INTERNATIONAL MARKET SELECTION USING FUZZY WEIGHING AND MONTE CARLO SIMULATION

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Abstract: This article aims to develop a methodology for the international market selection (IMS), using fuzzy logic for the uncertainty of the variables in the market evaluation. Therefore, several procedures are proposed, including market pre-selection, criteria definition, criteria weighting, data collection, data variability and a market evaluation model. Through Monte Carlo simulation, the market evaluation model measures the stability of international markets for exporting when criteria are fuzzy. A case study for the export of frozen beef from Colombia validates the methodology. The proposed approach helps to improve the exporting performance, and it is applicable for small and medium enterprises because the model uses free access data sources, and the algorithms of the market evaluation model can be performed in spreadsheets.

Key words: international market selection, fuzzy logic, Monte Carlo simulation, hierarchical weighing, decision-making

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Introduction

In business environments, the market of a company is not restricted to a particular geographic location (Zhang et al., 2007), which means that companies must perform an international market selection (IMS) process (Cano and Baena, 2015). IMS is one of the most complicated and time-consuming problems in many companies, due to the large number of alternatives, conflicting objectives, and variety of factors (Aghdaie et al., 2011). This implies that the decision-making process must consider several criteria, which makes IMS a multicriteria decision-making problem, whose objective is to find an optimal alternative among candidate (Aghdaie et al., 2013; Dat et al., 2015). If the available information for the IMS is limited, ambiguous or incomplete, and a high level of uncertainty is considered, it is useful to use the fuzzy logic, which allows the use of truth levels on variables and criteria values. In the case of the IMS, it is useful to include uncertainty to improve the performance of exports in the absence of historical or comparative information for exports in new markets (Gómez et al., 2016). Therefore, fuzzy logic deals with some degree of uncertainty in criteria and variables in real-life problems (Marchi et al., 2014; Shipley et al., 2012). In the case of IMS, fuzzy logic

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has been used in conjunction with tools such as the AHP (Aghdaie et al., 2013; Farzipoor, 2011; Fazlollahtabar and Mahdavi-Amiri, 2013), TOPSIS (Dat et al., 2015), neural networks (Zhang et al., 2007), Fuzzy Inference Systems (Golsefid et al., 2012), among others. Because of this, this paper proposes a fuzzy model for international market selection based on multiple decision-making criteria. We incorporate fuzzy logic with Monte Carlo Simulation in order to validate the stability of the markets when uncertainty in criteria and sub-criteria exists.

Methodology for the International Market Selection

International market selection is considered as a complex problem and it is difficult to define because many factors influence international business success (Zhang et al., 2007). In the structuring of the IMS problem, the decision maker must be able to establish, define and isolate the problem to give a satisfactory solution (Andersen and Buvik, 2002). Based on a review of the contribution of Andersen and Buvik (2002), Aghdaie et al. (2013), Aghdaie and Alimardani (2015), Dat et al. (2015), Golsefid et al. (2012), Marchi et al. (2014), and Zhang et al. (2007), Table 1 defines the IMS problem, detailing different steps to be developed, defining a coherent market selection for the export of goods.

Table 1. Problem definition of IMS according to the literature

Step	Description
1	Establish a country market set from a large number of countries, discarding unsuitable countries for further analysis. Generate alternatives for the IMS.
2	Identify selection criteria and sub-criteria from a wider set of variables.
3	Structure the decision problem and criteria evaluation as a hierarchy, breaking down the problem into a hierarchy of criteria and sub-criteria. Aggregate selected sub-criteria into criteria, and criteria for the overall evaluation of the country markets.
4	Define the weights for each criterion and sub-criterion according to the hierarchy structure.
5	Collect data for the criteria and sub-criteria, and assess information relating to these criteria.
6	Normalize the values of the criteria and sub-criteria.
7	Evaluate the country through the criteria and sub-criteria for each alternative using rules, weights, or other mechanisms. Generate the output of the decision process, i.e., the market ranking.
8	Rank and compare the performance of the alternatives. Determine the priority order of the alternatives and select an international market.

