Electronic Government and Electronic Participation
E. Tambouris et al. (Eds.)

Policy Compass: FCM-based Policy Impact Evaluation using Public Open Data

Youngseok CHOI, Habin LEE[1] and Uthayasankar SIVARAJAH
College of Business, Arts and Social Sciences, Brunel University,
Youngseok.Choi@brunel.ac.uk, Habin.Lee@brunel.ac.uk,
Sankar.Sivarajah@brunel.ac.uk

Abstract. This paper presents how Fuzzy Cognitive Map (FCM) technique can be applied by a policy maker to support the policy impact evaluation using the example of Policy Compass, an EU research project. The practical usage example on interest rate policy shows the potential of FCMs as a policy impact modelling tool. Through the provision of a more intuitive and easier means of using open data based on FCM techniques, the Policy Compass project can play a critical role for both policy maker and lay public to evaluate the policy impact and prepare for future policy making.

Keywords. Open Data, Fuzzy Cognitive Map, Policy Impact Modelling, Policy Impact Evaluation, Policy Compass

1. Introduction

The demand for open data analytics to support policy making is-increasing along with the growing importance of utilizing big and open data. Developments in open data solution and platform are used to open up governments, engage stakeholders, creates value from the huge amounts of data, and inform decision and policy making. Policy impact and evaluation is one of the representative areas that can benefit from data analytics. Open data such as historical records, social indicators, and even survey results from citizens can be an important standard to measure the success of past policies and be the basis to develop future policies. Since the United Kingdom (UK) government introduced the concept of evidence-based policy making in the 1990s [1], the importance of the use of public open data as evidence to support the decision on and evaluation of policies has been emphasized as significant more than ever.

In this regard, policy making has become a more complex process that needs to consider environmental and political variable factors. Policy makers are now are under the situation where they should check not only the political dynamics, but also the evidence of the past policy based on enormous data for their future policy making. This makes analysing the policy impact more difficult and complex. However, analytics tool or platform for facilitating this complex policy making situation can be hardly found in the research area as well as existing project.

Given the lack of availability of such tools, Policy Compass aims to be an innovative analytics platform for policy impact evaluation and potential policy making.

[1] Corresponding Author.

Based on Fuzzy Cognitive Maps (FCMs), Policy Compass seeks to enable the policy maker and the lay public to evaluate the impact of a causal policy model according to various open data in an intuitive manner. As FCMs are particularly suited to modelling complex and dynamic social problems [4], it has the potential to transform an interactive policy ecosystem with vague conceptual terms into a specific concrete form (i.e., the FCM) that can be readily understood by both policy maker and the general user.

This paper uses the example of the Policy Compass to explore how FCMs can be applied to support the policy maker in evaluating the impact of a policy and provide guidance for future policy development. The paper is organized as follows. The fundamental concept of FCM techniques and their formal definitions are briefly introduced in Section 2. The possibility of FCM as a policy impact modelling tool is outlined in Section 3. In Section 4 we show how the policy maker can use FCM as a policy impact evaluation tool and finally, we conclude in Section 5 with future research.

2. Preliminaries – Short Introduction of FCM

FCMs are fuzzy signed graphs with feedback [8]. They consist of nodes representing concept C_i and the relationships w_{ij} between concepts C_i and C_j. An FCM models a dynamic complex system as a collection of concepts and cause–effect relationships between concepts [6]. A simple illustration of an FCM consisting of five node concepts is depicted in Figure 1 below.

