The use of fuzzy logic and expert systems for rating and pricing firms

A new perspective on valuation

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Abstract

Purpose – The purpose of the paper is to focus on the rating, ranking and valuing of firms.

Design/methodology/approach – Fuzzy logic and expert systems are used in order to provide a score for the firm(s) under consideration, representing the firm value-creating power.

Findings – The fuzzy expert system introduced is capable of dealing with both quantitative and qualitative variables and integrates financial, managerial and strategic variables. A sensitivity analysis corroborates the model.

Research limitations/implications – The system is apt to rate and rank firms within a sector. Some regression analysis can lead to a determined price for the target firm.

Practical implications – The expert system may be used by rating agencies for ranking firms, and by financial analysts and potential buyers to furnish a price for acquisition.

Originality/value – The use of a fuzzy expert system for ranking firms within a sector and pricing firms is a first attempt at an alternative way of measuring performance and value.

Keywords Organizations, Market value, Strategic evaluation, Fuzzy logic, Modelling

Paper type Research paper

1. Introduction

In this paper, we construct a formal model that takes into account the experience of the decision maker and combines logic and intuition to assess a firm's ability to create value. The approach followed results in a method of rating and ranking firms, and (if an acquisition is under examination) a price for the target firm may be extracted. Furthermore, the model may be used to inform about the impact of a particular management's decision on value creation or to compensate managers on the basis of their performance.

The approach followed makes use of expert systems and fuzzy logic. An expert system is a tool meant for replicating the way of reasoning of one or more experts. Fuzzy logic is a cognitive framework that aims at formalizing the way human beings cognize the world and think about problems and situations and at formalizing qualitative and vague concepts. We think that the integration of expert systems and fuzzy logic for company valuation and, in general, for decision-making purposes represents a reliable methodology that could be appealing for managers, practitioners, analysts. The model proposed does not rest on simplistic assumptions (as often financial models do for mathematical tractability), it does not excessively simplify description of reality, it does not engage in complicated formalization and does not require advanced knowledge of mathematics, it is intuitive and comprehensible by any evaluator, it is extremely flexible (it can be changed by the evaluator), it is able to

handle both quantitative and qualitative variables, it is not restricted to a small number of variables (29 inputs are considered, but many more can be added). The evaluation derives from logical implications ("if-then" rules). Implications are our natural cognitive tools so anyone can understand them and construct them. Our approach is just a first attempt to develop a new methodology for appraising firms and business units. We think that this path is fruitful when dealing with complex situations where a great number of value drivers must be taken into account, both qualitative and quantitative, and/or where explicit account of their interrelations must be taken for a better description and rationalization of the evaluation process.

2. Theoretical background

The literature suggests that firms can derive a superior capability to create value from both the structure of the industry where the company operates (or intends to invest) and from its internal resources and core competencies. According to the Structure-Conduct-Performance paradigm the sources for creating a sustainable competitive advantage (Porter, 1985) have to be found in the industry structure, which determines the intensity of rivalry inside the competitive arena (Porter, 1980). These studies focus on how the structure of the sector influences firms' strategic behavior and performance, starting from the idea that the supply and demand characteristics determine the nature of the competition (Pellicelli, 2002). An example of the use of some typical structural variables is given by the variable we call Power. This variable identifies the bargaining power of the target firm towards customers and suppliers and depends on two input variables: Customer Concentration and Supplier Concentration [1]. Power, in turn, affects (along with Processes Efficiency) the Operating Costs and (along with Product Quality) the Revenues. Further studies have postulated that firms can actually influence the industry structure's evolution using a strategic conduct (strategic behavior) aimed at increasing their market power vis-à-vis their rivals. Creating synergies and pre-empting competitors are typical strategies moves to this end (Vickers, 1985). In our model we take Synergies into consideration, which represent one of the three fundamental determinants of the target firm's Rating (the other two are Equity Value and Additional Financial Value). We have decided to limit the determinants of Synergies to three input variables[2]: the presence in the target firm of complementary resources (Complementarities) and of resources and skills fundamental to compete in the specific industry (Consistency), and the Economies of Scale. We have not incorporated diversification as a determinant of Synergies, because too often the supposed purpose of reducing the risk of the business by investing in some anticyclical activity conceals some personal goals of the management not aligned with the shareholders' interests (building empires). However, some empirical evidences showing that performance differences among firms inside the same sector were bigger than the ones among different sectors (Rumelt, 1991) can be considered as the call for a new theory. The Resource-based Theory changes the focus of the analysis, postulating that firms can derive a superior capability to create value principally from its ability to develop and exploit superior competencies and skills (Grant and Robert, 1995). The endowment of resources and capabilities are the primary sources of the firm's profitability (Grant, 1991).

In our model, we have not given priority to either of the two approach (Structural or Resource-based), believing that for building a sustainable competitive advantage it is important to consider both the structure of the industry and the resources and capabilities of the firm. Our model is therefore constructed on the assumption that it is

equally important to identify the Strategic Assets and the Strategic Industry Factors (Amit and Schoemaker, 1993). Examples of strategic assets in our model are represented by Resources and Skills, Technology, (quality of) Management, which affect the Strategic Risk. The input Resources and Skills expresses the resources and skills owned by the target firm while Technology indicates the quality and degree of Technology present in the target firm. Both Technology and Resources and Skills have a double correlation in the model, because they also affect Product Quality, alongside the input Expenditure in Research and Development. (We are aware that a single variable can hardly express the complexity of a judgment relative to the Resources and Skills owned by the target firm and the degree of Technology, nevertheless we have decided to limit the numbers of variables to balance complexity and accuracy[3].).

