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A Fuzzy Approach to the Empirical Identification of Industrial Districts

by

Gisella Facchinetti*
Giovanni Mastroleo**
Sergio Paba***

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Università degli Studi di Modena e Reggio Emilia
Dipartimento di Economia Politica
Via Berengario, 51
41100 Modena (Italia)
* e-mail:facchinetti@unimo.it
** e-mail:mastroleo@unimo.it
*** e-mail:paba@unimo.it

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Abstract

Building on Istat [5], Brusco and Paba [4] developed a mathematical algorithm which tries to identify the Italian industrial districts and to quantity their importance in the manufacturing industry. Unfortunately, this algorithm is too rigid and it rules out some important small-firm specialized local systems. To solve this problem, we propose a Fuzzy System. We obtain three main results. (1) With the fuzzy approach, most of the industrial districts identified in the current literature are still included, but it is now possible to recover some important local systems ruled out by the crisp approach. (2) The score obtained allows us to rank, sector by sector, all the industrial districts according to their quantitative importance and to their adherence to the characteristics emphasized in the literature, whereas the crisp approach says only yes or not. (3) We can provide a more reliable estimate of the overall importance of the industrial districts over total manufacturing employment in Italy.

Keywords:

Industrial Districts, Fuzzy Inference Systems.

1. Introduction

With the passage of time and accumulation of experience, it is becoming increasingly clear that the real-world decision-making is too much complex, uncertain and imprecise to lend itself to precise, prescriptive analysis. It is this realisation that underlies the rapidly growing shift from conventional techniques of decision analysis to technologies based on fuzzy logic. Up to now, engineering applications of fuzzy logic have gained much more attention than business and finance applications, but an even larger potential exists in the latter fields. In this paper, we show that the fuzzy approach may be useful in industrial economics. In particular, we address a very important issue in the industrial districts literature, namely how to identify empirically the industrial districts using official statistical data. This issue has also important policy implications: according to the law, industrial districts might benefit from subsidies or specific development policies. Pyke and Sengenberger [10] defined an industrial district as a "local productive system, characterised by a large number of firms that are involved at various stages, and in various ways, in the production of a homogeneous product. A significant feature is that a very high proportion of these firms are small or very small". Istat [5] and Brusco and Paba [4] tried to estimate the overall importance of industrial districts in the Italian economy using 1991 census data on economic activity. In both studies, the spatial units of observation are the "local labour systems", defined for the year 1981 and 1991 by Istat-Irpet [6] and Istat [7]. According to the first study, the share of employment in the industrial districts over total Italian manufacturing employment was equal to 42,5% in 1991, while according to the second study, which follows a slightly different estimation approach, the share was equal to 32%. Both estimates are obtained by using roughly the same statistical algorithm. This algorithm is based on four distinct indexes. The first measures the share of manufacturing employment in the local system, the second the share of manufacturing employment in small firms (less than 250 employees in the case of ISTAT, less than 100 employees in the case of Brusco-Paba), the third is a specialisation index for each 2-digit manufacturing sector, the fourth measures the share of employment in small firms in the specialised sector. All indexes are computed with respect to national averages. A local labour system is defined as industrial district only if the above indexes result simultaneously greater than one for at least one 2-digit local manufacturing sector. Unfortunately this algorithm is too restrictive and rules out some important and well-known small-firms, specialised local industries. This, for example, is the case of the textile district of Biella, a small town in which 850 firms and 12,000 employees work in the textile sector. The furniture industry of Udine, in which more than 11,000 workers are employed in hundreds of small firms, is another case in point. In order to solve this problem and provide more reliable estimates of the industrial districts, we propose a Fuzzy Inference System, [1], [12]. This method includes the fuzzification of the variables, the creation of the rules block, and the fuzzy inference, which permits to evaluate the rules. The rules chosen are such that if, for each 2-digit manufacturing sector, one index turns out slightly less than one, this deficiency is balanced by a good performance of the other indexes. We decided to add three new variables to the four indexes, whose aim is to evaluate the relative importance of the local industry within each national manufacturing sector, and to control for the presence of large firms. As a result, our Fuzzy System provides a total score for each local system and for each manufacturing sector. We have tested this system using the census data from 1951 to 1991 relative to the 955 local labour systems. We obtain three main results. (i) Most of the industrial districts identified in the current literature are still included, but it is now possible to recover some important small-firm specialized local industries ruled out by the crisp approach. (ii) Using the scores obtained, we are able to rank the districts according to their degree of adherence to the requisites suggested by the literature and to their relative importance in the industry, a result that is not possible with the crisp approach. We present an example for the textile and wood-furniture sectors in 1991. (iii) Finally, we provide a more reliable estimate of the overall importance of industrial districts in the Italian manufacturing industry for the five census years and for each 2-digit industrial sector.

