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Service supply characteristics

Developing indicators to measure technology institutes' performance

Aurelia Modrego-Rico, Andrés Barge-Gil and Ramón Núñez-Sánchez

Technology institutes (TIs) are non-profit innovation and technology organisations aimed to encourage competitiveness of firms. They are a key organisation in the Spanish National Innovation System because of their size and closeness to the productive sector. Despite this, there is a lack of studies trying to measure their performance and its determinants. This work sheds some light on this. We study the influence of operative, financial, organisational, relational and general variables on three measures of results: self-finance, impact and added value. Our conclusions show the relevance of this approach and are confirmed by grouping TIs according to their service supply characteristics.

Aurelia Modrego-Rico is at the Universidad Carlos III de Madrid, Departamento de Economía y Laboratorio de Análisis y Evaluación del Cambio Técnico, Calle Madrid 126-128, 28902 Getafe, Spain; tel: +34916249302, fax: +34916249517; email: modrego@eco.uc3m.es

Andrés Barge-Gil is at the Universidad Carlos III de Madrid, Laboratorio de Análisis y Evaluación del Cambio Técnico, Calle Madrid 126-128, 28902 Getafe, Spain; tel: +34916249302; fax: +34916249517, email: abarge@eco.uc3m.es

Ramón Núñez-Sánchez is at the and Universidad de Cantabria, Avda. Los Castros, s/n 39005 Santander, Spain; and at the Universidad Carlos III de Madrid; tel: +34942201692; fax: +34942201603; email: nunezr@unican.es

TECHNOLOGY INSTITUTES (TIs) or technological centres are non-profit innovation and technology organisations, which perform a wide range of technological activities oriented to enhance competitiveness of firms. In almost all developed countries, public actions focused on improving technology external provision to firms are increasingly recognising the key role played by this type of organisation.

Despite this, there is a lack of theoretical and empirical studies about their performance and its determinants. Although many tools have been developed to deal with the study of firms' internal and external capabilities, they have not been applied until now to TIs. In this work we develop a model for the TIs, which allows us to elaborate some indicators specific to non-profit research and technology organisations based on the information provided by 61 Spanish centres. These indicators are crucial to understanding how these organisations work, recommending some actions oriented to improve their performance and evaluating the impact of these initiatives.

In this context, our contribution aims to explore the working patterns and factors affecting Spanish TIs performance based on information provided by them. We have developed a method of analysis to answer the following questions:

- What are the characteristics of the services that Spanish TIs supply, and how are they connected with the degree of evolution of these organisations?
- What strategies do they use to access public funds, and how do they help their financial stability and growth expectations?

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- How do they use their environmental relationships to achieve their strategic goals?
- Do they use practices from learning organisations to identify and solve firms' problems?
- What are their outputs and how can their impact in the productive environment be measured?
- Which factors contribute to create added value in the productive sector?
- Are public initiatives fostering TI impact in firms?

Theoretical framework

TIs have to design a service supply aimed to enable innovation in the entrepreneurial sector. As a consequence, they need to identify firms' technological demands and attain a wide knowledge of the environment where both firms and TIs perform their activities. These two aspects influence the design of their organisations, their internal management processes and the mechanisms used to interact with other environmental agents.

As we see in Figure 1, to achieve their goals TIs have to confront two information problems. First, firms sometimes suffer from a lack of information about the type of service they need to develop innovations (Izushi, 2003). Even more, they sometimes have the required information but find difficulty in making explicit their demand (Justman and Teubal, 1996). That is to say, they show capability failures in making use of externally generated technology (Arnold, 2004). In this situation firms delegate to TIs the task of detecting their needs. As a consequence, the quality of service provided by TIs depends to a large extent on the degree of communication among them and client firms.

In other words, the level of utilisation and quality of services provided by TIs depends on the existence of good communication with firms (O'Farrell and Hitchens, 1990), which eases mutual knowledge and the identification and understanding of problems and needs existing in the productive sector.

The second problem is related to the difficulties found by firms when estimating the benefits they can obtain from the various services that TIs are able to provide to them. This problem exists because services impact is distributed among a wide range of activities, which hinders its measurement, and because benefits are not instantaneous. Instead they often become clear in the medium or long term (Ham and Mowery, 1998; Geisler, 2001). In most cases, an appropriate valuation of technological services impact is obtained only through accumulated experience resulting from repeated transactions, which build confidence on firms.

