



Estimation of Social Capital Index in Iran Using the Fuzzy Logic

Zana Mozaffari^{a,*} , Fateh Habibi^a , Ramin Amani^b 

a. Department of Economics, University of Kurdistan, Sanandaj, Iran

b. Department of Economics, Development, and Planning, University of Tarbiat Modares, Tehran, Iran

* Corresponding author, E-mail: z.mozaffari@uok.ac.ir

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Abstract

The present paper aims to estimate the level of social capital and its trend in Iran and determine the main components and variables of social capital in Iran from 1988-2019. For this purpose, by analyzing the theoretical and empirical foundations of social capital, three main components (crime-participation-awareness) and the associated social capital were considered for calculating the social capital index. Then, using the Mamdani fuzzy inference system and a fuzzy approach, the social capital index was estimated. A review of the trend of this index indicates that in the period under study until 2001, there has been significant growth so, in 2001, this index was estimated to be 0.67. However, from 2001 to 2019, there was a downward trend with different fluctuations, so in 2018, this index was examined at its lowest level during the period under study. One of the reasons for the decrease in social capital could be the increase in the crime rate due to the growing trend of migration from rural to urban areas. Furthermore, to more accurately evaluate the estimation of the social capital index, based on the methods of previous studies, the estimation of social capital was performed using the Dagum method. The results of this method showed that according to the status of input variables and determinants of social capital, fuzzy estimation has provided a more accurate and appropriate estimate of social capital.

Keywords: Awareness, Crime, Fuzzy Logic, Participation, Social Capital.

JEL Classification: Z13, D83, C22.

1. Introduction

Social capital is a concept currently discussed in the economic and social research of modern societies. It can be argued that social capital is generally more significant than physical and human capital because, if it is absent, other capitals will not be effective. Social capital has a key role in all areas, and various attitudes towards it reflect the significant position of this capital in all aspects of life as evidenced by increasing research on this issue (Zugravu-Soilita et al., 2021). According to the World Bank, social capital is a phenomenon resulting from the impact of social institutions, human relations and norms on the quantity and quality

of social interactions and the experiences show that such a phenomenon significantly impacts the economy and progress of various countries (Muringani et al., 2021). Social capital is generally based on cultural and social factors. Various aspects of connections, collaboration, mutual trust, and communication between members of a network help its members to achieve their goals. Furthermore, social capital is successful for development programs (Congdon, 2012). The existence of social capital is a proper platform for human productivity and economic and physical capital. On the contrary, the lack of social capital eliminates the impact of other capital on achieving development. Without social capital, it is difficult to go through development paths and economic and cultural evolution. Accepting this concept as a kind of capital at the macro-management level of countries' development can create a new understanding of socio-economic systems and help authorities to better guide society towards development (Harriss, 2002). Social capital is defined based on the function it has. Social capital is not a single concept but is composed of various concepts, all of which have two characteristics in common. First, they include a form of a social construct. Second, they can simplify some individual measures inside the construct, whether natural or legal people and achieve specific goals possible, but it was impossible in their absence (Santamouris et al., 2007). Social capital is one of the hidden variables that highly impact the economic condition of society. Many studies have been conducted on the influence of social capital on different economic and social aspects, and in these studies, an alternative proxy for social capital has often been used. Reviewing different studies shows that in the time series economics research, proxies including crime, awareness, participation, and trust were used. However, these indices used in time series research cannot be a complete proxy for social capital because as stated in the economics literature and described in the following sections, the components of social capital cover various dimensions. Therefore, using an alternative proxy for this variable in economics research can increase the estimation bias. Thus, in this research, it is attempted to estimate a comprehensive time series for the social capital index using Iranian statistics and data and also the fuzzy logic method. One of the most important features of this index is the comprehensiveness and inclusion of various dimensions of social capital.

2. Literature Review

2.1 Theoretical Foundations

In the present economics literature, in addition to physical capital, human capital, natural capital, and recently social capital have been introduced as factors influencing the growth and development of societies. Although the term was first coined by Hanifan (1916), in economics it was first used by Richardson (1986), and its scientific and serious application in this field was mentioned by Colman

(1986). Social capital refers to the internal cultural and social cohesion of a society, the norms and values governing the interactions between people, and the institutions that use such norms and values. Social capital is like a glue that ensures the cohesion of societies, without which no economic growth or human well-being is possible (Fine, 2001). It was argued by Colman that social capital, in turn, arises when relationships among people are transformed in such a way that facilitates actions. From Colman's perspective, social capital is the value of a dimension of the social structure provided to members as a resource for achieving their purposes. Social capital creates a common ground for members and networks to use this capital to achieve higher profits and well-being (Dinda, 2008).

Generally, social capital is those networks and norms enabling people to act collectively. Its dimensions are social trust, social values, social security, social participation, awareness, and social cognition and cohesion. According to some experts, trust is the most important dimension of social capital impacts other dimensions, and is the basis for participation and cooperation among members of society. Social capital accumulates when people interact within the family, workplace, neighborhood, and public relations in local and public communities (Woolcock and Narayan, 2000). Social capital takes place at three levels (European Commission, 2000):

- The level of relationships between people, such as family, friends, and neighbors.
- The level of affiliated organizations and associations, such as membership of clubs, companies, and political parties.
- The degree of social institutions at the macro level.

For Bourdieu, the "capital" concept is much broader than the monetary concept of capital in economics. Capital is a common resource that can exist in a monetary or non-monetary type as well as tangible or intangible (Anheier et al., 1995). According to Bourdieu (1984), the social structure of any advanced capitalist society is like a complex social space where various forms of capital determine social situations that are horizontally and hierarchically distinct. Although any asset, property, or commodity that is valued in society can be a form of capital. Three main kinds of capital include economic, social, and cultural ones which were mentioned by Bourdieu in an article entitled "Forms of Capital", and these three were considered more valuable than other capitals (Owen and Videras, 2009).

