Content validation of a measure of R&D effectiveness

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The overall purpose of this paper is to analyse the content validity of a tool for measuring research and development (R&D) effectiveness in industry using an approach known as scale or construct validation.

Since a large number of indicators is needed in order to measure this concept, and it is often difficult to find qualitative measures that would provide more information than quantitative measures or purely numerical magnitudes, we have constructed a scale that enables us to create a multiindicator to measure R&D inputs, processes, outputs and results. This multiindicator also enables us to group together all the relevant data obtained from the R&D management literature, which we then validate by consulting the opinion of experts from two firms that are very active in R&D and we have consulted two more nationally recognized Spanish researchers on R&D.

1. Introduction

In this paper, we present a proposal for the measurement of research and development (R&D) effectiveness in order to address some of the problems associated with the use of traditional indicators to measure this aspect of firm performance. One such problem is the lack of consensus over which indicators to select. Another is the need to measure both R&D input and output. Finally, there is the difficulty involved in identifying the common attributes and distinguishing features of firms that succeed in reaching a high level of effectiveness and efficiency in the development and implementation of R&D.

We pursue our main objective in the following stages:

- We define and classify R&D resources and activities in firms. In this way, we aim to distinguish among all the innovating activities undertaken by the firms, which take place in their R&D departments, considering these as either cost centres or profit centres.
- We then identify the determinants of success in R&D most frequently cited in the literature.
- We propose a method for measuring the dimensions of the 'R&D production system', broken down into inputs, processes, outputs and results both financial and commercial and improvement in management as a result of R&D activities. This involves a review of the existing literature and consultation of expert opinion, specifically that of the R&D managers of two firms with a high level of investment in R&D and we have consulted two more nationally recognized Spanish researchers on R&D. In this way, we aim to reach the highest possible level of consensus as to how to measure the variables involved in each dimension of the system.

The paper is divided into two sections: in the first, we attempt to arrive at a definition of R&D effectiveness, by analysing R&D as a production system, and conclude with an analysis of the indicators commonly used to measure R&D effectiveness and the advantages to be gained from using aggregate measures. In the second section, we state the aims of the investigation and describe the methodology we have chosen to develop our proposed scale. Our specific proposal uses the scale validation approach to test content validity in the 'R&D effectiveness' construct. Finally, we present our results and conclusions, with an analysis of the final dimensions and components of this construct, based on a review of the literature and consultation with experts.

2. R&D as a system within the organization

The Frascati Manual states that scientific and technological innovation can be understood as the transformation of an idea into the launching of a new or improved product, a new or improved industrial or commercial process, or a new method by which to serve society. The term 'innovation' may take on different meanings in different contexts and the choice of meaning will depend on the specific objectives pursued in its measurement and analysis. Innovation also involves a series of scientific, technological, organizational, financial and commercial activities. R&D is only one such activity and may be present at various stages in the innovation process, not only as the original source of novel ideas, but also as a solution to problems (OECD, 1991).

Both the Frascati Manual (OECD, 1994) and the Survey of technological innovation in firms, INE (1999) define R&D as: '..creative work undertaken on a systematic basis in order to increase the stock of knowledge, including the knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications'.

Taking the definition of R&D effectiveness to be success in achieving the objectives and results pursued by firms in the above activities, we examine the factors that affect the degree of success. In doing so, we consider the R&D department as a system within the organization. Forrester (1977) defines the system as 'a set of components, both tangible and intangible, that interact in the pursuit of common goals'. R&D activities involve the consumption of a series of inputs, the development of a scientific process, and obtain from these inputs and processes a series of outputs that are essential for the continued financial and commercial growth of firms.

Coccia (2001) analyses the performance of research centres, by treating them as systems. This author defines the mathematical expression of the system as follows:

$$S_{\mathrm{srb}=}f(\mathrm{P}, \mathrm{A}, \mathrm{AO}, \ldots)$$

where S_{srb} = system of a scientific research organization; P = research personnel, A = assets, O = organization, etc.

Research personnel (P) are considered one of the main factors of success in R&D activities and results, since their knowledge is what helps to perfect the processes involved. Assets (A) refer to available resources, other than human resources, such as equipment, laboratories and infrastructure in general. Finally, organization (O) affects both personnel and tangible and intangible resources; this refers to the process by which economic forces drive the system, exerting their effect on the operations performed in R&D departments in order to achieve the desired objectives, both of the departments themselves and the firm as a whole.

Brown and Svenson (1998) used a systems approach to examine the effectiveness of R&D departments. These authors believe the R&D production system to be characterized by the consumption of resources, which, after undergoing a certain process, give rise to R&D outputs, considered to be intermediate outputs by which the organization is able to achieve its overall aims at corporate level. The specific dimensions involved are as follows:

(1) *Inputs:* the resources used to generate the cognitive process in the system. These include the human factor, data, ideas, equipment, organization and funding sources. According to Autio and Laamanen (1995), there are three types of input measuring indicators: tangible resource and monetary indicators, capacity indicators and technological input indicators.
(2) The production *process* in an R&D department converts inputs into outputs through research projects, appropriate planning of activities, human resource training, technological services, among others.
(3) *Output* from these departments includes, for example, the publication of books, development of software, product innovation, process innovation, internal and external technology transfer, patents and utility mod-

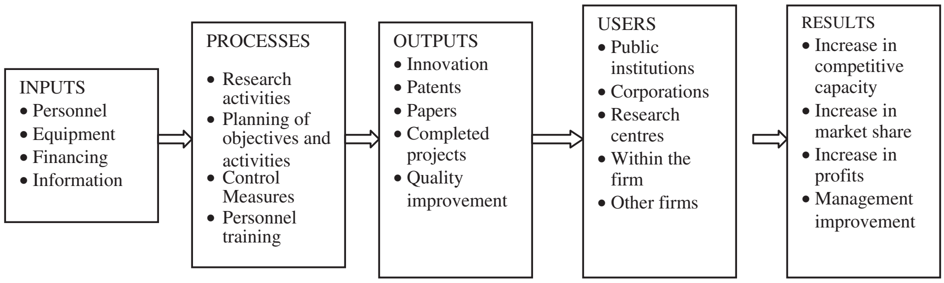

Figure 1. Production system of research and development departments. Adapted from Brown and Svenson (1998).

els. The output indicators, again according to Autio and Laamanen (1995), are also of three types: research and technological, commercial and monetary. To these Rubenstein and Geisler (1991) add changes in production rate, productivity and profit.

(4) The *end consumer* of R&D output varies according to the type of firm (public or private, division or otherwise). Another important factor is whether the transfer of output is to production departments, marketing departments or outside the firm.

(5) R&D output *results* also depend on the end consumers. Shareholders will seek to maximize profits, while managers will aim to reduce costs, increase sales and market share or develop new products.

A graphical representation of the production system in an R&D department, according to Brown and Svenson (1998), is shown in Figure 1.

3. Problems in measuring R&D effectiveness: aggregate measures

In the past, when defining R&D effectiveness, many authors have alluded to some or all of the following factors as being decisive to the success of R&D Quinn and Mueller (1963), Rothwell (1977), Steele (1988) and Szakonyi (1994):

- accurate planning of R&D activities;
- identification of the market's R&D needs;
- competent R&D personnel management;
- effective transfer of technology to manufacturing;
- the use of appropriate financial criteria for R&D assessment;
- effective teamwork between the various functions involved in exploiting R&D.

