A Fuzzy Cognitive Map System to Explore Certain Scenarios on the Cyprus Banking System

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Keywords: Fuzzy Cognitive Maps, Intelligent Systems, Private Sector Involvement.

Abstract: The model of Fuzzy Cognitive Maps (FCMs) allows a user to investigate how the influencing parameters of a cause-effect system behave under the implementation of desired scenario. Human knowledge and experience is used to define the structure and the parameters of a FCM model. This paper proposes a methodology which smoothly directs the steps that the experts should take in building an FCM system in order to reduce the subjectivity which characterizes such expert systems. Furthermore, an update rule for the parameters during the simulation phase is presented. Finally, the novel FCM construction methodology and the proposed FCM update rule are tested on a real-life system to investigate the repercussions of the combination of the Greek private sector involvement (PSI) with the decrease of people's confidence towards the Cyprus banking system. The results resemble what actually happened to the Cyprus economy a short period after the implementation of the Greek PSI.

1 INTRODUCTION

A wide variety of realistic socio-politico-economic systems are dynamic and may be characterized by the intra-system causality of their interrelated constituent components. Their dynamic behaviour makes their modelling, manipulation and handle difficult. Hence, investigating how these systems respond to different scenario cases regarding their parameters is crucial for the right and beneficial use. Fuzzy Cognitive Maps (FCM) modelling offers an alternative approach for the building of intelligent systems, through the use of interactive influencing parameters (Koulouriotis et al., 2001; Carvalho, 2013; Andreou et al., 2005).

An FCM system is constituted by a set of certain concepts of the system and a set of the concepts' interconnections. By using the FCM technology one can apply the changes he/she wishes to any of the parameters, and then observe the effects on any other parameters or subsystem. After a change is applied to selected initial states of the concepts of interest, the system is let to evolve for a number of steps until the concept states converge to stable values. Further analysis and work can be done on the converged final states of the system for understanding how indirect cause – effect relations drive the system's behaviour.

The success of the process strongly depends on the proper set-up of the FCM system. Even though in the last decade, efforts have been made to extract the structure of an FCM system by using machine learning methods, the predominant FCM construction procedure is highly depended on integrating experience and knowledge from human experts (Stach et al., 2010). The human expert based FCM building methodology is very suitable modelling socio-politico-economic FCM systems, especially when there no historical data available that could be used in order to employ machine learning processes to construct the system (Papageorgiou, 2011).

Hence, since the construction of FCM systems highly relies on targeted knowledge that is extracted from experts, it is substantially crucial to establish a certain methodology for developing qualitative FCM models. Thus, the success of the FCMs' developmental phase is based on an accurate extraction of expert knowledge or experience. A framework of such a methodology was presented

Papaioannou M., Neocleous C., Papageorgiou C. and Schizas C..
A Fuzzy Cognitive Map System to Explore Certain Scenarios on the Cyprus Banking System.
DOI: 10.5220/0005039701030110
In *Proceedings of the International Conference on Fuzzy Computation Theory and Applications* (FCTA-2014), pages 103-110
ISBN: 978-989-758-053-6
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analytically in Papaioannou et al. (2013).

The parameters and their interrelations of an FCM system constitute veritable semantic terms of the modelled system. Hence, they can be interpreted by whoever builds the system in an explicit manner. Additionally, the update rule describes the degree of influence between different parameters of a cause – effect system which basically comprises the cornerstone of the Fuzzy Cognitive Maps. Furthermore, in order to satisfy the limitation of keeping the concept state values in the range of [0, 1] (Stylios and Groumpos, 2004) the update rule uses a transformation squashing function (e.g. logistic function) which basically squashes each new concept state value into the desired limited range. However, the use of the transformation function cannot be explained using semantics from FCM background theory and hence it cannot be interpreted. The idea behind the FCM technology is the modelling of how real cause-effect systems work. All FCM modelling elements can be described using causality semantics, except the update function. For avoiding any squashing functions when updating the parameters' state value in every running iterations of the FCM system, a novel update rule is used which is described in a later section of this paper.

