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A Hybrid Neural System to Study the Interplay between Economic Crisis and Workplace Accidents in Spain

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Abstract: Workplace accident rates are always a constant source of concern in different scenarios. On the other hand, different economic cycles modify employment indicators, thereby affecting both the health and the wellbeing of workers. In this study, a Hybrid Neural System is proposed to support the analysis of both workplace accidents and different macroeconomic variables. The application of exploratory projection and nonlinear autoregressive models allow us to recognize patterns and subsequently study the interplay between the two fields, providing valuable information, so that directors can take more informed management decisions.

Keywords: Artificial Neural Networks, Exploratory Projection, Nonlinear Autoregressive, Workplace Health and Safety, Workplace Accidents, Economic Crisis.
Categories: I.2.6, I.5.1, I.5.4

1 Introduction

The economies of different countries undergo different cycles over time; thus, a cycle of economic growth is followed by one of economic decline, which define different economic cycles. Between each cycle, the economy passes through what are known as economic cycles or transitional periods. At times of crisis, the Macroeconomic Indicators will in general undergo adverse evolution, GDP will fall, inflation (CPI) will rise, the public debt will increase, the risk premium will be higher, bank arrears will rise, etc. The different economic cycles that the Spanish economy has experienced over the past twenty-five years, which is the time span chosen for this study, are shown in Table 1.

The data used in this study was gathered from within the geographical confines of the Spanish state, over the period between 1990 and 2014, in which two economic crises were recorded at a national level: the crisis of the nineteen-nineties (from 1992 to 1994) and the present crisis (beginning half way through 2007). The study included no data prior to 1990, as none were available.

With regard to the first period, the work of Vázquez [Vázquez, 2007] demonstrated how, since 1992, a period of recession began in Spain. On the other hand, numerous explanations are offered at both a global and a national level [Jimeno et al., 2014] for present crisis, that began at the beginning of 2007. In August of that year, there was a collapse of active mortgages that directly affected many European and US banking entities, provoking a direct shock on the financial markets, and the subprime mortgages surfaced in October of that same year, the repercussions of which started to appear in a serious way at the start of 2008.

Greater interest, mainly in the most developed countries of the world, may be noted in workplace accidents even before the turn of the century. In Spain, high workplace accident rates are observed in the workplace as around three people die due to workplace accidents, with estimated costs of around 1% GDP [INE, 2018]; while in countries like Sweden and Great Britain [Eurostat, 2018], the same statistics are between four and five times lower than in Spain. A need therefore arises along with an interest in deepening our knowledge of workplace accidents in Spain.

The study of workplace accidents and their costs was performed in [Manzanedo del Campo et al., 1996], by analysing all the costs arising from each accident. Likewise, a model was prepared for the calculation of the costs of accidents that linked assured and non-assured costs. García and Montuenga [Manzanedo del Campo et al., 1996] also investigated the influence of the workers and their jobs on the incidence of workplace accidents as a function of their severity. They inferred that the workers with greater working experience presented a lower risk of serious or fatal accidents. Some other experts call for greater support for prevention as the tool both for the reduction of workplace accidents and for the implementation of a working culture and practices that provide an environment capable of promoting the effectiveness of the organization [Teixidó, 2009].

Although some authors previously studied the relation between economic crises and unemployment [Audiffren et al., 2013], there are few investigations published on the joint study of economic crises and workplace accidents. Moënne [Moënne B, 2008] affirmed that stress in the workplace increases at times of economic bonanza and the time available for prevention falls, which finishes by affecting workplace accidents. Also, other authors [Villanueva et al., 2001] analysed the variation in accident rates in relation to changes in the economic cycle, demonstrating a reduction in accident rates during times of recession, while in expansive phases of the economy, an increase in employment occurred with precarious contracts and a higher risk of accidents.

Some other authors [Alcázar, 2014] analysed the legacy that this crisis has left us after the harsh economic adjustment enforced in Spain. They deduced that its effects on the economy will be observed for years, affecting GDP, inflation, salaries, income, firms, financing, consumption, etc. On the other hand, [Fernández-Muñiz et al., 2018] analyses the sensitivity of occupational accidents to the economic cycle in Spain (from 1994 to 2014) by regression and variance decomposition analysis. Regressions were also applied in [Chang et al., 2018] to check whether workplace injury incident rates change in commensurate with economic situation. Monthly insurance payment data from Taiwan, during 2002–2014, are analysed. In a similar but different study, [Sønderstrup-Andersen et al., 2018] analysed whether the onset of a general economic recession has had an impact on companies' and public institutions' preventive occupational health and safety activities. Time evolution of such indicators is analysed based on Cochran-Armitage trend test.