Additional Financial Value, one of the three fundamental building blocks of the model, identifies the financial value that could be created through an optimization of the capital structure of the target firm. The construction of the Additional Financial Value framework has been inspired by the Static trade-off approach which postulates the existence of an optimal capital structure. Due to this theory the management would move toward predetermined levels of capital structure and pay-out ratios (Myers, 1984). Additional Financial Value is affected by the Optimal (financial) Leverage, along with the Cost of Adjustment and the Current Leverage (the higher the difference between Current Leverage and Optimal Leverage, the higher the Additional Financial Value). While the latter are inputs, the Optimal Leverage is determined by both debt's costs and benefits, also taking the need for future financial Flexibility into consideration. The debt's benefits, for example, (Borrowing Benefits in the model) are determined by two drivers: Tax Rate and Separation. The variable Separation is a qualitative variable representative of the separation between management and shareholders and is positively correlated with Borrowing Benefits: the higher the separation, the higher the convenience of increasing (the) debt (other things equal). In fact, according to the theory of Agency Costs and Ownership Structure (Jensen and Meckling, 1976), debt should be used as a disciplinary device by the stockholders in order to control the management, avoiding cash slack and preventing management from investing in nonprofitable projects making a bad use of the excess cash (Stewart, 1991). One of the three determinants of the variable Borrowing Costs is the Bankruptcy Risk. The latter depends on the input variable Coverage Ratio (EBIT/Financial expenses), and on the Operating Risk: empirical studies confirm that the higher the operating margin volatility the higher the probability of distress, and therefore the lower the optimal financial leverage (e.g. Bradley *et al.*, 1984).

3. Fuzzy logic and expert systems
The way we cognize the world is vague and multivalued and fuzziness is often encountered in real life. In a business context, the sentence "the quality of this firm's products is high" is always true at a certain degree (possibly a zero degree) as well as the sentence "the quality of this firm's products is low" is always true at a certain degree (possibly zero). Fuzzy logic rests on the assumption that all things belong to a set at a certain degree (see Kosko, 1993), so the quality of a product always belongs to both the set of high-quality products and the set of low-quality products (to a certain degree), in the same sense a man always belongs to the set of old men at a certain degree (as well as to the set of young men at a certain degree). Also, variables such as quality of outputs, reputation, company image, employee morale, experience with new technology, consistency with corporate strategy, etc. may not be treated with the

classic "crisp" financial criteria and often are integrated in the decision process in a nonfinancial way or even neglected. Some other drivers have a direct financial impact but are not suited for mathematical tractability (at least not directly), e.g. financial Flexibility, bargaining power, customers' loyalty, Synergies. In all these cases fuzzy logic may be used.

Fuzzy logic enables us to formalize linguistic attributes such as "low", "high", "good", "excellent", "positive", "interesting", "fruitful", "adequate", and so on. For a single variable, more attributes may be used and graphically represented in the same graph. As an example, we describe the input Coverage Ratio[4] by using six linguistic attributes and the corresponding degrees: Coverage Ratio is then at one time VeryLow, Low, MediumLow, MediumHigh, High, VeryHigh. Graphically, we may represent these attributes through fuzzy numbers[5] as in Figure 1. The x-axis collects all possible numerical values for the Coverage Ratio, whose unit of measure is given by EBIT/ Financial Expenses. The y-axis collects the degrees at which a linguistic attribute is activated (membership degrees). The VeryLow attribute is represented by a trapezium (its basis ranges from 0 to 1.5) and the others are depicted as triangles (their bases range, respectively, from 1 to 2.5, from 1.5 to 5.5, from 2.5 to 8, from 8 to 9). For example, a Coverage Ratio of 1.25 is VeryLow at a degree of 80 per cent, Low at a degree of 20 per cent, MediumLow at a zero degree, MediumHigh at a zero degree, High at a zero degree, VeryHigh at a zero degree. A Coverage Ratio of 6.5 is VeryLow at a zero degree, Low at a zero degree, MediumLow at a zero degree, MediumHigh at a degree of 60 per cent, High at a degree of 40 per cent, VeryHigh at a zero degree[6]. In other words, once the decision maker fixes a value for Coverage Ratio, the latter is fuzzified (i.e. translated in fuzzy terms), and the corresponding fuzzy numbers is individuated by the pair (linguistic attribute, membership degree).

The number of scientific contributions using fuzzy logic in business and finance has sharply increased in the recent past. Sugeno (1985), Tanaka (1997), Bojadziev and Bojadziev (1997) and Von Altrock (1997) show that fuzzy logic may be safely and usefully applied to business, financial, industrial applications. Zebda (1989, 1991) deals with vagueness and accounting. Abdel-Kader *et al.* (1998) cite a large number of nonquantifiable factors that firms consider important for investments' decisions. Buckley *et al.* (2002) show economic and engineering applications of fuzzy mathematics.