Our work takes FCM modelling technology a step forward since both the FCM construction methodology and the novel update function rule are implemented and applied to a real life, strongly intricate system describing the interacting concepts of the Cyprus banking system and economy.

It is well known, that in 2008 a new global financial crisis emerged. This crisis was transmitted to the European economies and especially the weakest of them in the southern European belt, evolving into "national debt crises". Greece was the first country which had to deal with the possibility of a national bankruptcy in 2009. As a result of the continuous and strong increase in Greek government debt levels, Greece's sovereign debt was downgraded by the International Credit Rating Agencies to junk status in April 2010. There was a fear that other countries could be affected by the Greek economic crisis. This forced Europe to take important and decisive corrective actions under the pressure of time. In May of 2010, the Troika which is a tripartite committee constituted by the European Commission, the International Monetary Fund (IMF) and the European Central Bank, agreed to give Greece a three-year €110 billion loan. As part of the deal with Troika, the Greek government implemented a series of austerity measures. These, led Greece to an even deeper recession. As a result, in February of 2012, Troika decided to provide Greece a second bailout package accompanied with a restructuring agreement by enforcing losses on the private sector holders of Greek sovereign debt, a process known as "private sector involvement" (PSI). The debt restructuring deal declared that private holders of Greek government bonds had to accept a 53.5% so-called "haircut" to their nominal values. Eventually, in March 2012, the bond swap was implemented with an approximately 75% effective write-off.

The Cypriot and Greek economies are strongly related and connected. As a consequence the Greek PSI agreement had serious repercussions to the Cyprus economy. More specifically, the Cypriot banking system was strongly impacted by the Greek PSI, since it was highly exposed to the Greek government bonds. Cypriot banks lost the equivalent of 20% of Cyprus GDP in this unfortunate investment. At the same time the Cyprus economy was dealing with other serious economic problems such as a stagnating economy and an increasing fiscal deficit.

Added to this, the revelation of such unsuccessful and injurious investments on the Greek government bonds led people to lose their faith in the Cypriot banking sector. The future of the Cypriot economy and especially its banking system seemed uncertain.

In this work, an attempt has been made to model the dynamics of the above problem and general situation using the technology of fuzzy cognitive maps. That is, once we manage to produce an FCM model of the situation, to study the long term impacts the banking system as a result of the Greek PSI in combination with the decline in confidence towards the Cypriot banking system.

For the purposes of this work, four basic scenarios were implemented and tested. Namely, introducing to the system a 75% Greek PSI and decreasing the level of confidence of people to the Cypriot banking system by 25%, 50% and 75%.

2 THE FCM MODEL

Dynamical systems and in particular political–economic–social systems which are characterized by causality tend to reach steady states. A change to the initial state vector describing such a system stimulates a series of subsequent influencing changes to the parameters of the system which eventually settles to stable state vector. For real life systems, it is crucial for the decision makers to have an estimate on the cost of changing a state of a concept and how will that change affect other concepts of interest.

FCMs are a soft computing methodology of modelling such dynamic systems, which constitute causal relationships amongst their parameters. They manage to represent human knowledge and experience, in a certain system's domain, into a weighted directed graph model and apply inference presenting potential behaviours of the model under specific circumstances. The parameters are led to interact until the whole system reaches equilibrium. FCMs allow a user to observe intricate and hidden causal relationships and to take advantage of the causal dynamics of the system in order to observe the effects of a possible action scenario.

Most of the times, human experts in the system's domain are used to identify the important parameters and their interactions in the system. However, although the experts might be characterized by a great expertise, it is difficult for them to make a right prognosis of the future states under different scenarios, mainly due to the high complexity of the systems.

2.1 FCM Novel Building Methodology

In order to reach meaningful conclusions, the FCM model must be built based on knowledge regarding the system that is distilled from several experts. For that reason, the proposed FCM building methodology (Papaioannou et al., 2013) using experts' knowledge and experience was applied to the system described in the present work.

