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# Innovation Research: A Bibliometric Analysis

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## Abstract

Innovation research is becoming very significant during the last decades due to the strong development of research and technology worldwide. The aim of this study is to present the evolution of academic research in innovation between 1989 and 2013. In order to do so, this work uses the Web of Science database, which is usually regarded as the most significant one for scientific research. The article analyzes the most influential journals, authors and universities in this field, providing several bibliometric indicators, that includes the total number of publications and citations, and the *h*-index. The results show a strong increase of innovation research during the last years with many leading management journals publishing significant studies in this field.

## Keywords

Innovation, bibliometrics, journals, authors, universities, Web of Science.

## 1.- Introduction

Innovation is a fundamental concept for the development of an economy because it brings new products and services into the market increasing the wealth of the society. During the last decades, the interest on innovation has grown a lot due to the rapid development of research and technology around the world. Multinationals are continuously improving their products in order to remain competitive in the market. Due to this, in the last few decades the number of academic articles on research innovation has grown exponentially (Fagerberg and Verspagen, 2009; Martin, 2012; Shafique, 2013). Such growth, annually exceeds the growth rate of the set of disciplines on other areas of research (Cancino *et al*., 2015), which allows us to understand that academics from different areas of knowledge are interested in publishing how activities, processes and results of innovation are affecting our economies and promoting development, not only of new businesses, but also of greater social and economic well-being.

A practical way to analyze a research field over a period of time is by using bibliometric indicators. Bibliometrics is the field that studies quantitatively the bibliographic material (Broadus, 1987). Bibliometric studies are becoming very popular in the scientific literature strongly motivated by the development of computers and internet that has facilitated the access to bibliographic information. Some studies have developed bibliometric analyses in innovation. Thieme (2007) studied the leading authors in innovation. Some other authors have studied the leading journals in the field developing different types of rankings according to a wide range of indicators (Linton, 2004; Shafique, 2013).

The purpose of this paper is to complement previous research, presenting a bibliometric analysis of the most influential journals, authors and universities in innovation research over the past 25 years (1989 to 2013). In order to search for articles that have focused on innovation research, we obtained the data by considering all articles published in present academic journals in the Web of Science (WoS), first filtering by keyword innovation, second for the time period between 1989 and 2013, and third filtering by eighteen research areas of WoS related with managerial perspective, presenting the information with the university affiliation of the authors.

Essentially, two types of journals lead the field: leading management journals that sometimes publish some high quality innovation papers and specialized journals that concentrate most of the innovation papers. Also, the results indicate that the most influential professors over the last 25 years, according to their highest h-index, are David Audretsch, Michael Hitt, Shaker Zahra, Rajshree Agarwal, Eric Von Hippel, David Teece, Will Mitchell and Robert Cooper. And finally, the study show that USA and UK universities are the most productive and influential institutions in innovation research.

This work is organized into five sections. This first section shows the introduction of the study. Section 2 presents the literature review. Section 3 presents the research methodology. Section 4 presents a description of the results. Finally, section 5 presents the results of the work, limitations and future research.

## 2.- Literature Review

For many decades, bibliometric studies have been very common in literature, due to its state of art contribution in making certain areas of interest known. In order to understand the relevance of these studies, diverse definitions of the concept bibliometrics can be found. According to Pritchard (1969), it is a method of applying mathematics and statistics to the media of written communication in order to understand the nature and course of development of a discipline. Also, Broadus (1987)

states that bibliometrics is the quantitative study of physically published units, or bibliographic units, or surrogates of either. More simply Norton (2001) defines bibliometrics as the measurement of texts and information. Furthermore, in the last few years new uses have been given to bibliometrics. According to Daim et al. (2006), it helps to explore, organize and analyze large amounts of historical data helping to identify hidden patterns that may help researchers in the decision making process.

Several disciplines on economics and management have used bibliometric studies, to either help us understand the data previously analyzed or show us possible hidden patterns that could be very interesting to address (Neely, 2005; Wagstaff and Culyer, 2012; Chun-Hao and Jian-Min, 2012; Carvalho et al., 2013; Bonilla et al., 2015). Focusing on innovation research, and given that scholarly literature on innovation is now rapidly growing, it is possible to find some studies that have developed analysis through bibliometric methodologies (Martin, 2012). Fagerberg and Verspagen (2009) show that there are several thousand scholars worldwide that identify with innovation studies.

One of the most recent works about bibliometrics on innovation studies belongs to Fagerberg et al. (2012). Among its results, this paper shows that a sizeable quantity of literature on innovation has developed, mostly from the 1950s onwards, with a particularly strong growth in recent years. In which, it is possible to find three stages in the evolution of the field. The first stage, up to 1970, constitutes the early childhood of the studies on innovation, mainly focused on the study of economic and sociologic aspects, where there is a limited interaction with other fields. The second phase, after 1970 approximately, was developed through the work of a limited number of researchers from research centers in Stanford, Yale and Sussex (Dosi et al., 2006). According to Fagerberg et al. (2012), a number of important contributions to the core literature emerged during the 1970s and 1980s that developed to shape the cognitive platforms of researchers in innovation for years to come. In this second phase, a distinctive characteristic of innovation studies was a strong emphasis on multi and interdisciplinarity. The third phase referred to by Fagerberg et al. (2012) is called the mature phase. In this phase, specialized professional associations were created and were involved in the development of innovation discipline (International Joseph Schumpeter Society-ISS, 1986; Technology and Innovation Management Division-TIM, 1987).

Finally, different studies on innovation are currently under development, which are addressing a variety of problems, the particularities of regions and its multidisciplinary nature (Ball and Rigby, 2006; Thieme, 2007; Yang and Tao, 2012). Some examples are those developed by Seol and Park (2008), who present an investigation of the knowledge sources of Korean innovation studies using

citation analysis. At a country level, Rafols et al. (2012) conducted a bibliometric study to compare the degree of inter-disciplinarity and the research performance of a number of innovation study units with that of leading business and management schools in the UK. Also Linton (2004) identified the centers of active research on the management of technology and innovation through the use of a publication-based study. This paper determined that schools with capabilities in innovation research are distributed across the world. Yang and Tao (2012) investigated general topics that have been studied and identify as the most popular research topics in the field of innovation management.

With the aspiration of expanding on the previous studies, in this paper we hope to contribute to the literature analyzing the most influential journals, authors and universities in innovation research.

## 3.- Methods

Bibliometrics is a research field that studies quantitatively the bibliographic material (Broadus, 1987) providing a general overview of a research field according to a wide range of indicators. There are different ways for ranking the material in a bibliometric analysis. The most common approaches use the total number of articles or the total number of citations. Another useful indicator is the h-index (Hirsch, 2005) that combines articles with cites indicating the number of studies X that have received X or more citations. In the literature, there is a lot of discussion regarding the optimal measure for evaluating research (Alonso et al. 2009; Egghe, 2006). This work uses several indicators in order to provide a more complete picture of a set of papers. The information is ranked according to one of the indicators. But the other ones are also included in the analysis so the reader can get a general idea and see the leaders according to different indicators. Note that the general assumption is that the number of articles shows the productivity while the total cites reflects the influence of a set of articles. WoS is one of the most popular databases for classifying scientific research worldwide. The assumption is that it only includes those journals that are evaluated with the highest quality. Currently, WoS includes more than 15.000 journals and 50.000.000 articles that encompass all the known sciences. In order to search for articles that have focused on innovation research, the study uses the keyword innovation in the title, abstract and keywords of any work available in WoS between 1989 and 2013. In order to focus on a management perspective, an additional filter is used that only considers the research areas of Business & Economics, Public Administration, Operations Research & Management Science, Government & Law, Geography, Social Sciences and Other Topics, Computer Science, Sociology, Urban Studies, History and Philosophy of Science, Transportation, Social Work, Social Issues, Area Studies, Behavioral

Sciences and Asian Studies. This search finds 40865 articles that becomes 36644 studies if only considering articles, reviews, letters and notes. The search was developed in December 2014 and January 2015.

## 4.- Results

This section presents the results of the paper. First, the study analyzes the most influential journals in innovation research according to WoS. Next, the study develops a ranking of authors who have been leaders in innovation research over the past 25 years. Finally, the study analyzed the leading research universities in innovation from 1989 to 2013.

### 4.1- Leading journals in innovation research

There are many journals in the scientific community that publishes material related to innovation research. Table 1 presents a list with the twenty journals with the highest h-index in innovation research. Many other indicators are included in order to get a general picture of all these leading journals.

| R | Journal | TP | TC | H | %PI |
|---|---|---|---|---|---|
| 1 | Strategic Management Journal | 351 | 55721 | 116 | 21,2% |
| 2 | Research Policy | 1318 | 51505 | 110 | 67,6% |
| 3 | Academy of Management Journal | 194 | 28853 | 93 | 13,3% |
| 4 | Organization Science | 294 | 35886 | 85 | 24,3% |
| 5 | Management Science | 298 | 20948 | 80 | 9,4% |
| 6 | Journal of Product Innovation Management | 595 | 17943 | 71 | 65,9% |
| 7 | Academy of Management Review | 87 | 15382 | 57 | 10,1% |
| 8 | Journal of Business Venturing | 155 | 7856 | 51 | 18,9% |
| 9 | Journal of Marketing | 106 | 11057 | 51 | 11,3% |
| 10 | Technovation | 799 | 13274 | 50 | 53,1% |
| 11 | Regional Studies | 309 | 8826 | 48 | 17,8% |
| 12 | Journal of Management Studies | 183 | 6852 | 47 | 14,8% |
| 13 | Administrative Science Quarterly | 63 | 27095 | 47 | 12,3% |
| 14 | R & D Management | 423 | 8032 | 45 | 54,4% |
| 15 | Harvard Business Review | 271 | 8532 | 45 | 5,6% |
| 16 | MIS Quarterly | 92 | 12503 | 44 | 12,0% |
| 17 | MIT Sloan Management Review | 160 | 5200 | 42 | 34,8% |
| 18 | California Management Review | 142 | 6945 | 41 | 19,7% |
| 19 | Journal of Management | 90 | 4756 | 41 | 8,4% |
| 20 | Small Business Economics | 259 | 5196 | 40 | 22,6% |

***Table 1: The most influential journals in innovation research according to WoS***

Most of the leading management journals are well placed in the list because most of them regularly publish highly cited articles in innovation research which represents 10 to 20% of the publications of the journal. Moreover, those journals with a strong focus in innovation research also obtain a very good position in the ranking. An important issue to remark is that Table 2 aims to be informative but it does not represent a strict ranking. The main reason for this is that depending on the perspective considered, different journals may obtain a more influential position. This is proved in Table 2 by looking to other indicators included in the list which shows different rankings depending on the criteria used.

### 4.2- Leading authors in innovation research

Some leading authors in innovation research stand out in this discipline, not only because of the large number of publications which they develop but also because of their high influence on the rest of the researchers of the world. Table 2 presents a ranking with 20 leading authors in innovation research, which are classified according to their h-index, which allows us to analyse their influence on other researchers.

| R | Name | University | Country | TP | TC | H |
|---|---|---|---|---|---|---|
| 1 | Audretsch DB | Indiana University | USA | 63 | 4510 | 32 |
| 2 | Hitt MA | Texas A. M. University | USA | 28 | 4511 | 25 |
| 3 | Zahra SA | University Of Minnesota Twin Cities | USA | 35 | 4682 | 23 |
| 4 | Agarwal R | University Of Maryland | USA | 36 | 2708 | 22 |
| 5 | Von Hippel E | Massachusetts Institute of Technology | USA | 29 | 3200 | 22 |
| 6 | Teece DJ | University of California Berkeley | USA | 31 | 7988 | 21 |
| 7 | Mitchell W | University of Toronto | CAN | 31 | 1583 | 20 |
| 8 | Cooper RG | Mcmaster University | CAN | 26 | 1784 | 20 |
| 9 | Verspagen B | Maastricht University | NED | 29 | 961 | 19 |
| 10 | Bessant J | Imperial College London | GRB | 43 | 1253 | 18 |
| 11 | Cooke P | Bergen University College | NOR | 40 | 1549 | 18 |
| 12 | Wright M | Imperial College London | GRB | 29 | 1026 | 18 |
| 13 | Duysters G | Tilburg University | NED | 28 | 1070 | 18 |
| 14 | Song M | University of Missouri-Kansas City | USA | 44 | 923 | 17 |
| 15 | Fritsch M | University of Jena | GER | 27 | 887 | 17 |
| 16 | Aghion P | Harvard University | USA | 23 | 3038 | 17 |
| 17 | Veugelers R | Ku Leuven | BEL | 23 | 1911 | 17 |
| 18 | Birkinshaw J | London Business School | GRB | 22 | 1837 | 17 |
| 19 | Lichtenthaler U | University of Mannheim | GER | 45 | 931 | 16 |
| 20 | Leydesdorff L | University of Amsterdam | NED | 38 | 1484 | 16 |

***Table 2: The most influential authors in innovation research according to WoS***

The first results shown in Table 1 are that researchers from the U.S. lead the ranking of the most influential authors in innovation research. Among the first 10 authors, 60% works in U.S. universities and from the total of 20 leading authors 35% do so. Following the USA, researchers from the UK and Netherlands are the most influential present in our rankings, representing 15% of the total number of authors. Another important highlight is that the most influential authors come from different universities; the generation of the most influential knowledge on innovation research is not gathered in any particular university. In fact, among U.S. universities, none presents two authors in our rankings.

### 4.3.- Leading universities in innovation research

There are many universities publishing papers about innovation research. Among them all, within the period of 1989 to 2013, we can single out the most important in terms of their h-index (HI), the most productive in terms of the total number of papers published on the subject (TPI), and finally the most influential universities based on the total citations their publications are receiving (TCI).

| R | Name | Country | TP | TC | H |
|---|---|---|---|---|---|
| 1 | Harvard University | USA | 588 | 42664 | 93 |
| 2 | Massachusetts Institute of Technology MIT | USA | 395 | 25169 | 76 |
| 3 | University of North Carolina | USA | 424 | 12348 | 54 |
| 4 | University of Sussex | GRB | 303 | 11360 | 53 |
| 5 | University of Manchester | GRB | 410 | 7917 | 45 |
| 6 | Erasmus University Rotterdam | NED | 329 | 6581 | 44 |
| 7 | University of Cambridge | GRB | 310 | 7255 | 41 |
| 8 | Georgia Institute of Technology | USA | 237 | 6341 | 41 |
| 9 | Maastricht University | NED | 220 | 6315 | 39 |
| 10 | Eindhoven University of Technology | NED | 222 | 5290 | 39 |
| 11 | Imperial College London | GRB | 200 | 5153 | 39 |
| 12 | Rensselaer Polytechnic Institute | USA | 151 | 4751 | 39 |
| 13 | University of Utrecht | NED | 238 | 5015 | 36 |
| 14 | Copenhagen Business School | DEN | 201 | 6151 | 34 |
| 15 | Aalto University | FIN | 176 | 3638 | 31 |
| 16 | Centre National de la Recherche Scientifique | FRA | 265 | 3614 | 30 |
| 17 | Delft University of Technology | NED | 198 | 2211 | 26 |
| 18 | Polytechnic University of Milan | ITA | 161 | 2625 | 25 |
| 19 | Chalmers University of Technology | SWE | 105 | 1956 | 23 |
| 20 | University of Twente | NED | 136 | 1656 | 20 |

***Table 3: The most influential universities in innovation research according to WoS***

As can be seen in Table 3, the most influential institutions worldwide are mainly american, accompanied by some of the most prestigious universities in the UK. If we look at the top 10 leading universities in the theme, ninety percent are american institutions, with the University of Sussex standing out as the only British university appearing at the top. When we advance in our analysis to the top 20 leaders in innovation research universities, american institutions maintain a high percentage, with 16 of the 20 listed. With this group of universities 3 are now from the UK and 1 from France.

## 5.- Conclusions

The study presents a journal analysis with a list of the twenty most influential journals in the field. Most of the leading management journals tend to publish a significant number of papers focused on innovation research every year that have influenced the field a lot including the Strategic Management Journal and the Academy of Management Journal. Moreover, there are several specialized journals that have a strong impact in the scientific community including Research Policy and the Journal of Product Innovation Management. Also, the analysis focused on studying a ranking of 20 leading authors that present a greater h-index in the discipline. In this ranking, it is possible to observe an interesting discussion that reveals that the most productive researchers, those who have a greater quantity of published work, are not necessarily the most influential, those who have a greater number of citations by the scientific community. There are several authors who despite presenting fewer publications, are frequently cited by other researchers. Finally, the results show that the most prestigious american universities are not only the most influential, taking into account the number of citations of their publications, but are also highly productive universities in this area, given the greater number of publications that they have accumulated on innovation research in the last twenty five years. There are also some universities in the UK, France and the Netherlands which are worth mentioning.

The study gives an updated list of influential journals in innovation research taking into account a wide range of indicators. The results are in accordance with previous studies although some important deviations are found. While we believe that the results of authors are valuable, we believe that it is necessary to deepen and complement the information presented with new studies that allow understanding how innovation research publications in different journals in the Web of Science have increased, specialized and general and see what the ratio of citations between these journals is. And, the results of this paper about universities are particularly different from those earlier studies, such as by Linton (2004), which only considered American institutions in its analysis. Although we

believe the results found are valuable, we still see need to further develop studies to complement the analysis of what the most influential universities in innovation research are, who the most prominent authors are and which journals have greater impact and influence on the material. Furthermore, a comparison of variation of results over the years could be very important.

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*Lectures on Modelling and Simulation; A selection from AMSE # 2016-N°1; pp 21-31*
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# Exchange Rate Forecast by Econometric Models, Time Series and HOWMA

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## Abstract

In this research we analyze econometric models for forecasting the exchange rate, combined with two different techniques of projection of variables, time series and HOWMA operators. The results are analyzed by each of the techniques, finding that while the results of time series were more accurate by little, however the HOWMA operators can generate different scenarios according to the characteristics of the decision maker and expectations of the economy.

## Key words

Exchange rate forecast, econometric models, time series, HOWMA Operators

## 1. Introduction

Since elimination of Bretton Woods system in the early seventies, the risk in global markets increases, leading to the adoption of floating exchange regime. For this situation the exchange risk management has become a strategic activity of the corporate governance of international companies. (e.g. Miller & Reuer (1998), Froot & Thaler (1990), Allayannis & Ofek (2001) and Bartman & Bodnar (2005)).

Because this high volatility of the exchange rate, points Jorion & Sweeney (1996), Zhang & Hu (1998), Bodyanskiy & Popov (2006) and Majhi, Panda, & Sahoo (2009), it is necessary to generate models that predict the future of it. In this regard Engel, Mark, & West (2007), Rogoff & Stavrakeva (2008) and Molodtsova & Papell (2008) state that the exchange rate is a reflection of basic macroeconomics, as the interest rate, purchasing power parity and trade balance.

One of the limitations of traditional models to forecast exchange rate, say McLeod 1964) and Boyer & Young (2005) is that use variable whose behavior is complex, so it is base on simple

assumptions of the future behavior of the variables, so the result is a reflection of the conditions used and the possibility of different scenarios exist.

In this sense it is necessary to use models in which accurate data is not used, because these become ineffective in situations of uncertainty (e.g. Gil Lafuente (2001) and Gil Aluja (2004)). So considering the opinion of the currency market experts within the models will allow assumes different expectations of the future. (e.g. Goldeberg & Tenorio (1997) and Lyons & Evans, (2002)).

In the present work, it is study a combination of traditional econometric models with a prediction of each variable through time series and moving averages using aggregation operators HOWA (HOWMA), the latter tool is used to consider the expectation that the decision maker has about the variables.

## 2. Preliminaries

Some of the basics you should know in this research are as follows

**Definition 1**. The theory of purchasing power parity (PPP), indicate Dornbusch (1985) is:

$$\mathrm{TC_F} = \beta_0 + \beta_1 \mathrm{PI_E} + \beta_2 \mathrm{PI_D} \tag{1}$$

Where $\mathrm{TC_F}$ is future exchange rate, $\mathrm{PI_E}$ is foreign price index and $\mathrm{PI_D}$ is domestic price index.

**Definition 2**. The theory of parity of interest rates, points Aliber (1973) and Fama(1984) is formulated

$$TC_F = \beta_0 + \beta_1 I_E + \beta_2 I_D \tag{2}$$

Where $TC_F$ is future exchange rate, $I_E$ is foreign interest rate and $I_D$ is domestic interest rate.

**Definition 3.** The theory of the balance of payment, according to Dornbusch (1979) says

$$TC_F = \beta_0 + \beta_1 BC + \beta_2 IEC + \beta_3 IED + \beta_4 R \tag{3}$$

Where $TC_F$ is future exchange rate, *BC* is current account balance , *IEC* is foreign investment in portfolio, *IED* is direct foreign investment y *R* is reserves account.

**Definition 4.** The multiplicative decomposition time series model, points Fischer & Planas (2000), is formulated

$$Y_t = T_t * S_t * I_t \tag{4}$$

Where $Y_t$ is observed value, $T_t$ is tendency, $S_t$ is seasonality, $C_t$ is cycle y $I_t$ is irregularity.

**Definition 5.** The moving averages, according to Kenney & Keeping (1962), are defined as a sequence given $\{a_i\}_{i=1}^{N}$, where a moving average $n$ is a new sequence $\{s_i\}_{i=1}^{N-n+1}$ defined from $a_i$ taking the arithmetic mean of the sequence of $n$ terms, such that

$$s_i = \frac{1}{n}\sum_{j=i}^{i+n-1} a_j \tag{5}$$

**DDefinition 6.** According to Yager, (1988) an OWA operator of dimension $n$ is an application $F: R^n \to R$ with an associated weight vector $w = [w_1, w_2, \dots, w_n]^T$ so that $w_j \in [0,1]$, $1 \leq i \leq n$ y

$$\sum_{i=1}^{n} w_{i=} w_1 + w_2 + \cdots + w_n = 1 \tag{6}$$

Where

$$F(a_1, a_2, \dots, a_n) = \sum_{k=1}^{n} w_j b_j \tag{7}$$

Being $b_j$ is the *j*th element largest of the collection $a_1 a_2, \dots, a_n$.

**Definition 7.** A heavy aggregation operator, points Yager (2002) is an extension to OWA operator that allows the weight vector goes up to $n$. So a HOWA operator is an application $R^n \to R$ which are associated to a weight vector *w* which $w_j \in [0,1]$ y $1 \leq \sum_{j=1}^{n} w_j \leq n$, so that

$$HOWA\ (a_1, a_2, \dots, a_n) = \sum_{j=1}^{n} w_j b_j \tag{8}$$

Being $b_j$ is the *j*th element largest of the collection $a_1 a_2, \dots, a_n$.

**Definition 8.** A HOWMA operator is defined as a given sequence $\{a_i\}_{i=1}^{N}$, where you get a new sequence $\{s_i\}_{i=1}^{N-n+1}$ which is multiplied by a heavy weight vector, such that

$$HOWMA(s_i) = \sum_{j=1}^{n} w_j b_j \tag{9}$$

Being $b_j$ is the *j*th element largest of the collection $a_1 a_2, \ldots, a_n$.

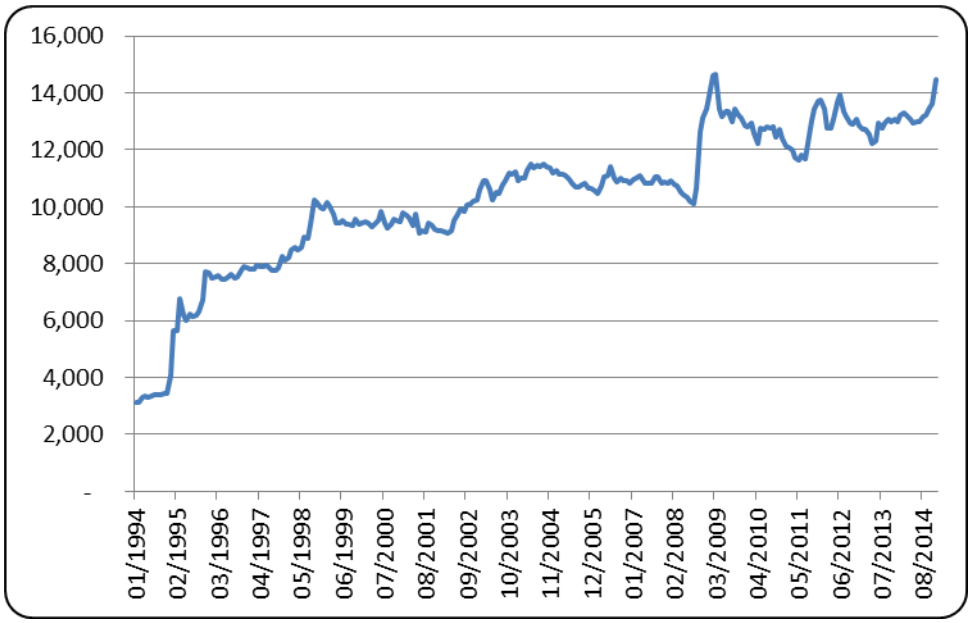
## 3. Exchange rate in Mexico's economy

The results of the 1994 crisis in Mexico, Cartens & Werner (2000), Martínez & Werner (2002) and Ramos & Torres (2005) forced to leave the default floating regime and adopt a free floating regime against the various world currencies. Those responsible for the fluctuations in the price of currencies, claim Dornbusch (1976), Flood & Rose (1995), Jeanne & Rose (1999) and Edwards, Cavallo, Fraga & Frenkel (2003) are the changes in supply and demand of financial markets, influenced by numerous external factors and the regime of free float, which creates a kind of unexpected, obscure and volatile change that threatens the future cash flows of the companies. (e.g. Adler & Dumas(1984), Flood & Lessard (1986), Lewent & Kearney (1990) and Bartram (2008))

The effect of adopting the system of free floating exchange rate issue has generated considerable uncertainty in the value of the currencies in Mexico, mainly in the exchange rate USD/MXN, that since 1994 to 2014 has faced a high variation in price and volatility (See Figure 1 and 2)

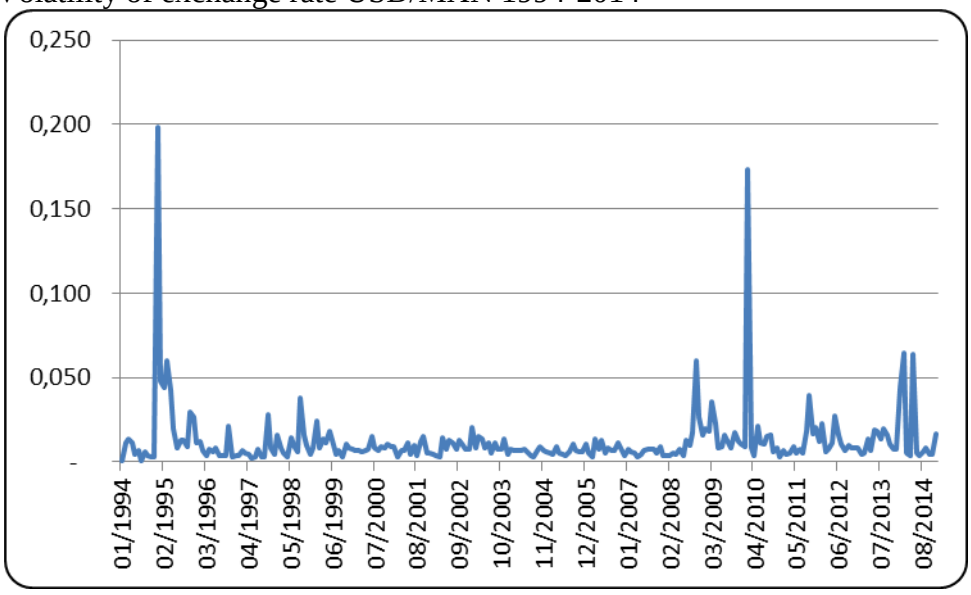
Currency risk exposure, expressed Allayannis & Ofek (2001) and Domínguez & Tesar (2006) is linked to the daily operations of the company, among which include imports, exports, investment and foreign currency loans. In that way foreign exchange risk, note Froot & Thaler (1990), Kogut (1993) & Tenti (1996) and Miller & Reur (1998) leads decision makers to accurately measure the exchange rate, in that way design strategies to reduce it to acceptable levels, that is why determine the future exchange rate becomes necessary.

Graph 1. Spot exchange rate USD/MXN 1994-2014




Source. Own elaboration with data from Banxico (2015)

Graph 2. Volatility of exchange rate USD/MXN 1994-2014




Source. Own elaboration

## 4. Application of the model

In this research are used three econometric models in order to forecast the exchange rate USD/MXN for the months of January to September 2015, for this was generated a multiple linear regression model considering USD/MXN exchange rate as dependent variable and for independent variables price index, interest rates and balance of payments. (e.g. Taylor(1995), Flood & Rose (1995), Flood & Rose (2002), Taylor & Taylor (2004) and Phillips (2004)).

The information used to generate each of these models were from 1994 to 2014 data for each variable that integrated the model, obtaining the following models

Model based on price index

$$tc_F = 0.107 + 0.914tc_{-1} + 0.0235v - 0.00195pi_E + 0.0408pi_D \quad (10)$$

Model based on interest rates

$$tc_F = 0.0908 + 0.960tc_{-1} + 0.0225v - 0.000019i_E - 0.00228i_D \quad (11)$$

Model based on balance of payment

$$TC_F = 0.175 + 0.978TC_{-1} + 4.59V - 0.000041BC - 0.000023IED - 0.000016IEC + 0.000002R \quad (12)$$

Where $tc_F$ is future exchange rate, $tc_{-1}$ is spot exchange rate with one lag, *v* is volatility, $pi_E$ is foreign price index, $pi_D$ is domestic price index, $i_E$ is foreign interest rate, $i_D$ is domestic interest rate, where all of the above variables are expressed in logarithm , $TC_F$ is future exchange rate, , $TC_{-1}$ is future exchange rate with one lag, *V* is volatility, *BC* is current account balance, *IBC* is foreign investment in portfolio, *IED* is direct foreign investment y R is reserved account.

*Forecast of the variables*

For forecast every variable first it was used multiplicative decomposition time series method, in which determine the type of tendency and its equation, further seasonality, cycle and irregularities for each of the months of the year.

