The valuation of technology in buy-cooperate-sell decisions

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Abstract

Purpose – This paper is aimed at studying the technology in buy-cooperate-sell decisions process in order to identify and analyse the logical steps that should characterise a complete and reliable appraisal process.

Design/methodology/approach – The paper develops a framework to support the whole process, based on literature analysis and an empirical study. A case study is presented in order to discuss some of the theoretical and practical problems affecting the appraiser during a technology valuation.

Findings – It is found that the use of the proposed framework: forces the appraiser to perform a systematic and rational analysis, coherent with the internal and external context of the valuation; points out the most critical elements that could lead to a misleading and/or unusable and/or biased valuation; forces the appraiser to solve some critical trade-offs and to deal with contrasting elements; imposes coherence throughout the process and consistency among the various hypotheses and assumptions needed to finally identify a (range of) final value(s); gives the appraiser a communication tool, as different people are involved during the process; allows people (even if not directly involved in the process) to understand how the value of the asset has been determined and the validity, reliability and precision of the results obtained; and increases the bargaining power of the appraiser during the negotiation with a potential counterpart, allowing a clear and complete understanding of the value of the asset.

Originality/value – This paper analyses the entire process and gives emphasis to the critical aspects of each phase, suggesting some solutions.

Keywords Asset valuation, Intangible assets, Technology led strategy, Decision making, Italy

Paper type Case study

Introduction

In the last few years the importance of external technology acquisition has greatly increased and this is critical for the success of the innovation process within firms (Chatterji, 1996). In fact, in the area of technology, firms much more frequently contract-out their own technology to third parties or contract-in technology from external sources than they did in the past (Escher, 2001). In the literature this topic is widely analysed and discussed, especially from the perspective of companies that access external sources of knowledge and technology (Roberts and Liu, 2001). The following topics have already been given significant attention: the motivation that pushes companies towards external sources of knowledge and technology (Atuahene-Gima and Patterson, 1993); the organisational forms for accessing

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external sources (Chatterji, 1996; Chiesa and Manzini, 1998); and the management of technological collaborations (Chiesa, 2001). These studies reveal a significant problem, which affects the definition, organisation and management of collaborations aimed at exchanging technology and technical know-how. This problem is related to the valuation of technology-based assets, such as patent, process and technical know-how.

The aim of this paper is to analyse the process of appraisal for technological assets involved in a buy-cooperate-sell decision, in order to develop a framework to support managers in dealing with this type of process.

The valuation of intangible assets in the literature

In the literature as well as corporate practices, great attention is given to intangible assets. An intangible asset is defined as a resource that does not have a physical embodiment and whose industrial and economic exploitation gives a claim to a future benefit (Bouteiller, 2000; Smith and Parr, 2000; Lev, 2001). There are several intangible assets' classifications (Brugger, 1989; Anson, 1998, 2001; Gotro, 2002); one illustrative, although not comprehensive clarification has been put forward by the Financial Accounting Standards Board (Holzmann, 2001) (see Table I).

As shown in Table I, the term "intangible asset" covers a wide range of resources; in fact it could be:

- part of an integrated group of other business assets: such as trained staff, mailing lists, customer lists, agreements; or
- an independent economic unit: such as patents, copyrights, trademarks, technological know-how, technical drawings.

This paper focuses on assets belonging to the second group, i.e. on separable and identifiable assets (Brugger, 1989; Guatri, 1989). In particular the paper considers technology-based assets such as patents, process and technical know-how, engineering drawings, computer software and databases. These technology-based assets[1] can generate income (and therefore value) separately from the business enterprise and can be bought, sold or licensed-in/out as independent assets. This phenomenon is becoming increasingly relevant, and it is highlighted by the fact that firms are increasingly relying on external sources of technology to support their innovation

Intangible assets	Examples
Customer-based or market-based assets	Customer base, mailing list, distribution channels, presence in geographic location or markets
Workforce-based assets	Technical expertise, assembled workforce, trained staff
Corporate organizational-based and financial-based assets	Favourable government relations, outstanding credit rating
Contract-based assets	Consulting agreements, advertising contracts, rights (water, gas allocation, lease)
Statutory-based assets	Patents, copyrights, trademarks
Technology-based assets	Computer software and programs, technical drawings, database

Source: Holzmann (2001)

Table I.
Intangible assets

process (Roberts, 2001, Jones *et al.*, 2000, Howells, 2000, Chatterji, 1996, Chatterji and Manuel, 1993). The nature of technological innovation – the need for technology fusion, the increasing specialisation in knowledge production, the pressure on time and costs – forces companies to search for partners able to support their innovation process, particularly those that serve their need for technological assets (Kodama 1992, Chiesa and Manzini, 1998, Chiesa, 2001). In this context, a "market for technology" is emerging (Arora *et al.*, 2001), in which technology is exchanged among different companies through buy/sell transactions or within several forms of co-operative agreements (such as joint ventures, alliances, consortium etc.). Whatever the form of transaction, the commercialisation of technology calls for a definition of the "value" of the subject technology.

In the existing literature there are several articles dedicated to the importance of these technological assets and to the problem of their valorisation. The importance and the value of technological assets have increased consistently in the past two decades. In fact, today the value of intangibles exceeds the value of tangibles by six-seven times (Lev, 2001); whilst at the beginning of the 1980s the value of tangible assets was twice that of intangibles. A great deal of research concentrates on this first aspect (Morris, 2001; Korniczky and Stuart, 2002).

In the past, companies derived a significant part of their own value from hard assets and manufacturing processes (Gotro, 2002) investing heavily in the use of tangible assets to gain a competitive advantage. Today, technological assets play a key role in determining the value of the company (Daum, 2001). This is consistent with the changes affecting the competitive context. In recent years the competitive context has become more and more dynamic and turbulent. In other words, there is not only competition among tangible assets, that either change very rapidly or are not able to sustain the competitive advantage over the long run, but also (and even more) with intangible ones. This is particularly emphasised in the area of technological assets. Hence these intangible assets are becoming a powerful tool in facing competitive market forces alongside the traditional assets (WIPO, 1998).