2. Crisp algorithm

The algorithm developed by Brusco and Paba [4] utilizes four indexes that must be greater than one. Indicating employment with L, the local labour system with the subscript j, each manufacturing sector with the subscript i, the whole manufacturing industry with the subscript m, we get:

$$\frac{L_{jm}}{L_j} \Big/ \frac{L_m}{L} > 1 \qquad \text{[share of manufacturing]} \qquad (1)$$

where L represents total employment in the nation.

$$\frac{L_{jm,small}}{L_{jm}} \bigg/ \frac{L_{m,small}}{L_m} > 1 \qquad \text{[small firm condition]} \qquad (2)$$

where the subscript *small* indicates employment in firms with less than 100 employees and *Lm* is total manufacturing employment in the nation.

For at least one sector i :

$$\frac{L_{ji}}{L_{jm}} \bigg/ \frac{L_i}{L_m} > 1 \qquad \text{[specialization index]} \qquad (3)$$

where L_i is total national employment in the sector i.

For at least one sector i for which the index defined in 3 is satisfied, it is required that:

$$\frac{L_{ji,small}}{L_{ji}} \bigg/ \frac{L_{i,small}}{L_i} > 1 \text{ [small firms in the specialized sector]} (4)$$

If a local system satisfies conditions (1) and (2) and, for at least one sector i, conditions 3 and 4 are also satisfied, the local system is called «industrial district» and the sector i, for which conditions (3) and (4) are satisfied, is called «specialization» of the district. One district may have more than one specializations. In this case, the sector with the highest specialization index is called «dominant sector» and usually the district is identified by that sector.

3. Fuzzy Set Theory

Fuzzy set theory was originally proposed as a means for representing uncertainty and formalising qualitative concepts that have no precise boundaries. In many situations, it is difficult to describe phenomena simply in terms of black and white distinctions. Language, our primary means of communication, is anything but precise. For example, we speak of "medium-sized companies", "high leveraged companies", "low level of employment", and we use all these adjectives as useful approximations to classify objects. Classification provides a simple mean of expression. It lets us state things in general terms and interpret these generalisations depending on the context. For example, in the case of industrial districts the first condition of the crisp algorithm is

$$\frac{L_{jm}}{L_j} \bigg/ \frac{L_m}{L} > 1 \qquad (1)$$

This is a mathematical translation of the following linguistic expression: "The share of manufacturing employment over total employment in the local labour system j has to be *greater than* the share of manufacturing employment over total employment at country level". What do we mean by *greater than*? The crisp definition has translated this linguistic statement in 1, treating in the same way quotient results like 1.5, 4, 10.7, and considering in a really different way a result like 0,9999. The Boolean translation of the linguistic statement *greater than* does not allow us to distinguish between different values of the index, except at the boundary. But, in economic terms, is it reasonable to consider a local labour system with a value of 0.9999 so different from one that shows for the same index the value of 1,0001? This problem has been at the base of our idea to apply a fuzzy logic approach to the definition of industrial districts. In fact, fuzzy set theory supports reasoning about these kinds of situations. It is based on gradation instead of sharp distinction. It is a method of reasoning that allows for partial or "fuzzy" description of reality.

Consider a classical (crisp) set A contained in a universe X. A fuzzy set A is defined by a set of ordered pairs,

$$A = \{(x, \mu_A(x)) : x \in A, \mu_A(x) \in [0,1]\}$$

where $\mu_A(x)$ is called Membership function of the set A.

The **height** of a fuzzy set is the maximum value that its membership function realises.

A fuzzy set is called **normal** if its height is 1.

If the fuzzy set is not normal, it is always possible to **normalise** it, changing $\mu_A(x)$ with:

$$\tilde{\mu}_A(x) = \frac{\mu_A(x)}{\max_{x \in A} \mu_A(x)}$$

The **domain** of a fuzzy set A is the domain of. $\mu_A(x)$.

The **support** of a fuzzy set A is the subset of X in which the membership function is positive.

A fuzzy set A is a **Convex fuzzy set**, if

$\forall \lambda \in [0,1]$ and $\forall x_1, x_2 \in A$

$$\mu_A[\lambda x_1 + (1-\lambda)x_2] \geq \min\{\mu_A(x_1), \mu_A(x_2)\}$$

A **fuzzy number** is a fuzzy set defined on the universe R, which is convex and normalised. A great variety of membership functions have been proposed in the scientific literature. The more common types of membership functions are the piece-linear or spline shapes. In this paper we use triangular, trapezoidal types called "Standard Membership Function".