The high level of uncertainty involved in R&D activities makes totally accurate measurement impossible. The great number of indicators needed to show how firms are working to achieve their R&D objectives calls for detailed examination of the best way to measure them. The factors involved are controlled not only by heads of department but also by company directors.

Since the measurement of R&D effectiveness requires consideration of both tangible and intangible aspects of the R&D production system, measured in terms of both financial and non-financial indicators, the best approach, according to Werner and Souder (1997), in their bibliographic review of R&D metrics, is to use aggregate measures. These combine both quantitative and qualitative elements, in such a way as to generate in many cases more information regarding R&D effectiveness than if they were taken separately.

One of the best-known aggregate measures is 'the technology pyramid' (Tipping et al., 1995) which comprises 33 measures, both qualitative (e.g. self-assessment) and quantitative (e.g. financial ratios), that represent in hierarchical order the five aspects of management that sum up the innovative capacity of the firm (assessment of R&D processes as a source of innovation, technology assessment, integration with firm objectives, project evaluation and value creation). The measures of each of these factors enable this pyramid to be used to analyse R&D effectiveness in an organization and provide guidelines for improvement.

Another integrated measure that has been widely used in recent years is benchmarking. This involves qualitative and quantitative measures used in combination to identify market best practices, against which to measure firms' R&D activities (Welch and Mann, 2001; Sharif, 2002).

Aggregate techniques are more accurate but also more complex than individual measures. They require more effort, are more costly and more time consuming. Their main advantage is that, in addition to measuring R&D effectiveness, they can be analysed to find ways in which to improve it.

Scale content validation, which is the methodology used in the present study, has enabled us to construct an aggregate measure by:

- Selecting the most important qualitative and quantitative aspects (inputs, processes, outputs and results) of R&D based on an extensive review of the literature.
- Validating these aspects through consultation with experts.
- Applying a scale that enables us to handle in conjunction both quantitative and qualitative aspects and quantitative and qualitative measures (self-assessment and statistical techniques), through which we are able to develop an aggregate measure or construct.

By means of this scale we will attempt to order observable firm characteristics that represent the dimensions and components of the 'R&D effectiveness' construct. This construct should include all the measures commonly associated with success in this type of activities, observable in results that may transcend both throughout and beyond the firm.

All the dimensions of the construct can be examined by selecting items that correspond to the definitions featured in existing theories of R&D effectiveness and to the observations of the researcher. This first approach to the construct is of supreme importance, since this is the time to select and evaluate the empirical indicators that will be used to develop a theoretical framework upon which to study associations with other constructs or variables, though this will be the object of a future project.

Scale validation, therefore, enables us to obtain crucial qualitative data when there are no major databases from which to draw information for research projects. In addition, they allow us to gather data on a large number of firms, and thus provide a basis on which to develop theories. In our view, therefore, this methodological approach to the evaluation of R&D effectiveness is an improvement on the use of traditional indicators, since it leads to a unique value that captures the greatest possible number of concept defining dimensions, and can be used in studies to examine its relationships to other variables or scales (accounting change, efficiency, performance, etc).

Theoretical or content validation of the construct 'R&D effectiveness' enables us to measure concepts that may inevitably involve one or more indicators. These indicators can be measured in a wide variety of ways, and can provide information on both quantitative and qualitative aspects of R&D, which, for the purposes of the present study, will relate either to economic and financial resources or to behavioural attitudes or variables among employees or R&D managers, for example. Some indicators, such as those relating to financial data, will, of course, be expressed in numerical terms or as ratios, while others, relating to intangible factors, and therefore difficult to obtain from databases, will be subjective evaluations on the part of the researcher.

4. Content validation study of the 'R&D Effectiveness' scale

4.1. Objectives

The objective of this paper is, on the one hand, to design a measuring tool, or scale, to capture both the financial and non-financial variables cited in the literature on R&D management as being related with success in the production process in R&D departments; and, on the other hand, to validate the content of this instrument, using a scale or construct validation approach.

We have split this main objective into the following parts:

(1) *Identification of the main dimensions and components of the R&D production process*. The components, or indicators, are the various elements that, according to our review of the literature, are considered to be the factors of success in achieving objectives, both in R&D departments, and companies as a whole.
(2) *Definition of what these components are intended to measure*. This stage is designed to provide us with the explanations needed in the interviews with experts when discussing the measurement objectives of the dimensions and each of their components.
(3) Design of a questionnaire in which each item reflects part of the measurement objective of the dimensions of the R&D production process and their components or indicators.

4.2. Procedure for content validation

Just as in other academic fields, empirical research into R&D management examines relationships between relevant variables. It is in this respect, however, that we may encounter our first problem: that is, how to obtain an accurate and

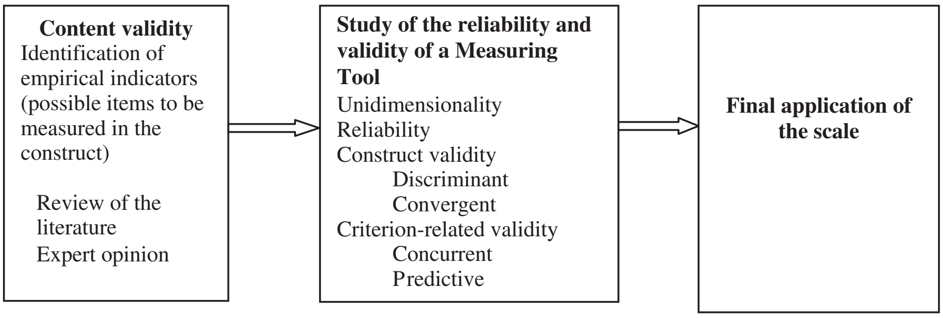

Figure 2. Stages in the methodology for scale validation.

reliable measurement of the relevant variables (Schwab, 1980). Given that the findings of research studies of firm behaviour and its consequences are very often the result of observation, measurement errors are a very real possibility. Research in this field is characterized by a lack of R&D management studies.

The complete methodology for the validation of a measuring tool involves a multiphase process, as illustrated in Figure 2:

(1) The first step is to identify the group of items (empirical indicators) that will be selected to measure the construct (R&D effectiveness). Prior to this it is necessary to demonstrate that the empirical indicators are logical and related with the construct or scale. This step is concerned with content validity (Pedhazur and Schmelkin, 1991). It is based on a review of the literature and expert opinion.
(2) The second step is to determine the degree of Reliability and Validity of the measuring instrument.[1] This begins with a series of statistical tests to determine the statistical power of the empirical indicators (O'Leary-Kelly and Vokurka, 1998). Next, as a part of the validity study, follows a construct validity test to analyse both convergent and discriminant validity; after which the instrument is tested for criterion-related validity, which covers both concurrent and predictive validity.
(3) Finally, the scale is applied in the survey of the firm or firms.

The present study uses the methodology described in the first phase of the scale validation process: content validity.

The content validity of a measuring instrument is defined as a test of sample suitability of the test items. In practice, content validation is a systematic examination of test content, to determine whether the sample is relevant and representative of the behavioural domain that is to be measured. In content validation, the following steps are necessary: (a) Definition of the Universe of admissible observations; (b) identification of experts in the field covered by that universe; (c) consultation of expert opinion concerning the degree of relevance and representativity of the Universe and (d) application of a procedure to summarize the data obtained in the preceding step.

