Analysis and Development of Innovative Soft-Computing Techniques with Expert Knowledge Integration.
An Application for Financial Credit Risk Measurement. MERITO Project.
TIC2002-04371-C02

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Abstract

The MERITO co-ordinated project aims at studying and developing several innovative Artificial Intelligence techniques in order to analyse and evaluate problems involving qualitative information and defined in changing environments. The study is oriented towards the modelling and resolution of a financial problem: the measurement of credit or default risk.

The methodology is based on the improvement of soft-computing techniques, such as support vector machines (SVM) and radial base functions (RBF) by using orders of magnitude qualitative models. The use of these techniques will, on the one hand, permit the introduction of experts' knowledge and, on the other, to extract knowledge from results. It is planned to develop a methodology based on the study findings in order to measure firms' credit risk using their financial data and market and environment information.

As a consequence of this project, there is the intention of launching a software tool, which measures the risk of default from financial and qualitative information. This product would provide a valuable decision support system and confer firms and financial bodies with a significant competitive advantage.

Keywords: Learning Algorithms, Orders of Magnitude Reasoning, Radial Basis Functions, Support Vector Machines.

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1 Project objectives

The MERITO co-ordinated project's global objective is the development of an innovative methodology especially suitable for aiding decision making in the analysis of default risk, for the later construction of an efficient software tool adapted to market and able to evaluate financial credit risk.

The MERITO co-ordinated project has two well-defined sides: On one hand, innovation and technological improvement; on the other, the modelization and solution of a financial problem. For this reason it has two specialised closely related subprojects and therefore it contributes to the knowledge exchange between the research areas of Artificial Intelligence and Finance, contributing to the solution of complex problems.

Subproject 1 is devoted to the design of soft-computing techniques. The group of researches working on this subproject is composed of computer scientists, artificial intelligence experts and mathematicians from the Universitat Politècnica de Catalunya (UPC). Subproject 2 is devoted to the analysis and measurement of credit risk. The team of researchers is composed of specialists in artificial intelligence, applied mathematics and finances from the Management School ESADE (Universitat Ramon Llull - URL). Subproject 2 is also in charge of the global coordination of the MERITO project.

The overall goal of the MERITO project can be summarised in the following objectives:

Objective 1: Delimitate and define a framework for the problem to be addressed. Determine the set of relevant quantitative/qualitative variables for the analysis of credit risk. (Subproject 2).

Objective 2: Study and improve qualitative techniques based on orders of magnitude models to be used in expert knowledge acquisition. (Subproject 1).

Objective 3: Study and improve the applicability of Support Vector Machine (SVM) and Radial Basis Function RBF to the proposed problem and to the introduction of experts' information. Evaluation and analysis starting from the database obtained in the initial phase. (Subproject 1).

Objective 4: Integrate the studied techniques in order to design a theoretical model suitable for credit risk measurement. (Subproject 1).

Objective 5: Establish a methodology to be applied to the proposed problem. (Subproject 2).

Objective 6: Evaluate and analyse the results obtained from the defined methodology. (Subproject 2).

Objective 7: Build a software tool allowing the measurement of credit risk. (Subproject 1).

Objective 8: Study the viability of the software tool and design operation planning. (Subproject 2).

The main available means to achieve these objectives are the investigation made up by researchers in the two teams and the economical support of the Spanish Ministry of Science and Technology. With this economical support two databases have been purchased: the one to Standard & Poor's and the other to Thomson Financial (this has been the most expensive inversion of the project), also two PC and some bibliographical material have been bought, two diplomat engineers in computing science have been contracted, and the inscriptions and assistance to several national and international congresses of the researchers have been paid.

In order to get the mentioned objectives, the work corresponding to the co-ordinated project MERITO has been structured into 14 tasks or activities, keeping the next specified timing:

Task 1. Monitoring and scientific coordination of the project. Coordination of subproject 2.
Duration: 36 months.

Task 2. Coordination of subproject 1.
Duration: 36 months.

Task 3. Delimitate and specify the problem and determine the set of quantitative/qualitative variables.
Duration: 7 months (months from 1 to 7).
LANDMARK 1: This task ends with the elaboration of a report with a detailed description of the problem to deal with and the set of involved quantitative/qualitative variables.