4. A fuzzy expert system

An expert system is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions. The knowledge of an expert system consists of facts and heuristics. The facts usually constitute a body of information that is widely shared, publicly available, and generally agreed upon by experts in the field. Heuristics concerns mostly private information and rules of good judgement that characterise expert-level decision making in the field. A fuzzy expert system is an expert system that utilises fuzzy sets and fuzzy logic to overcome some of the problems which occur when the data provided by the user are vague or incomplete. The power of fuzzy set theory comes from the ability to describe linguistically a particular phenomenon or process, and then to represent that description with a small number of very flexible rules. In a fuzzy system, the knowledge is contained both in its rules and in fuzzy sets, which hold general description of the properties of the phenomenon under consideration. One of the major differences between a fuzzy expert system and another expert system is that the first can infer multiple conclusions. In fact it provides all possible solutions whose truth is above a certain threshold, and the user or the application program can then choose the appropriate solution depending on the particular situation. This fact adds flexibility to the system and makes it more powerful. Fuzzy expert systems use fuzzy data, fuzzy rules, and fuzzy inference, in addition to the standard ones implemented in the ordinary expert systems.

The following are the main phases of a fuzzy system design. [8]

1. Identification of the problem and choice of the type of fuzzy system which best suits the problem requirement. A modular system can be designed consisting of several fuzzy modules linked together. A modular approach, if applicable, may greatly simplify the design of the whole system,

dramatically reducing its complexity and making it more comprehensible.

2. Definition of input and output variables, their linguistic attributes (fuzzy values) and their membership function (fuzzification of input and output).
3. Definition of the set of heuristic fuzzy rules. (IF-THEN rules).
4. Choice of the fuzzy inference method (selection of aggregation operators for precondition and conclusion).
5. Translation of the fuzzy output in a crisp value (defuzzification methods).
6. Test of the fuzzy system prototype, drawing of the goal function between input and output fuzzy variables, change of membership functions and fuzzy rules if necessary, tuning of the fuzzy system, validation of results.

In building fuzzy expert systems, the crucial steps are the fuzzification and the construction of blocks of fuzzy rules. These steps can be handled in two different ways. The first is by using information obtained through interviews to the experts of the problem. The second is by using methods of machine-learning, neural networks and genetic algorithms to learn membership functions and fuzzy rules. The two approaches are quite different. The first does not use the past history of the problem, but it relies on the experience of experts who have worked in the field for years. The second is based only on past data and project into the future the same structure of the past. The first approach seems preferable for our purpose, because no systematic past data on industrial districts are available and because the empirical identification of the industrial districts requires a careful assessment of their characteristics that only experts in this field can make.
We can formalise the steps in the following manner.
For each linguistic variable, input x_i (i=1...m) and output y, we have to fix the one's range of variability U_i and V.

$\forall$ i, (i=1...m), if n_i is the number of the linguistic attribute of the variable x_i and

$\hat{n} = \max_{i \in [1,m]} n_i$, we define the set

$$A^i = \{A_1^i, A_2^i, .., A_{j_i}^i, ..., A_{n_i}^i\}$$

where $\forall\ j_i \in [1,\ n_i],\ \forall\ n_i\ \in [1, \hat{n}]\ \ A_{j_i}^i$ are the fuzzy numbers describing the linguistic attributes of the input variable x_i

In the same way we define the set

$$B = \{B_1, B_2, ..., B_k, ..., B_r\}$$

where $\forall k \in [1, r]\ \ B_k$ are the fuzzy numbers describing the linguistic attributes of the output variable y.

At every elements of A^i and B is associated a membership function

$$\mu_{A_{j_i}^i}(x) : U_i \to [0,1] \qquad \text{and} \qquad \mu_{B_k} : V \to [0,1]$$

The elements of A^i and *B* overlap in some "grey" zone which cannot be characterised precisely. Many phenomena in the world do not fall clearly into one crisp category or another. Experts that use abstraction as a way of simplifying the problem can contribute to identify these "grey" zones.

The choice of the slopes of the elements of A^i and *B* is a mathematical translation of what the experts think about the single terms.

The second step is the block-rules construction.

We define the set of L fuzzy rules, where $L \leq \prod_1^m n_i$,

$\forall\ j_i \in [1,\ n_i],\ \forall\ n_i\ \in [1, \hat{n}]\ \forall k \in [1, r]$

$$\text{IF } (x_1 \text{ is } A_{j_1}^1) \otimes (x_2 \text{ is } A_{j_2}^2) \otimes \ldots \otimes (x_m \text{ is } A_{j_m}^m) \quad (5)$$

THEN (y is B_k),

The relation (5) is called "precondition" and the symbol $\otimes$ represents one of the possible aggregation operators. In practical applications, the MIN and MAX operators, or a convex combination of them, are widely used and so a "negative" or "positive" compensation will occur for different values of γ.

$$\gamma MIN + (1-\gamma) MAX \quad \text{with } \gamma \in [0,1]$$

Instead of Min and Max, it is also possible to use other t-norms or conorms, which represent different ways of linking the "and" with the "or".