Both types of problems are common in all service transactions, depending on their intangibility and complexity (Howells, 1999; Guilhon, 2004). In addition, they become sharper when users are small and medium-sized enterprises, especially if they belong to low technological sectors. In many cases, firms' lack of capacity to identify their necessities in terms of clear goals makes services purchased to be low quality and inadequate. Furthermore, firms come into difficulties when evaluating services benefits and recognising quality differences among providers. All together this causes a level of services consumption below the needs of the entrepreneurial sector.

These problems have clear repercussions on TI performance. The first challenge TIs have to confront is to incorporate among their essential activities the task of building information common space with firms.

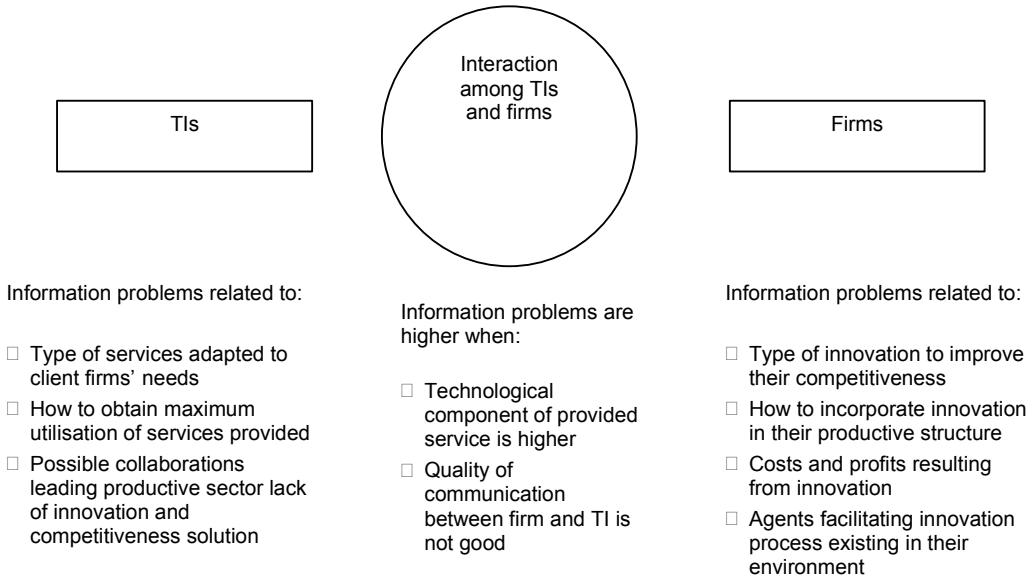

Figure 1. Information problems that affect TIs

This common space will allow TIs to identify and recognise firms' real demands, both actual and future, and adapt their service supply to them.

Building of information common space should be understood as the result of an interactive learning process involving not only firms, but also other environmental agents, such as universities, public research centres and public administration. Because of their specific characteristics, TIs are able to catalyse this process in order to achieve better articulation among the various actors involved.

This learning process is based on the information gathered by the TIs when transacting services with firms, and helps them to develop core competencies. These core competencies give them advantages to help to improve solutions to firms' innovation needs.

From this point of view, TIs' generic working model is founded on identifying and characterising their core competencies, taking into account that they are learning organisations involved in continuous interaction with firms and other environmental actors. This implies the analysis of factors related to:

- The characteristics of services supply offered to firms;
- Their financial structure and their survival capacity;
- Their communication strategies and the relationships with other environmental actors;
- Their internal management process.

These factors have been classified in the following dimensions, according to the balance scorecard concept (Kaplan and Norton, 1996): financial dimension, operative dimension, organisational dimension and relational dimension. The objective is to answer the following questions:

- *Operative dimension* What technical services do TIs supply, and how are these related to the degree of evolution of these organisations?
- *Financial dimension* What strategies do they use to access to public funds and how do they help their financial stability and growth expectations?
- *Relational dimension* How do they use their environmental relationships to achieve their strategic goals?
- *Organisational dimension* Do they use the practices from learning organisations to identify and solve firms' problems?