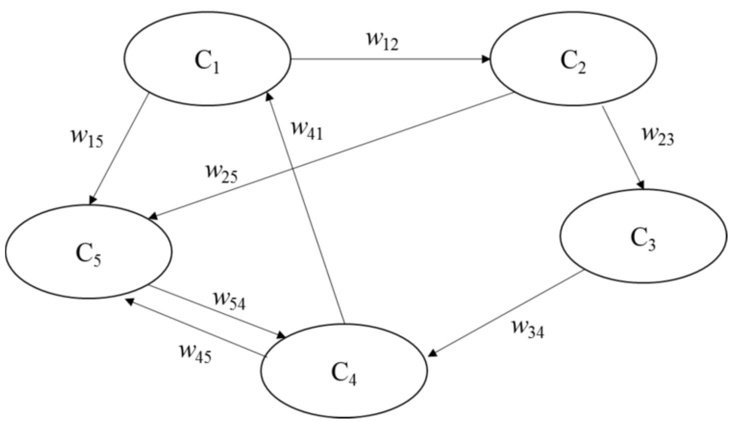

Figure 1. A Simple Fuzzy Cognitive Map

A weight w_{ij} describes the strength of causality between two concepts. Weight should take a value in the interval [-1, 1]. The sign of the weight indicates positive causality if $w_{ij} > 0$, which means that an increase in the value of concept C_i will cause an increase in the value of concept C_j. Similarly, a negative value of w_{ij} indicates negative causality. When no relationship exists between concepts, then $w_{ij} = 0$. The value of concept is usually fuzzyfied by mapping linguistic measure (i.e., very low, low, middle, high, and very high for 5 scale measure) to fuzzyfied value in the interval [0, 1]. According to the scale of the fuzzyfication scheme, every value of a fuzzyfied concept is a given fuzzy value. A fuzzyfication of linguistic measure enables the transformation from qualitative measure to quantitative value so that we can use cognitive map as a multivariate time series prediction model.

The value of each concept at time t is calculated by applying the calculation rule of the equation below, which computes the influence of other concepts on the target concept:

$$x_i(t) = f(\sum_{j=1, j\neq i}^{n} x_j(t-1)w_{ji}) \tag{1}$$

where is the value of concept C_i at time t, is the value of concept C_j at time t-1, is the weight of the relationship between concept C_j and C_i, and f is the activation function. At each time step, the values of all concepts in FCM change and recalculate according to this equation. The value of concepts in FCM at time t can also be expressed as a matrix form. Assuming that vector $\mathbf{X}(t)$ is the n by 1 vector that gathers the value of n concepts, then the matrix $\mathbf{W}$ is an n by n matrix representing the weights between n concepts:

$$\mathbf{X}(t) = f(\boldsymbol{W}^{\mathrm{T}}\boldsymbol{X}(t-1)) \tag{2}$$

The concept of activation function is borrowed from artificial neural networks. It is a function that calculates the output of a concept based on its inputs, usually on the total sum. The output of activation function has its upper/under bound as +1 / −1. The most common type of activation function in FCM is the sigmoid function, which is a reciprocal of negative natural logarithms with few parameters. In addition to this function, many different type activation functions are applied in various contexts.

Based on the definition of equation and activation function, the state vector can be calculated, which contains the values of all concepts at time t. In the simulation of FCM, the calculation of the state vector is iterated until the steady state is reached, indicating that no changes occurred in the state vector after one iteration. Not every simulation result can reach an idle state. Fluctuation of every concept value can be found according to the FCM model.

3. Advantage of FCM as a policy impact modelling tool

FCM is widely used to analyse the impact of policy or strategy changes, including social science, political systems, and engineering systems. Different types of impact analysis models and tools have been proposed in the existing literature[2], each with their own pros and cons in terms of functionalities and analyst needs. In the case of FCMs, it is useful for modelling systems that cannot be explained entirely mathematically or that need to represent both qualitative and quantitative information or model both tangible and intangible issues [7]. Thus, FCMs are able to represent domain or process or problems that can be considered to be complex, vague and even incalculable [3]. The advantages of FCM can be summarized as the following:

- Easy to use and parameterise
- Be able to model casual relations that are not known
- Easily understandable/transparent to non-experts and lay people

[2] Literature review on policy impact modelling and analysis can be found in [5].

- FCM can be used as a rich body of knowledge by combining views of experts or stakeholder from different information sources banding them in structural/understandable form
- FCM is a dynamic system capable of capturing the dynamic aspect of system behaviour

The next section discusses how these advantages can be applied for evaluating the impact of policy with an example of interest rate policy.

4. Strategic Usage of FCM as a Policy Impact Evaluation tool – Use Case for Interest Rate Policy

4.1. Description of the use case problem

Assume that a policy maker in the government wants to know the future impact of change in interest rate to stimulate productive investment. However, in this context, the side effect of increasing the interest rate remains to be the problem. The present level of interest rate is “low”, which can be fuzzifyied into a value of 0.4 in 5 scales fuzzyfication scheme (very low: 0.2, low: 0.4, middle: 0.6, high: 0.8, very high: 1.0)A policy maker estimates what will happen in the future by following different situations:

1. Situation 1: If the interest rate is **kept in the same level in the future**
2. Situation 2; If **the interest rate decreases to date**
3. Situation 3: Or if **the interest rate increases**

Considering these situations, the questions is how can FCM modelling and simulations help the policy maker to make better decision for interest rate?