More generally, indicating with $\mu_{A \cap B}$ a general membership of the intersection and with $\mu_{A \cup B}$ a general membership of the union, we can define as membership of the aggregated set $A \Theta B$

$$\mu_{A \Theta B} = \mu_{A \cap B}^{1-\gamma} * \mu_{A \cup B}^{\gamma} \qquad \text{with } \gamma \in [0,1]$$

This is not, in general, a t-norm or a t-conorm. In particular, if we use the algebraic product and sum as intersection and union, we obtain the Gamma operator [13]

$$\mu = \left(\prod_1^n \mu_i \right)^{(1-\gamma)} * \left(1 - \prod_1^n (1 - \mu_i) \right)^{\gamma}$$

The parameter γ denotes the degree of compensation. As it is shown in some recent work, this aggregator concept can represent the human decision process more accurately than others [12]. The relation (6) is called conclusion. The aggregation of precondition and conclusion can be made in several ways. The more used are the MAX and the BSUM methods. The choice depends of the type of application. The MAX has the meaning of keeping as "winner" the strongest rule, in the sense that if a rule is "firing" (activated) more then one time, the result is the maximum level of firing. In the BSUM case, all the firing degree is considered and the final result is the sum of the different level of activation (not over one). In any case, the two methods produce a fuzzy set, which has membership function $\mu_{agg}(y)$.

Now we have a result of the fuzzy inference system, which is a fuzzy replay. We need to return to a "crisp" value, and this step is called "defuzzification". This operation produces a "crisp" action $\bar{y}$ that adequately represents the membership function $\mu_{agg}(y)$. There is no unique way to perform this operation. To select the proper method, it is necessary to understand the linguistic meaning that underlies the defuzzification process. Two of these different linguistic meanings are of practical importance: the "*best compromise*" and the "*most plausible result*". A method of the first type is the Centre of Area (CoA) that produces the abscissa of the centre of gravity of the fuzzy output set

$$\bar{y} = \frac{\int_V y\mu_{agg}(y)dy}{\int_V \mu_{agg}(y)dy}$$

A method of the second type is the "Mean of Maximum" (MoM). Rather then balancing out the different inference results, this method selects the typical value of the terms that is most valid [12].

5. Fuzzy industrial districts

In this section, we propose a specific fuzzy expert system [1],[12] with the aim of identifying the industrial districts in the Italian manufacturing industry. We use the same data-set of Istat [5] and Brusco-Paba [4], based on census data on economic activity. We start with the crisp algorithm applied in the above literature. In particular, we use as initial inputs the four indexes described in section 2. These inputs are aggregated together to provide an intermediate output. We decided to consider the index of specialisation (3) as the most important of the four, provided that the conditions on firms' size are met. The crisp approach does not discriminate between a district with few employees and a district employing a relevant share of workers in a specific sector, because the crisp replay is "yes or not". As a consequence, the simple fuzzification of the four indexes provides a ranking in which industrial districts with a small number of workers may be ranked in a better position than districts that are much more important in the terms of employment [2], [3]. To avoid this and to provide a ranking that has a clear economic interpretation, we have added three new variables. For each 2-digit manufacturing sector, these are (i) the share of employment in firms with less than 200 employees (Empl 200), (ii) the share of employees in the local system over total national employment (Empl perc) (iii) the absolute number of employees in the local system (Employees) (figure 1).

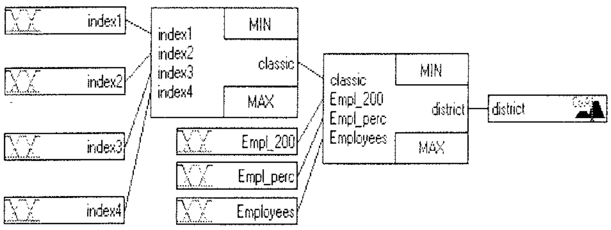

Figure 1. Layout of the fuzzy system.

The aim of these variables is, respectively, to control for the presence of medium sized and large firms, to weight the relative importance of the local industry in a specific sector, to rule out local industries that are too small in absolute terms to have economic significance. From Figure 1, is possible to see that we have used the MIN operator as aggregator of previous data while for the resulting aggregation we have used the MAX method.

For the defuzzification step we have used the Center of Area (CoA).

6. Fuzzification of the inputs

The first two indexes have been fuzzified using three linguistic terms.

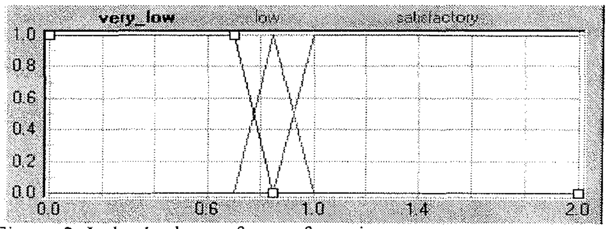

Figure 2. Index1: share of manufacturing

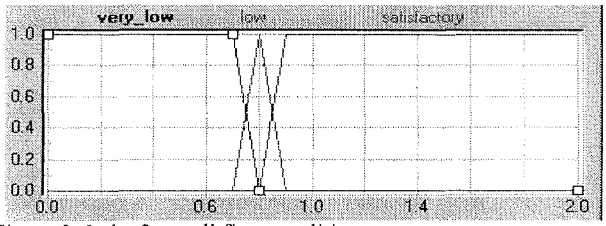

Figure 3. Index2: small firm condition

The other two indexes have been fuzzified using four linguistic terms.