Physical capital is quite tangible and is materially visible and embodied. Human capital is less tangible and is embodied in the skills and knowledge that an individual has acquired (Ahlborg et al., 2019). Social capital is less tangible because it manifests itself in the interactions between actors. Thus, it can be seen that social capital has special characteristics that make a conceptual distinction

between this capital and other known capitals (Westlund, 2006). The following subsection explains the components of the social capital index:

2.1.1 Crime

Crime includes those behaviors and actions that exceed the tolerance of a particular social group. Crime is actions that harm the interests of society so the government decides to make a policy to detect and deal with it. The occurrence of crime is a reflection of non-compliance of people and economic units with conventional laws and regulations and conventional contracts, which increases the costs of community administration, reduces security, and social instability and thus decreases the level of social welfare (Saegert and Winkel, 2004). The social dimension constitutes one of the most significant dimensions of crime prevention. Accordingly, it is one of the effective and influential factors of social capital that effectively prevents crime (Rose and Clear, 1998).

Social capital was examined by Fukuyama from the perspective of social deviations such as crime, drug use, family breakdown, litigation, suicide, tax evasion, and so on, and it was concluded that the existence of these deviations results in the lack of social capital. According to these definitions, it can be claimed that “the occurrence of crime indicates a low level of social capital or the perpetrators of crime are not in a favorable position in terms of indices of social capital; For example, a thief commits a crime for failure to adhere to the social rules and regulations accepted by the consensus of the people. A thief violates the principles governing social agreements and representing social capital, and as a result, commits a crime (Fukuyama, 2000).

Social capital emphasizes the importance of social relations and common norms of social welfare and economic efficiency, and various definitions have been provided in this regard. Social capital was measured by Fukuyama by relying on social deviations such as crime, drug use, family breakdown, suicide, and litigation, and believed that these factors would reflect “the lack of social capital” (Lederman et al., 2002). Lack of social capital undermines the quality of social relations governing the society and encourages people to engage in relationships and transactions outside the norm, which can lead to the growth of social anomalies such as lawlessness and criminal acts (Buonanno et al., 2009).

Crime reflects the lack of adherence and commitment of individuals to the laws and regulations of society, and the spread of crime indicates a decrease in social capital (Rosenfeld et al., 2001). Social capital includes concepts of trust, cooperation, and interrelationships between members of groups, in a way that leads the group towards achieving a positive goal based on common values and criteria. Social capital as an important component in crime prevention is a new mechanism, in other words, it creates a compact social network that maintains social order and

creates a sense of social responsibility and collective commitment in individuals to environmental issues (Deller and Deller, 2010). The results of social researchers' research show that with the decrease in social capital, deviations and crime increase and vice versa. As mentioned, social capital means to trust in others, the amount of dialogue between parents and children, self-sacrifice, decrease in the feeling of relative deprivation, etc. (Akçomak and Ter Weel, 2012).

2.1.2 Public Awareness

Social capital is one of the valuable attributes of people and the level of social awareness and trust is one of its main variables. The primary precondition for social participation is "awareness" (Patulny and Svendsen, 2007). Awareness is an epistemological variable belonging to individuals. Thus, where individuals are unaware of the nature of social issues or the tools available to address them, opportunities for social partnership and a powerful social feeling or social reserve will become lower (Yli-Renko et al., 2001). Indeed, social capital results from an action based on mutual awareness and cognition and is the product of an endless effort to institutionalize the values that establish lasting and useful relationships producing the material or spiritual benefits of the group.

Individuals' awareness of the community and knowledge of the living environment, as well as knowledge of the needs and shortcomings of the living environment, individual and collective rights and obligations of people who live in the surrounding areas, and the obligation of government agencies for the shortcomings and requirements, can enhance personal awareness and strengthen social capital (Pérez-Luño et al., 2011). Awareness may be formed or consolidated firstly by forming knowledge in the individual and, secondly, by training the rights and obligations of individuals for the living environment. In this way, by becoming aware of his rights and responsibilities for the community and the environment, the individual can do the right thing to improve the neighborhood's condition (Lesser, 2000).

In addition to the components mentioned in Bourdieu, Colman, and Putnam's definition of social capital, Putnam refers to the tendency to awareness and attention and inserts a group of thinking, opinion, and sensitivity to social and political life and consideration to the broadest meaning of public affairs which relates to the relatively weak tendency of the individual to follow common issues in the electronic and printed media, and the necessary and more active cognitive precondition for civil liability that arouses interest and encouragement. The opposite of awareness and attention to the cognitive status is ignorance, indifference, and the formation of an opportunistic attitude (Huang et al., 2009).

2.1.3 Collective Participation

Mutual participation or cooperation is another concept of interest and one of the aspects of social capital. regarding participation, there are two points, from which the idea of equality of human values is the most basic of the two (Dekker and Uslaner, 2003). One of the reasons for the difficulty of measuring social capital is that this phenomenon does not emerge at the individual level nor the collective level, but is observed between these levels and when the individual participates in the group. It is said that considering social capital as a metaphor for capital can be misleading because, unlike financial capital in the hands of individuals, the interests of various social organizations are not in the hands of the perpetrators, but result from their participation in groups organized for a particular benefit (Hoenig et al., 2016).

One of the factors affecting team composition is social capital, which has not been studied by researchers so far. Reflecting on the concept of collective participation, it is concluded that the integral part of collective participation is nothing but the resources available in social interactions, that is, the expansion of actions and the analysis of actors' goals to achieve a collective good. In this regard, it must be acknowledged that collective participation is the formation of social capital in society. The realization of collective participation depends on the realization of the social capital's components (Wellman et al., 2001).

One of the environments where social capital plays a critical role is teamwork environments. In these environments, the adherence or non-adherence of workers to the efforts or non-efforts of their group members leads to a decrease or increase in mass production and thus will have many effects on the economy (Hyypä and Mäki, 2003). Collective participation in the broadest sense includes different types of individual and group actions to intervene in determining one's destiny and that of society and to affect the public decision-making processes (Lee and Kim, 2018). Indeed, community participation is not just about consulting and engaging people or using their actual and potential capabilities (Qiu et al., 2019).