Moreover HOWMA operators were used to forecast the future of the variables in which a sequence $n = 6$ was used, this because the decision maker believes that this are the months that still hold important information for the forecast. Additionally, consider a $w = 1.05$, this is due the economic scenario for the 2015 was negative, so the exchange rate USD/MXN will depreciate with a valuation for each of the six months in the moving averages as follow $w = (0.05,0.15,0.15,0.25,0.40)$, also a maximization criterion was used in the result, that is the scenario that leads to greater exchange rate depreciation. All this based on the information provided by the decision maker.

The result of econometric models with time series and operators HOWMA are seen in Table 1 and 2 respectively.

Table 1. Forecast of exchange rate using econometric models and time series

| Time | Spot Exchange rate | Price Index Forecast | Error | Interest Forecast | Error | Balance of Payment Forecast | Error |
|---|---|---|---|---|---|---|---|
| 01-15 | 14.6808 | 15.6757 | 0.9949 | 15.6435 | 0.9627 | 15.5804 | 0.8996 |
| 02-15 | 14.9230 | 15.6272 | 0.7042 | 15.5716 | 0.6486 | 15.8417 | 0.9187 |
| 03-15 | 15.2136 | 15.2111 | -0.0025 | 15.1264 | -0.0872 | 15.3650 | 0.1514 |
| 04-15 | 15.2208 | 15.2666 | 0.0458 | 15.1832 | -0.0376 | 15.3671 | 0.1463 |
| 05-15 | 15.2475 | 15.4326 | 0.1851 | 15.3492 | 0.1017 | 15.5471 | 0.2996 |
| 06-15 | 15.4692 | 15.7162 | 0.2470 | 15.6489 | 0.1797 | 15.8292 | 0.3600 |
| 07-15 | 15.9225 | 15.8889 | -0.0336 | 15.8342 | -0.0883 | 15.9158 | -0.0067 |
| 08-15 | 16.5032 | 15.6731 | -0.8301 | 15.6062 | -0.8970 | 15.6174 | -0.8858 |
| 09-15 | 16.8519 | 15.6922 | -1.1597 | 15.6222 | -1.2297 | 15.7823 | -1.0696 |
| Average Errors | 15.5592 | 15.5760 | 0.0168 | 15.5095 | -0.0497 | 15.6495 | 0.0904 |

Table 2. Forecast of exchange rate using econometric models and HOWMA

| Time | Spot Exchange rate | Price Index Forecast | Error | Interest Forecast | Error | Balance of Payment Forecast | Error |
|---|---|---|---|---|---|---|---|
| 01-15 | 14.6808 | 14.4197 | - 0.2611 | 14.4255 | -0.2553 | 14.5448 | -0.1360 |
| 02-15 | 14.9230 | 14.4971 | -0.4259 | 14.4952 | -0.4278 | 14.5601 | -0.3629 |
| 03-15 | 15.2136 | 14.8056 | -0.4080 | 14.8092 | -0.4044 | 14.8402 | -0.3734 |
| 04-15 | 15.2208 | 15.1007 | -0.1201 | 15.1098 | -0.1110 | 15.1268 | -0.0940 |
| 05-15 | 15.2475 | 15.4455 | 0.1980 | 15.4622 | 0.2147 | 15.4882 | 0.2407 |
| 06-15 | 15.4692 | 15.7565 | 0.2873 | 15.7792 | 0.3100 | 15.7913 | 0.3221 |
| 07-15 | 15.9225 | 16.0647 | 0.1422 | 16.0965 | 0.1740 | 16.1272 | 0.2047 |
| 08-15 | 16.5032 | 16.3817 | -0.1215 | 16.4208 | -0.0824 | 16.4509 | -0.0523 |
| 09-15 | 16.8519 | 16.7113 | -0.1406 | 16.7585 | -0.0934 | 16.7916 | -0.0603 |
| Average Errors | 15.5592 | 15.4648 | -0.0944 | 15.4841 | -0.0751 | 15.5246 | -0.0346 |

## 4 Conclusions

The exchange rate risk has become a problem for most business worldwide, so find a way to forecast it and get to know the stages that wait us is indispensable for good management. In the present study were used different econometric models combined with time series and operators HOWMA, the first give a single result for the case, while the second allows the incorporation of economic expectations and experience of decision maker in the model.

With the application of the model can be seen that the results using time series are slightly better, within average errors, than results obtained by HOWMA operators, however within the first cannot be considered different types of scenarios, whether optimistic or pessimistic. In that way both tools are useful in preventing expectations of exchange rate USD/MXN. In future research is expected to deepen using expertons for determining HOWMA operator, also using another aggregation operator as probability. (e.g. Merigo & Gil Lafuente (2009) and Merigo & Gil Lafuente (2010))

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# Indirect Flow Analysis of International Trade during 2009-2013 between the Pacific Alliance, the USA, the European Union and China through the Forgotten Effects Model

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## Abstract

International trade consists of a complex network of direct connections between exporters and importers. Nevertheless, the indirect flows analysis of importations, which is made through an intermediary country, has been a big complexity issue. In order to identify these flows, it's necessary to apply a proper methodology such as the Forgotten Effects to model this type of systems. Given the exploratory nature of this research, direct flows of trade between countries from The Pacific Alliance were analyzed, using as commerce centers the United States, the European Union and China. The results reveal the existence of consistent second order effects during the studied period and also reveal "provider-producer" and "producer-producer" relationships.

## Key words

International Trade, Indirect Flows, Forgotten Effects.

## 1. Introduction

Worldwide Trade Organization points out that worldwide trade has grown as double as fast than the worldwide production (WTO, 2013). This fact shows how important the analysis of international trade relationships is. It is crucial to settle the existent international networks, as well as the effects that these could generate. The complexity of the existent flows is the imminent

cause that human beings are incapable of recognizing indirect connections at first sight. Worldwide economic dynamics are not at equilibrium, neither are predictable, there is a perpetual change in its behavior; therefore, economies live in constant change (Brian, 1999).

About economy's systemic behavior, (Bertalanffy, 1956) set the basis for its study. From this point of view, some authors applied the general systems theory, stating out the importance that the analysis of commercial networks acquires, together with the complexity that it implies (Cardoso, 1977; Barkley, 1999).

It is difficult for human beings to process all these relationships, requiring the use of specialized methodologies to revise those relations thoroughly, in order to avoid risks that oversights might generate (Kauffman and Gil Aluja, 1988). In their work, these authors present mathematical models that study different sequences of relationships, inferences and consequences which tend to have two or three reasoning scales; besides, they cannot be observed with a simple look. Their approaches use graphs that are valuated in confidence intervals, and they state the concept of "second generation effects", that correspond to those political and social-economic decisions related effects with their respective risks. Together with this, they introduce the concept of incidence, defined as the effects that a group of entities have on others or itself".

A similar statement is exposed by Gil-Lafuente and de Paula (2010) who claim that practically every single activity is subdued by some kind of cause-effect incidence. Despite an appropriate control system, there is always the possibility to voluntarily forget some causality relationships that are not always explicit, apparent or visible, and are not normally perceived.

The basis of our research is the methodology described by Kauffman and Gil Aluja (1988), who studied forgotten effects through first and higher order incidence matrices. The objective of this article is to identify and analyze indirect flows that international trade causes, through exports and imports in the countries of the Pacific Alliance, the United States, the European Union and China.

Through bibliographic review, it can be found that the Forgotten Effects Model has been used in many different knowledge areas. Gil-Lafuente and de Paula (2010), tried to determine the elements that a company needs to match economic growth with sustainability and environmental protection. To do this, the forgotten effects methodology was used, analyzing external causes and their incidences in the sustainability of the firms.

Gil-Lafuente and Bassa (2011) started on the need of the companies to retain and manage their clients, and the expenditure that it is made in client service projects, information

management, and market research, among others. In order to do this, the Forgotten Effects Model was used to show hidden characteristics that the clients value about a service or a good. Their conclusion was that there are many aspects that were forgotten by clients; therefore, they can be forgotten by companies.

Salazar-Garza (2012) presented a predictive model of the exchange rate behavior, based on the expert opinion of the participating economic agents in the Dollar/Peso market. These variables were processed with the fuzzy subset logic and the Forgotten Effects Model.

Modeling the economic system through international trade flows, i.e., as exports, is not something new. Hausmann and Hidalgo (2011) explained how most of the economic analysis is based on aggregate output. As it is done here, they also set a network structure by connecting countries to the products they export.

To sum up, this research uses the Forgotten Effects Model to quantify the second order incidences of international trade among countries, using this information to discuss the strategies and politics that studied countries might adopt.

## 2. Data and Methods

Our data corresponds to exports of the Pacific Alliance (Chile, Peru, Colombia and Mexico), the United States, the European Union and China for the period 2009-2013. The sources of this data were the respective official sites of each country like DIRECON (Chile), INEGI (Mexico), MINCETUR (Peru), US Department of Commerce (USA), DANE (Colombia) and the Worldwide Trade Organization. All of them calculated by FOB prices, including energy.

In the preliminary analysis of direct significant relationships, for the further indirect flow analysis, a basis matrix was made by setting in rows and columns the 7 origins and destinations (square matrix), i.e, let $A = (a_{i,k})_{nxm}$ be a matrix of direct effects of the set of countries $E = \{e_i\}, i = 1,..., n$, this matrix was normalized, dividing each row by its maximum value:

$$A = \left(\mu_{i,k}\right)_{nxn} \tag{1}$$

$$\mu_{i,j} = \frac{a_{i,k}}{\max\ a_{i,k}} \tag{2}$$

To represent this results graphically, and to analyze the second order effects obtained, binary graphs were used:

$$\Delta = (\beta_{i,k})_{nxn} \tag{3}$$

$$\beta_{i,k} = \begin{matrix} 0, if & \mu_{i,j} < \varepsilon \\ 1, otherwise \end{matrix} \tag{4}$$

In our case, $\varepsilon = 0.5$ was considered significant threshold. Second order effects were calculated through the Forgotten Effects Model. The "combined" matrix that contains both first and second order incidences is:

$$AC^{1+2} = (\mu_{i,k}^{1+2})_{nxn} \tag{5}$$

$$\mu_{i,k}^{1+2} = \vee(\mu_{i,j}^{1+2} \wedge \mu_{j,k}^{1+2}) \tag{6}$$

Where $\vee$ represents the "maximum" operator and $\wedge$ the "minimum" operator. The previous expression is known as the "max-min" relationship, or "maximum-minimum" composition. Then the second order effects whose matrix representation is:

$$AC = [\mu(a_i, c_k)]_{nxs} \tag{7}$$

Is obtained by subtracting the "combined" matrix with the "basis" matrix as it is shown:

$$AC^2 = AC^{1+2} - A \tag{8}$$

Where $[\mu(a_i, c_k)]_{nxs}$ is significant if μ≥ 0.5 and not significant, if else. The data described was processed through the statistical programming language GNU R.

## 3. Results

### *Direct effects*

Direct effects from 2009 are shown below. These effects remained unchanged through the studied period.

Table 1. Significant Direct Effects

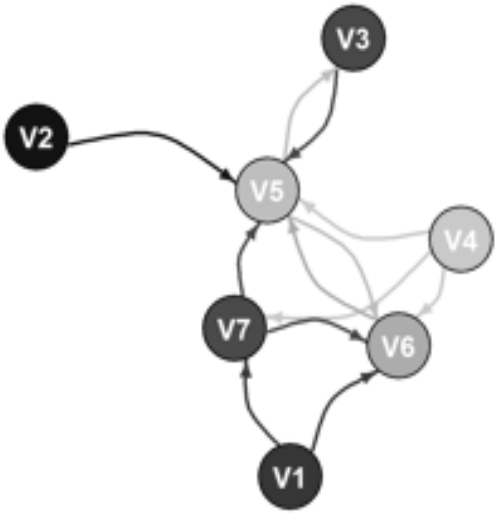
| From | To |
|---|---|
| Chile[1] | USA |
| Chile | European Union |
| Chile | China |
| Colombia | USA |
| Mexico | USA |

[1] The only effect which is not consistent for the 5 year period. It appears on 2012 and remains the following year, which suggests the increase of export proportion from this country to USA.

| | |
|---|---|
| Peru | USA |
| Peru | European Union |
| Peru | China |
| USA | Mexico |
| USA | European Union |
| European Union | USA |
| China | USA |
| China | European Union |

In addition to this, it is presented the binary graph described before, which shows direct relationships under a threshold of 0.5.

Figure 1. Direct Relationships for the year 2009.[2]




Given the first order relationships shown above, it can be observed that Pacific Alliance countries do not have an important exports relationship with their associates, because in this region the main importers are The United States and the European Union. Therefore, these countries are not taking the advantages generated by this commercial bloc. Nevertheless, this phenomenon might be interpreted as a lack of interest to increase commerce between the Pacific Alliance countries, given that they are not as economically attractive as the main worldwide economies.

A likely explanation could be given: the absence of important relations between these countries is caused by the similarity of the goods which they supply, due to their similar geography and climate. This drives countries to compete rather than to cooperate, in order to satisfy the foreign demand. This is the opposite of the initial cooperative spirit that founded the bloc.

[2] For: V1=Chile, V2=Colombia, V3=Mexico, V4=Peru, V5= United States, V6= European Union, V7=China

***Indirect Effects***

Here we present the indirect flows analysis studied through Forgotten Effects. We present the origin of the effect, as the intermediary and the destination of it. We also present the value range of the indirect effects obtained during 2009 to 2013, in order to quantify these relationships. A brief discussion about the results is presented in order to explain empirically the appearance of those effects by bibliographic review and our proper analysis.

From → Through → To:

**Chile → EU and China → USA**

$\mu(a_i, c_k) \ni [0.512, 0.59]$

Regarding Chile, it generates second order incidences with United States through the European Union and China during 2009 (0.54), 2010 (0.59) and 2011 (0.512). This is due to the main exports of Chile, represented basically by copper related products, besides other minerals such as iron. These products are processed by China and the European Union and sent to the United States as finished technological products. It means, that this relationship is born by the nature of Chile as a provider of raw materials, China and the UE as producers, and USA as an importer of technological products. A beneficial characteristic of these low indirect effects values, is that Chile is not a receiver of such severe effects during the spread of localized recessions. May be that resistance shown by Chile during the sub-prime crisis can be partially explained by this fact. An explanation of the second order effects values (close to the threshold) is the diversification of its exports between the "three big" economies, it means, Chile does not strictly depend on one particular buyer. This way, Chile manages to mitigate the consequences of recessions. Authors like Rosales and Kuyawama (2012) emphasize the importance that China had, not only for Chile, but for all Latin-American countries in the recovery and rescue of the regional exports during the crisis of 2012. China, with its continue demand for the raw materials that this region exports, influenced an increase in the prices of those commodities. Therefore, after the big crisis, the countries with best results in international trade were the ones of South America, in comparison of the countries that did not have China as a commercial partner.

**Colombia → USA → Mexico**

$\mu(a_i, c_k) \ni [0.53, 0.62]$

The main commercial partner of Colombia is The United States of America. This fact explains why this effect is caused through that country. Its exports are related to the Mining

Industry, therefore, the United States transforms these raw materials and exports finished goods to Mexico, mainly as machinery and cars.

**Colombia → USA → EU**

$\mu(a_i, c_k) \ni [0.58, 0.68]$

The direct relationship between Colombia and the United States was explained in the previous point. However, the trade between The USA and The EU consists mainly in manufactured goods, machinery and transport equipment. An important reason that causes this relation has to do with the growth of Colombian exports to the USA. Its characteristic, is that, as other associations between providers-producers, it is considered a typical "north-south" pattern, where primary goods are exchanged by industrial goods, under the theoretical frame of the comparative advantages model (Moncayo, 2006). The low participation of the Intra-industrial commerce between Colombia and The United States is explained by Caicedo and Mora (2010) who point out that only a 9.06% of the 5,000 products that the South American country sends correspond to technological goods. Therefore, there is no real trade of technological products in the Colombian case.

**Mexico → USA → EU**

$\mu(a_i, c_k) \ni [0.92, 0.93]$

An important aspect here, is that Mexico indirectly affects The European Union over a threshold of 0.9 and also, The European Union reciprocally generates second order effects to Mexico. In addition, both of these relations happen through the United States. Therefore, it is concluded that increasing the direct relationship between Mexico and the EU might be more beneficial than exporting directly to the USA, because this products finally end up in the EU. Having in mind that the main exports of the Mexico-USA relationship are oil and other derivatives, besides fruits and other types of food. According to the analyzed data this relation is not important just for the EU, but for many other countries, because Mexico is the country that receives the most of the indirect flows. This suggests the huge importance of its oil exports as a vital input in the productive processes of almost every industry in the world.

As this relation is bidirectional, for both countries would be better to strengthen this links, trying to place the European Union as the main buyer of Mexican products, which was also recommended by Caamal et al. (2014), who additionally emphasized the growing level of exports and imports between both economies through last years.

**Peru → USA →Mexico**

$\mu(a_i, c_k) \ni [0.5,0.78]$

Peru exports to the USA oil and coffee, as traditional goods, and as non-traditional, food and clothes. The other relation – USA and Mexico- was explained before. The main products sent by USA are machinery and cars. This states once again the role of the United States as a producer, with an undeveloped primary industry, which implies that it does not have enough raw materials or the food necessary to function by itself, so it has to inevitably import these commodities.

**China → USA → Mexico**

$\mu(a_i, c_k) \ni [0.55,0.72]$

China exports to the United States massive-consumed technological goods, marine products, toys and textiles. As seen, it is not observed a provider-producer relationship, but an industrial one. This is caused by the low-cost production system that China possess. In this case, indirect flows are produced by the huge level of exports from China. With such magnitude, these exports end up affecting other countries.

To sum up, a relationship generated by two of the largest economies is observed, which also affects Mexico subsequently. That country was characterized before as the one that most indirect flows receives in the analyzed data.

**EU → USA → Mexico**

$\mu(a_i, c_k) \ni [0.58,0.75]$

The indirect Mexico –EU relation is caused by machinery, vehicles and pharmaceutical goods that the European bloc sends to the USA. On the contrary, as stated a couple of times before, Mexico receives machinery and vehicles. Therefore, another producer-producer relationship is observed, where two economies trade finished goods. However, those transactions have such a magnitude that in the end affect a third party by generating second order effects. Thus, there is no doubt that this effect starts on the "trans-Atlantic" friendship, considering that this is, in fact, the biggest international trade relation, if we talk about export and investments. This fact is shown by Mix (2010), too.

**USA Case**

Even though, USA is the biggest economy in the world, it does not generate second order effects. Though, it is observed that it is the "bridge" where every second order effect is generated. So, the United States could be characterized as a picker and distributor of these effects, given its nature of importer of supplies (energy, raw materials) and exporter of processed goods. An interpretation of this noticeable feature is the dependence that this country generates to others. In other words, it is the country that might cause the biggest negative consequences. Therefore, it is of huge interest for the rest of the countries all over the world to be aware of its economic situation. As an example, the sub-prime crisis deeply affected almost every economy in the world (Dooley and Hutchinson, 2009).

## 4. Conclusions

It is possible to conclude that there are relationships of higher order in the international trade reality, like it was suggested on our initial assumption. These significant second order effects are highly related to the United States as an importer of raw materials and as exporter of final goods. This fact makes the Pacific Alliance countries to have a historical dependence with the north American economy, as said by Cardoso (1977).

Additionally, there are not important trade relationships between the countries of the Pacific Alliance. The main commercial flows have as destinies the United States and China, a fact that proves the lack of cooperation to accomplish full economic development for Latin American countries. This is confirmed by Bernal-Meza (2013), pointing out that given the characteristics of the economic inclusion and commercial politics of the countries that sign the Pacific Alliance agreement, the cooperation- key component in MERCOSUR and UNASUR- is replaced for competitiveness. In addition, all of them have free trade agreements with the United Stated and the European Union and they lead the process of internationalization of Latin American companies, looking for new relationships with the Asia-Pacific bloc. In other words, it is not a "commercial aid" bloc, but rather a group of countries that try to set a proper environment for foreign investments. About this topic, Rodríguez Aranda (2014) argues that in the new configuration of Latin American sub regions, two dynamics are produced. On one side, the settlement of a new area of liberalized regional commerce in the Pacific shore, and on the other, some dynamics of competition dominated by the interests of USA and China.

Another point of view is that the Pacific Alliance countries still have opportunities to achieve a true economic cooperation. Future challenges are formulated to develop a better exchange

proportion of international trade between these American countries, due to the development of their local markets and the constant increase of their GDP.

The Chinese case presents an interesting aspect, the lack of second order effects generation despite the fact of being one of the largest economies in the globe. Also, the Chilean case, that as an exporter of copper, an important commodity to manufacture technological products, could be an important generator of indirect flows, but given the results, it does not present a higher importance for the larger economies. This is explained by the diversification of its exports. In simple words, the weight of the Chilean exports in the larger economies is not significant. This is generated by the "open" commercial politic that has been adopted since 1973, by decreasing duties and signing free trade agreements (Meller, 1992; Schuschny, 2008, Vicuña, 1994).

Being in a globalized world, it is important for developing countries to be aware of the system conditions, and the study of indirect flows allow this, to see the "bonds" that link these economies. Extrapolating what Granovetter (1973) said, about the strength that links have, it can be said that the importance that a country could acquire in respect to another, varies directly with the strength of this link or bond, which for this case is represented by exports. For this reason, the Forgotten Effects model allows to observe how "tied" by this links an economy is, and of course, to plan actions to mitigate negative consequences and diversify its exports portfolio. As shown in the Chilean case, a country considered as a "multilateral trader" by Aggarwal and Espach (2004) given the liberalization of its economy to other countries and the bilateral and multilateral signing of agreements.

To finish this article, it's important to emphasize its exploratory nature, where a non-common method is applied to an unexplored area, allowing the study of indirect flows given certain direct relationships. This sets the possibility to continue in the future with further studies about related topics.

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# A Simulation Applied to Processes of Personal Attention for Taxpayers in the Eastern Regional Office of Santiago Chile.

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## Summary.

In order to improve the efficiency and quality of in-person taxpayer assistance, we studied the process of attention to the public in the Platform of Attention and Assistance for Taxpayers. The goals was to create a tool to help make decisions in a tactical and strategic manner. Therefore, we developed a simulation based on the strategic objectives of the Internal Revenue Service, to evaluate the impact of distinct configurations of attention in the medium and long term obtained in a form of configuration that permits us to improve the current model of attention.

## Keywords

Internal Revenue Service, Simulation, Process Design.

## 1. Introduction.

In 2013, the Chilean Internal Revenue Service (from now on indicated as the IRS or the Service) received requests from more than **3 million users** on its taxpayer attention and assistance platform that needed in person assistance from all over the country.

In order to create a tool to help with decision making in a tactical and strategic way, to ultimately improve the efficiency and quality of in person taxpayer assistance, a simulation was developed and applied specifically to the process of attention at the Eastern Regional Office of Santiago. This office was selected since it is one of the offices with the highest demand at the national level.

## 2. General Operations Model of the Platform of Attention and Assistance for Taxpayers

The Platform for Attention and Assistance for Taxpayers is made up of:

a) **An area of information and assistance**: Where taxpayer questions are handled.
b) **An area for help with general procedures:** Corresponds to *the first line of attention or front office* and is in charge of receiving, admitting, and processing the requirements of taxpayers.
c) **An area for help with specific procedures:** Corresponds to *the second line of attention or back office* of the platform and is in charge of receiving the requirements that arise from the areas of information and assistance, help with general procedures, or direct attention for taxpayers with pending situations with the IRS.

## 3. Methodology

The methodology used consists of the characterization of the process of arrival and attention to taxpayers in order to create a simulation of the reference system.

### 3.1 Process of Attention.

- **Step 1**: Entrance to the taxpayer or representative.
- **Step 2**: Emission of number from ticket dispensers. At this time the order of attention is determined and if it will be handled in the *front office* or *back office* module.
- **Step 3:** Taxpayer or representative enters the waiting room.
- **Step 4:** Taxpayer or representative leaves the waiting room and enters a module of attention for either the *front office* or *back office.*
- **Step 5:** Attention for the taxpayer or representative.

  If the attention is in the *front office* and it is determined that the procedure is complex, the taxpayer or representative is directed to the *back office* where the process of attention continues in the following manner:

  - Entrance of the taxpayer or representative to the waiting room.
  - Taxpayer or representative leaves the waiting room.
  - Attention in a module in the *back office*.

- **Step 6:** Taxpayer or representative complete their visit and leave the system.

## 3.2 Characterization of the process of arrival and attention for taxpayers.

In order to create a simulation model, it was necessary to identify the elements of the system and the attributes that characterize it.

### 3.2.1 Elements of the system.

The elements of the Platform of Attention and Assistance for Taxpayers are:

- **Entities:** Taxpayers or representatives that come to the attention area for procedures.
- **Locations:** Modules or workspaces for attention and the waiting areas.

Table 1: Description of system elements

| Element | Type | Description |
|---|---|---|
| *Taxpayer* | Entity | Person that arrives for a procedure. |
| *Representative* | Entity | Person that arrives for a procedure in representation of one or more taxpayers. |
| *Ticket dispenser* | Location | Its function is determined automatically through the emission of a number for attention, the order of attention, and if the attention will be in a module in the *front office* or *back office.* |
| *Front office module (Attention for general procedures)* | Location | The first line of attention for taxpayers or representatives. |
| *Back office module (Attention for specific procedures)* | Location | The second line of attention where the government auditor assists the taxpayer or representative. |
| *Waiting room* | Location | The location where the taxpayer or representative waits when there aren't any available modules. |

### 3.2.2 Entity attributes.

Each of the elements described in Table 1 has associated attributes that permit us to determine the dynamics of the system. They are characterized by:

- The type of procedure and

- The time between arrivals.

The time between arrivals is the time from the time the taxpayer or representative arrives until the next taxpayer or representative arrives to the system. This time between arrivals is a continuous random variable which can be described through its probability density function. In Table 2 we characterize the arrival process for taxpayers or representatives.

Table 2: Arrival Process.

| Element | Procedure | Time between arrivals | p-value |
|---|---|---|---|
| *Taxpayer or representative* | REGISTRATION | *LogNormal (1.09, 1.66) min* | K-S test: 0.216<br>A-D test: 0.2 |
| | Stamping<br>Express Stamping | *Pearson6 (1.43, 9.76, 2.55) min* | K-S test: 7.22 $x10^{-2}$<br>A-D test: 0.238 |

### 3.2.3 Attributes of the locations.

The attributes that characterize the locations are:

- Quantity.
- Procedures that are handled.
- Priority assigned.
- Duration of rest breaks during which the locations aren't available.
- Time of service or attention.

On the other hand, we should consider lost attention, which occurs when a taxpayer or representative abandons the system before starting their procedure. Just as the time between arrivals, the time of service at a location is a random variable, that is represented by its probability density function, which is characterized in Table 3.

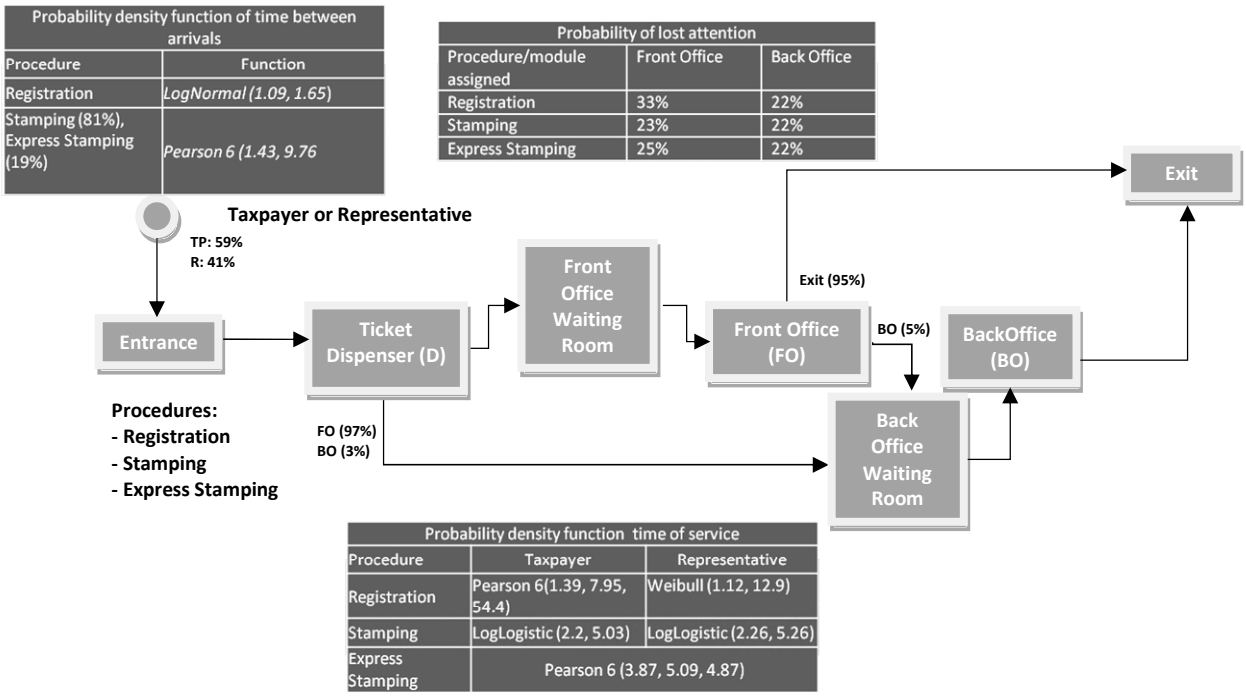
Table 3: Characterization of the attention process.

| Element | Quantity | Type of procedure | Service time | | p-value |
|---|---|---|---|---|---|
| *Ticket dispenser* | 2 | REGISTRATION, Stamping | 16 s | | N/A |
| | 1 | Express Stamping | | | |
| *Front office module (for general procedures)* | 7 | REGISTRATION (priority) | Representative | *Weibull (1.12, 12.9) min* | K-S test: 0.109<br>A-D test : 9.95 x$10^{-2}$ |
| | | | Taxpayer | *Pearson 6 (1.39, 7.95, 54.4) min* | K-S test: 0.119<br>A-D test: 4.84 x$10^{-2}$ |
| | | | Lost attention | 50 s | N/A |
| | | | Redirection to *back office* | *Uniform (0.75, 3.11) min* | - |
| | | Stamping | Representative | *LogLogistic (2.26, 5.26) min* | K-S test: 6.93 x$10^{-2}$<br>A-D test: 4.55 x$10^{-2}$ |
| | | | Taxpayer | *LogLogistic (2.2, 5.03) min* | K-S test: 8.88 x$10^{-2}$<br>A-D test: 6.44 x$10^{-2}$ |
| | | | Lost attention | 50 s | N/A |
| | | | Redirection to *back office* | *Uniform (0.75, 3.11) min* | - |
| | 9 | REGISTRATION | Representative | *Weibull (1.12, 12.9) min* | K-S test: 0.109<br>A-D test: 9.95 x$10^{-2}$ |
| | | | Taxpayer | *Pearson 6 (1.39, 7.95, 54.4) min* | K-S test: 0.119<br>A-D test: 4.84 x$10^{-2}$ |
| | | | Lost attention | 50 s | N/A |
| | | | Redirection to *back office* | *U(0.75, 3.11) min* | - |
| | | Stamping | Representative | *LogLogistic (2.26, 5.26) min* | K-S test: 6.93 x$10^{-2}$<br>A-D test: 4.55 x$10^{-2}$ |

| Element | Quantity | Type of procedure | Service time | | p-value |
|---|---|---|---|---|---|
| | | (priority) | Taxpayer | *LogLogistic (2.2, 5.03) min* | K-S test: 8.88 x$10^{-2}$<br>A-D test: 6.44 x$10^{-2}$ |
| | | | Lost attention | 50 s | N/A |
| | | | Redirection to *back office* | *Uniform (0.75, 3.11) min* | - |
| | 3 | Express Stamping | Taxpayer/Representative | *Pearson 6 (3.87, 5.09, 4.87) min* | K-S test: 0.765<br>A-D test: 0.611 |
| | | | Lost attention | 50 s | N/A |
| | | | Redirection to *back office* | *Uniform (0.75, 3.11) min* | - |
| *back office module (for specific procederes)* | 3 | REGISTRATION, Stamping, Express Stamping | Taxpayer/Representative | *Weibull (1.23, 15.5) min* | K-S test: 8.22 x$10^{-2}$<br>A-D test: 2.2 x$10^{-2}$ |
| | | | Lost attention | 50 s | N/A |
| *Waiting room* | 2 | REGISTRATION, Stamping, Express Stamping | N/A | | N/A |

In Figure 1 we present the model that constitutes the base scenario of the analysis.