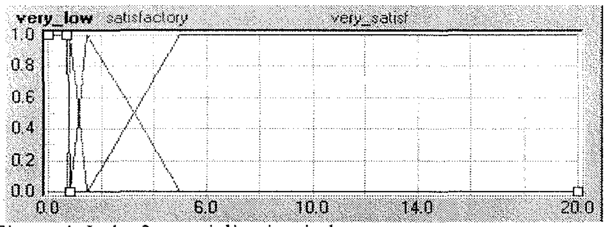

Figure 4. Index3: specialization index

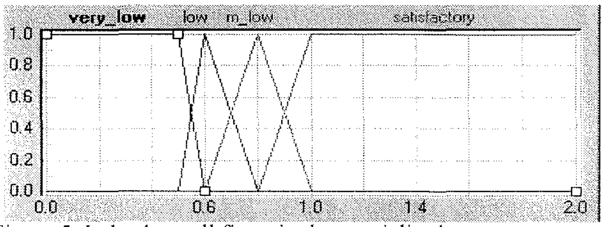

Figure 5. Index4: small firms in the specialized sector

The shapes and the numbers of the terms of every fuzzificated index have been obtained in two phases. First we analyse the distribution of the values of each index in the five decades. Second, in order to have a greater level of precision on every input, we use different numbers of terms in the fuzzification and a different localisation of the significant point of the terms. This last device allows us to take into account the zones of the distribution obtained in the first step, for which a greater information is required.

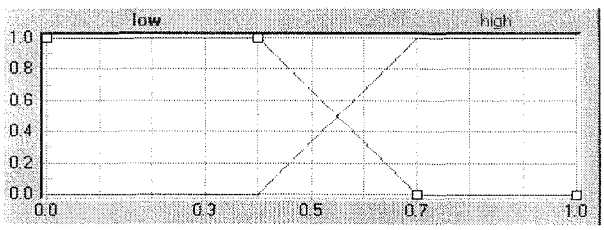

Figure 6. Empl_200: share of employment in firms under 200

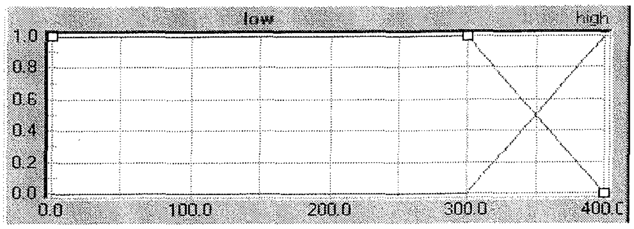

Figure 7. Employees

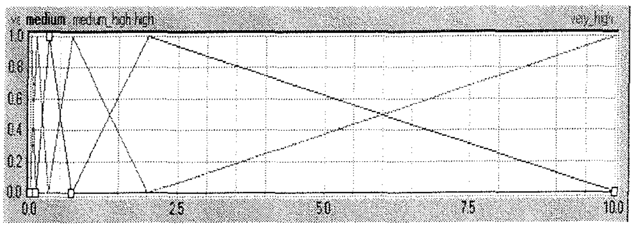

Figure 8. Empl_perc: rate of employed in the local system over the total of employees of the sector

7. Rule-Block

The first Rule-Block, which has 144 rules, is obtained combining the total terms of the four indexes. In figure 9 we show a rule block with only 25 rules containing all the rules written in compact structure. The intermediate output evaluates, for each local system, the structural characteristics of the manufacturing industry as a whole and of each 2-digit manufacturing sector.

#	IF				THEN	
	index1	index2	index3	index4	DoS	classic
1				very_low	1.00	low
2			very_low	low	1.00	low
3			low	low	1.00	low
4			satisfactory	low	1.00	low
5			very_satisf	low	1.00	medium
6	low	low	satisfactory	m_low	1.00	low
7	low	low	very_satisf	m_low	1.00	low
8	low	satisfactory	satisfactory	m_low	1.00	low
9	satisfactory	low	satisfactory	m_low	1.00	low
10	low	satisfactory	very_satisf	m_low	1.00	medium
11	satisfactory	low	very_satisf	m_low	1.00	medium
12	satisfactory	satisfactory	satisfactory	m_low	1.00	medium
13	satisfactory	satisfactory	very_satisf	m_low	1.00	high
14	low	low	satisfactory	satisfactory	1.00	low
15	low	low	very_satisf	satisfactory	1.00	medium
16	low	satisfactory	satisfactory	satisfactory	1.00	medium
17	satisfactory	low	satisfactory	satisfactory	1.00	medium
18	low	satisfactory	very_satisf	satisfactory	1.00	high
19	satisfactory	low	very_satisf	satisfactory	1.00	high
20	satisfactory	satisfactory	satisfactory	satisfactory	1.00	high
21	satisfactory	satisfactory	very_satisf	satisfactory	1.00	very_high
22	very_low				1.00	low
23		very_low			1.00	low
24			very_low		1.00	low
25			low		1.00	low

Figure 9. Rule block 1.

