	181	40.95%	0.450%	0.750%
	6	42	9.50%	0.830%	2.660%
				Groups Mean Values	
7	Value	Count	Percent	mean return	mean std.dev
	1	79	17.87%	1.270%	4.440%
	2	50	11.31%	0.990%	3.090%
	3	42	9.50%	1.610%	5.470%
	4	51	11.54%	2.140%	7.150%
	5	115	26.02%	0.400%	0.490%
	6	75	16.97%	0.540%	1.300%
	7	30	6.79%	0.370%	6.370%
				Groups Mean Values	
8	Value	Count	Percent	mean return	mean std.dev
	1	55	12.44%	2.120%	7.080%
	2	68	15.38%	1.220%	4.080%
	3	60	13.57%	1.520%	5.060%
	4	27	6.11%	0.520%	5.880%
	5	102	23.08%	0.390%	0.450%
	6	9	2.04%	0.430%	7.520%
	7	83	18.78%	0.520%	1.180%
	8	38	8.60%	0.870%	2.740%
				Groups Mean Values	
9	Value	Count	Percent	mean return	mean std.dev
	1	69	15.61%	1.420%	4.810%
	2	36	8.14%	0.840%	2.670%
	3	52	11.76%	1.190%	3.890%
	4	10	2.26%	0.410%	7.430%
	5	102	23.08%	0.390%	0.450%
	6	35	7.92%	1.780%	6.160%
	7	19	4.30%	0.280%	5.750%
	8	82	18.55%	0.520%	1.170%
	9	37	8.37%	2.180%	7.380%
				Groups Mean Values	
10	Value	Count	Percent	mean return	mean std.dev
	1	63	14.25%	1.370%	4.720%
	2	49	11.09%	1.180%	3.860%
	3	28	6.33%	1.660%	5.680%
	4	99	22.40%	0.390%	0.440%
	5	85	19.23%	0.520%	1.160%
	6	36	8.14%	0.840%	2.670%
	7	16	3.62%	2.300%	7.830%
	8	21	4.75%	0.350%	5.810%
	9	10	2.26%	0.410%	7.430%
	10	35	7.92%	2.070%	6.840%

Appendix 2 - TABLE VI

Results from GAME algorithm in correspondence of the Marriott's criterion
The dataset is composed by the whole mutual funds time series monthly returns
Each time serie has been considered as a single object with T features. T=number of dates from 12/95 up to 12/00.
The iterative procedure has been stopped for 10 groups.

Marriott's Criterion									
Number of Groups	2	3	4	5	6	7	8	9	10
Best Fitness Value	0.18880	0.0504	0.0068	0.004	0.0013	1.21E-04	6.09E-05	3.40E-05	**1.63E-05**

1st column: Number of groups
2nd column: Groups composition
3rd-4th columns: group mean value of the monthly returns and of the standard deviation of the monthly returns

Number of groups				Groups Mean Values	
2	Value	Count	Percent	mean return	mean std.dev
	1	410	92.76%	0.0101	0.0304
	2	32	7.24%	0.0037	0.0626
				Groups Mean Values	
3	Value	Count	Percent	mean return	mean std.dev
	1	411	92.99%	0.0101	0.0304
	2	19	4.30%	0.0032	0.0562
	3	12	2.71%	0.0046	0.0724
				Groups Mean Values	
4	Value	Count	Percent	mean return	mean std.dev
	1	209	47.29%	0.0152	0.0507
	2	19	4.30%	0.0032	0.0562
	3	13	2.94%	0.0044	0.072
	4	201	45.48%	0.0048	0.0092
				Groups Mean Values	
5	Value	Count	Percent	mean return	mean std.dev
	1	177	40.05%	0.012	0.045
	2	51	11.54%	0.0213	0.0698
	3	14	3.17%	0.0049	0.0712
	4	2	0.45%	0.0211	0.0877
	5	198	44.80%	0.0047	0.0089
				Groups Mean Values	
6	Value	Count	Percent	mean return	mean std.dev
	1	126	28.51%	0.0124	0.0413
	2	65	14.71%	0.0203	0.0669
	3	12	2.71%	0.0046	0.0724
	4	22	4.98%	0.0155	0.0528
	5	216	48.87%	0.0045	0.013
	6	1	0.23%	0.0029	0.0666
				Groups Mean Values	
7	Value	Count	Percent	mean return	mean std.dev
	1	149	33.71%	0.0127	0.0423
	2	62	14.03%	0.0205	0.0679
	3	10	2.26%	0.0048	0.0732
	4	2	0.45%	0.0211	0.0877
	5	197	44.57%	0.0047	0.009
	6	21	4.75%	0.0032	0.0574
	7	1	0.23%	0.0029	0.0666
				Groups Mean Values	
8	Value	Count	Percent	mean return	mean std.dev
	1	75	16.97%	0.0123	0.0433
	2	78	17.65%	0.0135	0.0437
	3	57	12.90%	0.0209	0.0677
	4	2	0.45%	0.0211	0.0877
	5	196	44.34%	0.0047	0.0086
	6	21	4.75%	0.0031	0.0541
	7	12	2.71%	0.0046	0.0724
	8	1	0.23%	0.0029	0.0666
				Groups Mean Values	
9	Value	Count	Percent	mean return	mean std.dev
	1	112	25.34%	0.0124	0.0124
	2	62	14.03%	0.0203	0.0203
	3	31	7.01%	0.0146	0.0146
	4	2	0.45%	0.0024	0.0024
	5	146	33.03%	0.0044	0.0044
	6	11	2.49%	0.0042	0.0042
	7	20	4.52%	0.0032	0.0032
	8	51	11.54%	0.0057	0.0057
	9	7	1.58%	0.015	0.015
				Groups Mean Values	
10	Value	Count	Percent	mean return	mean std.dev
	1	149	33.71%	0.0133	0.0443
	2	42	9.50%	0.0217	0.071
	3	7	1.58%	0.0129	0.0491
	4	4	0.90%	0.02	0.0668
	5	206	46.61%	0.005	0.0101
	6	1	0.23%	0.0027	0.061
	7	2	0.45%	0.0211	0.0877
	8	18	4.07%	0.0032	0.056
	9	3	0.68%	0.0031	0.0679
	10	10	2.26%	0.0048	0.0732

Appendix 2 - TABLE VII

Results from GAME algorithm in correspondence of the Variance Ratio criterion
The dataset is composed by the whole mutual funds time series monthly returns
Each time serie has been considered as a single object with T features. T=number of dates from 12/95 up to 12/00.
The iterative procedure has determined the optimal number of groups equal to 3.

Criterio RTR									
Number of Groups	2	3	4	5	6	7	8	9	10
Best Fitness Value	0.00310	0.0028	0.0031	0.0036	0.0041	0.0041	0.0048	0.0051	0.0057

1st column: Number of groups
2nd column: Groups composition
3rd-4th columns: group mean value of the monthly returns and of the standard deviation of the monthly returns