Figure 1: Base scenario of the simulation model.




### 3.3 The Simulation Process.

The simulation model was programmed in *ProModel* with the following considerations:

- **Time of simulation:** Each run of the simulation was for 7 hours. The entrance of entities to the system, however, was restricted to the first 5 hours. This is aligned with what happens in reality when attention begins at 9:00 and access is closed at 2:00. The modules continue attention only for the taxpayers or representatives that are already within the system.
- **Number of runs:** 245, which corresponds to the total number of days the service was open in 2013. In this way we have a sample consistent with the goals of the model which can be used to make decisions in the medium and long term.

## 4. Results and Validation of Simulation Model

### 4.1 Results of the model.

Below we show the results obtained from the developed simulation, considering the study of three variables of interest:

1. **Waiting Time:** Represents the sum of the times during which taxpayers/representatives were waiting.

2. **Time in the System.** Represents the total time that the taxpayer/representative is in the system from the emission of the ticket until he leaves. This considers waiting time as well as time during attention.

3. ***Back Office* waiting Time:** Represents the waiting time specifically for taxpayers/representatives in the "*Back office* waiting room."

In Table 5 you can see each variable, the average ($\bar{x}$), the standard deviation (σ), and the number of taxpayers/representatives (n) served by the regional office (real data) and the simulation.

Table 5: Results of the variables.

| VARIABLE | Regional Office (Real Value) | | | Simulation | | |
|---|---|---|---|---|---|---|
| | $\bar{x}$ | σ | n | $\bar{x}$ | σ | n |
| *Waiting time (min)* | 26,99 | 24,81 | 233.043 | 29,09 | 28,35 | 243.716 |
| *Time in the system (min)* | 31,87 | 24,99 | 168.612 | 41,32 | 39,32 | 178.170 |
| *Back Office Waiting Time (min)* | 16,90 | 14,59 | 16.880 | 13,00 | 16,66 | 16.750 |

### 4.2 Validation of the model.

In order to validate the model, we carried out an interpolation at the real number of taxpayers/representatives served with the average value simulation variables.

The indicated interpolation was conducted with the following procedure:

a. With the information of the 245 runs of the simulation we graphed the average value of each variable versus the number of taxpayers/representatives served.

b. Using the real number of taxpayers/representatives served (n) according to Table 5, in Table 6 we calculated this number divided by 245, which is the real daily average number of taxpayers/representatives served for each variable.

c. Lastly, we determined the interpolated average of the variables using the graph with the value of the variable when the number of taxpayers/representatives served was equal to the real daily average according to Table 6.

Table 6: Average number of taxpayers/representatives served daily.

| VARIABLE | Real Average of taxpayers/representatives served daily $\left(\frac{n}{245}\right)$ |
|---|---|
| *Waiting time* | 951,20 |
| *Time in the System* | 688,21 |
| *Waiting Time Back Office* | 68,90 |

Table 7: Results of the model validation.

| VARIABLE | Real Value $\bar{x}$ | Simulation Value (interpolated) $\bar{x}$ | Error |
|---|---|---|---|
| *Waiting time(min)* | 26,99 | 27,91 | 3,41% |
| *Time in the System (min)* | 31,87 | 39,29 | 23,29% |
| *Back Office waiting Time (min)* | 16,90 | 16,80 | 0,61% |

## 5. Evaluation of Scenarios

Continuing on, we proceeded to generate distinct scenarios of improvement of the process of taxpayer attention by evaluating them using the simulation

Table 8: Configuration of scenarios.

| Scenario | LOCATIONS | | | | TOTAL |
|---|---|---|---|---|---|
| | Locations Front Office | | | Locations Back Office | |
| | Locations Stamping/REGISTRATION (Priority Stamping) | Locations Stamping/REGISTRATION (Priority REGISTRATION) | Locations Express Stamping | | |
| *Base* | 9 | 7 | 3 | 3 | 22 |
| *1* | 10 | 7 | 2 | 3 | 22 |
| *2* | 11 | 5 | 3 | 3 | 22 |
| *3* | 11 | 6 | 2 | 3 | 22 |

We considered relevant issues such as restricted space, the influx of people and feasibility.

Given that information, we establish the different evaluation configurations in Table 8, starting with the control scenario or base.

Once the configurations were established, we went on to newly execute the simulation, with the goal of conducting an analysis that would permit us to establish which result is the best alternative. To do so, we established four measurements of performance:

- **Service:** Corresponds to “Average Waiting Time”.
- **Coverage**: Corresponds to “Number of Taxpayers/Representatives Served”.
- **Cost:** Corresponds to “Time of Attention”.
- **Risk of operation:** Corresponds to “Average Weighted Percentage of Occupation”. An increase in this figure means a major risk of saturation.

Table 9 summarizes the evaluation of each scenario with the values of each of the measures of performance defined as well as the associated variables.

Table 9: Summary of the results of measures of performance.

| ***VARIABLE*** | ***Measurement of Performance*** | ***Scenario*** | | | |
|---|---|---|---|---|---|
| | | ***Base*** | ***1*** | ***2*** | ***3*** |
| *Average Waiting Time (min)* | *Service* | 29,09 | 21,65 | 26,01 | 21,49 |
| *Number of Taxpayers/Representatives Served* | *Coverage* | 243.716 | 244.085 | 242.833 | 243.912 |
| *Time of attention (hours)* | *Cost* | 1.611 | 1.564 | 1.610 | 1.579 |
| *Average Weighted % of Occupation* | *Risk* | 73,13 | 75,48 | 73,20 | 75,28 |

For this case in particular, the strategy to follow will be focused on "Service" and "Coverage". In this way, the following factors are weighted for the objective function:

***Service*** = 40%; ***Coverage*** = 40%; ***Cost*** = 10% *and* ***Operation Risk*** = 10%

In Table 10 we see the normalized values:

Table 10: Comparison of normalized results by measurement of performance.

| **VARIABLE** | **Measurement of Performance** | **Scenario (normalized value)** | | | |
|---|---|---|---|---|---|
| | | **Base** | **1** | **2** | **3** |
| *Average Waiting Time (min)* | **Service** | 73,87 | 99,26 | 82,62 | 100,00 |
| *Number of Taxpayers/Representatives Served* | **Coverage** | 99,85 | 100,00 | 99,49 | 99,93 |
| *Time of attention (hours)* | **Cost** | 97,08 | 100,00 | 97,14 | 99,05 |
| *Average Weighted % of Occupation* | **Risk** | 100,00 | 96,89 | 99,90 | 97,14 |
| **Final Weighted Score** | | **91,81** | **99,16** | **94,28** | **99,31** |

Therefore, the best alternative for these criterion corresponds to scenario 3 since it has the best score.

## 6. Discussion

One of the important assumptions used in the development of the model was the use of information for one month of "average" operation such as June during which the influx of people isn't affected by extraordinary situations such as the collection of income taxes in April. The model is looking to be used in the simulation of tactical and strategic decisions that do not consider day to day contingencies.

To put the simulation in practice in the platform of attention of the Eastern Regional Office of Santiago, it is recommended to start with the implementation of the configurations that don't require investments or additional costs such as those that were evaluated in this paper which aren't above the base of the current infrastructure. In this way it's easy to go back if necessary.

For the implantation of the model, business variables such as the types of attention in relation to the degree of structure that they have and increases in the number of taxpayers needing attention due to timely situations associated with tax obligations should be kept in mind.

## 7. Conclusions

- By employing simulation techniques and tools in the modeling of attention to taxpayers, a model can be created that can predict the behavior of the system in a period of time.
- The simulation developed enables us to analyze and evaluate the behavior of variables and performance measures for different situations in a manner that allows the user to select the most convenient configuration.
- The use of simulation tools in the evaluation of different scenarios reduces the associated risks with the implementation of new configurations of attention. Using this methodology, the estimations of performance evaluation can be determined in advance.
- Of the evaluation of the scenarios performed, we observed that the actual process of attention can be improved by finding an important gap of improvement in performance. This can be done without increasing the quantity of locations or investing money or increasing costs.
- When observing the percentages of use that the simulation obtained, we can infer that there is an element of risk. This means that in the case of an unexpected event (for example, an official not being at work sometime during the workday) waiting times for taxpayers will increase considerably, therefore affecting the quality of service provided. Consequently, it's important to evaluate the incorporation of new locations that permit us to occupy less space.

- On the other hand, the model has great potential for the evaluation and creation of new regional offices, changes to buildings of current offices, and the fusion or division of regional offices. Additionally, this can help decide to increase or decrease the staff of certain procedures and make other relevant changes.
- There is potential in the simulation tool regarding the definition and evaluation of the feasibility of institutional goals related to taxpayer attention (for example, maximum wait time).

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# Small Business Innovation and Organizational Performance in an Ibero-American Context

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## Abstract

Facing uncertainties in today's global economy forces small businesses to rethink their strategies to achieve higher levels of performance. In this empirical study the relationship between innovation and organizational performance of Micro, Small and Medium-sized Enterprises (MSMEs) was analyzed, using the size and age as control variables. The scales were subjected to a confirmatory factor analysis (CFA) of first order, through the maximum likelihood method, having reliability and convergent and discriminant validity. The responses obtained through a sample of 288 MSMEs was processed by a Linear Regression Analysis using ordinary least squares (OLS), results providing sufficient empirical evidence that product, process and innovation management systems have a positive and significant relationship with the performance of MSMEs. Our case is compared with evidence based in Ibero-America.

## Key words

Innovation, Business performance, Industrial MSMEs, CFA, OLS.

## 1. Introduction

Standard economics depicts a small firm as a price taker, unalterable entity with automatic mechanisms to adjust it to an optimal equilibrium. In a more realistic view, small firms must struggle to survive, facing an ever intensive rivalry, taking risks to keep up with a turbulent environment. The current situation forces firms to perceive performance in a complex way considering efficiency, productivity, growth, resource acquisition and even human resource development, so alternative proposals must be delivered. Considering the small firm as an adaptive agent in a perpetual changing environment its results are derived from knowledge

accumulation and exploitation processes so innovation becomes its outcome and thus a predictor of performance.

In this paper we present evidence using a cross-industry survey of managers in Mexican MSMEs located in the State of Guanajuato and compare it to previous empirical works available from Mexico and other countries in Ibero-America, whereas similar constructs have been used to demonstrate the innovation-organizational performance relationship. In order to do so, this paper is organized as follows. In Section 2, we briefly comment some findings in a literature review. Section 3 presents the methodology used and the development of variables. Section 4 presents and discusses our empirical results and Section 5 settles main conclusions.

## 2. Literature review

### *2.1 Innovation and organizational performance*

Theoretical perspective on innovative capabilities aim to explain how organizations stand out and generate performance and efficiency as a means to build differentiation. Innovation is one of the core-value creating capabilities (Narver & Slater, 1990). Damanpour (1991) has stated that adoption of innovation is generally intended to contribute to the performance or effectiveness of the business. In the empirical field, some authors have found a positive relationship between innovation adoption and profitability (Ghisetti & Rennings, 2014). This discussion leads to:

**H1.** Innovation is positively related to the overall organizational performance.

### *2.2 Type of innovation and organizational performance*

Common categorizations of innovation include product, process or administrative innovation (Damanpour & Gopalakrishnan, 2001). It is important to recognize that different types of innovation might relate to performance in different ways.

Literature on new product development provides evidence on the positive influence of innovativeness on firm performance (Calantone *et al.*, 2002). Lyon & Ferrier (2002) showed the positive effect of product innovativeness on competitive advantage meanwhile Boone (2000) suggests it is related to financial performance. Several studies have shown that product innovation affects overall performance (Im & Workman, 2004; Yannele, 2005) but there are other results that oppose these findings (Chandler & Hanks, 1994).

Process innovation may result in an enhancement of productivity and cost savings (Nieto & Santamaría, 2010). The continuous efforts in innovation processes increase speed and quality (Koufteros & Marcoulides, 2006; López-Mielgo, Montes-Peón &Vazquez-Ordás, 2009).

Scholar literature shows abundant empirical evidence linking the degree of utilization of management systems and performance (Kennedy & Affleck-Graves, 2001; Maes, Sels & Roodhooft, 2005). Davila (2000) positively related management-system innovation with performance. Adler, Everett & Waldron (2000*)* found that the application of management systems influenced and improved product profitability. Anderson & Sohal (1999) concluded that strategic planning, information management and human resources have a positive impact on performance. The previous argumentation can sustain our second hypotheses:

**H2A.** The type of innovation contributes differently to overall organizational performance.

**H2B.** A different type of innovation may have a different relationship on each organizational performance dimension.

### *2.3 Control variables: Size and age*

Size and age, among other variables may impact organizational innovation outcomes (Laforet, 2013). So great differences in innovation types and efforts may exist amongst firms of different sizes and ages. Consequently, different innovation practices lead to different outcomes (Bos-Brouwers, 2009). Thus we have arrived to:

**H3:** Company size and age have a positive effect on the innovation-performance relationship.

## 3. Method

### *3.1 Sampling and data collection*

An empirical research was conducted with a quantitative explanatory and cross section approach, through a Confirmatory Factor Analysis (CFA) and Multiple Linear Regression by Ordinary Least Squares (OLS). The database provided by the *2015 Business Information System of Mexico* was taken as reference, in which a total of 3,056 industrial manufacturing companies from 1 to 250 workers were registered in the state of Guanajuato. Therefore, the sample consisted of 342 MSMEs, with a confidence level of 95% and a margin of error of 5%. The survey was designed based on the theoretical model that was applied randomly, yielding a response rate of 84.21%, and counting at the end with a total of 288 valid questionnaires.

### *3.2 Measurement of variables*

To measure innovation, an adapted scale proposed by Madrid-Guijarro, García & Van Auken (2009) was considered, which is composed of 7 items, and it is measured through three latent variables or first order factors: 1) product innovation (PI) measured with a scale of 2 items, 2) process innovation (PRI) with a scale of 2 items, and 3) management systems innovation (MSI)

with a scale of 3 items, all of them measured with a 5 point Likert- scale, which refers from low importance (1) to high importance (5). This scale has been tested previously (Cuevas, Aguilera, Estrada & Ruiz, 2015; Cuevas-Vargas, Aguilera & Hernández, 2014).

With regard to the measurement of organizational performance (ORPERF), we took into account the four dimensions proposed by Quinn & Rohrbaugh (1983) and tested in other studies by Estrada, Cuevas-Vargas & Cortés (2015), being these: the internal process model measured on a scale of 3 items; the open systems model on a scale of 3 items; the rational goal model also on a scale of 3 items as the human relations model; all of them were measured with a 5 point Likert-scale, which refer from total disagreement (1) to total agreement (5).

For performance assessment the size and age of the firms were considered as control variables. The size variable was measured by the number of employees of the companies under study. The age has been measured by the number of years since the constitution of the company until 2014. These variables have been used previously by Estrada et al. (2015) and Gálvez & García (2012).

### *3.3 Theoretical models*

In this regard, to test our hypotheses, the following theoretical models (TM) were considered:

$$Y\ (ORPERF) = \beta_0 + \beta_1 * Innovation + \beta_2 * Size + \beta_3 * Age + e \quad (TM1)$$

$$Y\ (ORPERF) = \beta_0 + \beta_1 * PI + \beta_2 * PRI + \beta_3 * MSI + \beta_4 * Size + \beta_5 * Age + e \quad (TM2A)$$

$$Y1\ (Internal\ Process\ Model) = \beta_0 + \beta_1 * PI + \beta_2 * PRI + \beta_3 * MSI + \beta_4 * Size + \beta_5 * Age + e \quad (TM2B)$$

$$Y2\ (Open\ Systems\ Model) = \beta_0 + \beta_1 * PI + \beta_2 * PRI + \beta_3 * MSI + \beta_4 * Size + \beta_5 * Age + e \quad (TM2B)$$

$$Y3\ (Rational\ Goal\ Model) = \beta_0 + \beta_1 * PI + \beta_2 * PRI + \beta_3 * MSI + \beta_4 * Size + \beta_5 * Age + e \quad (TM2B)$$

$$Y4\ (Human\ Relations\ Model) = \beta_0 + \beta_1 * PI + \beta_2 * PRI + \beta_3 * MSI + \beta_4 * Size + \beta_5 * Age + e \quad (TM2B)$$

### *3.2.4 Reliability and validity*

To assess the reliability and validity of the measurement scales a CFA was performed using the Maximum Likelihood Method through EQS 6.1 software, (Bentler, 2005; Brown, 2006; Byrne, 2006). The reliability of the 7 proposed measurement scales were assessed through Cronbach's Alpha coefficient and Composite Reliability Index (CRI) (Bagozzi & Yi, 1988). The whole scale values exceeded the recommended level for the Cronbach's Alpha and justified the internal reliability (Hair, Anderson, Tatham & Black, 1998). Also, to provide a better evidence of statistical adjustments we worked with robust statistical testing (Satorra & Bentler, 1988).

### *3.2.5 Model settings*

The settings that were used in the models under study were the Normed Fit Index (NFI), the Non-Normed Fit Index (NNFI), the Comparative Fit Index (CFI) and Root Mean Square Error of Approximation (RMSEA). It is noteworthy that values of NFI, NNFI and CFI between 0.80 and

0.89 represent a reasonable adjustment (Segars & Grover, 1993) and values equal to or greater than 0.90 are a good adjustment (Papke-Shields, Malhotra & Grover, 2002). The normed Chi-square index (S-B $X^2$/df) with a value equal to or less than 3.0 indicate a good fit (Hair, Black, Babin & Anderson, 2010). Likewise, RMSEA values below 0.080 are acceptable (Hair et al., 1998). Therefore, it was found that the original model showed level adjustment problems, so it was necessary to eliminate two variables to get a better adjustment taking into reference robust statistics (see table 1. footnote). From these values we can accept the models have content validity.

**Table 1.** Internal Consistence and convergent validity of the theoretical model

| Higher order variable | First Order Factors | Indicator- variables | Factor Loading | Robust t-value | Average Factor Loading | Cronbach's Alpha | CRI | AVE |
|---|---|---|---|---|---|---|---|---|
| **Innovation** | **Product Innovation** | PI1-Changes/improvements products | .785*** | 1.000[a] | 0.804 | 0.779 | 0.786 | 0.648 |
| | | PI2- New products commercialization | .824*** | 15.678 | | | | |
| | **Process Innovation** | PRI1-Changes/improvements in processes | .916*** | 1.000[a] | 0.840 | 0.817 | 0.830 | 0.711 |
| | | PRI2-Acquisition of new capital equipment | .764*** | 18.990 | | | | |
| | **Management Systems Innovation** | MSI1-Management & administration | .807*** | 1.000[a] | 0.804 | 0.842 | 0.846 | 0.647 |
| | | MSI2-Purchasing and supplies | .781*** | 18.645 | | | | |
| | | MSI3-Commercial/sales | .824*** | 21.462 | | | | |
| **Organizational Performance** | **Internal Process Model** | IPM1-Improving quality of product/service | .714*** | 1.000[a] | 0.815 | 0.855 | 0.858 | 0.670 |
| | | IPM2-Increasing efficiency in business | .894*** | 15.426 | | | | |
| | | IPM3- Improving organization of staff | .838*** | 15.204 | | | | |
| | **Open Systems Model** | OSM2-Quick adaptation to market needs | .811*** | 1.000[a] | 0.842 | 0.831 | 0.830 | 0.710 |
| | | OSM3- Improving image of the firm | .873*** | 23.487 | | | | |
| | **Rational Goal Model** | RGM1- Increasing market share | .809*** | 1.000[a] | 0.885 | 0.912 | 0.917 | 0.786 |
| | | RGM2- Increasing profitability | .921*** | 21.880 | | | | |
| | | RGM3- Increasing productivity | .925*** | 22.063 | | | | |
| | **Human Relations Model** | HRM2- Reducing staff turnover | .887*** | 1.000[a] | 0.895 | 0.891 | 0.890 | 0.801 |
| | | HRM3- Reducing work absenteeism | .903*** | 15.008 | | | | |
| **S-B $X^2$= 194.0112 on 98 df; (S-B $X^2$/df)= 1.97; p= 0.000; NFI= 0.981; NNFI= 0.987; CFI= 0.991; RMSEA= 0.059** | | | | | | | | |
| **Variables excluded: OSM1-**Achieving customers' satisfaction and **HRM1-**Improving employees' motivation with factor loadings < 0.6 | | | | | | | | |

[a] = Parameters constrained to this value in the identification process; *** = $p < 0.001$; ** = $p < 0.05$

As evidence of convergent validity, the results of CFA indicate that all items of the related factors are significant ($p < 0.001$), the value of all the standardized factor loadings are greater than 0.60 (Bagozzi & Yi, 1988) and the average standardized factor loadings of each factor are greater than 0.70 (Hair et al., 1998). There is a high internal consistency of the constructs, in each case the Cronbach's Alpha exceeds the value of 0.70 (Nunnally & Bernstein, 1994). The CRI represents the extracted variance between the group of observed variables and the fundamental construct, a value greater than 0.60 is considered desirable (Bagozzi & Yi, 1988), as in our

research. The Average Variance Extracted (AVE) was similarly calculated for each of the constructs, resulting in values higher than 0.50 (Fornell & Larcker, 1981).

With regard to the evidence of discriminant validity, the measurement is provided in two forms, the first one with a 95% interval of reliability, none of the individual elements of the latent factors of the correlation matrix contain the value 1.0 (Anderson & Gerbing, 1988). Second, the extracted variance between the pair of constructs is greater than its corresponding AVE (Fornell & Larcker, 1981). Based on this criteria, it can be concluded that the different measurements demonstrate sufficient evidence of reliability and convergent and discriminant validity.

Thus, in the first model in which innovation and organizational performance were considered as a higher or second order latent variables, it was necessary to get the arithmetic mean of every single type of innovation and performance (first order latent variables). In the following models every item was taken into account and all were computed by their arithmetic mean.

## 4. Results and discussion

A family of models was obtained looking upon the relationship between innovation and business performance, considering both variables as second order or higher order latent variables. By applying the Multiple Linear Regression Analysis by Ordinary Least Squares (OLS), through IBM SPSS Statistical Software V21, the results for the Theoretical Models are shown in Table 2

**Table 2. Results of Multiple Linear Regression Analysis by OLS for Theoretical Models.**

| Variables | Overall Organizational Performance | Overall Organizational Performance | Internal Process Model | Open Systems Model | Rational Goal Model | Human Relations Model |
|---|---|---|---|---|---|---|
| **Innovation** | **β= 0.558*** ** | | | | | |
| | **t = 11.333** | | | | | |
| **Product Innovation** | | **β= 0.214*** ** | **β= 0.223*** ** | **β= 0.179*** ** | **β= 0.206*** ** | β= 0.082 (N.S.) |
| | | **t = 3.433** | **t = 3.489** | **t = 2.774** | **t = 3.159** | t = 1.076 |
| **Process Innovation** | | β= 0.126* | β= 0.113 (N.S.) | β= 0.067 (N.S.) | β= 0.087 (N.S.) | **β= 0.165** ** |
| | | t = 1.742 | t = 1.514 | t = 0.879 | t = 1.145 | **t = 2.268** |
| **Management Systems Innovation** | | **β= 0.391*** ** | **β= 0.358*** ** | **β= 0.368*** ** | **β= 0.296*** ** | **β= 0.271*** ** |
| | | **t = 6.331** | **t = 5.608** | **t = 5.765** | **t = 4.569** | **t = 3.726** |
| **Firm Size** | β= 0.094* | **β= 0.108** ** | β= 0.088* | **β= 0.142** ** | **β= 0.175*** ** | β= -0.028 (N.S.) |
| | t = 1.893 | **t = 2.177** | t = 1.732 | **t = 2.770** | **t = 3.363** | t = -0.511 |
| **Age of the Firm** | β= 0.046 (N.S.) | β= 0.049 (N.S.) | β= -0.006 (N.S.) | β= 0.010 (N.S.) | β= 0.053 (N.S.) | β= 0.099* |
| | t = 0.936 | t = 1.011 | t = -0.125 | t = 0.194 | t = 1.038 | t = 1.824 |
| **R** | **0.558** | **0.570** | **0.524** | **0.533** | **0.505** | **0.400** |
| **R-Square** | **0.311** | **0.325** | **0.275** | **0.284** | **0.255** | **0.160** |
| **Adjusted R-Square** | **0.309** | **0.318** | **0.270** | **0.276** | **0.247** | **0.154** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **F value** | **128.446*** ** | **45.330*** ** | **53.619*** ** | **37.106*** ** | **32.192*** ** | **26.885*** ** |
| **Higher VIF** | **1.000** | **1.618** | **1.590** | **1.624** | **1.618** | **1.779** |

***P < 0.001; ** P < 0.05; * P < 0.1

Noting that the whole models showed a positive and highly statistically significant F values (p < 0.001). Regarding collinearity statistics, a Variance Inflation Factor (VIF) of or over 1.000 was obtained, indicating that models did not present any multicollinearity problems (Hair et al., 1998). In that regard, these models are validated, since a high positive relationship between innovation and organizational performance of MSMEs was found though the Adjusted R-Square values at range of (0.154-0.309), which is above .070 marked by Cohen & Cohen (1983), therefore, they may explain the increased organizational performance through innovation.

With regard to the first hypothesis, innovation is correlated in 55.8% to the overall organizational performance of industrial MSMEs and business performance of these enterprises is explained in 31.1% by innovation. According to the results regarding the β values, we conclude that about 55.8% of the overall organizational performance is due to the innovation (t-value = 11.333; p <0.001). Hence H1 is accepted.

Regarding the H2A, it was found in the model that product innovation, process innovation, management systems' innovation and the size of the firm are correlated in 57% with the overall business performance, and the overall organizational performance is explained in 32.5% by these variables. In this sense, according to the results regarding the β values, it is concluded that product innovation impacts positively and significantly by 21.4% in the overall business performance (t=3.433, p<0.001); innovation in management systems positively and significantly impacts by 39.1% (t=6.331, p<0.001) and, even, process innovation that presents a weak significant value (p<0.1) has a positive impact of 12.6%. Regarding that the type of innovation contributes differently to overall organizational performance, H2A is accepted.

Similarly when applying the multiple linear regression analysis by OLS to models 2B, we found:

1) For the internal process model the summary indicates that product innovation and management systems innovation are correlated in 52.4% with the internal process, and this kind of organizational performance is explained by 27% for product innovation and management systems innovation. Also, according to the results regarding the β values, we conclude that the 22.3% yield is due to product innovation (t= 3.489; p<0.001) and 35.8% is due to innovation in

management systems (t= 5.608; p<0.001). Finding no significant β values neither for process innovation nor for the age.

2) For the open systems model it was found that product innovation, management systems innovation and company size are correlated in 53.3% with the open systems model, this kind of organizational performance is explained in a 27.6% by product innovation, management systems innovation and the size of the firm. Also, according to the results regarding the β values, we conclude that product innovation impacts positively and significantly by 17.9% on organizational performance under the open system model (t= 2.774, p<0.001) and innovation in management systems positively and significantly impacts it by 36.8% (t= 5.765; p<0.001). Finding no significant β values neither for process innovation nor for age of the firm.

3) As for the rational goal model it was found that product innovation, management systems innovation and the size of the firm are correlated in 50.5% with organizational performance according to the model of rational goal of industrial MSMEs of Guanajuato, and that this kind of organizational performance is explained in a 25.5% by product innovation, management systems innovation and company size. Similarly, according to the results regarding the β values for this model, it is concluded that product innovation positively and significantly impacts by 20.6% on this kind of organizational performance (t= 3.159; p<0.001) and innovation in management systems positively and significantly impacts by 29.6% (t= 4.569; p<0.001) in this kind of organizational performance. Finding no significant β values neither for process innovation nor for the firm's age.

4) Regarding the human relations model it was found that the process innovation and management systems innovation are correlated by 40% with this model and that this kind of organizational performance is explained in 16% by process innovation and management systems innovation. Also, according to the results regarding the β values for this model, it is concluded that process innovation impacts positively and significantly by 16.5% on business performance (t= 2.268, p< 0.05); management systems innovation positively and significantly impact by 27.1% (t= 3.726; p<0.001). It is noteworthy, no significant β values were found neither for product innovation nor for the size.

Once we have analyzed the effects, the results show that there is a different relationship on each organizational performance therefore we can accept H2B.

With respect to H3, we found across the family models that the size of the firm influences positively and significantly the impact that innovation has in organizational performance with the

exception of human resources performance. In regard to age, there was no significant β across the models, so it is not possible to demonstrate its mediation effect, except for the case of human resources. Consequently, H3 is partially accepted.