Considering the main stages of the IMS process, the proposed fuzzy approach for the IMS is described in Figure 1. For the market preselection, it starts from the base of all the markets that are able to import the merchandise to be exported. As a preselection criterion, it is proposed to select as candidates those countries whose

total imports value per year exceeds a certain reference value, which must be given by the decision maker.

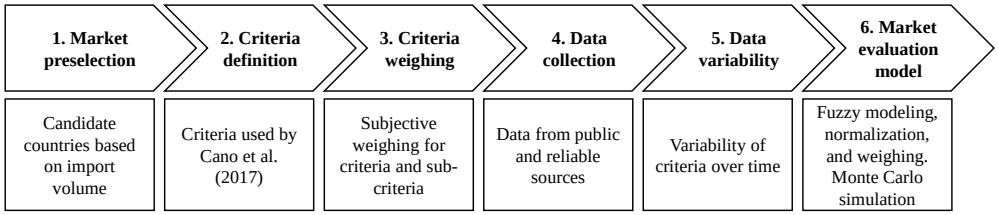

Figure 1. International market selection approach

The proposed methodology for the IMS takes into account sub-criteria corresponding to the input and output variables established by Cano et al. (2017a), which have also been used by Gaston-Breton and Martín (2011), and Miečinskienė et al. (2014) to describe factors such as economic and market development, logistics and foreign trade, cultural and geographic distances, financial development, among others. Succeeding, these sub-criteria are grouped in criteria (market criteria, logistics and foreign trade criteria, sociocultural criteria, financial and economic criteria), in order to evaluate a candidate market. Figure 2 shows the IMS hierarchy structure and the relationship between sub-criteria and criteria for market evaluation.

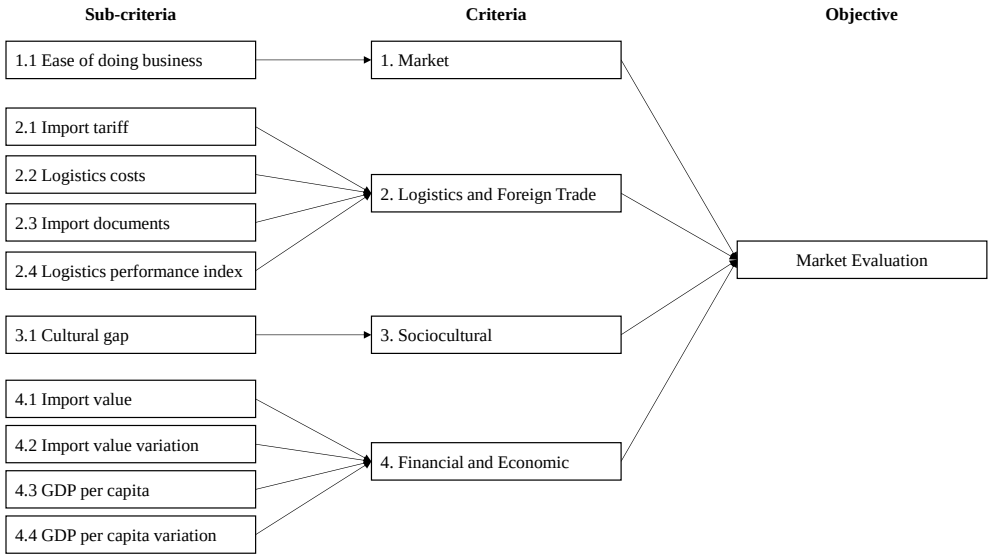

Figure 2. International market selection hierarchy structure

In IMS hierarchy structure, weights are assigned to each criterion allowing the decision maker to assign greater importance to the criteria which best meet the

company needs and the characteristics of the product to be exported. Similarly, weights are assigned to the sub-criteria composing each criterion, assigning more importance to the most relevant sub-criteria in each criterion. Hence, the IMS structure provides flexibility in decision making, allowing the methodology to adapt to different companies and products to be exported.
For each sub-criterion, Table 2 presents the measurement scale, the desired value (low if the sub-criterion implicates a negative aspect, high if the sub-criterion implicates a positive aspect), desired score and undesired score according to the measurement scale of each sub-criterion. The measurement scales can have standardized maximum and minimum values as is the case of Ease of doing business, Logistics performance index, and Cultural gap sub-criteria. For the other sub-criteria, the maximum and minimum scores are relative and must be calculated based on available data from the candidate markets.