Task 4. Construction and analysis of the database.
Duration: 21 months (months from 4 to24).
LANDMARK 2: At the end of this task a database with the qualitative and quantitative values on which the research of the problem is based will be available.

Task 5. Study and development of qualitative techniques based on orders of magnitude models to use expert's knowledge and reasoning.
Duration: 9 months (months from 4 to 12).
LANDMARK 3: This task ends with the elaboration of a report with the obtained results.

Task 6. Study and adaptation of RBF neural networks.
Duration: 9 months (months from 4 to 12).
LANDMARK 4: This task ends with the elaboration of a report with the obtained results.

Task 7. Study and adaptation of SVM neural networks.
Duration: 9 months (months from 4 to 12).
LANDMARK 5: This task ends with the elaboration of a report with the obtained results.

Task 8. Integration of the studied techniques.
Duration 12 months (months from 12 to 24).

LANDMARK 6: At the end of this task a report with the detailed description of the necessary algorithms to develop the methodology will be available.

Task 9. Development of a methodology fitting for the analysis and measurement of credit risk.
Duration: 12 months (months from 15 to 24 and from 30 to 31).
LANDMARK 7: This task ends with the design of the methodology for the analysis and measurement of credit risk.

Task 10. Evaluation of the methodology starting from the database.
Duration: 9 months (months from 22 to 30).
LANDMARK 8: This task ends with a report of the evaluation together with improvement proposals.

Task 11. Construction of the software tool.
Duration: 13 months (months from 24 to 36).

Task 12. Evaluation and refinement of the software.
Duration: 4 months (months from 33 to 36).
LANDMARK 9: At the end of tasks 11 and 12 a software adapted to the problem will be available.

Task 13. Study of viability and operation planning.
Duration: 4 months (months from 33 to 36).
LANDMARK 10: This task ends with a report with the study of viability and the operation planning for a commercial product.

Task 14. Diffusion of results.
Duration: 27 months (months from 10 to 36).
LANDMARK 11: This task ends with a report with all the generated publications in journals and communications to congresses.

2 Success level reached in the project

The success level reached in the project for the time being is described below for each one of the activities already accomplished as well as the activities in progress.

Task 1. Monitoring and scientific coordination of the project. Coordination of subproject 2.
Task 1 is evidently in progress and it will end at the conclusion of the project.
20 work meetings (one per month) have been carried up for the scientific coordination of subproject 2, supervising the tasks of the researchers following the established chronogram, as well as 2 plenary meetings.

A web page, accessible to all the MERITO co-ordinated project's members under username identification, has been designed. This intranet reflects the entire project's evolution; it reflects the state and evolution of every task of the project by using different colours. At each time, during the progress of the project, it is viewed in green the already accomplished tasks, and in orange the tasks which are in progress. In addition, it points the dates of MERITO's work meetings and it provides

access to all publications related to the project and information about congresses and meetings that have to do with the MERITO project's range of topics.

Task 2: Coordination of subproject 1.
Task 2 is evidently in progress and it will end at the conclusion of the project.
20 work meetings (one per month) have been carried up for the scientific coordination of subproject 2, supervising the tasks of the researchers following the established chronogram.

Task 3: Delimitate and specify the problem and determine the set of quantitative/qualitative variables.
Task 3 is over; it ended successfully in the beginning of the summer 2003.
The financial problem has been delimited and the set of indicators or variables from which the information has to be extracted has been chosen.

Starting from original numerical data from 1240 companies, and according to the criteria of the experts in finances, a set of 21 variables has been chosen. Variables have been split up depending on their characteristics. In this way, there are variables of "identification", of "rating", "descriptive", of the "size of the company", of the "stock-market volatility", of "activity", "financing", "liquidity" and "profitability". Specialists in finance and statistics have been involved in this task, taking part in the analysis of the kind of expert information to be introduced in the model (importance of the industry and the country or countries where the firm operates in the evaluation…). Some of the variables have been discretised in a qualitative model of absolute orders of magnitude to be used by the automatic learning systems that are being developed in the MERITO co-ordinated project.
A report with the obtained results has been elaborated (LANDMARK 1).