First, he/she lists the factors related to the change in interest rate. Based on the listed factors, he/she can make the causal relationship diagram between the factors. Assuming that occupation and inflation are considered for the estimation of the relationship between interest rate and product investments, the policy maker can model the FCM with appropriate causality between them. Figure 2 illustrates the FCM model among the four related concepts and their causal relationships.

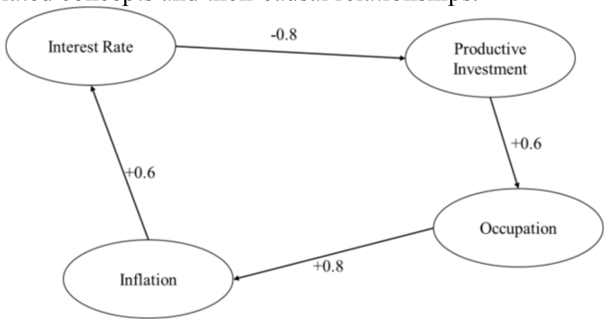

Figure 2. FCM for interest rate policy

The initial state of four concepts can be fuzzyfied with the 5-scale fuzzyfication scheme: ***Interest rate: 0.4 (low), Productive Investments: 0.2 (very low), OccupationT 0.8 (high), Inflation: 0.2 (very low).*** Finally, the possible future with this scenario can be analysed. Usually, the initial value of concepts and weights among concepts can be determined based on the discussion of panels and domain experts. In the context of policy making and evaluation, policy makers and related experts can evaluate the current level of given values based on linguistic measure and fuzzyfication scheme. Policy Compass platform provides option for defining initial values and weights. Also, the weights that can explain the given FCM model with historical value can be automatically calculated using data mining techniques.

4.2. Simulation results[3]

Situation 1. If the interest rate is ***kept in the same level in the future***

In this scenario, we can simulate the model with a given initial value. The sigmoid activator is used for all concepts. The simulation result can be obtained using the equation for calculating the next state vector (see the figure below).

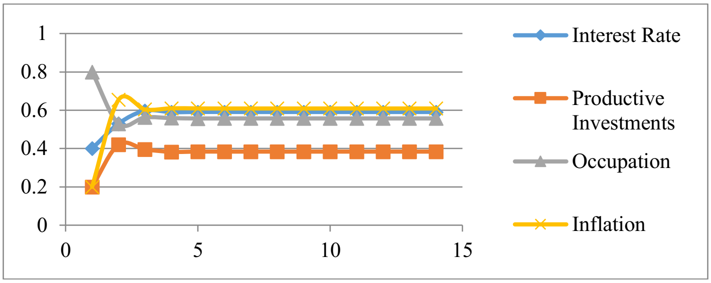

Figure 3. Simulation Result – Low interest rate, without fixed output effect

The model converges to an idle state after a number of iterations; each value of the concept is shown in the final state. In the final state, productive investment increases to 0.384, whereas occupation decreases to 0.557. Inflation also increases to 0.609. Even the future interest rate is estimated to increase to 0.59. However, this simulation has a ***critical mistake***. Interest rate should be seen as a policy variable, which can be determined by policy rather than independent variable affected by other variables. Assuming that the interest rate is ***"kept"***, this model should be in a totally different manner. In this case, we can enjoy the "fixed output" option for the concept value of "interest rate." If we consider the interest rate as a fixed output variable, it always returns fixed output regardless of the input value in a more realistic manner.

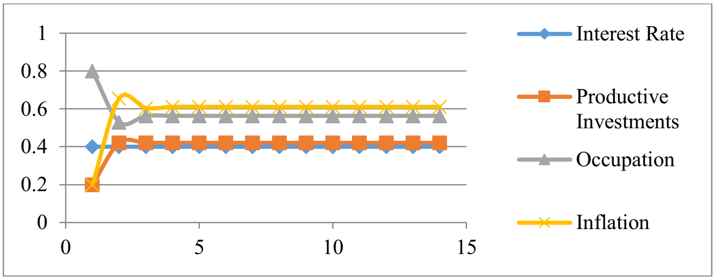

Figure 4. Simulation Result – Low interest rate, without fixed output effect

[3] We use the sigmoid function as an activator function.

