SGD Sosyal Güvenlik Dergisi
Journal of Social Security
P-ISSN: 2146-4839
E-ISSN: 2148-483X

Determining the Premiums of General Health Insurance by Fuzzy Rule Base

Bulanık Kural Tabanı ile Genel Sağlık Sigortası Primlerinin Hesaplanması

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Nisan 2018, Cilt 8, Sayı 1, Sayfa 9-32
April 2018, Volume 8, Issue 1, Page 9-32

P-ISSN: 2146-4839
E-ISSN: 2148-483X

2018-1

e-posta: sgd@sgk.gov.tr

SGD
Sosyal Güvenlik Dergisi
Journal of Social Security

Cilt: 8 - Sayı: 1 - Yıl: 2018
Volume: 8 - Issue: 1 - Year: 2018

P-ISSN: 2146-4839
E-ISSN: 2148-483X

Yayın Türü: Uluslararası Süreli Yayın / *Type of Publication: Periodical*
Yayın Aralığı: 6 aylık / *Frequency of Publication: Twice a Year*
Dili: Türkçe ve İngilizce / ***Language:*** Turkish and English
Basım Tarihi/*Press Date:* 20/04/2018

Sosyal Güvenlik Dergisi (SGD),
TUBİTAK ULAKBİM-TR
EBSCO HOST -US
ECONBIZ - GE
INDEX COPERNICUS INTERNATIONAL -PL
SCIENTIFIC INDEXING SERVICES - US
JOURNAL FACTOR
ASOS INDEX - TR
SOBIAD - TR
DERGİPARK - TR
tarafından indekslenmektedir.

Tasarım / *Design:* PERSPEKTİF Matbacılık Tasarım Tic.Ltd.Şti. (0 312) 384 20 55 - Ankara
Basım Yeri / *Printed by:* PERSPEKTİF Matbacılık Tasarım Tic.Ltd.Şti. (0 312) 384 20 55 - Ankara

İletişim Bilgileri / *Contact Information*
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EVALUATION STATISTICS FOR THIS ISSUE

Toplam gelen makale başvurusu	28
Yayına kabul edilen makale sayısı	11
Hakem süreci devam eden makale sayısı	6
Red edilen makale sayısı	3
Ön inceleme aşamasında red edilen makale sayısı	8
Makale kabul oranı	%39

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Derginin güncel sayısı ve arşivine aşağıdaki linkten ulaşabilirsiniz.
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Determining the Premiums of General Health Insurance by Fuzzy Rule Base[1]

Geliş Tarihi/Received : 30/10/2017
Güncelleme Tarihi/Revised : 27/02/2018
Kabul Tarihi/Accepted : 18/04/2018

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Sosyal Güvenlik Dergisi
Journal of Social Security
Cilt: 8 Sayı: 1 Yıl: 2018
Volume: 8 Issue: 1 Year: 2018
Sayfa Aralığı: 9-32
Pages: 9-32

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ABSTRACT

As of 2008, under the name of Social Security Reform, Health Transformation program has been launched in Turkey and nobody has been aimed to remain out of the system. Even though this system provides comprehensive advantages to citizens, it also has some drawbacks about premium calculations. In the current system, premiums are calculated by using fixed ratios for different income levels. However, this causes inequalities among the citizens. Therefore, in this article, the elimination of inequalities and the establishment of fairer premium system that provides an interdisciplinary perspective about the general health insurance was aimed to present. As a methodology fuzzy logic that provides fuzzy grading among individuals was determined. The scope of the application has been limited to individuals who are considered as poor, who have no social security and who are insured on a voluntary basis. Premiums were calculated by fuzzy rules based on expert opinion with the help of MATLAB Fuzzy Logic Designer Toolbox for 4,650 people participating in the TURKSTAT's income survey. Then, total premium will be paid by the number of 9,749,855 people was estimated by weighting the calculated premiums. As a result, the premiums were calculated more fairly and the situations that create inequalities among the citizens were abolished. In addition, besides income and expenses, age was used for equitable calculation in order not to make voluntarily insured be advantageous. When literature was examined, it was thought that this article will contribute to the interdisciplinary literature since fuzzy logic applications are very rare in social sciences.

Keywords: General Health Insurance, insurance premium, fuzzy logic, approximate reasoning

ÖZ

2008 yılı itibari ile Türkiye'de Sosyal Güvenlik Reformu adı altında Sağlıkta Dönüşüm programı başlatılmıştır ve kimsenin sistem dışında kalmaması amaçlanmıştır. Sistem vatandaşlara kapsamlı avantajlar sunmasına rağmen, prim hesaplamaları noktasında bazı dezavantajlara da sahiptir. Mevcut sistemde, primler farklı gelir düzeyleri için sabit oranlar kullanılarak hesaplanmaktadır. Bu durum vatandaşlar arasında eşitsizliklere yol açmaktadır. Bu nedenle, makalede, eşitsizliklerin giderilmesi ve daha adil bir prim sistemi oluşturulması için genel sağlık sigortası hakkında disiplinler arası bir bakış açısı sunulması amaçlanmıştır. Yöntem olarak bireyler arasında bulanık derecelendirme sağlayacak olan bulanık mantığın kullanılması uygun görülmüştür. Uygulamanın kapsamı yoksul olarak nitelendirilen bireyler, sosyal güvencesi olmayan bireyler ve isteğe bağlı sigortalılar ile sınırlandırılmıştır. Primler, TÜİK' in gelir araştırmasına katılan 4.650 kişi için uzman görüşüne dayalı olarak bulanık kurallarla MATLAB Bulanık Mantık aracı kullanılarak hesaplanmıştır. Daha sonra, hesaplanan primlerin ağırlıklandırılmasıyla 9.749.855 kişinin ödeyeceği toplam prim elde edilmiştir. Dilsel değişkenlerle derecelendirilen kişi başına düşen aylık harcanabilir gelir kullanılarak daha adil derecelendirme sağlanmış ve eşitsizlikler ortadan kaldırılmıştır. Buna ek olarak, gelir ve giderlerin yanı sıra, isteğe bağlı sigortalıların avantajlı olmamalarını sağlamak için yaş değişkeni çalışmaya dâhil edilmiştir. Sonuç olarak, primler daha adil bir şekilde hesaplanarak vatandaşlar arasında eşitsizlik yaratan durumlar ortadan kaldırılmıştır. Literatür incelendiğinde, bulanık mantık sosyal bilimlerde oldukça az uygulandığından, bu makale disiplinler arası literatüre katkıda bulunacaktır.

Anahtar Sözcükler: Genel Sağlık Sigortası, sigorta primi, bulanık mantık, yaklaşık çıkarsama

Önerilen atıf şekli: Ertuğrul, İ. & Öztaş, G. Z. (2018). Determining the Premiums of General Health Insurance by Fuzzy Rule Base. *Sosyal Güvenlik Dergisi (Journal of Social Security)*.8(1). 9-32

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[1] The study has been derived from the master thesis ("Bulanık kural tabanı ile genel sağlık sigortası açısından yoksulluk sınırlarının ve prim miktarlarının belirlenmesi üzerine bir uygulama") of Gülin Zeynep Öztaş who is supervised by Prof. Dr. İrfan Ertuğrul.

INTRODUCTION

Fuzzy logic can be applied in many areas. Especially in engineering and health science fields, many electronic devices used today are modeled by making use of fuzzy logic. In social sciences, fuzzy logic has not been studied much. But for real-life problems limited to crisp values, exploiting fuzzy logic will provide more realistic and ideal results. The fuzzy logic system is similar to people's feelings and inference processes. Although not noticed, fuzzy reasoning is used quite often in daily life. For example, when the answers to the questionnaires are deducted, they are actually fuzzy or uncertain, such as "not very satisfied" or "somewhat satisfied" (Coleman, 2006: 17). Thus, looking from the fuzzy perspective provides eligible solutions to various problems.