The concept of nascent social capital consists of three important components including social trust, social cohesion, and social participation. This concept is both the effect and expansion of these three components. In addition, this vital capital has a strong interdependence and relationship with physical, economic, and human capital, and helps to accelerate economic, cultural, and information expansion and social growth; It creates a kind of cooperation and collaboration among the society members. The development of social capital is increased with the expansion of the atmosphere of cooperation and participation in society. The more the activity of people and their participation in work, such as trade unions and local organizations, the more the social capital will be (Li and Tan, 2019).

2.1.4 Research Background

To the best of our knowledge, still, there is no single factor for social capital. This gap is obvious in the literature and a proper social capital model must be developed on the basis of the empirical patterns observed in reality.

Zhai et al. (2022) investigated the effect of suicide on social capital in United States counties from 2005 to 2017. The results of this study show suicide is strongly and significantly correlated with social capital.

Li and Guo (2022) render new evidence on the dynamics of social capital across the life course and over different periods in urban China by using three cross-sectional datasets of job search and social network surveys. The effects of the period show a significant increase in social capital from 1999 to 2014, during which family-centered social capital decreased, while labor-based social capital was strengthened and became the main social capital. Furthermore, the source of social capital for urban dwellers shows the effects of cohorts on political events and institutional reforms have profound effects on the accumulation of social capital for different age groups.

Narayan and Pritchett (1999) pioneered the study of micro- and meso-level social capital measurement in rural Tanzania. They carried out the study to estimate the relationship between social capital and economic outcomes in the village. Therefore, they used common indices such as membership in voluntary companies and trust, in combination with social capital.

Krishna and Uphoff (1999) also studied public trust and voluntary companies as key indices of social capital in India. The authors showed that such a measure had a positive relationship with economic performance. They concluded that the social capital index had a significant positive relationship with the development-oriented collective action index.

Rose (1999) defined social capital as the inventory of formal or informal social networks used for producing or allocating goods and services at the micro-level. In this way, he aimed to determine the scope of formal and informal networks and also the interplay between both network groups. Finally, he showed that there were no valid empirical indices of social capital, even in countries rich in OECD data.

In another study, Uslaner (2001) mentioned that social capital can be affected by the level of corruption in a society. When there is no corruption, there might be a superior level of social capital and consequently higher economic development, since a lower level of corruption requires strict enforcement of agreements and thus encourages voluntary trust-building between business parties (Paldam and Svendsen, 2001).

Uslaner (2001) and Bjørnskov (2003b), who used the general trust as a representative of social capital, found that trust has a significantly stronger effect on corruption than the inverse causal relation. Generalized trust is applied as a

representative of social capital in a study creating the impact of social capital on economic development (Zak and Knack, 2001; Beugelsdijk et al., 2002).

Putnam (1993) developed a measure of social capital while analyzing differences in organizational effectiveness and its impact on the economic growth between northern and southern Italy. He explained this by historically identifying differences among voluntary institutions. This criterion was the starting point of social capital estimations and was used as an explanatory factor.

Saadat (2008) estimated the level of social capital, and its trend and determined the main elements and variables that make up social capital in Iran by the fuzzy method. The results show that social capital has several fluctuations during the period. These fluctuations are due to political, historical, and cultural issues. In general, the time series of social capital, in the long run, shows a slight downward trend.

Mehregan et al. (2013) in their research estimated the amount of social capital for the provinces of Iran from 2000 to 2009 by using the Varimax method. The results of this study show that the highest average of social capital in Iran was related to 2008 and the lowest average was related to 2002. This study also shows that in 10 years, Tehran and South Khorasan provinces had the lowest and highest average social capital in Iran, respectively.

Saadat (2006) in a study using the Dogom method estimated the level of social capital in Iran in 2001. The results of this study show that human capital and religion are the most important constituent elements of social capital in Iran. Also in terms of ranking, Yazd province has the highest amount of social capital among the provinces of Iran.

Moayedfar (2006) studied the developments of social capital and its economic consequences in Iran. In this study, by combining descriptive methods and causal analysis to test the research hypotheses, it has been concluded that the trend of changes in social capital in Iran from 1989 to 2004 has had a downward trend. This study also concludes that social capital has a positive effect on economic growth in Iran.

Elmi et al. (2006) ranked social capital in provincial centers of Iran using the Stone and Hughes (2003) method on three levels: micro, generalized, and macro using factor analysis methods and taxonomy. The results of this study show that the capital of Ilam province has the best average and Tehran has the lowest average in terms of social capital.

3. Research Methodology

3.1 Data

Different studies have been conducted on the methods of measuring social capital. However, a general measurement method has not yet been introduced. This goes

back to the literature and analysis of social capital. According to the economic literature, the social capital variable is a hidden variable and is influenced by various factors. There are different proxies for the social capital index. Given the fact that the present study has been conducted in Iran and since not all statistics and information are collected and published coherently, the main limitation of the present study for calculating social capital is the lack of access to statistics and information containing all the aspects of social capital in the calculations. Restrictions on access to research data before 1988 led to the selection of the period 1988 to 2019. Therefore, considering the limited availability of statistics in Iran, the following proxies and accompanying variables have been used (It should be noted that all research variables are per capita because they are relative to the population):

A. Crime-to-population Ratio: In this regard, the crime index is measured by calculating the United Nations Human Development Index and macro incidents such as premeditated murder, embezzlement, theft, bounced cheques¹, beatings, threats, coercion and reluctance, drugs, pretending to hooliganism and attempting suicide. Furthermore, In this paper, the method of previous studies such as Motafker et al. (2016) has been used to calculate the crime index.