To get a critical outlook of our findings we can review some studies that share common characteristics with our research (Van Auken et al., 2008 for Spain, Uc- Heredia et al., 2008; Maldonado et al., 2009 for Mexico and Gálvez & García, 2012; Ortega-Muñoz, 2013 for Colombia). The reliability of the scales can be validated using the Cronbach's Alpha, comparing own reliability with the average of the five studies: on the measurements of performance our estimates are higher and for innovation constructs, only the product innovation reliability scale is below. Comparatively, our figures prove evidence of reliability and internal consistence.

In respect with actual effects, our review provides several insights. Only product and process innovation have appeared to be positively related to overall performance in similar studies (Gálvez & García, 2012; Uc-Heredia et al., 2008). Product innovation exerts a positive influence in the openness performance and with internal process showed the same tendency with exception of Uc-Heredia et al. (2008). Similar results presented the relationship product innovation-rational effectiveness. In the case of the human resource area of performance our evidence seems to unbalance the tendency towards a non-significant effect.

Looking up for the influence of process innovation our results were against the trends found in the selected studies. Adding our evidence to the effect on internal process performance the relationship turns inconclusive, in the openness and rational areas our results contested the positive impact but confirm the supposed deviation found in the Mexican case as it does with the abnormality of the Spanish case showing a positive effect on human resources performance.

In the case of the impact of management systems innovation on performance our findings tends to obscure the actual influence on the areas of performance related to internal process and human relations but provide more evidence on the positive effect on openness and rational performance.

For our sample it is clear the role that control variables play, size stands out as an important moderator of the innovation-performance relationship, especially in the openness dimension while age only has a selective effect on the human relations area. And these two special features may be endemic from Mexico because the other Ibero-American cases show a different behavior.

## 5. Conclusions

A brief summary of conclusions may be drafted as it follows:

1. Performance is influenced by innovation and there is a simultaneous effect of different kinds of innovation on the different dimensions of performance. A clue is that product and process innovation are intertwined with management system innovation to get a higher impact.

2. We got inconclusive evidence on which innovation mix has the greatest impacts on the different dimensions of performance. In Ibero-America there is a clearer picture on the product innovation impacts on performance and its dimensions.

3. The study of process and management system innovations is an unfinished task meanwhile control variables such as size and age may be expressing local features of productive systems.

Our overall conclusion is that any kind of innovation must be supported because there is strong evidence that innovation improves manufacturing SME´s performance. Differences found in the Ibero-American context must show knowledge of our national cases: In Spain small businesses are affected with a problem of low productivity while in Latin America we are still pending to know more precisely the effects of innovation on performance. Our research contributes for modeling distinct dimensions of innovation and their impacts on several measures of performance, as opposed to one continuum path in small businesses.

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# Fuzzy Logic in Legal Science

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## Abstract

This paper presents a methodological proposal in the field of uncertainty management *Fuzzy Logic*, to support efficient and effective decision-making in the field of *Legal Sciences*. We aim to contribute to provide more elements to a better guidance in law application. Another goal is to interest people in the design of new public policies capable of qualifying the sentences derived from law infringement in all areas where justice anticipates.

**Keywords**: right, justice, uncertainty, public policy, fuzzy logic, effective, efficient.

## 1. Decision making in law sciences

Decision making in law sciences also applies to jurisprudence systems. Just like in other application areas, the stages to consider for effective and efficient administration are: forecast, planning, integration, organization, and control. With these elements it is possible to establish the present state and the directions to follow to make the right decisions. This paper presents basic ideas on uncertainty useful in the field of law science. These ideas direct the public policy efforts to review the sentence levels for several cases of felonies against society, which by those means will be qualified more precisely, still maintaining the role of the responsible judge. Thus, the problem to be addressed is the study of fair criteria that allow decision making in the assignment of sentences according to the closest scenario to that of where the felony was committed, from all possible variants that exist.

Currently, fuzzy logic has not been extensively applied to law in terms of legal reasoning [Mazzarese Tecla (2012)]. Generally, legal decisions are a matter of fact, and as principle questions, they must be of logical-deductive nature. That is, legal decisions must be made following the rules of inference of two-valued logics. The application of fuzzy logic, on the other hand, takes place on an uncertain environment, that is, by means of a multivalent logic. Legal decisions are characterized as judicial syllogism chains. Nowadays, the judicial syllogism theory is widely accepted; it is conceived as the main warranty of the rationality of judicial decisions, and as a necessary mean to assure that the value of judicial certainty can be achieved.

Any human being who dares to face the logical-deductive problems in legal decisions is considered as a defender of the subjectivism, which gives raise to many situations in legal power. Nevertheless this is considered a wrong idea, given that the analysis is performed using a two-valued logic. On the other hand, the scenarios and facts in most of the cases are given in uncertain environments. These environments are suitable for fuzzy logic and qualitative reasoning, drawn upon multi-valued logics.

Classically, a logical reconstruction of facts in a law case does not necessarily guarantees rationality. This reconstruction can be achieved by an explicative model that includes all scenarios to be evaluated by confidence intervals, established subjectively by a panel of law experts. After this, we need to use semantic labels, associated to a numeric scale that map from ambiguous to precise terms, allowing an effective and efficient label assignment, removing ambiguity from human decisions.

## 2. The decision-making process

Decision-making must follow that the search for certainty is a search for peace, hunted by risk and fear. In life is not uncertainty that bothers humans, but the danger it entails.

Decisions can be made in strategic and operative contexts. Decision-making theory assumes responsible decision makers are willing to maximize their satisfaction level and decrease the risk. The decider basic analysis process is based on the administrative process, which contains the following stages:

- Problem statement
- Statement of possble alternatives
- Selection of the best solution
- Solution implantation
- Follow-up and evaluation
- Feedback

Decision thoughts are associated to:

1. Analizing the causes and defining the facts
2. Detect problems
3. Visualize consequences and apply solutions

In the study of judicial decisions [Mazzarese Tecla (2012)], the application of fuzzy logic will not go against the legal process. People may get confused in the use of a

judicial language, considered as the set of necessary languages in judicial decisions, to formulate:

- The right issue – major premise of the judicial syllogism
- The fact issue – minor or factual premise of the judicial syllogism
- The case norm – conclusion of the judicial syllogism
- The justification of the judicial decision itself, when required in a judicial decision

These stages form a process that can be formulated by fuzzy logic. This process requires the study of historical files to determine the formation of a felony and its evolution to these days, when a law will be issued or modified to assign a sentence. These tools allow us to effectively and efficiently define the felony and the scenarios where it occurred; this way we can define semantic labels and establish a numeric relation with the sentence in the interval corresponding to the assessment of the felony. This mechanism allows us to assign a more rational sentence than a simple subjective personal valuation of the judge.

Judge decisions are based on a process that applies scientific research . For [*Kaufman A, Gil Aluja J.* (1987)], the efforts are oriented towards: objective knowledge (facts) and ideal entities (whose existence resides in the human mind only).

These orientations classify the scientific knowledge in formal and empirical sciences. Thus, we can establish that reality is the foundation of empirical sciences; in this approach there is a group that acts on a social reality, called social sciences (law falls into this class) [*González S. F. et al.(2000)*]. Within social sciences there are measuring technique that follow the concepts of Galileo Galilei, measuring what is measurable and trying to measure what is not measurable yet.

In justice administration not every concept of interest can be quantified. Nonetheless, it is possible to make a good approximation performing a fuzzy situational analysis.

When addressing a problem, the questions refer to the object of study. Knowing what or investigating how are questions whose answers involve the objects of study. It is important to note that justice management there is a possibility the directly or in the future, certain phenomena be quantified. This brings about the concept of equilibrium, whose determination conveys the computation of matrices like minimum, fair mean, and maximum.

Descriptive statistics is used to determine the different variables used in decision-making (minimum, mean, maximum). In law, these are terms used in setting sentences for a felony. In the case of writing the Penal Laws for the state of Michoacan, let us say, article W, to determine the sentence time for a given felony, we need to study the different scenarios in a given time interval. These scenarios provide a minimum and a maximum sentence time, from which we can compute mean time = (minimum time +

maximum time)/2. Nevertheless, there is a big void in the determination of the sentence time in the intervals between the extremes and the mean. This void calls for new analysis criteria and methodologies that allow us to determine that information and make more certain decisions for the case at hand.

Humans deal with imprecise estimations, such as terrible, bad, good, very good, and excellent, among others. Different approaches to deal with those estimations and their precision have been used in the past. Those estimations were somehow quantifies through classical mathematics, written in a two-valued logic. But, in order to be able to include those terms in reasoning mechanisms, we need to deal with uncertainty.

A logical reconstruction can be made using an explicative model that includes all scenarios, evaluating them by confidence intervals, using estimations from judicial experts. These intervals need to be associated to semantic tags, and to a numeric scale that allow us to transform imprecision into precise terms. Using this mechanism we can assign numerical values to the intervals between the extremes and the mean, in order to quantify the time sentence for a felony. All this can be accomplished using fuzzy logic.

## 3. Study case

As a study case we will use the following case. This case presents the following information:

- Case number 1 000 000/2009.
- Felony: *Parricide*
- Accused: "W"
- Against: Mrs. "X"
- Sentence time: 25 years

According to the Penal Law of the State of Michoacan (2009), Art. 283: Anyone that deprives of life to any consanguineous ancestor, legitimate or natural, knowing the delinquent that kinship, the felon will be sentenced to twenty to forty years in prison.

The judge's decision is highly influenced by his or her experience and subjective estimations. In this case, the felon is sentenced to 25 years in prison.

The expected sentence time E(X) = 30 is the mean sentence time. Those 25 years correspond to a subjective evaluation of the judge. Statistically, the corresponding sentence is the mean value, between the extremes.

**Use of fuzzy logic**

From the perspective of uncertainty, the case can be evaluated in an interval where subjectivity is supported by the existence of information derived from an exhaustive study of the case. A panel of experts uses non-traditional scales to assign values to determine ideal felony characterization profiles. This characterization varies from state to state. If more information is needed, we review other scenarios, present in different cases in historic archives. This methodology requires precise historic records of that felony and its evolution and qualification up to the present time, where we may be modifying the law for that felony.

Therefore, the assigned values to each scenario correspond to the determination of minimum, maximum, and mean sentence time. To this end, we need a reference scale, to qualify the state of the felony in the case. To illustrate these means, we use an 11-valued scale; each value of that scale corresponds to a semantic term, as shown in Table 1.

Como medio para ejemplificar esta orientación se expresara a través de la fijación de una escala endecadaria en la que serán asignadas etiquetas semánticas a cada estado como se muestra:

Table 1. 11-value Reference Scale

| Indicator | Qualification |
|---|---|
| 1 | Perfect |
| 0.9 | Very good |
| 0.8 | Quite good |
| 0.7 | Good |
| 0.6 | Almost good |
| 0.5 | Regular |
| 0.4 | Almost bad |
| 0.3 | Bad |
| 0.2 | Qutite bad |
| 0.1 | Very bad |
| 0 | Worst |

For this case, the maximum time sentence corresponds to Perfect and the minimum to Worst. It is important to characterize the felony, approximating an ideal profile to all possible behavior scenarios. Therefore, this characterization changes from state to state, and corresponds to different time intervals. This information is acquired from the historical records found in the time horizon for the study.

The felony profile can have different components ($C_i$, i = 1, 2, 3, …, n)) as indicated:

$C = \{ C_1, C_2, \ldots, C_n\}$

where, $C_i$ = behavior scenario, i= 1, 2, 3, …,n, and $\mu^i$ = membership level (i = 0, 01, …,1)

| $C^1$ | $C^2$ | $C^3$ | $C^4$ | | | | | $C^n$ |
|---|---|---|---|---|---|---|---|---|
| $\mu^1$ | $\mu^2$ | $\mu^3$ | $\mu^4$ | • | • | • | • | • |

Using triangular fuzzy numbers, the membership level can be established for the different characterizations as show in Figure 1.

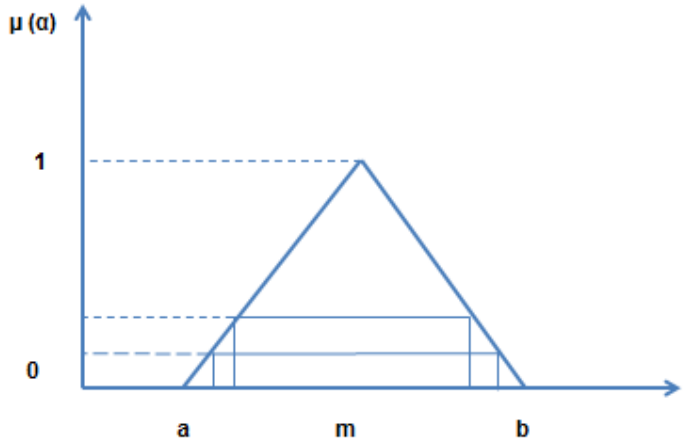


Figure 1. Membership Function of a Triangular Fuzzy Number. μ(α) = Estimation level.

This mechanism enables the estimation of each interval, where the sentence time can be qualified in the interval analysis [a, b], where a and b are the minimum and maximum sentence time.

We compute the mean in the analysis subinterval , given by:

Mean = (Li + Ls) / 2 = (a+b)/2

Using these tools, supported by the information system that characterizes the case. In this case, the felony in question in the state of Michoacan dictates a sentence from 20 to 40 years. The judge may assign different values for the sentence time. To determine the sentence time, the judge may use a scale as the one shown in Table 1. This scale allows a more precise analysis and decreases the variation level from judge to judge. This happens because there is no reference to judge in a more precise form. This situation leads to establish processes under certainty, probability, and uncertainty, using

a multi-valued logic, such as fuzzy logic. Fuzzy logic enables us to effectively and efficiently characterize all possible scenarios that present the felony.

In the study case, the felony was assigned a sentence of 25 years, which does not correspond to the mean, 30 years. Nonetheless, the judge decide to sentence the felon to 25 years, which is the mean 20+30/2 = 25 años. This decision is highly influenced by personal subjectivity. To avoid subjectivities, the judge needs more information that qualifies the different subintervals of the felony enclosed by the minimum and maximum sentence found in the history, for a given region and time.

## Conclusion

Following the form of the law to qualify sentences related to felonies, and that the decision is tied to the personal point of view of the judge (the justice decision maker). If the judge has a high level of experience in the qualification of some kind of felons, the decision approximates the mean of the interval corresponding the real scenario. Since this is regularly not happening, we recommend incorporating techniques based on uncertainty theory, more specifically, on fuzzy logic, to evaluate cases in the justice domain. We also recommend to make public policies that can be translated to laws that allow the law professional to make decisions in a more effective and efficient way.

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# The Hungarian Algorithm: A Solution for the Training Course Assignation in Business

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## Abstract

The current work is based in the following question: is it possible to develop a Training Course Assignation Model attempting the search of an optimal solution to satisfy both the companies' interests and their workers? The proposed proceeding is solved through the fuzzy Hungarian algorithm methodology, where the work with experts is also added, in order to achieve the consensus between the corporative objectives of the company and the individuality of every single worker. The proposed proceeding helps reaching an optimal assignation of the training courses that can be offered by the companies to their workers, which was in addition tested by the company CUBAEXPORT.

**Key words –** Human resources, Training, Hungarian Algorithm, Fuzzy Subsets Theory

## 1. Introduction

The human resources are strategic resources for every single modern organization, since it figures out to be a source of competitive benefits, given its capacity to be carriers and generators of knowledge. In order to make these benefits last, a special attention to the constant development of this knowledge must be ensured. Therefore, more every time the Training processes obtain particular significance at survival and company growth.

The Formation processes must be considered as an inversion carried out by the organizations, in order to improve the workers' competences and qualifications. To achieve the required quality for this process, the companies must assign each Training option to the right person at the right moment. In this sense, the Fuzzy Subsets Theory is presented as a tool, which allows minimizing the current subjectivity in the Training processes, in order to achieve the optimal assignation for each worker.

## 2. The Training process. Its role within the Human Resources Management.

The Formation is one of the elements which will change (or not) towards the human resources within the "basic competitive benefit" for an organization.

The Training is considered an extracurricular learning form, required for a qualified staff development, and essential for the requirements of the technological progress, as well as raising productivity in any organization. Companies are currently submitted to transformation processes or unceasing changes, forced to constantly adapt their members to the new circumstances and prepare them to face possible coming changes. In these cases, Formation will play an essential role in the company's survival and growth, since it will bring the necessary knowledge, skills and attitude for the adaptation to the changes. A company which performs training actions over the basic realistic situations, will not only improve the working environment, but obtain a more competitive human capital aswell (Leal Millán et al 2004).

You could find several definitions given by the various authors of the Training or Formation process such as Fletcher (2002), Sastre et al (2003), Leal Millán et al (2004), Chiavenato (2008), Gomez Mejía (2008), Cuesta (2012), Castillo (2012) or Puchol (2012)

The Formation must be understood as a process, a group of consecutive phases, which purpose dwells in training an individual in order to prepare him to conveniently realize a determined task. It usually focusses in providing specific skills to the employees, or helping them at correcting deficiencies in their efficiency. Moreover, it must contribute to the development of the employees within the organization, so they can occupy major responsibility positions.

## 3. The Hungarian Algorithm

The Hungarian Method is an optimization algorithm that is used to solve assignation problems, and it is basically based on the work of two Hungarian mathematicians: Dénes König and Jenö Egerváry. The first known version of it was conceived and published in 1955 by Harold William Kuhn, American mathematician and emeritus professor of the University of Princeton. Afterwards, in 1957, James Munkres revised the algorithm and it has been known since them as "the Algorithm of Munkres' assignation", or the "Kuhn.Munkres Algorithm", as well.

The comprehension of the following terms, *transport problem and assignation problem*, are the required condition for a contextualization of the Hungarian Method (Taha, 2012).

- A transport problem is a particular case of a lineal programming problem, in which the requirements of a series of demand spots must be satisfied, from a group of offer spots. In

this kind of transport problem, *m* origins and *n* destinations exist, and the flux is elaborated from an origin towards each one of the different destinations.

- An assignation problem is a special subclass of the transport problems. As its own name signals, the problem intends to decide which origin should be assigned to each destination. The offer (demand) in each origin (destination) equals to 1, meaning the same number of offers and demands must be associated equally, for which each agent will be assigned once and only one single task, and vice versa.

In the resolution of a transport or assignation problem, we look for a distribution or assignation path to optimize a concrete goal: the minimization of a total cost, the maximization of the utilities or the minimization of the total involved time.

The minor assignation problems can be solved with the enumeration of all the combinations and the selection of the best one. But for an "*n x n*" problem, *n!* possible solutions exist. It could be solved in a direct way using the transport method or the general solving methods of Lineal Programming such as Simplex. However, due to the particular structure of the assignation problems, the best approach is using the Hungarian Method, more efficient than the last ones and specially developed for this kind of problems (Taha, 2012).

The Hungarian Method summarizes in the following steps, facing a problem of costs minimizations (Taha, 2012):

Given the costs matrix $C_{m,n}$:

1) Determining the element of minimum cost from each row, which deducts from the rest of the elements of the pertinent row (row reduction), thus building a new matrix$C'_{m,n}$.

$$C'_{m,n} = C_{m,n} - \min C_m .$$

2) In the $C'_{m,n}$ matrix, an element of minimum cost from each column is tagged and is deducted to all the elements in the pertinent column (column reduction), thus building a new $C''_{m,n}$matrix, known as reduced costs matrix.

$$C''_{m,n} = C'_{m,n} - \min C'_n .$$

The prior steps provide at least a 0 cost cell in each row and in each column. This means that the use of that cell for an assignation gives the assignation of the smallest possible cost.

3) Based on the $C''_{m,n}$ matrix, we try to determine a feasible assignation among all the 0 resultant entries. If an assignation can be found, it will result as optimal. If none can be found, the method goes on.
4) The minor number of horizontal and vertical lines are traced, in order to coat all the zero entries in the reduced costs matrix.

5) The minor non-covered element is selected, which is deducted to each non-covered entry, and is then added up to each element located in the intersection of two lines. We then come back to the 3rd step and, if an optimal assignation can still not be done, steps 4 and 5 must be redone.
6) When the number of lines equal to the number of rows, we proceed to assign those rows and columns that contain only one single zero, granting that each of them will exactly get one assignation. When elaborating the optimal assignation, there must be a cell with zero for each pair of row and column. This is the only optimal solution for this problem.

When using the Hungarian Method to solve a problem of maximization, the profits matrix must be multiplied (-1) times, and the problem must be solved such as a minimization problem would. The utility provided by an assignation can be represented with monetary numbers, or either be an estimation, relying on the expert's opinions.

# 4. Proceeding for the Assignation of Training Courses through the Hungarian Algorithm

Inside the Human Resources Management, the formation and development of the human resources results in a key process. In order to make the corporative entities understand it better, one must conceive it as a form of inversion and adaptation of that mean to the companies' requirements. It must be accomplished in an organized way, in order to avoid the interruption of the production processes, besides of complementing the training requirements of both the workers and the company itself. Within this training and development process, we suggest to employ the fuzzy subsets theory's tools in two essential actions: the determination of the training requirements and the efficient assignation of the available courses.

- Determination of the Training Requirements

Just like it has previously been commented, the Determination of the Training Requirements is the step that ensures the success of an effective planning. The companies pay attention to the fundamental concerns for their workers, in order to obtain their formation interests. These same companies move throughout a dynamic that adapts the static job positions profiles to the technological and information science's evolution. It is essential to watch over the workers and provide them with the opportunity of self-improvement.

In order to objectify the determination process of the training requirements, we will start by using a Matrix that will cross the job profiles requirements with the results obtained by the workers in their performance tests, on behalf of searching this integrative and systematic approach, as well as a modern management of the human resources. Therefore, we keep in mind the workers' efficiency valuations, and we identify those competences that need to be strengthened. Those results will be

complemented with the aspirations of the workers' development by trying to reconcile the organizations with each individual, leading the action towards the compatibility of the business goals. This matrix will be known as [$\tilde{\underset{\sim}{U}}$].

- Course assignation

Once the Training Requirements are determined, the following step for the Training or Formation Plans' confection is the search of the corresponding courses fitting the concerns and the programming of the most suitable moment for the worker. Obtaining the course offers will depend on the environmental conditions. Gathering the requirements by using the fuzzy subsets theory allows to give a major response by opening the ream of formation possibilities.

A very sensitive point is the course assignation. The courses must be awarded in a tiered manner, in order to not interrupt or affect the organizational processes. In order to grant the effectivity, we suggest using the Hungarian Algorithm as a resolution method of the assignation problem. This algorithm considers a common use tool, especially for the decision taking processes in the ecoefficiency practices. Its goal will be looking for the optimal combination of courses for each worker.

With this aim, we start out from a second matrix, where the course offers and the training requirements (previously obtained) will remain crossed.

We suggest to work in a matricial way, seeking the organization of the gathered information and its design, starting out from the use of the fuzzy mathematics theories, which provide major possibilities when evaluating intervals, strengthening an answer from each single part to the interests. This matrix will be defined following the experts' opinions, which must maintain the line and the human resources staff balanced. The Fuzzy-Delphi Method must be equally built up, in order to mitigate the possible subjectivity that could arise when considering whether a worker must be engaged in a specific course or not. The business goals must be compatible with the workers' goals.

The model for the course assignation can be used as a guideline for the cost assignation of sending away the workers to specific courses, but this would mean a setback in the handling of human resources, where, again, it would be seen as a cost instead of an investment. This is why we decided to use the significance level for the company to arrange the correct course for each worker as a guideline. The model for the training assignation would remain formulated this way:

**Definition of Variable:**

$$Xij = \begin{cases} 1 \text{ if the } i \text{ course is assigned to the j worker} \\ 0 \text{ if there is no assignation} \end{cases}$$

$i = 1, \dots n \quad j = 1, \dots n$

**Parameters:**

$Uij$: *Associated significance level for the assignation of the i course to the j worker*

**Model:**

$$MAXZ = \sum_{i=1}^{n} \sum_{j=1}^{n} UijXij$$

**Held to:**

$$\sum_{j=1}^{n} Xij = 1 \quad i = 1, \dots n$$

$$\sum_{i=1}^{n} Xij = 1 \quad j = 1, \dots n$$

$0 \leq Xij \leq 1$ *and whole*

$0 \leq Uij \leq 1$

The Hungarian Algorithm will be used for the resolution of this problem.

The first step will be the optimization of the $[\underset{\sim}{\bar{U}}]$ matrix through the maximization principle, leading the course assignation to those who will affect the most the workers' performance. The OSDE relies on the Institute's benefits, which is ordered to improve the performance of their workers, without costing more than the time they spend on that improvement. That means, through the experts' opinions, that an analysis of the significance of the correct course assignation for every worker is gathered, starting out from the compiled information in the Training Requirements Matrix. Those opinions will be summarized within an experton that will shape the matrix.

The $[\underset{\sim}{\bar{U}}]$ matrix is built up, assigning the Training Requirements to the columns and the Courses Offer to the rows. Note that this matrix might not be necessary squared. In that case, it must be transformed by adding the required rows or columns – then, the [1:1] interval would be placed – in order to keep in mind the maximum distance possible between the options included.

The adapted Hungarian Method is summarized in the following steps:

1. A $\underset{\sim}{U_{i,j}}$ matrix is elaborated, of which $u_{i,j}$ elements are the expertons' values, referring to the significance or utility level (expressed with intervals) of the courses for every job position.
2. As it is a maximization problem, a transformation is carried out. The problem is then solved like a minimization problem. This transformation consists in removing all the elements of

the $\underset{\sim}{U}_{i,j}$. matrix from the [1:1] interval (which represents the maximum utility possible). It is obvious that $\underset{\sim}{U}_{i,j}$max and $\left(1 - \underset{\sim}{U}_{i,j}\right)$min share the same optimal point.

The problem about this operation dwells in the extremes of the obtained interval, which can change. In other words, the minor extreme is higher than the major extreme. Therefore, the solution will be to modify the Minkowski subtraction, in order to switch again the extremes, obtaining the $\underset{\sim}{U}'_{i,j}$ matrix.

3. If $u_j$ is the minimum[i] value of the $j^{th}$ column, belonging to the $\underset{\sim}{U}'_{i,j}$ matrix, $\underset{\sim}{U}''_{i,j}$ will be constructed as:

$$\underset{\sim}{U}''_{i,j} = \underset{\sim}{U}'_{i,j} - u_j .$$

The modification of the Minkowski subtraction is used in this operation:

4. If$u_i$is the minimum[ii] value of the$i^{th}$row, belonging to the $\underset{\sim}{U}''_{i,j}$ matrix, $\underset{\sim}{U}'''_{i,j}$ will be constructed as:

$$\underset{\sim}{U}'''_{i,j} = \underset{\sim}{U}''_{i,j} - u_i .$$

The modification of the Minkowski subtraction is also used in this operation.

This way, we grant at least a [0;0] interval for each row and$\underset{\sim}{U}'''_{i,j}$column.

In case that all $\underset{\sim}{U}'''_{i,j}$ equal to [0;0], we will be facing a trivial solution.

5. For every row of the $\underset{\sim}{U}'''_{i,j}$ matrix, starting from the row with the least [0;0] interval quantity, one of the [0;0] intervals is stood out for each row, and the rest is crossed out. If a single [0;0] interval is obtained for each row and column, the solution has been hit.
6. All the rows where any [0;0] interval was stood out, are tagged with an arrow (→).
7. All the columns containing a crossed [0;0] interval in a tagged row (a tagged row from step 6) are tagged with an arrow (↑).
8. All the rows containing a stood out [0;0] interval in a tagged column from step 7 are tagged with an arrow (→).
9. The area belonging to the tagged columns and not tagged rows is stood out as well.
10. The smallest of the intervals among the elements of the matrix that have not been stood out in step 9 are chosen. This interval is subtracted to each element in the not stood out rows, and then it is added to each element belonging to the stood out rows and columns, simultaneously. Then we get back to step 5.

Once all the required interactions are done, and once the Method's development is concluded, the optimal assignation of the training options for every job position will be obtained.

# 5. Application of the suggested Proceeding to the company Cubaexport.

CUBAEXPORT is a service company that acts as an intermediate in the exportation and importation chains. Regarding the application of the proceeding, 12 workers occupying key positions for the company were selected, and then called as "substantive positions", meaning those who influence and have a direct implication in the company's goal achievement with their activity, as well as the consecution of both operative and strategic business goals.

From that moment on, the selected positions will be referred such as their identification number, as, even if some of them share the same name[iii], the people who occupy them are distinct. Once everything is cleared up, we proceed to develop the Method.

**Step 1:**

In order to elaborate the first matrix, the Competences Profile and the Performance Evaluation[iv] of each position were required, with the objective to detect those topics where the workers had the need of training for the achievement of a better working performance. With the aim of seeing the detected training requirements, we have itemized them for every job position. Overall 12 requirements were detected. The main requirements allude to: Updating the knowledge about the payment and earning forms within the International Commerce; Increasing the knowledge about international finances; Improve and perfect the English language; Deepen in the knowledge about industrial property; Increasing the knowledge about price matters; Increasing the knowledge about commercial activities and stock-market commerce, as well as the international prices.

Afterwards, the workers' particular aspirations or formative interests were compiled and selected, for what documents bringing about the Management of Human Capital were checked. The general aspirations were: Increasing the knowledge about financial and accounting matters; Perfecting the knowledge and skills for the exterior commerce activity, from the economical, commercial point of view, as well as the payment and earning distribution point; Expanding the territory over the Quality Management System; Expanding the knowledge about commercial matters, international market and the financial risks prevention; Increasing the knowledge about the international purchase and sale processes.

When crossing the training needs with the aspirations in the first matrix, we confirmed the existence of common interests between the workers and the Company, when deepening in the knowledge of accountable, financial and exterior commerce matters, as well as the regulations governing those

activities. It was equally demonstrated that there is an interest in increasing the knowledge about the economical hiring, the Quality Management in the purchase and sale proceedings, the stock-market commerce, the international prices and the financial risks prevention. We present now a sample of the matrix.