Especially on governmental issues, the systems that classify individuals according to specified criteria on nonscientific basis cause individuals suffered in daily life. Tax rates, insurance premium rates can be thought as example issues. In general, the rates used for these calculations are adapted from other countries. However, since each population has its own characteristics such as level of development, location, culture, adaptation from another country may lead to some problems. For that reason, in order to handle these problems methods that constructed on scientific basis should be required.

The calculation of the general health insurance premiums is a critical issue in Turkey. Since its calculation is based on the proportioned gross minimum wage, the classification of people in terms of their wages have some drawbacks. As the level of income determined by crisp boundaries without any scientific background, inequality among citizens arises. For example , the person who earns 1776.5 Turkish liras as wage is expected to pay 71,1 Turkish liras premium, whereas the person who earns 1778 Turkish liras is expected to pay 213,3 Turkish liras premium. Therefore, the 2 Turkish liras difference in wages is reflected in premiums as 142,2 Turkish liras. It is thought that this inequality can be eliminated by calculating the premiums to be paid based on various variables and softening the transitions in income levels. In order to be able to soften the transitions, fuzzy logic provides useful tools. Therefore in this paper, in order to solve the problems in the current system, a fuzzy rule base has been established for General Health Insurance premium calculation. For this purpose, MATLAB Fuzzy Logic Toolbox which is explained in detail in the fourth section was used as software.

In the following parts of the paper, fuzzy logic concepts, a literature review of fuzzy logic, the current application of the general health insurance in Turkey and the proposed method with fuzzy logic will be addressed respectively.

I- FUZZY LOGIC

Over the years, the traditional view that uncertainty is an undesirable situation should be avoided has given place to an alternative view that argues science

cannot avoid uncertainty. Therefore, being able to explain uncertainty with a certain degree derives the uncertainty from the undesirable situation. In the framework of classical logic, the propositions are either true or false. So an element belongs to a set or not. This poses a problem for situations where there is no decision about a statement, since a statement may be "true" to various degrees such as: completely true, half true, half false, completely false (Şen, 2010: 13).

In 1920, Lukasiewicz, a Polish philosopher, put forward three-valued logic against the two-valued logic. According to Lukasiewicz, there is an intermediate value between true and false situations (Baykal and Beyan, 2004: 35). In 1965, Lotfi A. Zadeh introduced fuzzy set theory into the literature (Zadeh, 1965: 338). The fuzzy set theory was put forth by Zadeh who combines classical logic with the Lukasiewicz logic. Since fuzzy logic uses approximate values, it is called soft methods (Yager and Zadeh, 1992). Thus, contrary to classical logic, the propositions can be true or false, as well as various degrees of precision in fuzzy logic.

Fuzzy logic refers to all the theories and technologies that use fuzzy sets with classification without definite boundaries (Yen and Langari, 1998: 3). It can be seen as the formulation of two talents that attract people. One of these abilities is the ability to make rational decisions in an environment where partial accuracy, conflicting, uncertain information exists. The other one is the ability to do many physical and mental tasks without making calculations and measurements (Zadeh, 2008: 2753). The fuzzy logic grades uncertainty with the help of fuzzy functions. It uses linguistic expressions such as very little, little, medium, too much, very much based on human thoughts. Members of the fuzzy sets that have been identified belong to the members with membership degree defined in the [0, 1] interval.

Fuzzy set theory and fuzzy logic play important roles in the investigation of fuzzy control systems. The most fundamental contribution of the fuzzy control theory, a new area of control system theory, is that fuzzy control techniques can cope with many problems by exploiting fuzzy logic when the conventional control techniques cannot be able to handle these problems (Chen and Pham, 2000: 139). This fuzzy system is a non-linear scale conversion of the input data vector (property) to scalar output. Fuzzy set theory and fuzzy sets are the details of this conversion (Mendel, 1995: 345).

The fuzzy control system consists of fuzzification, knowledge base, fuzzy inference system, and defuzzification components. Fuzzification tool which measures the values of input variables makes the scale conversion and provides fuzzy functions that convert crisp values into linguistic variables (Lee, 1990: 407). The knowledge base contains all the necessary information for control. This information includes the fuzzy rule base and the database (Feng, 2006: 677). The fuzzy rule base can be considered as an expert opinion in any field of application. Fuzzy rules can be explained by a set of (if - then) forms. Creating

fuzzy rules is based on human thoughts and experiences (Coleman, 2006: 26). Although there are various if-then rule types in literature, in fuzzy control system generally Mamdani rule type is utilized. With m antecedent variables X1, X2,…, Xm, n consequent variables Y1, Y2,…, Yn, the fuzzy rule has the form shown as follows (Zadeh, 1994: 51):

IF X1 A1 AND … Xm Am, THEN Y1 B1 AND … Yn Bn (1)

In Equation (1), A1,.., Am and B1,…, Bn are the linguistic variables that represent inputs and outputs respectively. As an example of the fuzzy rule, "if the brake temperature is warm and the speed is normal, then the speed must be reduced and the speed must be reduced slowly" can be considered (Ertuğrul, 1996: 19). As mentioned in the example, fuzzy logic deals with approximate reasoning by using linguistic variables which provides flexibility.

Moreover, the process of obtaining crisp output values from fuzzy sets is called defuzzification (Pfluger et al., 1992: 717). This process is performed through membership functions of the fuzzy sets resulting from the fuzzy operations (Lotfi and Torabi, 2011: 434). Consequently, fuzzy set information can be converted to numerical values as outputs.

II- LITERATURE REVIEW

The methods based on the fuzzy set theory are applied in many situations that are confronted in everyday life. The fuzzy control system was first applied by Mamdani (1974) with the help of a fuzzy algorithm to control the steam machine. In literature, although there are many studies which utilize fuzzy logic, only the current applications of fuzzy logic will be mentioned in this section. It would be better to classify the studies according to the areas of expertise such as engineering, health, and social sciences.

When the studies in the literature were examined, it is clear that fuzzy logic has been applied mostly in the field of engineering. Schmöcker et al. (2008) developed a multipurpose traffic signal controller with a genetic algorithm that optimizes fuzzy logic membership functions for a region where both pedestrian and vehicle traffic is intense. Teodorović and Lučić (2006) conducted a study on smart parking system using fuzzy logic and integer programming. As a result of the proposed model, it is possible to give information about whether there is a suitable parking place for vehicles arriving at the parking lot and to follow the request of the park with the fuzzy system. Dixon (2005) developed a method to be used to generate potential pollution maps in groundwater. In addition to the existing methods, the fuzzy rule base model was used to generate the groundwater susceptibility map. Lin et al. (2007) developed an approach based on fuzzy logic to design consumer-focused products. In this study, fuzzy rule clusters were set up to determine how to combine mobile phone items best. Özçil et al. (2015) used the fuzzy COPRAS method which is multi-criteria decision-making method and the fuzzy inference mechanism, to determine the rules of the working levels of the combi boilers.