Number of Groups				Groups Mean Values	
2	Value	Count	Percent	mean return	mean std.dev
	1	228	51.58%	1.400%	5.350%
	2	214	48.42%	0.490%	1.050%
				Groups Mean Values	
3	Value	Count	Percent	mean return	mean std.dev
	1	177	40.05%	1.120%	4.670%
	2	67	15.16%	2.010%	6.600%
	3	198	44.80%	0.470%	0.890%
				Groups Mean Values	
4	Value	Count	Percent	mean return	mean std.dev
	1	145	32.81%	1.300%	4.340%
	2	62	14.03%	2.030%	6.690%
	3	35	7.92%	0.450%	6.310%
	4	200	45.25%	0.470%	0.900%
				Groups Mean Values	
5	Value	Count	Percent	mean return	mean std.dev
	1	140	31.67%	1.280%	4.210%
	2	66	14.93%	2.010%	6.650%
	3	18	4.07%	0.810%	7.090%
	4	20	4.52%	0.320%	5.680%
	5	198	44.80%	0.470%	0.890%
				Groups Mean Values	
6	Value	Count	Percent	mean return	mean std.dev
	1	137	31.00%	1.270%	4.180%
	2	65	14.71%	2.030%	6.680%
	3	10	2.26%	1.480%	6.220%
	4	13	2.94%	0.440%	7.200%
	5	198	44.80%	0.470%	0.890%
	6	19	4.30%	0.320%	5.620%
				Groups Mean Values	
7	Value	Count	Percent	mean return	mean std.dev
	1	65	14.71%	1.260%	4.460%
	2	45	10.18%	1.150%	3.420%
	3	42	9.50%	1.530%	5.200%
	4	59	13.35%	2.060%	6.790%
	5	198	44.80%	0.470%	0.890%
	6	19	4.30%	0.320%	5.620%
	7	14	3.17%	0.490%	7.120%
				Groups Mean Values	
8	Value	Count	Percent	mean return	mean std.dev
	1	62	14.03%	1.320%	4.860%
	2	34	7.69%	1.320%	4.020%
	3	20	4.52%	1.480%	5.140%
	4	19	4.30%	0.320%	5.620%
	5	197	44.57%	0.470%	0.880%
	6	52	11.76%	2.120%	6.970%
	7	12	2.71%	0.390%	7.250%
	8	46	10.41%	1.210%	3.790%
				Groups Mean Values	
9	Value	Count	Percent	mean return	mean std.dev
	1	54	12.22%	1.310%	4.660%
	2	38	8.60%	1.390%	4.260%
	3	21	4.75%	1.480%	5.590%
	4	55	12.44%	2.110%	6.900%
	5	198	44.80%	0.470%	0.890%
	6	10	2.26%	0.480%	7.320%
	7	20	4.52%	0.320%	5.680%
	8	2	0.45%	0.320%	6.850%
	9	44	9.95%	1.130%	3.590%
				Groups Mean Values	
10	Value	Count	Percent	mean return	mean std.dev
	1	71	16.06%	1.310%	4.600%
	2	68	15.38%	1.210%	3.660%
	3	14	3.17%	1.800%	6.030%
	4	47	10.63%	2.140%	7.020%
	5	196	44.34%	0.470%	0.880%
	6	9	2.04%	0.510%	7.420%
	7	13	2.94%	1.420%	5.560%
	8	4	0.90%	0.300%	6.690%
	9	19	4.30%	0.320%	5.620%
	10	1	0.23%	2.510%	9.280%

Appendix 2 - TABLE VIII

1. Maria Cristina Marcuzzo [1985] "Yoan Violet Robinson (1903-1983)", pp. 134

2. Sergio Lugaresi [1986] "Le imposte nelle teorie del sovrappiù", pp. 26

3. Massimo D'Angelillo e Leonardo Paggi [1986] "PCI e socialdemocrazie europee. Quale riformismo?", pp. 158

4. Gian Paolo Caselli e Gabriele Pastrello [1986] "Un suggerimento hobsoniano su terziario ed occupazione: il caso degli Stati Uniti 1960/1983", pp. 52

5. Paolo Bosi e Paolo Silvestri [1986] "La distribuzione per aree disciplinari dei fondi destinati ai Dipartimenti, Istituti e Centri dell'Università di Modena: una proposta di riforma", pp. 25

6. Marco Lippi [1986] "Aggregations and Dynamic in One-Equation Econometric Models", pp. 64

7. Paolo Silvestri [1986] "Le tasse scolastiche e universitarie nella Legge Finanziaria 1986", pp. 41

8. Mario Forni [1986] "Storie familiari e storie di proprietà. Itinerari sociali nell'agricoltura italiana del dopoguerra", pp. 165

9. Sergio Paba [1986] "Gruppi strategici e concentrazione nell'industria europea degli elettrodomestici bianchi", pp. 56

10. Nerio Naldi [1986] "L'efficienza marginale del capitale nel breve periodo", pp. 54

11. Fernando Vianello [1986] "Labour Theory of Value", pp. 31

12. Piero Ganugi [1986] "Risparmio forzato e politica monetaria negli economisti italiani tra le due guerre", pp. 40

13. Maria Cristina Marcuzzo e Annalisa Rosselli [1986] "The Theory of the Gold Standard and Ricardo's Standard Comodity", pp. 30

14. Giovanni Solinas [1986] "Mercati del lavoro locali e carriere di lavoro giovanili", pp. 66

15. Giovanni Bonifati [1986] "Saggio dell'interesse e domanda effettiva. Osservazioni sul cap. 17 della General Theory", pp. 42

16. Marina Murat [1986] "Betwin old and new classical macroeconomics: notes on Lejonhufvud's notion of full information equilibrium", pp. 20

17. Sebastiano Brusco e Giovanni Solinas [1986] "Mobilità occupazionale e disoccupazione in Emilia Romagna", pp. 48

18. Mario Forni [1986] "Aggregazione ed esogeneità", pp. 13

19. Sergio Lugaresi [1987] "Redistribuzione del reddito, consumi e occupazione", pp. 17

20. Fiorenzo Sperotto [1987] "L'immagine neopopulista di mercato debole nel primo dibattito sovietico sulla pianificazione", pp. 34

21. M. Cecilia Guerra [1987] "Benefici tributari nel regime misto per i dividendi proposto dalla commissione Sarcinelli: una nota critica", pp. 9

22. Leonardo Paggi [1987] "Contemporary Europe and Modern America: Theories of Modernity in Comparative Perspective", pp. 38

23. Fernando Vianello [1987] "A Critique of Professor Goodwin's 'Critique of Sraffa'", pp. 12

24. Fernando Vianello [1987] "Effective Demand and the Rate of Profits. Some Thoughts on Marx, Kalecki and Sraffa", pp. 41

25. Anna Maria Sala [1987] "Banche e territorio. Approccio ad un tema geografico-economico", pp. 40

26. Enzo Mingione e Giovanni Mottura [1987] "Fattori di trasformazione e nuovi profili sociali nell'agricoltura italiana: qualche elemento di discussione", pp. 36

27. Giovanna Procacci [1988] "The State and Social Control in Italy During the First World War", pp. 18

28. Massimo Matteuzzi e Annamaria Simonazzi [1988] "Il debito pubblico", pp. 62

29. Maria Cristina Marcuzzo (a cura di) [1988] "Richard F. Kahn. A discipline of Keynes", pp. 118

30. Paolo Bosi [1988] "MICROMOD. Un modello dell'economia italiana per la didattica della politica fiscale", pp. 34

31. Paolo Bosi [1988] "Indicatori della politica fiscale. Una rassegna e un confronto con l'aiuto di MICROMOD", pp. 25

32. Giovanna Procacci [1988] "Protesta popolare e agitazioni operaie in Italia 1915-1918", pp. 45

33. Margherita Russo [1988] "Distretto Industriale e servizi. Uno studio dei trasporti nella produzione e nella vendita delle piastrelle", pp. 157

34. Margherita Russo [1988] "The effect of technical change on skill requirements: an empirical analysis", pp. 28

35. Carlo Grillenzoni [1988] "Identification, estimations of multivariate transfer functions", pp. 33

36. Nerio Naldi [1988] "'Keynes' concept of capital", pp. 40

37. Andrea Ginzburg [1988] "locomotiva Italia?", pp. 30

38. Giovanni Mottura [1988] "La 'persistenza' secolare. Appunti su agricoltura contadina ed agricoltura familiare nelle società industriali", pp. 40

39. Giovanni Mottura [1988] "L'anticamera dell'esodo. I contadini italiani della 'restaurazione contrattuale' fascista alla riforma fondiaria", pp. 40

40. Leonardo Paggi [1988] "Americanismo e riformismo. La socialdemocrazia europea nell'economia mondiale aperta", pp. 120

41. Annamaria Simonazzi [1988] "Fenomeni di isteresi nella spiegazione degli alti tassi di interesse reale", pp. 44

42. Antonietta Bassetti [1989] "Analisi dell'andamento e della casualità della borsa valori", pp. 12

43. Giovanna Procacci [1989] "State coercion and worker solidarity in Italy (1915-1918): the moral and political content of social unrest", pp. 41