**Table No.2:** Matrix No. 1, crossing between the training requirements and the workers' aspirations.

| **Detected aspirations/needs** | **Updating the knowledge about the payment and earning forms within the International Commerce** | **Deepen the knowledge about the Accounting Cuban Rules and main accounting and financial regulations** | **Increasing the knowledge about international finances** |
|---|---|---|---|
| **Expanding the domain of regulations for the exterior commerce** | **0** | **1** | **0** |
| **Increasing the knowledge about financial and accounting matters** | **0** | **1** | **1** |
| **Perfecting the knowledge and skills for the exterior commerce activity, from the economical, commercial point of view, as well as the payment and earning distribution point** | **1** | **0** | **0** |

**Step 2:**

When the training requirements were detected and confirmed those aspects where common interests between the Company and the workers exist, we proceeded to the arbitration of the competences of the experts who participated in the proceeding. The Experts Committee was formed by the Director and two Specialists about the Human Capital Management in Business. The arbitration between the competences was carried out by an inquiry, designed with two questions, oriented towards the calculation of the knowledge coefficients (*Kc*) and the argumentation coefficients (*Ka*), in order to finally determine the competence coefficient (*K*). The competence coefficient, the result of the average weighting of the last two, shows that the selected experts are very competitive, as it reached scores higher than 0,8.

**Step 3:**

Once we ensured that the experts own the required competences, we requested their opinion about how important is for the Company the circulation of the selected workers through the dissimilar courses, which, year by year, are offered by the Exterior Commerce Improvement and the Abroad Inversion Centre. For the proceeding's application, a sample of these courses was selected, considering those which saved a major relation with the previously detected training requirements. They are: Exterior Commerce Degree; Electronic Commerce from the Exterior Commerce's optic;

Products Stock Market and Risks Management; Exterior Commerce Basic Course; INCOTERMS; Extern Prices Analysis; International Finances; Exterior Commerce Accounting Basic; International Marketing; English Language Intensive Course; English Language Regular Course; Legal aspects of Cuban Exterior Commerce.

The experts' opinions were compiled through a survey where the matrix crossing the workers' aspirations with the real detected training requirements was added as additional information. The experts had to complete a matrix showing the job positions in the rows, and the selected courses in the columns.

Once the survey is applied, we proceed to the calculation of expertons, the tool which allows grouping the experts' criteria in the process of summarizing them in one single expression, transforming the 0-10 scale values into decimal numbers. 144 expertons were built up in total, representing the experts' considerations about the significance of each course for the correct compliance by the workers in their respective positions. Once all the expertons are calculated, we proceed to apply the Hungarian Method, adapted to the Fuzzy subsets Theory, for the resolution of a maximization problem of utility. The assignation of the training options was carried out considering the impact that they would have for the correct workers' performance, just as it had been told before. It is necessary to clear up that no every worker will get the Formation ant the same time, due to the fact that the assigned courses have different starting schedules and a different duration, depending on the approached matters and the study programs' extension.

The application of the Hungarian Method based on the Fuzzy Subsets Theory grants the course assignation to provide the maximum possible utility both for the Company and the workers. This distribution of the courses satisfy the detected training needs and contributes to the workers' aspirations.

The utility, showed with intervals, that reports this assignation is calculated by adding the pertinent expertons' values. It is shown right below:

**Table No. 3:** Reported utility for each course.

| Courses | Position | Utility |
|---|---|---|
| **A** | 3 | [0,67;0,97] |
| **B** | 9 | [0,80;0,97] |
| **C** | 12 | [0,83;0,93] |
| **D** | 10 | [0,70;0,90] |
| **E** | 6 | [0,77;0,90] |
| **F** | 8 | [0,70;0,93] |
| **G** | 2 | [0,63;0,87] |
| **H** | 1 | [0,63;0,90] |

| | | |
|---|---|---|
| **I** | 7 | [0,90;1,00] |
| **J** | 4 | [0,53;0,70] |
| **K** | 11 | [0,60;0,77] |
| **L** | 5 | [0,63;0,83] |
| **Total Utility** | | **[8,40;10,67]** |

It is important to stand out that the use of the traditional Hungarian Method for the assignation of these training options is for sure valid, yet it doesn't adequate to this case, as it discards a big part of the supplied information by the experts. The assignations will be elaborated keeping in mind the minimum, maximum or mid values of those intervals.

Afterwards, aiming to contrast how different the assignations are against the ones obtained in the prior paragraph, the traditional Hungarian Method was employed. The reported utility by the course distribution with the traditional method equals to 10,7 (concerning the maximum values of the intervals), 8,35 (concerning the minimum values) and 9,48 (concerning the mid values). It is essential to stand out that, even if the assignation following the traditional Hungarian Method using the maximum values provides a major utility that the one achieved through the Hungarian Method based in the Fuzzy Subsets Theory ([8,40;10,67]), this last method is the one to adequate the better to the present uncertainty and subjectivity in the Training Processes.

Once this point is reached, it is essential to stand out the significance of employing the Fuzzy Subsets Theory over the Training Process, especially when it comes to assign the different training options, because of the uncertainty and subjectivity level concerning those activities.

## Final Considerations

The human factor builds a strategic competitive benefits generator resource for the modern organizations. The Human Resources Management's goal is to organize the workers according to the company's strategy and its implementation through the workers' daily work.

The Training must be an arranged, consequent, efficient process, able to respond to the real needs of the company and its workers.

The use of the fuzzy subsets theory allows incorporating subjective information through the experts, bringing flexibility to the company in the decision taking.

The developed proceeding is structured in three steps: Detection of the Training Needs, Selection of the Experts Group and finally, the Assignation. The course assignation obtained with the Hungarian Method based in the Fuzzy Subsets Theory appears to be optimal and provides the maximum utility both for the workers and the company.

Using the traditional Hungarian Method for the assignation within a high subjectivity context results in a not so adequate proceeding, as it discards a big part of the information provided by the experts.

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[i] The judgments about the confidence intervals' comparative were stablished by Gil Lafuente y Rojas Mora, 2007.
[ii] Ídem
[iii] The position´s denomination is generic.
[iv] The Performance Evaluations belong to 2013, as for the ones relating 2014 were not yet elaborated at the moment of requesting this information

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# Solution of Dispute Resolution Method for Labor Conflicts through IPOWA

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## Abstract:

Alternative dispute resolution methods have generated a range of options to resolve conflicts, so that identify which is the best choice for different types of problem it is necessary, that is why is essential to create an arrangement using the experience and characteristics of the decision maker. In this article various information aggregation operators are used as the OWA and IPOWA in order to obtain the best method for solving labor

**Key words:** Alternative dispute resolution, selection method, OWA, IPOWA.

### 1 Introduction

Locally, the company, whether produces and/or uses inputs and tradable and non tradable goods, has persistent links with an increasingly uncertain and volatile global environment. This uncertainty makes management decision more complex, is a clear example those aimed at improving the competitive position and increases the market value of the organization. (e.g. Figueira, Greco & Ehrgott (2005) Gil-Lafuente & Merigó (2010) and León & Contreras (2013))

In organizations located in developing economies, among the most complex and costly decisions, are those relating to labor disputes. The coexistence of imperfect markets and systematic institutional fragility, says Martin (2000) deteriorates their competitive position and discourages new investment.

Therefore, care, monitoring and expeditious resolution of labor disputes, designed to minimize the catastrophic financial costs and protect labor-management relations, warned Rodriguez (2002) and Halegua (2008), is obligated task of the decision maker.

The amendment to Article 17 of the Constitution of the United Mexican States in 2008 introduced in the legislation, alternative methods of conflict resolution, among which are: conciliation, mediation, negotiation and arbitration. This has enabled reducing caseload of the courts, design strategies with effective solution.

While the constitutional reforms have resulted in more effective and efficient procedures in solving conflicts, the discussion has moved to another area. Now, you need to identify which method, depending on the type of problem is most suitable for the case in question. In this regard, match Gil Lafuente (2001), Gil Aluja (2004), Merigó, Casanovas y Palacios-Marqués (2014) y Merigo (2016) is effective use selection tools that consider the available information, characteristics and experience of the decision maker.

The study aims to formalize a system of methods of settling labor disputes used in Mexico, using OWA aggregation operators, probabilistic aggregation (PA), induced OWA (IOWA), probabilistic OWA (POWA) and induced probabilistic OWA (IPOWA), considering the subjectivity, experience and the expectations of the decision maker.

The paper is organized as follows. In section 2 points out the methodological approach. Later, alternative methods of dispute resolution are identified. Then the application of the model to a specific case of decision is rendered. Finally, is the conclusion.

## 2 Methodological approach

**Definition 1**. According to Yager (1998) an OWA operator of dimension $n$ is an application $F: R^n \to R$ with a weight vector $w = [w_1, w_2, \dots, w_n]^T$ where $w_j \in [0, 1]$, $1 \leq i \leq n$ y

$$\sum_{i=1}^{n} w_{i=} w_1 + w_2 + \cdots + w_n = 1 \tag{1}$$

Where

$$F(a_1, a_2, \dots, a_n) = \sum_{k=1}^{n} w_j b_j \tag{2}$$

Being $b_j$ is the *j*th element largest of the collection $a_1 a_2, \dots, a_n$.

**Definition 2.** Probabilistic operator (PA) is a function of aggregation using probability. Merigo (2012) indicated that an operator PA of dimension $n$ is an application $PA: R^n \to R$ having an associated weight vector P, where $p_i \in [0,1]$ y$\sum_{i=1}^{n} p_i = 1$, so that

$$PA(a_1, a_2, \ldots, a_n) = \sum_{i=1}^{n} p_i a_i \tag{3}$$

**Definition 3.** A POWA, points Merigo (2012) that an operator of dimension $n$ is an application $POWA: R^n \to R$ having an associated weight vector P, where $p_i \in [0,1]$ y$\sum_{i=1}^{n} p_j = 1$, expressed as follows

$$POWA(a_1, a_2, \ldots, a_n) = \sum_{j=1}^{n} \hat{p_j}\, b_j \tag{4}$$

Being $b_j$ is the *j*th element largest of the collection $a_1 a_2, \ldots, a_n$, where each argument $a_i$ is associated to a probability $p_i$ where $\sum_{i=!}^{n} p_i = 1$ and $p_i \in [0,1]$,$\hat{p}_j = \beta w_j + (1-\beta) p_j$ with $\beta \in [0,1]$ and $p_j$ is the probability of $p_i$ ordered according to $b_j$, according to the *j*tj element largest of $a_i$.

**Definition 4.** An IOWA operator, according to Yager and Filev (1999) y Merigo and Gil Lafuente (2009) of dimension $n$ is an application $IOWA: R^n \to R$ that has a weight vector associated *W* of dimension *n* where the sum of the weights is 1 and $w_j \in [0,1]$, where a induced set of variable of order are include $(u_i)$ so the formula is

$$IOWA(\langle u_1, a_1\rangle, \langle u_2, a_2\rangle, \ldots, \langle u_n, a_n\rangle) = \sum_{j=1}^{n} w_j b_j \tag{5}$$

Where $(b_1, b_2, \ldots, b_n)$ is simple $(a_1, a_2, \ldots, a_n)$ reordered descending or ascending according to the values of $u_i$.

**Definition 5.** An IPOWA operator, points Merigó (2012), of dimension *n* is an application $IPOWA: R^n x R^n \to R$ that has an associated weight vector *W* of dimension $n$ where $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$ so that

$$IPOWA(\langle u_1, a_1\rangle, \langle u_2, a_2\rangle, \ldots, \langle u_n, a_n\rangle) = \sum_{j=1}^{n} \hat{v}_j b_j \quad (6)$$

Where $b_j$ is *j*th element that has the largest value of $u_t$. $u_t$ is the induced order of variables, additionally each element $a_i$ has an associated probability $p_i$ with $\sum_{i=!}^{n} p_i = 1$ and $p_i \in [0,1]$,$\hat{v}_j = \beta w_j + (1-\beta)p_j$ where $\beta \in [0,1]$ and $p_j$ is the probability of $p_i$ ordered according to $b_j$, that is according to the *j*th largest $u_t$.

## 3 Alternative dispute resolution in Mexico

Among the Alternative Dispute Resolution (ADR) applied in the country include those of: negotiation, mediation, conciliation and arbitration. Each one with specific characteristics that distinguish them, but all, without exception, are aimed at finding a peaceful, friendly and accepted by people in conflict solution.

Mediation argues Pelayo (2011), Green (2012) y Stipanowich y Lamare (2013) is a procedure guided by a third party, allowing the conflicting parties to reach a solution through dialogue. In this process the mediator's main function is to facilitate dialogue and finding a joint solution promoting the opening of the other viewpoint.

Conciliation, point Cucarella (2003) y Wong (2014), is a tool that consists of three main elements: the parties, the conflict and conciliation proceedings. Such procedural structure allows to solve the differences between two or more people, where the role of the intermediary is crucial to guide the parties to produce a solution

Negotiation is a process in which two or more people use different techniques of communication in order to obtain a result that satisfies reasonable and fair objectives, interest, needs and aspirations of each of the parties in the conflict. (e.g. Fiadjoe (2013) y Folberg y Taylor (1997))

Arbitration, underline Sendra (1999) y Martin (2013) is a heterocompositive method for conflict resolution, in which the parties, prior and voluntarily choose to undergo to one or more third parties to give a definitive and irrevocable solution by the use of objective law or in accordance with their knowledge.

## 4 Model Application

In the present paper we consider the following alternatives for settling labor disputes

$a_1$ Mediation
$a_2$ Negotiation

$a_3$ Conciliation
$a_4$ Arbitration
$a_5$ Trial

For each of the alternatives, the decision maker was asked, based on their experience, in what percentage of cases one of the following qualities of settlement is reach

$s_1$ Very bad
$s_2$ Bad
$s_3$ Regular
$s_4$ Good
$s_5$ Very good

Obtaining the results reported in the following table

Table 1. Quality of the solution achieved for each method

| Solution Method | Very Bad | Bad | Regular | Good | Very Good |
|---|---|---|---|---|---|
| Mediation | 5 | 10 | 25 | 30 | 30 |
| Negotiation | 10 | 15 | 25 | 30 | 10 |
| Conciliation | 10 | 20 | 25 | 20 | 25 |
| Arbitration | 10 | 10 | 25 | 30 | 25 |
| Trial | 25 | 25 | 30 | 15 | 5 |

Considering an induced ascending order

$$\langle u_i, a_i \rangle: \langle 1, a_1 \rangle, \langle 4, a_2 \rangle, \langle 2, a_3 \rangle, \langle 3, a_4 \rangle, \langle 5, a_5 \rangle$$

According to the decision maker a weight vector $w = [0.30,0.10,0.30,0.10,0.20]$, which is complemented by the probability of the company to achieve a labor solution for each of the scenarios, generating

$$p = [0.10,0.10,0.40,0.20,0.20]$$

Finally the importance of the information obtained by the weight vector and the probability vector are 40% and 60%, respectively.

Using the above information operators OWA, PA, IOWA, POWA and IPOWA applied to generate various selection scenarios. (See table 1 and 2)

Table 2. Results using aggregation operators

| | OWA | PA | POWA | IOWA | IPOWA |
|---|---|---|---|---|---|
| Mediation | 24.5 | 23.5 | 23.9 | 22.5 | 23.1 |
| Negotiation | 21.5 | 20.5 | 20.9 | 21.0 | 20.7 |

| | | | | | |
|---|---|---|---|---|---|
| Conciliation | 22.0 | 22.0 | 22.0 | 21.0 | 21.6 |
| Arbitration | 23.0 | 23.0 | 23.0 | 22.0 | 22.6 |
| Trial | 23.5 | 21.0 | 22.0 | 21.5 | 21.2 |

Table 3. Raking of the alternatives

| | Order |
|---|---|
| OWA | Mediation > Trial > Arbitration > Negotiation > Conciliation |
| PA | Mediation > Arbitration > Conciliation > Trial > Negotiation |
| POWA | Mediation > Arbitration > Conciliation and Trial > Negotiation |
| IOWA | Mediation > Arbitration > Trial > Conciliation and Negotiation |
| IPOWA | Mediation > Arbitration > Conciliation > Trial > Negotiation |

## 5 Conclusions

Alternative dispute resolution methods in Mexico introduced ways to end labor disputes that undermine the competitiveness of companies and regions in its attempt to expand and attract new investment forms. In organizations, labor disputes are of high incidence, also generating catastrophic cost and complicate the organizational environment if not accepted and convenient to the parties involved in the problem resolutions are reached.

Among the most significant results the differences between aggregation of information operators stands. We prove that in a labor dispute the suggested method is initially mediation and then arbitration. Thus, decision makers should make use of ADR before going to the courts for resolution.

To deepen the discussion of this research and its methodology, it is suggested to pursue the subject of trade disputes and the use of new information aggregators such as generalized and prioritized operators. (e.g. Merigó & Gil-Lafuente (2009) and Merigño, Casanovas & Palacios (2014))

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# Property Valuation using Machine Learning Algorithms: A Study in a Metropolitan-Area of Chile

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## Abstract

Machine learning techniques are applied to the analysis of real data on the new housing market of Santiago, Chile. The objective is to compare the predictive performance of the Neural Network, Random Forest and Support Vector Machine approaches with traditional Ordinary Least Squares Regression. The database for our analysis consists of a sample of 16,472 price records for new housing units or residential properties within the area covered. The results of the analysis show that Random Forest performed better than the other models in modeling housing prices. More generally, we conclude that machine learning techniques can provide a useful set of tools for acquiring information on housing markets.

## Key words:

Machine Learning, Hedonic Pricing Models, Neural Network, Random Forest, Support Vector Machine, Property Valuation

## 1. Introduction

This paper uses machine learning techniques to analyze the residential property market in the city of Santiago, Chile. Previous research on the Santiago housing market has taken an econometric approach. In practice this has meant modeling prices using the method of ordinary least squares (OLS), considered by some manuals as “the most straightforward statistical technique employed by economists" (Triplett, 2004). Most Santiago case studies have employed either this method or one of its variants (i.e., semi-log or log-log).

In recent years, machine learning (ML) techniques have been used for analyzing the housing markets of more and more cities around the world. The field of ML is devoted to the building and testing of supervised, unsupervised and semi-supervised learning algorithms that automatically recognize patterns in the ever increasing quantity of available data. However, analyses in other contexts comparing different ML techniques have shown that their performance can vary significantly depending on the data domain they are applied to (Dietterich, 1998; Huang, Zhou, Ding, and Zhang, 2012; Verrelst, Muñoz, Alonso, Delegido, Rivera, Camps-Valls, Moreno, 2012; Japkowicz, 2011). This implies that the ML techniques we use here with Santiago housing market data must be evaluated to determine how well they perform comparatively with OLS.

The present article is an exploratory study aimed at making just such a comparative evaluation. Based on the existing literature reviewed in Section 2, we will use the ML approach to do the following: Compare the performance of Random Forest, Support Vector Machine and Neural Network with that of classical multiple linear regression using OLS in predicting Santiago residential property prices.

The remainder of this paper is organized into four sections. Section 2 reviews existing research on the Santiago, Chile housing market; Section 3 details the methods used to construct the new housing unit price prediction models; Section 4 report the valuation models, and Section 5 discusses the results and limitations of the methods used and presents our conclusions as well as some indications for future research.

## 2. Research on the Santiago housing market

Various international economic events of the last decade have prompted a growing interest in research into residential property markets. The subprime mortgage crisis in the United States and the housing bubbles in Ireland and Spain have underlined the need for better information on the behavior of housing markets for both short-term and long-term decision making. Studies of the Santiago market using the hedonic approach go back almost 40 years to 1978, when economist Ricardo Lira posited that “a housing unit can be seen as a set of characteristics such as size, construction quality, desirability of location, etc. Conceiving of a home in this manner can be a good research strategy for comparing or predicting the prices of housing with different characteristics" (Lira, 1978, p. 67).

Lira's paper incorporated the hedonic hypothesis formulated by Rosen (1974) itself an extension of the work of Lancaster (1966) which suggested that commodities are valued by consumers on the basis of their characteristics or attributes. Most published Santiago housing market studies employ econometric techniques to estimate the market price of housing units. Some, for example, use a linear model (see, Aguirre, et al., 2011; Castellon, 2005; Agostini and Palmucci, 2008) others employ semi-log models (see, Quiroga, 2005; Iturra and Paredes, 2014). The emphasis in these studies is on determining elasticities and devising formulations that provide a simple interpretation of the market rather than comparing different regression techniques with a view to establishing which one delivers the best housing price predictions.

In short, existing studies have investigated various aspects of the Santiago residential property market but none have yet determined which regression techniques perform best in predicting the prices of new housing. In what follows we attempt to fill these gaps in the literature using a method based on machine learning techniques.

## 3. The method

We construct the hedonic models using Random Forest (RF), Support Vector Machine (SVM), Neural Network (NN) and classical multiple Linear Regression (LR) using OLS and compare their predictive performance. The experimental setup is described in what follows.

### 3.1. Area of study

As noted earlier, the techniques used in this case study are applied to the city of Santiago, Chile's capital and its largest urban region. Although it covers 52 communes or urban districts, we limit our focus to the 33 that are the most central and heavily urbanized. As of the 2002 Census, this area was home to 4,728,443 people and had a population density of 2,304.83 inhabitants per $km^2$.

### 3.2. Sample

The database for our analysis consists of a sample of 16,472 price records from 2008 for new housing units or residential properties (hereafter also RP's) within the area covered. Of these records, 13,992 are for apartments while the remaining 2,480 are for houses.

### 3.3. Independent and dependent variables

The dependant variable to be predicted is numerical and represents the price of an RP in inflation indexed monetary units known as Unidades de Fomento (hereafter UF), published by the Central Bank of Chile and generally used in Chilean real estate listings. The independent variables are listed and defined in Table 1.

Table 1: Independent variables

| *Variable* | *Definition* | *Data Type* | *Measure Unit* |
|---|---|---|---|
| dist | Distance from property to city centre | Numerical | [m] |
| time | Minimum time by car to city centre from property | Numerical | [minutes] |
| type | House or apartment | Dummy | [–] |
| Comuna | District (communes) of Santiago property is located in | Categorical | [–] |
| grdvalue | Land price in UF | Numerical | UF/$m^2$ |
| surface | Usable floor area in square meters | Numerical | $m^2$ |
| bath | Number of bathrooms | Numerical | [–] |
| bedrms | Number of bedrooms | Numerical | [–] |
| Colx | Latitude of property location | Numerical | [Degrees] |
| Coly | Longitude of property location | Numerical | [Degrees] |
| dgreen | Distance in meters to the nearest green area | Numerical | [m] |
| daccess | Distance in meters to the nearest urban highway access | Numerical | [m] |
| dhighway | Distance in meters to the nearest urban highway | Numerical | [m] |
| dmall | Distance in meters to the nearest shopping mall | Numerical | [m] |
| dschool | Distance in meters to the nearest school | Numerical | [m] |
| dpolice | Distance in meters to the nearest police station | Numerical | [m] |
| dhospital | Distance in meters to the nearest hospital | Numerical | [m] |
| dsubway | Distance in meters to the nearest Metro station | Numerical | [m] |
| poll | Average maximum air pollution value | Numerical | [ppm] |
| dcenter | Distance in meters to the nearest central business district | Numerical | [m] |

### 3.4. ML regression algorithms

In what follows we describe the NN, RF and SVM regression algorithms.

- NN: A neural network (NN) is a set of N neurons used to estimate non-linear functions of two or more neurons. Each neuron represents a parametrized non-linear function. An input variable value is entered into a neuron and depending on the function *f* the latter represents (normally with an associated parameter as a weight factor), an output value is obtained that may in turn be the input value for some other neuron. The function *f* is known as an activation function given that it may be activated depending on the input

value. In this study we use a single hidden layer neural network with three layers (Ripley, 1996). The first one is the input layer in which the neurons receive the dependent variable values and the third one is the output layer in which a neuron receives the linear combinations of the values of the second, or hidden, layer. This latter receives the input neuron values and from this information calculates the weights of the activation functions so as to optimize an output criterion. For this study the criterion is the minimum mean square error (MMSE). Various sizes of hidden-layer networks were tested with a view to maintaining the simplicity of the network without sacrificing performance. The size finally decided upon was 8 neurons. The weight decay is 0.1, which avoids problems of overfitting and improves the generalization of the network (Krogh and Hertz, 1991).

- RF: The RF algorithm is a method of bagging trees (Breiman, 1996) Under it, multiple unpruned classification trees are trained through iteration of samples without replacement of the original data set. Each tree classifies the instances individually and the forest as a whole then chooses the classifications having the most individual votes (over all of the trees) (Breiman, 2001). A key characteristic of this method is that the trained trees do not depend on the trees trained previously given that at each iteration a bootstrap sample of the data set is used. In this study, RF is used with regression trees given that the dependent variable is continuous. The procedure is the same as that for training classification trees, the sole difference being that in regression trees the leaves predict the actual number instead of a class. In this context the partition criterion is not entropy but rather the minimum root-mean-square-error (RMSE). The parameter found to generate the least RMSE was 10 variables at each growth of the tree.

- SVM: A support vector machine is a supervised classification algorithm that searches for a hyperplane separating data into classes. The separation is identified by maximizing the distance between the hyperplane and the region that defines the limit of each class. The SVM transforms the training data using a function known as kernel that maps the data to a higher-dimensional space, thus permitting a better hyperplane separator to be found. In the process of maximizing the distance, SVM assigns a cost or penalty to the classification of an instance in the wrong class and then minimizes these errors. Strictly speaking, the version of SVM utilized in this study is known as Support Vector Regression, whose algorithm is the same as SVM except that the cost function is modified for use with a distance measure, in this case the conventional RMSE (for details, see Smola, 2004). To build the SVM model we performed a set of simulations with a variety of parameter combinations, in particular the gamma and cost parameters. The least RMSE was obtained with equal to 0.1 and a cost of 10.

### 3.5. Calibration and validation of models and performance measures

To calibrate and validate the models generated by NN, RF and SVM, training and validation data sets were selected at random from the sample. The training set was 70% of the sample while the validation set was the other 30%. The performance measures used to evaluate the models were root-mean-squared-error (RMSE), mean-absolute-error (MAE) and the Pearson coefficient of

determination ($R^2$) (see Table 2). To ensure these measures were mutually comparable, we used the same training and validation sets for each regression algorithm.

| Measure | Formula | Min Value | Max Value | Desirable Outcome |
|---|---|---|---|---|
| $RMSE$ | $\sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}}$ | 0 | $\infty$ | min |
| $MAE$ | $\frac{1}{N}\sum_{i=1}^{N}\lvert\hat{y}_i - y_i\rvert$ | 0 | $\infty$ | min |
| $R^2$ | $1 - \frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$ | 0 | 1 | close to 1 |

Table 2: Performance measures for evaluating property price prediction models. Note the following observations regarding the three measures: RMSE is an accuracy measure often used to compare the sample standard deviation of the differences between observed and predicted values. It also indicates the aggregate size of the errors in a model's predictions and is thus a measure of predictive power MAE gives the average of the squared errors. It is similar to RMSE except that the differences between the observed and predicted values are not squared; $R^2$ indicates how well the models fit the training and validation data sets. It measures the proportion of the variance explained by the models. The closer this proportion is to unity, the better.

## 4. Results

In this section we first set out and compare the performance results of the hedonic model algorithms, then report the cluster analysis results, and conclude by presenting the importance rankings of the variables for both the Santiago market as a whole and each of its submarkets.

### 4.1. Hedonic model predictive performance results

The performance of the four algorithms in predicting Santiago housing prices is indicated by the results shown in Table 3. As can be seen, LR scored reasonably well, especially with the validation data set ($R^2$=.86, RMSE=.33, MAE=.004). Both SVM and RF performed better on this set, however, the former attaining values of $R^2$=.94 and RMSE=.06 while RF did even better at $R^2$=.96 and RMSE=.04.

Table 3: Performance indicators for each algorithm

| | *RF* | *SVM* | *LR* | *NN* |
|---|---|---|---|---|
| Training RMSE | 0.019 | 0.054 | 0.366 | 0.264 |
| MAE | 0.000 | 0.008 | 0.001 | 0.271 |
| $R^2$ | 0.980 | 0.946 | 0.632 | 0.739 |

| | | | | |
|---|---|---|---|---|
| Validation RMSE | 0.041 | 0.057 | 0.334 | 0.244 |
| MAE | 0.003 | 0.009 | 0.004 | 0.279 |
| $R^2$ | 0.956 | 0.939 | 0.856 | 0.744 |

The results for NN, on the other hand, fell below what was expected, with values for the validation set of $R^2$=.74, RMS=.24 and MAE=.28 as compared to 0.334, 0.004 and 0.856, respectively, for LR. That Neural Network did not outperform linear regression might mean that the parameters chosen for NN's construction were not optimal, although as noted in the section on method they were the values that produced the lowest RMSE value. We may therefore conclude that RF was the algorithm which performed best, followed by SVM, LR and NN in that order.

## 5. Discussion

This study presented an empirically based analysis of the residential property market in Santiago, Chile using machine learning techniques. The proposed approach generated results on the power of different models to predict the prices of housing market. In light of these findings, the following observations are in order.

In section 4 it was shown that the Random Forest model produced the best predictions of Santiago housing prices. This is consistent with the findings of the international literature, which have demonstrated the superior predictive performance of the RF algorithm for explaining housing prices in other markets. For example, in Antipov and Pokryshevskaya (2012), the first study to apply RF to this analytical problem, it performed better than such techniques as CHAID, CART, KNN, multiple regression analysis, Artificial Neural Networks and Boosted Trees. More recently, Yoo, Jungho, and Wagner (2012) also found that RF came out on top in a study of housing sales prices in Onondaga County (New York) and modeled prices more accurately than the traditional OLS method. A third case is a study by Lasota, Luczak, Trawinski (2011), in which RF again scored higher than the other tested methods. Our results thus corroborate those of previous investigations.

### 5.1. Limitations of the study and future research

This study has two main limitations. First, the sample we used contained only new housing units and thus did not reflect the whole Santiago housing market. A future study could include housing units of all ages, with unit age then becoming one of the explanatory variables. This would result in a model with better price predictions, more meaningful market segmentation and more accurate measures of variable importance.

The second limitation of our research has to do with spatial correlation of the model residuals, particularly in linear models estimated with OLS. This typically arises when one or more of the independent variables for a given geographical area are correlated with the corresponding

dependent variable. In a previous application of RF to housing price data, it was found that "RF reduces the training and validation spatial autocorrelation in model residuals for both buffer sizes than the OLS regression method (...) This result confirms that RF is recommended as a variable selection method for the hedonic equation" (Lasota, Luczak, Trawinski, 2011, p. 305). Since this reduction is a strictly empirical finding, further research is needed to put this apparent ability to reduce spatial autocorrelation on a firmer theoretical basis. This could be done using simulated data but a fuller investigation, both mathematical and based on machine learning theory, will also be required.

### 5.2. Conclusion

The results of this case study point to the great potential of machine learning for predicting housing prices. This corroborates the findings of earlier studies conducted for other cities. we conclude that ML techniques can provide a useful set of tools for acquiring information on housing markets. More research is needed to improve the results generated by ML techniques for housing price analyses and decision–making.