When fuzzy logic applications in health were examined, it was seen that Pena-Reyes and Sipper (1999) focused on fuzzy system and evolutionary algorithms to automatically generate a breast cancer detection system. Ohayon (1999) used fuzzy systems to examine sleeping disorders. Fuzzy systems are used to integrate the uncertainties in the assessment and diagnostic features of findings. The membership grades for each of the findings in the study were calculated. Bates and Young (2003) showed that making medical decisions for patients in intensive care units can be done on the basis of fuzzy logic. Because of the similarity between fuzzy logic and expert clinical thinking, it is predicted that fuzzy logic can be used in some clinical decision-making situations. Zoroğlu (2015) designed a fuzzy expert system to estimate the severity of the obstructive sleep apnea-hypopnea syndrome disease. Seriousness levels were determined in the direction of the fuzzy rule base that was created by using expert opinions in the study. Likewise, Boz Eravci (2016) modeled the risks by using the data of people who were diagnosed with silicosis, the occupational disease.

Fuzzy logic applications are also encountered in the field of social sciences, but not as much as the other fields. Imriyas et al., (2006) proposed a framework for the calculation of premiums for Worker's compensation insurance. They used project hazard, constructor's safety performance, overhead cost, competition level, demand for worker's compensation insurance as inputs and claims unit cost and markup as outputs in the fuzzy system. As a result, the authors found out that proposed model is more advanced than the existing method. Baran et al. (2010) established a fuzzy rule base based on expert opinion for the evaluation of green card applicants in order to prevent human error and abuse. Fuzzy rule base was created separately by 10 different sub-expert systems. As a result, it has been determined that individuals are not able to buy a green card in the direction of their characteristics and they were compared with expert opinions. The results obtained were in accordance with the current system results. It has been shown that the use of fuzzy logic in the areas where evaluations based on the expert opinion were made with this study gives healthy results. Bulğurcu (2014) estimated the unemployment rate for 2013 with the fuzzy inference system (ANFIS) based on adaptive network structure using the unemployment rates between 2000 and 2012. Alptekin and Yeşilaydın (2015) categorized Organization for Economic Co-operation and Development (OECD) countries by fuzzy clustering analysis in terms of health variables.

As it can be seen from the studies mentioned above, fuzzy logic is preferred especially in the field of engineering. However, it should take place more in social sciences as demonstrated by Baran et al. (2010). In the light of this study, it was thought that in the field of social sciences, systems that include fuzzy logic should take more place so that evaluations based on expert opinion can be made better. For that reason, this paper aimed at providing another application example of fuzzy logic in social sciences.

III- GENERAL HEALTH INSURANCE SYSTEM IN TURKEY

Social insurance differs from social welfare and social services because it is a system based on premiums. Premiums are collected from people covered by the insurance. However, the premiums to be taken are determined according to the level of income, not according to the personal and family status of the individual (Sözer, 2015: 1). The principle of necessity is the distinguishing and determining characteristics of social insurance. However, with the Law No 5510 (Republic of Turkey The Official Gazette, 2006) "optional insurance", an exception, was made to this principle (Güzel et al., 2014: 215). This has shown that in addition to expanding the scope of social insurance, it may have similar characteristics to private insurance. Therefore, the basic principle of insurance law, "compulsory insurance and voluntary insurance relations cannot be realized at the same time" has been abandoned (Alper, 2015: 123).

Under the name of Social Security Reform, the Health Transformation program at the beginning of 2003 was aimed at turning around 8 themes. One of the objectives is to establish the General Health Insurance System, which gathers everyone under a single roof (Republic of Turkey Ministry of Health, 2008). No one is left outside of the health system. Even if the individual is unemployed, he/she is covered by health insurance and is guaranteed by the state without paying compulsory insurance (Pekten, 2006: 120). Karadeniz (2012a) stated that the General Health Insurance is one of the important components of the healthcare transformation project and that they are collecting different health care assurance systems under a single roof. In addition, health services will be provided by the state if the income per capita of the individual is less than one-third of the gross minimum wage (Karadeniz, 2012b: 117).

The amount of income per capita in the household must be determined for the people applying for general health insurance before determining the premium amounts to be paid by the general health insurance holders. This determination process has been conducted by Social Assistance and Solidarity Foundation and General Directorate of Social Assistance. Before the application to income determination, the status of the persons related to the general health insurance should be checked. If it is "Out-of-scope" and "60 / g insured", income determination application can be conducted.

The variables required for the calculation of household income per capita in Circular Letter no. 2012/7 (Procedures and Principles for the Determination of Income under the scope of General Health Insurance) have been expressed. In addition to household income, many parameters such as ownership, rental income, land income, the fair value of the vehicle are used by households. In order to be able to calculate the premium amount to be paid, the monthly values of the variables used to calculate the household income per capita are collected. A certain percentage of the property owned by a person is added to the calculation of the monthly household income per capita. In addition, if the expenditure of a citizen is more than the household income per capita, the

difference between expenditure and income is added. Moreover, "If the income per capita is more than twice the gross minimum wage in line with the declaration of the applicant, no income test is performed" (Circular Letter no. 2012/7, item: 1.11). In Table 1, registration codes are given according to monthly income per capita.

Table 1. *Income Levels*

Monthly Income Status Per Capita	Registration Code
Per Capita Income of Households $< \frac{\text{Gross Minimum Wage}}{3}$	G0
$\frac{\text{Gross Minimum Wage}}{3}$ < Per Capita Income of Households < Gross Minimum Wage	G1
Gross Minimum Wage < Per Capita Income of Households < Gross Minimum Wage × 2	G2
Gross Minimum Wage × 2< Per Capita Income of Households	G3

"Income levels can be determined on the basis of the statement of household declaration and the declaration form of the person will be subjected to a social survey within 1 year from the date of decision of the Board of Trustees for the outcomes of the final income level G0 and G1" (Circular Letter no. 2012/7, item: 2.1). After determining the registration codes of policyholders, their premium to be paid can be calculated based on a certain rate of the gross minimum wages. The amounts of premiums required to pay for those subject to general health insurance are demonstrated in Table 2.

Table 2. *Premium Amounts to be Paid*

Registration Code	Premium calculation	Amount of the premium*	Liable
G0	$\frac{\text{Gross Minimum Wage}}{3} \times 0.12$	71.1 TRY	It will be covered by the government.
G1	$\frac{\text{Gross Minimum Wage}}{3} \times 0.12$	71.1 TRY	The individual will pay for himself/herself.
G2	Gross Minimum Wage × 0.12	213.3 TRY	The individual will pay for himself/herself.
G3	Gross Minimum Wage × 2 × 0.12	426.6 TRY	The individual will pay for himself/herself.

Source: TÜBİTAK-BİLGEM Software and Data Engineering Department, Integrated Social Assistance Services Project General Health Insurance Income Identification Transactions Document

(*The Gross Minimum Wage for the dates 01.01.2017 - 31.12.2017 was taken into consideration. Source: The Republic of Turkey the Ministry of Labor and Social Security)

As a result of an income test, citizens are expected to pay their premiums on time. If anyone who does not apply income test, the premium will be calculated as if the income per capita is more than twice the gross minimum wage.

According to the report published in the newspaper (NTV News, 2017), there is approximately total of 12 billion lira premium credits of 4.5 million people who do not apply to General Health Insurance (GHI). Since 2012, the one who has not entered the income test finds the debt of 20 thousand Turkish liras. Consequently, the government proposed a new arrangement mentions that the penalty and interest for the past are erased and the debt is restructured from 53.33 Turkish liras per month for a certain time period. Although this new arrangement is aimed to relief, since the income levels of people who do not apply income test may differ, it actually generates new unequal premium problems among citizens.