The second theme analysed in the literature is the valorisation of intangible assets. The valuation of these types of assets is critical for company shareholders. It is critical in assessing the true value of shareholder companies. It is also an important tool for the management of the firm in supporting the decision-making process. The literature contributions are focused on different aspects of the valuation. A number of authors have analysed the methods and techniques applied to perform a proper economic analysis. These methodologies can be classified into two main groups (Mun, 2002):

(1) traditional methods (among them, the most important are the cost, market and income method); and

(2) innovative methods (among them the most important is the real option method).

These methodologies are diffused not only in the academic literature (Anson, 1998; Mard, 2001), but also in corporate practice (Mullen, 1999). As regards these contributions, the valuation techniques will be presented in the next section.

Other authors have frequently discussed different problems, such as:

- the coherence between the techniques and the type of intangible asset (Smith and Parr, 2000);

- the coherence between the techniques and the objective of leveraging technology (Khoury, 1998); and
- the linkage between the appraisal method and a specific form of transaction (e.g. licensing) (Berkman, 2002).

Little literature has been written on the valuation process and in particular about: the most important principles of the appraisal process; the specific activities to be conducted; and how the process should be organised and managed. Some contributions derived from available consulting literature, which draws on some guidelines from the direct experience of companies. There are, in fact, different international valuation firms that provide independent valuation services to the business, financial and legal communities (such as Appraisal Economics Inc., The Patent & License Exchange, Inc. or Willamette Management Associates). They define the main steps making up the process as:

(1) *Definition of the problem.* This implies the identification of the intangible assets to be valued, the description of the scope of analysis, and the identification of some limiting conditions such as the assumed accuracy of data used in the appraisal.

(2) *Preliminary analysis and data selection and collection.* The appraiser must analyse and understand the forces, which guide and influence the entire valuation process, such as, the relative bargaining power and the relationship existing between the buyer and the seller.

(3) *Application of the three traditional methods.* The practice focuses strongly on the cost, market and income method.

(4) *Reconciliation of values.* When an analyst uses several valuation methods, he or she rarely obtains the same value indications. In this case he or she has to define a range of "significant" values so as to understand why a method is producing outlier value indications.

The consulting literature shows the appraisal process is composed of different and critical activities. The overall weakness of these contributions is that although a set of activities is described, a systematic view of the whole process (of the links among activities and of the relative managerial problems) is not discussed in detail. In view of what is expressed in the academic and consulting literature, the attempt here is:

(1) to study in depth the entire appraisal process and activities, thus presenting a systematic vision of the entire process;

(2) to understand how the management of different activities influences the effectiveness of the valuation, identifying the critical problems to be solved during the appraisal; and

(3) to suggest some guidelines by ascertaining some solutions to the identified problems.

Techniques for valuing technological assets

Appraisal methods and techniques are broadly classified into:

- cost method;
- market method;

- income method; and
- real option method.

These valuation methods are well documented in an extensive bibliography: Gilardoni, 1990; Anson, 1996; Khoury, 1998; Stiroh and Rapp, 1998; WIPO, 1998; Martin, 1999; Razgaitis, 1999; Reilly and Schweihs, 1999; Mard, 2000; Mard *et al.*, 2000; Smith and Parr, 2000; Anson, 2001; Anson and Serrano, 2001; Damodaran, 2001; Khoury *et al.*, 2001, King, 2001; Mard, 2001; Spadea and Donohue, 2001; Benninga, and Tolkowsky, 2002; Hoffman and Smith, 2002; Khoury, 2002; Mun, 2002; Tenenbaum, 2002; Khoury, 2003; Park and Park, 2004. In this paper, the methods and techniques are presented for an illustrative purpose and are not intended to reflect a comprehensive review of valuation issues.

The cost method

The cost method appraises the value of technology assets by measuring the expenditure necessary to create and develop the technology asset. This method is based on the economic principle of substitution in which a prudent investor would pay no more for a technological asset than it would cost to create or acquire a similar asset. The technology asset value is related to its cost structure. The structure of cost to be considered during the valuation process can vary. In the literature, there are several definitions of cost which include:

- Cost of avoidance (or cost savings) quantifies either historical or prospective costs that are not incurred by the owner of the technology due to the ownership of the subject technology.
- Trending historical costs. Current historical asset development costs are identified and quantified and then "trended" to the valuation data by an appropriate inflation-based index factor.
- Re-creation cost (or reproduction cost) is the total cost, at current price, to develop an exact duplicate or replica of the subject technology. This duplicate asset would be created using the same materials, standards, design, layout and quality used to create the original technology.
- Replacement cost is the total cost to create, at current price, an asset having equal utility[2] to the technology subject to be appraised. However, the replacement technology would be created with modern methods and developed according to current standards, state of the art design and layout and the highest possible quality. Accordingly, the replacement technology may have greater utility than the subject technology.

Among these, the most common types adopted in practice are reproduction and replacement costs.

However, many authors consider the structure of cost irrelevant to establish the value of a technological asset. At most, it could be used as a benchmark value. In fact the cost-based method has too many weaknesses. It does not take into consideration the amount of economic benefits related to the ownership and exploitation of assets, whereas it includes the sunk R&D costs. The second main weakness is the implicit assumption that expenditure should always create value, as a matter of fact not all costs lead to successful assets. Another weakness is related to the efficiency of

investments. The cost method assumes that the level of past investment-effectiveness will be the same in the future. This is a false assumption as there are several situations in which an investment can be characterised by different levels of efficiency.

This method is usually used when the application is at such an early stage of development that its market application is still unclear. In this case, in fact, the level of uncertainty is higher and the knowledge of the future business is very limited. In conclusion, the cost-based method appears inappropriate to establish the value of the technology, as it is applicable only when the extent of uncertainty is very high. Even then only a benchmark value is provided.