### 5.3. Conflicts of interest

The authors do not have any conflict of interest with the content of this paper.

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# Hidden Ripples: Forgotten Effects in the Synchronization of Business Cycles in Mercosur

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## Abstract

In this article we present a methodology for the evaluation of indirect effects in the synchronization of economies. Traditionally, the different indicators designed for the analysis of economic synchronization have focused on the pairwise comparison of a set of economies. Our work, based on the graph and forgotten effects theories, intends to give a systemic view of the synchronization process, identifying synergic clusters and indirect synchronization effects. We applied the methodology to the Mercosur countries, adding as control economies the USA, China and Iceland. In the analysis of our sample, the role of the US economy on Latin American countries is highlighted, observing significant relations both of first (direct synchronization) and second (indirect synchronization) order. We identified countries that serve as or can serve as risk attenuators, those who do not present direct or indirect significant synchronization with other economies in the sub-region. We can therefore conclude that this methodology is adequate for the systemic evaluation of the economic cycle synchronization, identifying synergies as well as indirect risk clusters.

## Key words

Business Cycle, Synchronization, Forgotten Effects, International economics.

## 1. Introduction

The economic cycle and its effects on the economy is a subject that has been widely studied since the beginning of the 21st century with many efforts dedicated to analyze the behavior of macroeconomic variables on this phenomenon. In some of the past studies, stylized facts have

been identified and corroborated in various economies of the world by widely known scholars (Burns and Mitchell, 1946; Moore and Zarnowitz, 1987). A topic that, however interesting, has been less studied is the relationship and dependencies between economies and how economic crises can spread internationally, with particular attention to the study of business cycles and their synchronization.

The 2008 economic crisis had interesting effects from the point of view of how international economic relations function, and of the non-homogeneity in its effects on different economies. On the one hand, it can be observed that the U.S. economy still plays a leading role at the international level, prompting responses all around the world, while on the other, the heterogeneity of response and recovery times was very visible, with clear lags in the propagation of the crisis (Dwyer and Lothian, 2012).

Examples of this case are the economies of Latin America and the Caribbean, hereafter referred to as LAC, where some countries hit by the crisis, such as Mexico and Chile, quickly recovered and returned to growth, unlike the economies in the EU such as Greece, Italy, Portugal and Spain, who are still suffering the effects of the crisis. Despite the severity and geographical extent of the crisis, it was also observed that there were countries that did not experience the crisis, or that its effects were so mild that their trend of long-term growth was almost unaffected, as was the case in Canada, Australia, China and Brazil (Mondaca, 2012). With regard to the explanations of the above situations, there are still debates on the actual extent of the crisis, its duration, and on the subject of our interest, whether the cause of the crisis was the behavior of the U.S. economy and its great impact on other economies, where the aftershock was felt with varying levels (Dwyer and Lothian, 2012).

This study aims at providing new information on two issues which we believe may be relevant to macroeconomic management at the international level. Firstly, to provide background for a better understanding of “significant” economic relations between countries that are visible in periods of economic crisis and can be understood as “first-order” relations; these relations can be studied from the perspective of classical business cycles (or level of cycles) and methodologies for determining synchronization between business cycles (Artis et al., 1995; Artis and Zhang, 1997; Wynne and Koo, 2000; Harding and Pagan, 2002; 2006; Crosby, 2003). Secondly, we aim at providing a new methodology that facilitates the study of indirect, collateral or “hidden” effects of the crisis between countries. These indirect effects, which can be understood as “second-order” relations, can be used to model the phenomenon of the crisis

propagation resulting from certain existing conditions that favor crisis transmission from a particular country to another, via a third one.

This methodology proposes to solve the problem of indirect effects that existing methodologies omit. These methods generally seek to determine the similarities between sets of countries at all times, thus, not capturing all the significant relationships that can be observed in periods of economic crisis or recession of economies. For example, there may be some set of economies that are very similar in their behavior in periods of normal or economic expansion, but not necessarily in periods of economic recession, and these brief periods, in general, are underestimated when considering the behavior of the time series for an extended period. In this sense, we propose to apply a new methodology derived from the forgotten effects theory (Kaufmann and Gil-Aluja, 1988), which analyzes the synchronization relationships between countries' economic cycles in order to find and visualize second-order relations or hidden effects, related to the behavior of the business cycle, particularly in periods of economic recession.

The structure of the paper is as follows: Section 1 introduces the study and its background. In section 2 we present a brief theoretical review about the synchronization between business cycles and the forgotten effects theory. In Section 3 we present the methodology to determine second order effects between cycles, using an index of synchronization between business cycles and graph analysis tools. In addition, Section 3 presents the sample of countries selected for the study and the data sources. Finally, in Section 4, we present the main conclusions of the study.

## 2. Theoretical Framework

### *Synchronization between cycles*

The phenomenon of the business cycle has been a topic of great interest, due to the effects they can have on the economic system. Because of its importance, research efforts have focused on a very general level, in three areas: its characterization and thorough analysis of its behaviors, focusing efforts on determining the frequency of occurrence of the phases (expansion and recession) and the behavior of the main macroeconomic variables; the proposal of theoretical models to help understand why such a phenomenon occurs in modern economies, and the identification of variables and relationships that help explain why there have been contractions and/or recessions in the growth of the economy; and the side that has focused its efforts, thanks to the knowledge gained in other areas of science, to build aggregate indexes or models to predict

the occurrence of a recession in the short term, commonly called leading indicators of economic cycle or early warning models (Mondaca, 2012).

Studies and evidence accumulated over the years have shown the occurrence of international crisis (Anas et al., 2008) caused by anomalous behavior in some economies (for example, the United States in 2007), and that these problems seem to be transmitted between countries (Dwyer and Lothian, 2012). The study of synchronization between business cycles has taken center stage in recent times and an example of this is the growing contributions to this topic using various methodologies (Loayza et al., 2001; Crosby, 2003; Harding and Pagan, 2006; Miink et al., 2007; Aguiar-Conraria et al., 2011; Akin, 2012; Rua, 2013).

The synchronization between business cycles has been investigated from various perspectives, methodologies and time series analysis, which has hampered comparability of the results presented by researchers. For example there is no agreement on whether analyzing classic economic cycle or levels or growth cycle or deviations from the trend. Others choose to analyze the behavior of growth rates and evaluate co-movements between countries. Furthermore, the methodologies are varied such as those presented by Artis et al (1995), and used in the procedure of Bry and Boschan (1971) to detect the turning points and later proposed the Pearson index for determining the degree of synchronization between two countries, using GDP series as reference. Or more elaborate, using the original proposal of Hamilton (1989) and extended the analysis to a multivariate one, and with that, able to determine the transitions in the change regime in a simultaneously way, using several series of one or more countries (Anas et al., 2006).

### *The theory of Forgotten Effects*

Given a graph with the first level of relationship between countries, our interest lies in identifying higher order or indirect relationships, those that occur through one or more nodes, and whose magnitude is not easily noticeable from the available information. In this case, we want to see if there is a higher order synchronization between economies, that is, if the economy of a country serves as a “bridge” in the synchronization between two economies, i.e., if the aftershock generated by an economy in crisis can be transmitted indirectly.

The forgotten effects theory was developed by Kaufmann andd Gil-Aluja (1988) in order to allow the identification of higher-order relations that are generated from a graph. Its application has been extended in different areas of management and economics, such as that carried on in (Gil-Lafuente, 2005; Anselin-Avila and Gil-Lafuente, 2009; Vizuete et al., 2013). The main tool

of the analysis conducted using this theory is the "maxmin" composition. In general, for two graphs represented as adjacency matrices $AB = (ab_{ij})_{nxm}$ and $BC = (bc_{jk})_{mxs}$, the maxmin composition matrix $AC' = (ac'_{ik})_{nxs}$ is defined as:

$$AC' = AB \circ BC, \tag{1}$$

Where:

$$ac'_{ik} = \max_{j=1,\ldots,m} \min(ab_{ij}, bc_{jk}), \text{i=1,…,n, k=1,…,s} \tag{2}$$

The matrix $AC'$ contains both first order (direct) as well as second order (indirect) effects. To isolate the second order effects, which we refer to as $AC^{(2)} = (ac_{ik}^{(2)})_{nxs}$, we need the matrix of first order effects $AC = (ac_{ik})_{nxs}$, so that:

$$AC^{(2)} = AC' - AC\,. \tag{3}$$

## 3. Data and Methods

### *Sample*

For this study, we selected a sample of six countries that make up the Mercosur in Latin America (Venezuela, VEN; Argentina, ARG; Brazil, BRA; Paraguay, PAR; Uruguay, URY; and Chile, CHL). We also added, as controls, three world economies; the USA and China (CHN) for their magnitude, and Iceland (ISL) for its low social, political and economic relationship with Latin America. We used the GDP at purchasing power parity, PPP of the database Penn World Table for business cycle analysis. To obtain the turning point for each country, we used the dated method proposed by Mondaca (2012) using the transformed wavelet to get the cyclical dating.

### *Evaluation of synchronism between cycles using Pearson's contingency coefficient*

To determine the synchronization between business cycles, we used one of the most widely accepted indices to study the co-movements between cycles: Pearson's contingency coefficent. This method chooses the cyclical chronology of the two reference series $y_1$ and $y_2$ and defines a binary variable for each of them, $y'_i, i = 1,2,$ such that the value 1 represents expansions and 0 recessions. These two variables act as the foundation for the contingency table showed in Table 1, and thus a revised version of Pearson's contingency coefficient is calculated as:

$$CC_{corr} = \sqrt{\aleph^2 / (N + \aleph^2)} \cdot (100 / \sqrt{5}) \quad (4)$$

Where N is the total amount of observations and $\aleph^2 = \sum_{i=1}^{2} \sum_{j=1}^{2} \frac{(n_{ij} - n_i n_j / N)^2}{(n_i n_j / N)}$ is the Pearson's statistic (Artis et al., 1997).

Table 1. Contingency table showing the construction of the contingency coefficient

| | $y_2$ expanding $(y_2'' = 1)$ | $y_2$ stagnating $(y_2'' = 0)$ |
|---|---|---|
| $y_1$ expanding $(y_1'' = 1)$ | $n_{11}$ | $n_{12}$ |
| $y_1$ stagnating $(y_1'' = 0)$ | $n_{21}$ | $n_{21}$ |

This index was the tool to analyze synchronization between business cycles used in (Artis et al., 1997; 1999; 2004; Mejía-Reyes, 2003). The independence on the contingency table is regarded as the absence of synchronization, and the index then equals 0. Conversely, if a complete dependency is found (one out of two diagonals in the table displays null values) thus, the synchronization will be at its maximum, although in this second case we might find pro-cyclical and counter-cyclical relations.

***First Order Effects***

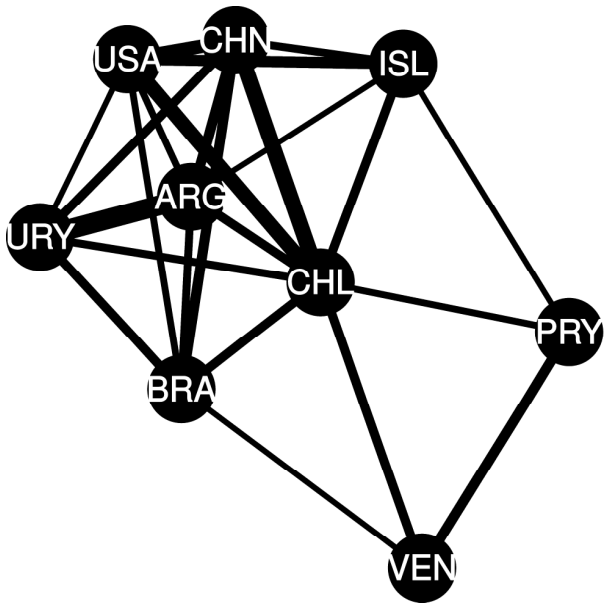
Table 2 shows the degree of synchronization according to Pearson's contingency coefficient in our sample countries between 1990 and 2010. This degree of synchronization as discussed in the theoretical section can also be seen as the degree of relationship between economies. If we set a threshold, which we have decided to place at 25% of synchronization of the evaluation period, we can obtain a graph of significant relationships (see Figure 1), so any relationship below the threshold is not shown. The degree of synchronization between two economies is shown by the thickness of the edge that connects them. In the following, we are going to present a numerical example of the new approach concerning political decision making problems.

Table 2. First order synchronization effects

| | VEN | ARG | BRA | PRY | URY | CHL | USA | ISL | CHN |
|---|---|---|---|---|---|---|---|---|---|
| VEN | 1 | .158 | .263 | .474 | .211 | .421 | .211 | .053 | .158 |
| ARG | | 1 | .368 | .158 | .947 | .421 | .316 | .263 | .474 |
| BRA | | | 1 | .158 | .421 | .421 | .316 | .053 | .474 |
| PRY | | | | 1 | .105 | .316 | .105 | .263 | .053 |
| URY | | | | | 1 | .368 | .263 | .211 | .421 |
| CHL | | | | | | 1 | .684 | .421 | .737 |
| USA | | | | | | | 1 | .526 | .632 |
| ISL | | | | | | | | 1 | .368 |
| CHN | | | | | | | | | 1 |

In this graph we can see that the maximum clique is that formed by Chile, Argentina, USA, China, Brazil and Uruguay. This implies that Mercosur largest economies, along with Uruguay, have a significant degree of synchronization with China and USA. What we see is that they form a synergic group in which their economies go right or wrong simultaneously a significant percentage of the time. From a systemic risk perspective, it will be important to further develop this line of research, in order to verify this behavior in periods of crisis, since the simultaneous investment in these economies could increase investor exposure. On the other hand, there is a maximal clique formed by Chile, Venezuela and Paraguay, which suggests that for Mercosur, it is important to introduce Venezuela and keep Paraguay since their asynchronous behavior with other members mitigates the systemic risk in the regional economy. Nevertheless, as time goes by it is expected there will be a development of synergic links between these countries and the remaining partners of Mercosur, so further analysis of their economic synchronization should be continuously carried out. Chile is the country with more significant first order synchronization edges, having a degree of 8. Chile is shown as a critical node within the sub-regional economy by serving as a gateway to all the other economies studied. USA and China have a degree of 6, which implies a significant influence on the behavior of the business cycle in Latin America, with similarities to a large majority of countries in the sample analyzed. Iceland, an economy in our control sample, only has similarity with the other control economies (USA and China) and Argentina and Chile in the Mercosur. Our objective was to introduce an economy that reflected this behavior to see how significant its second-order relations with the sub-region are.

Figure 1. Significant first order synchronization effects



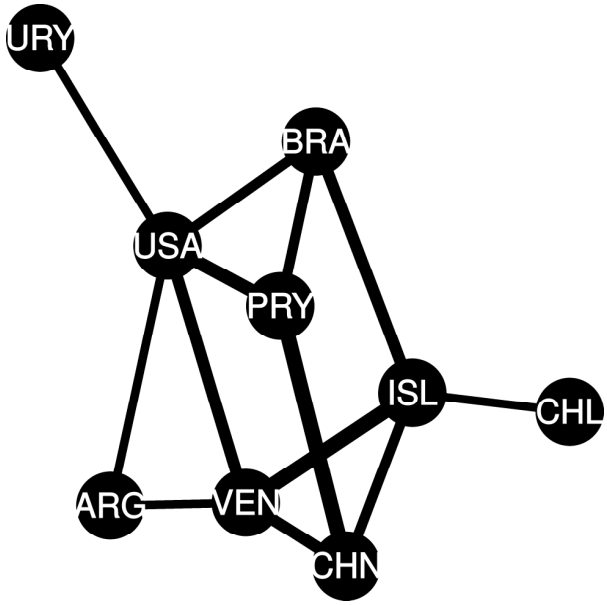

***Second Order Effects***

In Table 3 we can see the isolated effects of second order. The graph obtained from it, using the same threshold of the first order effects graph, is shown in Figure 2. The maximal cliques generated in this graph have no more than three elements, being the only interesting one in our analysis that formed by Venezuela, Argentina and USA. These three countries form an interesting synergic cycle, given the recent political dispute of the first two with the latter. It seems that rhetoric goes much less far in economic terms than common sense and the media lead us to believe.

Table 3. Second order relations

| | VEN | ARG | BRA | PRY | URY | CHL | USA | ISL | CHN |
|---|---|---|---|---|---|---|---|---|---|
| VEN | 1 | .263 | .158 | .053 | .211 | .211 | .368 | .474 | .368 |
| ARG | | 1 | .211 | .158 | .000 | .158 | .263 | .158 | .105 |
| BRA | | | 1 | .316 | .105 | .211 | .316 | .368 | .158 |
| PRY | | | | 1 | .211 | .211 | .421 | .105 | .474 |
| URY | | | | | 1 | .158 | .263 | .211 | .105 |
| CHL | | | | | | 1 | .105 | .263 | .000 |
| USA | | | | | | | 1 | .158 | .105 |
| ISL | | | | | | | | 1 | .316 |
| CHN | | | | | | | | | 1 |

Figure 2. Significant second order synchronization effects




In this graph, the USA is the country with the largest degree, as it has significant relations in the second order with 5 countries. Of these, we need to note those with Argentina, Uruguay and Brazil, as they had already appeared as first order relationships. This undoubtedly shows that the effect of the U.S. economy in these Latin American countries is very high, creating significant impacts, both directly and indirectly. By contrast, China has only either first order (with Argentina, Brazil, Chile and Uruguay) or second order (with Venezuela and Paraguay) effects on the Mercosur economies. Thus, U.S. economic fluctuations can be far more dangerous to the Mercosur that those of China. Paraguay has no significant synchronization effects with Brazil and Uruguay of either first or second order, while Venezuela has no second order synchronization relationship only with Uruguay. Among Mercosur economies, Venezuela is the country with the most significant second order synchronization links, although 75% of them correspond to the control countries. Chile, the country that had the highest degree in the first order relationship graph, appears isolated in the second order relationship graph but with significant synchronization effects with Iceland, with which it already had a significant first order relationship. We can see that Chile fulfills its role as the bridge of economic synchronization in the sub-region, allowing the emergence of second order relations, but itself lacking significant links at this order.

To conclude this discussion, it is important to note that this analysis can continue through to superior orders. However, with our data this graph has no significant third order effects. We

could conclude that the synchronization loses its "energy" from the third level onwards, i.e, all possible synchronization effects are either of the first or the second order.

## 5. Conclusions

The leading role of the U.S. economy in Latin America is unquestionable throughout this paper, with significant first and second order relationships in the sub-region. This implies that when the country suffers an economic crisis, it widely spreads, affecting all economies of Latin America. Its effect is direct in some Latin American countries, propagating indirectly to the remaining ones. The case of Argentina, Brazil and Uruguay, as members of Mercosur, with Chile, as an associate member, and their significant first order relations is interesting, due to the systemic risk that simultaneous investment in these countries would see. A special case that can be noted due to the high level of synchronization is that of Argentina and Uruguay. At the second order, this block has significant relationships with the remaining members (Paraguay and Venezuela). Nevertheless, Paraguay has no significant synchronization effects with Brazil and Uruguay of either first or second order, while Venezuela has no relationship with Uruguay. This can be seen as a strategy to hedge against crisis propagation, although with a common market more synchronization effects of both first and second order are expected to appear in the future. Finally, Chile can be considered as an element of regional stability to the extent that stable macroeconomic behavior, low level of relations with Mercosur member countries on their economic cycles, and many international trade links, position it as a strategic country that could reduce systemic risk in the region. However, its role as a synchronization "bridge" across the region and from the region with the rest of the World can also be inferred from our analysis.

We conclude that our approach is very useful in systemic analysis of economies and their synchronization effects, a problem difficult to assess beyond the direct effects that occur. In assessing higher order effects, we are able to identify feedback loops that amplify the adverse effects that appear in the first order. Furthermore, diversification of investment in countries with mixed synchronization effects of first and second orders exposes the investor to a risk that is not easy to see directly from the traditional synchronization analysis. In this sense, we hope to expand our work to assess synchronization effects relative to periods of crisis, creating a new methodology for systemic risk analysis.

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# The Chilean Experience with Chinese Cards Brands: Application of the Forgotten Effects Theory

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## Abstract

In this investigation we apply an instrument to the Chilean market to measure and check brand experience differences between Chinese car brands. Furthermore, we investigate the relationship between brand experience, brand personality, brand trust, satisfaction, and loyalty. The methodology used is the Theory of Forgotten Effects for evidencing the hidden effects. The study was applied in Chile to 25 Chinese automobile brands considering their market relevance, with a total final sample of 97 users. The findings from the proposed conceptual model helps to explain the forgotten effects that finally contribute in determining the indirect effects that should be considered when analysing the experience of emerging brands. The study proposed work fuzzy logic methodologies with the purpose of providing evidence regarding the importance of considering hidden effects when analysing brand experience of emerging brands in a market.

## Keywords

Brand Experience, Brand Personality, Brand Trust, Loyalty, Satisfaction, Chinese Car Brands, Fuzzy logic.

# 1. Introduction

In today's globalized world companies must maintain a fast globalized pace. It is therefore important to identify key aspects that enable companies to eliminate borders and offer their products anywhere in the world. Because of this companies are interested in tools that help them meet their market and brand experiences.

Academic research of brands has significantly advanced the study of the relationship, as well as the emotional connection, with the consumer establishing this relationship through constructs such as trust, commitment, loyalty, and emotional bonds (Esteban, Ballester, & Muñoz; 2014).

There are also studies that specifically focus on consumer experience regarding services (Morrison & Crane, 2007), or consumer experience with the functional attributes of a product (Alba & Hutchinson, 1987), but not consumer experience offered by a brand which may be sensory, emotional, cognitive, behavioral, or social complementing the functional attributes (Brakus, Zarantonello & Schmitt; 2009).

This paper aims to contribute to this line of research by providing empirical evidence that verifies and highlights the importance of a company offering brand experience, and the impact of that brand experience in the market. This study demonstrates how greater brand experience has effects on relevant variables such as brand trust, brand personality, satisfaction, and loyalty.

In the following sections of this study: it starts with a review of the existing literature and the presentation of hypotheses, continuing with the study methodology, followed by the corresponding analysis, and ends with the results and conclusions of the research.

# 2. Conceptual framework

Brand experience has attracted much attention in marketing practice; understanding how consumers experience brands is essential for developing marketing strategies for products and services. Interest exists regarding the experiential aspects and the fact that, from a functional point of view, in many product categories there are many similar offerings making it difficult to differentiate between them (Brakus, Schmitt, & Zhang; 2008). This has led companies to seek and create experiences (Carú & Cova, 2003) for differentiating non-functional aspects of a product.

Therefore, offering experiences beyond the use of a product can result profitable for a company (Pine & Gilmore, 1998). In other words, the use of brand experience as a differentiation strategy is an opportunity for companies.

The study of Brakus et al. (2009) conceptualized and developed a scale for measuring brand experience. According to these authors, when consumers search, buy, use, or consume brands they are not only exposed to functional attributes but also to experiential attributes related to brand identity and design (packaging, color, logo, shape, etc.), as well as the environment and the way the product is sold (shops, events, websites, advertising, etc.).

The study focuses on four key behavioral outcomes: satisfaction, customer loyalty, brand personality and brand trust (Chandrashekaran, Rotte, Tax, & Grewal, 2007; Oliver, 1993). Unlike previous studies, we expect brand experience to affect these behavioral outcomes through direct and indirect relationships (Chaiken & Eagly, 1989; Petty & Cacioppo, 1986). If a brand evokes an experience this can only lead to satisfaction, loyalty, and trust. Additionally, the experience can be the base for elaborate information processing making inferences that result in associations related to the brand (Keller, 1993).

*Development of Hypotheses*

In this section we analyzed the effects of brand experience on brand personality, satisfaction, loyalty, and brand trust in the context that experiences are the result of stimuli and lead to positive results. This leads to the expectation that consumers will want to repeat the experience, not only generating consumer satisfaction, but also consumer loyalty (Brakus et al., 2009).

A large part of the literature appears to suggest that emotional and cognitive experiences are likely to be key in influencing consumer satisfaction and loyalty (Oliver, 1993; Phillips & Baumgartner, 2002; Bigné, Andreu & Gnoth, 2005). Other authors have studied measuring customer experience and its relationship in delivering customer satisfaction, thus boosting customer loyalty (Thompson, 2006; Frow & Payne. 2007; Kamaladevi, 2010; Johnston & Kong, 2011). Taking the aforementioned into consideration, it's possible to propose the following hypotheses:

H1: Brand experience positively affects consumer satisfaction.

H2: Brand experience positively affects consumer loyalty.

Brand personality has been discussed as a key concept in branding; this concept refers to the set of human characteristics that consumers associate with the brand (Aaker, 1997). It is important to consider that brand experience, as well as judgments regarding brand personality, increases when the consumer has contact with the brand (Johar, Sengupta & Aaker, 2005).

Aaker (1997) states that the personality of a brand can be derived from those parties associated with a consumer brand such as users, sales representatives, brokers, and others, or the attributes of the product such as brand name, product category, communications, and others.

Based on the Brakus et al. (2009) study, brand experience is expected to be a precursor of brand personality. In the brand experience scale, the higher the overall score the more likely that the consumer will associate it with brand personality.

The perception of brand personality can be created and shaped by the experiences of consumers with the brand (Plummer, 1985); (Shank & Langmeyer, 1994). Therefore, the brand experience is a factor preceding brand personality (Kim, Lee and Suh, 2015). Taking the aforementioned into consideration, it's possible to propose the following hypothesis:

H3: Brand experience positively affects brand personality.

A well-established brand personality inspires strong affection among consumers (Caprara, Barbaranelli, & Guido, 2001) and reduces any emotional risk during the purchasing process resulting in the development of greater trust and satisfaction, especially when consumers believe that the brand supports their needs (Blackston, 1993).

Several studies have found the link between brand personality and customer loyalty (Fournier, 1998; Villegas, Earnhart & Burn, 2000; Zentes, Morschett & Schramm, 2008; Das, 2014). In fact, according to Kim, Magnini, and Singal (2011) brand personality has a positive and direct effect on loyalty, and Kim et al. (2015) mentioned that the greater self-expression generated through client-brand relationship, in other words, the more the personality of the brand personality consumer related, the higher the satisfaction and consumer loyalty. Taking the aforementioned into consideration, it's possible to propose the following hypotheses:

H4: Brand personality positively affects consumer satisfaction.

H5: Brand personality positively affects consumer loyalty.

Additionally, it has been shown that customer satisfaction affects loyalty; in other words, when a consumer feels good about a product or brand the result is a high level of commitment and loyalty (Anderson & Sullivan, 1993; Oliver, 1997; Mittal & Kamakura, 2001; Brakus et al. 2009).

Empirical studies supporting the positive relationship between consumer satisfaction and consumer loyalty can be found in: Yoon and Uysal (2005); Lin and Wang (2006); Nam, Ekinci, and Whyatt (2011); Chen (2012); Chen and Phou (2013); Wong (2013); Alwi and Kitchen (2014). Taking the aforementioned into consideration, it's possible to propose the following hypothesis:

H6: Consumer satisfaction positively affects consumer loyalty.

Regarding the development of brand trust (Rempel, Holmes, & Zanna, 1985) suggests that trust develops from past experience and previous consumer interaction with the brand.

Trust is essential in building strong consumer-brand relationships (Fournier, 1998); (Urban, Sultan, & Qualls, 2000) , which implies a willingness by consumers to take the risk, as confidence on the promise of value that the brand offers (Delgado-Ballester, Munuera-Alemán, & Yagüe-Guillén, 2003). Consumers develop brand trust based on positive beliefs about their expectations of the behavior of the organization and operation of the products the brand offers (Ashley & Leonard, 2009).

Brand trust can be seen as a leverage of credibility, which in turn can help reinforce the repeat purchase behavior of consumers (Amine, 1998) since such consumers are more willing to accept a new product of a brand they trust and thus perceive as technically competent (Gurviez & Korchia, 2003). Taking the aforementioned into consideration, it's possible to propose the following hypothesis:

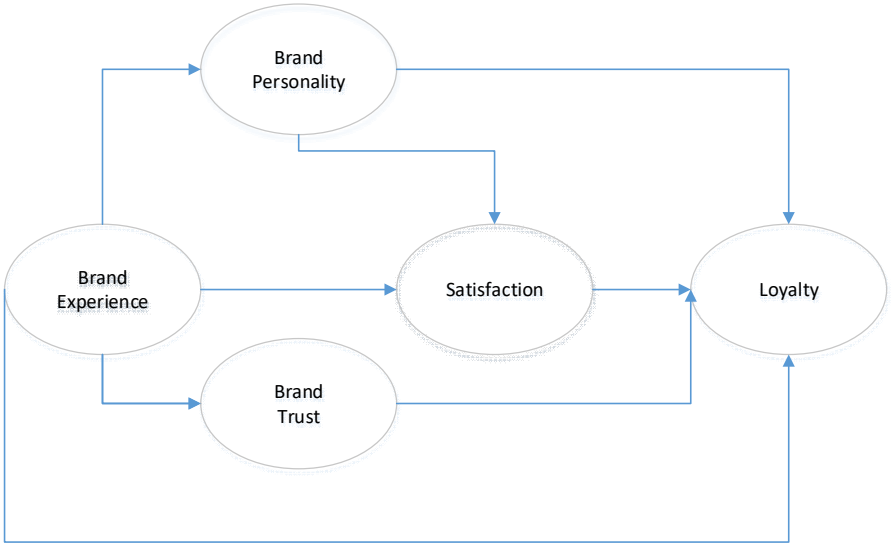
H7: Brand Experience positively affects brand trust.

Brand trust is identified as a key variable in developing brand loyalty and therefore brand value (Delgado-Ballester & Munuera-Alemán, 2005). Therefore, a consumer that trusts a brand is more likely to remain loyal, to pay a higher price, to buy new products introduced by the brand, and share information about his or her preferences and behaviors (Chaudhuri & Holbrook, 2001). Taking the aforementioned into consideration, it's possible to propose the following hypothesis:

H8: Brand Trust positively affects consumer loyalty.

From all the relations described above we constructed the following research model (Figure 1).

**Figure 1.** Conceptual model




Source: Based on Brakus et al. (2009), Aaker (1996), and Pappu, Quester & Cooksey. (2005, 2006)

# 3. Methodology

The analysis tool used to collect the data was a survey. This survey was taken on consumers of Chinese car brands in Chile. The sample was not probabilistic, specifically for trials. Our sample size was 97 users of Chinese car brands. Each participant rated the extent to which the items on the survey described his or her experience with the specific brand, the personality of the brand, and their feelings of satisfaction, loyalty, and trust towards the brand.