Independently from the new arrangement, the general health insurance aims to provide fair, equitable, preventive and quality health care services to the whole population (Çallı, 2012: 1). However, it is seen that the differences between premium levels are quite large compared to income levels. This may lead to inequality among the citizens. Inequalities that arise in the current system can be listed as follows:

- Premiums are calculated in line with the amount of income per capita in the range of certain ratios of the gross minimum wage. Therefore, premium amounts to be paid for income groups determined with strict boundaries create inequalities between individuals.
- The highest level of income groups identified includes per capita income that is twice as large as the gross minimum wage. This situation is very high in income and provides an advantage to individuals who want to be insured on demand. In this case, inequality arises between low-income individuals and high-income individuals.
- In addition, certain levels of the value of the movable and immovable properties of household income are added to household income during the income test period. This increases the amount of monthly income per person. This situation can show the income level of the low-income individuals as high.
- The premiums payable on social insurance are not determined by the individual's risks and health status. However, when determining premium amounts, focusing only on changes in income and expenditure creates inequality for those living in the same household but benefiting differently from health services.
- It is clear that the transfer of premiums from young people to elder people, from healthy people to sick people, will create inequality between individuals when they are considered "voluntary insurers" involved in the study. It is thought that this inequality can only be eliminated by making use of a variable other than income and expenditure variables.

As a solution to these problems, the range of premium amounts can be narrowed by different levels of income to be determined by the new calculations to be made in these directions. This can contribute to eliminating inequalities experienced by citizens at different income levels by taking the advantage of fuzzy logic.

IV- THE PROPOSED MODEL

In this paper, a fuzzy rule base was built on the basis of fuzzy logic in order to reduce the difference between the income levels and premium amounts. It was aimed at eliminating the disparity between the individuals by calculating the premium amounts more fairly in the proposed model.

When considered on the basis of social insurance, it is imperative for an individual to be insured and there is no premium calculation in the direction of personal characteristics of the individual. However, under the scope of the Law No. 5510 "voluntary insurance" has been taken. "On-demand insurance" is based on private insurance. In private insurance, premiums are determined on an individual basis according to the characteristics of the individual. Generally, all insurances are based on the allocation of the premiums collected from the people who are exposed to the same risk to those who has been exposed to the risk. Tuncay and Ekmekçi (2015) stated that private insurance is the pioneer of social insurance. However, unlike private insurance, a social insurance system has been established to provide a transfer from the young to the elder, from the healthy individual to the sick in order to protect the weak. However, since the "insured person" was included in the study, the increase in the amounts of premium to be paid as the age increased became an exceptional situation with the private insurance logic. Therefore, in terms of the variables added to the model, the fuzzy rule base and the model proposed are revealed as a hybrid model of social and private insurance.

The variables used in the application were determined from the data of the Turkish Statistical Institute by the 2012 Household Budget Survey. When the aggregate data collected on the basis of the individual surveys were examined, the age range included in the application was limited to 18-99 because individuals under the age of 18 can benefit from the general health insurance as an affiliated insured. The sample has been limited to individuals who are considered as poor, having no social security and being insured on a voluntary basis. Therefore, the number of individuals whose premiums will be calculated with the proposed model was obtained as 4,650. Moreover, it was determined that when the amount of expenses per capita of the individuals participating in the survey is larger than the amount of available income, the difference was calculated by adding the difference.

The General Health Insurance premiums to be paid in the current method were determined by the amount of monthly income per person obtained by dividing

the household income calculated as a result of the income test into the household size. This situation requires that people living in the household pay the same premium amount although they are at different ages. However, since the individuals included in the study were identified as "poor", "no social security" and "voluntary insured", the model age variable was included by taking advantage of the private insurance policy for a fair premium calculation system. Unlike social insurance premiums that are transferred from young people to elder people, healthy people to patients, the possibility of benefiting from health services increases as one gets older when it is considered on the basis of private insurance. Therefore, in the proposed model with the fuzzy rule base, the rules were designed to increase the premium amount to be paid as the age increases.

A- MATLAB Application

MATLAB (matrix laboratory) which is being developed by MathWorks is the fourth generation programming language and a software that provides numerical calculations. MATLAB allows users to interface with programs written in other languages such as C, C ++, Java, and Fortran and allows users to create matrices, draw functions and apply algorithms. However, it also provides various ready to use toolboxes that are professionally developed such as optimization, control system designer, map viewer, linear system analyzer, fuzzy logic designer (MathWorks Inc., 2017).

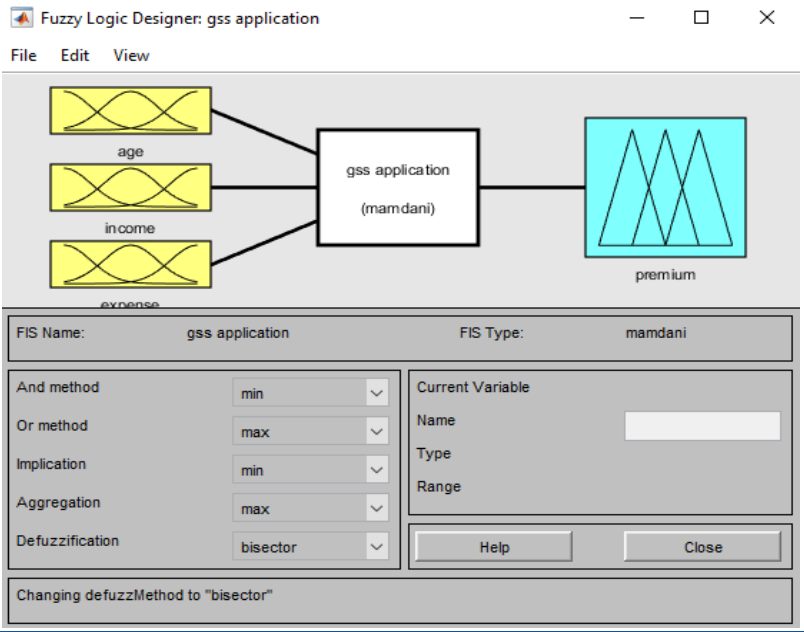
In this paper, MATLAB R2015a fuzzy logic designer toolbox was used to create fuzzy rule base, to define membership functions of linguistic variables, and to obtain fuzzy output variable. Three inputs and one output variable were specified for use in the fuzzy rule base. Fuzzy input values were transformed into fuzzy output values with Mamdani fuzzy inference mechanism. Finally, the fuzzy output values were obtained as the crisp value of the premium to be paid by using the defuzzification methods.

In Figure 1, the interface of the fuzzy logic designer toolbox is shown. On this screen, parameters were identified such as the inputs, the output, the inference system, the defuzzification method.

Thereafter, all variables should be identified. For each variable, membership functions and its ranges were determined respectively as shown below.

In order to fuzzify the age variable, linguistic expressions such as "too young", "young", "middle", "old" and "too old" were defined. The 18-99 age range was determined from the data of the household-based household budget survey. Membership functions for age were identified as trapezoidal membership functions. Trapezoidal membership functions and the fuzzy values of each linguistic statement are given in Equation 2, 3, 4, 5, 6 respectively.