The comparison table below shows that, if we do not consider the fixed output for interest rate, the simulation result underestimates the productive investment in the final state. This simulation result shows that, if the interest rate is to be maintained at its present level, productive investment will improve even if the inflation level increases.

Table 1. Comparison of the final state between with and without fixed output (interest rate: AS-IS)

	Interest Rate	Productive Investments	Occupation	Infliation
w/o fixed output	0.5904428	**0.3840592**	0.5573553	0.6096602
with fixed output	0.4	**0.4206757**	0.5627685	0.6106903

Using the fixed output option for interest rate, we can simulate other scenarios in a more realistic manner.

Situation 2. If ***the interest rate decreases to date***

The possible scenario for the stimulation of productive investments is to decrease the interest rate. This simulation allows the policy maker to estimate the potential impact to other important economic factors such as inflation. For this simulation, the interest rate is set at a very low level (0.2).

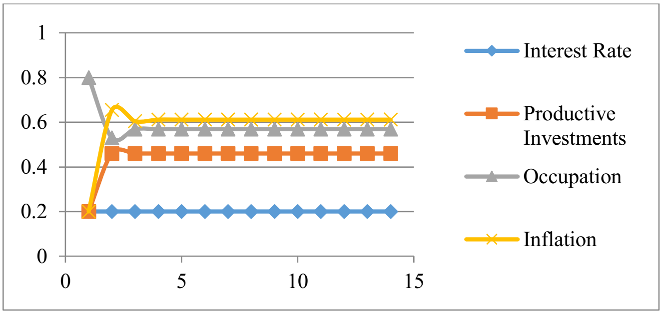

Figure 5. Simulation Result – Very Low interest rate, with fixed output effect

Figure 5 shows that inflation is getting worse (maximum 0.6547) in the first few iterations, and then stabilizes around 0.61 under very low interest rate condition. In terms of productive investments, the final value reaches 0.46, which improved compared with its current situation. To confirm the effect of lower interest rate on improvement in productive investment, we can assume the opposite, i.e., higher interest rate situation.

Situation 3. If ***the interest rate increases***

In the third situation we assume that if the interest rate increases and is maintained at a higher level, how will this affect the simulation results? By comparing this result with the prior simulation (lower interest rate scenario), decision makers can understand the impact of altering the interest rates.

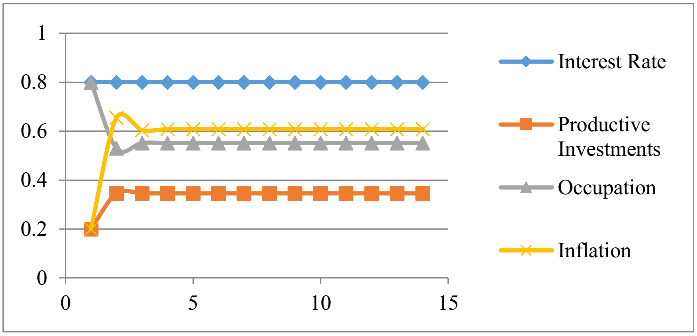

Figure 6. Simulation Result – Very high interest rate, with fixed output effect

Under higher interest rate assumption, the productive investments in the stable state are the lowest among the all scenarios assumed. Based on these three different simulation results, fruitful information about decision making can be derived.

4.3. Revisit the result – Why FCM modelling and simulation for impact analysis?

Policy impact evaluation assesses the changes that can be attributed to a particular intervention and change in policy. In contrast to outcome monitoring, which examines whether targets have been achieved, impact evaluation is structured to answer the question: how will outcomes change if the intervention will not be undertaken? This process involves counterfactual analysis; that is, "a comparison between what actually happened/will happen and what would have happened/will happen in the absence of intervention [2]. Counterfactual analysis enables evaluators to attribute the cause and effect between interventions and outcomes. The 'counterfactual' measures what would have happened to the beneficiaries in the absence of the intervention, and impact is estimated by comparing counterfactual outcomes to those observed under the intervention. From a perspective of impact evaluation, FCM modelling and simulation in Policy Compass platform can play an important role for policy impact evaluation. The simulation results of this scenario need to be revisited in this perspective (see table 2).