Table 2. Criteria and sub-criteria information for the IMS

Criteria weighing	Sub-criteria weighing	Scale	Desired value	Desired score	Undesired score
W_1=25%	$W_{1,1}$=100%	1 to 189	Low	1	189
W_2=30%	$W_{2,1}$=20%	%	Low	Minimum value of data	Maximum value of data
	$W_{2,2}$=20%	Thousand USD	Low	Minimum value of data	Maximum value of data
	$W_{2,3}$=20%	Documents	Low	Minimum value of data	Maximum value of data
	$W_{2,4}$=40%	1 to 5	High	5	1
W_3=20%	$W_{3,1}$=100%	1 to 100	Low	1	100
W_4=25%	$W_{4,1}$=20%	Million USD	High	Minimum value of data	Maximum value of data
	$W_{4,2}$=30%	%	High	Minimum value of data	Maximum value of data
	$W_{4,3}$=20%	USD, Thousand	High	Minimum value of data	Maximum value of data
	$W_{4,4}$=30%	%	High	Minimum value of data	Maximum value of data

Regarding the data collection for sub-criteria, Table 3 recommends searching in free access, reliable and consistent databases, which generally belong to prestigious institutions and organizations worldwide. This ensures that the IMS methodology can be replicated over time and can be applied to any merchandise to export from any country.

Table 3. Data source for sub-criteria

Data source	Sub-criteria	Website
World Trade Organization	Import tariff	https://tao.wto.org
World Bank	Ease of doing business, Import documents, GDP per capita, GDP per capita variation, Logistic performance index	http://www.doingbusiness.org http://data.worldbank.org
Hofstede Centre	Cultural gap	http://geert-hofstede.com
International Trade Centre	Import value, Import value variation	http://www.intracen.org
World Freight Rates	Logistic costs	http://worldfreightrates.com

Although the sub-criteria chosen for the IMS are objective variables, they are used for medium and long-term decisions. Therefore, the value of a sub-criterion in a given period can change in future periods. In addition, there are several information sources for the proposed sub-criteria, which generates uncertainty in the sub-criteria, suggesting the use of the fuzzy logic in order to model imprecise information by fuzzy numbers and membership functions.

Market Evaluation Model

In order to achieve an objective market selection, implying the handling of uncertainty, a fuzzy ranking approach is implemented (Cavusgil et al., 2004; Dat et al., 2015; Marchi et al., 2014; Miečinskienė et al., 2014; Shipley et al., 2012). Hence, the sequencing of markets in a ranking provides objective support for decision-making and facilitates the IMS for goods to be exported given a large number of candidate countries. Figure 3 presents the proposed model for the market evaluation, whose output is the selection of the best-placed market in the ranking of the candidate countries.

