

Yusta, Silvia Casado; Letamendía, Laura Nuñez; Pacheco Bonrostro, Joaquín Antonio

## Article

# Predicting corporate failure: The GRASP-LOGIT model

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## Predicting Corporate Failure: The GRASP-LOGIT Model

CASADO YUSTA, SILVIA

Departamento de Economía Aplicada

Universidad de Burgos (España)

E-mail: [scasado@ubu.es](mailto:scasado@ubu.es)

NUÑEZ LETAMENDÍA, LAURA

Departamento de Finanzas

IE Business School, IE University (España)

E-mail: [laura.nunez@ie.edu](mailto:laura.nunez@ie.edu)

PACHECO BONROSTRO, JOAQUÍN ANTONIO

Departamento de Economía Aplicada

Universidad de Burgos (España)

E-mail: [jpacheco@ubu.es](mailto:jpacheco@ubu.es)

### ABSTRACT

Predicting corporate failure is an important problem in management science. This study tests a new method for predicting corporate failure on a sample of Spanish firms. A GRASP (Greedy Randomized Adaptive Search Procedure) strategy is proposed to use a feature selection algorithm to select a subset of available financial ratios, as a preliminary step in estimating a model of logistic regression for predicting corporate failure. Selecting only a subset of variables (financial ratios) reduces the costs of data acquisition, increases prediction accuracy by excluding irrelevant variables, and provides insight into the nature of the prediction problem allowing a better understanding of the final classification model. The proposed algorithm, that it is named GRASP-LOGIT algorithm, performs better than a simple logistic regression in that it reaches the same level of forecasting ability with fewer accounting ratios, leading to a better interpretation of the model and therefore to a better understanding of the failure process.

**Keywords:** Financial distress; accounting ratios; feature selection; GRASP metaheuristic; logistic regression.

**JEL classification:** C39; C44; G33.

**MSC2010:** 62P20; 62J05; 68T20; 90C59; 91G50.

# Predicción de la quiebra empresarial: el modelo GRASP-LOGIT

## RESUMEN

La predicción de la quiebra empresarial es un problema que goza de una gran relevancia en las ciencias empresariales. En este trabajo se propone un nuevo método para predecir la quiebra empresarial en una muestra de empresas españolas. Concretamente se trata de un algoritmo de selección de variables basado en la estrategia metaheurística GRASP (procedimiento de búsqueda adaptativa aleatoria y voraz) para seleccionar un subconjunto de ratios financieros, como un paso preliminar para estimar un modelo de regresión logística que prediga la quiebra empresarial. La selección de un subconjunto de ratios financieros, de entre todos los disponibles, reduce los costes de adquisición de datos, aumenta la precisión de la predicción al excluir las variables irrelevantes y proporciona información sobre la naturaleza del problema de predicción. Todo lo anterior permite una mejor comprensión del modelo de clasificación final. Nuestro nuevo modelo, al que llamamos modelo GRASP-LOGIT, funciona mejor que una simple regresión logística en el sentido de que alcanza el mismo nivel de capacidad de predicción con menos ratios contables, lo que lleva a una mejor interpretación del modelo y, por lo tanto, a una mejor comprensión del proceso de quiebra empresarial.

**Palabras claves:** dificultades financieras; ratios contables; selección de características; metaheurístico GRASP; regresión logística.

**Clasificación JEL:** C39; C44; G33.

**MSC2010:** 62P20; 62J05; 68T20; 90C59; 91G50.



## 1. INTRODUCTION

Since the pioneering works of Beaver (1966) and Altman (1968), many studies have been devoted to predicting financial distress (throughout this paper, we use the terms “corporate failure” and “financial distress” to refer to both bankruptcy and temporary receivership) using accounting-based variables; however, theoretical approaches to corporate failure are rare. Some papers have based bankruptcy prediction models on the gambler’s ruin model of probability theory. There has been also some other attempts of building a bankruptcy theory as Scott (1977), who proposes a model that, contrary to the gambler’s ruin model, allows the firm to access external capital. For a survey of these theoretical papers, see Scott (1981). But, as Laitinen and Laitinen (2000) pointed out, these theoretical grounds are too simplified or too indefinite to give advice for the selection of the functional form of the model; yet there is not a general accepted economic theory about corporate failure. The lack of a unified theory makes difficult to use an economically grounded approach by stating theoretical *a priori* reasons for using one variable or another and then testing whether the theoretical hypotheses can be supported by the empirical evidence. But, as Jones (1987) has argued, the lack of a theory is not necessarily a serious impediment to studying corporate failure, if we can apply an economic interpretation to an empirically derived model. In fact, empirical findings that can be interpreted via economic reasoning can help to build a corporate failure theory.

Existing empirical studies reflect a lack of consensus on what constitutes the best methodological approach to analyze financial distress. Preliminary studies on insolvency used univariate techniques (Beaver, 1966). Two years later, discriminant multivariate analysis, which became the predominant technique during the 1970s, was introduced by Altman (1968). Subsequently, in the 1980s, discriminant analysis, whose principle of normality for predictors and equality for variance-covariance matrices is usually violated by the distributions of financial ratios, was complemented by a logit and probit analysis; see Ohlson (1980), Zmijewski (1984) and Lennox (1999), among others. Despite the drawbacks of discriminant analysis, it produces classification results very similar to those of the logit models. Nonparametric models were also applied; e.g. the recursive partitioning algorithm (Frydman *et al.*, 1985) and the ID3 (Messier *et al.*, 1988). Researchers have used other approaches to address the problem of predicting failure, namely: Neural networks (Altman *et al.*, 1994; Etheridge *et al.*, 1996; Baesens *et al.*, 2003a; Iturriaga and Sanz, 2015), genetic algorithms (Varetto, 1998; Sexton *et al.*, 2003), decision trees (Curran and Mingers, 1994), Bayesian analysis (Sarkar and Sriram, 2001), multidimensional scaling (Neophytou and Molinero, 2004), hazard models (Shumway, 2001; Lee and Urrutia, 1996), support vector machine (Wu *et al.*, 2007; Hua *et al.*, 2007) or more sophisticated logit models (Laitinen and Laitinen, 2000; Jones and Hensher, 2004; Li *et al.*, 2011). In Balcaen and Ooghe (2006), an overview of classic statistical methodologies that analyze business failure prediction and their related problems is shown. More recent works about bankruptcy prediction were published by Yang *et al.* (2011), Jeong *et al.* (2012), Lu *et al.* (2015) and Liang *et al.* (2016).

This study uses a new methodological approach based on the idea that a model performs better when it uses a subset of superior variables from a set of candidate variables. There can be many reasons for selecting only a subset of the variables instead of the whole set of candidate variables –see Liu and Motoda (1998) and Reunanen, 2003–: (1) It is cheaper to measure only a reduced set of variables; (2) prediction accuracy may be improved through exclusion of redundant and irrelevant variables; (3) the predictor to be built is usually simpler and potentially faster when fewer input variables are used; and (4) knowing which variables are relevant can give insight into the nature of the prediction problem and allows a better understanding of the final classification model. This last point is important in this field, where it is necessary to know not only whether a company is likely to fail, but why. As pointed out by Baesens *et al.* (2003b, p.312), “[m]ost of these studies

*[credit-risk studies] focus primarily on developing classification models with high predictive accuracy without paying any attention to explaining how the classifications are being made. Clearly, this plays a pivotal role in credit-risk evaluation, as the evaluator may be required to give a justification for why a certain credit application is approved or rejected”.*

How to choose this superior subset of variables is the problem known in the literature as feature selection. Research in feature selection started in the early 1960s (Lewis, 1962; Sebestyen, 1962). Over the past four decades, extensive research into feature selection has been conducted. Some of these works are Ganster *et al.* (2001), Lee *et al.* (2003), Crone and Finlay (2012) and Mangalova and Agafonov (2014). Besides, the problem of selecting variables from a large candidate pool abounds in areas such as discriminant analysis (Pacheco *et al.*, 2006), linear regression (Wang *et al.*, 2007, Arslan, 2012) and logistic regression (Pacheco *et al.*, 2009; Matsui, 2014). The selection of the best subset of variables for building the predictor is not a trivial question, because the number of subsets to be considered grows exponentially with the number of candidate variables. Even with a moderate number of candidate variables, not all the possible subsets can be evaluated, which means that feature selection is a NP-hard problem –non-deterministic polynomial-time hard in computational complexity theory, see Kohavi (1995) and Cotta *et al.* (2004– and therefore, there is no guarantee of finding the solution.