An expert system is a software addressed to achievements usually performed by a human expert. It consists of a knowledge base and an inferential engine. If a question is asked, the system will try to infer the answer from the knowledge base, using the logic and the heuristics of the inferential engine. The knowledge base must be represented in symbolic forms so as to be stocked and used by a computer. The most common method to this end is to use rule blocks. Fuzzy expert systems use fuzzy data, fuzzy rules and fuzzy inference, in addition to the standard ones implemented in the ordinary expert
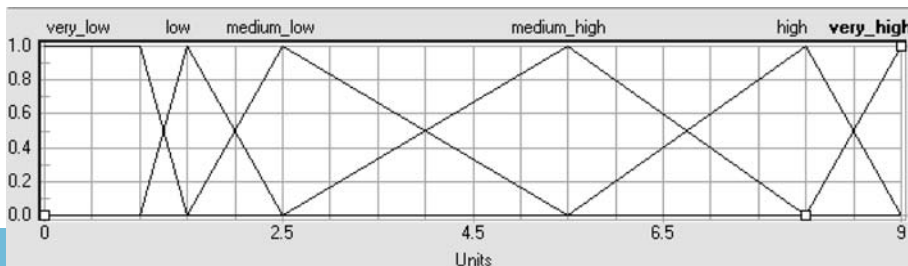

Figure 1.

systems For example, a simple rule based on conditional ("if-then") implications is the following:

>IF entry barriers are medium at a degree of x

>AND the prospective operating costs are low at a degree of y

>AND the prospective revenues are high at a degree of z

>THEN the prospective operating margin is high at a degree of w

with x, y, z, w being real numbers in $[0, 1]$. If the system receives the piece of information provided by the above antecedent, it infers (using its inferential engine) the sentence "the prospective Operating Margin is high" and simultaneously provides a corresponding degree w that substantiates such a "high" value. The value of w is obtained through aggregation of the membership degrees x, y, z of the antecedent variables. To this end, fuzzy algorithms are used and automatically implemented by the expert system (see Von Altrock, 1997, for details).

4. The model
Figure 2 shows that the target firm's Rating is a function of three fundamental blocks: the stand-alone value (Equity Value), the additional value derived by the optimization of the capital structure (Additional Financial Value), the synergies realizable (Synergies). The first two provide an objective rating, the addition of the third one provides a subjective rating, which changes from investor to investor.

These three variables are described by fuzzy numbers, i.e. by the pair (linguistic attribute, membership degree) as in the Coverage Ratio example. To determine the final Rating starting from the three variables, the expert system rests on a rule block containing "if-then" implications. Table I is an extract of such a rule block. The rule block is self-explaining. For example, row 16 says that if Additional Financial Value is High, and Equity Value is Low, and Synergies are VeryHigh, then Rating is High. Row 6 (where a blank space is left in the first column) is to be read as follows: whatever the value of Additional Financial Value, if Equity Value is VeryHigh and Synergies is High, then Rating is VeryHigh (as one may note, Rating, seen as a function of the three variables, is positively correlated to each of them: the greater one of the three, the greater the Rating). The rule block is composed by 113 rules and exhausts all possible cases, that is for each possible pair (linguistic attribute, membership degree) of the three variables we determine a corresponding pair for Rating. Therefore, Rating is described by a fuzzy number; but we need a "crisp" value, e.g. a normalized number in the interval $[0, 1]$ giving us the value-creation power of the firm (the higher the Rating, the higher its capability to generate value). This step is accomplished by a defuzzification process (see Von Altrock, 1997, for details).
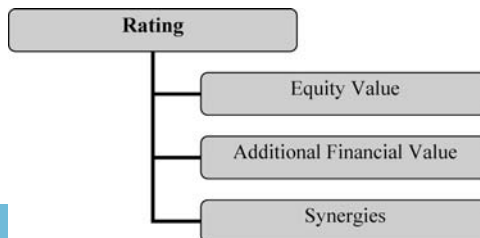

Figure 2.

| | IF | | THEN |
Additional Financial Value	Equity Value	Synergies	Rating
Zero	High	High	High
Low	High	High	High
MediumLow	High	High	High
MediumHigh	High	High	VeryHigh
High	High	High	VeryHigh
	VeryHigh	High	VeryHigh
Zero	VeryLow	VeryHigh	MediumLow
Low	VeryLow	VeryHigh	MediumLow
MediumLow	VeryLow	VeryHigh	Medium
MediumHigh	VeryLow	VeryHigh	MediumHigh
High	VeryLow	VeryHigh	MediumHigh
Zero	Low	VeryHigh	MediumLow
Low	Low	VeryHigh	Medium
MediumLow	Low	VeryHigh	MediumHigh
MediumHigh	Low	VeryHigh	MediumHigh
High	Low	VeryHigh	High
Zero	Medium	VeryHigh	MediumHigh
Low	Medium	VeryHigh	MediumHigh
MediumLow	Medium	VeryHigh	High
MediumHigh	Medium	VeryHigh	High
High	Medium	VeryHigh	VeryHigh
	High	VeryHigh	VeryHigh
	VeryHigh	VeryHigh	VeryHigh

Table I.
Extract from the Rule
Block "Rating"

The three variables Equity Value, Additional Financial Value and Synergies are intermediate variables, as they depend in turn on other variables (through rule blocks of the kind above mentioned), which in turn depends on other variables and so on (see Appendix, Figures A1-A3). Take for example the Equity Value: it depends on Firm Value and Outstanding Debt. Firm Value is in turn affected by the Free Cash Flow to Firm[7], the Growth Rate and the Operating Risk. These three variables in turn depend on other variables and so on. Iterating backwards through all the intermediate variables of the system one finally gets to the very inputs of the system (the value drivers).