The market method

The market method measures the present value of future benefits by obtaining a consensus of what others in the marketplace have judged it to be. This provides an indication of value by comparing the price at which similar intangibles have been exchanged between willing buyers and sellers. In other words, when the market approach is used, an indication of the value of the specific item of intangibles can be gained from looking at the price paid for comparable asset. This appraisal method is based on the economic principle of competition and equilibrium; in a free and open market the supply and demand factors will drive the price of all goods to a point of equilibrium. This method is largely intuitive and easily understood, for this reason it is widely adopted.

The application of the market method can be summarised as follows:

(1) Identifying the units of comparison (comparables). In order to do this, the selected units have to be comparable each other. Elements commonly looked at to select the appropriate comparables are: industry, market share, capital investments required for the exploitation.

(2) Identifying the appropriate information. For each comparable, the appraiser has to collect data about: the transaction, i.e. the value at which the transaction has been concluded; and an economic measure, such as revenue, or margin or net profit associated to the technology-based asset, or, alternatively, an operative measure such as, for example, the number of users of the technology.

(3) Calculating the ratio between the value of transaction and the economic or operative measure. This ratio is called "multiple".

(4) Applying the "multiple" to determine the value of the technology.

Requirements for successful use of this approach include the following:

- the market has to be active: having a few number of exchanges does not make a real market; and
- the market has to be public: the information of exchanges have to be available.

The main weakness concerns the point that transactions are unique (referring, for example, to the specific characteristics of the buyer and/or of the seller), in fact this is not considered by the market method as it assumes that the value of the transaction is similar to that of comparables.

The income method

The value of any asset can be expressed as the present value of the future stream of financial benefits that can be obtained from the exploitation of the specific technology considered.

This method is based on the principle of expectation. For the application of this technique, the calculation of the future cash flows, related to the specific asset, the time horizon considered, i.e. time in which the above cash flows can be generated and reliably estimated, and the actualisation rate, which reflects the business risk and is usually estimated with the Capital Asset Pricing Model, is needed. The expression of the value of the asset is shown below:

$$V_T = \sum_{t=1}^{T} \frac{NCF(t)}{(1+k_b)^t}$$

where:

V_T = technological asset value.

$NCF(t)$ = net cash flow.

k_b = actualisation rate reflecting business risk.

T = time horizon.

This method is the most accurate to value technology as it considers the specific operating environment (market size, pricing, cost structure, risk) in which the technology is exploited. However, its practical application may present problems, as the required data can be difficult to estimate.

The real option method

The cost, market and income methods all have significant limitations because they consider given technological assets without considering the opportunity (but also the risk) embedded in them. In particular the income method assumes that the projection will meet the expected cash flow and it handles the risk in the actualisation rate. However, cash flow is usually stochastic and risky by nature, the risk has different characteristics and can change across project time.

A method that overcomes this limitation is the real option method; it, in fact, is considered an extension of income analysis. The real option is an instrument to respond to uncertain events. The theory behind option pricing was originally developed for use in financial development. It has recently received growing attention in R&D and in new technology development because it can support the decision process. In fact, not all decisions are made in the present but are deferred to examine the future. The real option is also applied to establish the value of technological assets during a transaction process: when information is incomplete and, in particular, unknown the appraiser can (has to) use the option theory in order to make risk and uncertainty explicit.

This new method is tailored to deal with uncertainty and flexibility. The adoption of this method requires the identification of factors such as:

- present value of project cash flows;
- standard deviation of the project value;
- investment cost of project;
- time left to invest in; and
- risk-free interest value

These factors are used to calculate the value of intangibles using a specific formula; the most famous is The Black-Scholes Model. The real option method represents a new way of thinking; uncertainty is considered an opportunity to create economic value.

These methods have not been presented in order to give a comprehensive review of valuing issues related to valuation methods, but to underline their strengths and weaknesses (Table II). As shown in Table II, each valuation method requires specific data and information and different resources in terms of the appraiser's competencies and skills and is suitable only in specific situations and contexts. In addition after balancing advantages and drawbacks for each valuation method, the appraiser could choose to use more than one method simultaneously.

The appraisal process: a reference framework

According to the current literature presented in the above sections, a framework has been developed aiming to give a systematic vision of the appraisal process and to identify the most critical problems. This framework is described in Figure 1.

Within the framework, three different elements should be distinguished: activities, constraints and links. The activities represent the logical phases of the appraisal process:

(1) identifying the unit of analysis;
(2) identifying the aim and scope of analysis;
(3) identifying the most appropriate valuation method(s);
(4) comparing available and necessary data;
(5) collecting data; and
(6) determining the value of the asset.

The process is affected by constraints such as:

- available data;
- necessary data and resources/time required to apply a method; and
- available time and allocated resources.

The links represent the relationship between two or more logical phases. Obviously such links do not indicate a sequential relationship, but a logical one. As a consequence, in some case, different phases can be conducted contemporarily, and/or there could be feedbacks throughout the process.