The desired information has been extracted from the statistical yearbook during different years. To obtain the crime index, all the raw indices are standardized through the following equation, i.e. by subtracting the average of each index from the observations related to that index and dividing it by the respective standard deviation.

$$X^+_{it} = \frac{X_{it} - \bar{X}_i}{Se(X_i)} \quad (1)$$

In this way, according to the characteristics of the “standard form of data”, the observations of different indices are disintegrated and comparable. Next, the crime index has been calculated using the method of calculating the human development index provided by the United Nations (Ghatak, 1995). In the first step, using Equation (1) from the observations related to each of the indices, the minimum value recorded for that index is subtracted and the result is divided by the range of its changes (thus the numerical values of all indices are in the range of zero and one).

$$X^*_{it} = \frac{X^+_{it} - \text{Min}(X^+_{it})}{\text{Max}(X^+_{it}) - \text{Min}(X^+_{it})} \quad (2)$$

¹. If the person receiving the cheques fails to collect it, he or she can return it, which is called an bounced cheques

After performing this calculation for all components, the crime index of that year is extracted from the algebraic average of all indices for each year of the study period.

$$SC^T = \frac{1}{N} \sum_{i=1}^N X_{it}^* \quad t=1,2,\dots,T \quad (3)$$

This index varies between zero and one. The closer it is to one, the greater the crime will be.

B. Public Awareness: The number of books borrowed from public libraries relative to the population. Public awareness and collective participation in the study of Saadat (2006) have been used to calculate social capital.

C. Collective Participation: The number of members of non-governmental organizations (NGOs), cultural centers, and charities to the population.

Considering the availability of these data for Iran, the above-mentioned variables are the most important factors affecting the formation and the main variables of social capital. It is worth noting that the source of collecting statistics and information related to the variables determining social capital (crimes – number of books borrowed – number of NGO members, charities, and cultural centers) is the Statistical Center of Iran – statistical yearbooks of each province for different years. Thus, it is possible to create a comprehensive index for social capital using fuzzy logic, which is influenced by the above variables. In other words, in this study, an index for social capital over different years is estimated using fuzzy logic. After determining the determinants of social capital, the fuzzy inference system (FIS) for calculating this index is as follows:

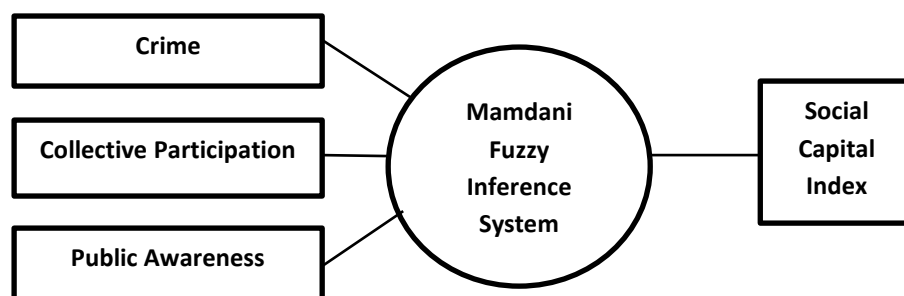


Figure 1. Fuzzy Inference System (FIS) for Social Capital Index

Source: Research finding.

As seen in Figure 1, the variables affecting social capital, determined based on the research background and literature, calculate the social capital index using the Mamdani fuzzy inference system. The fuzzy logic method is applied in any field where there is ambiguity (uncertainty) in measuring a variable under study or

inaccessibility to the information of that variable. Thus, the fuzzy logic method can also be used to estimate the social capital index.

Table 1 shows the descriptive statistics of the research. As can be seen, the average crime-to-population ratio in Iran during 1988 to 2019 was high at about 0.106 which means that in Iran, on average, out of 100 people, 10.6 people have been convicted. These crimes can include premeditated murder, embezzlement, theft, bounced cheques, beatings, threats, coercion, drugs, and suicide attempts. Additionally, the average social awareness which indicates the number of books borrowed from public libraries relative to the population is 0.064, which shows the low level of public awareness in Iran, hence only 6.4 out of every 100 people borrow books from public libraries. On the other hand, the average public participation in Iran which indicates the number of members of non-governmental organizations (NGO), cultural centers, and charities in the population is 0.021, which means that only 2.1 out of every 100 people in Iran are members of non-governmental organizations or centers.

Table 1. Descriptive Statistics

Variables	Obs.	Mean	Std. dev.	Min	Max
Crime to population ratio	32	0.106	0.034	0.050	0.169
Public awareness	32	0.064	0.016	0.038	0.098
Collective participation	32	0.021	0.0058	0.012	0.020

Source: Research finding.

Figure 2 shows the trend of the variables in Iran from 1988 to 2019. As is evident, the crime-to-population ratio in Iran is almost high and the level of collective participation and public awareness is low. Further, whenever the level of collective participation and public awareness is at its lowest (1988), the crime rate against the population is at its lowest. On the other hand, while collective participation and public awareness are at their maximum (2009), the crime-to-population ratio is at its lowest. From the above, it can be concluded that there is a close relationship between crime to population ratio, collective participation, and public awareness.

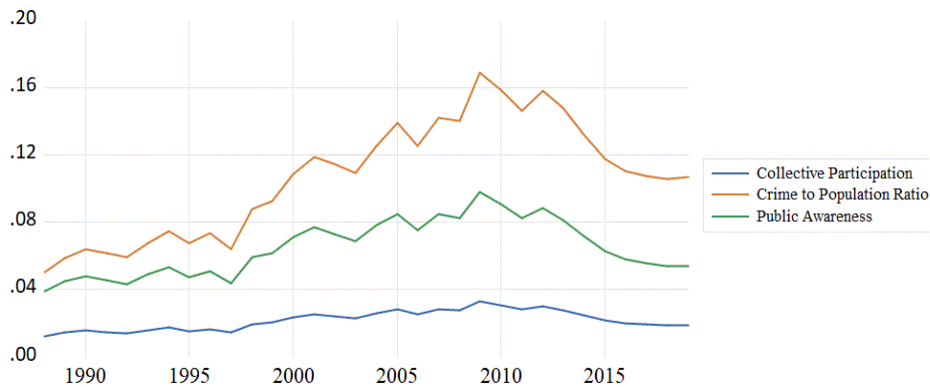


Figure 2. Time Trend of Variables

Source: Research finding.

