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ORIGINAL PAPER

R&D and eco-innovation: opportunities for closer collaboration between universities and companies through technology centers

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Abstract It is widely accepted that eco-innovation is the direction to make progress towards a sustainable innovation. Public and private actors seem to share a common point of view and agreement on the benefits of implementing eco-innovation. If this is the case, why eco-innovative activities are still exceptional and exemplary instead of being the usual reasoning and inspiring driver for all kind of actions? Going in depth into the reasons why eco-innovation techniques are not broadly spread, the main one is the lack of internalization of this attitude in all the everyday actions taken by companies and employees in the form of social responsibility. Definitively, society as a whole is responsible for the eco-innovation promotion. Large companies have long ago incorporated Social Responsibility into their strategic planning and invest on innovation as a competitive advantage. However, they are reluctant to contribute to the eco-innovation. Therefore, universities and technology centers (TCs) have to play this role and link the private sector, specially medium, and small size companies, with the society needs. However, Universities are not often leading the eco-innovation initiative. Currently, in the case of Spain, it is observed a huge gap between the scientific research efforts made by the Public University and the academic offering and the real needs of the private companies. In fact, mixed structures as TCs are needed in order to overcome this disconnection, increasing opportunities for subsequent cooperation in eco-innovation projects. This paper points out the causes of the Spanish R&D and innovation lag, and highlights the reasons of the disconnection between public and private research for innovation, while giving hints on what is working fine and what needs to be reviewed to catch up with the R&D reference countries in Europe.

Keywords R&D · Eco-innovation · University · Technology centers · Public and private sector cooperation

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Introduction

It is of common acceptance that, for the society progress, research and development (R&D) is of paramount importance. In fact, there is a straight correlation between a society's research effort and its level of wealth, as pointed out by Charles (1995). The R&D is carried out by two funding sources: public or private funds. Both ways pursue the same long-term utopian goal of progress but the motivations behind are different, and so is the methodology to achieve it.

Public funded research is mainly made by public institutes and universities. There is a small contribution by public companies but negligible for this paper's purposes. Traditionally scientific research has been the domain of public universities due to the uncertainty of the results

obtained and the long-term needed, while development has usually corresponded to private companies and the wish of achieving competitive advantages by creating new innovative products and services. Very often minor development steps achieve interesting scientific findings reducing risks and relying mainly on private initiative.

In the particular case of Spain, the total amount invested in R&D lags far behind that of the leading EU countries, although with a positive increasing trend, as shown in Chart 1 in which R&D investment in Spain is compared to the UE-27 and Euro area average as % of gross domestic product (GDP).

In addition, there seems to be an imbalance between the research efforts made by the universities and the innovation demanded by society. This mismatch relies on the disconnection existing between the two researching worlds: universities and companies. This scenario is applicable when dealing with eco-innovation. There is little doubt in the fact that a higher investment on R&D and innovation, and a closer collaboration between universities and companies would bring about better results in terms of eco-innovation.

For our analysis, eco-innovation is defined as "the innovation based on and striving for eco-efficiency" according to the World Commission on Environment and Development, as expressed in the "Brundtland Report" (WCED 1987), and the principles of sustainability of Costanza and Daly (1992). Eco-efficiency is, in this case, applied as the ratio between the economic value of a product or service to the environmental impact caused by the product or service (Huppes and Ishikawa 2005) while considering the social value of eco-innovation (Fussler and James 1998) as a third factor of the paradigm.

Opportunities for closer collaboration university–companies

Situation of the eco-innovation activity in Spain

To find out the reasons of the Spanish shortage in R&D efforts a break-down of the R&D investment figures shown above should be done. The first-step would consist on an analysis of the investment source by country, as shown in Chart 2 from the "Organization for Economic Co-operation and Development" (OECD) for year 2008 for the most relevant European countries where the investments are split up into private and public sources. The most interesting difference between countries like Italy and Spain is the low comparative investment coming from private sources, mainly companies. Countries like Germany and the US have a 68 % private investment while 27 % come from public sources. However, if the analysis is normalized by the GDP, since the investment effort has to be proportional to the wealth of the country and the resources available (Chart 3), it is remarkable that the % of public investment in Spain is not radically different from the rest of the most developed countries. The difference lays mainly in the investment made by the private sector. This investment, added to the public effort, is a multiplicative effect affecting directly companies' competitiveness.

The key question is then why Spanish companies are reluctant to invest in R&D for innovation. There are many reasons for that, just to name a few:

- *Type of company* R&D investments are tightly related to the size of a company and the resources available.