Figure 1. *Fuzzy Logic Designer Toolbox Interface*



$$\mu_{\text{tooyoung}}(x;18;18;25;30) = \begin{cases} if & x = 18, & 1 \\ if & 18 \le x \le 25, & 1 \\ if & 25 \le x \le 30, & (30-x)/(30-25) \\ if & x > 30 \quad or \quad x < 18, & 0 \end{cases} \tag{2}$$

$$\mu_{\text{young}}(x;25;30;40;45) = \begin{cases} if & 25 \le x \le 30, & (x-25)/(30-25) \\ if & 30 \le x \le 40, & 1 \\ if & 40 \le x \le 45, & (45-x)/(45-40) \\ if & x > 45 \quad or \quad x < 25, & 0 \end{cases} \tag{3}$$

$$\mu_{\text{middle}}(x;40;45;60;65) = \begin{cases} if & 40 \le x \le 45, & (x-40)/(45-40) \\ if & 45 \le x \le 60, & 1 \\ if & 60 \le x \le 65, & (65-x)/(65-60) \\ if & x > 65 \quad or \quad x < 40, & 0 \end{cases} \tag{4}$$

$$\mu_{\text{old}}(x;60;65;80;85) = \begin{cases} if & 60 \le x \le 65, & (x-60)/(65-60) \\ if & 65 \le x \le 80, & 1 \\ if & 80 \le x \le 85, & (85-x)/(85-80) \\ if & x > 85 \quad or \quad x < 60, & 0 \end{cases} \tag{5}$$

$$\mu_{\text{tooold}}(x;75;85;99;99) = \begin{cases} if & 75 \le x \le 85, & (x-80)/(85-80) \\ if & 85 \le x \le 99, & 1 \\ if & x = 99, & 1 \\ if & x > 99 \quad or \quad x < 80, & 0 \end{cases} \tag{6}$$

In addition to the age variable included in the model exclusively, the monthly amount of available income per capita variable was added. Unlike the income test, which calculates monthly household income per capita, the monthly available income per capita was calculated by dividing the annual household income by the household size and dividing by 12. The linguistic expressions of the amount of monthly available income per capita were determined as "very low", "low", "medium", "high" and "very high". Membership functions of these linguistic expressions are trapezoidal membership functions and are shown in Equation 7, 8, 9, 10, 11 respectively.

$$\mu_{\text{verylow}}(y;0;0;500;700) = \begin{cases} if & y = 0, \quad 1 \\ if & 0 \le y \le 500, \quad 1 \\ if & 500 \le y \le 700, \quad (700 - y)/(700 - 500) \\ if & y > 700 \quad or \quad y < 0 \quad 0 \end{cases} \tag{7}$$

$$\mu_{\text{low}}(y;500;750;1000;1250) = \begin{cases} if & 500 \le y \le 750, \quad (y - 500)/(750 - 500) \\ if & 750 \le y \le 1000, \quad 1 \\ if & 1000 \le y \le 1250, \quad (1250 - y)/(1250 - 1000) \\ if & y > 1250 \quad or \quad y < 500, \quad 0 \end{cases} \tag{8}$$

$$\mu_{\text{medium}}(y;1000;1500;2000;2500) = \begin{cases} if & 1000 \le y \le 1500, \quad (y - 1000)/(1500 - 1000) \\ if & 1500 \le y \le 2000, \quad 1 \\ if & 2000 \le y \le 2500, \quad (2500 - y)/(2500 - 2000) \\ if & y > 2500 \quad or \quad y < 1000 \quad 0 \end{cases} \tag{9}$$

$$\mu_{\text{high}}(y;2000;2500;3000;3500) = \begin{cases} if & 2000 \le y \le 2500, \quad (y - 2000)/(2500 - 2000) \\ if & 2500 \le y \le 3000, \quad 1 \\ if & 3000 \le y \le 3500, \quad (3500 - y)/(3500 - 3000) \\ if & y > 3500 \quad or \quad y < 2000, \quad 0 \end{cases} \tag{10}$$

$$\mu_{\text{veryhigh}}(y;3000;4000;8000;8000) = \begin{cases} if & 3000 \le y \le 4000, \quad (y - 3000)/(4000 - 3000) \\ if & 4000 \le y \le 8000, \quad 1 \\ if & y = 8000, \quad 1 \\ if & y > 8000 \quad or \quad y < 3000, \quad 0 \end{cases} \tag{11}$$

Moreover, the amount of monthly spending per capita was also added as an input. The household monthly spending was divided into the household size. The amount of monthly spending per capita was expressed linguistically as "very little", "little", "medium", "excess" and "too much". The membership functions of each linguistic form are shown in Equation 12, 13, 14, 15, 16 respectively.

$$\mu_{\text{verylittle}}(z;0;0;500;700) = \begin{cases} if \quad z = 0, \quad 1 \\ if \quad 0 \le z \le 500, \quad 1 \\ if \quad 500 \le z \le 700, \quad (700 - z)/(700 - 500) \\ if \quad z > 700 \quad or \quad z < 0, \quad 0 \end{cases} \tag{12}$$

$$\mu_{\text{little}}(z;500;750;1000;1250) = \begin{cases} if \quad 500 \le z \le 750, \quad (z - 500)/(750 - 500) \\ if \quad 750 \le z \le 1000, \quad 1 \\ if \quad 1000 \le z \le 1250, \quad (1250 - z)/(1250 - 1000) \\ if \quad z > 1250 \quad or \quad z < 500, \quad 0 \end{cases} \tag{13}$$

$$\mu_{\text{medium}}(z;1000;1500;2000;2500) = \begin{cases} if \quad 1000 \le z \le 1500, \quad (z - 1000)/(1500 - 1000) \\ if \quad 1500 \le z \le 2000, \quad 1 \\ if \quad 2000 \le z \le 2500, \quad (2500 - z)/(2500 - 2000) \\ if \quad z > 2500 \quad or \quad z < 1000, \quad 0 \end{cases} \tag{14}$$

$$\mu_{\text{excess}}(z;2000;2500;3000;3500) = \begin{cases} if \quad 2000 \le z \le 2500, \quad (z - 2000)/(2500 - 2000) \\ if \quad 2500 \le z \le 3000, \quad 1 \\ if \quad 3000 \le z \le 3500, \quad (3500 - z)/(3500 - 3000) \\ if \quad z > 3500 \quad or \quad z < 2000, \quad 0 \end{cases} \tag{15}$$

$$\mu_{\text{toomuch}}(z;3000;4000;8000;8000) = \begin{cases} if \quad 3000 \le z \le 4000, \quad (z - 3000)/(4000 - 3000) \\ if \quad 4000 \le z \le 8000, \quad 1 \\ if \quad z = 8000, \quad 1 \\ if \quad z > 8000 \quad or \quad z < 3000, \quad 0 \end{cases} \tag{16}$$

After the input variables are expressed linguistically, also the output value must be expressed linguistically in order to create the fuzzy rule base. In practice, the amount of premium to be paid as an output variable was considered. Based on the Law No. 5510, the premiums that should be paid based on the amount of income per capita of the general health insurance nowadays were divided into four different classes. However, further classification of the amounts of premiums that people need to pay based on their income, expenditures and their age will contribute to the elimination of inequalities among people.

Firstly, the premium variable to be paid was dealt with in two stages. The first part will be paid by the state and the second part will be paid by the individuals themselves. It is necessary that the amount of premium to be paid by the state on behalf of the citizen should vary according to the age of the individual. Therefore, the amounts of premiums for the individuals whose premiums will be paid by the state is classified as "the state will pay more" and "the state will pay less". In addition, the classification of premiums to be paid by citizens with better income was made in the form of “very little", "little", "moderate", "more" and "a lot". As a result, the amount of premium that should be paid out, which

is output variable, was linguistically defined in seven different ways. Revenue was defined as the amounts of premiums to be paid to poor individuals who are so bad that they cannot afford to pay premiums. It will be able to be separated from other premium amounts in this way. Membership functions of linguistic expressions of output variable were defined by triangular membership function different from input variables. Representations of membership functions of each linguistic form are given in Equation 17, 18, 19, 20, 21, 22, 23 respectively.