44. Carlo Alberto Magni [1989] "Reputazione e credibilità di una minaccia in un gioco bargaining", pp. 56

45. Giovanni Mottura [1989] "Agricoltura familiare e sistema agroalimentare in Italia", pp. 84

46. Mario Forni [1989] "Trend, Cycle and 'Fortuitous cancellation': a Note on a Paper by Nelson and Plosser", pp. 4

47. Paolo Bosi , Roberto Golinelli , Anna Stagni [1989] "Le origini del debito pubblico e il costo della stabilizzazione", pp. 26

48. Roberto Golinelli [1989] "Note sulla struttura e sull'impiego dei modelli macroeconometrici", pp. 21

49. Marco Lippi [1989] "A Shorte Note on Cointegration and Aggregation", pp. 11

50. Gian Paolo Caselli e Gabriele Pastrello [1989] "The Linkage between Tertiary and Industrial Sector in the Italian Economy: 1951-1988. From an External Dependence to an International One", pp. 40

51. Gabriele Pastrello [1989] "Francois quesnay: dal Tableau Zig-zag al Tableau Formule: una ricostruzione", pp. 48

52. Paolo Silvestri [1989] "Il bilancio dello stato", pp. 34

53. Tim Mason [1990] "Tre seminari di storia sociale contemporanea", pp. 26

54. Michele Lalla [1990] "The Aggregate Escape Rate Analysed throught the Queueing Model", pp. 23

55. Paolo Silvestri [1990] "Sull'autonomia finanziaria dell'università", pp. 11

56. Paola Bertolini, Enrico Giovannetti [1990] "Uno studio di 'filiera' nell'agroindustria. Il caso del Parmigiano Reggiano", pp. 164

57. Paolo Bosi, Roberto Golinelli, Anna Stagni [1990] "Effetti macroeconomici, settoriali e distributivi dell'armonizzazione dell'IVA", pp. 24

58. Michele Lalla [1990] "Modelling Employment Spells from Emilia Labour Force Data", pp. 18

59. Andrea Ginzburg [1990] "Politica Nazionale e commercio internazionale", pp. 22

60. Andrea Giommi [1990] "La probabilità individuale di risposta nel trattamento dei dati mancanti", pp. 13

61. Gian Paolo Caselli e Gabriele Pastrello [1990] "The service sector in planned economies. Past experiences and future prospectives", pp. 32

62. Giovanni Solinas [1990] "Competenze, grandi industrie e distretti industriali,. Il caso Magneti Marelli", pp. 23

63. Andrea Ginzburg [1990] "Debito pubblico, teorie monetarie e tradizione civica nell'Inghilterra del Settecento", pp. 30

64. Mario Forni [1990] "Incertezza, informazione e mercati assicurativi: una rassegna", pp. 37

65. Mario Forni [1990] "Misspecification in Dynamic Models", pp. 19

66. Gian Paolo Caselli e Gabriele Pastrello [1990] "Service Sector Growth in CPE's: An Unsolved Dilemma", pp. 28

67. Paola Bertolini [1990] "La situazione agro-alimentare nei paesi ad economia avanzata", pp. 20

68. Paola Bertolini [1990] "Sistema agro-alimentare in Emilia Romagna ed occupazione", pp. 65

69. Enrico Giovannetti [1990] "Efficienza ed innovazione: il modello "fondi e flussi" applicato ad una filiera agro-industriale", pp. 38

70. Margherita Russo [1990] "Cambiamento tecnico e distretto industriale: una verifica empirica", pp. 115

71. Margherita Russo [1990] "Distretti industriali in teoria e in pratica: una raccolta di saggi", pp. 119

72. Paolo Silvestri [1990] " La Legge Finanziaria. Voce dell'enciclopedia Europea Garzanti", pp. 8

73. Rita Paltrinieri [1990] "La popolazione italiana: problemi di oggi e di domani", pp. 57

74. Enrico Giovannetti [1990] "Illusioni ottiche negli andamenti delle Grandezze distributive: la scala mobile e l''appiattimento' delle retribuzioni in una ricerca", pp. 120

75. Enrico Giovannetti [1990] "Crisi e mercato del lavoro in un distretto industriale: il bacino delle ceramiche. Sez I", pp. 150

76. Enrico Giovannetti [1990] " Crisi e mercato del lavoro in un distretto industriale: il bacino delle ceramiche. Sez. II", pp. 145

78. Antonietta Bassetti e Costanza Torricelli [1990] "Una riqualificazione dell'approccio bargaining alla selezioni di portafoglio", pp. 4

77. Antonietta Bassetti e Costanza Torricelli [1990] "Il portafoglio ottimo come soluzione di un gioco bargaining", pp. 15

79. Mario Forni [1990] "Una nota sull'errore di aggregazione", pp. 6

80. Francesca Bergamini [1991] "Alcune considerazioni sulle soluzioni di un gioco bargaining", pp. 21

81. Michele Grillo e Michele Polo [1991] "Political Exchange and the allocation of surplus: a Model of Two-party competition", pp. 34

82. Gian Paolo Caselli e Gabriele Pastrello [1991] "The 1990 Polish Recession: a Case of Truncated Multiplier Process", pp. 26

83. Gian Paolo Caselli e Gabriele Pastrello [1991] "Polish firms: Pricate Vices Pubblis Virtues", pp. 20

84. Sebastiano Brusco e Sergio Paba [1991] "Connessioni, competenze e capacità concorrenziale nell'industria della Sardegna", pp. 25

85. Claudio Grimaldi, Rony Hamaui, Nicola Rossi [1991] "Non Marketable assets and households' Portfolio Choice: a Case of Study of Italy", pp. 38

86. Giulio Righi, Massimo Baldini, Alessandra Brambilla [1991] "Le misure degli effetti redistributivi delle imposte indirette: confronto tra modelli alternativi", pp. 47

87. Roberto Fanfani, Luca Lanini [1991] "Innovazione e servizi nello sviluppo della meccanizzazione agricola in Italia", pp. 35

88. Antonella Caiumi e Roberto Golinelli [1992] "Stima e applicazioni di un sistema di domanda Almost Ideal per l'economia italiana", pp. 34

89. Maria Cristina Marcuzzo [1992] "La relazione salari-occupazione tra rigidità reali e rigidità nominali", pp. 30

90. Mario Biagioli [1992] "Employee financial participation in enterprise results in Italy", pp. 50

91. Mario Biagioli [1992] "Wage structure, relative prices and international competitiveness", pp. 50

92. Paolo Silvestri e Giovanni Solinas [1993] "Abbandoni, esiti e carriera scolastica. Uno studio sugli studenti iscritti alla Facoltà di Economia e Commercio dell'Università di Modena nell'anno accademico 1990/1991", pp. 30

93. Gian Paolo Caselli e Luca Martinelli [1993] "Italian GPN growth 1890-1992: a unit root or segmented trend representatin?", pp. 30

94. Angela Politi [1993] "La rivoluzione fraintesa. I partigiani emiliani tra liberazione e guerra fredda, 1945-1955", pp. 55

95. Alberto Rinaldi [1993] "Lo sviluppo dell'industria metalmeccanica in provincia di Modena: 1945-1990", pp. 70

96. Paolo Emilio Mistrulli [1993] "Debito pubblico, intermediari finanziari e tassi d'interesse: il caso italiano", pp. 30

97. Barbara Pistoresi [1993] "Modelling disaggregate and aggregate labour demand equations. Cointegration analysis of a labour demand function for the Main Sectors of the Italian Economy: 1950-1990", pp. 45

98. Giovanni Bonifati [1993] "Progresso tecnico e accumulazione di conoscenza nella teoria neoclassica della crescita endogena. Una analisi critica del modello di Romer", pp. 50

99. Marcello D'Amato e Barbara Pistoresi [1994] "The relationship(s) among Wages, Prices, Unemployment and Productivity in Italy", pp. 30