Task 4.   Construction and analysis of the database.
Task 4 is over; it has recently ended successfully.
A database containing data from year 2002 from 1240 companies has been constructed matching data from the databases provided by Standard & Poor's and Thomson Financial . Data are referred to December 31st of 2002. First, companies have been identified and validated, then data have debugged and prepared in two formats: MS Excel 2000 and SPSS version 11.0 for MS Windows containing descriptive information of the companies and representative data of the financial, economic and market position.
A report with the obtained results has been elaborated (LANDMARK 2).

Task 5.   Study and development of qualitative techniques based on orders of magnitude models to use expert's knowledge and reasoning.
Task 5 is over; it ended successfully at the end of 2003.
We have studied the modelization of expert's knowledge and reasoning through the development and implementation of qualitative techniques based on orders of magnitude models.
A qualitative system, based on absolute orders of magnitude, that represents factors involved in the evaluation of a firm's credit risk or an issue of bonds has been constructed. This system allows a classification of companies by means of their level of credit risk, emulating financial rating, by using qualitative operators and taking into account the different influence degrees of the variables.
A software application has been constructed in order to verify the correct performance over data of the database built in task 4.

A report with the obtained results has been elaborated (LANDMARK 3).

Task 6.   Study and adaptation of RBF neural networks.
Task 6 is over; it ended successfully at the end of 2003.
We have studied how to improve the structure of radial basis function neural networks in order to introduce experts' information and to extract knowledge for their applicability to financial credit risk measurement. A dating of inputs (patterns) has been done with the aim of introducing expert's information in the learning process. In the improvement of RBF's performance, special attention has been paid to the qualitativization of the domain of activation functions. Orders of magnitude models have been introduced in the development of this non-linear type of algorithm and the selection of the stopping criteria has been discussed. The running of the inputs' adaptation starting from the use of expert's knowledge has been tested over data, of the database built in task 4, to study the results of credit risk prediction over a set of companies by using companies' economic-financial variables and their Standard & Poor's risk classification. The results of tests show that the learning capability of a RBF neural network is improved when using qualitative information.
A report with the obtained results has been elaborated (LANDMARK 4).

Task 7.   Study and adaptation of SVM neural networks.
Task 7 is over; it ended successfully at the end of 2003.
The applicability of Support Vector Machines to the problem of financial credit risk measurement has been studied, by analysing how to improve their structure in order to introduce experts' information and to extract knowledge.
Specifically a methodology that allows constructing kernels able to work with data described in a qualitative space of orders of magnitude has been developed. At the present time three alternatives for these kernels have been built and the way in which these kernels measure the degree of "remoteness" and "closeness" between the different descriptors of the companies has been studied. In order to test the correct operation, the results of credit risk prediction over data from the database built in task 3 have been studied.
A report with the obtained results has been elaborated (LANDMARK 5).

Task 8.   Integration of the studied techniques.
Task 8 is in progress and it will end at December 2004.
Once the three previous tasks had been performed, in which orders of magnitude qualitative techniques have been studied and developed and RBF and SVM have been studied and adapted to be applied to the analysis and measurement of credit risk, these three techniques are integrated to shape the methodology of the project. This integration is made both in the description of the input variables and in the kinds of kernel functions and parameters used in the corresponding architectures, as well as in the qualitative distances used in the process of classification of the companies according to their credit risk.

Task 9.   Development of a methodology fitting for the analysis and measurement of credit risk.
Task 9 is in progress and it will end at summer 2005.
Task 9 is currently in its first stage, it runs from the progress of task 8, and intimately related with it. Its second stage will begin in spring 2005 once task 10 provides results and proposes improvements.

<u>Task 14. Diffusion of results.</u>
Task 14 is evidently in progress and it will end at the conclusion of the project.
Diffusion of obtained results in national and international congresses from the areas of Artificial Intelligence and Finances, as well as publication in book chapters and recognised journals from these areas and university technical reports and PhD Thesis have been planned, encouraged and monitored. It has resulted in:

Book Chapters
1) L. Travé-Massuyès, P. Dague, N. Agell, F. Prats, M. Sánchez, A. Missier, "Le raisonnement sur les ordres de grandeur". Capítulo del libro " Modèles et raisonnements qualitatifs ". Lavoisier, Hermes Science Publications, 2003 (ISBN : 2-7462-0744-3)
2) C. Angulo, L. González, F.J. Ruiz, A. Català, F. Velasco, N. Agell. "Qualitative Kernels for Sustainability Indicators". Capítulo de libro en "Progress of Artificial Intelligence in Sustainability Science". Kropp, Scheffran et al. ed., 2004

Journal Articles
1) X. Parra, C. Angulo, N. Agell, X. Rovira. "Aproximación a un problema financiero mediante redes neuronales con funciones de base radiales y máquinas de soporte vectorial". Revista Iberoamericana de Inteligencia Artificial, vol. 14, 54-67, 2001.