For feature selection problems, two different methodological approaches have been developed: Exact techniques (enumerative techniques), which guarantee an optimal solution, but are applicable only in small instances; and approximate techniques, which can find good solutions (although they cannot guarantee the optimum) in a reasonable amount of time. Among the latter, the Narendra-Fukunaga algorithm (Narendra and Fukunaga, 1977) is one of the best known, but as Jain and Zongker (1997) pointed out, this algorithm is impractical for problems with a large number of features. Among the heuristic techniques, there are for example those based on genetic algorithms (Bala *et al.*, 1996; Jourdan *et al.*, 2001; Oliveira *et al.*, 2003; Meiri and Zahavi, 2006; Zhang *et al.*, 2015).

A feature selection algorithm based on the heuristic approach is proposed as a preliminary step in estimating a logit model for predicting corporate failure. In this paper, only quantitative variables (accounting ratios) are used to classify firms as healthy or financially distressed. Using only quantitative variables allows a better measurement and comparison of their classificatory capacity. Thus, a variable selection method especially adapted to these kinds of variables can be developed, which will therefore be more efficient. Specifically, GRASP (Greedy Randomized Adaptive Search Procedure) is designed to solve the feature subset selection problem. The GRASP algorithm (Feo and Resende, 1995) is used to select accounting ratios, for a sample of 198 Spanish companies, which are then used in a logit model that is called the GRASP-LOGIT model. The results obtained by the GRASP-LOGIT model are superior to those from the traditional logit in the sense that the GRASP-LOGIT model reaches the same level of forecasting ability with fewer variables (accounting ratios), leading to a better interpretation of the model and therefore to a better understanding of the failure process. As far as we know, this is the first study that has combined both methodologies, the GRASP and the logistic regression, logit.

The remainder of this paper is organized as follows. Section 2 describes the sample, and Section 3 describes the GRASP procedure. Section 4 presents data from the estimation of the GRASP-LOGIT model. Section 5 reports the main conclusions.

## 2. SAMPLE SELECTION AND ACCOUNTING RATIOS

### 2.1 COMPANIES

The data have been obtained from the SABI database from Bureau Van Dijk (BVD), one of Europe's leading publishers of electronic business information databases and one of the providers of the Wharton Research Data Services. SABI comprises all the companies whose accounts are placed on the Spanish Mercantile Registry. BVD databases have been used in previous failure studies on companies from European countries (e.g. Ooghe and Balcaen, 2002). The sample consists of 198 Spanish companies, of which approximately one-third (67) are failed companies placed under temporary receivership (18, or 27%) or declare bankrupt (49, or 73%). The remaining 131 companies are healthy or, at least, "active," firms. We use also an additional testing sample of 61 companies, of which 40 are healthy and 21 are failed firms. All these companies have complete data available for three consecutive years. Thus, our sample selection method does not pair failed/healthy firms by sector and size. Although the paired sample method is usual, not all authors follow it, because of its arbitrariness and the lack of empirical evidence to support or disconfirm its superiority (see Ohlson, 1980: p. 112). It might actually be more interesting to include the variables "size" and "sector" as predictors than their use for matching (see Lennox, 1999).

CNAE	Failed	Healthy
01 Farming	0	3
02 Forestry	0	1
15 Food and beverage sector	5	6
17 Textile industry	3	1
18 Clothing industry	1	1
19 Shoemaking	0	1
20 Wood and cork industry	1	2
21 Paper industry	0	1
22 Publishing and graphic arts	2	3
24 Chemical industry	0	4
25 Manufacturing of plastic and rubber products	1	2
26 Manufacturing of other mineral products	0	1
27 Metalwork	2	1
28 Manufacturing of metal products	4	3
29 Building machinery	5	3
31 Manufacturing of electric equipment	2	0
33 Manufacturing of medical equipment	0	1
34 Manufacturing of motorized vehicles	0	1
35 Manufacturing of other transport material	1	0
36 Manufacturing of furniture; other industries	4	3
41 Water collecting, purifying, and distribution	0	1
45 Building	10	16
50 Sales and repair of. motorized vehicles	0	5
51 Wholesale sales	12	16
52 Retail sales	7	11
55 Hospitality sector	0	4
60 Land transport	0	2
61 Sea transport	0	1
63 Transport-related activities	1	1
65 Finance trading (except insurance)	0	1
70 Real estate agents	2	16
74 Other business activities	2	12
80 Education	2	0
85 Hospital and veterinary activities	0	2
92 Cultural, recreational, and sport activities	0	4
93 Personal services activities	0	1
<b>Total</b>	<b>67</b>	<b>131</b>

**Table 1:** Failed/healthy firms by CNAE classification

Table 1 shows the distribution of failed and healthy firms by sector. We can observe that 55 of the 67 failed firms do have healthy counterparts in the same sector (as defined by the two-digit CNAE [Spanish Classification of Economic Activities] code). The extra 12 failed companies are distributed over 8 sectors, where failed firms outnumber healthy ones.

Table 2 shows the distribution of healthy and failed firms by mean size (measured by the number of employees) and age (number of years since the company was founded), and the proportions of firms having the two legal structures (corporation and limited liability company). As was expected, the mean size of solvent companies was greater than that of insolvent companies. However, once the ten solvent companies with more than 100 employees is removed from the sample, the mean size of the remaining ones was reduced to that of the insolvent group. The companies were about equally distributed across both groups by legal structure, with 60% being limited liability companies and the remaining 40%, corporations. Surprisingly, the mean number of operating years for both groups of companies was the same, 18 years, with a very similar standard deviation; even though it is usually argued that most failures take place in the first years of the company's existence. This analysis includes a survival bias that might partially explain this contradiction: We consider only companies with data available for three consecutive years. The data on operating years seem to indicate that once companies operate for more than 2 or 3 years, their probability of becoming insolvent is not related to their longevity.

	Failed (67)	Healthy (131)
<b>Size*</b>		
Mean number of employees	22 (22)	36 ( 65)
Mean number of employees (<100 employees)**	22 (22)	20 (23)
<b>Legal format***</b>		
Corporation	27 (40%)	52 (40%)
Limited liability company	40 (60%)	79 (60%)
<b>Years in business*</b>		
Mean number of years in business	18 (15)	18 (13)

\* Standard deviation in parentheses; \*\* After eliminating from the sample those solvent companies with more than 100 employees (a total of 10); \*\*\* Number of companies (percentage in each sample in parentheses).

**Table 2:** Failed/healthy firms by mean size, legal format, and years in business

## 2.2 FINANCIAL RATIOS

Out of the ratios published in the SABI database, 36 ratios have been selected for each company for 3 consecutive years. This has yielded a total of 108 ratios per company. It has been included all the ratios published in SABI for the Spanish companies<sup>1</sup>, except for a few for which there is no consistent available information, as is the case for the ratio "credit period", which unfortunately has been excluded. On the other hand, we have added new ratios representing time trends for 11 of the 36 ratios previously selected. For each of these ratios, three time trends have been calculated: The trend between year t-1 and t-2, between t-2 and t-3, and between t-1 and t-3. Therefore, there is a total of 141 data points for each company (108 plus 33). Including time variations for the ratios is not a common practice in insolvency analysis, with the exception of a few studies like those of Pompe and Bilderbeek (2005) and Dambolena and Khoury (1980). Such variations can be of interest, as it is well known that the ratio distribution in healthy companies tends to be constant over time; whereas in insolvent companies, it deteriorates greatly (see, e.g., Beaver, 1966). Indeed, time variations in some ratios could have a greater predictive power than the simple ratio value. However, there is no consensus on the predictive ability of the trend ratios: Some empirical studies show positive

<sup>1</sup> The set of ratios used does not include cash-flow ratios. Market value ratios have been omitted since practically all the companies in the sample are private firms.

evidence (i.e., Dambolena and Khoury, 1980), whereas others find negative evidence (i.e., Pompe and Bilderbeek, 2005). As an additional advantage, it seems *a priori* that such variations might have greater independence from the activity sector and the company size than from the simple ratio. Tables 3a and 3b show the definitions of the financial ratios and their main descriptors respectively (M=mean and SD= Standard Deviation).