100. Mario Forni [1994] "Consumption Volatility and Income Persistence in the Permanent Income Model", pp. 30

101. Barbara Pistoresi [1994] "Using a VECM to characterise the relative importance of permanent and transitority components", pp. 28

102. Gian Paolo Caselli and Gabriele Pastrello [1994] "Polish recovery form the slump to an old dilemma", pp. 20

103. Sergio Paba [1994] "Imprese visibili, accesso al mercato e organizzazione della produzione", pp. 20

104. Giovanni Bonifati [1994] "Progresso tecnico, investimenti e capacità produttiva", pp. 30

105. Giuseppe Marotta [1994] "Credit view and trade credit: evidence from Italy", pp. 20

106. Margherita Russo [1994] "Unit of investigation for local economic development policies", pp. 25

107. Luigi Brighi [1995] "Monotonicity and the demand theory of the weak axioms", pp. 20

108. Mario Forni e Lucrezia Reichlin [1995] "Modelling the impact of technological change across sectors and over time in manufactoring", pp. 25

109. Marcello D'Amato and Barbara Pistoresi [1995] "Modelling wage growth dynamics in Italy: 1960-1990", pp. 38

110. Massimo Baldini [1995] "INDIMOD. Un modello di microsimulazione per lo studio delle imposte indirette", pp. 37

111. Paolo Bosi [1995] "Regionalismo fiscale e autonomia tributaria: l'emersione di un modello di consenso", pp. 38

112. Massimo Baldini [1995] "Aggregation Factors and Aggregation Bias in Consumer Demand", pp. 33

113. Costanza Torricelli [1995] "The information in the term structure of interest rates. Can stocastic models help in resolving the puzzle?" pp. 25

114. Margherita Russo [1995] "Industrial complex, pôle de développement, distretto industriale. Alcune questioni sulle unità di indagine nell'analisi dello sviluppo." pp. 45

115. Angelika Morison [1995] "50 Jahre Deutschland. 1945 - 1995" pp. 21

116. Paolo Bosi [1995] "Un punto di vista macroeconomico sulle caratteristiche di lungo periodo del nuovo sistema pensionistico italiano." pp. 32

117. Gian Paolo Caselli e Salvatore Curatolo [1995] "Esistono relazioni stimabili fra dimensione ed efficienza delle istituzioni e crescita produttiva? Un esercizio nello spirito di D.C. North." pp. 11

118. Mario Forni e Marco Lippi [1995] "Permanent income, heterogeneity and the error correction mechanism." pp. 21

119. Barbara Pistoresi [1995] "Co-movements and convergence in international output. A Dynamic Principal Components Analysis" pp. 14

120. Mario Forni e Lucrezia Reichlin [1995] "Dynamic common factors in large cross-section" pp. 17

121. Giuseppe Marotta [1995] "Il credito commerciale in Italia: una nota su alcuni aspetti strutturali e sulle implicazioni di politica monetaria" pp. 20

122. Giovanni Bonifati [1995] "Progresso tecnico, concorrenza e decisioni di investimento: una analisi delle determinanti di lungo periodo degli investimenti" pp. 25

123. Giovanni Bonifati [1995] "Cambiamento tecnico e crescita endogena: una valutazione critica delle ipotesi del modello di Romer" pp. 21

124. Barbara Pistoresi e Marcello D'Amato [1995] "La riservatezza del banchiere centrale è un bene o un male? ,Effetti dell'informazione incompleta sul benessere in un modello di politica monetaria." pp. 32

125. Barbara Pistoresi [1995] "Radici unitarie e persistenza: l'analisi univariata delle fluttuazioni economiche." pp. 33

126. Barbara Pistoresi e Marcello D'Amato [1995] "Co-movements in European real outputs" pp. 20

127. Antonio Ribba [1996] "Ciclo economico, modello lineare-stocastico, forma dello spettro delle variabili macroeconomiche" pp. 31

128. Carlo Alberto Magni [1996] "Repeatable and una tantum real options a dynamic programming approach" pp. 23

129. Carlo Alberto Magni [1996] "Opzioni reali d'investimento e interazione competitiva: programmazione dinamica stocastica in optimal stopping" pp. 26

130. Carlo Alberto Magni [1996] "Vaghezza e logica fuzzy nella valutazione di un'opzione reale" pp. 20

131. Giuseppe Marotta [1996] "Does trade credit redistribution thwart monetary policy? Evidence from Italy" pp. 20

132. Mauro Dell'Amico e Marco Trubian [1996] "Almost-optimal solution of large weighted equicut problems" pp. 30

133. Carlo Alberto Magni [1996] "Un esempio di investimento industriale con interazione competitiva e avversione al rischio" pp. 20

134. Margherita Russo, Peter Börkey, Emilio Cubel, François Lévêque, Francisco Mas [1996] "Local sustainability and competitiveness: the case of the ceramic tile industry" pp. 66

135. Margherita Russo [1996] "Camionetto tecnico e relazioni tra imprese" pp. 190

136. David Avra Lane, Irene Poli, Michele Lalla, Alberto Roverato [1996] "Lezioni di probabilità e inferenza statistica" pp. 288

137. David Avra Lane, Irene Poli, Michele Lalla, Alberto Roverato [1996] "Lezioni di probabilità e inferenza statistica - Esercizi svolti - " pp. 302

138. Barbara Pistoresi [1996] "Is an Aggregate Error Correction Model Representative of Disaggregate Behaviours? An example" pp. 24

139. Luisa Malaguti e Costanza Torricelli [1996] "Monetary policy and the term structure of interest rates" , pp. 30

140. Mauro Dell'Amico, Martine Labbé, Francesco Maffioli [1996] "Exact solution of the SONET Ring Loading Problem", pp. 20

141. Mauro Dell'Amico, R.J.M. Vaessens [1996] "Flow and open shop scheduling on two machines with transportation times and machine-independent processing times in NP-hard, pp. 10

142. M. Dell'Amico, F. Maffioli, A. Sciomechen [1996] "A Lagrangean Heuristic for the Pirze Collecting Travelling Salesman Problem", pp. 14

143. Massimo Baldini [1996] "Inequality Decomposition by Income Source in Italy - 1987 - 1993", pp. 20

144. Graziella Bertocchi [1996] "Trade, Wages, and the Persistence of Underdevelopment" pp. 20

145. Graziella Bertocchi and Fabio Canova [1996] "Did Colonization matter for Growth? An Empirical Exploration into the Historical Causes of Africa's Underdevelopment" pp. 32

146. Paola Bertolini [1996] "La modernization de l'agricolture italienne et le cas de l'Emilie Romagne" pp. 20

147. Enrico Giovannetti [1996] "Organisation industrielle et développement local: le cas de l'agroindutrie in Emilie Romagne" pp. 18

148. Maria Elena Bontempi e Roberto Golinelli [1996] "Le determinanti del leverage delle imprese: una applicazione empirica ai settori industriali dell'economia italiana" pp. 31

149. Paola Bertolini [1996] "L'agriculture et la politique agricole italienne face aux recents scenarios", pp. 20

150. Enrico Giovannetti [1996] "Il grado di utilizzo della capacità produttiva come misura dei costi di transizione. Una rilettura di 'Nature of the Firm' di R. Coase", pp. 65

151. Enrico Giovannetti [1996] "Il 1° ciclo del Diploma Universitario Economia e Amministrazione delle Imprese", pp. 25

152. Paola Bertolini, Enrico Giovannetti, Giulia Santacaterina [1996] "Il Settore del Verde Pubblico. Analisi della domanda e valutazione economica dei benefici", pp. 35

153. Giovanni Solinas [1996] "Sistemi produttivi del Centro-Nord e del Mezzogiorno. L'industria delle calzature", pp. 55

154. Tindara Addabbo [1996] "Married Women's Labour Supply in Italy in a Regional Perspective", pp. 85

155. Paolo Silvestri, Giuseppe Catalano, Cristina Bevilacqua [1996] "Le tasse universitarie e gli interventi per il diritto allo studio: la prima fase di applicazione di una nuova normativa" pp. 159