The inputs are the starting points of the decision process: the decision maker just has to fix the appropriate values for each input, then the expert system fuzzifies the inputs and using the "if-then" rule blocks infers the Rating, which is then defuzzified in order to obtain a number in [0, 1], as seen. Our model incorporates 29 value drivers, 16 of them are qualitative, 13 of them are quantitative (see Appendix for description); there are 22 intermediate variables, 23 rule blocks and 730 fuzzy rules. It is worth noting that some variables affect more than one intermediate variables. For example, the Operating Risk is relevant not only for determining the Equity Value but also for computing the Additional Financial Value. In particular, it affects both the need for financial Flexibility and the Bankruptcy Risk. The same is true for the inputs Technology and Resources and Skills, as already seen.

Any model needs corroboration. To this end, we have analyzed different scenarios and realized a sensitivity analysis by changing one or more inputs to verify if changes in the output are theoretically correct. Let us consider, for example, two firms with the inputs: shown in Table II which determine the following values for the intermediate

	Firm A	Firm B
Acquisition	0	0
Cost of adjustment	0.1	1
Barriers	0	0
Capital expenditures	0	0.8
Competitive rivalry	0.05	0.5
Consistency	0.4	0.7
Coverage ratio	9	4
Complementarities	0.4	0.7
Current leverage	0.1	0
Customer concentration	0.1	0
Direct costs	0.1	0.1
Economies of scale	0	0.7
Expenditures in R&D	0.8	0
Indirect costs	0.4	0.4
Management	0.8	0.8
Monitoring costs	0	0
NonCash working cap	0	0
Operating leverage	0.1	0
Outstanding debt	0.1	0.3
Price sensitivity	0.1	0
Processes efficiency	0.8	0
Reinvestment rate	0.1	0
Resources and skills	1	1
ROI	0.16	0
Sensitivity to economy	0.1	0.7
Separation	1	0.5
Supplier concentration	0.1	0
Tax rate	0.6	0.2
Technology	1	0.5

Table II.

variables (in alphabetical order) shown in Table III. This is so that the three fundamental blocks are valued as shown in Table IV. This which in turn determines the Rating shown in Table V.

Firm A has a medium value-creation power, due to a low value of Synergies, a medium value of the stand-alone Equity Value and a very high Additional Financial Value. The low value of Synergies is due to Medium Low values of Consistency and Complementarities and nonexistent Economies of Scale. The medium value of equity is determined by a very low Outstanding Debt and a medium Firm Value. The latter is in turn determined by a low value for FCFF (which is so because even if the Operating Margin is not bad and there are no cash outputs for Reinvestment Needs, the Tax Rate is very high), medium values for growth expectations (derived from medium values of ROI and Reinvestment Rate)[8] and no Operating Risk (look at the very favorable values of the inputs affecting Business Risk, Specific Risk and Strategic Risk). As for Firm B, its Equity Value coincides with that of Firm A, because the higher value of Outstanding Debt is compensated by a slightly higher Firm Value (owing to the fact that Tax Rate is very low, Operating Margin is medium, but Reinvestment Needs are higher than in Firm A). Synergies for Firm B are significant (there are good values for the three inputs) so they are much higher than those of Firm B. However, the Additional Financial Value that may be reached with an Optimal Leverage is only medium for Firm B, especially because the cost of adjustment is very high. The net

	Firm A	Firm B
Bankruptcy Cost	0.4	0.4
Bankruptcy Risk	0	0
Borrow Benefits	1	0.25
Borrow Costs	0	0
Business Risk	0.05	0.5
FCFF	0.25	0.5
Firm Value	0.5	0.55
Needs for Flexibility	0	0
Growth	0.5	0
Operating Costs	0.133	0.667
Operating Margin	0.5	0.5
Operating Risk	0	0.125
Optimal Leverage	1	0.833
Power	0.5	1
Product Quality	1	0.5
Reinvestment Needs	0	0.333
Revenues	0.667	0.667
Specific Risk	0	0.167
Strategic Risk	0	0.133

Table III.

	Firm A	Firm B
Equity Value	0.5	0.5
Synergies	0.2	0.714
Additional Financial Value	1	0.5

Table IV.

	Firm A	Firm B
Rating	0.46	0.64

Table V.

effect is a higher Rating for Firm B, since Synergies for Firm A are so low that a higher Additional Financial Value is not able to compensate (and the Additional Financial Value for B is not so bad).

Let us now take Firm A and consider favorable changes in the Economies of Scale, leaving other inputs unvaried. Owing to the importance of such a variable, we expect the Rating to increase. Our system complies with our expectations (Table VI).

Raising from 0 to 1 the Economies of Scale, the Synergies considerably increase from 0.2 to 0.7 (while Equity and Additional Financial Value keep constant), and this reverberates on the Rating which increases from 0.46 to 0.8.

Economies of Scale	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Synergies	0.2	0.25	0.29	0.33	0.37	0.45	0.5	0.54	0.58	0.62	0.7
Rating	0.46	0.5	0.53	0.56	0.58	0.63	0.67	0.69	0.72	0.75	0.8

Table VI.

Another simulation may be considered with Firm B. Let us check how the output changes as both Operating Leverage and Price Sensitivity changes from 0.3 to 1. A higher operating leverage means that a higher proportion of fixed costs determines an increase of Specific Risk. Likewise, if customers' Price Sensitivity increases, customers are more likely to leave the product if price is not sufficiently low, so that the Specific Risk increases. Specific Risk affects both the Equity Value and the Additional Financial Value. In particular, we expect Equity Value to decrease, because increasing values of Specific Risk imply increasing values of Operating Risk and thus smaller values for Firm Value. The Additional Financial Value should also decrease in value, since a higher Specific Risk (and then Operating Risk) means a higher Bankruptcy Risk and therefore higher Borrowing Costs, which in turn entail a smaller Optimal Leverage (whereas Synergies is obviously untouched). As a result, the Rating should decrease. The system actually fulfills our expectations (See Table VII). (We have accomplished many other simulations, which seem to corroborate the model, but we omit them for reasons of space.)