<b>Activity Ratios</b>	
Sales growth (%)	$[(\text{Sales}_t - \text{Sales}_{t-1}) / \text{Sales}_{t-1}] \times 100\%$
Asset turnover	$\text{Sales} / \text{Total assets}$
Productivity	$[\text{Operating revenues} - \text{Consumption and oper. expenditures}] / \text{Personnel expend.}$
Personnel expenditures (%)	$[\text{Personnel expenditures} / \text{Operating revenues}] \times 100\%$
Value added growth (%)	$[(\text{Value added}_t - \text{Value added}_{t-1}) / \text{Value added}_{t-1}] \times 100\%$
Operating margin (%)	$[\text{Earnings before taxes} / \text{Operating revenues}] \times 100\%$
Net asset turnover	$\text{Operating revenues} / \text{Permanent funds}$
<b>Return Ratios</b>	
ROCE	$[\text{Earnings before taxes} + \text{Financial expenses}] / \text{Permanent funds}] \times 100\%$
ROA	$[\text{Earnings} / \text{Total assets}] \times 100\%$
ROA before taxes	$[\text{Earnings before taxes} / \text{Total assets}] \times 100\%$
ROE	$[\text{Earnings} / \text{Equity}] \times 100\%$
ROE before taxes	$[\text{Earnings before taxes} / \text{Equity}] \times 100\%$
Financing costs (%)	$[\text{Financing costs} / \text{Sales}] \times 100\%$
<b>Equilibrium Ratios</b>	
Working capital (€)	$\text{Equity} + \text{Provisions for C \& E+ LT creditors} - \text{Fixed assets}$
Need for working capital (€)	$[\text{EHNDP} + \text{Accrued expenses} + (\text{Inventory} + \text{Accounts receivable})] -$ $[\text{Accrued incomes} + \text{Accounts payable}]$
Cash (€)	$\text{ST financial investments} + \text{Cash} - \text{ST debt}$
Equilibrium	$\text{Equity} + \text{provisions for C \& E+ LT debt}] / \text{Fixed assets}$
<b>Kinetic Equilibrium Ratios</b>	
Working capital (days)	$[\text{Working capital} / \text{sales}] \times 360$
Need for working capital (days)	$[\text{Need for working capital} / \text{Sales}] \times 360$
Cash (days)	$[\text{Cash} / \text{Sales}] \times 360$
Clients' credits (days)	$[\text{Accounts receivable} / \text{Operating incomes}] \times 360$
Clients' credits due to sales (days)	$[\text{Accounts receivable} / \text{Sales}] \times 360$
<b>Solvency Ratios</b>	
Debt (%)	$[\text{Total liabilities} / \text{Total liabilities and owners' equity}] \times 100\%$
Solvency ratio (%)	$[\text{Equity} / \text{Total assets}] \times 100\%$
Equity over permanent funds (%)	$[[\text{Equity} / [\text{Equity} + \text{LT creditors} + \text{Provisions for C \& E}]]] \times 100\%$
Repayment capabilities	$[\text{LT and ST creditors} / (\text{Sales} + \text{Depreciations} + \text{Provisions} + \text{Equity})]$
<b>Liquidity Ratios</b>	
Immediate liquidity	$[\text{ST Financial investments} + \text{Cash}] / \text{Accounts payable}]$
Current liquidity	$[\text{Cash} + \text{ST financial investments} + \text{Accounts receivable} + \text{Inventory}] / \text{ST Liabilities}$
Liquidity	$[\text{Cash} + \text{ST financial investments} + \text{accounts receivable}] / \text{ST liabilities}$
Interest cover	$\text{Operating profit} / \text{Financial expenses}$
<b>Ratios per employee</b>	
Profit per employee	$\text{Earnings before taxes} / \text{Number of employees}$
Income per employee	$\text{Operating incomes} / \text{Number of employees}$
Personnel costs per employee	$\text{Personnel expenses} / \text{Number of employees}$
Equity per employee	$\text{Equity} / \text{Number of employees}$
Working capital per employee	$\text{Working capital} / \text{Number of employees}$
Total assets per employee	$\text{Total assets} / \text{Number of employees}$

\*Abbreviations: EHNDP (Equity Holders by Non-Demanded Payments); ST (Short Term); LT (Long Term); C&E (Contingencies and Expenses).

**Table 3a:** Definitions of ratios



RATIO	FAILED						HEALTHY					
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
<b>Activity Ratios</b>	<b>t-1</b>	<b>t-1</b>	<b>t-2</b>	<b>t-2</b>	<b>t-3</b>	<b>t-3</b>	<b>t-1</b>	<b>t-1</b>	<b>t-2</b>	<b>t-2</b>	<b>t-3</b>	<b>t-3</b>
Sales growth (%)	-3.2	49.6	8.6	30.7	39.3	110.5	14.5	48.4	29.0	90.0	36.9	104.8
Asset turnover	1.9	1.2	1.7	0.8	1.9	1.2	1.7	1.5	1.6	1.4	1.5	1.2
Productivity	0.8	0.9	1.3	0.6	1.4	0.6	1.9	2.4	1.9	2.2	1.8	1.4
Personnel expenditures (%)	34.8	45.1	25.7	17.2	25.1	17.5	26.9	25.2	25.5	20.3	25.4	20.0
Value added growth (%)	-12.0	37.9	11.2	28.5	33.4	91.2	38.9	121.0	51.2	140.3	40.4	110.8
Operating margin (%)	-11.6	20.4	-1.4	7.1	0.0	5.3	-1.8	79.4	8.2	48.4	8.4	54.6
Net asset turnover	9.9	42.0	8.3	11.2	8.7	21.7	4.8	9.7	5.9	37.6	5.9	10.1
<b>Return Ratios</b>												
ROCE	-4.7	199.2	17.3	95.4	32.7	91.5	21.9	37.2	19.5	36.5	20.5	34.8
ROA	-25.8	59.7	-1.7	10.9	1.0	6.3	2.8	15.5	3.1	11.4	3.7	7.8
ROA before taxes	-24.7	57.0	-1.2	10.8	1.3	7.9	4.6	15.6	4.1	16.2	4.9	10.7
ROE	15.4	167.9	15.2	134.6	12.6	57.4	12.9	85.2	11.5	56.2	5.7	65.2
ROE before taxes	7.8	182.3	8.5	87.2	14.1	70.0	19.2	93.2	19.7	70.0	14.6	44.4
Financial costs (%)	4.8	12.2	2.9	2.2	2.7	2.4	15.0	88.3	13.0	56.1	9.2	53.1
<b>Equilibrium Ratios</b>												
Working capital (Mil)	-163	1418	-76	1194	58	498	2049	15018	2669	11733	3159	17870
Need of working capital (Mil)	-19	1447	206	1154	252	1066	-182	14217	1078	7024	186	13888
Cash (Mil)	-144	912	-282	1258	-194	1004	2231	21583	1591	13070	2973	29669
Equilibrium	-2	27	3	5	3	9	11	72	7	39	5	26
<b>Kinetic Equilibrium Ratios</b>												
Working capital (days)	-49	243	-9	172	-6	164	361	5608	1139	6770	525	5793
Need of working capital (days)	-61	266	-14	173	-13	173	-130	1659	298	3437	-65	888
Cash (days)	12	49	6	42	7	45	491	5286	841	6115	590	5993
Clients' credits (days)	179	753	86	61	89	65	281	1002	215	769	149	234
Clients' credits due to sales (days)	178	753	86	61	88	65	234	800	109	128	127	191
<b>Solvency Ratios</b>												
Debts (%)	107.0	76.5	83.8	22.0	81.4	23.0	68.8	45.4	68.0	43.1	67.9	39.0
Solvency ratio (%)	-7.0	76.5	16.2	22.0	18.6	23.0	31.2	45.4	32.0	43.1	32.1	39.0
Equity over permanent funds (%)	64.5	61.0	57.5	48.6	65.5	31.3	75.8	38.4	74.6	34.1	75.7	31.8
Repayment capabilities	2.1	11.0	0.6	0.6	0.6	0.6	5.7	46.5	2.2	10.7	1.8	8.1
<b>Liquidity Ratios</b>												
Immediate liquidity	1.6	11.8	0.2	0.9	0.2	0.8	5.5	54.7	4.7	43.6	0.7	2.1
Current liquidity	8.2	58.4	1.3	1.0	1.3	0.9	7.9	56.1	6.1	43.8	2.2	3.2
Liquidity	2.6	15.7	0.8	0.9	0.8	0.9	7.4	56.1	5.5	43.8	1.5	2.5
Interest cover	-24.6	170.1	-18.5	170.7	-5.9	75.7	30.7	518.6	173.0	1325.0	207.9	1347.2
<b>Ratios per employee</b>												
Profit per employee (Mil)	-21	60	-4	32	0	13	76	694	34	173	26	146
Income per employee (Mil)	183	234	196	290	199	303	471	1854	302	639	247	457
Personnel expenditures per employee (Mil)	35	81	33	89	44	136	32	51	27	16	25	14
Equity per employee (Mil)	3	49	19	48	22	68	459	2060	390	1962	318	1812
Working capital per employee (Mil)	79	139	78	130	76	137	255	1001	167	436	136	323
Total assets per employee (Mil)	140	220	133	214	124	209	930	3928	597	2097	499	1920
	FAILED						HEALTHY					
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
<b>Ratio Trends (%)</b>	<b>t-1_2</b>	<b>t-1_2</b>	<b>t-2_3</b>	<b>t-2_3</b>	<b>t-1_3</b>	<b>t-1_3</b>	<b>t-1_2</b>	<b>t-1_2</b>	<b>t-2_3</b>	<b>t-2_3</b>	<b>t-1_3</b>	<b>t-1_3</b>
<b>Activity Ratios Trend</b>												
Operating margin (%)	-10.2	18.8	-1.4	6.4	-11.6	20.7	-13	96.4	-0.2	26.4	-13.2	98.1
<b>Equilibrium Ratio Trend</b>												
Working capital (Mil)	-87	377	-134	1076	-221	1306	-620	7173	-491	8554	-1110	9858
Need for working capital (Mil)	-224	960	-46	920	-271	1733	-1259	9573	891	9911	-368	7909
Cash (Mil)	137	774	-88	460	49	538	640	10116	-1382	17489	-743	9376
<b>Solvency Ratio Trend</b>												
Debts (%)	23.3	67.6	2.3	12.9	25.6	71.5	0.9	16.6	0.1	12.8	1.0	19.4
Solvency ratio (%)	-23.3	67.6	-2.3	12.9	-25.6	71.5	-0.9	16.6	-0.1	12.8	-1.0	19.4
Equity over permanent funds (%)	7.0	63.2	-8.1	39.6	1.1	68.3	1.2	32.6	-1.1	23.7	0.1	38.0
Repayment capabilities	1.4	10.9	0.0	0.3	1.5	11.0	3.5	44.3	0.3	11.2	3.8	45.8
<b>Liquidity Ratio Trend</b>												
Immediate liquidity	1.4	11.8	0.0	0.2	1.4	11.8	0.9	11.3	3.9	41.8	4.8	52.9
Current liquidity	7.0	58.5	0.0	0.4	6.9	58.5	1.9	16.2	3.9	42.1	5.8	54.5
Liquidity	1.8	15.8	0.0	0.2	1.8	15.8	1.9	16.1	4.0	42.0	5.9	54.4