By following the proposed steps of this novel FCM construction procedure the experts define and set the parameters of the system (called concepts in the standard FCM formalism) and the interconnections between the concepts (called weights or sensitivities in FCM theory).

2.1.1 Step 1: Define Time Period

The very first thing the experts were called to do was to accurately define the time period in which they wish to study the system. Specifying the time horizons in which the experts were asked to describe the system helped to limit the amount of information that was needed to properly define the system. For example, in this work, the experts were asked to study the economic consequences of Greek PSI in combination with the decrease of people's confidence in Cyprus banking sector as they were performed in April 2012. Therefore, the valuation of the parameters' states will be done based on material, statistics or any other information describing them in the specified time window. In this case the experts defined the time window at +/- 3 months from April 2012.

2.1.2 Step 2: Identification of the Parameters of the System

Having defined the time period, the experts proceeded to the identification of the principal parameters of the system and their special features. In order to enhance the experts' perception about the actual and up-to-date interpretation of each concept without semantic confusion, they were asked to fill a table of different fields describing the system's parameters.

Specifically, the experts had to conclude to a formal description of each parameter, the measurement units describing each parameter, the maximum and the minimum value that each parameter scored in the pre-specified time window and the degree of variation of each concept that the experts believed it would happen by the implementation of the scenario to be tested.

Finally, the experts had to consider the actual value characterizing each parameter in April 2012. These values comprised the reference point for the definition of the initial states of the concepts. In the context of the formal FCM theory, the concept states are described by a value in the range of [0,1]. Hence, the initial activation value of each concept was normalized to scale [0%, 100%], just like the conventional FCM models.

2.1.3 Step 3: Calculation of the Sensitivities (Weights) of the FCM Interrelations

In the next phase, the calculation of the sensitivities values of the system's interrelations followed, which is different from the traditional way of defining them in the FCM bibliography. The reasoning behind this deviation from the conventional FCM, is because we have a different apprehension of what substantially a sensitivity value means in the context of FCM. Thereafter it is important to clarify the definition of the sensitivity. A sensitivity value indicates the degree of the influenced concept's change in respect to the change of the influencing concept's state. The sensitivity of the relation describes the impact of changing the state of Ai on the concept Aj. The above statement can be mathematically formulated into Equation (1):

$$S_{ij} = \frac{\left(A_j^{t+1} - A_j^{t}\right) / A_j^{t}}{\left(A_i^{t} - A_i^{t-1}\right) / A_i^{t-1}} \tag{1}$$

In Equation (1), t is the iteration counter. Furthermore, A_i^{t-1} is the initial activation state of the influencing concept whereas A_j^t is the initial activation state of the influenced concept. A change happens in the state of the influencing concept which is depicted in A_i^t. This change stimulates the change of the influenced concept state which drives to a new state A_j^{t+1}. The change of a concept's state, between two discrete consecutive time cycles, is measured as a percentage to the concept's initial state. Indeed, the sensitivities of the modelled system described in this work were calculated by using Equation (1).

For each parameter, a simple scenario of changing its initial state was developed. The degree of that change was based on the corresponding degree of variation as the experts had already defined in the previous FCM developmental stage. For better understanding, an example of a sensitivity calculation is given. Consider the relation between the STOCK MARKET VALUE (concept 7, C7) and the RECAPITALIZATION BY PRIVATE EQUITY (C6). The experts defined the initial states of C7 and C6 as 40% and 20% respectively. Furthermore, they expected a negative relationship of high intensity of the degree of variation for the STOCK MARKET VALUE as a result of the implementation of the Greek governmental bonds "haircut". Therefore the question for this sensitivity was finally formed as:

"If the level of the parameter STOCK MARKET VALUE gets reduced from 40% to 0%, what will be the new state of the concept RECAPITALIZATION BY PRIVATE EQUITY if now is 20%?". For this example the experts answered 0%. However, measuring the change of the two consequent states of a concept, as a percentage of its initial value gives a better feeling about the strength of the variation. Therefore by applying the Equation (1) the resulting sensitivity between the concepts C7 and C6 is:

$$S_{7,6} = \frac{(0-0.2)/0.2}{(0-0.4)/0.4} = 1 \tag{2}$$

In that way, each expert forms his own sensitivity matrix reflecting his own beliefs about the system's structure and behaviour. By using this sensitivity matrix along with the already set initial values, the FCM system is let to "run" until it reaches equilibrium. At this point, the number of iterations the system needs to converge is regarded as the duration period the system needs to reveal the total impact on each concept. Hence, in order to calculate the effect that each concept receipts per iteration, the sensitivities are divided by that number of iterations (needed by the system to settle to stable values the very first time). For this system this number was 10 and thus the final value of $S_{7,6}$ = 0.1. That is called the "absolute sensitivity".

2.2 FCM Update Rule Function

A set of concepts and their interrelations are necessary to form the structure of an FCM system. An activation function in FCMs defines the way the system will process causality for simulation purposes. An activation function calculates the updated state values for each concept after interacting with its influencing neighbours.

The traditional FCM activation function approach has been slightly modified. The modified version was first presented in Papaioannou et al. (2013). This modified activation has been used in the present study. The central idea of this novel activation function is that an impact is created onto the FCM system when and only when a parameter changes its equilibrium state value. Therefore it is the change itself that causes the system perturbation and forces it to reach a new equilibrium state. Consequently, the concept state should be updated by taking into account, the changes that happened during each iteration to its influencing neighbours. Besides, this was the main idea of the way the sensitivities were calculated, as described in the previous section.

At each iteration the new activation state value must be calculated for each influenced concept, where in Equation (1) the term A_j^{t+1} stands exactly for that. Thus, solving Equation (1) for A_j^{t+1} and aggregating this change with the existing influence concept state will result in Equation (3) where t is the iteration counter, A_j is the activation strength of the concept of interest and s_{ij} is the sensitivity (weight) which is a measure on how much a change in the current standing of concept A_i affects the changes in the standing of concept A_j.

$$A_j^{t+1} = A_j^t + \sum_{i=1}^{n} s_{ij} \left(A_i^t - A_i^{t-1} \right) \frac{A_j^t}{A_i^{t-1}} \qquad (3)$$

Summarizing, a change to the initial states of an FCM system, stimulates the interaction of its parameters leading to an iterative process of updating their states using the activation function given by Equation (3) until the system converges to a stable state. Then the user of the system may observe and make conclusions on the direct or indirect effects of that change reflected on the final states of the system.

3 THE FCM EXAMPLE OF CYPRUS BANKING SYSTEM AND ECONOMY

FCM model has been around in scientific area for more than 25 years. However, there is a lack of FCM applications in real-life complex systems. In order to contribute towards the empirical justification of the usability of this model, a system taken from the Cypriot economic and banking reality was chosen to test the novel FCM building methodology and update activation function. More specifically, we used the proposed FCM technology to investigate how the Cypriot banking system is impacted by the combination of the Greek PSI with the decrease in people's confidence to the Cypriot banking sector during the April of 2012. Two experts in political and economic fields were called to contribute in building an FCM model as previously described in this work (Papaioannou et al., 2013).

Through a series of discussions, the experts decided that the 15 influencing parameters adequately and appropriately represent the system to run the aforementioned scenarios. The parameters are: Cost of Money (COM), Liquidity of Cyprus Banks (LCB), Degree Of PSI of Greek Government Bonds (PSI), Degree of Deposits of Greek Citizens and Companies in Cyprus Banks (GDCB), Degree of Deposits of Cypriot Citizens and Companies in Cyprus Banks (CDCB), Degree of Success of Bank Recapitalization by Private Equity (BRPE), Stock Market Value of Banks (SMVB), Evaluation of the Cyprus Economy by Authoritative Rating Agencies (ECEARA), Confidence of People and Companies in Cyprus Banking System (CCBS), Level of Greek Economic Crisis (GEC), Level of Greek Workforce that Comes to Cyprus for Work (GWC), Degree of Bank Recapitalization Done by the Republic of Cyprus (BRRC), State of Cyprus Economy (CE), Probability of the Republic of Cyprus Entering EU Support Mechanism (PESM) and Probability of Cutoff of the Cypriot Bank Branches that Operate in Greece (PCCB).