Table II. The major appraisal methods

Methods and scope	Major advantages	Major disadvantages
Cost method – reproduction cost: find the value of the asset starting from its recreation cost. Replacement cost: find the value of the asset starting from the recreation of its own utility	The idea of the minimum value is given. The information and data are available and highly reliable (reproduction cost)	The future earnings of the asset is not reflected. The efficiency of past investments is not considered. There is the implicit assumption that expenditures should always create value
Market method – find the value of the asset starting from sales comparison	A practical and logical method applicable to all type of intangible assets. Most direct method	Most technological assets are not traded frequently enough to be able to establish a comparison. The intangible assets are commonly traded within a business and it is difficult to dissociate them from the business. Get enough details on similar transactions is difficult. The market is characterised by the buyer's interest and this may bring in distortions
Income method – find the value of the asset starting from the appraisal of the future benefits associated to the asset	Some elements that in the other methods are considered implicitly, such as the income generating capacity, the appropriate cost of capital and the risk associated with the asset, are made explicit. Adaptable and flexible method. Well know and widely recognized method	The projection of the future net cash flows is difficult. The estimation of the actualisation rate is complicated. It has to consider not only the cost of capital but also the risk associated to the intangible asset. The required data and information need to be estimated
Real option method – find the value of the asset starting from the appraisal of the future benefits associated to the asset and considering uncertainty and variability in future outcomes	Most complete method. Uncertainty and variability are considered	Option calculation required to use a complex formula. The project value uncertainty is difficult to estimate. The underlying has to be estimated

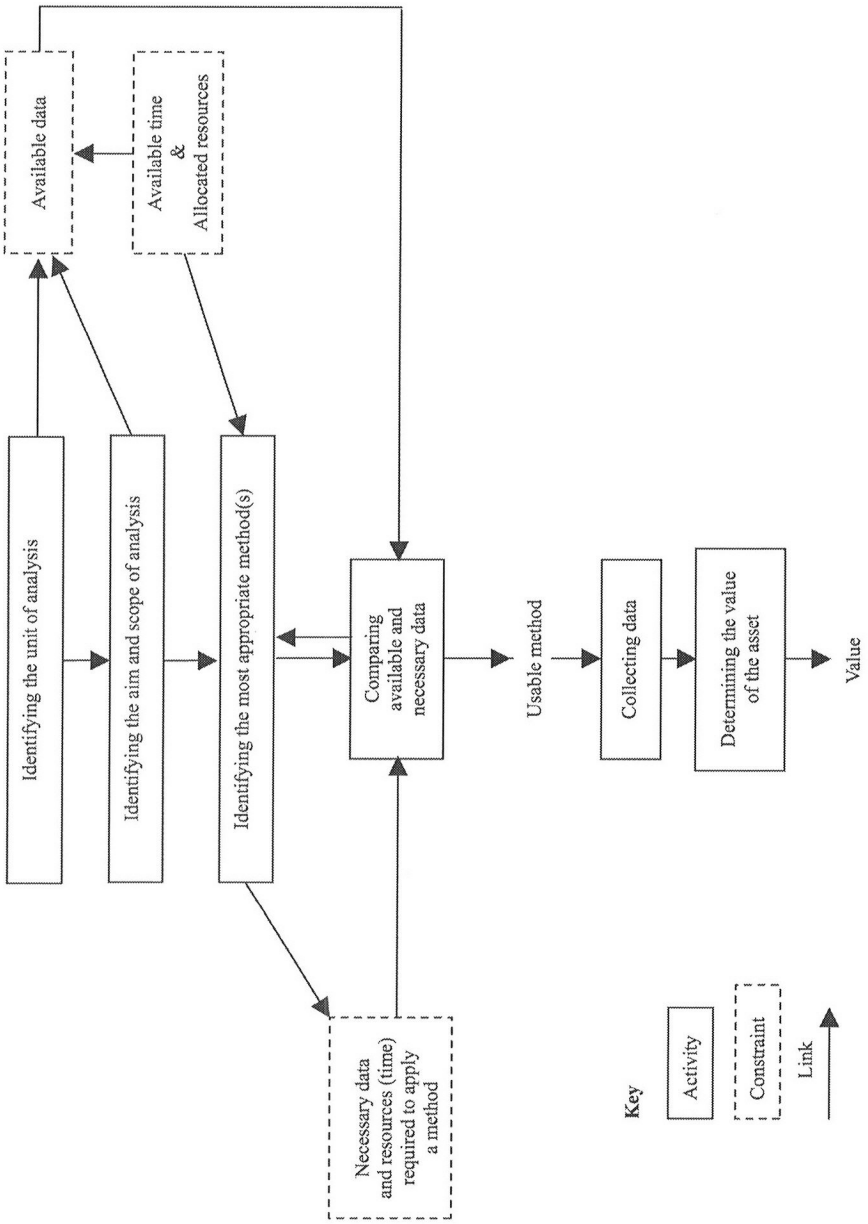

Figure 1.
The appraisal process framework

The activities of the appraisal process

Identifying the unit of analysis. A correct appraisal process starts by identifying the unit of analysis. Problems can emerge during the appraisal process of the technological asset. Even though an asset is an independent economic unit, it can be a part of a product, system or service. In a number of cases, there is a difference between the technological asset and the product, which embeds the technology and is available on the market. Electrical products representative of the industrial sector present such a case, where the technological asset is a component of a system. For example, the microchip is a component of several products such as PCs and mobile telephones. If the technological asset is a component of a system, it is important to recognize that not all the income (or value) generated by the system is related to it. In some cases, indicators measuring the technological asset's value compared to the value of the system can be identified. But it is not possible to suggest a general method to identify such indicators at this point. In fact it is due to the technological asset and the system. For example, a possible solution can be identified considering the incidence of the reproduction cost of the technological asset on the system. The same incidence could be used to estimate the value of future cash flows generated by the technological asset analysed. At some point it would be interesting to understand the exact contribution of the technological asset to the functioning of the entire system. The higher the contribution, the higher the value generated by the technology.

Another aspect of the problem arises when the technological asset has different uses, i.e. when it can represent, in different situations, an end product, a component or a work in progress. For example a company can use a pharmaceutical molecule as an end product and can sell it on the market; the same pharmaceutical molecule can be used as a catalyst in a chemical process. This implies that different values can correspond to various uses, i.e. that the unit of analysis is not the single molecule, but the "molecule plus its relative use". As pointed out in these examples, recognizing the right unit of analysis can be difficult. But it is important for the appraisal process because it allows for making a correct definition of the context and borders of analysis. Thus, it is fundamental because it defines the unit of reference for all the other activities.