2) N.Agell, X.Rovira, M.Sánchez, F.Prats. "Support Vector Machines over a Discrete Structure: a Kernel for Qualitative Orders of Magnitude Spaces". Artificial Intelligence Research and Development, Vol.100 de la serie Frontiers in Artificial Intelligence and Applications. IOS Press, 2003 (ISSN: 0922-6389)

3) F.J. Ruiz, C. Angulo, N. Agell, X. Rovira, R. Campos, M. Sánchez. "Funciones núcleo en un espacio de órdenes de magnitud absolutos". Computación y Sistemas. Vol 7 n.1, 2003 (ISSN 1405-5546)

4) H. Núñez, C. Angulo, A. Català. "Hybrid architecture based on support vector machines". Lecture Notes in Computer Science, vol. 2686, pp. 646-653, June 2003

5) C. Angulo, X. Parra, A. Català. "K-SVCR, A support vector machine for multi-class classification". Neurocomputing, vol. 55, Issues 1-2, pp.57-77, September 2003

6) L. González, F. Velasco, C. Angulo, J.A. Ortega, F.J. Ruiz. "Sobre núcleos, distancias y similitudes entre intervalos". Revista Iberoamericana de Inteligencia Artificial. Número 23, Volumen 8, 2004.

7) M. Sánchez, F. Prats, N. Agell, X. Rovira. "Kernel Functions over Orders of Magnitude Spaces by means of Usual Kernels. Application to Measurement of Financial Credit Risk". Aceptado para su publicación en Lecture Notes in Artificial Intelligence. Springer-Verlag.

Proceedings Papers
1) X. Parra, N. Agell. "Qualitative Input Conditioning to Enhance RBF Neural Networks Generalization in Financial Rating Classification". 15th International Workshop on Qualitative Reasoning, 177-181, San Antonio, Texas, USA, 2001.

2) X. Parra, N. Agell, X. Rovira. "Generalisation Improvement of Radial Basis Function Networks based on Qualitative Input Conditioning for Financial Credit Risk Prediction". International Conference on Artificial Neural Networks, 127-134, Viena, Austria, 2001.

3) X. Parra, N. Agell, X. Rovira. "An Application to Financial Credit Risk Prediction based on Radial Basis Function Networks". Jornadas de ARCA, Valladolid, 2001.

4) C. Angulo, L. González. "1-v-1 Tri-Class SV Machine" Proceedings of the European Symposium on Artificial Neural Networks (ESANN'2003). D-Side ed., pp 355-359. Bruges, Belgium, April 2003.

5) C. Angulo. "Kernels sobre información con incertidumbre". Jornadas de ARCA 2003. Lanzarote, Junio 2003

6) F.J. Ruiz. "Máquinas Núcleo sobre órdenes de magnitud". Jornadas de ARCA 2003. Lanzarote, Junio 2003

7) C. Angulo, A. Català. "Online learning with kernels for smart adaptive systems. A review". Proceedings of the European Symposium on Intelligent Technologies, Hybrid Systems and their implementation on Smart adaptive Systems (eunite 2003). Verlag Mainz ed. Oulu, Finland, July 2003

8) N. Agell, X. Rovira, M. Sánchez, F. Prats. "A Kernel Defined over Qualitative Spaces of Orders of Magnitude". 17th International Workshop on Qualitative Reasoning QR-2003. Brasilia, Brasil, Agosto 2003

9) N. Agell, X. Rovira, M. Sánchez, F. Prats. "Support Vectors Machines over a Discrete Structure: a Kernel for Qualitative Orders of Magnitude Spaces". 6è Congrés Català en Intel.ligència Artificial CCIA 2003. Palma de Mallorca, España, Octubre 2003.