$$\mu_{\text{statemore}}(p;-125;-125;-75) = \begin{cases} if & p=-125, \quad 1 \\ if & -125 \le p \le -75, \quad (-75-p)/(-75-(-125)) \\ if & p>-75 \quad or\ p<-125, \quad 0 \end{cases} \tag{17}$$

$$\mu_{\text{stateless}}(p;-100;-75;-50) = \begin{cases} if & -100 \le p \le -75, \quad (p-(-100))/((-75)-(-100)) \\ if & -75 \le p \le -50, \quad (-50-p)/(-50-(-75)) \\ if & p>-50 or \quad p<-100, \quad 0 \end{cases} \tag{18}$$

$$\mu_{\text{verylittle}}(p;25;75;125) = \begin{cases} if & 25 \le p \le 75, \quad (p-25)/(75-25) \\ if & 75 \le p \le 125, \quad (125-p)/(125-75) \\ if & p>125 \quad or\ p<25, \quad 0 \end{cases} \tag{19}$$

$$\mu_{\text{little}}(p;100;150;200) = \begin{cases} if & 100 \le p \le 150, \quad (p-100)/(150-100) \\ if & 150 \le p \le 200, \quad (200-p)/(200-150) \\ if & p>200 or \quad p<100, \quad 0 \end{cases} \tag{20}$$

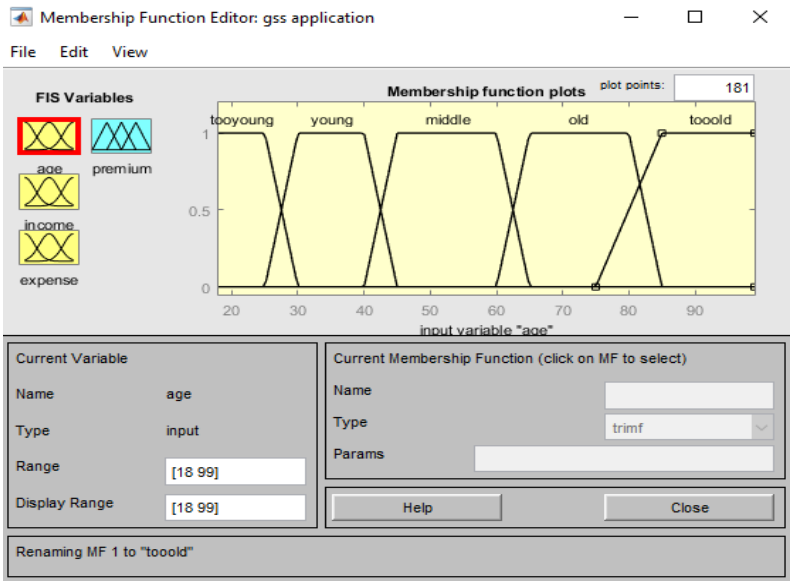
$$\mu_{\text{moderate}}(p;175;225;275) = \begin{cases} if & 175 \le p \le 225, \quad (p-175)/(225-175) \\ if & 225 \le p \le 275, \quad (275-p)/(275-225) \\ if & p>275 or \quad p<175, \quad 0 \end{cases} \tag{21}$$

$$\mu_{\text{more}}(p;250;300;350) = \begin{cases} if & 250 \le p \le 300, \quad (p-250)/(300-250) \\ if & 300 \le p \le 350, \quad (350-p)/(350-300) \\ if & p>350 or \quad p<250 \quad 0 \end{cases} \tag{22}$$

$$\mu_{\text{alot}}(p;325;400;400) = \begin{cases} if & 325 \le p \le 400, \quad (p-325)/(400-325) \\ if & p=400, \quad 1 \\ if & p>400 or \quad p<325, \quad 0 \end{cases} \tag{23}$$

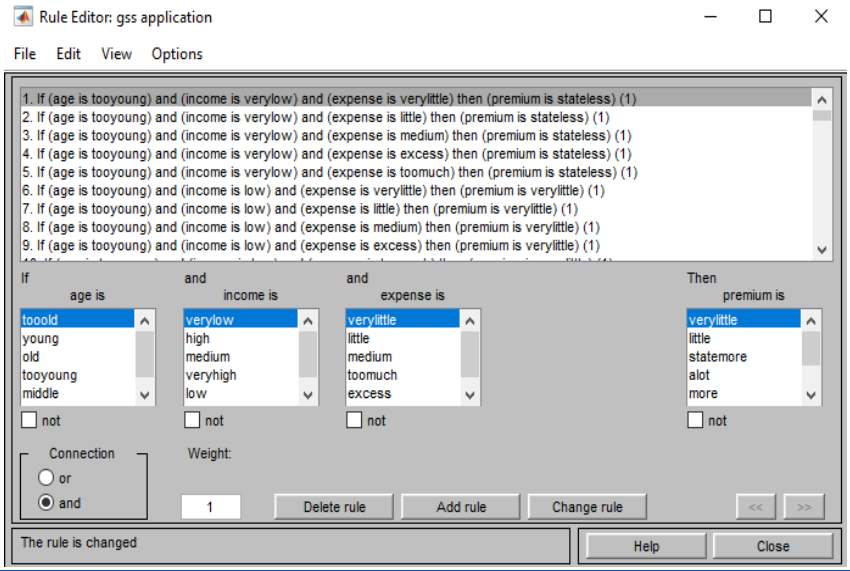
The determined membership functions and their ranges should be entered in MATLAB by clicking on each variable respectively. The process of identification of the inputs and output was conducted on the screen displayed in Figure 2. Only the “age” variable was demonstrated as an example.

Figure 2. *Membership Functions of Each Variable*



By considering all combinations of inputs, 125 pairs of rules[2] were evaluated with the help of expert opinion and entered as shown in Figure 3. An example of these rules can be mentioned as: "If the person is old, the amount of monthly available income per person is very high and the amount of monthly spending per person is very little then he will pay a premium a lot".

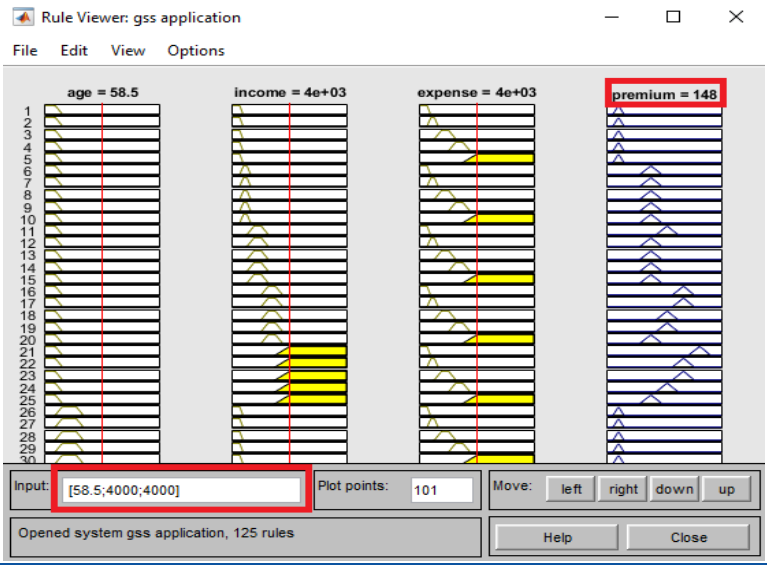
Figure 3. *Fuzzy Rules*



[2] A table of 125 fuzzy rules can be requested from authors if it is needed.