Description of variables

According to this approach, the analysis of TI working has focused on the definition and elaboration of a set of indicators, aimed to give reliable information for all four dimensions defined and also for TI output (Table 1).

The database has been elaborated using answers given to a detailed questionnaire sent to a set of Spanish TIs during second half of year 2001; 83 questionnaires were mailed and we obtained 61 valid answers (73.5%). Information has been analysed using different techniques of factorial analysis to ensure the reliability of the results.

Operative dimension

With the aim of analysing the services supply, we had taken into account not only the type and quantity

Table 1. Summary of partial and final indicators related to the study of Tis

	Operative dimension	Financial dimension	Relational dimension	Organisational dimension
Partial indicators	R&D activities Technical services Strategic consultancy Tactical consultancy Academic diffusion Non-academic diffusion Training	Subsidies Non-competitive funds Local and regional competitive funds National competitive funds European competitive funds Incomes from contracts Incomes from member fees Incomes from technology transfer	% firms with <20 employees % firms with 20 to 250 employees % firms with >250 employees Closeness to scientific environment Closeness to entrepreneurial environment Closeness to public administration Collaboration with scientific administration Collaboration with scientific environment Collaboration with entrepreneurial environment Collaboration with public administrations	General strategy Strategic planning Human resources management R&D projects management Marketing, promotion and diffusion management
Final indicators	Operative dimension R&D intensity	Self-financing	No	No

With the aim of analysing the services supply, we had taken into account not only the type and quantity of their activities but also the incomes obtained from them

of their activities but also the incomes obtained from them. Using this information, several indicators have been defined, relating each TI activity in: R&D, technical services, strategic consultancy, tactical consultancy, academic diffusion, non-academic diffusion and training.

These indicators have been summarised in two indicators. The first is the operative dimension indicator (OD) and refers to the level and diversity of each TI service supply. The second is the R&D intensity indicator (RDI), measuring the knowledge generation capacity of each TI. Using both indicators together, it is feasible to identify those TIs choosing a wide service supply among those more oriented to R&D specialisation. This selection affects organisation design, internal management processes and mechanisms utilised to build relationships with other environmental agents.

Financial dimension

We have employed financial information with the aim of identifying TI strategies to access different financial sources, their financial stability and their medium- and long-term growth expectative.

Partial indicators obtained give information about: subsidies (SUB), non-competitive funds (NCF), local and regional competitive funds (LRCF), national competitive funds (NACF), European competitive funds (ECF), income from contracts (CI), income from member fees (FI), income from technology transfer (TTI) and total revenues (TR).

Departing from these indicators we define a self-financing indicator (SF, Equation 1), which can be interpreted as a measure of TI capacity to obtain funds in competition with other agents.

$$SF = \frac{NACF + ECF + CI + FI + TTI}{TR} \quad (1)$$

Relational dimension

We have defined a set of indicators to study the characteristics of their client firms and how TIs interact with other environmental agents to build an information common space and design a service supply more adapted to firm needs. These are: the percentage of client firms with fewer than 20 employees (S_CL), the percentage of client firms with between 20 and 250 employees (M_CL) and the percentage of client firms with more than 250 employees (B_CL), closeness to scientific environment (CLO_SC), closeness to entrepreneurial environment (CLO_EN), closeness to public administration (CLO_PA), collaboration with scientific environment (COL_SC), collaboration with entrepreneurial environment (COL_EN) and collaboration with public administration (COL_PA).

Organisational dimension

Factors related to practices from learning organisations have been analysed and characterised using the following indicators: general strategy (GS), strategic planning (SP), human resources management (HRM), R&D projects management (RDPM), and marketing, promotion and diffusion management (MK).

Output variables

We have obtained two output variables departing from questionnaire information; that is to say, output indicators obtained dependent on information provided by TIs. They are the result of factorial analysis considering subjective and objective measures.[1] Factorial analyses allow us to distinguish two indicators. First factorial axis scores give information about the amount of impact achieved by each TI. Alternatively, a second factorial axis can be interpreted as a measure related to impact added value. This second axis separates the creation of new products, processes and services from improvements in quality and costs and time reduction. From this analysis we obtain an indicator about 'amount of impact' (AIMP) and another about 'impact added value' (IAD).