3.2 Fuzzy Logic Method

The fuzzy theory approach, by considering ambiguity and uncertainty, instead of eliminating and ignoring it, promotes multi-value logic instead of dual-value logic, allowing for a more detailed study of the problems. In classical logic, information is either completely true or completely false, and it is not possible to control incomplete and inaccurate information, while the same information contains data that gives us the ability to have better answers to problems. In the fuzzy logic, if a component does not belong to a set, it is denoted by the number zero, and if it belongs to that set, it is denoted by the number one, but in the fuzzy logic, it belongs to the set in the closed interval of 0 and 1. Therefore, it can be said that the development of classical logic (Zadeh, 1992).

It was believed by Qiao et al. (2009) that the core of the fuzzy logic method is based on three basic concepts:

- **Fuzzy set:** Unlike classical sets, a fuzzy set has soft and flexible ranges, so that the components of the fuzzy set can be partially inside the set. Membership functions are used to gradually transfer the components from areas that are completely outside the set to areas that are completely inside the set.

- **Linguistic variables:** They are variables that are quantitatively and qualitatively described by a fuzzy set. A fuzzy set can describe the value of a variable, like regular sets.

- **If-then fuzzy rules:** These rules are logical formulas or applied programming implying a concept of dual-value logic. The main feature of applying “if-then” fuzzy rules is their ability to make inferences under partial matching conditions in which a degree is calculated for the input data based on the conditions of each rule. This degree of consistency is combined with the rule result to conclude the inference by the fuzzy rule.

Fuzzy logic is one of the branches of fuzzy theory that has different implementation methods, including a fuzzy inference system (FIS) as a popular one. FISs are also known as rule-based fuzzy systems, fuzzy expert systems (FES), fuzzy models (FM), fuzzy associative memory (FAM), and fuzzy controllers (Jang et al., 1997). Figure 3 shows the process of FIS.

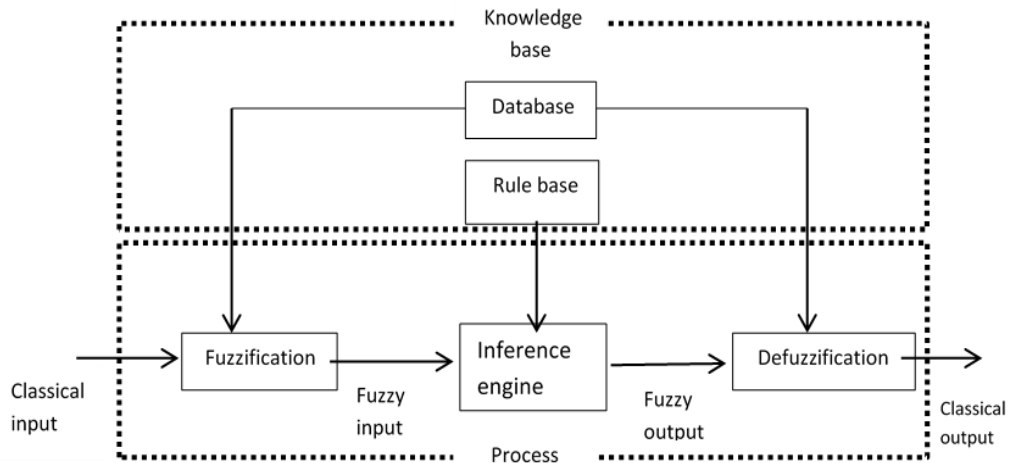


Figure 3. Fuzzy Inference System (FIS)

Source: Research finding.

As can be seen in this figure, FIS has two parts: the knowledge base and the process stage. The knowledge base provides a function of memberships and rules for the process step. In the process stage, system input variables, which are classical numbers, go through a phase of fuzzification and are converted into linguistic variables as fuzzy inputs for the inference engine. Fuzzy input is converted to fuzzy output using the rules in the inference engine. These results are linguistic and for the output of the system to be in the form of classical numbers, the defuzzification step must also be performed (Shapiro, 2004). There are different types of fuzzy inferences, the most famous of which are Sugeno's (1985) reasoning system and Mamdani's (1977) reasoning system. In this study, the Mamdani reasoning system is used.

Fuzzy logic uses a special algorithm to perform approximate reasoning. In this algorithm, it is assumed that $x=[x_1, x_2, \dots, x_n]$ is a vector of properties describing each phenomenon or state, and $y=[y_1, y_2, \dots, y_m]$ is a vector of system outputs. In such cases, the rules can be defined as follows:

$$\begin{aligned}
 R^r: & \text{ if } x_1 \text{ is } A_1^r \text{ and } x_2 \text{ is } A_2^r \text{ and } x_n \text{ is } A_n^r, \\
 & \text{ Then } y_1 \text{ is } B_1^r, y_2 \text{ is } B_2^r, \dots, y_m \text{ is } B_m^r \\
 & \text{ where } x \in X = X_1 \times X_2 \times \dots \times X_n, y \in Y = Y_1 \times Y_2 \times \dots \times Y_m
 \end{aligned}
 \tag{4}$$

and $A^r = A_1^r \times A_2^r \times \dots \times A_n^r \subseteq X$, $B^r = B_1^r \times B_2^r \times \dots \times B_m^r \subseteq Y$ show a fuzzy set (Stojić, 2012).

The high significance of fuzzy logic is in the probability of its application to model complicated systems in which it is very hard to determine the correlation between model variables.