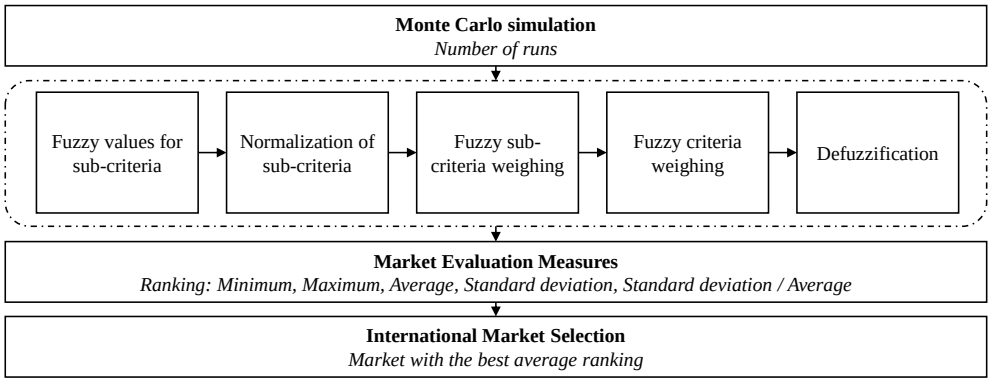

Figure 3. Market evaluation model

The sub-criteria of the IMS methodology is modeled using fuzzy triangular numbers, and the central value (CV) of each fuzzy number corresponds to the information from data sources mentioned in Table 3. The calculation of the lower value (LV) and upper value (UV) for a fuzzy number is represented by Equation (1) and Equation (2), where RND1 and RND2 are random numbers between 0 and 1, and UNC is the percentage of maximum uncertainty that the decision maker considers for the values of each sub-criterion.

$$LV = CV * \left(1 - (RND_1 * UNC)\right) \quad (1)$$

$$UV = CV * \left(1 + (RND_2 * UNC)\right) \quad (2)$$

Once the fuzzy numbers of the sub-criteria are calculated, a standardization procedure is proposed to eliminate the scales of the sub-criteria, ensuring a consistent weighting between the sub-criteria. Normalization is performed for the lower, central and upper values of the fuzzy numbers, and normalization depends on whether the sub-criterion value implies a negative or positive aspect. In Equation (3), *i* is index for sub-criteria, j is an index for criteria, f is an index for triangular fuzzy elements (*f=1* for lower value, *f=2* for central value, *f=3* for upper value). Therefore, s^f_{ij} is the value of the sub-criterion *i* belonging to criterion *j* of the fuzzy value *f*, and n^f_{ij} is its corresponding normalized value.

$$n^f{}_{ij} = \begin{cases} \frac{s^f{}_{ij} - s^{f\,und}_{ij}}{s^{f\,des}_{ij} - s^{f\,und}_{ij}} \; if \; s^f{}_{ij} \; implicates \; a \; negative \; aspect \\ \frac{s^{f\,und}_{ij} - s^f{}_{ij}}{s^{f\,und}_{ij} - s^{f\,des}_{ij}} \; if \; s^f{}_{ij} \; implicates \; a \; positive \; aspect \end{cases} \quad \forall j, f \quad (3)$$

Where $s^{f\,des}_{ij}$ and $s^{f\,fund}_{ij}$ are desired and undesired scores in each sub-criterion respectively, according to Table 2. However, in the IMS in addition to the criteria and dimensions of the decision-making model, the preferences of the decision-maker and the company are included by assigning subjective weights to the criteria and sub-criteria (Cano et al., 2017b). This gives more flexibility to the model and greater ease to adapt to the preferences of the decision maker. The weights are assigned to the lower (*f = 1*), central (*f = 2*) and upper (*f = 3*) values of the fuzzy sub-criteria. The weights between fuzzy numbers are calculates using addition arithmetic operations, and multiplication of a scalar number by a fuzzy number. Thus, equation (4) represents the weighing to obtain the values that define the triangular fuzzy number of criterion *i*, where w_{ij} represents the weighing assigned for the sub-criterion *i* belonging to criterion *j*. Hence, a criterion *j* is represented by a triangular fuzzy (c_j^1, c_j^2, c_j^3).

$$c_j^f = \sum_i n^f{}_{ij} \times w_{ij} \qquad \forall j, f \quad (4)$$

$$\sum_i w_{ij} = 1 \qquad \forall j \quad (5)$$

In equation (6), a weighing between the criteria of the market selection model is performed to obtain the evaluation of each market in a triangular fuzzy number (m^1, m^2, m^3), where w_j represents the weighing assigned for criterion j.

$$m^l = \sum_j c^f{}_j \times w_j \qquad \forall f \tag{6}$$

$$\sum_j w_j = 1 \tag{7}$$

In order to generate the output of the evaluation market process, Equation (8) represents the centroid method, a defuzzification method to convert a triangular fuzzy number in a crisp number ME.