Workplace accident rates in Spain have been influenced by the economic crises of the 1990s and the present day, making it necessary to understand the relation that can exist between different indicators that are representative of both concepts. Therefore, this study seeks to examine the relation between economic crisis and workplace accidents, in order to understand the possibility of considering the economic crisis as a variable related with workplace accidents and, by doing so, to contribute new knowledge that will permit improvements in health and safety conditions.

In present paper, economic crises and workplace accidents data are analysed through a novel Hybrid Neural System that is described in section 3. Despite the great variety of options for both regression and visualization of multivariate data, in so far as the authors of this study are aware, it is the first to combine exploratory projection techniques together with autoregressive models and then apply it to this kind of problems. Although selected neural networks (see section 3) have been previously proposed and used, they are applied for the first time to a data-set about two different domains: economic crises and workplace accident rates. Some other neural models have been previously applied to different problems in the economic field [Chauvet et al., 2013], [Bredahl Kock et al., 2016], [Demir et al., 2017]. From a more general Artificial-Intelligence standpoint, scant attention has been devoted to analyse workplace accidents, as only recently some publications have addressed this topic. In [Marshall et al., 2018] a Bayessian model is proposed in order to validate Heinrich's pyramid. It focuses on the severity distribution of occupational accidents with no relation to economic crisis. On the other hand, actors of safety culture and ranking occupations in jobsites are identified in [Ardeshir et al., 2018], in order to improve the safety culture of construction projects. In order to do it, Fuzzy models are built.

Advancing from this previous work, a novel study is conducted in present paper not only to analyse the interactions between economic crisis and workplace accidents.

2 Experimental Development

Data were retrieved from the following government agencies and one Spanish government ministry: The National Institute of Safety and Health in the Workplace (Instituto Nacional de Seguridad e Higiene en el Trabajo) (INSHT), the National Institute of Statistics (Instituto Nacional de Estadística) (INE), and the Ministry of Employment and Social Security (Ministerio de Empleo y Seguridad Social) (MEYSS).

The values of the annual series of some of the most relevant macroeconomic variables were employed and, likewise, the public database on workplace accidents, together with the public databases on the number of net contributors to the Social Security system. In addition, the lists of reported incidents on the MEYSS webpage were used. The total number of accidents under analysis in the present work amounted to close to seventeen-million (17,221,070). In addition, it is worth highlighting that this number is not inclusive of accidents that occur *in itinere*, accidents that involved no loss of working days, nor the relapses that might ensue. The variables used for this study were as follows:

- Gross Domestic Product (GDP): the total value of all goods and services produced within a country over a specific period that is, in general, a quarter or one year.
- Inflation: a macroeconomic variable that indicates the aggregate growth of the price of goods, services, and productive factors within an economy in a set period; occasioned by the imbalance between production and demand that causes a continuous rise in the prices of most products and services and a fall in the acquisitive power of money for buying and making use of them.
- Unemployment (number of unemployed): a situation in which people find themselves fit for work (age, capability, and wish to work) but without a job and who are actively searching for employment.
- Employment rate: covers everybody of 16 years or over who during the selected week have been working for at least one hour in exchange for money or payment in kind and those in work who have been temporarily absent due to illness, vacations, etc.
- Salaried: as pointed out above, salaried workers represent a sub-segment of employed workers. Its computation includes salaried workers employed full time (a normal working week above 30 hours) and part time (with a normal working week of less than 35 hours).
- Gross National Savings (GNS): the value that results from the gross national income subtracted from total consumption plus net transfers.
- Remuneration of salaried workers: value of payments for wages and salaries paid in cash and in kind to the salaried worker in compensation for the work completed during the accounting period.
- Gross Wages and Salaries (GWS): refer to the total amount that a worker receives in the payslip for the work that is done, before the deduction of all the corresponding obligatory (retentions and contributions) payments: that is the net salary plus supplements.
- Average earnings per worker: this variable refers to the average monthly earnings of a worker, which represents gross earnings, before income tax deductible and other taxes.
- Minimum interprofessional salary (MIS): is the minimum amount of remuneration that the worker receives for the legally stipulated working day in any activity.
- Non-Working Days (NWD): the working days during the year when no work took place for any reason, such as holidays, temporary incapacity, maternity, personal reasons, labour conflict, absenteeism, management lock outs, etc.
- Workers Registered with the Social Security: a situation in which those people in employment and in receipt of a salary for their work, are registered with the Social Security System (Tesorería General de la Seguridad Social) on account of their employment activity, which means they are covered by the Social Security System.