10) M. Sánchez, F. Prats, N. Agell, X. Rovira. "Funciones kernel en espacios cualitativos de órdenes de magnitude. Aplicación a la evaluación del riesgo de crédito". Proc. De la X Conferencia de la Asociación Española para la Inteligencia Artificial. Universidad del País Vasco, San Sebastián, España, Noviembre 2003.

11) R. Campos, F. Ruiz, N. Agell, C. Angulo "Financial credit risk measurement prediction by using innovative soft-computing techniques". Computational Finance 2004. 21-23 Abril 2004 - Bolonia, Italia.

12) X. Rovira, N. Agell, M. Sánchez, F. Prats, X. Parra. "An Approach to Qualitative Radial Basis Function Networks over Orders of Magnitude". 18th International Workshop on Qualitative Reasoning QR-2004. Chicago, US, Agosto 2004

13) M. Sánchez, F. Prats, N. Agell, J. Aguilar-Martin. "A Characterization of Linearly Compensated Hybrid Connectives Used in Fuzzy Clasification".16th European Conference on Artificial Intelligence ECAI 2004. ISBN: 1 58603 452 9. Valencia, Agosto 2004.

14) N. Agell, C. Angulo, F.J. Ruiz. "A Kernel Intersection Defined on Intervals". Congrés Català d'Intel•ligència Artificial (CCIA 2004) Barcelona, Octubre 2004.

15) X. Rovira, N. Agell, M. Sánchez, F. Prats, X. Parra "Qualitative Radial Basis Function Networks Applied to Financial Credit Risk Prediction". Congrés Català d'Intel•ligència Artificial (CCIA 2004) Barcelona, Octubre 2004

16) F.J. Ruiz, N. Agell, C. Angulo. "Una función núcleo en un espacio cualitativo". 1ª Jornada de Recerca en Automàtica, Visió i Robòtica. Sometido a publicación. Febrero 2004

17) F.J. Ruiz. "Máquinas Núcleo sobre órdenes de magnitud". Jornadas de ARCA 2004, Menorca, Junio 2004

18) N. Agell, F.Prats, M. Sánchez. "Ulilizaciòn de conectivos híbridos en problemas de classificaciòn". Jornadas de ARCA 2004. Menorca, Junio 2004

University Technical Reports
1) M. Sánchez, F. Prats, N. Agell, G. Ormazabal, "Synthesising Information for Multiple Criteria Evaluation: an Application to Value Management in Civil Engineering". Reporte técnico MA-II –IR-03-00014. Universitat Politècnica de Catalunya. Junio 2003

2) J. Bruna, N. Agell, F. Prats, M. Sánchez, "A characterization on hybrid connectives". Reporte técnico MA-II –IR-03-00029. Universitat Politècnica de Catalunya. Octubre 2003

3) F.J. Ruiz, C. Angulo, N. Agell, X. Rovira, R. Campos, M. Sánchez, F. Prats. "Funciones núcleo y funciones de similitud en un espacio de órdenes de magnitud absolutos". Reporte técnico MA-II –IR-03-00031. Universitat Politècnica de Catalunya. Noviembre 2003

4) C. Angulo. "Notación vectorial binaria en el razonamiento cualitativo para el modelo absoluto de los órdenes de magnitud". Reporte técnico ESAII-RR-01. Abril 2003

5) C. Angulo, L. González, F.J. Ruiz, A. Català, F. Velasco, N. Agell. "Qualitative Kernels for Sustainability Indicators". Reporte técnico ESAII-RR-03. Universitat Politècnica de Catalunya. Septiembre 2003

PhD Thesis
1) H. Núñez. "Sistemas híbridos con aprendizaje basados en máquinas de soporte vectorial y redes neuronales de función de base radial". Universitat Politècnica de Catalunya, Diciembre 2003.

PhD Thesis in progress
1) R. Campos. "Una metodología para la evaluación del rating interno de compañías utilizando nuevas tecnologías" ESADE. Universitat Ramon Llull. In progress (Its presentation is planned for January 2006).
2) F.J. Ruiz. "Funciones núcleo en sistemas dinámicos con información no vectorial". Universitat Politècnica de Catalunya. In progress (Its presentation is planned for December 2005).