As part of the content validation process, a literature review will be performed in order to determine the most significant components of the construct or scale. Following this expert opinion will be taken into consideration in order to corroborate or extend the set of defining indicators to be used in the scale.

The first stage was to determine the test specifications on which to base the items. These specifications show: the content areas to be covered, processes to be evaluated and the relative importance of the various aspects and processes. Though content validity decisions tend to be qualitative rather than quantitative; we propose a number of indices to summarize expert opinions:

(a) percentage of items paired with objectives;
(b) correlation between the weight given to the objective and the number of items measured by it;
(c) item–objective congruity index;
(d) percentage of items not evaluated by any of the items.

The methodology employed in our study is based on the first step of the scale validation process: content validation, which is performed in two stages:

(1) *First stage*: a literature review that enabled us to identify the dimensions and indicators of the construct, which we based on the R&D department production system model devised by Brown and Svenson (1998).

(2) *Second stage*: the use of expert opinion to validate the content of the measurement instrument proposed in the first stage.

4.2.1. First Stage: identification of the dimensions and indicators of the 'R&D effectiveness' construct by means of a literature review

In our proposal for the construction of an 'R&D Effectiveness' scale and the validation of its content, each group of items (or empirical indicators) represents four dimensions. These four dimensions are the ones featured in the scales validated by Lee et al. (1996) in Korean firms, to which we add some items from the scale validated in the United States by Tracey et al. (1999). A number of additional items were chosen on the basis of findings from our review of the R&D management literature.

Our scale dimensions relate both to the resources used by firms to pursue their R&D activities and to the appropriacy of R&D planning and budgetting. Adequate use of economic, financial and human resources and accurate design of resource planning and control, as will be shown later, according to the R&D management literature, are decisive factors for R&D success. The outputs and results considered in our scale are a reflection of this success, measured with tangible and intangible indicators, and taking into account the financial, commercial and management aspects of firm strategy.

For every one of these dimensions we consider a series of components, each aimed at a particular measurement objective (Figure 3). The items which, according to the experts, best match their measurement objective are then selected (Table A3, appendix).

4.2.1.1. The input dimension. The input variable most widely used in the literature is 'R&D expenditure'. This input indicator measures the effort firms that put into R&D activities and that may later generate output (Lee et al., 1996; Hagedoorn and Cloodt, 2003). This variable can provide information about the innovating capacity of a firm trying to improve its performance, since current R&D expenditure is usually the result of previous R&D expenditure that led to success (Branch, 1974).

Some studies analyse the factors that may lead firms to achieving better R&D outputs and performance. Galende and Suárez (1998), for example, in a study of Spanish firms, reach the conclusion that some factors such as: *the generation of self-funding and availability of own resources* influence R&D in firms. Also, greater *capital intensity and better infrastructure* may encourage investment in R&D, as becomes obvious when we compare industrial firms with service companies. The findings of these studies indicate, therefore, that R&D investment and the *infrastructure cost/benefit relationship* are considered by firms as the two most important aspects of the resources used in their R&D departments.

However, equally or perhaps even more important than the influence of financial or technological factors on R&D effectiveness, we might consider *the training of human resources, culture or the competitive environment*. In this respect, research by Clark et al. (1987) and Clark and Fujimoto (1991) found that R&D productivity is influenced not only by R&D expenditure levels, but also by factors such as the *capacity to coordinate human resources*, or *to find solutions to technical problems*.

The literature includes many studies that highlight the importance of human resources in R&D effectiveness (Halls, 1992; Brooking and Motta, 1996; Myers, 1996; The Conference Board, 1997; Halliday et al., 1997; Haanes and Lowendahl, 1997). These authors agree on the positive effect on R&D effectiveness of such factors as the *knowledge* of R&D department personnel, and also their *skills and capacities*; the presence of a higher percentage of workers employed in the R&D department, and aspects such as the attitude, level of professional qualifications and training among R&D employees (Schoenecker et al., 1995; Lee et al., 1996; Souitaris, 2002).

West and Iansiti (2003) also examine the importance of the experience of R&D personnel and of experimentation for the creation and acquisition of knowledge from R&D activities and the subsequent effect of this on innovation within the firm.

Also analysed in the literature is another important factor relating to the attitude of R&D personnel, i.e. their motivation to innovate (Hoyt and Gerloff, 2000); numerous studies have focused directly on incentive schemes to motivate R&D personnel towards innovation. In this respect, authors such as Balkin and Gómez-Mejía (1984); Gómez-Mejía and Balkin (1985, 1989) and Muhlemeyer, (1992) highlight issues such as the need for diversity in the schemes used to incentivate R&D personnel, scientists' preferences in this area and the positive impact on the progress of