Empirical working model of Spanish TIs

After elaborating TIs indicators and grouping them in four dimensions —operative, financial, relational and organisational —we analysed the relationships among them in order to identify which of them give more representative information about TI performance.

With this goal, we have built a TI general working model including the following three groups of variables:

1. *Service supply variables* Supply diversity is recognised by the OD indicator and research orientation by the RDI indicator.
2. *Output variables* We consider three types of output: amount of impact, impact added value and self-financing degree.
3. *Explicative factors* Other variables related to financial, organisational and relational aspects, as well as other general characteristics such as size,

percentage of PhD staff —representing human capital qualification —and age —indicating accumulated experience —have been taken account. From now, these variables will be called 'explicative factors'.

The model scheme, represented in Figure 2, considers that service supply variables are the materialisation of service provision to firms and play a key role in TI working. They determine the answer that TIs give to explicit and non-explicit productive sector needs. The analysis of the relationships among these three type of variables — explicative factors, service supply variables and outputs — has the following goals:

1. To investigate the compatibility between a diversified services supply, measured by the OD indicator, and high levels of RDI;
2. The identification of general factors affecting service supply diversification as well as RDI;
3. To discover the relationships among output variables and, on the one hand, OD and RDI indicators and, on the other hand, organisational, financial, relational and general variables.

With these goals, we have estimated two simultaneous equation models:

Model 1 (Equations 2, 3 and 4)

$$SF_i = \alpha_0 + \alpha_1 AIMP_i + \alpha_2 AGE_i + u_i \quad (2)$$

$$AIMP_i = \beta_3 + \beta_4 AGE_i + \beta_5 OD_i + v_i \quad (3)$$

$$OD_i = \gamma_6 + \gamma_7 STAFF_i + \gamma_8 SP_i + w_i \quad (4)$$

Model 2 (Equations 5 and 6).

$$IAD_i = \delta_0 + \delta_1 GS_i + \delta_2 RDI_i + u_i \quad (5)$$

$$RDI_i = \varphi_3 + \varphi_4 NCF + \varphi_5 COL\_SC + \varphi_6 STAFF + v_i \quad (6)$$

Table 2. Model 1 results

Dependent variable: self-financing degree (SF)		
Constant	1.230**	(5.243)
Amount of impact	0.053**	(0.02)
Age	–0.006**	(0.002)
R square: 0.2607		
Dependent variable: amount of impact (AIMP)		
Constant	5.990*	(3.278)
Age	–0.030*	(0.016)
Operative dimension	0.332**	(0.136)
R square: 0.2101		
Dependent variable: operative dimension (OD)		
Constant	–0.691**	(0.235)
Staff	0.013**	(0.003)
Strategic planning	0.156	(0.152)
R square: 0.3325		

Note: Coefficients and standard errors in parenthesis. Significant at the less 5% (**) and 10% (*) levels of significance. Estimation method: OLS

Model 1, as we observe in Table 2, states that the degree of self-financing (SF) is positively affected by amount of impact (AIMP) and age. Besides, AIMP is positively affected by age and OD. Finally, STAFF and strategic planning (SP) positively affect the OD.

The results of Model 2 (Table 3) point out that TIs' impact added value (IAD) is positively affected both by their general strategy (GS) and RDI. Simultaneously, non-competitive public funds (NCF), the degree of collaboration with scientific environment and size affect positively the orientation to R&D activities (RDI). These results suggest the following important aspects:

- TI age is clearly correlated with the operative dimension, the amount of impact and degree of self-financing. This result points out the importance of implicit factors related to learning and confidence-building processes among different environmental agents, especially the firms. In this