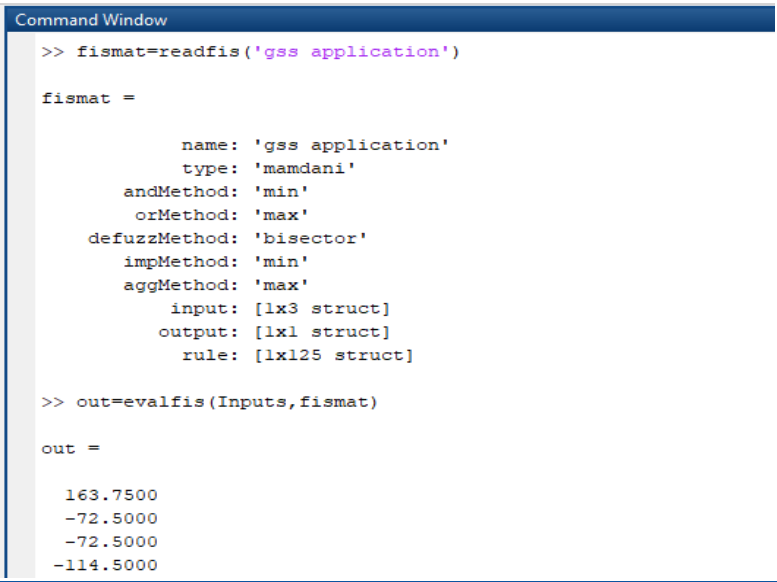
After forming the fuzzy rule base by expert opinion, the Household Budget Survey data prepared by Turkish Statistical Institute in 2012 was used as inputs. However, the fuzzy logic designer toolbox provides just manually data entering as demonstrated in the bottom of Figure 4 as 'Input' section.

Figure 4. *Output screen*



Since the data consist 4650 individuals, the manual calculation is not feasible. For that reason, the premium calculation for 4650 individuals was conducted by using "evalfis" function displayed in the command window in Figure 5.

Figure 5. *Premium Calculation (Command Window)*

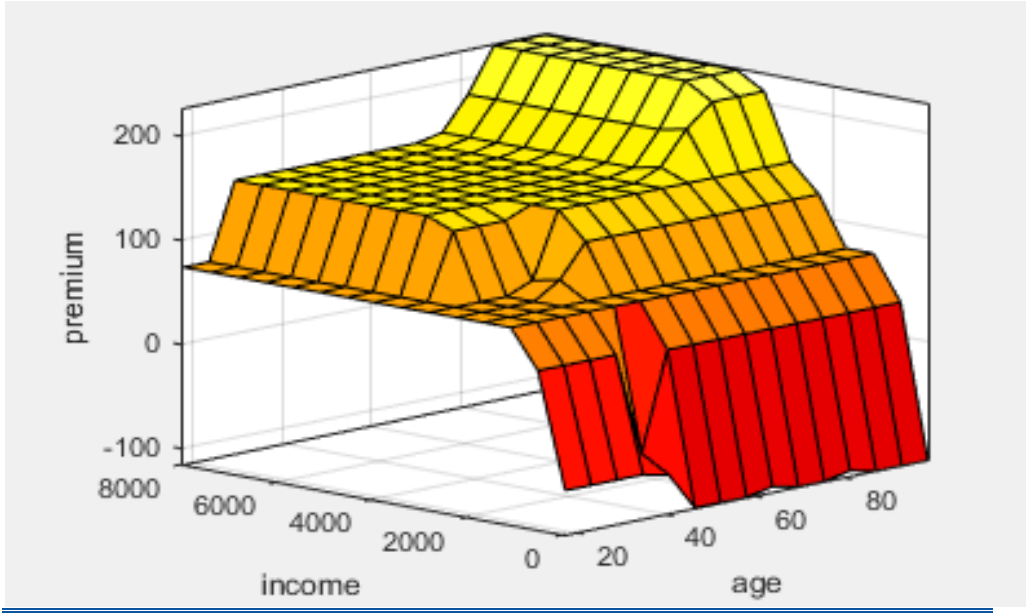


In this command window displayed in Figure 5 firstly, the rule base was described by 'fismat = readfis('gss application')' row. Then the input file 'Inputs.xlsx' was imported to MATLAB as a numeric matrix from the 'Import Data' menu. Finally, by using rule base and the input file, the output was obtained by 'evalfis' function. The calculated premiums mentioned as output (only the first four rows are shown in Figure 5) were obtained for 4650 individuals.

A number of defuzzification methods have been applied to the basis of the fuzzy rule in order to determine the most appropriate method to be used in the study. When the defuzzified output values are examined, the bisector method which is the most suitable result giving method was determined. In this method, the defuzzified value is a straight line dividing the membership function into two equal parts.

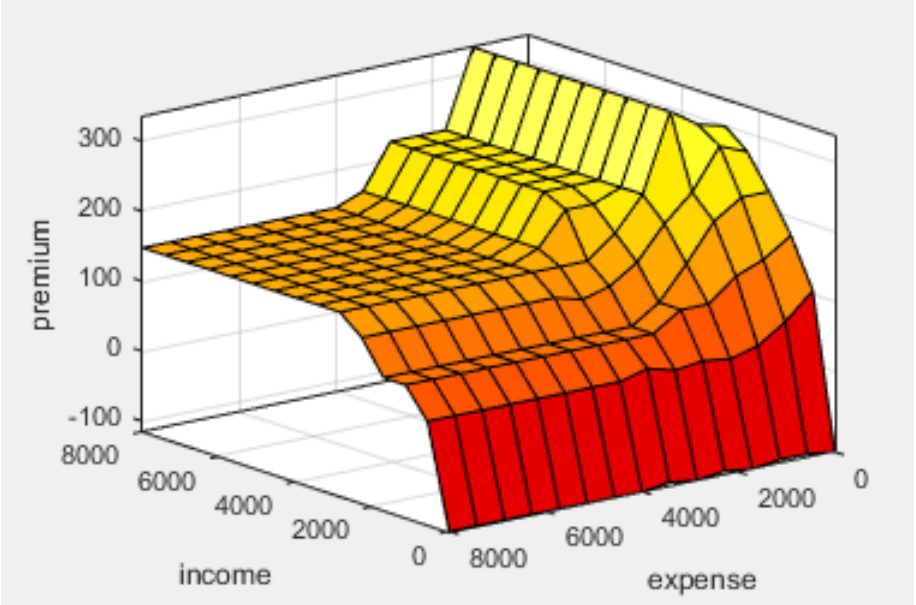
Rather than giving all the premium amounts calculated, the graphical representations were demonstrated as follows. The surface of inputs and output can be obtained as shown in Figure 6, 7 and 8 respectively. Each of them shows the gradual change of insurance premium according to the income, expense, and age of individuals.

Figure 6. *Income-Age Surface*



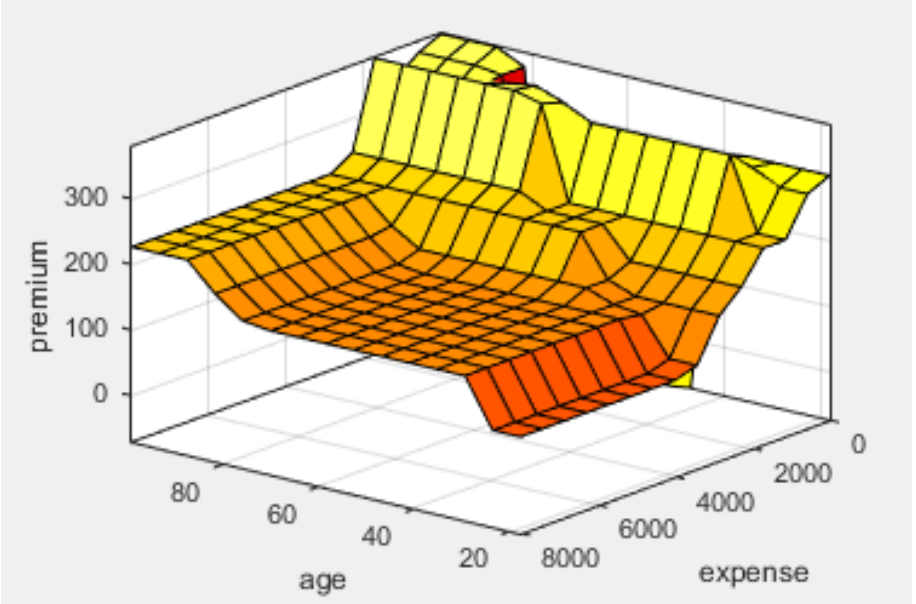
According to the Figure 6, it can be observed that when the amount of income increases and the individual is getting old, the premium to be paid will increase.