5. From Rating to Price
The value provided by the expert system is a normalized score in [0, 1]. This may be used for rating firms in a market or in a sector by a rating agency, by a financial analyst or by a decision maker willing to objectively score a class of firms with respect to their ability to generate value. As for rating agencies and financial analysts willing to rate firms so as to provide information to the market, they should fix a particular value for each input in each firm considered. An objective rating is independent of any particular potential buyer and aims at providing objective information about the firm. Because synergies have to do with beneficial interrelations between the target firm and the acquiring firm (which change from buyer to buyer) the evaluators should fix a value of zero for Consistency, Complementarities, Economies of Scale. If this is done, Synergies is nullified, i.e. it does not affect Rating, which then depends only on Additional Financial Value and Equity Value. Once all value drivers are fixed, the expert system automatically provides the final score. The firms rated can then be ranked by dividing them into classes according to their value-creation power (in the same sense as bonds are classified into risk classes). As an example, one may stipulate that firms in the interval [0, 0.2] have a very poor value-creation power, firms in the interval [0.2, 0.4] are mediocre, firms in the interval [0.4, 0.6] are medium, the interval [0.6, 0.8] is a sign of good value-creation power, [0.8, 1] is outstanding. This use of the model may provide investors in the market with helpful information. Periodic publications of firms' rating will shed lights on the firm's power of generating value in the future, thus helping investors to take more rational decisions. Also, this kind of rating could represent a tool which adds to the information provided by current rating agencies (bond rating) and financial analysts (multiples analysis). In this sense, the rating would inform whether a particular decision taken by the firm positively or negatively affects the value-creation power: if a particular decision results in a higher

Operating Leverage	0.3	0.37	0.44	0.51	0.58	0.65	0.72	0.79	0.86	0.93	1
Price Sensitivity	0.3	0.37	0.44	0.51	0.58	0.65	0.72	0.79	0.86	0.93	1
Equity Value	0.5	0.5	0.5	0.49	0.45	0.41	0.39	0.35	0.33	0.29	0.25
Additional Financial Value	0.5	0.5	0.43	0.37	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Rating	0.64	0.64	0.63	0.59	0.54	0.53	0.52	0.49	0.48	0.46	0.42

Table VII.

Rating, this will turn into an increase of the firm's value-creation power (beneficial to the shareholder); if Rating decreases, the public communication of this result will inform investors that the value is being destroyed. Further, in front of firms that are equally priced by the market, the expert system may be of some help to distinguish the one that generates more value (and to understand how that value is generated). If the evaluator is a decision maker willing to buy the firm (or some shares of the firm), it may be an individual or a company. In the former case the individual will act as just explained: Synergies will be nullified (there are no synergies for individuals). Conversely, in the latter case, Synergies will be taken into account; in particular, a specific value for Consistency, Complementarities, Economies of Scale should be selected to determine the value of Synergies, which now plays an important role: the value-creation power of the target firm increases with increasing values of Synergies. For example, even with a low value of both Equity Value and Additional Financial Value, Synergies is able to partially compensate if it is VeryHigh: in this case Rating is medium (see Table I).

If a potential buyer intends to acquire the firm and needs to know the price at which the firm should be acquired, it is possible to convert the scoring provided by the expert system into a price. One of the possible methods to extract a price is to make use of regression analysis. As previously seen, the expert system we have constructed is conceptually and technically divided into three main blocks: Equity Value, Additional Financial Value and Synergies. It is possible to price each block separately and then sum the three shares to obtain the price an investor should pay for acquiring the firm. As for Equity Value the evaluator should comply with the following steps:

(1) Choose a subclass of firms in the market that are regarded as fairly priced.

(2) Isolate the value drivers that actively affect Equity Value: They are Tax Rate, Competition, Sensitivity to Economy, Operating Leverage, Price Sensitivity, Management, Reinvestment Rate, ROI, Acquisition, Capital Expenditures, NonCash Working Capital, Barriers, Processes Efficiency, Customer Concentration, Supplier Concentration, Expenditures in R&D, Resources and Skills, Technology. Fix the correct values for the firms at hand and compute, via expert system, the defuzzified Equity Value for each of these firms.

(3) Associate to each Equity Value so obtained its Price/Earning ratio and plot the pairs (x, y) on an xy-plane, where x is the (defuzzified) Equity Value provided by the system and y is the Price/Earning ratio of the firm.

(4) Run a (linear or quadratic) regression to infer the function $y = f(x)$ connecting Equity Value and the Price/Earning ratio.

(5) Consider the target firm, compute its (defuzzified) Equity Value and put it in the analytic expression of the function as the independent variable.

From the number obtained in step (5) one can get the money value of Equity, i.e. the maximum price any investor should be ready to pay in order to acquire the firm, leaving aside any consideration of synergies and assuming that capital structure remains unvaried. As for appraising the additional value due to optimal structure an analogous linear regression analysis can be conducted. The number obtained is the premium any investor should be ready to pay in order to acquire the firm, considering that an optimal financial leverage will be reached (leaving aside any consideration of synergies). As for the money value of synergies, the steps are similar and one gets the premium any investor should be ready to pay in order to acquire the firm (leaving aside

any consideration about optimal structure). Summing the three values so obtained one finds the total money value of the acquisition for the potential buyer. That is the maximum price an investor should be ready to pay for the firm[9].