The proposed framework aims at putting into evidence these issues and, in synthesis, at alerting the appraiser to pay attention to these problems:

- an intangible asset can be a part of a product or system, even if it is considered as an independent economic unit; in this case, it is necessary to separate the value generated by the intangible from the value of the product/system; and
- the same intangible asset can have different uses, in this case it is important to identify a specific use, to which a specific value is associated.

Identifying the aim and scope of analysis. The valuation of technological assets can be performed in different contexts and, hence, may have many different aims (Rabe and Reilly, 1996; KPMG, 1999). The context of the valuation can be:

- *The accounting process*: due to the rising interest and relevance of intangible assets, a correct accounting of intangible assets is necessary. This, in fact, allows managers and stakeholders to increase their own knowledge of the dynamics of value creation and to define the value to be considered within the accounting reports and the external financial reports.

- *The decision-making process*: valuing technological intangibles is critical for managers that are required to make decisions on: technology acquisition versus internal development; direct versus indirect technology exploitation; technology selling versus technology licensing.
- *The transaction process*: an intangible asset analysis and valuation is often required to define the terms of the contract related to the transaction process (e.g. the negotiated price). The main commercial transaction forms are: the transfer of ownership – this category includes all business transactions, in which there is a complete shift of the ownership title of the asset that a part grants to another without restriction; and the transfer of the right of use – it is the right that the owner of a technological asset grants to a third part, under the payment of an earning (Brooke and Skilbeck, 1994).
- *The infringement process*: sometimes the intellectual property rights on intangibles can be infringed and in these situations a valuation of damage is required.
- *The bankruptcy process:* in dividing and distributing the debtors' assets, the value of intangible assets has to be established to identify, for example, any cancellation of debt income.

The comprehension of the aim and scope of the analysis affects the appraisal process since it influences the available data and the identification of the most appropriate valuation method(s) (see Figure 1). These links will be analysed later.

Identifying the aim and scope of the analysis often requires a specification of the set of actors potentially involved in the use of the intangible valued. For example, in a transaction or in case of bankruptcy, the identification of the potential buyer/seller or licensee/licenser or creditor is required. The specific characteristics of the counterpart (its competence, marketing strategy, cost structure etc.) affect the valuation, since they determine the specific data to be used when the valuation method is actually implemented.

It is critical to underline:

- The correct identification of the context of analysis influences the identification of the most appropriate method(s) for the valuation and the relative application.
- The identification of the aim and scope of the valuation defines the context in which the valuation takes place. It allows for the improvement of the accuracy of data used and the quality of the valuation itself.

Identifying the most appropriate method(s). The appraiser has to identify a method (or methods) to be used to determine the intangible's value. As shown in Figure 1, this activity is influenced by several factors:

- *The availability of time and resources.* A first selection of the method is made considering the level of resources allocated to the process. In fact, the appraiser has to select a suitable method, according to the resources (in terms of quantity, but, first of all, competence) that are actually available. Some sophisticated method, such as the income or the real options method, can be used only by expert and trained analysts.

- *The identification of the aim and scope of analysis.* For example, consider an appraiser who has to support the accounting process. In this case, the accounting rules must comply with the historically sustained costs that have to be considered and, hence, the cost method is required. Instead, if the analysis is conducted in order to support a transaction process, the appraiser has to value the future potential benefits generated by the asset and the cost for exploiting it. Hence, a method able to take into account the future benefits associated with the intangible asset is necessary, such as the income or the real options methods.

In synthesis, it is important to observe that the choice of the valuation method is not trivial, and that several elements are to be considered. In particular, the advantages and disadvantages of the various methods (shown in Table II) should be evaluated in the light of the specific aim, scope and resources identified for the analysis.

Comparing necessary and available data. As mentioned previously, in the literature review the major appraisal methods are widely explained and discussed. The main characteristics of the methods are described in Table III, in terms of necessary data, time horizon and resource required. These must be considered to correctly use the techniques. In particular, matching necessary data with available data is critical. As a matter of fact, beyond theoretical considerations about the coherence of the method with the specific context, aim and scope of the valuation, a definite set of data is necessary to adopt each method. As a consequence, if the necessary data is not available (due to a lack of time, resources or competence etc.) the (theoretically) selected method cannot be adopted. In other words, comparing necessary data with available data allows for the identification of the "usable" method(s), among those previously selected as appropriate for the specific case.

In several cases the available data is not coherent with the context and bundles of valuation and/or with the necessary data. Sometimes, in fact, the specific context requires the use of a particular valuation technique (e.g. the income method), but the necessary data is not available (e.g. the projection of future net cash flow). However, the analyst has to resolve the problem and come to a valuation. In this case, the appraiser may decide to accept a lower level of accuracy of the valuation, using "proxies" or fuzzy estimations for the unavailable data. The value indication will be less precise, but will be obtained with a method, which has the right "perspective". The result obtained can be improved, in the future, with greater resources, time, etc.

As pointed out above, defining the usable method is a critical step that implies for coherence with the other steps previously described. In some cases, this step forces the appraiser to accept compromises or to select the "best solution" when the "optimal solution" (in terms of accuracy, precision, overall coherence etc.) cannot be identified.

Collecting data. In order to determine the value of the technological asset, it is important to access and collect data concerning different aspects (financial, operational and market oriented) and different time (historical, contemporaneous and future). The unit of analysis, the aim and scope of the valuation and the usable method identified, determine the types of data that have to be collected (Figure 1).