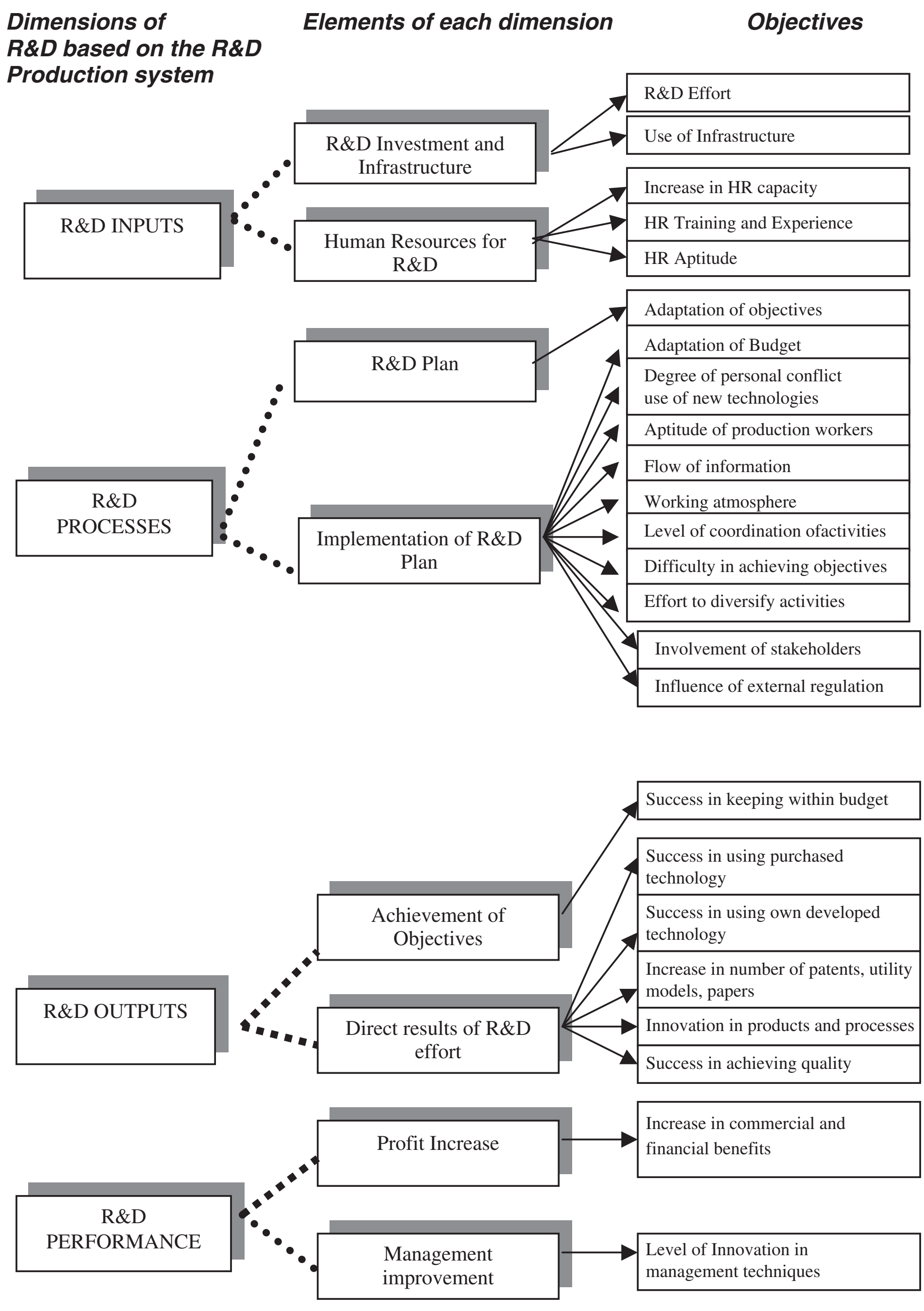

Figure 3. Dimensions and elements for the research and development (R&D) effectiveness measuring scale.

the project (Coombs and Gómez-Mejía, 1991) and firm performance (Molleman and Timmerman, 2003).

Bringing together the findings from the literature review, therefore, the Inputs dimension of our scale is made up of two component elements: R&D Investment and Infrastructure, and Human Resources employed in developing and implementing R&D activities (Figure 3 and Table A1 in the appendix).

These dimensions have been considered in several analyses of the factors that intervene in the effectiveness of R&D. For example, not only the Oslo Manual (OECD, 1991) and The Conference Board (1997), but also the study of R&D effectiveness in Korean firms by Lee et al. (1996), consider that a positive increase, both in absolute terms and relative to firm income, in the rate of R&D investment over a 3-year period, and the infrastructure used in R&D activities, play a decisive role in achieving a high rate of R&D effectiveness (Nolan et al., 1980; Hall, 1987).

4.2.1.2. The processes dimension. When it comes to Processes as a dimension of R&D, some studies reveal that the planning of R&D activities, both at operational and strategic level, and consensus as to these processes should be reflected in the firm budget, are crucial to the success of R&D activities (Lee et al., 1996; Stojilkovic, 1998; Tracey et al., 1999; Presley and Liles, 2000; Heidenberger et al., 2003). The need to set clear objectives and anticipate results is the first step towards success in implementing the plan. It is not enough, therefore, to analyse the information that shows whether or not the plan is well designed, or whether the budget is properly drawn up; it will also be necessary to evaluate the firm's efforts in this respect, and identify any barriers to the implementation of the plan as well as the factors that will help it to prosper. Included in the implementation process of the R&D plan are factors such as how well the R&D objectives are tailored to the budget (Lee et al., 1996; Demirag 1998), the degree of personnel adaptation to technological changes, the level of understanding and communication between the production, marketing and R&D departments, human relations within these departments (Lee et al., 1996; Roos and Roos, 1997; Young, 1997; The Conference Board, 1997; Demirag, 1998; Tracey et al., 1999; Cañibano et al., 1999; Di Benedetto, 1999; Hoyt and Gerloff, 2000; Maltz et al., 2001; Leenders and Wierenga, 2002) and the effort the firm needs to make in order to diversify and extend their range of these activities (Lee et al., 1996; Young, 1997).

The presence of an internal organizational structure to fully mobilize the resources just mentioned, with the capacity to coordinate them all and promote the generation of new resources can also be considered decisive factors in R&D investment (Gassmann and Von Zedtwitz, 1999; Christensen, 2002). The structure includes *planning and control* systems, and the *information* system within the firm that will enable an accurate assessment to be made not only of research and development, but also its effects (Cohen, 1995; Lee et al., 1996; Roos and Roos, 1997; Young, 1997; Haanes and Lowendahl, 1997; The Conference Board, 1997; Stojilkovic, 1998; Demirag, 1998; Cañibano et al., 1999; Tracey et al., 1999).

Analysing the data obtained from the literature review, therefore, shows Processes to contain two elements: the development of the *R&D plan*, and successful *Implementation,* these objectives being the factors that intervene in R&D success, according to the literature. They are shown in Figure 3 and Table A1 of the appendix.

4.2.1.3. The output dimension. R&D outputs and results have traditionally been measured by means of indicators. Of these, the most widely used are *patents* and *utility models* Patel and Pavitt (1995); Coombs et al. (1996); Petrash (1998); Ernst (2001). These are used to create barriers to maintain competitive advantages. In Spain, for example, few products are patented, because firms have little confidence in the protection to be gained in this way and prefer to compete more successfully with their rivals by improving their products and thereby increasing their market share. In fact, some studies do not consider patents to be a good indicator for comparing different sectors or different countries, though they are relatively useful for comparing firms in homogeneous sectors.

The *technological balance of payments*, meanwhile, is another of the indicators of R&D outputs, in spite of its drawbacks, the main one being the difficulty of using it to measure the principal channels of technology transfer between different countries (Patel and Pavitt, 1995). The *origin of the technology* used by a firm is also considered to be a good indicator of its R&D performance; that is, whether it is produced inside or outside the firm; and also whether technology purchased outside the firm is of domestic or foreign origin.

Doubtless, however, there will emerge new ways to measure R&D performance, particularly effectiveness and efficiency, provided that firms are able to understand the causal relationship between investment and performance in this area. Abdel-Kader and Dugdale (1998), for example, analyse both the tangible and intangible results of these activities. Their study is based on the survey of a sample of UK firms who were questioned about the advantages of investing in R&D in the area of manufacturing processes. Some are given below:

They mentioned advantages from the *cost saving* perspective, particularly cost reduction in materials, labour, the costs involved in keeping inventories and financial expenditures. Moreover, by improving *quality in processes*, they were also able to reduce costs associated with reprocessing and breakages.

In addition, from the commercial point of view, as their production capacity increased, so did product quality at no extra cost. Thus, they were able to develop their capacity to meet the *needs of the market* and increase their *sales quota*. Finally, the authors also reported better adaptation of firms to strategy and of course, better ability to programme production.

The literature on measures of innovation and its diffusion also mentions proposals for indicators based on *bibliometric studies*, such as the number of publications in leading journals, or the number of papers presented at congresses or scientific gatherings, etc. (Patel and Pavitt, 1995). Though this type of indicator is usually used to measure research effectiveness in academic departments, or public research centres, it is interesting to observe that they are also recommended as measurement criteria for R&D performance in firms.

When we analyse the literature reviewed for the purposes of our scale, the Outputs measure emerges as having two elements: *Achievement of the objectives stated in the R&D plan and budget*, and *Results*, both of them directly related to the firm's R&D effort. This last measure is made up of tangible outputs such as: number of patents or utility models, and even papers published or presented at congresses; in other words, knowledge acquired by the firm through its R&D activities (OECD: the Oslo Manual, 1991; Ministerio de Industria y Energía, 1994; Patel and Pavitt 1995; Lee et al., 1996; Coombs et al., 1996; Urraca, 1998). It also incorporates more intangible outputs such as: the utility derived by the firm from technologies purchased outside and technologies developed within the firm itself (Ministerio de Industria y Energía, 1994; Demirag, 1998). Other important aspects viewed by firms as a direct result of their R&D efforts are the number of new products launched since starting their R&D activity (Di Benedetto, 1999; Chryssochoidis and Wong, 2000; Sherman et al., 2000; Gemser and Leenders, 2001), innovation in processes (Saraph et al., 1989; Sakakibara et al., 1993; Flynn et al., 1994; Ward et al., 1994; Small and Yasin, 1997), and the quality achieved through R&D (Brennan, 2001), evidence of this quality will appear later in the firms results, both in terms of sales figures and the improvement of their image in the eyes of customers, and in an improvement in the management of the firm as a whole (Hirons et al., 1998), these elements are also present in the next measure of our construct that we are about to discuss.