The price so obtained is already naturally decomposed into three components: one is the stand-alone value, another is the value added by an optimal structure, the third one is the value of the additional benefits due to synergies with the acquiring firm. The threefold partition provides additional information for the decision process: Firstly, it enables to distinguish an objective price (sum of the former two components) from a subjective price (sum of all components). Secondly, it furnishes a justification for the price, because each of the three components of the price of the firm is isolated (different firms resulting in equivalent prices may have different price decomposition). Thirdly, one may need to deduce not a total money value but a value for just one or two of the three dimensions for comparing firms on this basis. Moreover, managers themselves may be interested in knowing the money value of one or the other component of the firm, in order to take more rational decisions.

6. Managerial implications

Our model is actually alternative to those existing in the literature and in practice, of which it is independent. Yet, one may be willing to use it in combination with other techniques (DCF, Real Options) in a "plurimethodological" approach. Unlike the standard valuation techniques, it gives a clear and clean sight on the determinants of value, specifying their relationships in an explicit and transparent way and using a rigorous formalization. The DCF approach for example shows a lack of transparency (it is not possible to understand the "background" of the decision process). In this sense, our approach can be particularly useful for managers and financial analysts whenever it is necessary to understand and justify a premium paid for an acquisition, to substantiate a price paid which leads to a high (or low) value of multiples, to justify managerial policies, etc. This model is therefore both an evaluation technique and a device for assessing the increase in value associated to particular decisions. Also, managers themselves may be motivated and compensated on the basis of how much they increase the value of the rating, so that the model can be used as a corporate governance tool. The class of subjects interested in the model is actually rather ample: rating agencies, financial analysts, investors (shareholders, bondholders), banks and managers. In particular, it may be used for:

(1) rating listed or unlisted companies;

(2) pricing firms;

(3) decomposing rating and pricing into three driving factors (rating/pricing of Equity Value, rating/pricing of Synergies, rating/pricing of Additional Financial Value) for analysis purposes (two equally priced/rated firms may have very different decompositions);

(4) rewarding and compensating managers;

(5) evaluating and comparing business units of a firm;

(6) measuring the impact of the firm's possible policies and strategies on value creation;

(7) evaluating the impact of particular decisions taken by managers on value creation;

(8) analyzing under- or overvaluation of a firm by the market;

(9) helping decision makers in strategic decisions; and

(10) helping decision makers about selling or buying shares.

7. Conclusions

Finance suggests that we need formal models for a better description and rationalization of the evaluation process, whereas business economics suggests that reality cannot be described by merely resting on mathematical models, complex in their application and simplified in their assumptions. Human intuition and experience are relevant in a decision process and individuals are highly tolerant for ambiguity (Isenberg, 1984). This paper proposes a model which seems to meet both requirements: we have a formal tool rationalizing the decision process and are, at the same time, able to fruitfully exploit human intuition and experience, overcoming difficulties in dealing with ambiguity. To this end, expert systems and fuzzy logic, combined together, seem to be an interesting tool for valuing firms[10]. The approach we offer is easy to understand and easy to implement, it does not require advanced knowledge of mathematics and does not make any particular assumption on the variables affecting the value of the option. The solution derives from logical implications ("if-then" rules), so anyone can understand them and construct them. At the same time we have a formal model, which rationalizes the evaluation process and automatically gives the final value. Fuzzy logic seems to be a reliable tool for describing the value of a firm, since the complexity of real-life situations is handled through "vague" variables and "vague" interactions, which better replicate human mind as well as economic phenomena. Also, a fuzzy approach, unlike classical ones, seems to be capable of integrating qualitative and quantitative analysis, so that the model is not forced to limit its scope to numerical variables with well-specified units of measures but can handle any type of qualitative drivers. We are able to shape the problem so as to take explicit consideration of business, strategic, organizational, financial aspects. The system is extremely flexible, one can introduce many more value drivers and change in any moment the rules connecting drivers and intermediate variables.

Notes

1. For a complete description of the value drivers used in our model see Appendix.

2. To reduce the complexity of the model we have not included the post merger costs which are often an important factor in an acquisition. Our expert system is flexible so that we can add other determinants (for example, the cultural matching between buyer and target firm).

3. Note that any input variable in our model can be the output of an accurate and deep propaedeutic study (and, possibly, the output of another expert system).

4. Coverage Ratio is to be considered as a random variable in a forward-looking perspective.

5. See Buckley *et al.* (2002), for a detailed introduction to fuzzy mathematics.

6. As for any value greater than nine, the system considers it VeryHigh at a degree of 100 per cent and the other linguistic attributes are activated at a zero degree.

7. A more rigorous term for what we mean is Capital Cash Flow (Ruback, 2002; Fernàndez, 2002). In our fuzzy perspective to use either term is a matter of convention.

8. The fuzzy numbers we have used for ROI are such that a 16 per cent ROI is considered medium, but this judgment may change from sector to sector (the same holds for the other inputs).

9. For reasons of space, we may not concentrate on technical details such as how to infer useful data, how to select the relevant firms to run the regression, how to cope with cases where data are not available.

10. Magni *et al.* (2002) present a fuzzy expert system evaluating a real option. Magni *et al.* (2004) study a real-life firm acquisition with intrinsic options of abandon, growth and expansion.