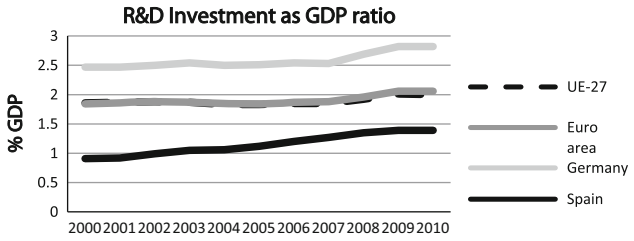

Chart 1 R&D investment evolution comparison between Spain and EU-27 as % of GDP. *Source* Eurostat, European Commission 2011

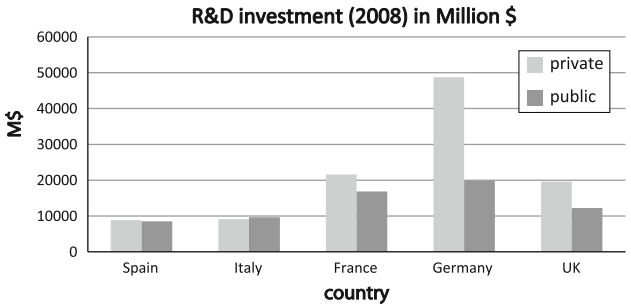

Chart 2 R&D investment by source and by country in million $. (*Source* Authors' compilation from OECD statistics data)

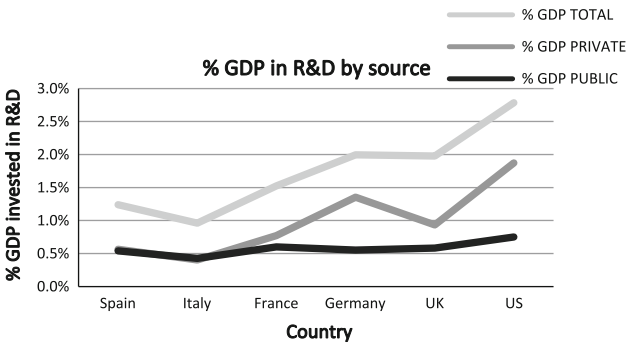

Chart 3 R&D investment by source and by country in % GDP. (*Source* Authors' compilation from OECD statistics data)

Table 1 Company size distribution in Spain 2009

Employees	0–9	10–49	50–249	Over 250	Total
1,772,355	1,352,363	136,843	21,934	3,879	3,287,374
53.91 %	41.14 %	4.16 %	0.67 %	0.12 %	100 %

Source INE (2010)

Table 2 Company sector distribution in Spain 2009 in number of companies

Industry	Construction	Retail	Services	Total
229,537	510,909	796,746	1,750,182	3,287,374
6.98 %	15.54 %	24.24 %	53.24 %	100 %

Source INE (2010)

According to the National Statistics Institute (INE[1]), 99,21 % of the Spanish companies at January the 1st 2010 had less than 50 employees (INE 2010), see Table 1. Although there are many innovative small and medium enterprises (SME[2]) the investments made by them are usually small, at the level of their incomes.

- *The sectoral distribution of the companies* Most innovative companies usually are in the industry and technological services. As shown in Table 2, few companies lay in these groups since the service sector mainly deals with local traditional services.
- *Technological colonization* Many technologically successful Spanish companies have been absorbed by multinational companies to gain the local market and get rid of local competitors. On the other hand, foreign industrial investments in Spain have always had a production interest based on the traditionally lower labor costs. A clear example is the car industry. According to the "International Organization of Motor Vehicle Manufacturers" OICA (2010), Spain is the 2nd largest European car producer and the 7th worldwide, but none of the companies are Spanish based, nor are the car designs made in Spain.
- *Competing strategy* There are mainly two ways to compete in any market, price and differentiation. Although both need innovation, research is mainly applied to the second. Due to the reluctance of the Spanish company management to the R&D, many companies have no option but to go for the first competing strategy. As raw material prices and workforce costs increase many of these companies will have to shut down, unable to compete any further in price, according to Von Zedtwitz and Gassmannb (2002).
- *Cultural* This low confidence on R&D investment has always been present in Spain's recent economical history, traditionally due to the isolation of the country for political reasons, and the bad road and railway connections with the rest of Europe. However, it is very important to remark that this reason is becoming less and less relevant as more trained generations pick up the baton and step into managing positions within Spanish companies.

  Another important data that show how management culture influences R&D investment prioritization is the interesting fact that in times of crisis, companies tend to reduce costs that are not strictly necessary for the everyday operations of the company. In a vast majority of companies the R&D investment is the first to be cut down, whereas commercial costs are usually increased in an effort to gain more customers and get higher sales. However, relevant analysis shows that tough times are the best times to create competitive advantages with respect to competitors and differentiate products and services attempting to increase value added, and therefore, sales margins since sales volume will most likely decrease.