4.2.1.4. The results dimension. The R&S Results dimension relates to aspects of the final outcome of the R&D activity, such as an increase in profits, or managerial improvements in the areas of production or sales. There are no doubts in this respect; as far as the link between R&D and profit is concerned, the reviewed literature mentions income growth through increased sales, growth in market share, or customer satisfaction as being the most accurate indicators (Lee et al., 1996; Abdel-Kader and Dugdale, 1998; Cañibano et al. 1999; Del Monte and Papagni, 2003). Finally, improvement or innovation in management techniques can also be included as part of this measure, especially if they are implemented in R&D departments. These techniques include the adoption of new technologies for the control of production processes, the Just-in-Time approach, or Flexible production, among others (Lee et al., 1996; Abdel-Kader and Dugdale, 1998).

Once these data are analysed, we obtain two elements to measure Results on our scale: these are Profit Increase and Management Improvement.

Figure 3 is a schematic representation of the elements and measurement objectives for each dimension of the R&D Production System, taken from the R&D management research reviewed.

4.2.2. Methodology

The second stage of this content validation process for the 'R&D effectiveness' scale was to consult a group of experts from two firms in sectors where substantial amounts are invested in R&D. One is an aeronautics firm, the other belongs to the defence industry. They therefore represent two of the top innovating sectors in Spain according to the Spanish Institute of Statistics (INE, 1999).

Each of the individuals who were interviewed holds a position of responsibility in one of the two firms; specifically we interviewed the controller in the first and the divisional director in the second. In addition, to strengthen the results obtained, we have consulted two more nationally recognized Spanish researchers on R&D, applying the same methodology as with the first group of experts. Some research studies have also included academic experts in the process of content validation, as in the cases of Saraph et al. (1989) and Small and Yasin (1997).

The object of the first interview was to draw up the test specifications, on the basis of which we constructed the items. The specifications indicate which content areas are to be covered, which processes evaluated and the relative weight of the various topics and processes. The following points were explained in this interview: 1. the objective of the study; 2. the way that each of the items of the scale had been constructed – based on the bibliographical review, and on how we believed that the questionnaire devised could help us to measure those aspects – and the areas that should be involved in the future validation of the construct – the R&D departments.

It was also explained to the experts that the purpose of the interviews was basically to consult their informed opinion on three specific aspects: 1. their degree of agreement on the need to include certain aspects relating to the construct 'R&D effectiveness'; 2. the suitability of the formulation or wording of the different questions; and 3. the degree of correspondence between the items themselves and the parameters which those items were intended to measure. For this purpose, in this first interview, Table A1 was presented to them, and the specific measurement objectives sought in the study were explained to them. In addition, they were presented with the questionnaire that we had previously devised having consulted the bibliography, for the purpose of obtaining their opinion on the suitability of the formulation of the questions posed.

Later, in the second interview, the specifications were drawn up in the form of a double-entry table with the items in columns and the objectives in rows, after which we performed the following procedure:

(1) *List of objectives*: the process was to assume the same weight for all the objectives. The experts were now asked to assign weights to the various objectives (+1 meant that they agreed that the item matched the objective, 0 that they disagreed, and –1 that they were uncertain).
(2) *Matching items to objectives*: We presented the experts with a list of objectives with each item on a separate row; the expert had to compare each item with the list and enter a score on a reply sheet, indicating the number of an objective beside each item. We then calculated each expert's average score for each item, and the synthetic global score was the degree to which each item matched the objective.
(3) *Aspects of the item taken into consideration*: The experts were given clear descriptions of the characteristics of the items and of the domain they had to consider, for example, level of complexity, mode or format of reply and presentation.
(4) *Results*: The item–objective congruity index was calculated following Hambleton and Rovinelli (1986):

$$I_{IK=}\frac{N}{2N-2}(\mu_{IK-}\mu_I)$$

where $N=$ number of objectives; $\mu_{IK}=$ average score given by the experts to item I on objective K; $\mu_I=$ average score given by experts to item I on all objectives.

The item–objective congruity index described by Hambleton and Rovinelli (1986) is used to assess the validity of the items. The formula is based on the assumption that in an ideal case, an item would match only one objective from the set.

The highest possible congruity score for any item is 1, and this can only be reached when the experts pair the item with only one objective. Therefore, a very important step in this stage of content validation is the wording of the questionnaire where each of the single elements that make up the object of measurement is represented by one or more items (Table A2 of the appendix). The steps taken to draw up the questionnaire in this case were to collect the data from the literature review, select the questionnaire and question type for each variable, the code definitions, scoring system and scales, the order and wording of the questions, and, finally, conduct a pilot test and revise the questionnaire.

The highest congruity indices, that is, those with values equal to 1, and therefore the result of a complete match between an item and an objective according to the experts, are the ones that were used to construct the scale.

5. Results

Table A1 shows the dimensions, elements and measurement objectives drawn from our review of the literature. The first column lists the item types and indicates to which dimensions of the R&D production process they belong (inputs, resources, outputs or results). This was the table used in the initial interviews with the experts from the two firms that were consulted and with the two academic experts on this subject also consulted. The objective in this case was to present our initial proposal for scale dimensions, elements and measurement objectives. This provided the opportunity to check the design and the definition of objectives for each item, which were then set out in Table A2, which also contains the questionnaire used in the scale validation.

Table A3 of the appendix shows the final scores on the item–objective congruity indices. These scores reflect the experts' views as to the congruity of each item *i* with the measurement objectives, and the average score of each item *i* on all the objectives.

By observing these results, it can be seen that items given a score of 1 on the congruity index had been paired with the measurement objective with which they were associated in the questionnaire, and were therefore included in the scale. Those with scores of 0 or –1 were omitted.

The results of this scale content validity will be used in future stages of validity testing, to be undertaken at a later date, when we will present empirical evidence for the hypothetical relationships between items in the scale tested for its validity in this paper.

As Table A3 shows, R&D effort is represented in the scale by items 1 and 2 of the questionnaire. Use of infrastructure is covered by the R&D infrastructure cost–benefit relationship as estimated by the firms. After this came Human Resources, for which three items were initially considered: improvement in numbers, training and aptitudes of R&D personnel, to which we added an extra aptitude-related item, namely, degree of experience. It should be clarified that the increase in the number of researchers in the R&D departments is not necessarily an indicator of increased effectiveness (despite being picked up in the literature, see Table A1). According to the experts consulted, increased numbers could be indicative of increased needs for the execution of new or bigger projects.