$$ME = \frac{m^1+m^2+m^3}{3} \tag{8}$$

Through the calculation of crisp numbers, the candidate markets are ranked according to the score *ME*, ranking first the country with the highest score, and lastly the country with the lowest score. In this way, the decision maker must select the country in the first place in the ranking as the preferred market for the export of goods. However, since the assignment of uncertainty to sub-criteria depends on random values in Equation (1) and Equation (2), it is necessary to apply a Monte Carlo simulation process to generate different lower and upper values of the triangular fuzzy numbers of the sub-criteria. Therefore, the Monte Carlo simulation process ranks the candidate countries in each run, and at the end of the simulation process measures such as Minimum ranking, Maximum ranking, Average ranking, Standard deviation for ranking, Standard deviation / Average ranking are computed. These measures verify the stability of each candidate country as the sub-criteria vary, and allows analyzing the sensitivity of each candidate country regarding the changes and inaccuracies in the information of each sub-criterion.

Results and Discussion

This section validates the methodology developed for the IMS by analyzing a case study of frozen beef export from Colombia. As a requirement to implement the proposed methodology, it is suggested to know the characteristics of the product to be exported, know how to extract information from the suggested databases, have the ability to establish priorities and weightings to the criteria and sub-criteria, as well as to have skills on the use of spreadsheets. In the case study, candidate countries are those countries whose frozen beef import value is more than USD$50 million per year. Another aspect to consider a candidate country is the availability of information from the country in the data sources mentioned in Table 2. Thus, out of 224 countries importing frozen beef, 32 countries were preselected. The central values of the triangular fuzzy numbers of sub-criteria of the candidate countries were obtained from the database used by Cano et al. (2017a). Based on these values and assuming an uncertainty of up to 15% (UNC = 15%), the lower and

upper values of the fuzzy numbers were calculated using Equation (1) and Equation (2). Table 2 shows the proposed weights for the criteria and sub-criteria for the export of frozen beef from Colombia, however, these weighing values may vary as required by the decision maker. Once the model parameters were set, 1.000 runs were executed in the Monte Carlo simulation process, generating fuzzy sub-criteria of candidate markets in each run. As a result of the Monte Carlo simulation, Table 4 presents the ranking of countries according to the average ranking obtained from the simulation process.

Table 4. Market ranking from Monte Carlo simulation

Ranking									
Market	**Min**	**Max**	**Avg.**	**Std Dev. /Avg.**	**Market**	**Min**	**Max**	**Avg.**	**Std Dev. /Avg.**
USA	1	2	1	3%	ESP	17	20	17,8	5%
HKG	1	2	2	2%	PRT	17	19	18	4%
SGP	3	3	3	0%	ISR	17	20	18,1	5%
CAN	4	4	4	0%	VNM	19	23	20,5	4%
SWE	5	8	5,4	13%	CHN	19	23	21	4%
GBR	5	8	6,3	14%	SAU	20	23	21,6	3%
DEU	5	9	6,8	14%	ITA	20	23	22,9	1%
DNK	5	10	7,5	10%	THA	24	24	24	0%
KOR	7	12	9,3	6%	PHL	25	26	25,3	2%
ARE	8	13	10,2	8%	RUS	25	26	25,7	2%
FRA	9	14	10,8	8%	EGY	27	30	27,8	3%
CHL	9	15	12,6	7%	JOR	27	30	28,1	4%
MYS	10	14	12,7	7%	BRA	27	30	28,9	3%
JPN	10	15	13,4	6%	IDN	27	30	29,2	3%
NLD	14	16	15,1	2%	VEN	31	31	31	0%
BEL	15	16	15,8	2%	AGO	32	32	32	0%

Table 4 shows that different conditions of uncertainty in the information of the sub-criteria, USA is the most recommended international market for the export of frozen beef from Colombia, followed by HKG, SGP, and CAN. It is also observed that the evaluations of these countries are very stable and their position in the ranking presents little or no significant deviations in the simulations conducted. These results allow making decisions with a greater degree of certainty about which market is better for the export of goods and about how stable the market is from possible fluctuations in the values of the sub-criteria. On the other hand, SWE, GBR, DEU, and DNK are good options for the export of frozen beef from