Input variables of a fuzzy system are called linguistic variables, and all outputs are in a continuous state. For all possible outcomes, the sum of the output variables is determined by an exact level of belonging. If U is a set of elements denoted by x , then the fuzzy set \tilde{A} in U is defined as a sequential pair:

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)|x \in U\} \quad (5)$$

$\mu_{\tilde{A}}(x)$ is called a member function or feature function of \tilde{A} , which indicates the degree of belonging or membership of x to the fuzzy set, \tilde{A} . In other words, $\mu_{\tilde{A}}: U \rightarrow M$ means that the membership function, $\mu_{\tilde{A}}(x)$, links the set, U , to the membership function space, M . The membership function space, M , of the closed interval, is zero and one. The closer the value of $\mu_{\tilde{A}}(x)$ is to one, the greater the degree of element x belonging to the fuzzy set, \tilde{A} , will be, and $\mu_{\tilde{A}}(x)$ being zero means that the element x does not belong to the fuzzy set, \tilde{A} (Stojić, 2012).

After determining the membership functions and creating the rules database, in the next step, the model outputs must be defuzzified. Defuzzification is a process that quantifies the results of fuzzy logic (derived from fuzzy sets and degrees of membership). The best method for defuzzification is the center of gravity (COG) method. This method calculates the COG of the membership sub-function. The defuzzified output, x^* , obtained by the COG method, is calculated by the following equation (Van Leekwijck & Kerres, 1999):

$$x^* = \frac{\sum_{i=x_{\min}}^{x_{\max}} x_i \cdot \mu(x_i)}{\sum_{i=x_{\min}}^{x_{\max}} \mu(x_i)} \quad (6)$$

Fuzzy logic systems using modern methods of mathematical calculations are trying to reduce some of the ambiguity in the process of measuring the desired variables.

3.3 Dagum Method

In this paper, in addition to estimating social capital using the fuzzy logic method, other methods have been used for the calculation and estimation, and the results have been compared. Various studies have been conducted on methods of measuring social capital, but a general method for measuring this capital has not yet been introduced. This goes back to the literature and analysis of social capital. Saadat (2006) in a paper estimated the social capital in Iran according to the available data. Using the Dagum method, he estimated the social capital of the

provinces of Iran in 2001. In this paper, the following variables have been used: crime to population ratio - collective participation (the number of members of recreational and cultural centers relative to the population) - public awareness (the number of borrowed books relative to the population).

In the present paper, following the study of Saadat (2006), the Dagum method will be used. Thus, using the Dagum method, an index for social capital in Iran has been calculated from 1988 to 2019. In this method, the dependent variable is a function of independent variables and a qualitative variable transfer function is used as an independent variable to estimate the level of social capital. Therefore, the following linear function is introduced:

$$Z_s = \alpha_1 X_1 + \alpha_2 X_2 + \dots + \alpha_p X_p \quad (7)$$

where X_1, X_2, \dots, X_p are the independent variables concerning the subject under study and Z is the standard hidden variable. Due to the significance of each of the coefficients of X_i variables on Z , appropriate variables are selected to estimate the social capital. Finally, after placing the desired numbers in the equation, the amount of social capital in the desired year is obtained. In this method, first, the independent variables are collected, and then the standardized variables are fitted on the independent variables to obtain the coefficient of each variable. Then, after placing in the obtained equation, the amount of social capital in Iran during different years was calculated.

4. Research Findings

First, low (L), medium (M), and high (H) linguistic terms are considered for each of the input and output variables. To create a base value, we use the moving average for each input variable. A 5-year moving average is taken from the data to account for possible cycles in the data. The mean value represents the normal value of the elements of the set of variables. Then, to determine the failure points of the data, one or two standard deviations around the normal value in each period are obtained. Membership functions are provided in Table 2 (the output of fuzzy systems is highly sensitive to the shape of membership functions and the number of modes of language variables).

Table 2. Membership functions.

LOW	MEDIUM	HIGH
-SD	Mean	+SD

Source: Research finding.

After determining the data breakpoints, depending on the system designer, different functions in terms of shape or degree of complexity can be selected for each variable because the triangular and trapezoidal membership functions have

high simplicity and accuracy (Stojić, 2012)¹. In this study, these two types of membership functions are used. After performing the stated steps, the membership functions of the input variables, i.e. crime, participation, and awareness, and output variable, i.e. the social capital index, are calculated and shown in Figures 4, 5, 6, and 7, respectively.

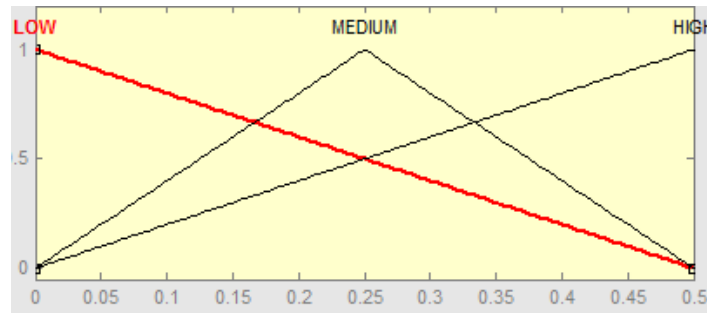


Figure 4. Crime Variable Membership Function

Source: Research finding.

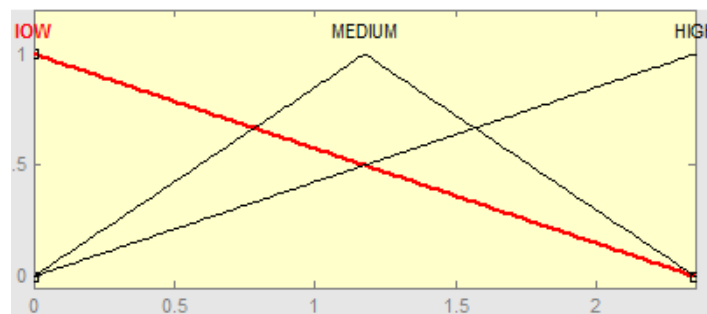


Figure 5. Participation Variable Membership Function

Source: Research finding.