During this activity the main problems are related to:

- *The identification of data sources.* The necessary data, in general, has to be partially collected outside the appraiser's company. This means that data

Table III.
Characteristics of major appraisal methods

Methods	Necessary data	Time horizon	Resources required for a correct application[a]
Cost Reproduction cost	*Material*: it includes expenditures related to the tangible elements of the intangible asset development process *Labour*: it includes expenditures related to the human capital efforts associated with intangible asset development process *Entrepreneurial incentive*: it is the amount of expenditures required to motivate the owner of the intangible asset to enter into the development process or to produce a new patent, trademark, chemical formulation, etc. The previous types of cost should be adjusted in order to express the historical costs to current price (a capitalisation rate has to be considered); and take into consideration the obsolescence, i.e. the reduction in the value of the intangible asset due to improvements in technology or its inability to perform its originally function (e.g. the remaining useful life)	Past	↓
Replacement cost	*Material*: it includes expenditures related to the tangible elements used during the intangible asset development process *Labour*: it includes expenditures related to the human capital efforts associated with intangible asset development process	Present-Future	↓

(*continued*)

Methods	Necessary data	Time horizon	Resources required for a correct application[a]
	Entrepreneurial incentive: it is the amount of expenditures required to motivate the owner of the intangible asset to enter into the development process or to produce a new patent, trademark, chemical formulation, etc		↓
Market	*Similar transactions*: the comparison is made with reference to transactions involving similar assets that have occurred recently in similar markets	Present	
Income	*Future net cash flows*: incremental revenues; decremental expenses; additional investments *Time horizon*: the period during which the intangible is expected to generate net cash flows *Actualisation rate*: the future net cash flows will be actualised	Future	
Real option	*Underlying:* it is the current value of asset, that is the present value of expected cash flows *Exercise price*: it is the present value of investment cost *Time of expiration*: time until opportunity disappears *Risk:* project value uncertainty *Interest rate*: risk-less interest rate	Future	

Note: [a]The amount of resources (time) required to apply the method increases following the arrow; in fact the methods are listed in increasing order of sophistication (Pitkethly, 1997). For example, the cost method (e.g. reproduction cost method) could require a lower amount of time and resources than income method. This is justifiable because the income approach involves some element of forecasting the future cashflows. Moreover, the higher the level of sophistication, the higher is the amount of time required for a correct application and the higher is the level of competences and skills needed

Table III.

sources are both internal and external, with respect to the appraiser's intangible[3]. Obviously, data that has to be collected from external sources can create several problems, due to the confidentiality and "secrecy" of some information. Some public sources can be used, such as legal and trade publications, databases, newspapers. Even if the source of information is internal, the data is not always easily accessible, for example, when data is "dispersed" among databases and systems that are not integrated.

- *The identification of the "right" data and information to be collected, according to the aim, scope and context of the valuation.* Particularly when a great deal of data is available, selecting what is really necessary can be difficult.
- *The completeness and accuracy of data.* The same information, obviously, can be collected with a different level of accuracy. This affects the final result: a valuation is more reliable as the accuracy of data and information increases. But as previously explained, the accuracy of data is influenced by time and resources allocated to the process. In fact, increasing time and resources available usually means availability of a more complete, detailed and precise set of data and information.

Determining the value of the asset. This is the phase in which the selected valuation technique(s) is (are) actually applied in order to come to the final value of the technological asset. This activity can present different problems concerning:

(1) *The method.* Each valuation method presents some specific criticalities (as shown in Table II) that make the application difficult; and

(2) *Its correct application.* Sometimes there are difficulties related to the correct analysis and use of data previously collected. This challenge is influenced not only by the appraiser's capability and experience, but also by the time and resources allocated to the process.

(3) *The management of the different values obtained when more than a single method is applied.* Generally, different valuation methods produce different results. This is coherent with the fact that the technological asset cannot have a definite, precise, "universally" valid value. Different methods and results allow us to define a range of significant values. The single results are valid in the specific context and hypothesis under which they have been calculated and in relation to the level of accuracy of data and information.

The constraints of the appraisal process

The constraints can be classified into:

- necessary data and resources (time) required to apply a method;
- available time and allocated resources; and
- available data.

Necessary data. This is the information needed for a correct application of a definite method. It is determined by the characteristics of each method and, in this sense,

cannot be modified. Hence, it represents a critical constraint within the process. The appraiser has to analyse in depth the information needed to apply to a specific method for implementing it in the correct manner.

Resources (time) required. These represent the resources needed to properly apply the usable method and to establish the value of the technology with a high level of accuracy. Techniques, such as the real options method, undoubtedly require a complex data elaboration, a sophisticated analysis and, hence, a vast amount of time and competent resources.

Available time and resources. These are usually determined by decisions taken at top management level, depending on the relevance assigned to the valuation. These variables affect the level of precision of expected results, influencing first of all the identification of the usable method, the collection of data (and the relative completeness and reliability) and the implementation of the method (and the relative theoretical coherence).

Available data. This is the information that can be accessed during the appraisal process and that is identified by the specific context of analysis. In more detail, the available data is influenced by:

- *The unit of analysis.* For example, in the case of very innovative technological assets, data on the future cash flows is usually unavailable.
- *The aim and scope of the valuation.* For example in the context of the accounting process, data and information is generally accessible and can be obtained in a short time and with little cost. In the case of transactions, another element is the identification and knowledge of the potential buyers. As previously explained, this information is necessary in order to quantify particular data. Also the appraiser's position, with respect to the valued asset, is important. In fact if the company possesses the asset, undoubtedly more data and information will be available than for an external appraiser.
- *The available time and the level of allocated resources.* These elements impact on the quality and the degree of accuracy and completeness of available data.

The links within the appraisal process

As shown in Figure 1 there are several links within the framework. A careful management of the entire valuation process is assured by links; in fact activities and constraints are consistent due to the links.

The importance of same links and their meaning have already been discussed above, in particular:

- "unit of analysis – aim and scope of analysis" link was analysed during the definition of activity related to the identification of the unit of analysis;
- "aim and scope of analysis – available data" and "aim and scope of analysis – most appropriate method" links are presented within the description of "identifying the aim and scope of analysis" activity;
- "time and resource allocated – most appropriate method" link is illustrated throughout the discussion of "identifying the most appropriate method" activity;
- the links related to the activity "compared available and necessary data" have just been examined during the presentation of this activity.