Processes were represented on the scale by: the appropriateness of planned objectives and activities to conditions within the firm and its environment, which was measured by items 8 and 9; tailoring the budget to R&D objectives; degree of conflict between R&D personnel faced with changes deriving from the use of new technologies; the aptitude of production personnel for transfers of production technology from R&D, the flow of information between the R&D department and the remaining departments in the firm, the working atmosphere among R&D personnel and between them and their supervisors, which is measured by items 14 and 15; level of coordination between the activities that take place in the R&D department and those that take place in the marketing and production departments and the level of difficulty in attaining set objectives. Finally, the item, level of effort to diversify and increase R&D activities, was omitted from the scale, because $I_{ik} = 0$.

With respect to the R&D output dimension, objectives relating to planning and budgetting were represented by the difficulty typically encountered by firms in trying to keep within budget, and were eventually removed from the scale. Meanwhile, success in achieving the direct outputs of these R&D activities, planned, budgeted and managed as part of the processes dimension, is linked to results obtained from regular use of technology purchased or developed by the firm itself, to an increase in the number of patents and quality of final performance, and also to the number of new product references and innovation in processes. The experts were uncertain how to assess the question of papers presented at congresses, or publications in general as an R&D output ($I_{IK} = -1$)

Finally, the results dimension, according to the experts, was represented by an increase in economic and commercial benefits achieved through the application of R&D results, which is measured by the following items: increase in sales revenue from the application of R&D results; the subsequent increase of market share, customer satisfaction, general improvement in the firm's positioning relative to rival firms and customers' perception of the firm's products.

Improvement in the firm's general management was included in the scale as an element to measure the degree of innovation introduced into management techniques by R&D departments; we were unable, however, to establish any direct relationship between R&D results and improvements in management practices.

Finally, among the items that were initially absent from the scale but introduced later after consultation with the experts, an important example was the experience of human resources as a key factor in attaining positive results, both in R&D departments and the firm as a whole, another was performance-linked pay as one of the indicators of R&D effectiveness. The issue of the organizational structure of the firm in which the R&D takes place (centralized, decentralized, etc.) is a variable that will be examined on a future occasion, once the scale validation is complete.

In addition, two items have been included, related, first, to the involvement of the firm's stakeholders in planning its R&D objectives and activities, and second, to the influence of the various relevant regulations external to the company. The items that represent these measurement objectives are numbered 19 and 20, respectively (Table A3).

6. Final remarks

The purpose of this paper, was to perform a content validity assessment of an instrument for measuring the effectiveness of R&D activities in firms. First, we reviewed past research dealing directly or indirectly with the issue of how to measure this type of activity, either in relation to the resources employed or to the results achieved within a suitable R&D management framework.

Given the wide variations found in the literature on the choice of suitable indicators and methodology for measuring the R&D concept, we propose using the scale validation approach. As far as were able to judge from the results of previous studies in which it was used, such as the R&D efficiency assessment in Korean firms performed by Lee et al. (1996) and another by Tracey et al. (1999) who focused on firms in the United States, the advantage of our chosen method is that it provides the opportunity to obtain qualitative information, which is important when large databases are not available. In addition, this methodology is more useful for assessing R&D effectiveness than indicators that have been used in the past, in that it can bring together all the relevant data in order to obtain a single value to cover all the concept-defining measures, and can be incorporated as a variable in future studies in which we might examine relationships with other scales or variables such as: efficiency, performance, or accountancy changes in organizations.

This method of measurement, therefore, enables us to evaluate intangible concepts, necessarily involving more than one indicator, and informs on both quantitative and qualitative aspects of R&D. In the case at hand, the range of aspects covers not only economic and financial resources, but attitudinal or behavioural variables involved in R&D activities, among both workers and management.

A further advantage of this methodology has to do with the information firms stand to gain on various aspects of the R&D investment and development process, which may serve as a starting point in the debate over how to assess intangibles, in this case in relation to R&D, human resources in R&D activities, and the future outcome of investment in this area. We believe that by evaluating all the variables simultaneously in a single effectiveness model it will be easier to obtain a clear picture of the situation in each firm, and to identify the factors that may be operating within. The results a firm can expect to obtain from whatever level of investment it makes in R&D should also be analysed from the point of view of the atmosphere among those responsible for R&D activities and the skill they possess to pursue their proposed goals to the end.

Though all the measures and elements of the scale we propose for measuring the 'R&D effectiveness' construct, which is the object of this paper, have been thoroughly checked against the opinion of experts in R&D management, it is our intention in a future study to undertake a reliability assessment, and a construct and scale criterion validity assessment, which could give rise to some modification in the definition of measures or the grouping of items. Meanwhile, the theoretical validation that we have performed indicates, at least, that all the elements included in the scale are aspects generally considered by firms to be of importance in R&D management.

Furthermore, this scale has been validated exclusively in Spain; therefore, when it is intended for application in other countries with cultural differences, and where differences in certain regulations, like financial and environmental protection, may be relevant and have a significant influence, the scale should be re-validated in the country where it is to be applied, as has traditionally been accepted in the general process of validation of scales (Figure 2)

Among the drawbacks of this type of methodology we must mention not only the difficulty involved in devising the scale and finding the most representative sample of firms, but also the costs involved in the survey design and distribution. A further problem is the need for a very high rate of response, without which the reliability of the results would suffer. Finally, we must add that this method carries the disadvantage that it is sometimes impossible to observe contingency factors, which may vary across firms; in this respect, case-study techniques would be more useful.

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Notes

1. The second and third steps that make up the complete scale validation process will be undertaken in a future study.

Appendix

Table A1. First stage: review of the literature on dimensions, elements and objectives of the 'R&D effectiveness' construct.

Dimension	Element	Objectives	Definition	Source
R&D inputs	R&D investment and infrastructure	R&D effort	Firm uses resources to finance R&D activities in relation to the average in previous years	Lee et al. (1996); The Conference Board (1997); OECD: The Oslo Manual (1991); Souitaris (2002)
			Firm dedicates a percentage of its investments to R&D (R&D expenditure) as a share of total revenue over the last 3 years in relation to the average in previous years	
		Utilization of R&D infrastructure	Investment cost–benefit relationship	Lee et al. (1996); Galende and Suárez (1998)
	Human resources for R&D	Increase in capacity of R&D human resources	Increase in the personnel (number of persons) in the R&D departments, in relation to the growth in the number and scope of projects handled	Lee et al. (1996); Halliday et al. (1997); Souitaris (2002)
		Training of R&D personnel	Measure of training level in R&D human resources based on percentage of engineers, graduates, etc. out of total	The Conference Board (1997); Souitaris (2002)
		Aptitudes of human resources	Skills, abilities and experience of R&D personnel	Gómez-Mejía and Balkin (1989); Halls (1992); Muhlemeyer (1992); Schoenecker et al. (1995); Myers (1996); Brooking and Motta (1996); Lee et al. (1996); The Conference Board, (1997); Haanes and Lowendahl (1997); Randle (1997); Collinson (2001)
		Attitude of human resources	Motivation of R&D personnel	
R&D Processes	R&D Plan	Tailoring planned activities to objectives	Measure of the degree to which set objectives and activities match the current situation of the firm and its environment	Lee et al. (1996); Iansiti (1997); Stojilkovic (1998); Tracey et al. (1999); Molleman and Timmerman (2003)
		The right choice of processes and results	Suitability of selected R&D processes and definition of target performance	Lee et al. (1996); Stojilkovic (1998); Tracey et al. (1999)
	Implementation of R&D Plan	Tailoring budget to R&D objectives	Measure of success in preparing R&D budgets to match the specific objectives set by the department	Lee et al. (1996); Halliday et al. (1997); Demirag (1998); Heidenberger et al. (2003)
		Adaptation of R&D personnel to technological changes adopted by the firm for use in R&D	Conflict among R&D personnel arising from the use of new research technologies	Lee et al. (1996); Tracey et al. (1999)
		Aptitude of production workers for the transfer of production technology from R&D	Measure of degree to which production workers' knowledge is sufficient for them to adapt successfully to change arising from the adoption of new production technologies	Lee et al. (1996); Tracey et al. (1999); Cañibano et al. (1999)
		Information flow between the firm's departments	Level of communication between R&D and other departments in the firms	Gupta et al. (1987); Roos and Roos (1997); Young (1997); Iansiti (1997); Kahn and McDonough (1997); Omta and Van Engelen (1998); Cañibano et al. (1999); Hoyt and Gerloff (2000)
		Working atmosphere among R&D personnel and between the latter and their supervisors	Measure of the quality of human relations among members of R&D and between the latter and their supervisors	Dunegan et al. (1992); Roos and Roos (1997); Young (1997); The Conference Board (1997); Demirag (1998); Hoyt and Gerloff (2000)