Colombia; however, they are more sensitive to changes in the values of the sub-criteria. Under certain conditions, these four countries occupy the fifth position in the ranking, but in other scenarios, they can occupy the 8th, 9th or 10th position in the ranking. This makes it possible to deduce that these countries are sensitive to changes in the values of the sub-criteria, and it is not possible to guarantee certainty about their behavior since the standard deviation over the average ranking can be between 10% and 14%. Therefore, the novelty of the proposed IMS methodology focuses on incorporating uncertainty in multiple scenarios of the sub-criteria instead of analyzing a single scenario or solution, and through Monte Carlo simulation the methodology generates a significant number of scenarios to set the stability of the potential market according to the requirements of the decision maker. In addition, the proposed fuzzy approach for small and medium-sized businesses unlike other IMS models such as those proposed by Marchi et al. (2014), Golsefid et al. (2012), and Zhang et al. (2007), can show in detail the behavior of scenarios and variables, and can be easily applied in small and medium-sized businesses because it is performed in spreadsheets, uses free access data sources, does not require specialized software, and can be applied in wide range of products to export. As such, the export performance can increase as the fuzzy logic takes into account the uncertainty of the sources that provide the information of the sub-criteria, and in turn, allow the decision-maker to adjust the values of the sub-criteria based on its expertise. However, the subjective assignment of weights to the criteria and sub-criteria, and the scope on single products are some of the limitations of this study. Consequently, further research must focus on the development of objective procedures for the assignment of weights, and adapt this approach for the export of product families, making it useful for government entities and associations to promote abroad a variety of products that belong to a specific industry.

Summary

With the development of an IMS methodology that incorporates fuzzy logic with Monte Carlo Simulation it is possible to address the uncertainty in the sub-criteria related to economic and market development, logistics and foreign trade, cultural and geographic distances, and financial development. Thus, the proposed approach prioritize markets from the best to the worst ones after validating the stability of each candidate market in multiple scenarios. In the case of the export of frozen beef from Colombia, USA is the best market to choose because it best satisfies the preferences of the decision maker in the evaluated instances for the medium and long term, increasing the export performance.

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SELEKCJA RYNKÓW MIĘDZYNARODOWYCH Z WYKORZYSTANIEM LOGIKI ROZMYTEJ I SYMULACJI MONTE CARLO

Streszczenie: Artykuł ma na celu opracowanie metodologii doboru rynku międzynarodowego (IMS), z wykorzystaniem logiki rozmytej dla niepewności zmiennych w ocenie rynku. W związku z tym proponuje się kilka procedur, w tym wstępną selekcję rynku, definicję kryteriów, wagę kryteriów, zbieranie danych, zmienność danych i model oceny rynkowej. Poprzez symulację Monte Carlo model oceny rynkowej mierzy stabilność rynków międzynarodowych przy eksporcie, gdy kryteria są rozmyte. Studium przypadku dotyczące wywozu mrożonej wołowiny z Kolumbii potwierdza metodologię. Proponowane podejście pomaga poprawić wydajność eksportową i ma zastosowanie do małych i średnich przedsiębiorstw, ponieważ model wykorzystuje źródła danych o wolnym dostępie, a algorytmy modelu oceny rynkowej można przeprowadzać w arkuszach kalkulacyjnych.
Słowa kluczowe: wybór rynku międzynarodowego, logika rozmyta, symulacja Monte Carlo, ważenie hierarchiczne, proces decyzyjny

國際市場選擇使用模糊稱量和蒙特卡羅模擬

摘要: 本文旨在開發一種國際市場選擇(IMS)的方法, 利用模糊邏輯對市場評價中變量的不確定性進行評價。因此, 提出了市場預選, 標准定義, 標準權重, 數據收集, 數據可變性和市場評價模型等幾種程序。通過蒙特卡羅模擬, 市場評估模型在標準模糊的情況下衡量出口的國際市場的穩定性。哥倫比亞出口冷凍牛肉的個案研究驗證了方法。該方法有助於提高出口績, 適用於中小型企業, 因為該模型使用免費訪問數據源, 市場評估模型的算法可以在電子表格中執行。
關鍵詞: 國際市場選擇, 模糊邏輯, 蒙特卡洛模擬, 層次權重, 決策