Following that, the experts completed the desired information about each system's parameter. They collected, studied and properly evaluated the relevant material regarding the system's set parameters (e.g. scientific articles, press articles, statistical analysis results and other sources). This FCM building methodology demands from the experts to get involved in this procedure to refresh their knowledge about the specific parameters of the system in order to be updated about the parameters' details. Especially so, when setting their initial values and the interconnection sensitivities.

Further on, in order to calculate the initial values of the FCM system, the actual values of the concepts were normalized, as defined by the methodology, in the range of [0%, 100%]. However, it is important to note that there are some parameters that cannot be approximated based on raw numbers but rather using some kind of fuzziness. For example, it is difficult to be exact in quantifying the concept of the State of Cyprus Economy which encompasses characteristics like GDP, unemployment rate, housing, Consumer Price Index, stock market prices, industrial production, etc. In such cases the experts had to define the state of the concept based only on their "feeling" and their understanding of the dynamics of the system.

The final stage of the proposed FCM construction methodology was about setting the sensitivities of links between the concepts. Therefore, each expert had to go through the process of calculating the sensitivities amongst the causal relationships of the systems. The whole process was implemented through expert-computer interaction. For each possible interrelation of the system the computer screen presented to the expert the initial value of the potential affecting concept and how this is altered after applying the corresponding degree of variation (a factor of the table the experts created during prior construction phase). The computer also presented the initial value of the potential affected concept and right after the expert was asked to give the resulting new activation value of the potential affected concept. For each interrelation, the experts inserted their own estimations and the computer automatically calculated their sensitivities using the formula given by Equation (1).

As a result each expert created his/her own sensitivity matrix. Inevitably, there were some

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discrepancies between the values given by each expert. Finally, the average of the sensitivities was used to form the final sensitivity matrix.

4 RESULTS

Four different scenario cases were implemented and tested using FCM technology as described in previous sections. The first scenario was about observing how a 75% Greek PSI affects core factors of the economy of Cyprus. The other three scenarios involved the implementation of the 75% Greek PSI along with a gradually scaled decrease of confidence of people and companies in the Cyprus banking system and the way this combination affects the other parameters of the system.

During simulations, the changed values of the concepts of interest were “locked” in such a way that they would not be further changed during the simulation period as a result of interference with their causality neighbours, but rather remain constant. Hence, in the context of the first aforementioned scenario, the state value of the concept of Greek PSI would remain 75% through the whole process of simulation.

The remaining parameters were allowed to interact through causality paths using the update rule presented in Equation (3), leading the system to an iterative behaviour until it converged to steady state value. That means until the concept state vector was the same between two consecutive iterations. The values of the steady state concept vector were taken as the future response of the modelled system to the actions implemented in the concepts of interests.

It is emphasized that the objective when analysing the results of a FCM system is to carefully observe the trends rather than the actual final state values of the concepts. Hence, the absolute values are rather meaningful for the system’s analysis, whereas the relative changes are the ones which can shed some light on the decisions needed to be made.

The results of this work are graphically presented in Figures 1 to 4. In these Figures, the percentage change between the final state value of the concepts and their corresponding initial values, which happened in response to a certain scenario implementation, is presented. The blue colour columns represent the results of the scenario where only the 75% Greek PSI takes place. The other three columns (purple, green and orange) present the results corresponding to the scenarios where the Greek PSI is implemented in parallel with a fall of people’s trust in the Cypriot banking system by 25%, 50% and 75% respectively. In all of the figures, the horizontal axis exposes the parameter names. The vertical axis is showing the resulting percentage changes in the system’s parameters lying in the horizontal axis, which are due to the implementation of the aforementioned scenarios.