<u>Found Difficulties and their overcoming</u>
In reference to the development of Tasks 3 and 4, we have found some difficulties when harmonising and identifying the values of the DataStream platform which has been rented to Thompson Financial Worldscope with those of the global RATING obtained from Standard & Poor's. The arising problem due to the instability of the data of DataStream caused by the massive unloading through inadequate tools provided by Thompson Financial Worldscope is also remarkable. Both difficulties have been overcome by investing a lot of time in manipulation of data and, at the same time, coming into contact with Thompson Financial Worldscope when necessary.

3 Results indicators

The results indicators for the time being are listed below.

3.1   Personal on training

As has been pointed out in Task 14 of Section 2, one PhD Thesis has been already finalised in the frame of the MERITO co-ordinated project. The Doctor is one of the researchers of the staff and her Thesis is framed in the study and improvement of Support Vector Machines and Radial Basis Functions Networks.
Also, two PhD Thesis are in progress. The one related to financial aspects of the MERITO project, and the other to soft-computing techniques.
A Diplomat Engineer in Computing Science, who has been contracted to work in the frame of MERITO co-ordinated project from March 24th of 2004 to June 23rd of 2004 is at the moment ending the thesis "QOM: Estudi i Avaluació del Risc de Crèdit Financer amb Ordres de Magnitud" for his Degree as Engineer in Computing Science by the UPC.
Finally, a thesis of Degree in Business Administration "Análisis y evaluación del rating empresarial utilizando técnicas con aprendizaje automático" is in progress.

3.2   Publications

The publications framed in the MERITO co-ordinated project: 2 book chapters, 7 journal articles, 18 proceedings papers corresponding to different national and international congresses, conferences and workshops, 5 university technical reports and 1 PhD Thesis, are detailed in Task 14 of Section 2.

3.3   Collaborations

The MERITO co-ordinated project coordinator together with another of its members gave a scientific seminar in the frame of the 17th International Workshop on Qualitative Reasoning in the central office of the Bank of Brazil in Brasilia in August 2003:

Workshop on QR and Financial Analysis (QR-$)
Objective: to discuss applications of QR to financial analysis and risk analysis.
Target audience: post-graduate students, teachers, technicians, researchers.
Lecturer: Núria Agell & Xari Rovira (ESADE - Spain)

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Local: Auditorium of Bank of Brazil

4 References

[1] Altman, E.I. "Predicting Financial Distress of Companies: Revisiting the Z-score and ZETA® Models," http://pages.stern.nyu.edu/ealtman/Zscores.pdf. Working Paper Series. The Department of Finance New York University, 2000.

[2] Bredeweg, B. and Struss P. (eds), (2003) Qualitative Reasoning. Special issue of AI Magazine, Winter 2003, 24(4), AAAI Press, Menlo Park, USA.

[3] Broomhead, D.S. and Lowe, D.: Multivariable Functional Interpolation and Adaptive Network, Complex Systems, Vol. 2, pp. 321-355, 1988.

[4] Cristianini, N. and Shawe-Taylor, J. (2000) An introduction to Support Vector Machines and other Kernel-based learning methods, Cambridge University Press: Cambridge, pp. 189.

[5] Ching, J.Y., Wong, A.K.C. & Chan, K.C.C. Class-Dependent Discretization for Inductive Learning from Continuous and Mixed Mode Data, IEEE Transactions on Pattern Analysis and Machine Intelligence, 17 (7), pp. 641-651, 1995.

[6] Forbus, K. D. Commonsense physics. A: Annals Revue of Computer Science, pp. 197-232, 1988.

[7] Fryman, H., Altman, E.I. and Duen-Li, K. Introducing Recursive Partitioning for Financial Classification: The Case of Financial Distress. Journal of Finance, Mar85, Vol. 40, Issue 1, pp. 269-292, 1985.

[8] Kurgan, L. & Cios, K.J. Discretization Algorithm that Uses Class-Attribute Interdependence Maximization, Proc. of the 2001 International Conference on Artificial Intelligence (ICAI-2001): Las Vegas, pp.980-987, 2001.

[9] Prechelt, L.: PROBEN1: Set of Neural Network Benchmark Problems and Benchmarking Rules. Technical Report 21/94, University of Karlsruhe (1994).

[10] Travé-Massuyès, L.; Dague, P. Modèles et raisonnements qualitatifs. Hermès, 2003.

[11] "Public Finance Criteria 2000", de Diciembre 20 de 2000 (en www.standardandpoors.com).