**Table 3b:** Ratios: Mean (M) and standard deviation (SD) for each year

The relationship between the mean values of the ratios in both groups (healthy and failed) generally is the expected one, with some exceptions (e.g. financial costs % and liquidity ratios). However, when such exceptions are examined in detail, it can be seen that they are due to extreme values in the ratios of some of the companies.

### 3. THE GRASP ALGORITHM FOR FEATURE SELECTION

#### 3.1 THE FEATURE SELECTION PROBLEM

The problem of selecting the subset of financial ratios with superior classificatory performance can be formulated as follows: Let  $V$  be a set of  $m$  variables (financial ratios) such that  $V = \{1, 2, \dots, m\}$ , and let  $A$  be a set of cases (firms). For each case (firm), the class to which it belongs ("healthy" or "failed") is known. Given a predefined value  $p \in \mathbb{N}$ ,  $p < m$ , we have to find a subset  $S \subset V$ , with a size  $p$ , with the greatest classificatory capacity. The classificatory capacity for each subset  $S \subset V$  is estimated by the function  $f(S)$ , which is computed as follows: The partition  $A = A_1 \cup A_2$  is made in  $A$ . For each case (firm) in  $A_2$ , the Euclidean distance with every case in  $A_1$  is computed and the class (healthy or failed) of the closest case is assigned. The value of  $f(S)$  is the percentage of hits in the assigned classes (healthy or failed), namely the number of times that the assigned class is the same as the real class. The partitions  $A_1$  and  $A_2$  have approximately the same size (number of firms) and the same proportions of firms in both classes, healthy and failed.

#### 3.2 THE GRASP ALGORITHM

GRASP constructs solutions with controlled randomization and a greedy function. Most GRASP implementations also include a local search that is used to improve upon the solutions generated with the randomized greedy function. GRASP was originally proposed in the context of a set covering problem (Feo and Resende, 1989). Details of the methodology and a survey of applications can be found in Feo and Resende (1995) and Pitsoulis and Resende (2002).

In each iteration, a solution that is improved with a local search procedure is built. The final solution is the best solution from all the iterations. The stop criterion is executed when no exchange provides a better solution or when a maximum number of iterations or a maximum computational time is reached.

The remainder of Subsection 3.2 is organized as follows: Subsections 3.2.1 and 3.2.2 describe both procedures of the proposed GRASP algorithm, the greedy random procedure and the local search procedure, respectively; and, in Subsection 3.2.3, the performance of the GRASP method is evaluated carrying out some preliminary tests.

##### 3.2.1. The greedy random procedure

The functioning of the greedy random procedure is as follows: Starting from an empty initial solution ( $S = \emptyset$ ), a variable (financial ratio) is added in each iteration until the solution  $S$  reaches  $p$  variables ( $|S| = p$ ). A fitness function is used to decide which variable (financial ratio) is added to the solution in each iteration. In contrast with deterministic techniques, the GRASP algorithm does not take the variable with the best fitness value, but makes a "candidate list" denoted by  $L$ , comprising the subset of variables (financial ratios) with the highest fitness values and takes randomly one variable from  $L$ . The pseudo-code for the greedy random procedure is summarized in Algorithm 1.

**Algorithm 1.** Pseudo-code for the greedy random procedure

1. Start  $S = \emptyset$
2. Repeat
  - 2.1. Compute  $R_j, \forall j \in V - S$
  - 2.2. Determine  $R_{\max} = \max \{ R_j / j \in V - S \}$  and  $R_{\min} = \min \{ R_j / j \in V - S \}$
  - 2.3. Build  $L = \{ j / R_j \geq \alpha \cdot R_{\max} + (1-\alpha) \cdot R_{\min} \}$
  - 2.4. Select  $j^* \in L$  randomly and make  $S = S \cup \{j^*\}$
3. Until  $|S| = p$

The fitness function, denoted by  $R_j$ , is computed as follows:

- In the initial iteration ( $S = \emptyset$ ),  $R_j$  is given by the ratio “between-groups variance/within-groups variance” of the variable  $j$ .
- In the next iterations, for each variable  $j \in V - S$ , the residues from a linear regression model, where the dependent variable is  $j$  and the independent variables are the elements of  $S$ , are estimated. The value of  $R_j$  is given by the ratio “between-groups variance/within-groups variance” of these residues. The aim of taking the residues instead of the simple variables is to eliminate information that may already be in the selected variables in  $S$ .

The exclusive use of quantitative variables (financial ratios) allows to make use of the above well-known fitness function to build  $L$ , with the variables  $j$  with the highest value of  $R_j$ . As is shown in Statement 2.3 of Algorithm 1, the size of  $L$  depends on  $\alpha$ , a parameter that changes from 0 to 1. When  $\alpha = 0$ , then  $L = V - S$ , and therefore the method is completely random. When  $\alpha = 1$ , then  $L$  includes only the variable with the highest  $R_j$  and therefore the method is deterministic.

**3.2.2. The Local Search Procedure**

Each complete solution  $S$  generated by the greedy random procedure in the previous step (see Section 3.2.1) is improved by a simple local search procedure. In each local search step, a variable in the solution will be exchanged for another out of the solution. In more specific terms, given a solution  $S$ , let  $N(S)$  be the neighborhood of  $S$  such that

$$N(S) = \{ S' / S' = S \cup \{j'\} - \{j\}, \forall j \in S, j' \notin S \}.$$

The pseudo-code for the local search procedure is summarized in Algorithm 2:

**Algorithm 2.** Pseudo-code for the local search procedure

1. Read initial Solution  $S$
2. Repeat
  - 2.1. Make previous\_value =  $f(S)$
  - 2.2. Search  $f(S^*) = \max \{ f(S') / S' \in N(S) \}$
  - 2.3. If  $f(S^*) > f(S)$  then make  $S = S^*$
3. Until  $f(S^*) \leq \text{previous\_value}$

Thus, in each local search iteration, a variable in the solution will be exchanged for another out of the solution and the procedure ends when no exchange provides a better solution.

**3.2.3. Preliminary tests**

To evaluate the performance of the GRASP method, some preliminary tests are carried out. Table 3b with 141 financial ratios for the sample of 198 companies is used (see Section 2). From this table,

smaller tables with  $m$  financial ratios are obtained. The following values of  $m$  are considered:  $m = 40$  (corresponding to the first 40 financial ratios), 65, 90, 105, and 120. Solutions  $S$  of size  $p$  (number of financial ratios selected for classification), where  $p$  ranged from 4 to 16, are used. For each value of  $m$ , the algorithm is run one time for the deterministic method ( $\alpha = 1$ ) and 20 times for both algorithms, the greedy random method ( $\alpha=0.85$ ) and the GRASP ( $\alpha=0.85$ ). Previously, different values for  $\alpha$  were tested and the best results were obtained for  $\alpha = 0.85$ . The number of cases (firms) under consideration is 198, divided into classes “healthy” and “failed”, with 131 and 67 members respectively. A partition such that  $A = A_1 \cup A_2$ , where  $A_1$  consists of 100 items (66 solvent and 34 insolvent) and  $A_2$  consists of 98 (65 solvent and 33 insolvent), are considered. In Table 4, Columns 1 and 2 show the values of  $m$  and  $p$  respectively. Column 3 shows the classificatory power –values of  $f(S)$ – for the deterministic algorithm. Finally, Columns 4 and 5 show the values of  $f(S)$  for 20 iterations of both algorithms, the greedy random method and the GRASP (the greedy random method plus the local search).