In the framework, the appraisal process presents feedback. Feedback is required to assure the coherence of the entire valuation process with respect to constraints. Sometimes a loop is required if it is unable to identify a usable method during the comparison between necessary and available data. In this case, the appraiser has to repeat certain activities (the identification of available time and resources, the identification of the appropriate method etc.), modifying the relative conclusions.

The empirical study

The described framework has been based upon the most recent theoretical state-of-the-art literature and the empirical cases illustrated in this literature. An empirical research was necessary to enrich the framework and improve its completeness, clarifying:

- the factors considered by companies during the valuation process;
- how the management of different elements that compose the framework, has an effect on the process; and
- the main issues and the critical problems faced by the appraiser during the whole process.

The empirical research comprises qualitative interviews and a case study. The research has been conducted by interviewing five managers of private and public institutions, directly involved in the problem of valuing technology-based assets (Table IV).

The case study concerns the Technology Transfer Office (TTO) of Politecnico di Milano (an Italian University). The TTO has been appointed to manage the economic and industrial exploitation of patents belonging to the University. The case study has been conducted to:

(1) apply the framework to show the meaning of activities, constraints and links in a real and specific context;

(2) enrich and complete the framework; and

(3) highlight and discuss the problems faced by the appraiser during the whole process.

Firm	Brief firm's description	Role of interviewed people
Italtel	Supplier of telecommunications devices	Industrial Property Manager
Pirelli	Group operating in energy cables, telecom and tires businesses	Industrial Property Manager
Politecnico di Milano	Technical University	Director of Technology Transfer Office
Snamprogetti	Engineering company of the ENI Group (petrochemicals)	Licensing and Technology Planning Department Manager
STMicroelectronics	Global semiconductor company	Industrial Property Manager

Table IV.
Institutions involved in the research

Identifying the unit of analysis

The case study concerns the licensing of a patent applied for in the surgical field. The patent concerns a specific aortic cannula that will be used during surgical open-heart operations. In these particular operations the heart is stopped and a machine is used to pump blood into the patient's aorta through a cannula. The new device differs from the traditional cannula mainly in its terminal section that enters the patient's body. The traditional cannula has a pre-established and rigid final section, whilst the new device has a flexible final section folding in on itself and, therefore, with a variable area.

This new device could bring about many advantages that are briefly described below:

- The new device is less invasive. Having a flexible terminal section, the surgical cut is smaller than with the traditional devices.
- The terminal section is flexible. For this reason it can be larger than in the traditional cannula. Moreover, the speed of blood flow, pumped from the machine, is lower and does not damage the walls of the blood vessel (this problem often arises with the traditional cannulae).
- The flexible final section folds in on itself, when the heart starts working again, limiting the clogging of the aorta.

Examining the object of analysis, it is evident that the technological asset corresponds to the product to be sold. Therefore, establishing the value of the surgical device means appraising the technological asset. In this case the identification of the unit of analysis does not present any trouble.

Identifying the aim and scope of analysis

The University first identified and then exploited the patent. Licensing out is preferred, as an indirect form in the exploitation of patents. The main reasons underlying this policy are:

- maintaining a wide patent portfolio gives a positive image; and
- the selling of patents can create problems with the further researches of the University.

An analysis was carried out to support the transaction process and the TTO had to quantify the value of the patent in order to define the economic benefits arising from the licensing out of the patent. The identification of the potential licensee was required to improve the understanding of the context of analysis and consequently the accuracy of data.

Also in relation to this aspect, the TTO analysed the potential buyers of the license briefly described in Table V (letters used for confidentiality).

The TTO selected two licensees, firms A and F, among the different firms operating in the market for aortic cannulae. Firms D and E were not considered due to unavailable data (e.g. US market share). Among the firms, the TTO selected:

- firm A, because it is a world-wide leader in the sector of producers of pump machines for surgical open-heart operations and has recently acquired a small firm that produces traditional cannulae; and
- firm F, because it is a small company, specialising in the production of cannulae.

The first (A) has 38 per cent of the global market share, while the second (F) covered 6.5 per cent of the cannulae producing market (Table V). This case study shows that:

- The TTO had to identify the potential licensees in order to clarify the context of the valuation, and to define correctly and accurately the boundaries of analysis.
- The TTO has introduced subjectivity into the appraisal process (two specific potential licensees have been selected). This choice dramatically affects the following steps of the valuation.

Identifying the most appropriate method(s)

After the identification of the context in terms of unit of analysis and aim and scope of analysis, the analyst has to select the most appropriate method(s). As explained in Figure 1, this activity is influenced by the aim and scope of analysis. Due to the transaction process, the appraiser, very likely, will adopt a method able to consider the future benefits associated with the patent. So the cost method does not seem adequate to the aim of this valuation. This method does not take into account incremental profits that are critical for an external buyer[4]. On the contrary, the income and the real options methods seem to be the best option, according to the aim and scope of the analysis. The market method can be considered adequate as well, even if it is less precise and complete.

Beyond the aim and scope, the available resources have to be considered. From this point of view, traditional techniques are preferred, because the competencies needed to apply the innovative techniques are lacking. For this reason, the income method and the market method are the most appropriate methods.

Comparing necessary and available data)

Table VI and Table VII illustrate the situation of available and necessary data in the case of the valuation of the cannula according to the two most appropriate methods identified: income and market methods.

The following considerations emerge from the analysis of these elements:

- Critical information allowing for the application of the income method is the quantification for future net cash flows sprung from the use of the new device (see Tables III and VI). The advantages related to the use of the new cannula

Firm	UE (%)	USA (%)	Average (%)
A	40	36	38
B	22	33	27.5
C	10	12	27.5
D	8	na	na
E	7	na	na
F	5	8	6.5

Note: na = not available

Table V.
Potential buyers of the licence and their relative market share

cannot be easily expressed in terms of increases in revenues and/or decreases in expenses except in the case of claims for assurance related to surgical problems.

- Data needed for the market method is available, since it is possible to find out the current price of similar devices and the dimension of the market (see Table VII).