- Foreign work permits: foreigners over 16 years in age who wish to exercise profit-making, working, or professional activities in a self-employed capacity or as an employee, should previously obtain the corresponding administrative work permit.
- Salary cost per worker: covers all the gross remuneration, whether in cash or kind, made to workers for the professional performance of their services at work as employees.

The variables of workplace accident rates are also used in this study, which contributes highly relevant information on accident victims and the accident. The number of workplace accidents are presented for each of the years, computed for each of the following categories:

- Sex: man or woman.
- Age: age brackets have been established in accordance with the classifications from the Government ministry over the years under analysis. These are: 16-to-19 years old; 20-to-24 years old; 25-to-34 years old; 35-to-44 years old; 45-to-54 years old; and over 45 years in age.
- Seriousness: the seriousness of the accident inflicted on the worker is diagnosed by the medical staff during the examination of the injured worker. They are classified as: Slight, Serious, and Fatal.
- Economic Activity: this variable is based on the scale used in the National Classification of Economic Activities. The activities that were selected for this study were: Extraction Industries, Food Industry, Wood Industry, Metallurgy, Commerce, Hostelry, Transport, Health Activities, Economic Sector, Size of Firm, Place of Accident, Days away from Work.
- Economic Sector: under this variable, the construction sector is separate from the industrial sector because of its evident singularities, both in terms of accident rates and in the last economic crisis to have affected Spain. In consequence, this variable can take 4 different values: Agrarian, Industrial, Construction, and Services.
- Size of the Firm: in the European Union, the size of the firm will be defined by the number of workers that form part of it. The following values have been defined to classify the firms in accordance with these criteria: Micro-Firm (1-to-9 workers), Small Firm (10-to-50 workers), Medium-sized Firm (51-to-250 workers), and Large Firm (over 250 workers).
- Place of Accident: this variable distinguishes between the following modalities: at the Work Centre, on Duty (work-related travel during the working day), and at another Work Centre or Place of Work.
- Days off Work: temporary incapacity or days off-sick associated with a specific accident were classified in a total of five blocks, which are as follows: 1-to-3 days; 4-to-5 days; 16-to-20 days; 21-to-365 days; and 366-to-549 days (12-to-18 months).

Following the above descriptions, each of the years is described by a vector with 39 dimensions. Regarding the time, data are gathered from 2007 to 2013 as more recent data are not available for some of the features.

On the other hand, present paper addresses the Incidence Index (II), being calculated as the total amount of workplace accidents (with sick leave) that occurred on working days for every 10,000 workers exposed to such a risk.

3 Hybrid Neural System

Hybridization [Simić et al., 2017] has been successfully applied to combine intelligent paradigms. In order to analyse the above-described data, a novel Hybrid Neural System is proposed in present paper. Under the hybridization perspective, both unsupervised and supervised paradigms are combined in a new way and implemented in MATLAB software [Mathworks, 2018]. On the one hand, unsupervised projection models are applied for studying the data and for generating their visual displays, in such a way as to reveal the essential information in the multidimensional data-sets under study with greater clarity. On the other hand, nonlinear autoregressive models are also applied to forecast the Incidence Index (II). Applied models are described in following subsections. Up to the author's knowledge there is not any quantitative method to compare supervised with unsupervised models. However, due to their complementary nature, they have been applied in unison (for different tasks) in present research.

3.1 Principal Component Analysis

Principal Component Analysis (PCA) is a widely-used statistical method [Asencio-Cortés et al., 2017] based on the analysis of information, through the linear mapping of the dimension (reduction of the number of variables). Its end-purpose is to reduce the number of variables in a data-set with multiple variables, seeking to minimize information loss, in so far as is possible, for the new data. The new factors (principal components) obtained through that linear mapping are the result of a linear combination of the original variables that, in turn, will perform as independent variables between each other.