<b>m</b>	<b>P</b>	<b>Deterministic: <math>\alpha=1</math></b>	<b>Greedy random: <math>\alpha=0.85</math></b>	<b>GRASP: <math>\alpha=0.85</math></b>
40	4	0.67346939	<b>0.70408163</b>	<b>0.7755102</b>
	5	0.69387755	0.69387755	<b>0.7755102</b>
	6	0.68367347	0.68367347	<b>0.7755102</b>
	7	0.68367347	0.68367347	<b>0.79591837</b>
	8	0.71428571	0.71428571	<b>0.80612245</b>
65	6	0.67346939	<b>0.71428571</b>	<b>0.80612245</b>
	7	0.69387755	0.69387755	<b>0.81632653</b>
	8	0.70408163	0.70408163	<b>0.82653061</b>
	9	0.70408163	0.70408163	<b>0.84693878</b>
	10	<b>0.73469388</b>	0.68367347	<b>0.85714286</b>
90	8	0.65306122	<b>0.75510204</b>	<b>0.85714286</b>
	9	0.68367347	<b>0.75510204</b>	<b>0.85714286</b>
	10	0.69387755	<b>0.74489796</b>	<b>0.86734694</b>
	11	0.69387755	<b>0.70408163</b>	<b>0.86734694</b>
	12	0.67346939	<b>0.75510204</b>	<b>0.86734694</b>
105	10	0.64285714	<b>0.74489796</b>	<b>0.87755102</b>
	11	0.60204082	<b>0.75510204</b>	<b>0.87755102</b>
	12	0.60204082	<b>0.71428571</b>	<b>0.87755102</b>
	13	0.60204082	<b>0.7244898</b>	<b>0.8877551</b>
	14	0.59183673	<b>0.69387755</b>	<b>0.87755102</b>
120	12	0.66326531	<b>0.78571429</b>	<b>0.90816327</b>
	13	0.65306122	<b>0.78571429</b>	<b>0.8877551</b>
	14	0.68367347	<b>0.7244898</b>	<b>0.90816327</b>
	15	0.70408163	<b>0.73469388</b>	<b>0.8877551</b>
	16	0.68367347	<b>0.7244898</b>	<b>0.8877551</b>

**Table 4:** Results from computational tests for the deterministic, the greedy random and the GRASP algorithm

Table 4 shows that the greedy random method gives higher values for  $f(S)$  than the deterministic method: In 17 cases, it is better (in bold); in seven, it is the same: and only in one case, it is worse. In addition, it can be observed that the GRASP method strongly improves the results of the greedy random method on its own. Therefore, the local search is very efficient for improving the quality of the solutions obtained by both the deterministic constructive algorithm and the random constructive algorithm. It should be highlighted that the best result of the GRASP strategy is not always obtained with the highest values of  $p$ . For instance, for  $m=105$ , the best result is obtained when  $p=13$ ; and for  $m=120$ , the best result is obtained when  $p=14$ . This situation is not strange due to the use of approximate heuristic methods for both, the variable selection (deterministic, greedy random and GRASP) and the parameter fine-tuning methods that use logistic regression methods.

## 4. THE GRASP-LOGIT MODEL

### 4.1. APPLYING GRASP AS A RATIO PRESELECTION PROCEDURE

Now that the efficiency of the GRASP algorithm has been demonstrated, we proceed to solve the problem of variable selection for the considered sample. As it is stated above, we deal with 198 cases (firms), divided into two classes (healthy and failed), with 131 and 67 members respectively. The same partition as in previous tests –  $A = A_1 \cup A_2$ , where  $A_1$  has 100 items (66 healthy and 34 failed) and  $A_2$  has 98 (65 solvent and 33 insolvent) – is considered. In this case, the total number of variables or ratios ( $m=141$ ) is used.

Table 5 shows the values of the objective function obtained for the different values of  $p$  (number of ratios selected). Each column (Columns 2, 3 and 4) shows the result for one of the three strategies: *Deterministic*, *greedy random* (executed 20 times with  $\alpha = 0.85$ ) and *GRASP* (executed 20 times with  $\alpha = 0.85$ ).

Number of preselected ratios (%)	Constructive deterministic method	Greedy random method	GRASP method
10	0.66938776	0.71020408	0.80612245
11	0.67959184	0.70408163	0.80204082
12	0.67959184	0.7	0.80612245
13	0.68775510	0.71020408	0.81632653
14	0.67551020	0.71428571	<b>0.82040816</b>
15	0.66530612	0.70816327	0.81224490

**Table 5:** Value of the objective function  $f$  for different numbers of preselected ratios

The greedy random constructive method (Column 3) generates better results than the deterministic strategy (Column 2). However, for each value of  $p$ , the value of the fitness function (the percentage of hits) is best when the GRASP procedure is applied (Column 4 in Table 5). As happens in the preliminary test (Subsection 3.2.3), the GRASP strategy provides us with the best solutions.

This time, the number of financial ratios allowed in the subset ( $p$ ) ranges between 10 and 15. With the GRASP method, the best values for the fitness function  $f(S)$  were obtained for  $p=13$ ,  $p=14$ , and  $p=15$ . As explained above, note that when  $p$  increases, the value of  $f(S)$  does not necessarily increase, as happens for the greedy random method, for which  $f(S)$  reaches the value of 0.71020408 for  $p=10$  and of 0.70408163 for  $p=11$ , meaning that the percentage of hits is lower even though the value of  $p$  is higher.

Finally, Table 6 shows the frequency of selection for the different ratios. The first column shows the name of the ratio and the second column shows the kind of ratio, namely: A (activity), R (returns), E (equilibrium), S (solvency), L (liquidity), K\_E (kinetic\_equilibrium) and PE (per employee). Columns 3 to 5 show the number of times that each financial ratio is selected by the different strategies used: Constructive deterministic, greedy random constructive and GRASP, respectively. The last column shows the total number of times that this ratio has been selected by the set of strategies.

Non-Selected Ratios		Deterministic constructive	Random constructive	GRASP	TOTAL
Financial costs %	R	0	0	0	0
Working capital (days)	E_C	0	0	0	0
Need of working capital (days)	E_C	0	0	0	0
Cash (days)	E_C	0	0	0	0
Clients' credit (days)	E_C	0	0	0	0
Repayment capability	S	0	0	0	0
Current liquidity	L	0	0	0	0
Liquidity	L	0	0	0	0
Interest cover	L	0	0	0	0
Profit per employee	PE	0	0	0	0
Equity per employee	PE	0	0	0	0
Working capital per employee	PE	0	0	0	0
Total assets per employee	PE	0	0	0	0
Selected Ratios	*	Deterministic constructive	Random constructive	GRASP	TOTAL
<b>Value added growth</b>	<b>A</b>	<b>12</b>	<b>12</b>	<b>7</b>	<b>31</b>
Sales growth	A	1	0	0	1
<b>Productivity</b>	<b>A</b>	<b>12</b>	<b>12</b>	<b>2</b>	<b>26</b>
<b>Personnel expenditures (%)</b>	<b>A</b>	<b>6</b>	<b>6</b>	<b>3</b>	<b>15</b>
Operating margin (%)	A	0	1	3	4
Asset turnover	A	2	2	3	7
Net asset turnover	A	3	3	4	10
ROA	R	0	0	3	3
<b>ROA before taxes</b>	<b>R</b>	<b>12</b>	<b>6</b>	<b>5</b>	<b>23</b>
ROE	R	0	1	0	1
ROE before taxes	R	0	3	3	6
ROCE	R	2	3	5	10
<b>Solvency ratio</b>	<b>S</b>	<b>9</b>	<b>7</b>	<b>15</b>	<b>31</b>
<b>Equity over permanent funds</b>	<b>S</b>	<b>12</b>	<b>7</b>	<b>3</b>	<b>22</b>
<b>Debt ratio</b>	<b>S</b>	<b>4</b>	<b>6</b>	<b>7</b>	<b>17</b>
Equilibrium	E	0	0	4	4
Working capital (€)	E	0	0	1	1
Need of working capital (€)	E	0	0	2	2
Clients' credits due to sales (days)	E_C	0	2	0	2
Income per employee	PE	0	2	1	3
Personnel expenditures per employee	PE	0	2	1	3
Immediate liquidity	L	0	0	2	2
Cash	E	0	0	1	1
<b>TOTAL</b>		<b>75</b>	<b>75</b>	<b>75</b>	<b>225</b>

\* A: activity; R: returns; E: equilibrium; S: solvency; L: liquidity; K\_E: kinetic\_equilibrium; and PE: per employee.