A possible way to overcome this lack of interest of the private sector for R&D investment is to set in place an effective program of fiscal incentives. Most countries do have one in place and it pays off part of the uncertainty of an R&D investment. Spain's program evolves along the years to try to adapt it to the economical situation, along with the rest of the countries, as shown in the next chart for different countries in the period 2001–2008, according to the OECD statistics (2010a, b) (Chart 4).

Spain consistently offers higher fiscal incentives to invest on R&D, reaching up to 44 % of the investment. The subsequent investment risk is, this way, reduced. This amount exceeds that of other countries that are known to do very well on R&D (twice or three times more as an

[1] INE: Instituto Nacional de Estadística www.ine.es.

[2] SME: As commonly agreed, a company can be considered "small and medium company" when the total workforce is lower than 250 employees.

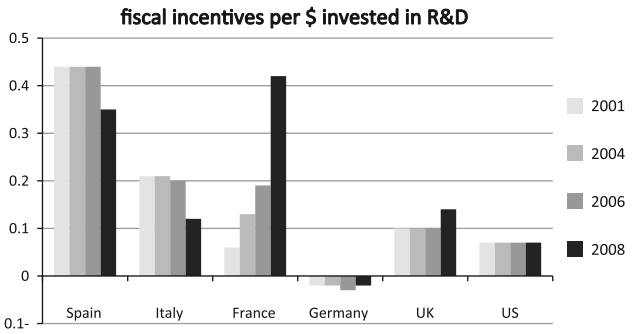

Chart 4 Fiscal incentives per $ invested in R&D from 2001 to 2008. *Source* OECD Main Technology Indicators (2010a, b)

average). The cases of Germany and the US, the two countries with the highest investments on R&D are very significant, the incentives being negative in the case of Germany. Therefore, increasing incentives are not the solution to the problem.

Why then, private investments in R&D are so low in Spain compared to our surrounding countries? The explanation must be sought at the differences of such investment return in every country. German company owners are more willing to spend money on R&D because they feel the profitability of their investments is higher in Germany than it is in Spain. We need to find then the root cause for the difference of the return on investments made in both countries to know the right lever to move.

The reasons why a particular investment gets better return rates in a country than it does in another can only be justified by two main reasons.

1. *The costs of the research activities are higher* Research is a labor-intensive activity. Although there are asset costs like facilities, equipment, tooling,…the highest part is due to researcher salaries. Below there is a table that shows the percentage of difference of cost per hour accepted by the EACEA (2011) in subsidized researching program calls by country and by category, taking Germany as a reference. It is observed that costs in Spain are currently between 23 and 42 % lower than in Germany. For researchers in particular it is 30 % difference. Therefore, this does not seem to be the cause of the apparent low R&D profitability in Spain (Table 3).
2. *Productivity is lower* Karlsson et al. (2004) describe many ways to measure R&D productivity. Starting by defining first the concept "productivity" in R&D from an economic point of view, all tangible and intangible assets have a market value that corresponds to the interest of a buyer to acquire the good and the abundance or scarcity of it in the market. This can also be applied to a trade mark, certain knowledge or a research result. In terms of accountability, the economical investment made by a company in R&D is placed as a liability. The research result appraisal is accounted as an asset in the company balance sheet, and the difference with the amount invested goes to the profit and loss account.
   Defining productivity as the ratio between the R&D and innovation output market value and the R&D and innovation cost, we have proven that the denominator is not the root cause for a possible lower R&D productivity, therefore the conclusion is that the value generated by the R&D output in Spain is much lower than it is in the leading countries of Europe

$$\text{ROI} = \frac{\text{R\&D output}}{\text{R\& D costs}}.$$

This low productivity is supported by statistical data about the perceived contribution of R&D to the companies' business figures. According to the 2006–2008 period inquiry about Technological innovations in Spanish

Table 3 Hourly staff cost difference in several countries with respect to costs in Germany for different professional categories

		Manager (%)	Researcher (%)	Technician (%)	Administrative (%)
France	FT	−3.8	−13.2	−16.3	4.9
The Netherlands	NL	27.2	15.5	4.1	16.3
Spain	ES	**23.4**	**31.6**	**26.2**	**42.4**
Austria	AT	16.0	38.1	13.1	10.8
United Kingdom	GB	15.3	−7.7	−4.5	24.6
Italy	IT	−8.4	3.9	9.5	14.3
Greece	GT	33.4	29.7	35.7	41.9
Poland	PL	74.0	75.2	76.9	80.8
Denmark	DK	13.8	8.4	−6.8	3.0
Germany	DE	0.0	0.0	0.0	0.0