*Sample Description*

Regarding the data, we considered the profile description of consumers of Chinese brands that participated in the study. The characteristics of consumers in terms of gender: male, 59%; female, 41%. Schooling; 68% degree. The principal brand of car they have is: CHERY (15,5%), GREAT WALL(15,5%), MG (12,4%), JAC(11,3%), FOTON (10,3%), BYD (9,3%), among others. Main reason for purchase: Desing (38,1), price (30,9%), Quality / Price (11,3%).

*Theory of Forgotten Effects*

Below is a theoretical description of the methodology for the ob-retention of the forgotten in order to establish the framework for the calculation of the relationships among variables effects model is proposed.

Where C = $\{c_1, c_2,\ldots, c_n\}$ a set of causes, and, y E = $\{e_1, e_2,\ldots, e_m\}$ a set of effects, the impact of the elements of C on the elements of E, $(c_i, e_j) = \mu_{ij}$, can be valued in the range [0, 1], where the value assigned greater the more intense the effect. So that:

$$\mu_{ij} \in [0, 1]; \qquad i = 1, 2,\ldots, n; \; j = 1, 2,\ldots, m$$

Then it has an incidence matrix $[\tilde{M}]$ as follows:

$[\tilde{M}] =$

| | $e_1$ | $e_2$ | … | | $e_m$ |
|---|---|---|---|---|---|
| $c_1$ | $\mu_{11}$ | $\mu_{12}$ | … | | $\mu_{1m}$ |
| $c_2$ | $\mu_{21}$ | $\mu_{22}$ | … | | $\mu_{2m}$ |
| … | … | | … | | … |
| $c_n$ | $\mu_{n1}$ | $\mu_{n2}$ | | | $\mu_{nm}$ |

Todo $\mu_{ij}$, c = 1, 2,…, n; j = 1, 2,…, m It represents the direct or first degree incidence of causes ($c_i$), the effects ($e_j$). But, as is known, the direct impact is only part of the to-tal impact and, on many occasions is only a small part. And so, as a result of causal relationships between each other and causes the effects together. These relations of incidence of the causes of the causes and effects effects can also be expressed by fuzzy relations such as the following:

$c_1$ $c_2$ … $c_n$

$[\widetilde{C}] =$

| | | | | |
|---|---|---|---|---|
| $c_1$ | $\alpha_{11}$ | $\alpha_{12}$ | … | $\alpha_{1n}$ |
| $c_2$ | $\alpha_{21}$ | $\alpha_{22}$ | … | $\alpha_{2n}$ |
| … | … | … | … | … |
| $c_n$ | $\alpha_{n1}$ | $\alpha_{n2}$ | ... | $\alpha_{nn}$ |

$[\widetilde{E}] =$

| | $e_1$ | $e_2$ | … | $e_m$ |
|---|---|---|---|---|
| $e_1$ | $\beta_{11}$ | $\beta_{12}$ | … | $\beta_{1m}$ |
| $e_2$ | $\beta_{21}$ | $\beta_{22}$ | … | $\beta_{2m}$ |
| … | … | … | … | … |
| $e_m$ | $\beta_{m1}$ | $\beta_{m2}$ | … | $\beta_{mm}$ |

Where we have:

$$\forall (c_i, c_k) \in [\widetilde{C}]: \alpha_{ik} \in [0,1]; i = k: \alpha_{ii} = 1$$

$$\forall (e_j, e_l) \in [\widetilde{E}]: \beta_{jl} \in [0,1]; j = l: \beta_{jj} = 1$$

Convolution $[\widetilde{C}] \circ [\widetilde{M}] \circ [\widetilde{E}]$ get used to write $[\widetilde{M}^*]$.The fuzzy relation $[\widetilde{M}^*]$ expresses the cumulative effects of first and second generation.

In order to obtain the cumulative effects of first and second generation estimated assuming the fuzzy relations $[\widetilde{M}]$, $[\widetilde{C}]$, $[\widetilde{E}]$.So we'll call $\upsilon (c_1, e_1)$ the corresponding assessment box $(c_1, e_1)$ result; $\upsilon (c_1, e_2)$ that of $(c_1, e_2)$, etc. So that we have:

$\upsilon (c_1, e_1) = (\alpha_{11} \wedge \mu_{11}) \vee (\alpha_{12} \wedge \mu_{21}) \vee \ldots \vee (\alpha_{1n} \wedge \mu_{n1})$

$\upsilon (c_1, e_2) = (\alpha_{11} \wedge \mu_{12}) \vee (\alpha_{12} \wedge \mu_{22}) \vee \ldots \vee (\alpha_{1n} \wedge \mu_{n2})$...

$\upsilon (c_i, e_j) = (\alpha_{i1} \wedge \mu_{1j}) \vee (\alpha_{i2} \wedge \mu_{2j}) \vee \ldots \vee (\alpha_{in} \wedge \mu_{nj})$

...

$\upsilon (c_n, e_m) = (\alpha_{n1} \wedge \mu_{1m}) \vee (\alpha_{n2} \wedge \mu_{2m}) \vee \ldots \vee (\alpha_{nn} \wedge \mu_{nm})$

It is obtained and a fuzzy relation can be considered as a global semi-convolution. For simplicity, it is replaced $\upsilon (c_i, e_j)$ por $\upsilon ij$, i = 1, 2,..., n; j = 1, 2,..., m.

$[\widetilde{C}] \circ [\widetilde{M}] =$

| | $e_1$ | $e_2$ | … | $e_m$ |
|---|---|---|---|---|
| $c_1$ | $\upsilon_{11}$ | $\upsilon_{12}$ | … | $\upsilon_{1m}$ |
| $c_2$ | $\upsilon_{21}$ | $\upsilon_{22}$ | … | $\upsilon_{2m}$ |
| … | … | … | … | … |
| $c_n$ | $\upsilon_{n1}$ | $\upsilon_{n2}$ | … | $\upsilon_{nm}$ |

A new convolution is performed, this time using the obtained relationship ($[\widetilde{C}] \circ [\widetilde{M}]$) with the fuzzy relation $[\widetilde{E}]$to obtain $[\widetilde{C}] \circ [\widetilde{M}] \circ [\widetilde{E}]$.If designated by $\omega (c_1, e_1)$,…, $\omega (c_n, e_m)$ the resulting valuations relative boxes $(c_1, e_1)$, $(c_1, e_2)$,…, $(c_n, e_m)$. So that it has:

$\omega (c_1, e_1) = (\upsilon_{11} \wedge \beta_{11}) \vee (\upsilon_{12} \wedge \beta_{21}) \vee \ldots \vee (\upsilon_{1n} \wedge \beta_{n1})$

$\omega (c_1, e_2) = (\upsilon_{11} \wedge \beta_{12}) \vee (\upsilon_{12} \wedge \beta_{22}) \vee \ldots \vee (\upsilon_{1n} \wedge \beta_{n2})$

...

$\omega (c_i, e_j) = (\upsilon_{i1} \wedge \beta_{1j}) \vee (\upsilon_{i2} \wedge \beta_{2j}) \vee \ldots \vee (\upsilon_{in} \wedge \beta_{nj})$

...

$\omega (c_n, e_m) = (\upsilon_{n1} \wedge \beta_{1m}) \vee (\upsilon_{n2} \wedge \beta_{2m}) \vee \ldots \vee (\upsilon_{nn} \wedge \beta_{nm})$

These results provide the overall convolution. If substitute for simplification purposes $\omega (c_1, e_1)$, $\omega (c_1, e_2)$,.., $\omega (c_n, e_m)$ respectively $\omega_{11}$, $\omega_{12}$,…, $\omega_{nm}$, You can present the results cited in matrix form as follows:

$[\widetilde{M}^*] = [\widetilde{C}] \circ [\widetilde{M}] \circ [\widetilde{E}] =$

| | $e_1$ | $e_2$ | … | $e_m$ |
|---|---|---|---|---|
| $c_1$ | $\omega_{11}$ | $\omega_{12}$ | … | $\omega_{1m}$ |
| $c_2$ | $\omega_{21}$ | $\omega_{22}$ | … | $\omega_{2m}$ |
| … | … | … | … | … |
| $c_n$ | $\omega_{n1}$ | $\omega_{n2}$ | … | $\omega_{nm}$ |

# 4. Empirical Results: The Forgotten Effects Theory

The correlations between each of the observables allows determiner incidents on each other. On the "causes", the items in each of the independent variables, and "effects", each of the items in the dependent variables, you can estimate the relations on the specimen by using the Forgotten Effects.

For example, the relationship between Brand and Brand Experience Personality is calculated for this incident matrices and convolution develop, as can be observed:

Matrix and incidents between causes $[\widetilde{C}]$

| | BE1 | BE2 | BE3 |
|---|---|---|---|
| BE1 | 0.451 | 0.707 | 1.000 |
| BE2 | 0.596 | 1.000 | 0.707 |
| BE3 | 1.000 | 0.596 | 0.451 |

Matrix and incidents between effects $[\widetilde{E}]$

| | BP1 | BP2 | BP3 | BP4 | BP5 |
|---|---|---|---|---|---|
| BP1 | 1.000 | 0.702 | 0.672 | 0.671 | 0.630 |
| BP2 | 0.702 | 1.000 | 0.697 | 0.696 | 0.653 |
| BP3 | 0.672 | 0.697 | 1.000 | 0.667 | 0.626 |
| BP4 | 0.671 | 0.696 | 0.667 | 1.000 | 0.625 |
| BP5 | 0.630 | 0.653 | 0.626 | 0.625 | 1.000 |

Matrix and incidents between causes and effects $[\widetilde{M}]$

| | BP1 | BP2 | BP3 | BP4 | BP5 |
|---|---|---|---|---|---|
| BE1 | 0.275 | 0.286 | 0.274 | 0.273 | 0.256 |
| BE2 | 0.364 | 0.377 | 0.362 | 0.361 | 0.339 |
| BE3 | 0.192 | 0.299 | 0.299 | 0.274 | 0.356 |

Semi-convolution matrix $[\widetilde{C}] \circ [\widetilde{M}]$

| | BP1 | BP2 | BP3 | BP4 | BP5 |
|---|---|---|---|---|---|
| BE1 | 0.364 | 0.377 | 0.362 | 0.361 | 0.356 |
| BE2 | 0.364 | 0.377 | 0.362 | 0.361 | 0.356 |
| BE3 | 0.364 | 0.377 | 0.362 | 0.361 | 0.356 |

Convolution matrix $[\widetilde{M}^*] = [\widetilde{C}] \circ [\widetilde{M}] \circ [\widetilde{E}]$

| | BP1 | BP2 | BP3 | BP4 | BP5 |
|---|---|---|---|---|---|
| BE1 | 0.377 | 0.377 | 0.377 | 0.377 | 0.377 |
| BE2 | 0.377 | 0.377 | 0.377 | 0.377 | 0.377 |
| BE3 | 0.377 | 0.377 | 0.377 | 0.377 | 0.377 |

In this analysis we calculate the correlations between each of the observable variables to determine their impact on each other. Taking into account the items that make up each of the independent variables as causes, and each of the items in the dependent variables as effect, we can estimate the relations established in the model by using the forgotten effects theory.

Thus it can be seen that the average ratio between Brand Experience and Brand Personality is 0.377, that is, each of the items (causes) used to build the variable Brand Experience affects 37.7% on each of the items (effects) used to build the variable Brand Personality.

If the calculations for each of the relationships between variables in the established model are made, the estimates of the total effects of these variables are obtained as seen in Table 2. When the direct effects obtained from the structural equation model are subtracted from the total effect, the forgotten effects among the variables of the model are obtained (Table 2).

**Table 2.** Incidence of Independent Variables over Dependent Variables.

| Independent Variable | Dependent Variable | Total Effects (Convolutions) | Regression Weights (SEM) | Forgotten Effects |
|---|---|---|---|---|
| Brand Experience | Brand Personality | 0.377 | 0.299 | 0.078 |
| Brand Experience | Satisfaction | 0.000 | -0.213 | 0.213 |
| Brand Experience | Brand Trust | 0.277 | 0.176 | 0.101 |
| Brand Experience | Loyalty | 0.184 | 0.000 | 0.184 |
| Brand Personality | Satisfaction | 0.179 | 0.000 | 0.179 |
| Brand Personality | Loyalty | 0.599 | 0.594 | 0.005 |
| Brand Trust | Loyalty | 0.365 | 0.467 | -0.102 |
| Satisfaction | Loyalty | 0.034 | 0.000 | 0.034 |

Source: Authors

In view of the results it can be seen that the total effect of brand experience on loyalty (0.184). This is due to the fact that indirect effects of brand loyalty on brand experience are important. The extent of the forgotten for each model effect relationship can also be seen.

# 5. Conclusions

Nowadays companies need to build up, maintain, and boost their links with customers. All of this is possible by creating marketing strategies based on brand experiences. The importance of companies having a highly experiential brand is that in the business world product offerings in each category are very similar so companies must offer attractive experiential benefits rather than functional.

The methodology of Forgotten Effects integrates the interactions between the items of independent variables and interactions between dependent variables of the model to get the overall incidence of the proposed relationships. Then, the results differ of the regression weights based on a structural equation modelling analysis

The fact that indirect effects of brand loyalty on brand experience are important, and they were identified by the theory of forgotten effects.

The most purchased brands in the survey are: CHERY, GREAT WALL, MG, JAC, FOTON, and BYD. On a scale of 1 to 7 the average evaluation of the experience with these brands is 4.3, implying that the experience has been regular. The main reason for purchasing was design and price.

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# Efficient Work Teams through Fuzzy Relations

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## Abstract

This paper proposes a methodology that uses dynamic programming based on complementary accumulated frequencies (expertons in fuzzy logic), to determine the optimal number of persons for labor tasks. Optimality is determined by hiring costs and excess personnel in the company. The proposed method is supported by the theory of forgotten effects, in decision making, implemented as products of max-min fuzzy matrices.

**Keywords:** expertons, forgotten effects, fuzzy logic, dynamic programming.

## 1. Introduction

This paper is composed of 1) introduction, 2) description of the methodology, in the first stage dynamic programming is used to obtain the optimal number of persons for each time period; in the second stage we apply fuzzy sets and matrices, known as forgotten effects. This is accomplished through max-min matrices and the association of indirect sets. 3) A study case, a plant of fat acids in the area of sterilization-bottling at "QUIMIC S. A. de C. V." in Morelia, Michoacán.

## 2. Proposed Methodology

The proposed methodology consists of heuristic strategies with operations research tools with fuzzy matrices and the application of fuzzy operators in related sets. First, we analyze the existing relation between the cost to hire people and the cost incurred when you hire persons in excess. For

this reason, the first weeks of activities we need to hire people according to the activities specified by the contract and position. In the second part, we present the costs associated to productivity and to productivity associated to customer's and inverstors' satisfaction. All this is determined using forgotten effects.

### *2.1 (Fuzzy) Dynamic Programming*

According to [Taha H. A. 2004], in some construction projects, hiring and firing keep the task force to satisfy the project's needs. Since hiring and firing convey additional costs, we try to maintain the working force to satisfy the market demand, which variable and uncertain. Thus, it is necessary to fuzzify the number of persons in the work area to perform their functions and satisfy the commercial requirements [Chávez et al. 2012].

According to [Taha H. A. 2004], projects execute during n weeks and the minimum work force in week *i* is $b_i$ workers. The ideal working conditions for the process are that the work force for week *i* be exactly $b_i$. Nonetheless, according to costs, it may be more cost efficient to let the size of the work force fluctuate. Since $x_i$ is the number of employees in week *i*, in that same week we generate the costs:

$C_1(x_i - b_i), cost\ of\ maintaining\ excess\ personnel$ (1)

$C_2(x_i - x_{i-1}), cost\ of\ integrating\ the\ work\ team$ (2)

$where: (x_i - x_{i-1})\ excess\ personnel\ personal\ adicional.$

Therefore, the dynamic programming model is defined as

1. Stage *i* is represented by *i, i=1, 2, 3…n.*
2. The alternatives in stage *i* are $x_i$, the number of persons for the team on week *i*.
3. The state on each *i* is represented by the number of available workers on stage (week) $i - 1$, which is $x_{i-1}$.

The recursive equation is:

$$f_i(x_{i-1}) = \lim_{x_i \geq b_i} \{C_1(x_i - b_i) + C_2(x_i - x_{i-1}) + f_{i+1}(x_i)\}, i = 1, 2 \ldots n \quad (3)$$

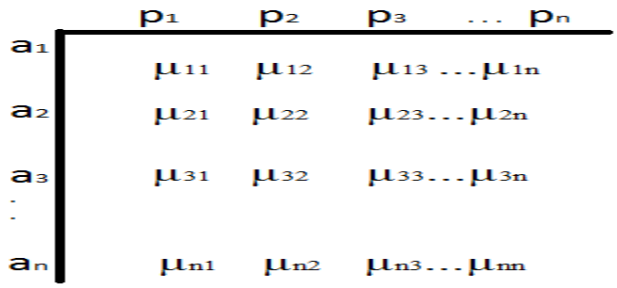
$$f_{i+1}(x_n) \equiv 0 \quad (4)$$

The computation starts in stage *n*, with $x_n = b_n$, and finish at stage 1.

### *2.2 Forgotten Effects (Fuzzy Logic)*

The association of sets and their relations is fundamental to modify the first assumptions about the number of workers assigned to operational areas (dynamic programming), particularly in those cases where a great amount of eventuality in the workers is present. According to [Gil A.J. 1999], we have adopted the term association, meaning the relation with other kind of connection whose knowledge and information is sparse. Gil ends saying that the latter resides on matrix representations. Let C be a set of entities that represent the hiring and firing costs: $C = \{c_1, c_2, c_3, \dots, a_n\}$, and P be a set of productivity: $P = \{p_1, p_2, p_3, \dots, p_n\}$. In matrix form:

Figure 1. Set Matrix




When you limit the relation force [Gil A.J. 1998], the assumption of the existence or not of it relies on $\mu_{ij} \in [0,1]$. The graph induced by the matrix can be solve in Boolean form. For the cases where there is uncertainty in the relation, the value lies in the interval [0, 1]. There may exist a relation among several sets, where one of them can be in the interface of the relation, as shown in Figure 2.

Figure 2. Associations among sets A, B, and C.

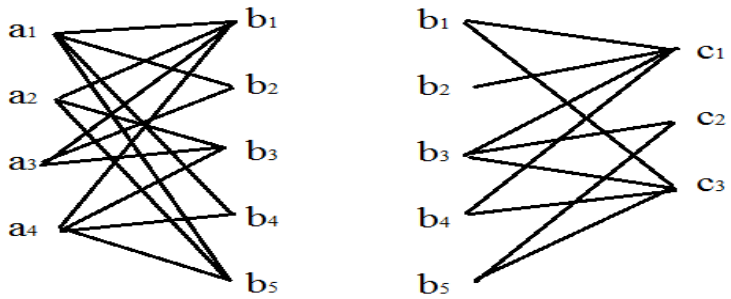


Figure 2, shows the relation of set A = {$a_1$, $a_2$, $a_3$… $a_n$} with set B = {$b_1$, $b_2$, $b_3$… $b_n$}, which in turn is related to set C = {$c_1$, $c_2$, $c_3$… $c_n$}. By transitivity, we can establish the relation between set A and set C.

The point is that using set theory we can relate (learn) when we make reflexions about the same set. When you have a fuzzy graph $G \in E\ x\ E$, what you have is a relation $R(x,y),\ x,y\ \in E$ [Gil A., J. 1998, 2002]. The graph shows a unitary diagonal by the reflexive property:

$\forall\, a_i \in E, i = 1, 2, \dots, n$

$\mu_{a_i a_j} = 1, si\ i = j$

$$\mu_{a_i a_j} \in [0,1], si\ i \neq j$$

We consider reflexive relations as Boolean matrices, which are independent sets. In those cases where association is fuzzy, is when the sets are independent (there exists an intersection between them). The product of fuzzy matrices are combined with $max - min$ operators. For vectors, for instance, the product:

$$\bigvee\left(\mu(a_1,b_2) \bigwedge \mu(b_2,c_1)\right), \bigvee\left(\mu(a_1,b_3) \bigwedge \mu(b_3,c_1)\right), \bigvee\left(\mu(a_1,b_4) \bigwedge \mu(b_4,c_1)\right), etc.$$

When working with fuzzy matrices, we can consider a 11-valued scale, as show in Figure 3:

Figure 3. 11-valued incidence or association scale.

| No incidence | Practically no incidence | Almost no incidence | Very weak incidence | Weak incidence | Medium incidence | Sensible Incidence | Vast incidence | Strong incidence | Very strong incidence | The greatest incidence |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |

Taking into account the set relation, they are used to determine the number of persons needed to perform the duties in the work area. So, $C = \{c_1, c_2, c_3, \dots, c_n\}$, is the set of persons assigned for the task. This set is related to the productivity set: $B = \{p_1, p_2, p_3, \dots,\ p_n\}$, which in turn is relate to the customer-investor satisfaction set: $S = \{s_1, s_2, s_3, \dots,\ s_n\}$. Finally, we need to find the $C \in S$.

## 3. Study Case

Experts suggest to assign a number of people to a task in a confidence interval, since we do not know the exact number of persons capable of satisfying the market demand. The chosen intervals

will remain the following five weeks of the project. During those weeks the fat acids plant (QUIMIC S. A. de C. V.) will be producing Glyceryl Stearate. As demand grows the number of people required increases, or decreases, if demand decreases.

Table 1. Confidence Intervals for the number of persons assigned per week by the group of experts.

| Week | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| No. of persons | 4, 5, 6 | 3 | 8 | 4, 5, 6 | 7 |

The excess of personnel has a cost of $4,000.00 per worker per week. Hiring a new worker has a fixed cost of $4,500.00, plus $3,000.00 per work per week.

Solution: In the first state, dynamic programming is applied to optimize the number of persons hired. This is done at three levels: lower, medium, and higher, assigned by the experts. After that, we apply forgotten effects (fuzzy logic) to determine the relation of the set of hiring and firing costs with customer and investor satisfaction.

In the following equations, consider thousands of pesos:

$$C_1(x_i - b_i) = 4(x_i - b_i),\ x_i > b_i \quad (1)$$

$$C_2(x_i - x_{i-1}) = 4.5 + 3(x_i - x_{i-1}),\ x_i > x_{i-1} \quad (2)$$

$$f_i(x_{i-1}) = \min_{x_i \geq b_i}\{C_1(x_i - b_i) + C_2(x_i - x_{i-1}) + f_{i+1}(x_i)\} \quad (3)$$

$$f_{i+1}(x_n) \equiv 0 \quad (4)$$

Where $x_n = b_n$ and the process starts at the final stage.

*For to week 5:*

Table 2. *Lower value (b = 7)* First Calculation on Week 5.

| $f_5(x_4) = C_1(x_5 - 7) + C_2(x_5 - x_4) + f_6(x_5)$ | | | Optimal Solution | |
|---|---|---|---|---|
| $X_4$ | $x_5=5$ | | $f_5(x_4)_{inf}$ | $x_5^*{}_{inf}$ |
| 4 | $4(0) + [4.5 + 3(7-4)] + 0$ | | 13.5 | 7 |
| 5 | $4(0) + [4.5 + 3(7-5)] + 0$ | | 10.5 | 7 |
| 6 | $4(0) + [4.5 + 3(7-6)] + 0$ | | 7.5 | 7 |
| 7 | $4(0) + [0] + 0$ | | 0 | 7 |

Table 3. Average value (b = 7)

| $f_5(x_4) = C_1(x_5 - 7) + C_2(x_5 - x_4) + f_6(x_5)$ | | | Optimal Solution | |
|---|---|---|---|---|
| $X_4$ | $x_5$=7 | | $f_5(x_4)_m$ | $x_5{}^*_m$ |
| 5 | $4(0) + [4.5 + 3(7-5)] + 0$ | | 10.5 | 7 |
| 6 | $4(0) + [4.5 + 3(7-6)] + 0$ | | 7.5 | 7 |
| 7 | $4(0) + [0] + 0$ | | 0 | 7 |

Table 4. Higher value (b=7)

| $f_5(x_4) = C_1(x_5 - 8) + C_2(x_5 - x_4) + f_6(x_5)$ | | Optimal Solution | |
|---|---|---|---|
| $X_4$ | $x_5$=8 | $f_5(x_4)_m$ | $x_5{}^*_m$ |
| 6 | $4(0) + [4.5 + 3(7-6)] + 0$ | 7.5 | 7 |
| 7 | $8(0) + [0] + 0$ | 0 | 7 |

For to week 4.

Table 5. Lower value (b = 4)

| $f_4(x_3) = C_1(x_4 - 4) + C_2(x_4 - x_3) + f_5(x_4)$ | | | | | Optimal Solution | |
|---|---|---|---|---|---|---|
| $X_3$ | $X_4$=4 | $X_4$=5 | $X_4$=6 | $X_4$=7 | $F_4(x_3)_{inf}$ | $X_4{}^*_{inf}$ |
| 8 | $4(0) + [0] + 13.5 = 13.5$ | $4(1) + [0] + 10.5 = 14.5$ | $4(2) + [0] + 7.5 = 15.5$ | $4(3) + [0] + 0 = 12$ | 12 | 7 |

Table 6. Average value (b = 5)

| $f_4(x_3) = C_1(x_4 - 5) + C_2(x_4 - x_3) + f_5(x_4)$ | | | | Optimal Solution | |
|---|---|---|---|---|---|
| $X_3$ | $X_4$=5 | $X_4$=6 | $X_4$=7 | $f_5(x_3)_m$ | $X_4{}^*_m$ |
| 8 | $4(0) + [0] + 10.5 = 10.5$ | $4(1) + [0] + 7.5 = 11.5$ | $8(2) + [0] + 0 = 16$ | 10 | 5 |

Table 7. Higher value (b=6)

| $f_4(x_3) = C_1(x_4 - 6) + C_2(x_4 - x_3) + f_3(x_4)$ | | | Optimal Solution | |
|---|---|---|---|---|
| $X_3$ | $X_4$=6 | $X_4$=7 | $F_4(x_3)_{sup}$ | $X_4^*{}_{sup}$ |
| 8 | $4(0) + [0] + 7.5 = 7.5$ | $8(1) + [0] + 0 = 8$ | 7.5 | 6 |

For to week 3.

Table 8. Only value (b=8)

| $f_3(x_2) = C_1(x_2 - 8) + C_2(x_2 - x_2) + f_4(x_2)$ | | Optimal Solution | |
|---|---|---|---|
| $X_2$ | $X_3$=8 | $F_3(x_2)$ | $X_3$* |
| 3 | $4(0) + [4.5 + 3(8-3)] + 12 = 31.5$ | 31.5 | 8 |
| 4 | $4(0) + [4.5 + 3(8-4)] + 12 = 28.5$ | 28.5 | 8 |
| 5 | $4(0) + [4.5 + 3(8-5)] + 12 = 25.5$ | 25.5 | 8 |
| 6 | $4(0) + [4.5 + 3(8-6)] + 12 = 22.5$ | 22.5 | 8 |
| 7 | $4(0) + [4.5 + 3(8-7)] + 12 = 19.5$ | 19.5 | 8 |
| 8 | $4(0) + [0] + 12 = 12$ | 12 | 8 |

For to week 2.

Table 9. Lower value (b=3)

| $f_2(x_1) = C_1(x_2 - 3) + C_2(x_2 - x_1) + f_3(x_2)$ | | | | | | | Optimal Solution | |
|---|---|---|---|---|---|---|---|---|
| $X_1$ | $X_2$=3 | $X_2$=4 | $X_2$=5 | $X_2$=6 | $X_2$=7 | $X_2$=8 | $f_2(x_1)_{inf}$ | $X_2^*{}_{inf}$ |
| 4 | $4(0) + [0] + 31.5 = 31.5$ | $4(1) + [0] + 28.5 = 32.5$ | $4(2) + [7.5] + 25.5 = 41$ | $4(3) + [10.5] + 22.5 = 44$ | $4(4) + [13.5] + 19.5 = 49$ | $4(5) + [16.5] + 12 = 48.5$ | 31.5 | 3 |
| | $4(0) + [0] + 31.5 = 31.5$ | $4(1) + [0] + 28.5 = 32.5$ | $4(2) + [0] + 25.5 = 33.5$ | $4(3) + [7.5] + 22.5 = 42$ | | | | |
| 5 | $4(0) + [0] + 31.5 = 31.5$ | $4(1) + [0] + 28.5 = 32.5$ | $4(2) + [0] + 25.5 = 33.5$ | $4(3) + [0] + 22.5 = 34.5$ | $4(4) + [10.5] + 19.5 = 46$ | $4(5) + [13.5] + 12 = 45.5$ | 31.5 | 3 |
| 6 | $4(0) + [0] + 31.5 = 31.5$ | $4(1) + [0] + 28.5 = 32.5$ | $4(2) + [0] + 25.5 = 33.5$ | $4(3) + [0] + 22.5 = 34.5$ | | | | |
| | $4(0) + [0] + 31.5 = 31.5$ | $4(1) + [0] + 28.5 = 32.5$ | $4(2) + [0] + 25.5 = 33.5$ | $4(3) + [0] + 22.5 = 34.5$ | $4(4) + [7.5] + 19.5 = 43$ | $4(5) + [10.5] + 12 = 42.5$ | 31.5 | 3 |
| 7 | | | | | $4(4) + [0] + 19.5 = 35.5$ | $4(5) + [7.5] + 12 = 39.5$ | 31.5 | 3 |
| | | | | | $4(4) + [0] + 19.5 = 35.5$ | $4(5) + [0] + 12 = 32$ | 31.5 | 3 |
| 8 | | | | | | | | |

Table 10. Average value (b=3)

| $f_2(x_1) = C_1(x_2 - 3) + C_2(x_2 - x_1) + f_2(x_2)$ | | | | | | | Optimal Solution | |
|---|---|---|---|---|---|---|---|---|
| $X_1$ | $X_2$=3 | $X_2$=4 | $X_2$=5 | $X_2$=6 | $X_2$=7 | $X_2$=8 | $f_2(x_1)_m$ | $X_{2m}^*$ |
| 5 | $4(0)+[0]+31.5=31.5$ | $4(1)+[0]+28.5=32.5$ | $4(2)+[0]+25.5=33.5$ | $4(3)+[7.5]+22.5=42.5$ | $4(4)+[10.5]+19.5=46.5$ | $4(5)+[13.5]+12=45.5$ | 31.5 | 3 |
| | $4(0)+[0]+31.5=31.5$ | $4(1)+[0]+28.5=32.5$ | $4(2)+[0]+25.5=33.5$ | $4(3)+[0]+22.5=34.5$ | $4(4)+[7.5]+19.5=42.5$ | $4(5)+[10.5]+12=42.5$ | | |
| 6 | $4(0)+[0]+31.5=31.5$ | $4(1)+[0]+28.5=32.5$ | $4(2)+[0]+25.5=33.5$ | $4(3)+[0]+22.5=34.5$ | $4(4)+[0]+19.5=35.5$ | $4(5)+[7.5]+12=39.5$ | 31.5 | 3 |
| 7 | $4(0)+[0]+31.5=31.5$ | $4(1)+[0]+28.5=32.5$ | $4(2)+[0]+25.5=33.5$ | $4(3)+[0]+22.5=34.5$ | $4(4)+[0]+19.5=35.5$ | $4(5)+[0]+12=32$ | | |
| | | | | | | | 31.5 | 3 |
| 8 | | | | | | | 31.5 | |
| | | | | | | | | 3 |

Table 11. Higher value (b=3)

| $f_2(x_1) = C_1(x_2 - 3) + C_2(x_2 - x_1) + f_2(x_2)$ | | | | | | | Optimal Solution | |
|---|---|---|---|---|---|---|---|---|
| $X_1$ | $X_2$=3 | $X_2$=4 | $X_2$=5 | $X_2$=6 | $X_2$=7 | $X_2$=8 | $f_2(x_2)_{sup}$ | $X_2{}^*_{sup}$ |
| 6 | $4(0)+[0]+31.5=31.5$ | $4(1)+[0]+28.5=32.5$ | $4(2)+[0]+25.5=33.5$ | $4(3)+[0]+22.5=34.5$ | $4(4)+[7.5]+19.5=42.5$ | $4(5)+[10.5]+12=42.5$ | 31.5 | 3 |
| | $4(0)+[0]+31.5=31.5$ | $4(1)+[0]+28.5=32.5$ | $4(2)+[0]+25.5=33.5$ | $4(3)+[0]+22.5=34.5$ | $4(4)+[0]+19.5=35.5$ | $4(5)+[7.5]+12=39.5$ | | |
| 7 | $4(0)+[0]+31.5=31.5$ | $4(1)+[0]+28.5=32.5$ | $4(2)+[0]+25.5=33.5$ | $4(3)+[0]+22.5=34.5$ | $4(4)+[0]+19.5=35.5$ | $4(5)+[0]+12=32$ | 31.5 | 3 |
| 8 | | | | | | | 31.5 | 3 |

For to week 1.