According to [Bishop, 1996], PCA may be described as a mapping of vectors X_d onto an N-dimensional space on vectors Y_d in an M-dimensional space, where $M <= N$. While X can be represented as a linear combination of a set of N orthonormal vectors W_i:

$$x = \sum_{i=1}^{N} y_i W_i \tag{1}$$

3.2 Unsupervised Neural Models

As previously stated, different unsupervised neural methods are compared in order to visualize multi-dimensional data. The exploratory techniques described below were used for the analysis of the multidimensional data, associated both with macroeconomic variables and the variables of workplace accidents. These techniques offer different displays of the structure of the multidimensional data under study. With the purpose of understanding their most significant characteristics, a brief individual description follows of the different methods that are applied.

3.2.1 Cooperative Maximum Likelihood Hebbian Learning

Cooperative Maximum Likelihood Hebbian Learning (CMLHL) is an unsupervised ANN that is characterized by its capacity to conserve a degree of global order in the data-sets. This technique permits a topological ordering of the different neurons, in keeping with a neighbourhood or similarity rule, permitting a search for exploratory projections to take place (Exploratory Projection Pursuit – EPP) [Friedman et al., 1974]. One neural implementation of EPP is Maximum Likelihood Hebbian Learning (MLHL) [Corchado et al., 2003], [Corchado et al., 2004], which consists in the following steps for each iteration:

Feed Forward Step:

$$y_i = \sum_{j=1}^{N} W_{ij} x_j, \forall i \tag{2}$$

Feedback Step:

$$e_j = x_j - \sum_{i=1}^{M} W_{ij} y_i \tag{3}$$

Updating of weights:

$$\Delta W_{ij} = \eta y_i sign(e_j) \left| e_j \right|^{p-1} \tag{4}$$

With regard to MLHL, the inclusion of lateral connections is proposed [Corchado et al., 2003]· [Seung et al., 1998] that are derived from the Rectified Gaussian Distribution (DGR) and that are based on cooperative distributions [Seung et al., 1998], generating the model known as CMLHL. The lateral connections are applied in accordance with the following equation:

$$y_i(t+1) = \left[y_i(t) + \tau (b - Ay) \right]^+ \tag{5}$$

Where $[\ ]^+$ is the necessary rectification so that the values of y remain in the positive quadrant and the strength of the lateral connections, τ , between the neurons of the output layer. An appropriate value for τ must be selected, so that the algorithm converges towards a stationary point of the energy function (generally a local minimum).

3.2.2 The Self-Organizing Map

The well-known Self-Organizing Map (SOM), based on unsupervised learning, obtains a discreet representation in the space of input samples called the map. To do so, the nearest neurons between each other will respond, in the presence of similar data in the input space. It is therefore a neuronal model that performs data mapping rather than data projection.

With regard to its competitive learning process, the neurons are said to compete against each other with the end-purpose of developing and thereby specializing in a task. It is expected that when a pattern of inputs into the network arises, only one of the output neurons (or a group of neighbours) is activated. The winning neuron, *C*, is determined by the following expression:

$$c = \arg\min_i \left(\left\| \mathbf{x} - W_i \right\| \right) \quad (6)$$

Where **x** is the input vector and W_i are the weights of each SOM neuron.

At the end, only one of the neurons wins, nullifying the rest that are forced to assume minimum response values. SOM has been widely applied in a multitude of studies. On this occasion, the SOM is used for the first time in the investigation on economic crises and workplace accident rates.

3.3 Non-Linear Autoregressive Models

Differentiating from previous models (based on unsupervised learning) that are applied to get intuitive visualizations, non-linear autoregressive models are also used under the frame of the proposed Hybrid Neural Model. As they are able to model nonlinear dynamic systems, they are applied to forecast the yearly Incidence Index (II). It is a key indicator of workplace accidents and predicting it could lead authorities to take preventive actions. In order to build an accurate prediction model, both NAR and NARX [Leontaritis et al., 1985] have been applied. The mathematical formulation for the former is:

$$y(t) = f\left(y(t-1), \dots, y(t-n_y)\right) \quad (7)$$

Being *y(t)* the variable that is to be predicted in *t* time, n_y the maximum number of time delays in the output to be considered in the model and *f()* the function to be approximated by the neural model. In the case of NARX, its mathematical formulation can be described as:

$$y(t) = f\big(y(t-1), \dots, y(t-n_y), x(t-1), \dots, x(t-n_x)\big) + \xi(\mathrm{t}) \quad (8)$$

Being *x(t)* the exogenous input, n_x the maximum number of time delays in the input to be considered by the model and $\xi(\mathrm{t})$ the noise term.