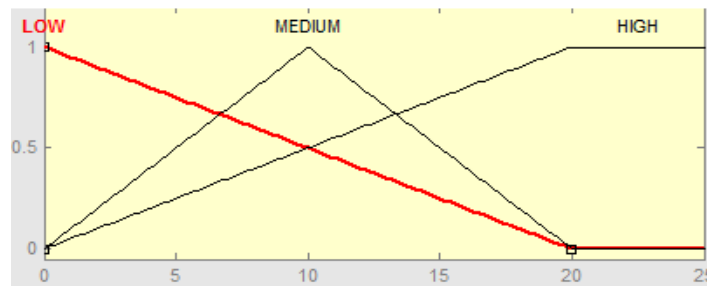


Figure 6. Awareness Variable Membership Function

Source: Research finding.

¹. The output of a fuzzy system is highly sensitive to the shape of membership functions and the number of modes of linguistic variables. Therefore, different modes of (5-mode, 7-mode, or 9-mode linguistic variables) membership functions were used, and the results showed that triangular and trapezoidal membership functions provided more consistent results. Due to the limited number of pages of the paper, other estimates have been refused. Therefore, only the results of calculating the trilingual mode were reported in the paper.

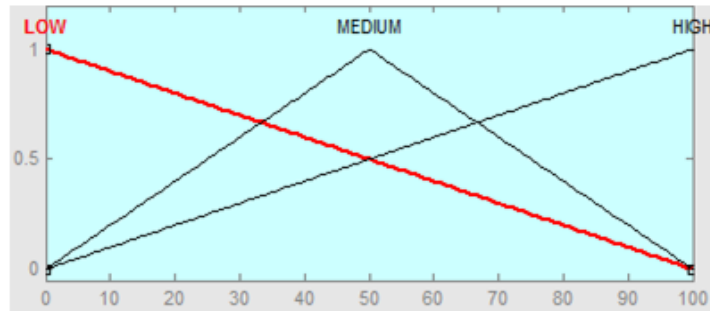


Figure 7. Social Capital Variable Membership Function

Source: Research finding.

Membership functions are used to gradually move from areas that are completely outside the set to areas that are completely inside the set. The membership function allows you to quantify a linguistic word and display a fuzzy set graphically. Figures 4 to 7 show the process of quantifying linguistic variables using triangular and trapezoidal membership functions. The decision rules of combining special levels determine the correlation between the three accompanying human social variables to create the correlation levels for the human capital index. The degree of correlation is the degree of quantification of the social capital index. These mental rules derived from previous studies are knowledge and rational perceptions of experts about the impact of these variables on social capital. Accordingly, consistent with the research literature and the opinion of experts in the field of social capital, the degree of significance of the crime index is greater than participation and awareness. In other words, crime, participation, and awareness indices have the highest impact factor in calculating and estimating human capital, respectively.

After determining the fuzzy rules, the type of function used for defuzzification (conversion of linguistic values into definite numbers) must be determined. In the present research, the surface center function has been used for defuzzifying the output variables. After performing the above steps, FIS for the social capital index is simulated using MATLAB software. This index generates output for each year using the input variables and the above inference system. This numerical index is between zero and one and shows the annual situation of social capital in Iran.

According to the methodology and literature and the inputs and fuzzy rules, the results of estimating the social capital index by the fuzzy logic method can be seen in Figure 8:

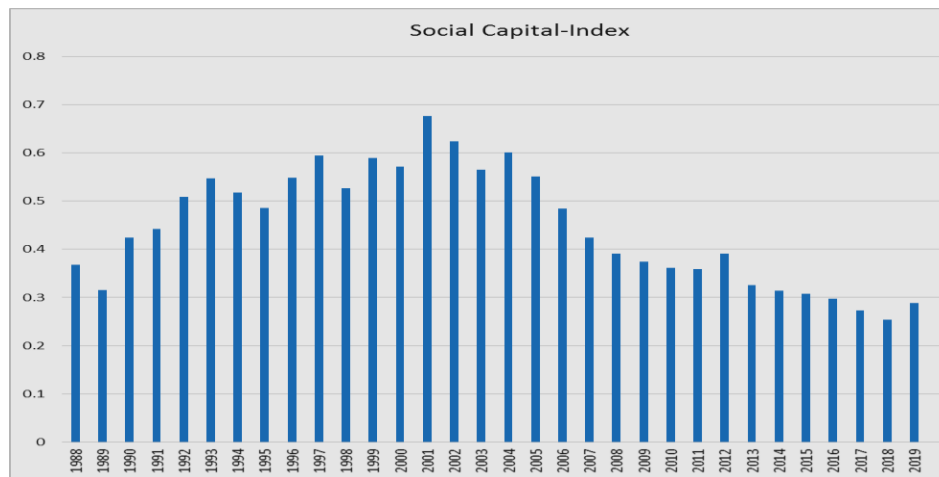


Figure 8. Social Capital Index during The Period 1988-2019 by Fuzzy Logic Method
Source: Research finding.