**Table 6:** Number of times that each financial ratio is selected by the different algorithms

If we focus on the selected financial ratios (that is, those ratios that predict better corporate failure), the following conclusions can be drawn:

- The ratios more often selected are those referring to activity, solvency and, to a lesser degree, return. In more specific terms, the most relevant ratios are value-added growth, solvency ratio, productivity, ROA before taxes, and equity over permanent funds. As a group, these financial ratios encapsulate good information regarding the solvency of the company. Interestingly, however, as Table 6 shows, the “leading” ratios are not always the same in each selection procedure. Liquidity, per employee, and kinetic equilibrium ratios are rejected by all three selection procedures. It was unexpected that liquidity ratios were selected only by GRASP and only in fewer than 3% of the cases. Economic sense suggests that liquidity ratios could be important to anticipate the financial distress of a company. However, some other studies converge with our findings; Beaver (1966) and Pompe and Bilderbeek (2005) did not find liquidity ratios having a predictive value for failure forecasting. A possible explanation might be that the “right” value of liquidity ratios depends on sector and firm characteristics (i.e., healthy big companies in the retail sector, like Wal-mart or Carrefour, present liquidity ratios below those of small manufacturing firms with financial problems), so that they are seldom useful except where failure forecast is focused on a specific sector or type of firms.
- On the other hand, ratios referring to trends (time variations) are the most prominent type within the selected ratios. Eighteen models have been tested: 6 models (with values of  $p$  ranging from 10 to 15) for each of the three strategies under consideration (constructive deterministic, greedy random constructive and GRASP). In 16 out of the 18 models, at least one trend ratio was always selected. Therefore, although trend ratios are not usually included in this kind of analysis, they are important. The relevance of time variability in financial ratios dealing with solvency and debts, which are the ones with the highest frequency in all the models tested, makes sense because the worsening of these ratios over time might suggest that the company is close to insolvency. From the beginning, the literature on financial distress (see Beaver, 1966) has suggested that the ratio distribution of healthy companies is steady over time, whereas it changes in a significant way for unsound companies.

## 4.2. APPLYING THE LOGISTIC REGRESSION

After solving the problem of variable selection, logistic regression is used to fine-tune the ratios that best predict insolvency.

Logistic regression models belong to the generalized linear models. Basically, logistic regression models estimate the probability that an individual belongs to a class by transforming a linear function of explanatory variables through the logistic function. Specifically, they calculate the value of a linear function of the explanatory variables and, from this value through the logistic function, they transform it into the probability of belonging to a certain class. To estimate the coefficients of this linear function, the maximum likelihood criterion is used.

To apply logistic regression, we take the selected ratios with the best value for the objective function, which corresponds to the GRASP metaheuristic strategy when  $p=14$  and  $f(S)= 0.82040816$  (shown in bold in Table 5). In this case, we apply logistic regression to the 14 variables selected, which are shown in Table 7. Note that 5 out of 14 are trend ratios. Furthermore, 5 of them are solvency ratios, 3 are return ratios, 3 are activity ratios, and the remaining 3 are equilibrium ratios.

Table 8 shows the financial ratios that best predict corporate failure (out of the 14 ratios in Table 7) after performing the logistic regression. Specifically, Column 1 is devoted to the name of the ratios, Columns 2 and 3 show the coefficients of the ratios and their standard error, respectively, and finally, Column 4 shows the signification level of the coefficients.

ROA before taxes_t-1	Working capital_t-1_vs_t-2
ROA_t-1	Need for working capital_t-1_vs_t-2
Equity over permanent funds_t-2	Debts_t-1_vs_t-2
Solvency ratio_t-2	Net asset turnover_t-2
Value added growth_t-2	Solvency ratio_t-1_vs_t-2
Equilibrium_t-2	ROCE_t-3
Debts_t-2_vs_t-3	Operating ratio_t-1

**Table 7:** Variables preselected by GRASP

		B	S.E.	Sig.
<b>Step 1</b>	ROA bt_t-1	0.066	0.015	0.000
	Constant	0.881	0.173	0.000
<b>Step 2</b>	VAG t-2	0.008	0.003	0.001
	ROA bt_t-1	0.077	0.016	0.000
	Constant	0.705	0.182	0.000
<b>Step 3</b>	VAG t-2	0.009	0.003	0.001
	ROA bt_t-1	0.077	0.016	0.000
	Solv_t-2	0.012	0.005	0.008
	Constant	0.395	0.213	0.063

**Table 8:** Results from the GRASP-LOGIT (78.9% of hits for in-sample data – 77.04% for out-of-sample data)

As can be seen in Table 8, the financial ratios that best predict corporate failure are: ROA before taxes\_t-1; Solvency ratio\_t-2 and Value added growth\_t-2.

We have introduced, into the GRASP-LOGIT model, control variables for the size of the company (measured by number of employees), for its age and for the sector that it belongs to (using the CNAE 2-digit code. However, these variables had no effect in the final results of the model. Neither the size of the company, nor its age<sup>2</sup> nor the sector that it belongs to, seems to have any predictive value regarding insolvency.

Given a cut-off probability of 0.5, the global percentage of hits in this analysis is 78.9%. Although we cannot state this analysis in terms of the hits in each group (healthy/failed), because type I and type II errors have not been taken into account in the ratio preselection process using GRASP, we have tried several different cut-off points in order to balance both types of errors while getting a global fitness similar to the total given above. For instance, a cut-off probability of 0.67 results in a global fitness of 77.8%, with fitness for type I and type II errors of 76.2% and 78.6%, respectively.

The result obtained makes economic sense because it uses three of the key variables in the financial analysis of a company. These include, on one hand, the business return (ROA before taxes t-1) and a variable that represents in some way the company's recent evolution (value added growth t-2); and, on the other hand, its leverage (solvency ratio t-2). Besides, these ratios are not biased by the activity sector that the firm belongs to. Interestingly, our final model (the GRASP-LOGIT) does not include any trend ratio, in spite of the results obtained in the preliminary step, when we applied the GRASP metaheuristic method.

- ROA shows the company's capacity to obtain returns from its assets and, to some extent, this variable is immune to which sector the company belongs to. In the well-known "DuPont" analysis, ROA is decomposed into sales margin and total turnover of assets, as follows:

$$ROA\_before\_taxes = \frac{Profit\_before\_taxes}{Sales} \times \frac{Sales}{Total\_Asset}$$

<sup>2</sup> Recall that there is an important bias in the analysis of age, as the sample included only firms with at least three years of life.



Normally, capital-intensive sectors have a greater sales margin than those that are less capital-intensive. However, capital-intensive sectors have a lower asset turnover (because they have greater fixed assets) than those that have smaller fixed assets and thus less need for capital. Because the two differences tend to cancel each other out, by including both variables, ROA palliates, to a great extent, the effect of belonging to one sector or another.

- The solvency ratio represents the equity-debt level of the company and, by combining this with ROA before taxes using DuPont analysis decomposition ratios, we obtain ROE before taxes as shown in the following expressions:

$$ROE\_before\_taxes = ROA\_before\_taxes \times leverage$$

$$ROE\_before\_taxes = \frac{Profit\_before\_taxes}{Sales} \times \frac{Sales}{Total\_Asset} \times \frac{1}{\frac{Total\_Equity}{Total\_Asset}}$$

- Finally, value-added growth shows the evolution of the company's operating profit over time. Thus, given an original level of solvency in the firm, a positive value of this rate would involve, initially, an improvement in the financial situation and in the return of the company; and a negative value, the worsening of its financial situation and its return.

To make sure that the forecasting ability of the model is not the result of overfitting, we have tested our GRASP-LOGIT model with out-of-sample data by using 61 companies (of which 40 are healthy and 21 failed firms) selected randomly from each group. The global fitness obtained with out-of-sample data is 77.04% (compared with a fitness of 78.9% for in-sample data), which confirms the forecasting ability of the model. We check again that type I and type II errors may be balanced by changing the cut-off point but maintaining the same level of global fitness.