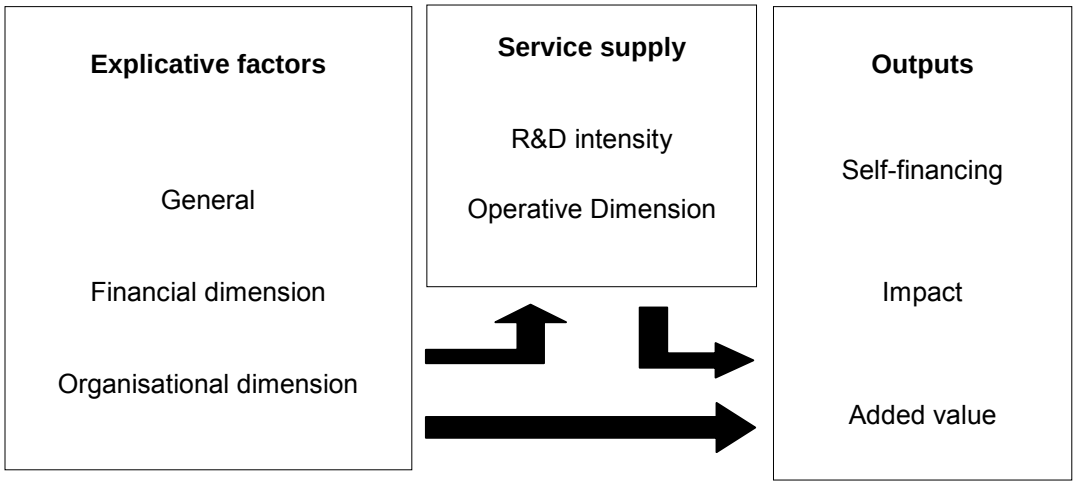

Figure 2. TI general model

Table 3. Model 2 results

Dependent variable: impact added value (IAD)		
Constant	–0.966**	(0.4344)
General strategy	0.289*	(0.1728)
RDI	2.177**	(0.7924)
R square: 0.3041		
Dependent variable: R&D intensity (RDI)		
Constant	0.208**	(0.0499)
Non-competitive public funds	0.001**	(0.0002)
Collaboration with scientific environment	0.066**	(0.0195)
R square: 0.5154		

Note: Coefficients and standard errors in parenthesis. Significant at the less than 5% (**) and 10% (*) levels of significance. Estimation method: OLS

sense, although some young TIs are able to capture resources, special public support is needed in their early development. This support should be stable but conditioned to well-defined and measured goals, to the implementation of adequate strategy and resources management and to the establishment of real links and collaborations with other environmental agents.

- Amount of impact is positively affected by size, strategy, and service supply diversity. Size is very important to generate impact in the productive environment. Critical mass, in terms of personnel, financial resources and scientific infrastructure, is a necessary condition to be able to design and develop a service supply matching firms' needs. This implies that small TIs can find big difficulties in achieving a certain impact, reducing their ability to capture resources.
- Some organisational factors —such as strategic planning commitment, and the existence of indicators to evaluate goal achievement and plan ongoing control —are very important. Lack of some of them will result in big difficulties in detecting and solving problems existing in the productive environment. As a consequence, resources access capacity will be affected.
- Impact added value is affected by R&D intensity and general strategy. Again, management variables appear to be very important to explain TI output. Here it is worth noting some considerations relating to R&D intensity-explaining factors.

Critical mass, in terms of personnel, financial resources and scientific infrastructure, is a necessary condition to be able to design and develop a service supply matching firms' needs

There is a close relationship between the amount of non-competitive public funds and R&D intensity, which is crucial to explain added value impact. Such public financing is devoted to R&D activities, especially those focused on the medium and long term. On the other hand, public subsidies are not positively related to any output or activity variables and, in fact, show some negative relationships. The point is that public subsidies do not require TIs to develop a project. On the contrary, non-competitive funds compel TIs to develop a research project although they do not have to compete with other agents to get the funds. Projects are generally proposed by themselves and are used to:

1. Complement other research projects done under market pressure;
2. Develop certain competencies that allow them to keep near the knowledge frontier; and
3. Open new research lines that can become potential financial sources.

Developing a taxonomy for TIs

Previous analysis has shown the importance of certain factors related to the design of service supply, represented by the two previously defined indicators: OD and RDI. Lineal correlation between them is almost zero. This made us believe that a more diversified supply was independent of one more oriented to R&D strategy. However, the fact that both of them are highly correlated with size has allowed us to identify a non-linear connection between them, by eliminating the size effect (Table 4).