The above analysis points to the use of the market method.

The selection of the appraisal method is linked not only to the comparison of available and necessary data, but also to the identification of the most appropriate method(s) (Figure 1). In particular the previous analysis has shown that the income method is not coherent with the data available, even if, from the point of view of the aim of the valuation, this seems to be the most desirable method. Therefore the choice of the method falls on the market method, as the necessary data is available. The market method is also coherent with the aim and scope of the valuation, (i.e. the transaction), since it considers the future economic benefits related to an economic exploitation of the asset.

As a consequence, the market method has been selected; the application of this method is quite easy and requires the only quantification of the selling price and the potential market. The case study underlines that this step is influenced not only by the comparison between available data and necessary data, but also by the specific context of valuation.

Collecting data

To implement the selected method the TTO had to know the market size and the market price of similar devices. The TTO decided to use only external data sources. In fact it examined several market analyses and interviewed many companies working in the field of surgical instruments. Thanks to external data sources the TTO was able to estimate the worldwide market for aortic cannulae: as 1.100.000 surgical open-heart operations during year 2000 in 3,000 heart-surgical centres located in 80 countries. In order to estimate the applicable price of the cannula, the price of similar existing products have been analysed. The price applied to the final users (that are the heart-surgical centres) is around € 50 per unit.

Necessary data	
Future net cash flows (incremental revenues; decremental expenses; additional investments)	Not available
Time horizon	Available
Actualisation rate	Available

Table VI. Necessary data vs available data (income method)

Necessary data	
Units of comparison	Available
Find the parameters on which carrying out the comparison	Available

Table VII. Necessary data vs. available data (market method)

Determining the value of the asset

In order to establish the value of the patent the appraiser has to draw up some hypotheses. In this case, the hypotheses are related to the success of the experimentation of the new cannula, the doctor's ability to pick the advantages related to the new cannula, and the strategic and marketing actions carried out by the manufacturer versus the medical class for promoting the new medical device. On the basis of previous elements the TTO has estimated a 10 per cent penetration rate for both the firms (even if the TTO for firm F could assume a higher rate than firm A's because F mainly concentrates on the cannulae market (Table VIII).

Table VIII presents the served market in terms of the number of cannulae that could be sold. To establish the potential value of the patent, the TTO has to consider not only the size of the potential market, but also the price of the new cannula (Table IX).

As shown in Table IX, the value ascribed to the patent will be € 2,090,000 if the patent is licensed to the worldwide leader (firm A), or € 357,500 if the licensee is a smaller company (firm F). As we can see the value is strongly dependent not only on the formulated hypotheses, but also on the characteristics of the licensee. This underlines the importance of the right identification of the context of analysis and especially of the licensee.

The appraisal process

The case study showed how the process should be characterised by contrasting elements. In particular during the identification of valuation method, some contrasting elements emerged. Examining the unit, the aim and scope of analysis, the income method would have been better, but the necessary information and data was not available. This problem was solved by selecting a method that represented a "second best" solution, from the point of view of the aim and scope of the analysis, but one that was also coherent with the data, resources and time available. An interesting and more complete analysis could be conducted to discuss the valuation of the patent. In fact, it would be interesting to understand how the value of the patent can change considering other transaction forms, such as the transfer of ownership or a solution in order to take direct advantage of the patent.

Table VIII.
The served market of the patent

	Firm A	Firm F
Market share	38 per cent	6.5 per cent
Potential market	418,000 units	71,500 units
Penetration rate	10 per cent	10 per cent
Served market	41,800 units	7,150 units

Note: World-wide market – 1.100.000 u

Table IX.
The value of the patent

	Firm A	Firm F
Served market	41,800 units	7,150 units
Price	€ 50 per unit	€ 50 per unit
Patent's value	€ 2,090,000	€ 357,500

Concluding remarks

In the literature as well as corporate practice great attention is paid to the problems of the valuation of the technological assets, however an in-depth analysis of the whole appraisal process is lacking. In view of this, this paper aims at taking some steps to amend this situation. The paper hopefully presents the complexity of the appraisal process. The first part of the process (from the identification of the unit of analysis to the identification of the usable method) is directed at contextualizing and defining the valuation problem. This part of the valuation process leads to the correct definition of the appraisal problem (in terms of unit of valuation, aim and scope, valuation method(s)) and it does not necessarily need, a real time sequence among the activities. The second part of the process (concerning the collection of data and the actual determination of the asset value), however, has to be executed in a sequenced way (even if some feedbacks are presented (see Figure 1)) and represents the operative phase of the appraisal process. Even if each valuation of the technological asset is unique, this paper aims at providing an analytical framework for estimating the value of a technological asset. As explained in the paper, it is possible to understand that the appraisal process is not simple, but quite multifaceted and that it is not systematic either in the literature or corporate practice.

This paper analyses the entire process and gives emphasis to the critical aspects of each phase, suggesting some solutions. In brief synthesis, it can be argued that the use of the proposed framework:

- forces the appraiser to perform a systematic and rational analysis, coherent with the internal and external context of the valuation;
- points out the most critical elements that could lead to a misleading and/or unusable and/or biased valuation;
- forces the appraiser to solve some critical trade-offs and to deal with contrasting elements;
- imposes coherence throughout the process and consistency among the various hypotheses and assumptions needed to finally identify a (range of) final value(s);
- gives the appraiser a communication tool, as different people are involved during the process;
- allows people (even if not directly involved in the process) to understand how the value of the asset has been determined and the validity, reliability and precision of the results obtained; and
- increases the bargaining power of the appraiser during the negotiation with a potential counterpart, allowing a clear and complete understanding of the value of the asset.

Notes

1. These type of resources will be called "technological assets".
2. Utility is an economic concept and it means the ability to provide satisfaction.

3. It is assumed that the appraiser is the owner's intangible.
4. TTO learned, by experience, that licensees are not interested in licensor's costs.

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