Finally, in order to analyze the advantages of the GRASP method for solving the problem of variable selection before applying logistic regression, we have also carried out a logistic regression on the 141 original variables so that we can make comparisons. These are the results:

- Despite the much greater number of variables included in this new model, its percentage of global hits is very similar to the one obtained for the 14 variables preselected by GRASP and reduced in GRASP-LOGIT to 3 (79.3%, compared to 78.9% for GRASP-LOGIT). Obviously, this is due to the good performance of the GRASP algorithm.
- The variables selected in the logit with 141 variables are the following: Value added growth\_t-1 (%), Value added growth\_t-2 (%), Productivity\_t-3, Equity over permanent funds\_t-1(%), Debts\_t-3 (%), ROA before taxes\_t-1 (%) and Personnel expenditures\_t-2 (%).

Within the seven variables selected in this case –or six if we do not take into account the time factor–, the three variables that were previously selected by the GRASP-LOGIT model (ROA before taxes\_t-1, value added growth\_t-2, and debts\_t-3) are found. The variable debts is equivalent to the solvency ratio that appeared in the GRASP-LOGIT model (although its reading is the opposite), because Solvency ratio = 100 – Debts. This latter variable now appears in the t-3 period, while in the first GRASP- LOGIT model, the solvency ratio appeared in the t-2 period. The remaining variables selected for this model are personnel expenditures (%), productivity (gross operating margin per monetary unit used in labor) and equity over permanent funds. The meaning of these variables as predictors of failure is not as clear as for the three variables obtained with the GRASP-LOGIT model. Personnel expenditures (measured as a percentage of the firm's income) show great dependency on

sector, because the more labor-intensive sectors are the higher values are for this variable. The opposite happens with productivity; i.e. the sector that is more labor intensive has lower figures for this indicator. Finally, the variable equity over permanent funds or long-term funds does not seem to be a good predictor of insolvency, because it does not take into account short-term debts, which in many cases can be decisive for assessing the payment capacities of the company.

Therefore, it seems that the results obtained by the GRASP-LOGIT model are more transparent to interpretation than the ones from the logit with 141 ratios, whereas the predictive capacity of both models is the same.

#### 4.3. APPLYING THE GRASP STRATEGY TO OTHER CLASSIFICATION MODELS

GRASP strategy can be applied to other well-known classification models to improve them (similar to that has been done in the paper with logistic regression). In this way, in Pacheco *et al.* (2012), GRASP is combined with decision-tree models, specifically with the variant of the model C4.5 proposed by Fayyad and Irani (1992). A set of experiments with 17 databases belong to the well-known UCI Repository of Machine Learning at the University of California, Irvine (see Murphy and Aha, 1994), and the financial database used in this paper is performed. These experiments show that the GRASP strategy improves the performance of the C4.5 model.

In addition, experiments combining GRASP with Support Vector Machine, SVM (Cortes and Vapnik, 1995), have been performed. Specifically, they have been programmed in MATLAB using the functions that exist for this model. These tests have been performed with the same database used in the previous sections. The tests are similar to those corresponding to Table 5 (same data and parameter values). Results are shown in Table 9.

Number of preselected ratios (%)	Constructive deterministic method for SVM	Greedy random method	GRASP-SVM method
10	0,691375963	0,729004251	0,828801363
11	0,700075040	0,739926856	0,836319241
12	0,717251325	0,747999498	0,837509731
13	0,718058322	0,756363947	0,867865397
14	0,731584376	0,766728715	0,879347788
15	0,747119069	0,772571942	0,885211169

**Table 9:** Combining GRASP with SVM models

As happens with the logistic regression model, both the Greedy Random method and the GRASP method improve clearly the classic methods of variable selection for SVM, being this last one the best selection method.

In brief, the use of the GRASP strategy to select variables applied to different classification models improved substantially the performance of the classic variable selection methods in each one of these models.

## 5. CONCLUSIONS

This work is focused on solving the problem of preselecting financial ratios to model business insolvency, from 141 financial ratios for a sample of 198 Spanish firms. To this end, the metaheuristic strategy GRASP is used. This strategy builds solutions by controlled randomness over a greedy function that guides the entry of variables into the solution and then improves them by local search. This strategy can be used to solve the feature subset selection problem when all the variables are quantitative. There are no references in the literature to algorithms designed “ad hoc” for this type of variables. The results obtained with GRASP and its elements (the greedy random algorithm and

the local search algorithm) are compared to those obtained by applying a deterministic algorithm. The systematic superiority of GRASP means that the quality of the solutions so found can be improved either by introducing randomness into the selection procedure or by using local search. GRASP strategy is also applied successfully to other models (as can be seen in Subsection 4.3).

In addition, business insolvency is modeled by applying a logistic regression model to the results from the GRASP procedure. GRASP is used to preselect 14 financial ratios from which the logit is built. We called this model GRASP-LOGIT and the results obtained with it are compared to those obtained by applying a logit directly to the original 141 financial ratios. Although the classificatory capacity of the GRASP-LOGIT is the same as that of the logit model with 141 ratios, the former has more explanatory capacity and greater simplicity, and thus improves our understanding of business insolvency. It also reduces the cost of data acquisition.

The GRASP-LOGIT model shows that the best combination of ratios to explain corporate failure is ROA before taxes, solvency ratio, and value-added growth. The first two ratios are the components of ROE identified by DuPont analysis. In contrast with our initial expectations, none of the trend ratios had predictive value in the final model (GRASP-LOGIT). Liquidity ratios are also rejected by the model. Our results also reveal that neither the size of the company (measured by the number of employees), nor its age nor the sector that it belongs to, seems to have any value in predicting insolvency.

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## REFERENCES

- Altman, E. (1968). Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *Journal of Finance*, 23, 589-609.
- Altman, E.; Marco, G. and Varetto F. (1994). Corporate distress diagnosis: Comparisons using linear discriminant analysis and neural networks. *Journal of Banking and Finance*, 18, 505-529.
- Arslan, O. (2012). Weighted LAD–LASSO method for robust parameter estimation and variable selection in regression. *Computational Statistics & Data Analysis*, 56 (6), 1952-1965.
- Baesens, B.; Setiono, R.; Mues, C. and Vanthienen, J. (2003a). Using neural networks rule extraction and decision tables for credit-risk evaluation. *Management Science*, 49(3), 312-329.
- Baesens, B.; Van Gestel, T.; Viaene, S.; Stepanova, M.; Suykens, J. and Vanthienen J. (2003b). Benchmarking state-of-the-art classification algorithms for credit scoring. *Journal of the Operational Research Society*, 54(6), 627-635.
- Bala, J.; Dejong, K., Huang, J.; Vafaie, H. and Wechsler, H. (1996). Using learning to facilitate the evolution of features for recognizing visual concepts. *Evolutionary Computation*, 4 (3), 297-311.
- Balcaen, S. and Ooghe, H. (2006). 35 years of studies on business failure: An overview of the classic statistical methodologies and their related problems. *The British Accounting Review*, 38 (1), 63-93.
- Beaver, W. (1966). Financial ratios as predictors of failures. In: S. Davidson (ed.), *Empirical Research in Accounting: Selected Studies* (pp. 71-111), Chicago: Institute of Professional Accounting.