156. Sebastiano Brusco, Paolo Bertossi, Margherita Russo [1996] "L'industria dei rifiuti urbani in Italia", pp. 25

157. Paolo Silvestri, Giuseppe Catalano [1996] "Le risorse del sistema universitario italiano: finanziamento e governo" pp. 400

158. Carlo Alberto Magni [1996] "Un semplice modello di opzione di differimento e di vendita in ambito discreto", pp. 10

159. Tito Pietra, Paolo Siconolfi [1996] "Fully Revealing Equilibria in Sequential Economies with Asset Markets" pp. 17

160. Tito Pietra, Paolo Siconolfi [1996] "Extrinsic Uncertainty and the Informational Role of Prices" pp. 42

161. Paolo Bertella Farnetti [1996] "Il negro e il rosso. Un precedente non esplorato dell'integrazione afroamericana negli Stati Uniti" pp. 26

162. David Lane [1996] "Is what is good for each best for all? Learning from others in the information contagion model" pp. 18

163. Antonio Ribba [1996] "A note on the equivalence of long-run and short-run identifying restrictions in cointegrated systems" pp. 10

164. Antonio Ribba [1996] "Scomposizioni permanenti-transitorie in sistemi cointegrati con una applicazione a dati italiani" pp. 23

165. Mario Forni, Sergio Paba [1996] "Economic Growth, Social Cohesion and Crime" pp. 20

166. Mario Forni, Lucrezia Reichlin [1996] "Let's get real: a factor analytical approch to disaggregated business cycle dynamics" pp. 25

167. Marcello D'Amato e Barbara Pistoresi [1996] "So many Italies: Statistical Evidence on Regional Cohesion" pp. 31

168. Elena Bonfiglioli, Paolo Bosi, Stefano Toso [1996] "L'equità del contributo straordinario per l'Europa" pp. 20

169. Graziella Bertocchi, Michael Spagat [1996] "Il ruolo dei licei e delle scuole tecnico-professionali tra progresso tecnologico, conflitto sociale e sviluppo economico" pp. 37

170. Gianna Boero, Costanza Torricelli [1997] "The Expectations Hypothesis of the Term Structure of Interest Rates: Evidence for Germany" pp. 15

171. Mario Forni, Lucrezia Reichlin [1997] "National Policies and Local Economies: Europe and the US" pp. 22

172. Carlo Alberto Magni [1997] "La trappola del Roe e la tridimensionalità del Van in un approccio sistemico", pp. 16

173. Mauro Dell'Antico [1997] ---ALinear Time Algorithm for Scheduling Outforests with Communication Delays or Two Processor-pp. 18

174. Paolo Bosi [1997] "Aumentare l'età pensionabile fa diminuire la spesa pensionistica? Ancora sulle caratteristiche di lungo periodo della riforma Dini- pp. 13

175. Paolo Bosi e Massimo Matteuzzi (1997) -Nuovi strumenti per l'assistenza sociale- pp 31

176. Mauro Dell'Amico, Francesco Maffioli e Marco Trubian [1997] "New bounds for optium traffic assignment in satellite communication" pp. 21

177. Carlo Alberto Magni [1997] "Paradossi,inverosimiglianze e contraddizioni dei Van: operazioni certe" pp. 9

178. Barbara Pistoresi e Marcello D'Amato [1997] "Persistence of relative unemployment rates across italian regions" pp, 25

179. Margherita Russo, Franco Cavedoni e Riccardo Pianesani [1997] "Le spese ambientali dei Comuni in provincia di Modena, 1993-1995" pp. 23

180. Gabriele Pastrello [1997] "Time and Equilibrium, Two Elisive Guests in the Keynes-Hawtrey-Robertson Debate in the Thirties"pp 25

181. Luisa Malaguti e Costanza Torricelli [1997] "The Interaction Between Monetary Policy and the Expectation Hypothesis of the Term Structure of Interest rates in a N-Period Rational Expectation Model" pp. 27

182. Mauro Dell'Amico [1997] "On the Continuous Relaxation of Packing Problems - Technical Note" pp. 8

183. Stefano Bordoni [1997] "Prova di Idoneità di Informatica Dispensa Esercizi Excel 5" pp 49

184. Francesca Bergamini e Stefano Bordoni [1997] "Una verifica empirica di un nuovo metodo di selezione ottima di portafoglio" pp. 22

185. Gian Paolo Caselli e Maurizio Battini [1997] "Following the tracks of atkinson and micklewright the changing distribution of income and earnings in poland from 1989 to 1995" pp. 21

186. Mauro Dell'Amico e Francesco Mafficli [1997] "Combining Linear and Non-Linear Objectives in Spanning Tree Problems" pp. 21

187. Gianni Ricci e Vanessa Debbia [1997] "Una soluzione evolutiva in un gioco differenziale di lotta di classe" pp. 14

188. Fabio Canova e Eva Ortega [1997] "Testing Calibrated General Equilibrium Model" pp 34

189. Fabio Canova [1997] "Does Detrending Matter for he Determination of the Reference Cycle and the Selection of Turning Points?" Pp. 35

190. Fabio Canova e Gianni De Nicolò [1997] "The Equity Premium and the Risk Free Rate: A Cross Country, Cross Maturity Examination" pp.41

191. Fabio Canova e Angel J. Ubide [1997] "International Business Cycles, Financial Market and Household Production" pp. 32

192. Fabio Canova e Gianni De Nicolò [1997] "Stock Returns, Term Structure, Inflation and Real Activity: An International Perspective" pp. 33

193. Fabio Canova e Morten Ravn [1997] "The Macroeconomic Effects of German Unification: Real Adjustmentsand the Welfare State" pp.34

194. Fabio Canova [1997] "Detrending and Business Cycle Facts"' pp. 40

195. Fabio Canova e Morten 0. Ravn [1997] "'Crossing the Rio Grande: Migrations, Business Cycle and the Welfare State" pp. 37

196. Fabio Canova e Jane Marrinan [1997] "Sources and Propagation of International Output Cycles: Common Shocks or Transmission?" pp. 41

197. Fabio Canova e Albert Marcet [1997] "The Poor Stay Poor: Non-Convergence Across Countrees and Regions" pp. 44

198. Carlo Alberto Magni [1997] "Un Criterio Strutturalista per la Valutazione di Investimenti" pp. 17

199. Stefano Bordoni [1997] "Elaborazione Automatica dei Dati" pp. 60

200. Paolo Bertella Farnetti [1997] "The United States and the Origins of European Integration" pp 19

201. Paolo Bosi [1997] "Sul Controllo Dinamico di un Sistema Pensionistico a Ripartizione di Tipo Contributivo" pp. 17

202. Paola Bertolini [1997] "European Union Agricultural Policy: Problems and Perspectives" pp .18

203. Stefano Bordom [1997] "Supporti Informatici per la Ricerca delle soluzioni di Problemi Decisionali" pp. 30

204. Carlo Alberto Magni [1997] "Paradossi, Inverosimiglianze e Contraddizioni del Van: Operazioni Aleatorie" pp. 10

205. Carlo Alberto Magni [19971 "Tir, Roe e Van: Distorsioni Linguistiche e Cognitive nella Valutazione degli Investimenti" pp. 17

206. Gisella Facchinetti, Roberto Ghiselli Ricci e Silvia Muzzioli [1997] "New Methods For Ranking Triangular Fuzzy Numbers: An Investment Choice" pp.