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Appendix
Value drivers

Acquisition. The portion of capital expenditures represented by the target firm's prospective external investments. This variable has been treated as a qualitative variable.

Cost of Adjustment. The costs that the target firm has to sustain to pass from the current capital structure to the optimal one is treated as qualitative variable.

Barriers. The entry barriers are treated as a qualitative variable.

Capital Expenditures. The net capital expenditures include the fair adjustments for the capitalizations of R&D and of SG&A. One may use an average of the firm's ratio NetCapitalExpenditures Revenues.

Competitive Rivalry. This variable is considered as a typical qualitative variable.

Complementarities. We use the term complementarities to identify resources and skills complementarities and market complementarities, considering the diseconomies derived from any kind of overlapping and cannibalization (qualitative variable).

Consistency. The consistency between resources and skills owned by the firm and resources and skills needed to compete in the specific sector in which the firm operates (qualitative).

Coverage Ratio. The ratio EBIT/Financial expenses represents a quick measure of financial rating of the target firm.

Current Leverage. The current debt/equity ratio of the company.

Customer Concentration. The ratio (average sales per client)/(total sales).

Direct Costs. The procedure's costs that have to be sustained in case of distress (qualitative).

Economies of Scale. The economies of scale that the merger can grant. It is highly subjective and depends on the unique match between a specific buyer and the target firm (we treat it as a qualitative variable).

Expenditures in R&D. Research and development expenses represent a capital expenditure. It is a quantitative variable but may be treated as a qualitative, in case monetary forecasts are not possible.

Indirect Costs. Indirect costs of bankruptcy depend on the specific characteristics of the firm. This variable is qualitative.

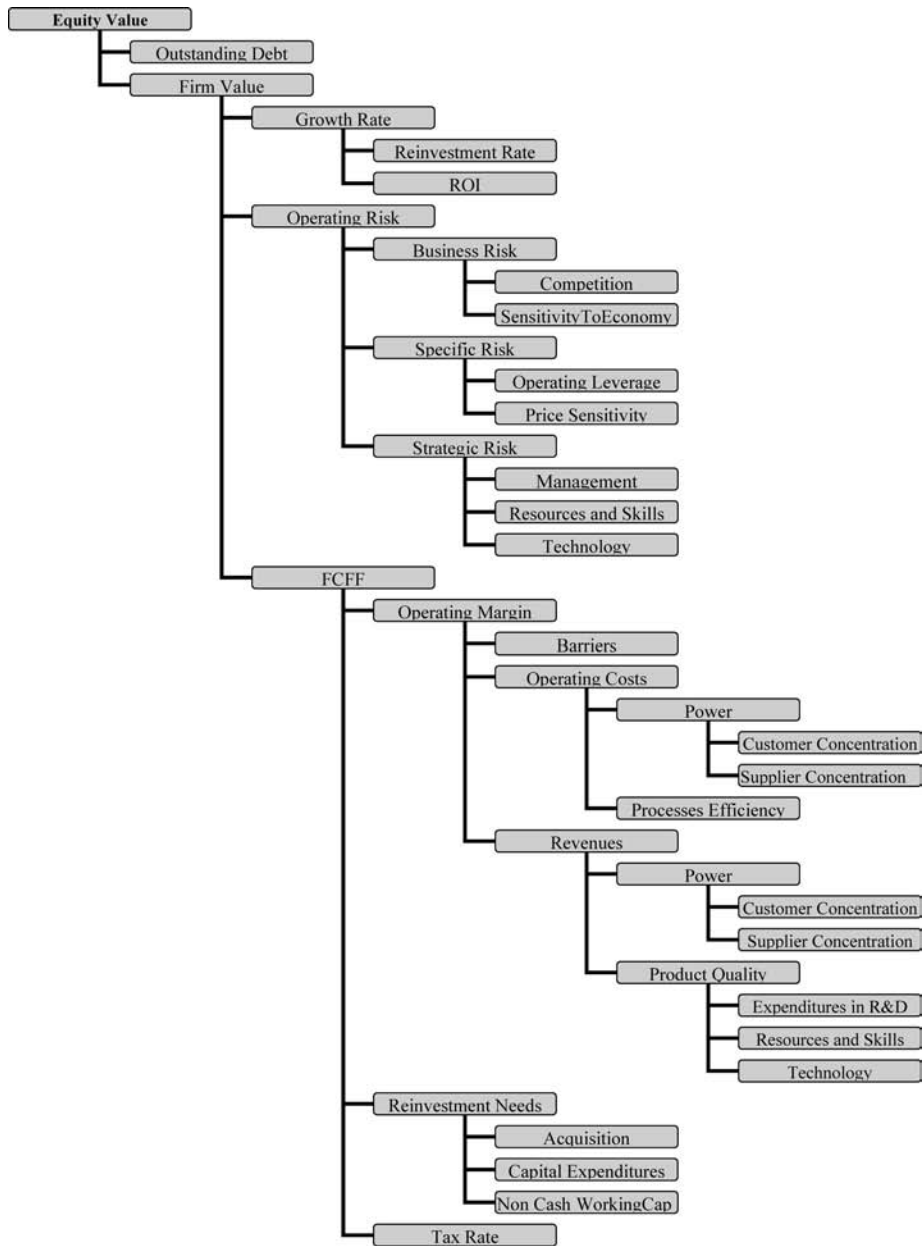*Management*. The quality of management (qualitative).

Figure A1.