The second Rule Block is obtained combining the intermediate output with the control variables. The final output provides, for each sector, a ranking of all the local systems according to their adherence to the characteristics emphasised in the literature. All the local systems that have a final valuation bigger or equal to 100% can be classified as «fuzzy industrial districts».

#	IF				THEN	
	classic	Empl_200	Empl_perc	Employees	DoS	district
1	low	high		high	1.00	very_low
2		low			1.00	very_low
3				low	1.00	very_low
4	medium	high	low	high	1.00	low
5		high	very_low	high	1.00	low
6	medium	high	medium	high	1.00	medium_low
7	medium	high	medium_high	high	1.00	medium
8	medium	high	high	high	1.00	medium
9	high	high	low	high	1.00	medium
10	high	high	medium	high	1.00	medium
11	very_high	high	low	high	1.00	medium
12	medium	high	very_high	high	1.00	medium_high
13	high	high	medium_high	high	1.00	medium_high
14	very_high	high	medium	high	1.00	medium_high
15	high	high	high	high	1.00	high
16	high	high	very_high	high	1.00	high
17	very_high	high	medium_high	high	1.00	high
18	very_high	high	high	high	1.00	very_high
19	very_high	high	very_high	high	1.00	very_high

Figure 10. Rule block 2.

The output variable of the system is represented by seven terms, which are more concentrated in the area of values greater than one. With this choice, we obtain a more refined final score of the districts (figure 11).

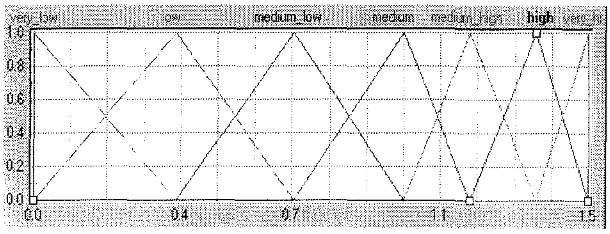

Figure 11. District: output variable

8. Some scores of fuzzy districts

In figures 4 and 5, we report some results relative to the textile and wood-furniture industries in 1991. First, notice that a number of important local systems that are not districts in the crisp sense, can now be defined as industrial districts with the fuzzy approach. This, for example, is the case of Biella, Busto Arsizio, and Como in the textile sector, and Udine, Pesaro and Sacile in the wood-furniture industry. This is because the relatively poor performance of some index is more than counterbalanced by a good performance of some other index. In particular, these districts employ a relevant share of national employment, are highly specialized, have a significant amount of employment in small firms, although the average size of firms may result slightly above the national average due to the presence of some medium sized firms. Second, we are now able to rank the districts according to their adherence to the characteristics emphasized in the literature and to their relative importance in terms of employment. As expected, Prato, Carpi, Gallarate and Biella show the highest scores in the textile industry, and Giussano, Udine, Pesaro and Monza are the first local systems in the wood-furniture sector.

Local system	Empl %	Empl	E<200	index 1°	index 2°	index 3°	index 4°	Classic	Fuzzy
Prato	**10,18**	38078	100%	1,4658	1,4456	10,7901	1,3263	YES	**150,0%**
Carpi	**2,10**	7856	100%	1,6482	1,3162	5,0465	1,3136	YES	**150,0%**
Gallarate	**3,20**	11984	96%	1,6558	1,1638	3,7814	1,1661	YES	**145,0%**
Biella	**3,32**	12430	82%	1,3074	**0,9944**	8,9354	**0,9229**	NO	**144,5%**
Asola	**1,09**	4076	88%	1,726	1,2759	9,1629	1,0808	YES	**139,9%**
Como	**2,90**	10855	88%	1,151	**0,9649**	5,5082	**0,8364**	NO	**138,3%**
Cossato	**2,35**	8771	79%	1,6748	**0,9632**	11,0225	**0,7922**	NO	**133,6%**
Olgiate Comasco	**1,60**	5975	86%	1,6295	**0,8859**	5,4742	**0,879**	NO	**132,3%**
Busto Arsizio	**4,09**	15283	81%	1,5404	1,0696	3,5943	**0,9274**	NO	**130,1%**
Leffe	**1,27**	4763	75%	1,7726	1,0485	6,816	**0,8419**	NO	**130,0%**
Treviso	**1,49**	5590	75%	1,2008	1,126	2,0015	**0,9793**	NO	**128,9%**
Oggiono	0,81	3031	76%	1,6882	1,1253	3,599	**0,9842**	NO	**128,2%**
Pistoia	0,78	2913	100%	1,1459	1,2905	2,6206	1,3634	YES	**125,2%**
Mirandola	0,71	2661	91%	1,5618	1,0679	2,2599	1,2451	YES	**122,2%**
Thiene	0,63	2341	88%	1,7222	1,0787	2,3327	1,1206	YES	**118,8%**
Palazzolo Sull'O	0,74	2779	93%	1,6548	1,2065	1,9682	**0,9327**	NO	**115,8%**