207. Mauro Dell'Amico e Silvano Martello [1997] "Reduction of the Three-Partition Problem" pp. 19

208. Carlo Alberto Magni [1997] "IRR, ROE and NPV: a Systemic Approach" pp. 20

209. Mauro Dell'Amico, Andrea Lodi e Francesco Maffioli [19971 "Solution of the cumulative assignment problem whit a well-structured tabu search method" pp. 25

210. Carlo Alberto Magni [1997] "La definizione di investimento e criterio del Tir ovvero: la realtà inventata" pp. 16

211. Carlo Alberto Magni [1997] "Critica alla definizione classica di investimento: un approccio sistemico" pp. 17

212. Alberto Roverato 11997] "Asymptotic prior to posterior analysis for graphical gaussian models" pp. 8

213. Tindara Addabbo [1997] "Povertà nel 1995 analisi statica e dinamica sui redditi familiari" pp. 64

214. Gian Paolo Caselli e Franca Manghi [1997] "La transizione da piano a mercato e il modello di Ising" pp. 15

215. Tindara Addabbo [1998] "Lavoro non pagato e reddito esteso: una' applicazione alle famiglie italiane in cui entrambi i coniugi sono lavoratori dipendenti" pp. 54

216. Tindara Addabbo [1998] "Probabilità di occupazione e aspettative individuali" pp. 36

217. Lara Magnani [1998] "Transazioni, contratti e organizzazioni: una chiave di lettura della teoria economica dell'organizzazione" pp. 39

218. Michele Lalla, Rosella Molinari e Maria Grazia Modena [1998] "La progressione delle carriere: i percorsi in cardiologia" pp. 46

219. Lara Magnani [1998] "L'organizzazione delle transizioni di subfornitura nel distretto industriale" pp. 40

220. Antonio Ribba [1998] "Recursive VAR orderings and identification of permanent and transitory shocks" pp. 12

221. Antonio Ribba [1998] "Granger-causality and exogeneity in cointegrated Var models" pp. 5

222. Luigi Brighi e Marcello D'Amato [1998] "Optimal Procurement in Multiproduct Monopoli" pp. 25

223. Paolo Bosi, Maria Cecilia Guerra e Paolo Silvestri [1998] "La spesa sociale nel comune Modena Rapporto intermedio" pp. 37

224. Mario Forni e Marco Lippi [1998] "On the Microfoundations of Dynamic Macroeconomics" pp. 22

225. Roberto Ghiselli Ricci [1998] "Nuove Proposte di Ordinamento di Numeri Fuzzy. Una Applicazione ad un Problema di Finanziamento" pp. 7

226. Tommaso Minerva [1998] "Internet Domande e Risposte" pp. 183

227. Tommaso Minerva 115k98] "Elementi di Statistica Computazione. Parte Prima: Il Sistema Operativo Unix ed il Linguaggio C" pp. 57

228. Tommaso Minerva and Irene Poli [1998] "A Gennetic Algorithms Selection Method for Predictive Neural Nets and Linear Modenls pp. 60

229. Tommaso Minerva and Irene Poli [1998] "Building an ARMA model by using a Genetic Algorithm" pp. 60

230. Mauro Dell'Amico e Paolo Toth [1998] "Algorithms and Codes for Dense Assignment Problems the State of the Art" pp. 35

231. Ennio Cavazzuti e Nicoletta Pacchiarotti [1998] "How to play an hotelling game in a square town" pp. 12

232. Alberto Roverato e Irene Poli [1998] "Un algoritmo genetico per la selezione di modelli grafici" pp. 11

233. Marcello D'Amato e Barbara Pistoresi [19981 "Delegation of Monetary Policy to a Central Banker with Private Information" pp. 15

234. Graziella Bertocchi e Michael Spagat [1998] "The Evolution of Modem Educational Systems. Technical vs. General Education, Distributional Conflict, and Growth" pp. 31

235. Andrè Dumas [19981 "Le systeme monetaire Europeen" pp. 24

236. Gianna Boero, Gianluca Di Lorenzo e Costanza Torricelli [1998] "The influence of short rate predictability and monetary policy on tests of the expectations hypothesis: some comparative evidence" pp. 30

237. Carlo Alberto Magni [1998] "A systemic rule for investment decisions generalizations of the traditional DCF criteria and new conceptions" pp. 30

238. Marcello D'Amato e Barbara Pistoresi [1998) "Interest Rate Spreads Between Italy and Germany: 1995-1997" pp. 16

239. Paola Bertolini e Alberto Bertacchini [1998] "Il distretto di lavorazioni carni suine in provincia di Modena" pp. 29

240. Costanza Torricelli e Gianluca Di Lorenzo [1998] "Una nota sui fondamenti matematico-firianziari della teoria delle aspettative della struttura della scadenza" pp. 15

241. Christophe Croux, Mario Fonti e Lucrezia Reichlin [1998] "A Measure of Comovement for Economic Indicators; Theory and Empirics" pp. 23

242. Carlo Alberto Magni [1998] "Note sparse sul dilemma del prigioniero (e non solo)" pp. 13

243. Gian Paolo Caselli [1998] "The future of mass consumption society in the former planned ecomomies: a macro approach " pp. 21

244. Mario Forni, Marc Hallin, Marco Lippi e Lucrezia Reichlin [1998] "The generalized dynamic factor model: identification and estimation" pp. 35

245. Carlo Alberto Magni [1998] "Pictures, language and research: the case of finance and financial mathematics" pp. 35

246. Luigi Brighi [1998] "Demand and generalized monotonicity" pp. 21

247. Mario Forni e Lucrezia Reichlin [1998] "Risk and potential insurance in Europe" pp. 20

248. Tommaso Minerva, Sandra Paterlini e Irene Poli [1998] "A Genetic Algorithm for predictive Neural Network Design (GANND). A Financial Application" pp. 12

249. Gian Paolo Caselli MaurizioUCaselli Maurizio m(/.U"The Changing Distribution of Earnings in Poland from 1989 to 1996 "pp. 9

250. Mario Forni Sergio Paba [1998] "Industrial Districts, Social Environment and Local Growth" Evidence from Italy " pp. 27

251. Lara Magnani [1998] "Un'analisi del distretto industriale fondata sulla moderna teoria economica dell'organizzazione" pp. 46

252. Mario Forni Lucrezia Reichlin [1998] "Federal Policies and Local Economies: Europe and the US" pp. 24

253. Luigi Brighi [1998] "A Case of Optimal Regulation whit Multidimensional Private Information" pp. 20

254. Barbara Pistoresi Stefania Luppi [1998] "Gli investimenti diretti esteri nell'America Latina e nel Sud Est Asiatico: 1982-1995" pp. 27

255. Paola Mengoli Margherita Russo [1998] "Technical and Vocational Education and Training in Italy: Structure and Changes at National and Regional Level" pp. 25

256. Tindara Addabbo [1998] "On-the-Job Search a Microeconometric Analysis on Italian Data" pp. 29

257. Lorenzo Bertucelli [1999] "Il paternalismo industriale: una discussione storiografica" pp.21

258. Mario Forni e Marco Lippi [1999] "The generalized dynamic factor model: representation theory" pp. 25

259. Andrea Ginzburg e Annamaria Simonazzi [1999] "Foreign debt cycles and the 'Gibson Paradox': an interpretative hypothesis" pp.38

260. Paolo Bosi [1999] "La riforma della spesa per assistenza dalla Commissione Onofri ad oggi: una valutazione in corso d'opera" pp. 56

261. Marcello D'Amato e Barbara Pistoresi [1999] "Go and soothe the row. Delegation of monetary policy under private information" pp.23

262. Michele Lalla [1999] "Sampling, Maintenance, and Weighting Schemes for Longitudinal Surveys: a Case Study of the Textile and Clothing Industry" pp. 27

263. Pederzoli Chiara e Torricelli Costanza [1999] "Una rassegna sui metodi di stima del Value at Risk (Var)"

264. Paolo Bosi, Maria Cecilia Guerra e Paolo Silvestri [1999] "La spesa sociale di Modena. La valutazione della condizione economica" pp. 74

265. Graziella Bertocchi e Michael Spagat [1999] "The Politics Co optation" pp. 14

266. Giovanni Bonifati [1999] "The Capacityt to Generate Investment. An analysis of the long-term determinants of investment" pp.22

267. Tindara Addabbo e Antonella Caiumi [1999] "Extended Income and Inequality by Gender in Italy" pp. 40

268. Antonella Caiumi e Federico Perali [1999] "Children and Intrahousehold Distribution of Resources: An Estimate of the Sharing Rule of Italian Households" pp. 24