Monitoring Costs. The costs that banks and bondholders have to sustain in order to control management's activity. We treat it as a qualitative variable, due to the difficulties in quantifying these costs.

NonCashWorkingCapital. Short-term investments in inventories and accounts receivable One may use an average of the firm's ratio NonCashWorkingCapital/Revenues.

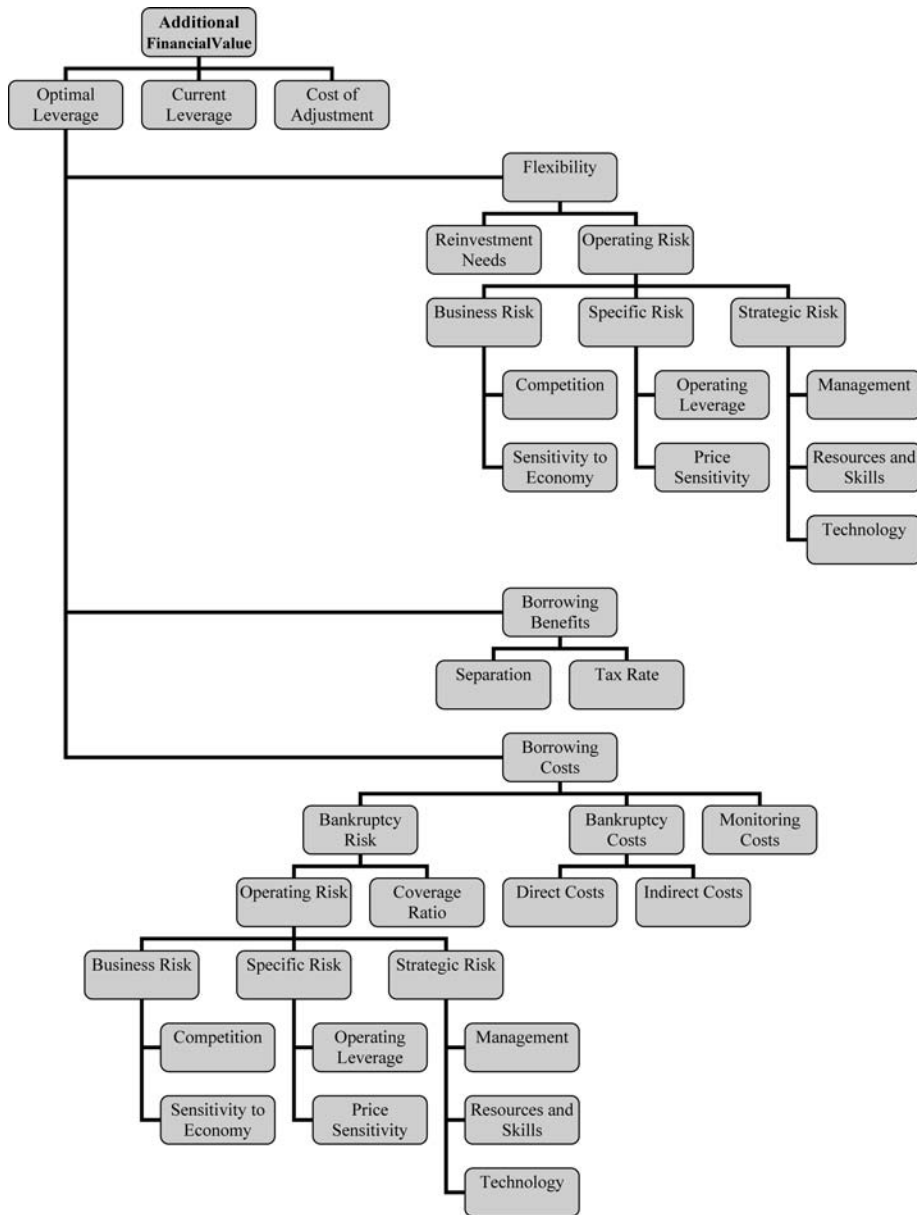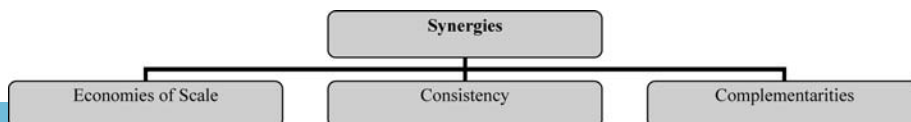*Operating Leverage.* The proportion of fixed costs on total costs.

Figure A2.

Figure A3.

Outstanding Debt. While we treat it as a qualitative variable in our model, one may directly use the market value of the outstanding debt, using the statistical distribution of debts' values of the firms of the industry to define the linguistic attributes.

Price Sensitivity. It expresses customers' price sensitivity (qualitative).

Processes Efficiency. A qualitative variable in our model, in some specific industry it is actually possible to find a quantitative measure identifying efficiency.

Reinvestment Rate. The ratio (Capital Expenditures – depreciation + Δ NonCashWorkingCapital)/[EBIT$(1-t)$].

Resources and Skills. Resources and skill owned by the target firm (qualitative).

ROI. The ratio EBIT$(1-t)$/capital invested.

Sensitivity to Economy. The sensitivity to macroeconomic factors is given by the unlevered beta of the industry.

Separation. Separation between management and shareholder is a qualitative variable.

Supplier Concentration. The ratio (average purchase cost of raw materials per supplier)/(total cost of raw materials' purchases).

Tax Rate. The marginal corporate tax rate.

Technology. The quality and degree of technology owned by the firm (qualitative).

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