Figure 12. Textile '91

Local system	Empl %	Empl	E<200	index 1°	index 2°	index 3°	index 4°	Classic	Fuzzy
Giussano	**2,30**	9317	98%	1,6815	1,2672	5,8384	1,0202	YES	**150,0%**
Udine	**2,81**	11372	100%	1,0198	1,1029	4,8667	**0,9959**	NO	**147,7%**
Pesaro	**2,07**	8363	93%	1,208	1,2762	6,5849	**0,9512**	NO	**146,5%**
Monza	**3,58**	14483	100%	1,3781	1,0535	2,8803	1,0262	YES	**141,3%**
Cerea	0,98	3972	100%	1,6131	1,2942	8,7285	1,0227	YES	**138,7%**
Pieve Di Sligo	0,99	4026	100%	1,682	1,2317	6,2504	**0,9887**	NO	**137,8%**
Cantù	**1,35**	5456	96%	1,5522	1,1942	5,6996	**0,9446**	NO	**137,4%**
Motta Di Livenza	0,86	3487	100%	1,5743	1,3948	7,5611	1,0594	YES	**137,4%**
Bovolone	0,85	3425	100%	1,5813	1,2598	6,8601	1,0052	YES	**137,3%**
Pistoia	0,89	3596	100%	1,1459	1,2905	2,9894	1,0546	YES	**128,7%**
Pontedera	0,96	3874	95%	1,4426	**0,9679**	2,7143	1,0356	NO	**128,5%**
Montagnana	0,52	2106	100%	1,532	1,382	5,4136	1,0923	YES	**127,8%**
Forlì	0,90	3651	100%	1,0254	1,2335	2,6209	1,0037	YES	**127,3%**
Bassano Del Grappa	0,88	3561	100%	1,5048	1,2455	1,9745	1,0595	YES	**124,1%**
Oderzo	0,76	3084	89%	1,3241	1,1225	4,864	**0,8589**	NO	**123,6%**
Sacile	**2,07**	8360	89%	1,5746	1,0417	7,9099	**0,7254**	NO	**122,3%**

Figure 13. Wood '91

9. The fuzzy industrial districts in the Italian manufacturing industry

So far we have discussed industrial districts as specific local manufacturing sectors satisfying a set of conditions. These sectors, however, are located in a small-firm industrial environment –the local labour system- sharing the same social, institutional and economic characteristics. For this reason, the literature usually identifies the industrial district not just with a specific sector but with the whole local system (the geographical space). For example, when we speak of the industrial district of Prato, we include in the definition not only the textile industry, for which all the indexes are easily satisfied, but also the employment in all other manufacturing sectors, even if some of them do not satisfy the specialization or the small-firm conditions. From this more general perspective, a local labour system is an industrial district if it satisfies conditions (1) and (2) and, for at least one manufacturing sector, also conditions (3) and (4). We use this broader definition, as it is usually done in the literature, in order to estimate the share of employment in industrial districts over total employment at country level. Note that in this case we sum all the manufacturing employment located in the districts, which may also include employment in large firms in sectors which fail conditions (3) and (4). This is reasonable, if the sectors satisfying all the conditions are relevant in terms of employment in the local system, but it is certainly undesirable if these sectors turn out to be locally unimportant. In the last case, it may be illegitimate to classify the local system as an industrial district. Note that Marshall [9] himself, the great economist who introduced the notion of industrial district in the economics literature, described the local predominance of a specific industry as a typical feature of the industrial district. In his own words, that industry is locally so important that its "secrets are in the air". To take account of this, we calculated the relative weight in terms of employment of the sectors that satisfy our fuzzy algorithm for each local system. We than labelled "industrial districts" only the local systems for which the sum of employment shares of the above sectors is bigger than 0,25. In other words, we require that more than a quarter of total manufacturing employment of a local system be employed in sectors that share the structural characteristics described by the four conditions. Using the census database, we are now able to estimate the relative importance of industrial districts in the Italian industry for the period 1951-1991. The estimates for the whole manufacturing sector are reported in Table 1 and compared with the results obtained by Brusco-Paba [4]. First, compared with the crisp algorithm, the total number of districts for each census year is much lower with the fuzzy approach, particularly in the last three periods. The main reason is that the former includes in the definition many small or very small local systems that are ruled out in our system.