The NARX model is implemented as a feedforward time delay neural network without any feedback loop [Haykin, 1994] and it has been proved to outperform linear models [Basso et al., 2005].

4 Results

Results from the above-defined models are shown in present section.

4.1 Principal Component Analysis

The PCA projection formed of a vertical and a horizontal axis represent linear combinations of the different original variables (all the ones described in section 2).

Each point in these (scatterplot) displays represents a datum of the original data, together with the corresponding number of the year. Few components are usually sufficient for a standard explanation of the data. That affirmation is confirmed in the case study, because the two primary components are respectively associated with the following variance coefficients with regard to the original data: 48.7690% and 41.8033% (90.5723% in total).

A deeper analysis of the pair of components 1-2 (Figure 1) is presented in what follows. In the plot, it may be seen how the points associated with the years under study organize themselves in a total of 6 areas, numbered from 1 to 6, for easy identification.

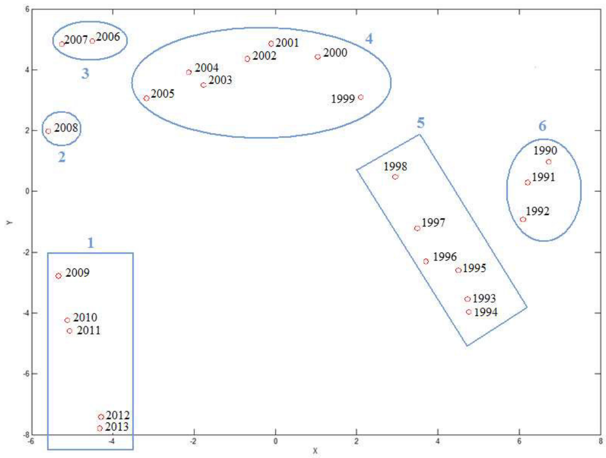

Figure 1: Projection of principal components.

Years from present crisis are located in area 1 and the 'crisis of the nineties' in area 6. Both areas are separated between each other, which might be due to the very few similarities that exist between both crises, although both have been associated with economic crisis. In addition, other data are placed in different and separate areas: on the one hand, the years that follow the 'crisis of the nineties' (area 5) and, on the other, the first years of this new millennium (area 4). In a coherent way, the years grouped in area 5 share a slow growth of both the economy and workplace accident rates. While, in the case of area 4, the economic growth takes off, but the probability of suffering an accident is lower and lower, year after year, in the new millennium. Hence, both areas are separated from each other.

It may also be appreciated within area 4 that the years 2003 and 2004 appear very close to each other and slightly separated from the other years that are within the same area, which leaves some signs of the special situation that Spain went through in that period.

Areas 2 and 3 of this PCA projection display the year leading up to the present crisis (2006) and its beginning (2007 and 2008). The first complete year of crisis was 2008, as the crisis began approximately half way through 2007. Hence the singularity of this short period and its independent position from the other areas. These three years are transitional: in 2006, Spain was still undergoing a period of economic boom, but the economy had slowed down considerably and was no longer growing in that year at the pace that it had done in previous years.

4.2 Cooperative Maximum Likelihood Hebbian Learning

The next step of present research was to perform numerous experiments of the CMLHL model with different values for its parameters on the same data. Only one was selected from among them all, which is shown in this section, due to the convergence achieved in the training and the quality of the result. This projection was obtained with the following values for the different CMLHL parameters:

η : 0.08009 / p: 2.19 / τ : 0.14 /Nº of iterations: 80.

In a coherent way to the positioning that is shown in the PCA projection, the years grouped in area 5 share a slow growth of both the economy and workplace accident rates. While, in the case of area 4, the economic growth takes off, but the probability of suffering an accident is lower and lower, year after year, in the new millennium. Hence, both areas are separated from each other.

The projection (1-2) obtained with CMLHL yields a well-defined structure of the data, which facilitates the identification of 4 large areas (see Figure 2). In area 1, the years of the present economic crisis, located at a long distance from area 4, which contains the years of the 'crisis of the nineties'. In the years of both areas (1 and 4), the workplace accident rates fall from one year to the next, in a larger proportion than in the other years or non-crisis periods.