Table 12. Lower value (b=4)

| $f_1(x_0) = C_1(x_1 - 4) + C_2(x_1 - x_0) + f_2(x_1)$ | | | | | | Optimal Solution | |
|---|---|---|---|---|---|---|---|
| $X_0$ | $X_1$=4 | $X_1$=5 | $X_1$=6 | $X_1$=7 | $X_1$=8 | $f_1(x_0)_{inf}$ | $X_1{}^*_{inf}$ |
| 0 | $4(0) + [4.5 + 12] + 31.5 =$ | $4(1) + [19.5] + 31.5$ | $4(2) + [22.5] + 31.5$ | $4(3) + [25.5] + 31.5 =$ | $4(4) + [28.5] + 19.5 = 74$ | 48 | 4 |

Table 13. Average value (b=5)

| $f_1(x_0) = C_1(x_1 - 5) + C_2(x_1 - x_0) + f_2(x_1)$ | | | | | Optimal Solution | |
|---|---|---|---|---|---|---|
| $X_0$ | $X_1$=5 | $X_1$=6 | $X_1$=7 | $X_1$=8 | $f_1(x_0)_m$ | $X_1{}^*_m$ |
| 0 | $4(0) + [19.5] + 31.5 = 51$ | $4(1) + [22.5] + 31.5 = 58$ | $4(2) + [25.5] + 31.5 = 65$ | $4(3) + [28.5] + 31.5 = 72$ | 51 | 5 |

Table 14. Higher value (b=6)

| $f_1(x_0) = C_1(x_1 - 5) + C_2(x_1 - x_0) + f_2(x_1)$ | | | | Optimal Solution | |
|---|---|---|---|---|---|
| $X_0$ | $X_1$=6 | $X_1$=7 | $X_1$=8 | $f_1(x_0)_{sup}$ | $X_1{}^*_{sup}$ |
| 0 | $4(0) + [22.5] + 31.5 = 54$ | $4(1) + [25.5] + 31.5 = 61$ | $8(2) + [28.5] + 31.5 = 76$ | 54 | 6 |

The optimal solution to the number of persons for each level: lower, mean, and higher are, respectively:

$$x_0 = 0,0,0 \rightarrow x_1^* = 4,5,6 \rightarrow x_2^* = 3,3,3 \rightarrow x_3^* = 8,8,8 \rightarrow x_4^* = 7,5,6 \rightarrow x_5^* = 7,7,7$$

Table 15. Conclusions in the decisions made in the integration and disintegration decisions regarding work teams.

| Week i | Current Work Force ($x_i$) | Minimum Work Force ($b_i$) | Decision: hiring, maintaining, firing | Fuzzy minimal costs |
|---|---|---|---|---|
| | | | | Miles $ |
| 1 | [4, 5, 6] | [4, 5, 6] | No change | [48, 51, 54] |
| 2 | [3] | [3, 3, 3] | No change | [31.5] |
| 3 | [8] | [8, 8, 8] | No change | [12] |
| 4 | [4, 5, 6] | [7, 5, 6]* | Hire three persons at the lower level. No change at levels mean and higher. | [12, 10, 75]* |
| 5 | [7] | [7, 7, 7] | No change | [0] |
| | | | Total | [103.5, 104.5, 172.5] |

*As can be seen in the week 4, does not have an order with respect to the minimum force of work, due response of the dynamic program model, and consequently, this affects the order of the range in the fuzzy minimal costs also.

In this case, we take the hiring and firing costs fuzzy sets C, C = {$c_1$, $c_2$}, and the productivity set relation P= {$p_1$, $p_2$, $p_3$}, which is in turn related to the satisfaction set S = {$s_1, s_2$}. Where: $c_1$=excess work force costs, $c_2$=new hiring cost, $p_1$=high production demand, $p_2$=timely product delivery, $p_3$=product quality, $s_1$=customer satisfaction and $s_2$=investors satisfaction.

According to the dynamic programming results in confidence intervals at levels lower and mean, practically there are no large differences in the hiring and firing costs. Nonetheless, the higher level does exhibit an excess cost of approximately 68% with respect to the other levels. Under those circumstances, we must exert care when making contracts at levels lower and mean, assigning the first level for this task, since we run the risk to have considerable looses.

Second stage: once we know the hiring and firing costs, we consider the fuzzy set relations: costs, productivity, and satisfaction. Those relations are produced by a set of experts, represented as matrices or expertons. If there exists a set relation or incidence it can be as shown in the following matrices, where productivity works as interface:

| | $p_1$ | $p_2$ | $p_3$ |
|---|---|---|---|
| $c_1$ | .8 | .6 | .5 |
| $c_2$ | .5 | .6 | .1 |

(5)

Matriz de (2x3) costos-productividad

| | $s_1$ | $s_2$ |
|---|---|---|
| $p_1$ | .7 | .6 |
| $p_2$ | .4 | .4 |
| $p_3$ | .9 | .7 |

(6)

Matriz de (3x2) productividad-satisfación

Figure 4. Set Relations


The relation with the costs of excess personnel and hiring costs ($C_1$ y $C_2$), are considered dependent. That is, there exists a fuzzy relation among them. So, we consider there does not exist significant learning in this process. The Fuzzy matrix:

$$\begin{bmatrix} 1 & .8 \\ .8 & 1 \end{bmatrix} \quad (7)$$

Consider the customer investor satisfaction relation or association. They are not directly associated, there exists an interface between them, the productivity set. The former matrix will be multiplied by the interface matrix, convolving costs and productivity:

$$\begin{bmatrix} 1 & .8 \\ .8 & 1 \end{bmatrix} * \begin{bmatrix} .8 & .6 & .5 \\ .5 & .6 & .1 \end{bmatrix} = \begin{bmatrix} .8 & .6 & .5 \\ .8 & .6 & .5 \end{bmatrix} \quad (8)$$

The costs matrix (2x2)* productivity costs Matrix (2x3) = productivity satisfaction Matrix (2x3) derived from dependent costs. The convolution the productivity costs matrix (2x3) with the productivity satisfaction matrix (2x3):

$$\begin{bmatrix} .8 & .6 & .5 \\ .8 & .6 & .5 \end{bmatrix} * \begin{bmatrix} .7 & .6 \\ .4 & .4 \\ .9 & .7 \end{bmatrix} = \begin{bmatrix} .7 & .6 \\ .7 & .6 \end{bmatrix} \quad (9)$$

The above result represents the relation between costs generated by hiring the excess personnel in the company, with the customer investor satisfaction.

## 4. Results and conclusions

The costs of maintaining excess personnel and firing do not reflect a large difference as a function of the assigned personnel (Table 15). That is the reason to choose a fuzzy matrix:

$$\begin{array}{c} \\ c_1 \\ c_2 \end{array} \begin{array}{c} \begin{array}{cc} c_1 & c_2 \end{array} \\ \begin{bmatrix} 1 & .8 \\ .8 & 1 \end{bmatrix} \end{array}$$

The matrix convolution process let us observe that the cost of excess personnel has a relation of 0.7 with customers and a relation of 0.6 with investors. While the costs incurred by the excess personnel exhibit a relation of 0.7 and the costs of hiring are also related by 0.6.

$$\begin{array}{c} \\ c_1 \\ c_2 \end{array} \begin{array}{c} \begin{array}{cc} s_1 & s_2 \end{array} \\ \begin{bmatrix} .7 & .6 \\ .5 & .6 \end{bmatrix} \end{array}$$

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# Quantification of the Incidence in Innovation Capacities by the Promotion of Specialized Economic Sectors

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**Abstract:** In the last decades, México has invested resources on the creation of innovation agendas for the economic development of States and Regions. Such agendas have as mission, the improvement of specific economic sectors in order to generate innovation spillovers and improve the local innovation capacities of firms. Applying the Forgotten Effects Theory, this research aims to quantify the incidence of specialized economic sectors in innovation capacities of firms. Results show high incidence of each economic sector in all the innovation capacities measurement areas, emphasizing the relevant indirect effect that the renewable energy sector presents, and the preponderant incidence of the ICT sector on Portfolio Management and Organization and Structure areas. This research presents a first step to quantify the direct and indirect effect that innovation efforts of a specific territory generate in order to influence local competitive capacities of firms.

**Keywords:** Economic Sectors, Welfare Indicators, Fuzzy Sets, Regional Development, Forgotten Effects Theory.

## 1. Introduction

In the last years the Mexican Council of Science and Technology (CONACYT) has made efforts towards the concept and activities of innovation as a main trigger for regional development. In that sense, the institute, in coordination with consultative groups, leading enterprises and academia, generated 32 State Innovation Agendas and 3 large Regional Innovation Agendas. Such documents present the strategic plan, that in coordination with the public and private sectors define the main innovative activities that will be promoted in order to generate economic progress.

In the present paper the Innovation Agenda of the State of Michoacán México (Conacyt, 2015) is discussed. The research is focused on this specific State because of its economic regional

relevance, strategic location, and the latent capacities that have not been adequately developed creating a wide gap between the rest of the States in the Nation.

The objective of the present paper is to quantify the direct and indirect incidence that the selected economic sectors have on the local innovation capacities, the results will show whether there has been an accurate selection of the selected sectors and will aid decision makers to strategically position the investment in such areas that generate a multiplicative effect, rather than those with low incidence.

In order to assess the task of identifying the role that economic sectors have in the innovation capacities of firms, we use the methodology of Forgotten Effects (Kaufmann & Gil – Aluja, 1988) and present the direct and indirect connections established between the variables selected from the Innovation Agenda of Michoacán.

The study is based on data obtained from the statistic information presented in the Innovation Agenda of Michoacán (Conacyt, 2015), however we also consulted information from the National Institute of Statistics and Geography of Mexico (INEGI, 2014).

## 2. Preliminaries

In the present research we discuss, first, the main economic sectors that the consultative group, academics, practitioners and government agents of the State of Michoacán selected to promote in order to create innovation spillovers in the region. The selected sectors are the result of the analysis of local industrial specialized and emergent areas with high growth potential. For a detailed explanation of the selection process see (Conacyt, 2015). Table 1 shows the industrial sectors selected by the current level of specialization in the State.

Table 1. Selected Industrial Sectors

| Industrial Sector | Level of Specialization |
|---|---|
| 1. Agro-industry | High |
| 2. Metal-mechanics | High |
| 3. Information and Communication Technologies | Medium |
| 4. Health | Emergent |
| 5. Renewable Energies | Emergent |

Source: Conacyt, 2015.

The Agro-industry sector in Michoacán represents the 11% of the total State Gross Domestic Product (GDP) and signifies the 18,08% of the manufacturing activities in the State. It comprehends 8.250 economic units and employs about 6.808 workers. In macro economic indicators, this sector provides the 1,64% of the national GDP, positioning itself in the 18th place nationwide. The main objective of the innovation agenda in this highly specialized sector is to provide

added industrialization value to agriculture products, focusing on fruit pulp processing, flavor extraction and extraction of active ingredients.

Metal-mechanics represents the 7% of the State GDP and the 50,12% of the manufacturing activities of the State. It comprehends about 3.304 economic units and employs over 4749 workers. This sector represents the 9,09% of the National GDP being the third place nationwide. The mission of the agenda for this specific industrial sector is to produce capital goods to articulate local productive chains specialized in machinery for agricultural products processing and compact electric energy steam and hydraulic generators.

Information and Communication Technologies represents the 2% of the State GDP, the 18,08% of the entity manufacturing activities and stands in the second place of the tertiary sector of the entity. It gathers a total amount of 891 economic units. This sector represents the 1,64% of the National GDP, being the 16th place nationwide. The objective of the innovation agenda in this medium specialized sector is to update and assimilate technologies for the participation in the international markets, focusing in image processing, marketing and social networks and automation of agriculture and renewable energy generation equipment.

The emerging health sector is a venture with high growth potential in the country. It represents the 1,9% of the State GDP and the 13,04% of the manufacturing activities in the entity. There are 161 economic units in the state. This sector represents the 1,30% of the Nation GDP positioning the entity in the 14th place nationwide. The mission of the innovation agenda for this emergent sector is to consolidate the State as an international referent in R&D, developing new medicines and medic devices. The main specialization area is Bio pharmaceutics.

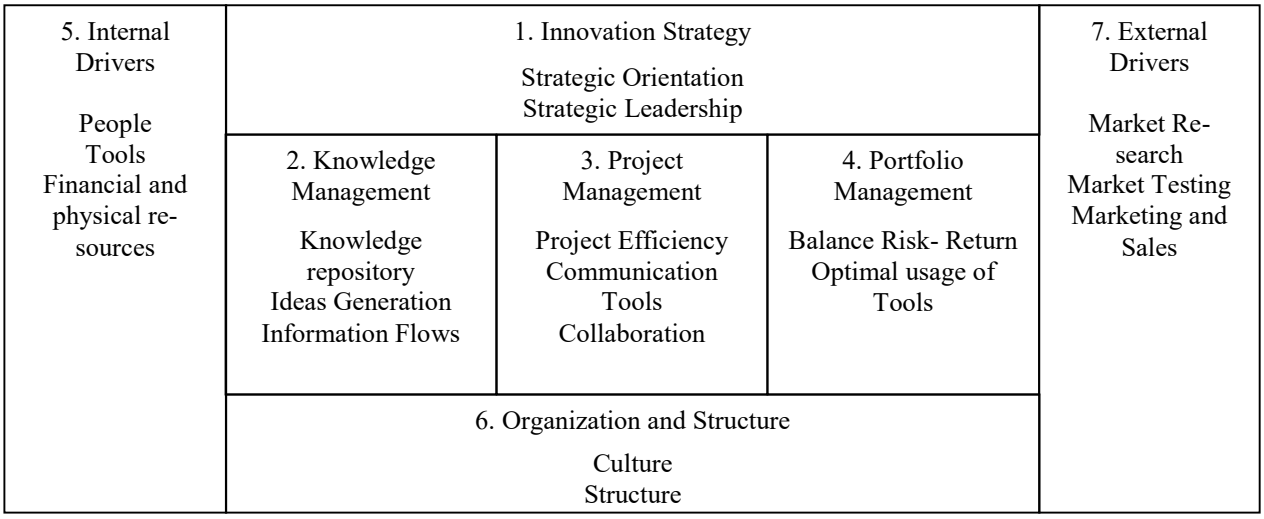
The second emerging area is the renewable energies sector. It represents an estimated value of 81% in the local intern market, being the 6th place of generation of renewable energy nationwide. It has over 7% of prospected annual growth. The specific mission is the use of natural resources to generate renewable energy from geothermic, hydraulic, biomass and solar sources. It is noteworthy that from all the chosen sectors, this is the less studied one from the innovation agenda.

### *Innovation Measurement Areas*

The innovation agenda of Michoacán aims to enhance the regional capabilities of the local firms. In order to quantify the degree of development that the chosen sectors could provide in terms of innovation spillovers, the present research takes the proposal developed by Adams et al.

(2006) as the main innovation measurement reference. Adams et al. (2006) proposal is based on a review of six models and frameworks of innovation measurement (Cooper and Kleinschmidt, 1995; Chiesa et al., 1996; Goffin and Pfeiffer, 1999; Cormican and Sullivan, 2004; Burgelman et al., 2004; Verhaeghet and Kfir, 2002). In that sense, from the seven main areas outlined by the authors, a framework for measuring innovation has been adapted, taking in count recurrent and relevant factors when quantifying the structural capabilities of companies to make and maintain continuous change. Figure 1 shows the seven areas of innovation measurement that have been adapted from Adams et al. (2006).

Figure 1. Innovation Measurement Areas




Source: Adapted from Adams et al., (2006).

## 3. Application of the model

Kaufmann and Gil – Aluja established the "Theory of the Forgotten Effects" (Kaufmann & Aluja, 1988). This theory allows obtaining all direct and indirect relations, with no possibility of errors, recovering the effects as it is called: “Forgotten Effects". According to the authors, all happenings that surround us are part of a system or subsystem. It means we could almost ensure that any activity is subject to a problem is a result of “causes” and “effects”. Despite a good system control, there is always the possibility of leaving voluntarily or involuntarily some causal relationships that are not always explicit, obvious or visible, and usually they are not directly perceived. It is common that there are some hidden reasons of the problems that we encounter due to effects of incidence effects on outcomes. The forgotten effects theory is an innovative and efficient approach taking into account many aspects of the relations, and which enables minimizing the errors that may occur in many processes (Gil-Lafuente, 2005).

For this study, we have two sets of elements: causes and effects (Kaufmann & Aluja, 1988). We start by valuating an occurrence of $a_i$ over $b_j$ with a membership functions estimated at [0,1]. Below we present two tables that include all the obtained statistical information, and have been normalized which means we divided all values of the column by the largest value. The aim is that all column values refer to the highest value, which takes the value 1. We need normalized values on base 1 because, as you can see, Tables 2 and 3 include, respectively, the variables that were used to choose the economic sectors to be enhanced, and the incidence that such criteria have on the innovation measurement areas.

Table 2. Chosen economic sectors evaluated by priority criteria

| | Existent Markets | Growth Rate | Value added | Internal Markets | Income | Higher Education Network | Specialized Centers |
|---|---|---|---|---|---|---|---|
| ICT's | 0,0 | 1 | 0,1 | 0,6 | 1 | 1 | 0,3 |
| Agro-industry | 0,2 | 0,2 | 1 | 0,5 | 0,5 | 0,6 | 1 |
| Metal-mechanics | 1 | 0,8 | 0,4 | 1 | 0,7 | 0,8 | 0,3 |
| Health | 0 | 0,8 | 0 | 0,6 | 0,6 | 0,4 | 0,3 |
| Renewable Energies | 0 | 0,6 | 0 | 0,9 | 0,6 | 0,3 | 0,6 |

Source: Retrieved from the statistics presented in Conacyt (2015).

Table 3. Priority criteria incidence on Innovation Measurement Areas

| | Innovation Strategy | Knowledge Management | Project Management | Portfolio Management | Internal Drivers | Organization and Structure | External Drivers |
|---|---|---|---|---|---|---|---|
| Existent Markets | 0,3 | 0,7 | 0,8 | 0,6 | 0,5 | 0,9 | 0,8 |
| Growth Rate | 0,9 | 0,9 | 0,7 | 0,7 | 1 | 0,6 | 1 |
| Value added | 0,8 | 0,5 | 0,4 | 0,7 | 0,3 | 0,1 | 0,4 |
| Impact on Internal Markets | 0,6 | 0,4 | 0,7 | 0,3 | 0,6 | 0,6 | 0,2 |
| Income | 0,2 | 0,6 | 0,7 | 0,5 | 0,9 | 0,4 | 0,1 |
| Higher Education Network | 0,4 | 1 | 0,6 | 0,7 | 0,7 | 0,5 | 0,8 |
| Specialized Centers | 1 | 0,9 | 0,8 | 0,7 | 0,4 | 0,9 | 0,7 |

Source: Retrieved from the statistics presented in Conacyt (2015).

In this stage, the priority criteria serve as a bridge between the economic sectors and the innovation measurement areas, such valuations offer enough information about the incidence displayed between the variables, however, this information is not useful to make a global study, as we should take into account the impact of economic sectors over the innovation measurement areas, hence we must perform a max-min composition between Tables 2 and 3. Table 4 represents the max-min composition of the five selected economic sectors and the innovation measurement areas.

Table 4. Max-min matrix Economic Sectors and Innovation Measurement Areas

| | Innovation Strategy | Knowledge Management | Project Management | Portfolio Management | Internal Drivers | Organization and Structure | External Drivers |
|---|---|---|---|---|---|---|---|
| ICT's | 0,9 | 1 | 0,7 | 0,7 | 1 | 0,6 | 1 |
| Agro-industry | 1 | 0,9 | 0,8 | 0,7 | 0,6 | 0,9 | 0,7 |
| Metal-mechanics | 0,8 | 0,8 | 0,8 | 0,7 | 0,8 | 0,9 | 0,8 |
| Health | 0,8 | 0,8 | 0,7 | 0,7 | 0,8 | 0,6 | 0,8 |
| Renewable Energies | 0,6 | 0,6 | 0,7 | 0,6 | 0,6 | 0,6 | 0,6 |

Source: Self – elaborated.

As it has been discussed, the direct impacts are not enough to make an overall analysis of the situation, given that causes (economic sectors) are conditioned by other causes, as well as the effects (innovation measurement areas) are affected not only by the direct causes, but also by other cross effects. Therefore it is necessary to construct two additional matrices. Table 5 shows the relations between the chosen economic sectors.

Table 5. Relationship matrix between economic sectors

| | ICT's | Agro-industry | Metal-mechanics | Health | Renewable Energies |
|---|---|---|---|---|---|
| ICT's | 1 | 0,5 | 0,7 | 1 | 1 |
| Agro-industry | 0,1 | 1 | 0,1 | 0,4 | 0 |
| Metal-mechanics | 0,2 | 0,8 | 1 | 0,5 | 0,7 |
| Health | 0,3 | 0,2 | 0,1 | 1 | 0 |
| Renewable Energies | 0,3 | 0,9 | 0,7 | 0,5 | 1 |

Source: Self – elaborated.

In Table 6, we show an asymmetric matrix with maximum value (1) when an indicator is related by itself.

Table 6. Relationship matrix between Innovation Measurement Areas

| | Innovation Strategy | Knowledge Management | Project Management | Portfolio Management | Internal Drivers | Organization and Structure | External Drivers |
|---|---|---|---|---|---|---|---|
| Innovation Strategy | 1 | 0,2 | 0,1 | 0,3 | 0,4 | 0,5 | 0,1 |
| Knowledge Management | 0,9 | 1 | 0,8 | 0,6 | 0,2 | 0,3 | 0,8 |
| Project Management | 0,9 | 0,5 | 1 | 0,7 | 0,2 | 0,3 | 0,1 |
| Portfolio Management | 0,9 | 0,7 | 0,4 | 1 | 0,2 | 0,1 | 0,2 |
| Internal Drivers | 1 | 0,6 | 0,8 | 0,7 | 1 | 0,8 | 0,9 |
| Organization and Structure | 1 | 0,8 | 0,9 | 0,8 | 0,7 | 1 | 0,8 |
| External Drivers | 0,8 | 0,7 | 0,8 | 0,9 | 0,6 | 0,4 | 1 |

Source: Self – elaborated.

Finally, from tables 4, 5, and 6 we calculate the final max-min composition matrix. This cause-effect matrix includes the impact of economic sectors on the innovation measurement areas; taking into account the possible effects of any variable that may have a direct effect. The results of the cumulative effects matrix are shown in Table 7.

Table 7. Final Cause - Effect matrix

| | Innovation Strategy | Knowledge Management | Project Management | Portfolio Management | Internal Drivers | Organization and Structure | External Drivers |
|---|---|---|---|---|---|---|---|
| ICT's | 1 | 1 | 0,8 | 0,9 | 1 | 0,8 | 1 |
| Agro-industry | 1 | 0,9 | 0,9 | 0,8 | 0,7 | 0,9 | 0,8 |
| Metal-mechanics | 0,9 | 0,8 | 0,9 | 0,8 | 0,8 | 0,9 | 0,8 |
| Health | 0,8 | 0,8 | 0,8 | 0,8 | 0,8 | 0,8 | 0,8 |
| Renewable Energies | 0,9 | 0,9 | 0,9 | 0,8 | 0,7 | 0,9 | 0,8 |

Source: Self – elaborated.

## 5. Results and Discussion

Once the calculations and relationship matrices are analyzed, we observe that on the cumulative basis, all the selected economic sectors affect the innovation measurement areas. We can see that, either directly or indirectly, the sectors display a minimum incidence of 0,7 over 1 (the case of Agro-industry and Renewable energies over Internal Drivers). The high incidence that all the variables present in Table 7 show, in general, a proper selection of the selected economic sectors in terms of improving the innovation measurement areas proposed. This fact proves that, firstly, the criteria utilized to select the economic sectors has been well studied, secondly, it demonstrate that each sector can generate a favorable multiplicative effect over the innovation measurement areas.

Results show that, despite the high incidence of all the selected economic sectors, health has the least influence over the innovation measurement areas. It is observable that the influence of Metal-mechanics and Renewable energies over the innovation measurement areas is positive, and finally, results convey that ICT and Agro-industry display the most incidence over the innovation measurement areas.

The Forgotten Effects Theory allows the analysis of the direct and indirect incidence that each of the selected economic sectors has on the innovation measurement areas. Table 8 shows the absolute difference between the direct effect (Table 4) and the indirect effect (Table 7) of the analyzed variables.

Table 8. Absolute Indirect Incidence

| | Innovation Strategy | Knowledge Management | Project Management | Portfolio Management | Internal Drivers | Organization and Structure | External Drivers |
|---|---|---|---|---|---|---|---|
| ICT's | 0,1 | 0 | 0,1 | 0,2 | 0 | 0,2 | 0 |
| Agro-industry | 0 | 0 | 0,1 | 0,1 | 0,1 | 0 | 0,1 |
| Metal-mechanics | 0,1 | 0 | 0,1 | 0,1 | 0 | 0 | 0 |
| Health | 0 | 0 | 0,1 | 0,1 | 0 | 0,2 | 0 |
| Renewable Energies | 0,3 | 0,3 | 0,2 | 0,2 | 0,1 | 0,3 | 0,2 |

Source: Self-elaborated.

The results obtained by the absolute indirect incidence are little, e.g. the maximum value is 0,3 (Renewable energies). Such values demonstrate that the missed expected effect of the selected sectors over the innovation measurement areas is slight; therefore, the selected sectors have been properly studied. However, results suggest that renewable energies have the most missed indirect incidence; further research is needed in order to analyze properly the factors that generate

such values; nonetheless it is worthy to point out that the innovation agenda of the state does not make a robust study of the Renewable energies sector as for the rest of the selected sectors.

The effect of the Renewable energies sector over the innovation measurement areas needs to be addressed, as it reflects an opportunity of retrieving more benefits than expected. For example, the effect that Renewable energy sector has on Innovation strategy, if we only consider the direct effect (see Table 4) is 0.6 over 1. When we look at the direct and indirect cumulative effect the result increases to 0,9. The difference between the two values 0,3 (0,9 - 0,3) represents the isolated indirect effect. This means that the indirect effect is more important than the direct effect. In this case it is possible to know which variables are interjected, making the indirect effect more important. To find it out it is necessary to follow the max-min composition process in the calculations. In this case the Renewable Energies Sector is highly (0,9) linked to the Innovation strategy variable on a maximum level (0,9) with the Knowledge Management variable. In this way, it is possible to find out the more important indirect effects for each relationship. This result is coherent to the importance that the renewable energies sector has had in the State, therefore gaining high knowledge in the topic.

## 6. Conclusions

The quantification of the incidence of the direct and indirect effect of the selected economic sectors presented in the Innovation Agenda of the State of Michoacán, reflects a profound analysis of the criteria designated to evaluate the impact over the economy of the region. Moreover, there is a coherent preponderance of the support to manufacturing activities, which accompanies the vision of making the State a pole for the creation of high value added products with the TIC sector as enabler.

Data comparison and normalized max-min composition processes have been realized in order to quantify the direct and indirect effect that variables display between each other. This operation allowed us to establish a benchmark and present bounded data (between 0 and 1), which facilitates the consequent analysis of the results.

It is shown that, despite all economic sectors influence the innovation measurement areas, the impact of each sector is singular with the following order from high to low: ICT, Agro-industry, Renewable Energies, Metal-mechanics and Health. All sectors present high direct incidence val-

ues, such information supports the objectives presented in the Innovation Agenda. On the other hand it is possible to identify the Renewable energy sector as an opportunity due to its high indirect incidence on the innovation measurement areas, such indirect causal relation could allow a performance level with a multiplicative effect.

Lastly, the application of the Forgotten Effects Theory allows the prevision and development of selected economic sectors, as it gives a first insight about the relationships that link them. That information could aid decision makers to manage resources in an efficient way, hence building sustainable and effective public policies.

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