Departing from this connection and employing a conglomerate analysis, we have obtained five groups of Spanish TIs. Two of them are characterised by showing different decisions about the design of their service supply. Group 1 is composed of TIs with high values in OD indicator and average values in RDI indicator. By contrast, the TIs in Group 2 present high values in RDI indicator and low diversity of service supply. On the other hand, TIs from Group 3 make certain service supply diversification compatible with a medium-high level of RDI. Group 5 is composed of TIs with low values in both indicators (see Figure 3).

Table 4. Model 3 results

Dependent variable: operative dimension (OD)		
Constant	–1.557**	(0.582)
Staff	0.021**	(0.004)
Strategic planning	0.294**	(0.114)
RDI	6.192**	(2.488)
RDI^2	–9.810**	(2.513)
R square: 0.65799		

Note: Coefficients and standard errors in parenthesis. Significant at the less than 5% (**) and 10% (*) levels of significance. Estimation method: OLS

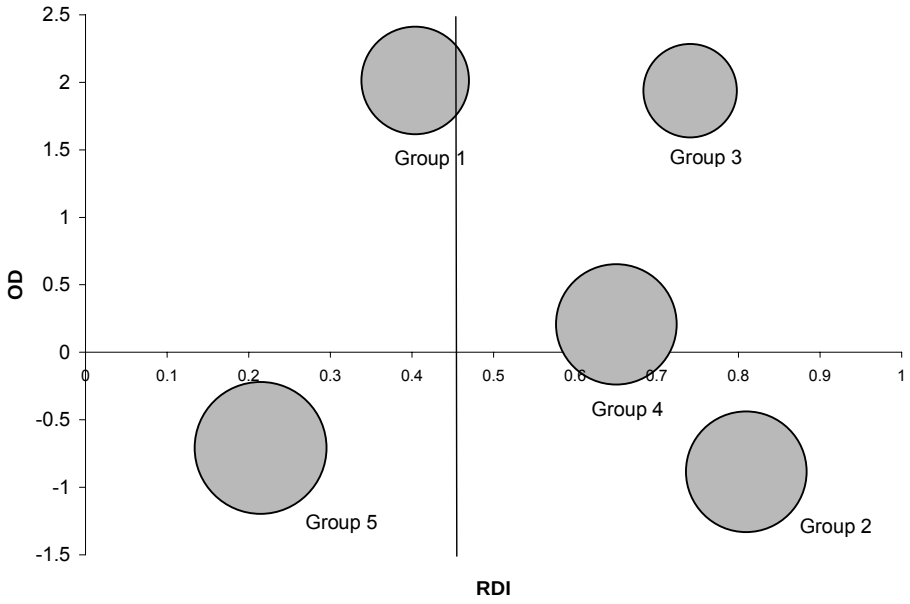

Figure 3. Relationship between OD and RDI

Through a more detailed analysis of TIs from an original Group 3, incorporating size, it was possible divide it into two different groups. The first of these, now called Group 3, was formed by big TIs making an ample and diversified service supply compatible with intensive R&D activity. The other (Group 4) corresponds to TIs with a similar actuation line despite being smaller. They also arrange to have above-the-average research activity and a medium-high diversification level. It seems that they are now walking the same path that TIs from Group 3 walked in the past.

Once this analysis had been carried out and after checking again the accuracy of information from the questionnaires, through a detailed study of TIs reports and web pages, we selected some TIs representative of each group to look more deeply into the characteristics of the five groups (Table 5). Differences among them reinforce those previously obtained.

TIs from Groups 1 and 5 show the lowest percentage of big clients. By contrast, this percentage is quite high in TIs from Groups 2 and 3 and slightly above average in TIs from Group 4. The financial structure of TIs also differs among groups. Non-competitive funds are highly relevant in Group 3 and very scarce in Groups 1 and 5.

By contrast, member fees are relatively important in Groups 1 and 5 and almost non-existent in the other three groups. Relating to European Competitive funds, TIs from Group 3 receive the highest amount and TIs from Group 5 the lowest. These TIs are also those with the lowest amount of impact and impact added value while TIs from Groups 1 and 3 shows the greatest impact and those from Groups 2 and 3 the highest impact added value.