Table 1. N° of districts	1951	1961	1971	1981	1991
N° of fuzzy districts	106	93	90	123	145
N° of Brusco-Paba districts	149	101	166	208	238

Second, in Table 2, the aggregate results in terms of employment are quite similar to those obtained by Brusco-Paba, but only for the last three census years.

Table 2. Employment in industrial districts over total manufacturing employment	1951	1961	1971	1981	1991
Fuzzy districts	0.176	0.248	0.191	0.270	0.319
Brusco-Paba districts	0.103	0.136	0.201	0.259	0.317

They differ significantly in 1951 and 1961, where the fuzzy estimates are respectively 7 and 11 percentage points higher.

Notice, however, that even when the estimates are similar, the list of districts can be quite different. The set of fuzzy districts includes not only all the important crisp districts, but it also includes important small-firm, specialized local systems excluded by the crisp approach. An idea of the importance of the fuzzy industrial districts for each manufacturing sector and for each census year is provided by figure 14. In terms of employment, this form of organization of industry has steadily increased its importance particularly in the leather, textile, clothing-footwear, and wood-furniture industries.

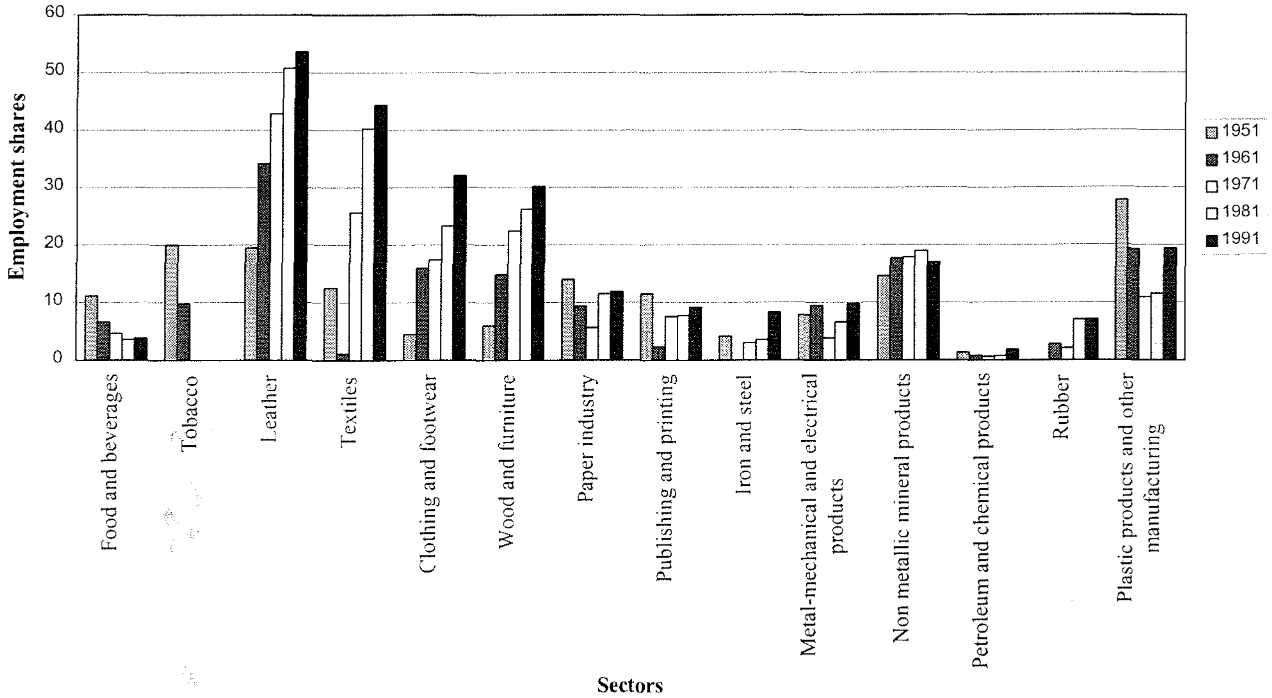

Figure 14. Share of employment in industrial districts for each manufacturing sector.

10. Conclusion

In comparison with the crisp approach prevailing in the literature, the application of a fuzzy algorithm to the empirical identification of industrial districts presents three main advantages. First, it allows the inclusion of some important districts that are usually ruled out by the rigid rules of the crisp algorithm. Second, it provides more reliable estimates of the importance of these systems of production relative to national manufacturing employment. Last, it provides a ranking of the districts according to their quantitative importance and to their adherence to the characteristics emphasized in the literature. This ranking not only improves our knowledge of this type of industrial organization but it is crucial for the analysis of the dynamic behaviour of industrial districts over time, which is the subject of our future work. The ranking may also be used for industrial policy purposes.

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