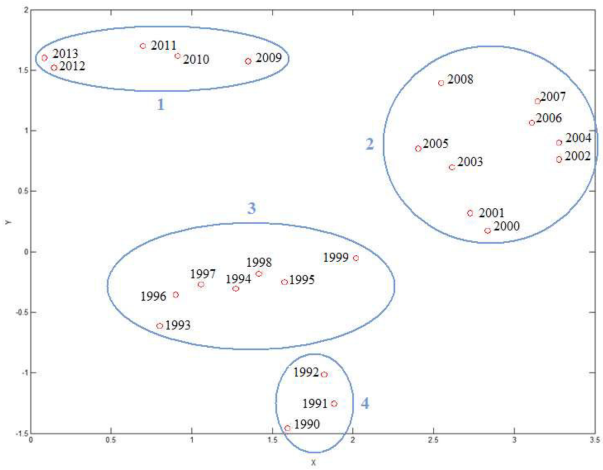

Figure 2: CMLHL Projection.

And in a similar way to the PCA analysis, the same variables (see section 4.1), in the results for components 1-2 of the CMLHL model, are positioned in an independent area, but close to area 4, for the years following the 'crisis of the nineties', which corresponds to a phase of sluggish economic growth and a progressive rise in workplace accidents, or the probability of having an accident.

Moreover, the years that run from the start of the millennium up until the present crisis (2000 to 2008) are grouped in area 2. These were years in which Spain underwent a period of unparalleled economic growth and in which workplace accident rates were progressively lower each year.

In this same area, it is worth highlighting the fact that some years such as 2002, 2004, 2006, and 2007 are found very close to one another. Comparing the PCA and CMLHL projections obtained for the joint macroeconomic and workplace accident rates, it is thought that the CMLHL results support the PCA projection, given that the grouping of years (associated with the different numbered areas) was practically identical in both cases.

4.3 Self-Organizing Map

Different experiments tested different values for the SOM parameters. In the following, only one of the results is shown, chosen from a selection of the best results obtained, with the following values:

Initialization: Linear / Training Algorithm: Batch / Size of map: Large 10x10 / Grid: Hexagonal / Neighbourhood function: Gaussian.

As a measure of the quality of the result that is generated, the values for the two principal indicators are shown: Final quantization error: 0.671 / Final topographic error: 0.0001.

The grid of neurons is shown in Figure 4, labelling each neuron with the years to which each one corresponds.

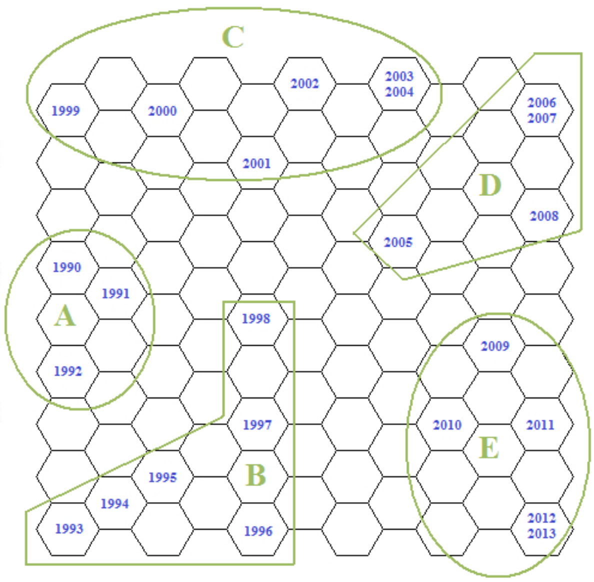

Figure 3: SOM grid of neurons for macroeconomic and workplace accident variables.

Five highly differentiated and separate areas (labelled A/B/C/D/E in green) are identified in the result, due in part to the large grid size that is used. The distribution of the different years in the neurons of the map, distributed into five different areas, follow a very similar pattern to the results of the other techniques of analysis (PCA and CMLHL).

Observing Figure 4, a very similar distribution to the different years is seen to repeat itself on the map that is generated. If the information of these years is added to the information from table 1, evidence of the similarity is ever clearer between the results of the different experiments performed with the various techniques.