It is worth noting that this taxonomy reflects inter-regional differences. Many of TIs from Group 1 are

Table 5. Features of the taxonomy groups[2]

	Group 1	Group 2	Group 3	Group 4	Group 5
Size	C	B	A	C	E
Age	C	C	A	D	C
RDI	C	A	B	C+	D
OD	B	D	B	C+	D
Amount of impact	B	C+	B	C+	D
Impact added value	D	A	B	C+	D
Self-financing	C+	C+	B	B	C–
%PhD	C+	B	B	C	D
Strategy	C+	C+	B	C+	D
Strategic planning	C	C+	B	B	C–
Non-competitive funds	E	B	A	B	E
European competitive public funds	C–	C+	A	C+	E
% of member fees	A	E	E	E	A
% of R&D income	C–	A	B	C+	E
% of technical services income	B	E	D	C	A
% of consultancy income	B	E	C	C	B
% training income	C–	E	E	D	A
Collaboration with scientific environment	C	B	C+	C+	D
Collaboration with entrepreneurial environment	B	C+	A	C+	D
Collaboration with public administration	D	B	B	B	D
Market relations with firms	D	C	B	A	C+
R&D activities	C+	B	A	C+	E
Technical services activities	A	D	C+	C–	C
Strategic consultancy activities	C–	D	C+	B	E
Tactical consultancy activities	A	D	C+	D	D
Academic diffusion activities	B	A	A	C	E
Non-academic diffusion activities	A	C–	C–	C	D
Training activities	C	D	C	D	C
R&D efficiency	D	A	A	B	E
% of clients with more than 250 employees	E	A	A	C+	E
% clients with low technological levels	B	D	D	D	D

Note: A = very high; B = high; C+ = medium-high; C = medium, C– = medium-low; D = low; E = very low

located in the Valencian region and are unisectorial, while most of TIs from Groups 2 and 3 belong to the Basque Country and are multisectorial. TIs from Groups 4 and 5 belong to several regions and can be unisectorial or multisectorial.

Conclusions

Technological institutes have the necessary characteristics to become catalysts of the process aimed at creating a common information space involving all environmental agents. This process will help them to identify firms' technological needs for the present and the future.

The design of an integral balance scorecard is consider a strategic factor, not only for TIs to know their relative position with respect to other TIs, but also for policy-makers. Dimensions from a balance scorecard play a key role in explaining TI performance.

Decisions about service supply are very relevant to the amount and nature of the output. Accordingly, TI strategy has to make service provision compatible with knowledge generation. The former contributes to augment firms' innovation capacity while the latter is essential for being able to develop the required capabilities to match firms' future needs. This decision is to a large extent conditioned by the environment in which TIs perform their activities. Those technological institutes with small sized clients from low technological level sectors encounter many more difficulties in generating high added-value impact.

Organisational design is very relevant to being able to make both orientations compatible. More precisely, design of strategic planning and the existence of indicators to evaluate goals achievement and plan ongoing control are factors affecting TI performance.

Public and/or private support to TIs has to be planned strategically. This support should be stable, adapted to each particular environment and aimed at encouraging their potential and at incentivising their mission to enable innovation in firms, in both the short and the medium/long term. This support has to encourage collaboration among TIs, universities and public research centres.

Developing this approach from the point of view of the firm would extend this study and allow us to reach a better understanding of the information problems involved. The main obstacles are related to the absence of data from firms that would permit the identification of their relationships with TIs.

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Notes

1. Subjective measures are, on the one hand, TIs' estimation of their own impact in terms of: new products, new processes, new services, quality improvements in products, quality improvements in processes, job creation, production costs reduction, time-to-market reduction and creation of start-ups; on the other hand, TIs' estimation of the frequency with which their R&D activities contribute to slightly improve a product/process, noticeably improve a product/process, create new product/processes for the firm or for the market. Objective measures are: number of new products, processes and services, number of quality improvements in products, number of quality improvements in processes, number of jobs created, production costs reduction percentage and number of start-ups created.
2. R&D efficiency shows R&D relative technical efficiency from a sub-sample of Spanish TIs. More details are available in Ramón Núñez's 2003 MSc dissertation, 'Evaluación de la eficiencia técnica de los CTs españoles' at Universidad Carlos III de Madrid.

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