269. Vincenzo Atella. Antonella Caiumi e Federico Perali [1999] "Una scala di equivalenza non vale l'altra" pp. 23

270. Tito Pietra e Paolo Siconolfi [1999] "Volume of Trade and Revelation of Information" pp. 31

271. Antonella Picchio [1999] "La questione del lavoro non pagato nella produzione di servizi nel nucleo domestico (Household)" pp.58

272. Margherita Russo [1999] "Complementary Innovations and Generative Relationships in a Small Business Production System: the Case of Kervit" pp. 27

273. André Dumas [1999] "L'Economie de la drouge" pp. 12

274. André Dumas [1999] "L'Euro à l'heure actuelle" pp. 12

275. Michele Lalla Gisella Facchinetti [1999] "La valutazione della attività didattica: un confronto tra scale di misura e insiemi sfocati" pp.32

276. Mario Biagioli [1999] "Formazione e valorizzazione dei capitale umano: un' indagine sui paesi dell'Unione Europea" pp.21

277. Mario Biagioli [1999] "Disoccupazione, formazione del capitale umano e determinazione dei salari individuali: un' indagine su microdati nei paesi dell'Unione Europea" pp. 15

278. Gian Paolo Caselli e Giulia Bruni [1999] "Il settore petrolifero russo, il petrolio del Mar Caspio e gli interessi geopolitici nell'area" pp. 28

279. Luca Gambetti [1999] "The Real Effect of Monetary Policy: a New Var Identification Procedure" pp. 22

280. Marcello D'Amato Barbara Pistoresi [1999] "Assessing Potential Targets for Labour Market Reforms in Italy" pp. 8

281. Gian Paolo Caselli, Giulia Bruni e Francesco Pattarin [1999] "Gaddy and Ickes Model of Russian Barter Economy: Some Criticisms and Considerations" pp. 10

282. Silvia Muzzioli Costanza Torricelli [1999] "A Model for Pricing an Option with a Fuzzy Payoff" pp. 13

283. Antonella Caiumi Federico Perali [1999] "Povertà e Welfare in Italia in Relazione alla Scelta della Scala di Equivalenza" pp.25

284. Marcello Galli Tommaso Minerva [1999] "Algoritmi Genetici per l'Evoluzione di Modelli Lineari *Metodologia ad Applicazioni*" pp. 36

285. Mario Forni Sergio Paba [1999] "Knowledge Spillovers and the Growth of Local Industries" pp. 20

286. Gisella Facchinetti Giovanni Mastroleo [1999] "Un confronto tra uno score card ed un approccio fuzzy per la concessione del credito personale" pp.27

287. Gisella Facchinetti Giovanni Mastroleo e Sergio Paba [1999] "A Statistical and Fuzzy Algorithm for the Identification of Industrial Districts" pp. 6

288. Tommaso Minerva [1999] "Didattica e Informatica- *Una indagine Statistica relativa alla Provincia di Modena sul rapporto tra Insegnanti e Nuove Tecnologie" pp.* 46

289. Andrea Ginzburg [1999] "Sraffa e l'analisi sociale: alcune note metodologiche" pp. 37

290. Consolato Pellegrino Carla Fiori [1999] "Piani Formalmente Euclidei" pp. 11

291. Nicolina A. Malara, Maria Teresa Brandoli e Carla Fiori [1999] "Comportamenti di Studenti in Ingresso all'Università di Fronte allo Studio di Disequazioni" pp. 15

292. Consolato Pellegrino Maria Teresa Brandoli [1999] "Il Principio D'Induzione Euristica-Mente Parlando" pp. 11

293. Paolo Bertella Farnetti [1999] "Winston Churchill e l'unità europea" pp. 25

294. Tindara Addabbo Massimo Baldini [1999] "Safety net and poverty dynamics in Italy in the early nineties" pp. 23

295. Margherita Russo [2000] "Innovation Dynamics and Industrial Dynamics
Agents/Artifacts Space in Tile Decoration: from Silk Screen to Laser Engraved Silicon Cylinder" pp. 45

296. Gianluca Masci e Margherita Russo [2000] "L'attività brevettale nel distretto ceramico, 1971-1998" pp. 41

297. Paola Mengoli e Margherita Russo [2000] "Competenze, innovazione e sviluppo locale" pp. 31

298. Gian Paolo Caselli e Tommaso Minerva [2000] "The Transition Process in Russia and China and the Ising Model" pp. 30

299. Gisella Facchinetti, Giovanni Mastroleo e Sergio Paba (2000] "A Fuzzy Approach to the Empirical Identification of Industrial Districts" pp. 7

300. Tommaso Minerva, Irene Poli and Sebastiano Brusco [2000] "A Cellular Automaton as a Model to Study the Dynamics of an Industrial District" pp. 6

301. Gisella Facchinetti [2000] "Il problema della misurazione del rischio di credito: una rassegna critica di metodologie" pp. 13

302. Marco Mazzoli [2000] "Investments and Financial Structure with Imperfect Financial Markets: an Intertemporal Discrete-Time Framework" pp.13

303. Giuseppe Marotta [2000] "Il credito commerciale in Italia: evidenza su dati d'imprese" pp. 29

304. Marco Mazzoli [2000] "Credit Channel and Industrial Firms' Market power" pp. 15

305. Gisella Facchinetti e Giovanni Mastroleo [2000] "The Mamdani and the γ-operator in a Fuzzy Logic Control System" pp. 17

306. Giovanni Solinas e Giovanni Mastroleo [2000] "Benchmarking certificazione della qualità e piccole imprese. La sperimentazione di un modello europeo nelle piccole imprese in Emilia Romagna" pp. 45

307. Margherita Russo, Giorgio Allari, Silvano Bertini, Paolo Bonaretti, Elio De Leo, Giuseppe Fiorani and Gianni Rinaldini [2000] "The Challenges for the Next Debite: Notes for a debite on the Development of the Emilia-Romagna Region" pp. 27

308. Giovanni Mastroleo [2000] "L' integrazione dell'indagine statistica con l' approccio fuzzy nel controllo di efficacia: il monitoraggio sugli obiettivi raggiunti nell'ambito di un P.O.M" pp. 24

309. Gisella Facchinetti, Stefano Bordoni e Giovanni Mastroleo [2000] "Bank Creditworthiness Using Fuzzy Systems: A Comparison whit a Classical Analysis Approach" pp. 13

310. Margherita Russo e Raffaele Giardino [2000] "Struttura e cambiamento nelle relazioni tra le imprese meccaniche.
I. La popolazione di imprese meccaniche della provincia di Modena procedure impiegate per integrare le informazioni amministrative del Registro Imprese e dell'Inps" pp. 32

311. Tommaso Minerva e Sandra Paterlini [2000] "Tecniche Computazionali per la Statistica, l' Economia e la Finanza, *Materiale Didattico a Supporto del Corso di Statistica Computazionale*" pp.52

312. Costanza Torricelli e Silvia Muzzioli [2000] "Combining the Theory of Evidence with Fuzzy Sets for Binomial Option Pricing" pp.20

313. Marco Mazzoli e Roberto Negrini [2000] "Strumenti finanziari negoziabili e incentivo-compatibili per le imprese cooperative. *Alcune considerazioni teoriche e di policy*" pp. 32

314. Giacomo Galeotti e Tommaso Minerva [2000] "Algoritmi ibridi per l' ottimizzazione di un Portafoglio Azionario. *Simulazione stocastica filtrata mediante wavelet decomposition*" pp.33

315. Alberto Roverato [2000] "Hyper Inverse Wishart Distribution for Non-Decomposable Graphs and its Application to Bayesian Inference for Gaussian Graphical Models" pp. 29

316. Carlo Alberto Magni [2000] "Scomposizione di sovrapprofitti: Economic Value Added e valore aggiunto sistematico" pp. 25

317. Carlo Alberto Magni [20001 "Decomposition of a Certain Cash Flow Stream: Systemic Value Added and Net Final Value" pp. 30