The results as shown in Figures 1 to 4 were given back to the experts to analyse them and make conclusions about the particular simulations of the system.

As expected, the higher the decrease of the people’s confidence to the Cyprus banking system the more unfavourable is the effect on the Cyprus economy and the banking sector.

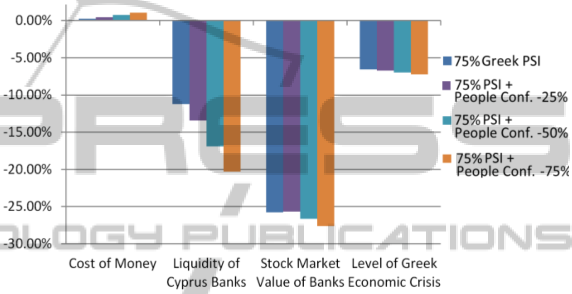

Figure 1: The impact of the four scenarios on the parameters COM, LCB, SMVB and GEC.

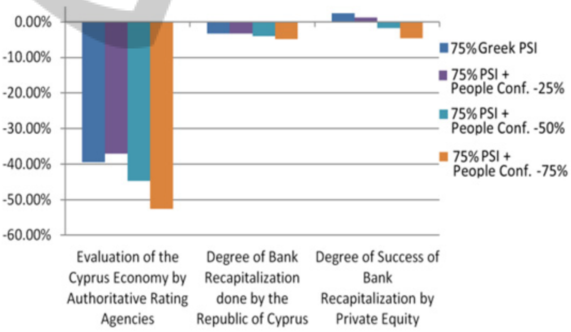

Figure 2: The impact of the four scenarios on the parameters ECEARA, BRRC and BRPE.

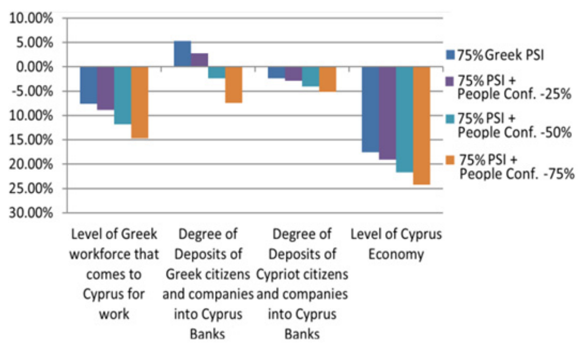

Figure 3: The impact of the four scenarios on the parameters GWC, GDCB, CDCB and CE.

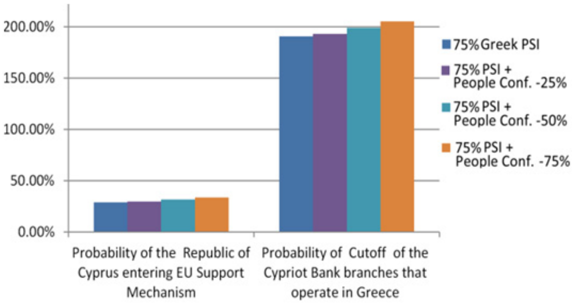

Figure 4: The impact of the four scenarios on the parameters PESM and PCCB.

The most interesting outcomes from the simulations of the four run scenarios will be presented further on. The State of the Cyprus economy is negatively affected as a response to the scenarios where only the Greek PSI takes place. Things become gradually worse for Cypriot economy as the confidence of people is decreased in the following scenarios. Also, the lack of people's trust to the banking sector would motivate people to withdraw their money from banks. Such a case would be decisive for the Cypriot banks which already had to deal with liquidity problems due to the Greek PSI. This totally justifies the results for the factor "liquidity of the Cypriot banks" which decreases when the Greek PSI is implemented alone. Furthermore, when the confidence of the people is decreased by 75% the liquidity of the banks present a 50% extra decrease. The response of the parameter Level of deposits of Greek citizens in Cypriot banks in the four scenarios was also very interesting. When the Greek PSI is implemented, an increase to the level of the Greek deposits in Cyprus is observed according to the system. However when the Greek PSI is accompanied with a decrease of people´s confidence in the Cypriot banking system a decrease of the people´s confidence in the Cypriot banking system this increase is diminishing and finally becomes a decrease. Similarly, the tendency of the Greek citizens to move to Cyprus for work is decreased when the Greek PSI is done and continues to decline in parallel with the decline in the confidence of people and companies in the Cypriot banking system. More specifically, when the Greek PSI is followed by a 75% decrease of people´s trust, the decrease in Greek workforce coming to Cyprus for work is almost double the decrease in the case that only the PSI takes place.