Figure 7. *Income-Expense Surface*



In Figure 7, the graph demonstrates that how the changes in income and expense affect the premium to be paid as visually. When the income level increases and the expenses of the individual are low, the premium will increase.

Figure 8. *Expense-Age Surface*



Since the fuzzy rules were constituted by focusing on the income levels and ages, the change of expense cannot affect the premium directly. Therefore, this graph has no steady structure as it can be seen from the Figure 8.

The comparison of the premium amounts obtained with the fuzzy rule base with the premium amounts calculated by the current system is shown in Table 3. Also, the situation where a fixed premium of 60 TL is taken from the individuals for comparison was included. Thus, Table 3 shows how the results change as current problems are removed and new variables are added. Input variables are expressed as [x; y; z]. Where x is age, y is the monthly available income, and z is the monthly expenditure. In Table 3, sample premium calculations were made for each model.

The premium amounts calculated for 4,650 people represent the sample. In order to make a countrywide comment, factor values (the weights) calculated by Turkish Statistical Institute were multiplied by calculated premium amounts. The amounts of premiums collected from the 9,749,855 individuals who have made the weighting result was estimated. As a result, the total premiums to be collected from 9,749,855 persons who are minimum 18 years old and have no social security, poor or voluntary General Health Insurance in Turkey was estimated as shown in Table 4.

Table 3. *Sample Calculation for the Proposed Model and Current Model*

Citizen	Inputs	Proposed Model (TRY)	Current Model* (TRY)	Fixed** Premium	Citizen	Inputs	Proposed Model (TRY)	Current Model* (TRY)	Fixed** Premium
36	[45;280;180]	-114.5	71.1 (State)	60	**633**	[33;2171;2171]	127	213.3	60
41	[47;320;263]	-114.5	71.1 (State)	60	**3722**	[22;2373; 2373]	137.5	213.3	60
42	[42;320;263]	-88.25	71.1 (State)	60	**4347**	[28;2765;2765]	148	213.3	60
37	[24;280;180]	-72.5	71.1 (State)	60	**1191**	[52;3060;3060]	153,25	213.3	60
43	[23;320;263]	-72.5	71.1 (State)	60	**628**	[87;2121;1039]	373,75	213.3	60
15	[22;661;661]	69.25	71.1	60	**2508**	[33;4415;4415]	148	426.6	60
13	[48;661;661]	79.75	71.1	60	**1**	[35;5048;2370]	163,75	426.6	60
12	[85;661;661]	142.75	71.1	60	**2993**	[39;3800;2117]	211	426.6	60
622	[48;1638;1167]	184.75	71.1	60	**3277**	[53;3611;1160]	268,75	426.6	60
2179	[50;1339;959]	226.75	71.1	60	**1064**	[36;5448;5448]	148	426.6	60

*Minimum gross wage was taken as 1647 TRY for the year of 2017.

**Fixed premium of 60 TRY for individuals (Source: Hürriyet News 2012)

In 2012, 75.02% of the total premiums collected in the current system was paid by the state while 24.98% was paid by the individuals themselves. When the model created by fuzzy logic is used, 74.27% of the collected premiums will be paid by the state and 25.73% will be paid by the individual himself. Therefore, when the values are examined, there is a small difference of about 1% between the percentiles falling to the state and the percentages being applied to the state in the proposed model. This difference indicates that the share of the total premium amount will decrease with the proposed model and the share that individuals will pay will increase. This can be interpreted as a consequence of

the government's premium grading. Therefore, if the proposed model is applied to real data, it is seen that it will give more healthy and fair results.

Table 4. *Collected Premium Amounts**

	Current System**	Proposed Model with Fuzzy Rule Base	Fixed Premium Assumption***
Total Premium Paid by State	540,051,139.10	627,636,036.99	455,739,357.89
Total Premium Amount to be paid by the individual	179,793,123.32	217,492,169.65	129,251,959.66
Total Premium Amount	719,844,262.42	845,128,206.64	584,991,317.55
State %	0.7502	0.7427	0.7791
Individual %	0.2498	0.2573	0.2209

*They were calculated in the direction of the 2012 data.

** It was calculated by using the household budget survey of TURKSTAT

*** Premium amount to be paid per person was taken as 60 TRY (Source: Hürriyet News, 2012)

In Table 5, the number of individuals in the current system and the number of individuals in the proposed model to be paid by the state or by itself are given. In the current system, the income levels are made in four classes, whereas in the proposed model seven classes. The comparison was made according to the premiums are paid by the state or not.

Table 5. *The Number of Individuals**

2012	Current System**	Proposed Model with Fuzzy Rule Base ***
Number of Individuals Covered by the State	7,595,656	7,305,638
Number of Individuals who pay their premiums themselves	2,154,199	2,444,217
Total Number of Individuals	9,749,855	9,749,855
State %	0.7791	0.7493
Individual %	0.2209	0.2507

*They were calculated in the direction of the 2012 data.

** Annual household income was used

*** They were obtained by weighting the survey data

As a result from Table 4 and Table 5, when the proposed model is applied, the total premium rate of the premiums to be paid by the state decreases in the total premiums collected, whereas the amounts of premiums collected increases. As a result, when the premium is calculated by the model created by the fuzzy rule base, premium amounts are obtained in a more fairly way than the method applied today. Individuals with high incomes are more likely to pay premiums than individuals with low incomes, or those who are in different age groups with the same amount of income and expenses, pay premiums in different amounts, indicating that the model is offsetting the inequalities among the citizens.

CONCLUSION

In this study, a model proposal was made in order to eliminate the inequalities between individuals, which mentioned above as problems in the existing system. This model was created by using fuzzy logic. In order to be able to calculate the premium amounts to be paid, the Household Budget Survey data prepared by Turkish Statistical Institute in 2012 was examined. Therefore, monthly available income amounts, monthly spending amounts and ages of the individuals for use in the study were determined as input variables. Because the specified input variables are not limited to crisp values, the variables were fuzzified by the linguistic expressions used in everyday life. 125 fuzzy rules were created with fuzzy input variables. Utilizing Mamdani inference mechanism, the fuzzy rule base provides the fuzzy output value premiums. Finally, the fuzzy output values were converted to numerical values.

When the citizens in the microdata set were restricted to voluntary work insurances, the poor and the minimum 18-years-old who have no social security, the amounts of premiums to be paid by 4650 people was calculated. Since the calculated premiums represent the sample, the amounts of premiums to be paid was weighted in order to be able to make a general estimation of Turkey. As a result, 9,749,855 people were found to collect premiums.

Suggestions for further studies can be given as follows: The number of variables included in the study is limited to three to make the model applicable. However, it is possible to determine the premium amounts to be paid by adding different variables to the study. In addition, the study can be repeated by taking advantages of income and expenditure variables calculated by different models and with recent dataset instead of the available income amount in the questionnaire prepared by Turkish Statistical Institute. Moreover, this approach can also be applied to the other countries' general health insurance systems. In addition to the suggestions mentioned above, similar studies can be done in systems where individuals are classified according to certain criteria, and in systems that random rates are used without scientific basis like tax rates.

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