		Coordination between R&D, production marketing:	Measure of the degree of coordination between activities carried out in the R&D department and those taking place in the production and marketing departments	Coombs and Gómez-Mejía (1991); Lee et al. (1996); Young (1997); Kahn and McDonough (1997); Di Benedetto (1999); Maltz et al. (2001); Leenders and Wierenga (2002)
		Success in meeting budgets	Measure of problems faced by firm as a result of introducing new activities marked out by the R&D department as part of the agreed R&D plan for the year	Lee et al. (1996); Young (1997)
		Effort to extend and diversify R&D activities	Estimated degree of effort made by R&D department to extend the range of activities	Lee et al. (1996); Young (1997); Omta and Van Engelen (1998)
		Degree of involvement of the stakeholders	Degree of involvement of the firm's various stakeholders in determining its R&D objectives and activities	May et al. (2003); Hirst and Mann (2004)
		Degree of influence of external regulation on R&D	Degree of influence of external regulation on the planning of R&D objectives and activities	Morrison and Donald (1996); Shoening et al. (1998); Rosenberg et al. (2003); Dowdell and Press (2004)
R&D Outputs	Goal attainment	Difficulties in achieving objectives set in R&D plans and budgets	Problems faced by firm in attaining goals set in R&D plans and budgets	Young (1997); Demirag (1998)
	Direct results of R&D efforts	Utilization of technology purchased	Measure of degree to which successful use is made of technology purchased outside the firm	Falguni and Rubenstein (1989); Ministerio de Industria y Energía (1994); Veugelers (1997); Demirag (1998); Veugelers and Cassiman (1999); Lin et al. (2002)
		Utilization of technology developed	Measure of degree to which successful use is made of technology developed in R&D departments	Ministerio de Industria y Energía (1994); Veugelers (1997); Demirag (1998); Veugelers and Cassiman (1999); Lin et al. (2002)
		Increase in number of patents, utility models, papers presented at academic conferences	Indicator of trend towards achieving direct results from the R&D effort	Ministerio de Industria y Energía (1994); Lee et al. (1996); Urraca (1998); OECD:The Oslo Manual (1991); Ernst (2001); Hagedoorn and Cloodt (2003)
		Innovation in product and processes	Firm succeeds in producing more novel products than rival firms as a result of meeting R&D objectives Firm succeeds in innovating in production processes and improving its performance by reducing costs and enhancing product quality	Di Benedetto (1999); Sherman et al. (2000); Chryssochoidis and Wong (2000); Gemser and Leenders (2001); Saraph et al. (1989); Sakakibara et al. (1993); Flynn et al. (1994); Ward et al. (1994); Small and Yasin (1997)
		Overall quality in R&D.	Measure of degree to which R&D quality parameters are met. Conformance to quality standards over costs in R&D departments; over research performance parameters; time, etc.	Lee et al. (1996); Abdel-Kader and Dugdale (1998); Brennan (2001)
R&D results	Profit increase	Success in obtaining financial and commercial benefits from the application of R&D results	Measure of firm's goal achievement in terms of sales revenue, market share and customer satisfaction through the application of R&D results	Armistead (1981); Odagiri (1983); Morbey (1988); Odagiri and Iwata (1986); Brenner and Rushton (1989); Morbey and Reithner (1990); Curtis and Ellis (1998); Lee et al. (1996); Abdel-Kader and Dugdale (1998); Patterson (1998); Cañibano et al. (1999); Wakelin (2001); Del Monte and Papagni (2003)
	Management improvement	Impact on improving firm management	Measure of firm's goal achievement in terms of improvement in the use of new management techniques resulting from the application of R&D results	Lee et al. (1996); Abdel-Kader and Dugdale (1998)

R&D, research and development.

Table A2. Second Stage: Experts are presented with items in questionnaire and measurement objectives.

Questionnaire items	Objectives
1. *How would you rate growth in R&D expenditure over the last three years in relation to the average in previous years*?	A. R&D effort
2. *How would you rate the increase in R&D expenditure as a share of total revenue over the last three years in relation to the average in previous years*?	B. Use of R&D infrastructure
3. *How would you rate the cost effectiveness of infrastructure used in R&D processes and activities?*	C. Increase in R&D personnel
4. *Indicate the rate of growth of R&D personnel, in relation to the number and scope of projects handled*	D. Level of training of R&D personnel
5. *Out of total R&D personnel, percentage of university graduates; percentage of tertiary college graduates, etc.*	E. Aptitude/attitude of R&D human resources
6. *Evaluate the abilities of the R&D personnel*	F. Matching planned objectives and activities to the current situation of the firm and its environment
7. *Indicate the experience of the R&D personnel*	G. Tailoring budget to R&D objectives
8. *How do you rate the feasibility of your firm's process for planning R&D objectives and activities*?	H. Degree of conflict among R&D personnel faced with using new technologies
9. *Do you consider the choice and design of R&D processes to be appropriate?*	I. Aptitude of production workers for the transfer of production technology from R&D
10. *Do you consider your firm to be successful in matching R&D objectives to funding needs?*	J. Flow of information within the R&D department and between this dept. and the rest of the firm
11. *Would you say that R&D personnel are successful in adapting to the technological changes adopted by your firm?*	K. Working atmosphere among R&D personnel and between the latter and their supervisors
12. *Do you consider them ready to accept new production and information technologies*?	L. Degree of coordination between R&D activities and those of the marketing and production depts
13. *Would you say that R&D personnel and the rest of the employees are well informed regarding the firm's R&D activities?*	M. Degree of success in meeting budgets
14. *How would you rate the quality of personal relations among R&D personnel?*	N. Level of effort to diversify and extend the range of R&D activities
15. *How would you rate personal relations between R&D personnel and their supervisors?*	O. Difficulties in achieving objectives set in R&D plans and budgets
16. *How would you rate coordination between the activities of the R&D department and those of the marketing and production departments*?	P. Use of technology purchased
17. *Do you see any obstacles to the satisfactory attainment of the objectives marked out in the R&D plans*?	Q. Use of technology developed
18. *How would you rate your firm's efforts to diversify in its R&D activities*?	R. Increase in number of patents, utility models, and papers published in relation to previous years