As shown in Figure 8, the social capital index has experienced fluctuations during the years under study. The social capital index in Iran shows a significant difference during the years under study so the social capital index in 2001 reflects the highest and in 2018 the lowest values. In 2001, the social capital index was at a high level because of the low crime-to-population ratio, as well as high public awareness and collective participation per capita compared to other years. It is worth noting that in the period 2008-2019, the crime-to-population ratio was high. Therefore, they have a lower social capital index. Similarly, in other years, the variables of participation and public awareness occupied different levels. Thus, this unbalanced distribution of data determining the social capital has led to different high and low values in the estimated index in some years. Overall, however, it can be said that social capital had an upward trend until 2001 and has since declined. Furthermore, Figure (9) shows the calculation results of the social capital index by the dagum method:

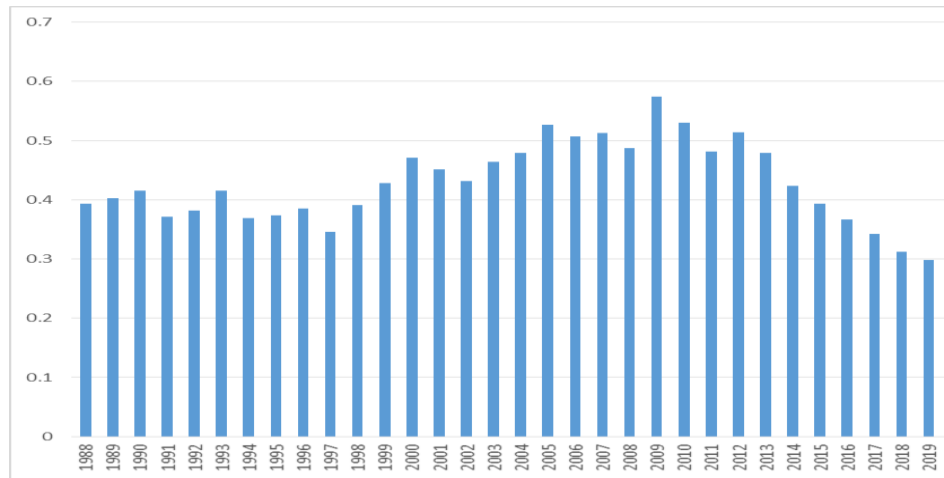


Figure 9. Social Capital Index between 1988 and 2019 by Dagum Method

Source: Research finding.

According to the calculation results of the social capital index by the Dagum method, it can be stated that social capital had the highest and lowest values in 2009 and 2019, respectively. Comparing the results of this calculation with the results of fuzzy logic estimation, it can be stated that the results of these two methods are slightly different. Considering that the raw input data are the same in performing the calculations of both indices, it can be concluded that according to the trend of input variables (crime, participation, and awareness), the estimation results of the social capital index using fuzzy logic seem more logical. For instance, in 2001, the variables of public awareness and public participation had high values, and on the other hand, the situation of the crime index was favorably compared to other years, so it is expected that social capital will have a high value this year, but given the results of calculating social capital using the Dagum method, this index showed a value of 0.45 for 2001, which was significantly different from the maximum value of the same index in 2009, i.e. 0.57. However, the variables and the corresponding input data show something different, and it is worth noting that the estimation results using fuzzy logic have provided an index of 0.37. Accordingly, it can be concluded that the index calculated by fuzzy logic has shown more logical and realistic results. On the other hand, in fuzzy logic, since linguistic variables are quantified during the process of fuzzy membership functions, it can be said that proper processing is done on raw data.

5. Conclusion

Different indices were considered by researchers to include social capital in economic discussions and econometric models. In most studies, social capital and its dimensions have been measured with the use of questionnaires and field

research. Crime is used according to Fukuyama. In this research, considering the availability of data in Iran, using three main components (crime, public awareness, and collective participation) determining social capital and using the fuzzy logic method, the social capital index was estimated and calculated between 1988 and 2019. The results of this estimation show that the social capital index in Iran has been different in various years and there has been a significant difference between them. Furthermore, in this study, social capital was calculated using the dagum method, and the results of this calculation were compared with the fuzzy estimation results. This evaluation showed that the results of estimation in the two methods used were significantly different and according to the values of input variables, it can be said that the results of estimating social capital by the fuzzy method have provided more appropriate and logical results.

Social capital is a process phenomenon. Social capital, unlike physical and human capital, does not consist of the resources held by individuals or groups but is a process of social interactions leading to constructive results. So, instead of being at a certain level of analysis (individual, group, community), social capital is created and operates between these levels. The variability, conditionality, and contextuality of this process complicate the social capital change. Although the effective and relevant processes of social capital can be identified in any field, the stages of strengthening social relations help the social capital to produce beneficial results for each group. Social capital has two parts: infrastructure and norm. The mentioned elements and components for calculating social capital in interaction with each other can produce the expected benefits of social capital. In other words, none of them alone can produce positive effects that are said to have social capital for a society, so in the present study, some years were in a good situation in one or two variables determining the social capital, but when one or two other proxies were not in a good situation, so the amount of social capital in that year was in a medium and low position. According to the crime index calculated in the years 2008 to 2019, it can be stated that the reason for the downward trend of the social capital index during these years was the increase in crime. One of the main reasons for the occurrence of crime during these years has been the increase in migration from rural to urban areas. There are sufficient reasons that migration influences social, economic, and demographic structures in a way that influences the overall crime rate without taking into account the criminological differences between migrants and residents at the personal level. Immigration leads to population inslity or housing transformation. This change in residence status increases crime because it weakens social solidarity and reduces informal social control. Immigration can increase crime because it increases the number of people with low levels of literacy and job ability. Indeed, new immigrants are less capable than older immigrants and locals. Immigrants are exposed to unemployment, poverty, and other social

damages, all of which are caused by severe environmental deficiencies. Immigrants may engage in illicit methods such as joining criminal gangs or selling drugs to gain wealth. Since one of the components of calculating social capital in the present study was the index of various crimes, it is suggested that the government must take more measures to reduce the occurrence of each of the crimes considered in this study.

In this paper, public awareness was another component considered for calculating Iran's social capital. Accordingly, it is recommended that planning be done to strengthen awareness through various means such as mass media and educational centers (especially schools). Collective participation was another variable that was considered in this study for calculating Iran's social capital. It is suggested that the government start a serious fight against corruption and especially make some arrangements and conditions for the promotion of social capital in governmental institutions by actively involving as many people as possible in the decision-making process, strengthening and encouraging popular institutions, and enacting laws and severe punishments for the factors that destroy social capital in the society.

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