318. Carlo Alberto Magni [2000) "Systemic Value Added, Residual Income and Decomposition of a Cash Flow Stream" pp 27

319. Gisella Facchinetti e Giovanni Mastroleo [2000] "La valutazione del rischio di frode nel ramo assicurativo R.C. auto: una proposta in logica Fuzzy" pp. 16

320. Gian Paolo Caselli e Gabriele Pastrello [2000] "Eltsin: Dimissioni o Licenziamento?" pp. 18

321. Gisella Facchinetti, Carlo Alberto Magni e Giovanni Mastroleo [2000] "Real Options: a Fuzzy Approach for Strategic Investments" pp.44

322. Stefano Bordoni [2000] "Applicazione Fuzzy per la determinazione del premio assicurativo" pp. 35

323. Gabriele Pastrello [2000] "Una distrazione di Marx" pp. 17

324. Marco Mazzoli [2000] "Canale creditizio, struttura di mercato, modifiche istituzionali e meccanismo di trasmissione della politica monetaria" pp. 18

325. Paola Bertolini e Luca Riazzi [2000] "L'applicabilità dello strumento futures al Mediterraneo riflessioni su un fallimento" pp.28

326. Enrico Giovanetti [2000] "Istituzioni e costi transattivi: l'impatto della regolazione dell'offerta nelle filiere agroindustriali" pp. 26

327. Gian Paolo Caselli e Marta Rosso [2000] "La moneta elettronica: aspetti di regolamentazione finanziaria".

328. Barbara Pistoresi e Chiara Strozzi [2000] "Labor Productivity and Labor Cost Dynamics in Italy: the Role of Wage Bargaining"pp. 23

329. Carlo Alberto Magni [2000] "Valore Aggiunto Sistemico: un'alternativa all'EVA quale indice di sovraprofitto periodale" pp.11

330. Carlo Alberto Magni [2000] "Ori Decomposing Net Final Values: Systemic Value Added and Shadow Project" pp. 26

331. Massimo Baldini [2000] "MAPP98: un Modello di Analisi delle Politiche Pubbliche" pp. 24

332. Paolo Bosi, Massimo Baldini, Maria Cecilia Guerra e Paolo Silvestri [2000] "La scelta tra ICI e Addizionale all'Irpef nella Politica tributaria locale: aspetti distributivi" pp. 27

333. Marina Murat e Sergio Paba [2000] "Flussi migratori e modelli di sviluppo industriale- *L'esperienza italiana dal dopoguerra agli anni novanta*" pp. 32

334. Marco Mazzoli e Roberto Negrini [2000] "Incentive-Compatible Financial Instruments for Co-Operative Firms: a Few Policy Considerations" pp. 27

335. Massimo Baldini e Paolo Bosi [2000] "Riforme trasparenti e proposte opache" pp. 10

336. Paolo Bosi [2000] "La selettività nelle politiche sociali in Italia: riflessioni sull'esperienza dell'Ise" pp. 16

337. Massimo Baldini, Paolo Bosi e Stefano Toso [2000] "Targeting Welfare in Italy: Old Problems and Perspectives of Reform" pp. 21

338. Tindara Addabbo e Massimo Baldini [2000] "The Gender Impact of Workfare Policies in Italy and the Effect of Unpaid Work" pp. 15

339. Gian Paolo Caselli e Thoma Grid [2000] "La storia economica albanese 1912-1939 e lo stabilirsi dell'egemonia italiana" pp. 46

340. Tommaso Minerva [2000] "La costruzione di modelli con algoritmi genetici" pp. 183

341. Giovanni Bonifati [2000] -PRODUZIONE, INVESTIMENTI E PRODUTTIVITA'. Rendimenti crescenti e cambiamento strutturale nell'industria manifatturiera americana (1960-1994)" pp. 43

342. Luciano Messori [2000] "Struttura e quantificazione di una imposizione fiscale Pigouviana sulla benzina" pp. 20

343. Carlo Alberto Magni [2000] "Zelig and the Art of Measuring Residual Income" pp. 18

344. Sandra Paterlini, Stefano Favaro e Tommaso Minerva [2001] "Genetic Approaches for Data Clustering" pp. 4

345. Enrico Giovanetti [2001] "Processi di vita delle imprese cooperative: mezzo secolo di cooperazione a Modena, dal dopoguerra a oggi" pp. 34

346. Giuseppe Marotta [2001] "Is Trade Credit More Expensive Than Bank Loans? Evidence from Italian Firm-level Data" pp. 26

347. Massimo Baldini e Paolo Bosi [2001] "Flat Rate Tax, Dividendo sociale e riforma dei programmi di spesa di assistenza" pp. 34

348. Paolo Bosi e Maria Cecilia Guerra [2001] "Meno Tasse per tutti:lusinghe e ambiguità di uno slogan" pp. 17

349. Danilo Mercurio e Costanza Torricelli [2001] "Estimation and Arbitrage Opportunities for Exchange Rate Baskets" pp. 27

350. Caselli e Grid Thoma [2001] "L'economia Albanese durante il secondo conflitto mondiale e il primo tentativo di pianificazione" pp n. 33

351. Massimo Baldini e Carlo Mazzaferro [2001] "Sistema pensionistico e distribuzione dei redditi in italia dal 1997 al 1998: un'analisi sull'archivio storico dell'indagine campionaria della banca d'Italia" pp.16

352. Silvia Giannini [2001] " La tassazione del reddito d'impresa e le scelte di investimento, finanziamento e localizzazione dell'attività produttiva" pp.

353. Michele Baccarini [2001] "Un quadro normativo delle fattispecie contrattuali "atipiche" in Italia. *Disciplina legislativa e definizioni statistiche del lavoro a tempo parziale"* pp. 29

354. Michele Baccarini [2001] "Sul grado di volontarietà e di sottoccupazione del lavoro dipendente "atipico". *Un'analisi delle valutazioni dei lavoratori"* pp. 43

355. Maria Cecilia Guerra [2001] "La Previdenza Complementare deve essere incentivata fiscalmente?" pp. 22

356. Gabriele Pastrello [2001] "An Oversight of Marx's" pp. 66

357. Alberto Roverato e Consonni Guido [2001] "Compatible prior distributions for DAG models" pp. 28

358. Luigi Brighi e Reinhard John [2001] "Characterizations of Pseudomonotone Maps and Economic Equilibrium" pp.25

359. Luigi Brighi [2001] "A Stronger Criterion for the Weak Weak Axiom" pp.16

360. Luigi Brighi [2001] "The Weak Axiom, the σ-Axiom and Complete Non-Transitive Rationality" pp.14

361. Luigi Brighi e Reinhard John [2001] "Some Conditions for Wald's Weak Axiom" pp. 10

362. Sebastiano Brusco, Tommaso Minerva e Giovanni Solinas [2001] "Un automa cellulare per lo studio dei distretti industriali" pp. 30

363. Nicola Walter Palmieri [2001] "Internet e la libertà di espressione" pp. 65

364. Marco Mazzoli [2001] "A Simple Enquiry on Heterogeneous Lending Rates and Lending Behaviour" pp. 37

365. Massimo Baldini e Paolo Onofri [2001] "Transizione demografica e mercati finanziari" pp. 19

366. Marco Mazzoli [2001] "Industrial Firms' Market Power and Credit Market Oligopsony in Developing Countries" pp.14

367. Gisella Facchinetti, Silvio Giove e Nicoletta Pacchiarotti [2001] "Optimisation of a Fuzzy non Linear Function" pp. 10

368. Silvia Muzzioli e Costanza Torricelli [2001] "Implied Trees in Illiquid Markets: a Choquet Pricing Approach" pp. 18

369. Cinzia Mortarino [2001] "A Decomposition for a Stochastic Matrix whit an Application to Manova" pp.

370. Sandra Paterlini e Tommaso Minerva [2001] "Evolutionary Cluster Analysis" pp. 8

371. Paola Bertolini [2001] "Globalisation et Systèmes Agro-alimentaires de qualité en Italie. Le cas du District de Trasformation des Viandes Porcines pp. 28