19. *Evaluate your firm's success in achieving the objectives of its R&D projects*	S. Success in product and process innovation
20. *Would you say that the technology purchased by your firm for use in R&D activities is bringing about positive results?*	T. Success in achieving quality in R&D
21. *Would you say that the technology developed by your firm for use in R&D activities is bringing about positive results?*	U. Measure of success in obtaining financial and commercial benefits from the application of R&D results
22. *How do you rate your firm's increase in the number of patents over the last three years*?	V. Measure of the degree of innovation in management techniques resulting from R&D.
23. *How do you rate your firm's performance in terms of the number of new products arising from R&D?*	W. Degree of influence/involvement of the stakeholders
24. *How do you rate your firm's performance with respect to innovation in processes as a result of R&D?*	Y. Degree of influence of external regulation on R&D
25. *Does your firm have set parameters for measuring the quality of its R&D activities?*	
26. *Indicate the degree of achievement, normally, of the quality parameters set for your firm's R&D activities.*	
27. *How would you rate your firm's degree of participation in recent scientific gatherings to present the results of its R&D activities?*	
28. *Is your firm successful in increasing its sales revenue by applying the results of R&D?*	
29. *Is your firm successful in increasing its market share by applying the results of R&D?*	
30. *Is your firm successful in increasing customer satisfaction by applying the results of R&D?*	
31. *Has your firm improved its overall positioning in relation to rival firms by applying the results of R&D?*	
32. *How do you rate your customers' image of the products sold to them by your firm?*	
33. *Would you say that your firm has improved in the use of new management techniques by applying the results of R&D?*	
34. *Indicate the degree of involvement of the various Stakeholders of your firm in its R&D objectives and activities.*	
35. *Indicate the degree of influence of external regulation on the R&D objectives and activities of your firm.*	

R&D, research and development.

Table A3: Results of second stage: matching of items to objectives on the R&D effectiveness measuring scale[1]

Dimensión	Element	Objectives	Questionnaire items
R&D inputs	R&D investment and infrastructure	R&D effort	1. *How would you rate growth in R&D expenditure over the last three years in relation to the average in previous years?* $I_{IK}=1$
			2. *How would you rate the increase in R&D expenditure as a share of total revenue over the last three years in relation to the average in previous years?* $I_{IK}=1$
		Utilization of infrastructure used in R&D departments	3. *How would you rate the cost effectiveness of infrastructure used in R&D processes and activities?* $I_{IK}=1$
	R&D human resources	Increase in number of R&D personnel	4. *Indicate the rate of growth of R&D personnel in relation to the number and scope of projects handled.* $I_{IK}=1$
		Level of training of personnel employed in firm's R&D department	5. *Out of total R&D personnel, percentage of university graduates; percentage of tertiary college graduates, etc.* $I_{IK}=1$
		Aptitude/attitude of R&D human resources	6. *Evaluate the abilities of the R&D personnel.* $I_{IK}=1$
			7. *Indicate the experience of the R&D personnel.* $I_{IK}=1$
R&D processes	R&D Plan	Appropriacy of planned objectives and activities to the current situation of the firm and its environment	8. *How do you rate the feasibility of your firm's process for planning R&D objectives and activities?* $I_{IK}=1$
			9. *Do you consider the choice and design of R&D processes to be appropriate?* $I_{IK}=1$
	Implementation of R&D Plan	Appropriacy of budget to R&D objectives	10. *Do you consider your firm to be successful in matching R&D objectives to funding needs?* $I_{IK}=1$
		Degree of conflict among R&D personnel faced with changes arising from the use of new technologies	11. *Would you say that R&D personnel are successful in adapting to the technological changes adopted by your firm?* $I_{IK}=1$
		Aptitude of production workers for the transfer of production technology from R&D	12. *Do you consider them ready to accept new production and information technologies?* $I_{IK}=1$
		Flow of information between firm's departments and R&D department	13. *Would you say that R&D personnel and the rest of the employees are well informed regarding the firm's R&D activities?* $I_{IK}=1$
		Working atmosphere among R&D personnel and between the latter and their supervisors	14. *How would you rate the quality of personal relations among R&D personnel?* $I_{IK}=1$
			15. *How would you rate personal relations between R&D personnel and their supervisors?* $I_{IK}=1$
		Degree of coordination between R&D department activities and those of the marketing and production departments	16. *How would you rate coordination between the activities of the R&D department and those of the marketing and production departments?* $I_{IK}=1$
		Degree of difficulty in achieving set objectives	17. *How would you rate the problems faced by R&D personnel in achieving the objectives marked out in their departmental plans and budgets?* $I_{IK}=1$
		Degree of effort to diversify and extend the range of R&D activities	18. How would you rate your firm's efforts to diversify in its R&D activities? $I_{IK}=0$
		Degree of involvement of the stakeholders in determining R&D objectives and activities	19. *Indicate the degree of involvement of the various stakeholders of your firm in its R&D objectives and activities.* $I_{IK}=1$

		Degree of influence of external regulation on the planning of R&D objectives and activities	20. *Indicate the degree of influence of external regulation on the R&D objectives and activities of your firm.* $I_{IK}=1$
R&D Outputs	Achievement of objectives	Difficulties in achieving objectives set in R&D plans and budgets	21. *Evaluate your firm's success in achieving the objectives of its R&D projects* $I_{IK}=1$
	Directos results of R&D efforts	Use of technology purchased	22. *Would you say that the technology purchased by your firm for use in R&D activities is bringing about positive results?* $I_{IK}=1$
		Use of technology developed	23. *Would you say that the technology developed by your firm for use in R&D activities is bringing about positive results?* $I_{IK}=1$
		Success in product innovation	24. *How do you rate your firm's performance in terms of the number of new products arising from R&D?* $I_{IK}=1$
		Success of innovation in processes	25. *How do you rate your firm's performance with respect to innovation in processes as a result of R&D?* $I_{IK}=1$
		Increase in number of patents, utility models, and papers presented at congresses in relation to previous years	26. *How do you rate your firm's increase in the number of patents over the last three years*? $I_{IK}=1$
			27. How would you rate your firm's degree of participation in recent scientific gatherings to present the results of its R&D activities*?* $I_{IK}=-1$
		Success in achieving quality in R&D	28. *Does your firm have set parameters for measuring the quality of its R&D activities?* $I_{IK}=1$
			29. *Indicate the degree of achievement, normally, of the quality parameters set for the R&D activities.*$I_{IK}=1$
R&D results	Profit increase	Success in obtaining economic and commercial profit from the application of R&D results	30. *Is your firm successful in increasing its sales revenue by applying the results of R&D?* $I_{IK}=1$
			31. *Is your firm successful in increasing its market share by applying the results of R&D?* $I_{IK}=1$
			32. *Is your firm successful in increasing customer satisfaction by applying the results of R&D?* $I_{IK}=1$
			33. *Has your firm improved its overall positioning in relation to rival firms by applying the results of R&D?* $I_{IK}=1$
			34. *How do you rate your customers' image of the products sold to them by your firm?* $I_{IK}=1$
	Management improvement	Measure of the degree of innovation in management techniques resulting from R&D	35. Would you say that your firm has improved in the use of new management techniques by applying the results of R&D? $I_{IK}=0$

R&D, research and development.[1]In this table, we have presented the results of pairing items on the measuring scale with our pursued measurement objectives, taking the highest value of the congruity indicator I_{IK} of each objective with each item. (1, total congruity; (0 and −1) no congruity, eliminated to the scales).