4.4 NAR

For a comprehensive validation of the model, different values of the model parameters have been tested:

- Number of output time-delays: 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10.
- Number of neurons in the hidden layer: 1, 5, 10, 15 and 20.
- Training algorithm: 1 - Levenberg-Marquardt, 2 - Batch Gradient Descent, 3 - Gradient Descent with Momentum, 4 - Adaptive Learning Rate Backpropagation, 5 - Gradient Descent with Momentum and Adaptive Learning Rate, 6 - Scaled Conjugate Gradient y 7 - Broyden–Fletcher–Goldfarb–Shanno Backpropagation (Quasi-Newton).

For each one of the value combinations, 100 trainings were run, being calculated the Mean-Squared Error (MSE) for each one of the combinations, summarized in Table 1.

Algorithm	**MSE**	
	Mean	**Deviation**
1	58.17	148.70
2	111811.02	1102520.61
3	2824.14	11993.08
4	134.11	307.62
5	151.21	281.69
6	46.82	97.01
7	8046.27	79862.76

Table 1: MSE of the forecasting results obtained by the NAR model (by training algorithm).

From Table 1 it can be seen that MSE and variance values greatly vary from some algorithms to other ones, being Batch Gradient Descent (algorithm 2 in the table) the one with highest values and the Scaled Conjugate Gradient (algorithm 6 in the table) the one obtaining lowest values. The best result is obtained with one time-delay, one hidden neuron and Scaled Conjugate Gradient algorithm, with an average MSE of 18. We can conclude that the big oscillation that can be appreciated is caused by the reduced set of years that is considered for analysis.

4.5 NARX

To improve the forecasting of the non-linear model, NARX has also been applied. In this case, the following exogenous inputs have been also considered:

- Gross Domestic Product.
- Unemployment.
- Salaried.
- Gross National Savings.
- Average earnings per worker.
- Non-Working Days.
- Foreign work permits.

These variables were selected from the macroeconomic features due to their low correlation rate. As in the case of NAR, different values of the model parameters have been tested:

- Number of input time-delays: 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10.
- Number of output time-delays: 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10.
- Number of neurons in the hidden layer: 1, 5, 10, 15 and 20.
- Training algorithm: same as for NAR.

Similarly, for each one of the value combinations, 100 trainings were run, being calculated the Mean-Squared Error for each one of the combinations. For the sake of brevity, only results grouped by number of hidden neurons and training algorithms are shown (Tables 2 and 3).

Neurons	**MSE**	
	Mean	**Deviation**
1	2152.37	17723.79
5	6799.81	63564.84
10	1845.96	13581.73
15	1071.96	4322.62
20	2113.73	13400.93

Table 2: MSE of the forecasting results obtained by the NARX model (by number of hidden neurons).

Algorithm	**MSE**	
	Mean	**Deviation**
1	84.79	175.19
2	6247.52	47561.40
3	12528.95	107814.72
4	195.76	452.80
5	226.99	499.79
6	91.10	170.32
7	202.24	957.23

Table 3: MSE of the forecasting results obtained by the NARX model (by training algorithm).

In tables 4 and 5 it can be seen that in some cases NARX suffers from high instability (huge error rates). The learning algorithms with smallest error rates are Levenberg-Marquardt and Scaled Conjugate Gradient. The best single model is obtained with 9 input delays, 5 output delays, 10 hidden neuron and Levenberg-Marquardt algorithm, with an average MSE of 0.67.

5 Conclusions and Future Work

The study that has been described has sought continuity with earlier works on accident rates and the economic cycle in Spain, such as those of [Román, 2006] and [Arango et al., 2000], among others, in which the close and directly proportional relation between the rise in workplace accident rates and economic growth has been noted. In these works, their relation during periods of crisis is not considered, for which reason an in-depth study of what specifically happened during those periods was considered of interest and even necessary.

The results obtained with the unsupervised neuronal models that have been applied allow us with great clarity to appreciate a very similar annual distribution between each other. This situation leads us to affirm that there is a close relationship between the economic cycles and the workplace accident rates under study, or in other words that a direct link exists between workplace accidents and economic crises. The evidence of the relation that exists between both types of variables is therefore clearly expressed in the neural projections, such that their distribution is practically the same in all cases.

In view of the above, a close relation between the economic crises and the workplace accident rates in Spain can be affirmed as can the variation of workplace accidents in accordance with the economic cycles, whence the relation of dependency that workplace accident rates have with economic crisis and economic cycles.

Result from the non-linear autoregressive models show that II can be predicted in an accurate way when appropriate values are selected for the different parameters.

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