Overall though, the parameter which exhibited the largest scale impact was the Probability of a cut-off of the Cypriot bank branches that operate in Greece. A higher than 190% increase of this parameter was observed in all scenarios. Such probability is significantly increased in either the case the Greek PSI is implemented alone or with people´s confidence in the Cypriot banking sector being decreased by 25%, 50% or 75%. In other words, the results of the modelled system state that the probability of cutting off the Cypriot bank branches that operate in Greece is mostly unaffected by the strength of the people´s faith in the banking system. This observations lead to the remark the Cypriot banking system could not escape from the decision of selling the Cypriot bank branches in Greece. In fact, in March of 2013 the Marfin Popular Bank and the Bank of Cyprus, the two largest banks in Cyprus, were forced to sell their branches in Greece. Thus, the system revealed the existence of strong causal paths connecting the concept of the Greek PSI and the Probability of cut-off of the Cypriot bank branches that operate in Greece.

Analogous conclusions can be drawn about the parameters, Stock Market Value of Banks and Probability of the Republic of Cyprus entering the EU Support Mechanism. Specifically, these parameters presented adverse responses to all scenarios. The Stock Market Value of Banks deteriorates by approximately 26% for the first two scenarios and 27% for the last ones. Similarly, the probability for Cyprus entering the EU Support Mechanism appears to increase by 29%-33% respectively in these scenarios. Hence, it can be argued in conformity with the modelled system, that the Greek PSI implementation was a significant factor in Cyprus having to ask for EU mechanism support.

The results of the system indicate that the damage done to the Cyprus banks by the implementation of the PSI was serious. This damaged was magnified by the loss of people's trust to the banking system. Unfortunately for Cypriot economy and banking sector, the last point was confirmed a year later. On the 16th of March of 2013, the Eurogroup forced the Cypriot government to impose a "bail in" as a precondition to receiving loans from the European Support Mechanism. Practically, this amounted to imposing a loss to deposit holders of the two biggest banks. The Cypriot government took appropriate measures to avoid massive withdrawal of remaining deposits, as people lost faith to the banking system. Cyprus then sunk into a severe recession from which it still struggles to recover.

5 DISCUSSION

The verification of the results of the pre-described FCM system by later history enhances the belief in the constructive role that the FCM model approach can play in decision making for socio-political-economic systems.

The whole system reflects how the experts understood the core factors of the Cyprus economy in April of 2012. The presented model does not necessarily represent fully the Greek and Cypriot economies or their interrelations, but it can be a valuable forecasting tool in the hands of the experts.

In summary, FCM models can act like decision-making indicators helping the handlers of the modeled system to consider all relevant impacts when taking a certain actions on their system. Thus, the involvement of a larger number of experts as well as the incorporation of the public opinion could enhance this work's reliability and objectivity.

Nevertheless, this work comprises another positive sign that FCMs can be used as a tool for helping humans to make wiser and more pragmatic decisions. That is why future work, currently in progress, is addressing the open issues concerning FCMs such as the real time dependency of the parameters, in an effort to increase their credibility and fine-tuned operation.

ACKNOWLEDGMENTS

This research was partly supported by the University of Cyprus, the Cyprus University of Technology, and the Cyprus Research Promotion Foundation structural funds (ΤΠΕ/ΟΡΙΖΟ/0308(ΒΕ)/03).

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