Table 2. Simulation Summary

	Interest Rate	Productive Investments	Occupation	Inflation
Low interest rate (as-is)	0.4	0.4206757	0.5627685	0.6106903
Very low interest rate	0.2	**0.4600851**	0.5685778	**0.6117947**
Very high interest rate	0.8	0.3452465	0.5516026	0.6085645

The policy maker may want to know that increasing interest rate will be effective to stimulate the productive investment. Although lower interest rate can induce productive investment, it may also cause unexpected and possibly related outcomes such as severe inflation (this scenario describes the situation with lower level of inflation). The policy maker has three options: keep the current interest rate, decrease the interest rate, or increase the interest rate. By analysing the simulation result above, we can develop an impact table for each of the decisions. Based on the results above, we can confirm that decreasing the interest rate is the most effective decision among the possible decisions. If the level of interest rate is maintained, future investments will approach to around 0.42. However, if the interest rate is decreased, we can expect the highest future productive investments among all decisions, even with marginal increase of inflation. The worst decision is increasing the interest rate because it leads to the lower level of inflation with poor expected investments in comparison to the decision to keep the interest rate as it is. With the confirmation on the marginal impact of interest rate on inflation, we can choose the most effective decision for interest rate, which can result in maximum investment.

In this decision making, the situation 1 and 3 will not be chosen for optimal decision, but they can play a role as counterfactuals that can confirm the impact of the chosen decision. By comparing the possible decisions and their outcomes, we can make a more realistic decision for the given policy development situation.

5. Conclusion

Considering the increased demands on open data analytics for policy making process, Policy Compass can play a critical role in evaluating past policy impacts and preparing the blueprint for future policy development. As described in the prior sections, FCMs enable the user to model the complex causal relationship between the concepts relevant to the policy very intuitively. Not only the policy maker can evaluate the impact of policy, but also consider the use of open public data to expect the future impact of policy more easily. This innovative approach can also be a key contribution to FCM research field where most studies depend on human interventions for FCM modelling.

The value of FCMs as a policy modelling tool lies in evaluating the past policy impact. FCMs can provide a more intuitive and easier way to make use of the Europe's increasing amount of public sector open and structured data resources. By doing so, the Policy Compass will offer easy-to-use tools for both the lay public, as well as professional policy makers to improve the quality and transparency of the policy analysis and monitoring phases of the policy life-cycle.

References

[1] Blair, T. Labour Party Manifesto.(1997) http://www.labour-party.org.uk/manifestos/1997/1997-labour-manifesto.shtml

[2] Gertler, P.J. Impact evaluation in practice, Washington, DC: World Bank, 2010

[3] Khan,M.S., M. A. Quaddus and A. Intrapairot, "Application of a Fuzzy Cognitive Map for Analysing Data Ware Diffusion. Applied Informatics: Artifical Intelligence and Applications; Advances in Computer Applications.," in IASTED International Symposia, Innsbruck, Austria, 2001.

[4] Mago, Vijay K., et al. "Analyzing the impact of social factors on homelessness: a Fuzzy Cognitive Map approach." BMC medical informatics and decision making 13.1 (2013): 94.

[5] Panagiotis Kokkinakos, Ourania Markaki, Sotiris Koussouris, Kostas Ergazakis, Kostas Koutras, and Sarantis Pantelias, "Survey on policy impacts evaluation methods and tools and eParticipation and Social Platforms," Policy Compass (EU research project) Deliverable D1.1., (2014)

[6] Stylios, C. D., and Peter P. Groumpos. "Mathematical formulation of fuzzy cognitive maps." *Proceedings of the 7th Mediterranean Conference on Control and Automation*. 1999a.

[7] Stylios, C.D., and Peter P. Groumpos. "A Soft Computing Approach for Modelling the Supervisor of Manufacturing System," *Journal of Intelligent and Robotic Systems*, 26 (1999b) 389-403.

[8] Stylios, C. D., and Peter P. Groumpos. "Fuzzy cognitive maps in modeling supervisory control systems." *Journal of Intelligent and Fuzzy Systems* 8.1 (2000) 83-98.