- Cortes, C. and Vapnik, V. N. (1995). Support-vector networks. *Machine Learning*, 20 (3). 273-297.
- Cotta C.; Sloper, C. and Moscato, P. (2004). Evolutionary search of thresholds for robust feature set selection: Application to the analysis of microarray data. *Lecture Notes in Computer Science*, 3005, 21-30.
- Crone, S. F. and Finlay, S. (2012). Instance sampling in credit scoring: An empirical study of sample size and balancing. *International Journal of Forecasting*, 28(1), 224-238.
- Curran, S. and Mingers J. (1994). Neural networks, decision tree induction and discriminant analysis: An empirical comparison. *Journal of the Operational Research Society*, 45 (4), 440-450.
- Dambolena, I. G. and Khoury, S. J. (1980). Ratio stability and corporate failure. *Journal of Finance*, 35, 1017-1026.
- Etheridge, H. L. and Sriram, R. S. (1996). A Neural Network Approach to Financial Distress Analysis. In: S. G. Sutton (ed.), *Advances in Accounting Information Systems, Volume 4* (pp.201-222), Bingley: Emerald Group Publishing.
- Fayyad, U. M. and Irani, K. B. (1992). On the handling of continuous-valued attributes in decision tree generation. *Machine Learning*, 8, 87-102.
- Feo, T. A. and Resende M. G. C. (1989). A probabilistic heuristic for a computationally difficult set covering problem. *Operations Research Letters*, 8 (2), 67-71.
- Feo, T. A. and Resende M. G. C. (1995). Greedy randomized adaptive search procedures. *Journal of Global Optimization*, 2, 1-27.
- Frydman, H.; Altman, E. I. and Kao, D. (1985). Introducing recursive partitioning for financial classification: the case of financial distress. *Journal of Finance*, 40(1), 269-291.
- Ganster, H.; Pinz, A.; Rohrer, R.; Wildling, E.; Binder, M. and Kittler, H. (2001). Automated melanoma recognition. *IEEE Transactions on Medical Imaging*, 20 (3), 233-239.
- Hua, Z.; Wang, Y.; Xu, X.; Zhang, B. and Liang, L. (2007). Predicting corporate financial distress on integration of support vector machine and logistic regression. *Expert Systems with Applications*, 33(2), 434-440.
- Iturriaga, F. J. L. and Sanz, I. P. (2015). Bankruptcy visualization and prediction using neural networks: A study of US commercial banks. *Expert Systems with Applications*, 42(6), 2857-2869.
- Jain, A. and Zongker, D. (1997). Feature selection: Evaluation, application, and small sample performance. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 19(2), 153-158.
- Jeong C.; Min, J. N. and Kim, M. S. (2012). A tuning method for the architecture of neural network models incorporating GAM and GA as applied to bankruptcy prediction. *Expert Systems with Applications*, 39(3), 3650-3658.
- Jones, F. L. (1987). Current techniques in bankruptcy prediction. *Journal of Accounting Literature*, 6, 131-164.
- Jones, S. and Hensher, D. A. (2004). Predicting firm financial distress: a mixed logit model. *The Accounting Review*, 79 (4), 1011-1038.
- Jourdan, L.; Dhaenens, C. and Talbi, E. (2001). A genetic algorithm for feature subset selection in data-mining for genetics. In: J. P. de Sousa (ed.), *Proceedings of the 4<sup>th</sup> Metaheuristics International Conference* (pp. 29-34), Porto: MIC.
- Kohavi, R. (1995). *Wrappers for performance enhancement and oblivious decision graphs*. Ph. D. Thesis, Computer Science Department, Stanford University.

- Laitinen, E. K. and Laitinen, T. (2000). Bankruptcy prediction. Application of the Taylor's expansion in logistic regression. *International Review of Financial Analysis*, 9, 327-349.
- Lee, S. H. and Urrutia, J. L. (1996). Analysis and prediction of insolvency in the property-liability insurance industry: A comparison of logit and hazard models. *The Journal of Risk and Insurance*, 63(1), 121-130.
- Lee, S.; Yang, J. and Oh, K. W. (2003). Prediction of molecular bioactivity for drug design using a decision tree algorithm. *Lecture Notes in Artificial Intelligence*, 2843, 344-351.
- Lennox, C. (1999). Identifying failing companies: A reevaluation of the logit, probit and DA approaches. *Journal of Economics and Business*, 51, 347-364.
- Lewis, P. M. (1962). The characteristic selection problem in recognition systems. *IEEE Transactions on Information Theory*, 8, 171-178.
- Li, H.; Lee, Y. C.; Zhou, Y. C. and Sun, J. (2011). The random subspace binary logit (RSBL) model for bankruptcy prediction. *Knowledge-Based Systems*, 24 (8), 1380-1388.
- Liang, D.; Lu, C. C.; Tsai, C. F. and Shih, G. A. (2016). Financial ratios and corporate governance indicators in bankruptcy prediction: A comprehensive study. *European Journal of Operational Research*, 252(2), 561-572.
- Liu, H. and Motoda, H. (1998). *Feature selection for knowledge discovery and data mining*. Boston: Kluwer Academic.
- Lu, Y.; Zeng, N.; Liu, X. & Yi, S. (2015). A new hybrid algorithm for bankruptcy prediction using switching particle swarm optimization and support vector machines. *Discrete Dynamics in Nature and Society*, 2015, Article ID 294930, 7 pp.
- Mangalova, E. and Agafonov, E. (2014). Wind power forecasting using the k-nearest neighbors algorithm. *International Journal of Forecasting*, 30(2), 402-406.
- Matsui, H. (2014). Variable and boundary selection for functional data via multiclass logistic regression modeling. *Computational Statistics & Data Analysis*, 78, 176-185.
- Meiri, R. and Zahavi, J. (2006). Using simulated annealing to optimize the feature selection problem in marketing applications. *European Journal of Operational Research*, 171, 842-858.
- Messier Jr., W. F. and Hansen, J. V. (1988). Inducing rules for expert system development: An example using default and bankruptcy data. *Management Science*, 34 (12), 1403-1415.
- Murphy, P. M. and Aha, D. W. (1994). *UCI Repository of Machine Learning*. Department of Information and Computer Science, University of California.
- Narendra, P. M. and Fukunaga, K. (1977). A Branch and Bound algorithm for feature subset selection. *IEEE Transactions on Computers*, 26(9), 917-922.
- Neophytou, E. and Molinero, C. M. (2004). Predicting corporate failure in the UK: a multidimensional scaling approach. *Journal of Business Finance and Accounting*, 31(5-6), 677-710.
- Ohlson, J. A. (1980). Financial ratios and the probabilistic prediction of bankruptcy. *Journal of Accounting Research*, 18(1), 109-111.
- Oliveira, L. S.; Sabourin, R.; Bortolozzi, F. and Suen, C. Y. (2003). A methodology for feature selection using multiobjective genetic algorithms for handwritten digit string recognition. *International Journal of Pattern Recognition and Artificial Intelligence*, 17(6), 903-929.
- Ooghe, H. and Balcaen, S. (2002). Are failure prediction models transferable from one country to another? An empirical study using Belgian financial statements. *Vlerick Leuven Gent Management School Working Paper*, 2002-3, 42 pp.

- Pacheco, J.; Alfaro, E.; Casado, S.; Gámez, M. and García, N. (2012). A GRASP Method for Building Classification Trees. *Expert Systems with Applications*, 39(3), 3241-3248.
- Pacheco, J.; Casado, S. and Núñez, L. (2009). A variable selection method based on tabu search for logistic regression models. *European Journal of Operational Research*, 199, 506-511.
- Pacheco, J.; Casado, S.; Núñez, L. and Gómez, O. (2006). Analysis of new variable selection methods for discriminant analysis. *Computational Statistics & Data Analysis*, 51, 1463-1478.
- Pitsoulis, L. S. and Resende, M. G. C. (2002). Greedy randomized adaptive search procedures. In: P. M. Pardalos and M. G. C. Resende (eds.), *Handbook of Applied Optimization*, Oxford: Oxford University Press.
- Pompe, P. P. M. and Bilderbeek, J. (2005). The prediction of small- and medium-sized industrial firms. *Journal of Business Venturing*, 20(6), 847-868.
- Reunanen, J. (2003). Overfitting in making comparisons between variable selection methods. *Journal of Machine Learning Research*, 3, 1371-1382.
- Sarkar, S. and Sriram, R. S. (2001). Bayesian models for early warning of bank failures. *Management Science*, 47(11), 1457-1475.
- Scott, J. (1977). Bankruptcy, secured debt and optimal capital structure. *Journal of Finance*, 33, 1-19.
- Scott, J. (1981). The probability of bankruptcy. A comparison of empirical predictions and theoretical models. *Journal of Banking and Finance*, 5, 317-344.
- Sebestyen, G. (1962). *Decision-making processes in pattern recognition*. New York: Macmillan.
- Sexton, R. S.; Sriram, R.S. and Etheridge, H. (2003). Improving Decision Effectiveness of Artificial Neural Networks: A Modified Genetic Algorithm Approach. *Decision Sciences*, 34(3) 421-442.
- Shumway, T. (2001). Forecasting bankruptcy more accurately: A simple hazard model. *Journal of Business*, 74(1), 101-124.
- Varetto, F. (1998). Genetic algorithms applications in the analysis of insolvency risk. *Journal of Banking and Finance*, 22, 1421-1439.
- Wang, H.; Li, G. and Jiang, G. (2007). Robust regression shrinkage and consistent variable selection through the LAD-Lasso. *Journal of Business and Economic Statistics*, 25(3), 347-355.
- Wu, C. H.; Tzeng, G. H.; Goo, Y. J. and Fang, W. C. ( 2007). A real-valued genetic algorithm to optimize the parameters of support vector machine for predicting bankruptcy. *Expert Systems with Applications*, 32(2), 397-408.
- Yang, Z.; You, W. and Ji, G. (2011). Using partial least squares and support vector machines for bankruptcy prediction. *Expert Systems with Applications*, 38(7), 8336-8342.
- Zhang, C. X.; Wang, G. W. and Liu, J. M. (2015). RandGA: Injecting randomness into parallel genetic algorithm for variable selection. *Journal of Applied Statistics*, 42(3), 630-647.
- Zmijewski, M. E. (1984). Methodological issues related to the estimation of financial distress prediction models. *Journal of Accounting Research*, 22(Supplement), 59-82.