Source EACEA (2011)

Bold values indicate Spain's hourly staff cost difference with respect to costs in Germany for different professional categories

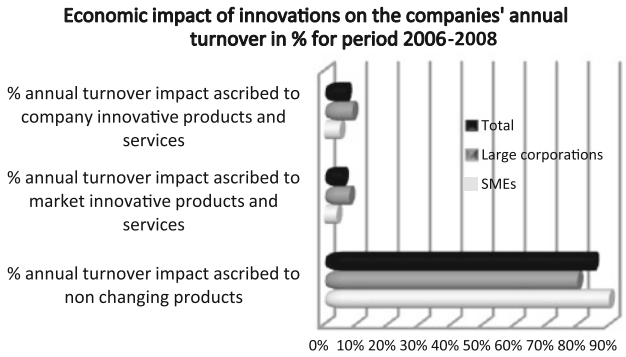

Chart 5 Economic impact of innovations on the companies' annual turnover in % for period 2006–2008. (*Source* INE 2008)

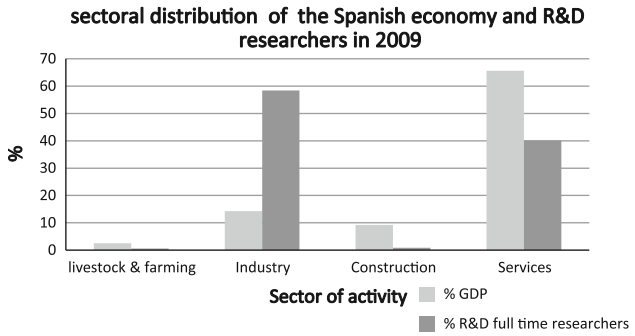

Chart 6 Sectoral distribution of the Spanish economy and R&D researchers in 2009. (*Source* INE 2010)

companies made by the INE,[3] most company managers claimed that the innovation investments had low or very low impact in the company turnover. In the case of SMEs the average contribution perceived for the R&D effort to the total turnover is less than 5 % as shown in the next chart. This negative perception discourages further investments in this field (Chart 5).

The next question that arises deals with the nature of this low value added of the privately funded R&D and innovation activity in Spain. We may wonder whether the reason for this low productivity is due to a low output in terms of quantity with respect to the resources invested or a low value of the research output in terms of quality.

The first consideration to be taken into account is a scale factor. Usually, great technological and scientific discovering comes as a result of incremental efforts of smaller progresses achieved in a set of chained projects that add up to get a relevant output. Due to the small size of the average company in Spain and the lower investment by employee, research projects and innovation investments are shorter in terms of scope, and the effort is not sustained along time, thus preventing the research teams from getting too deep into the topic.

The second important point is the sectoral distribution of the Spanish companies (Chart 6), with almost 13 % of the national GDP in sectors like livestock and farming, and construction, which allocates about 1.5 % of the country's total R&D resources, as shown in the following chart, according to the INE. Industry accounts for 58 % of the researchers with a continuous decrease since the end of the twentieth century, while the service sector employs 40 % of the total R&D staff, increasing since 1995 due to the development of internet, communication, and mobile phone companies.

[3] INE 2008. Innovation Collaboration Annex.

The positive view of this picture is that, due to the economic recession, the sectors with less R&D contribution are shrinking, while there are new opportunities for innovative companies, regardless of size, specially for eco-innovations in products or services, which is a sector with great growth potential in Spain.

To conclude, it is important to remark that not all economy sectors behave equally from an R&D standpoint. There are significant exceptions of successful R&D developments in the Spanish private sector, mainly on the renewable energy sector where important companies have taken center stage and lead the R&D efforts worldwide, particularly in the wind power and solar thermal industries. Other interesting experiences are the nano-material sector or the bio-pharmacy. In all cases, this success comes as a result of one or several companies that lead the market tendencies and lines of research, having international influence, for example in the field of renewable energy, such as Gamesa, Iberdrola Renovables, Enel Green Power, Acciona Renovables… These companies usually have taken advantage of their predominant position in a market with few competitors or have made the best of an advantageous legislative framework like the push to the renewable energy sources from the year 2000 onwards, being eco-innovative in the energy sector, although they do not often collaborate in their battle for competitiveness in the clean technology sector (Urpelainen 2012).

Barriers to collaboration between public and private sectors

On the other hand, we have pointed out at the beginning of this paper that the public sector keeps a good trend in R&D and innovation efforts, the investment in terms of GDP percentage being similar to other more successful countries. It is proven that collaboration between university and private companies is crucial to overcome the current situation of downturn and bad R&D figures. Chart 7 describes

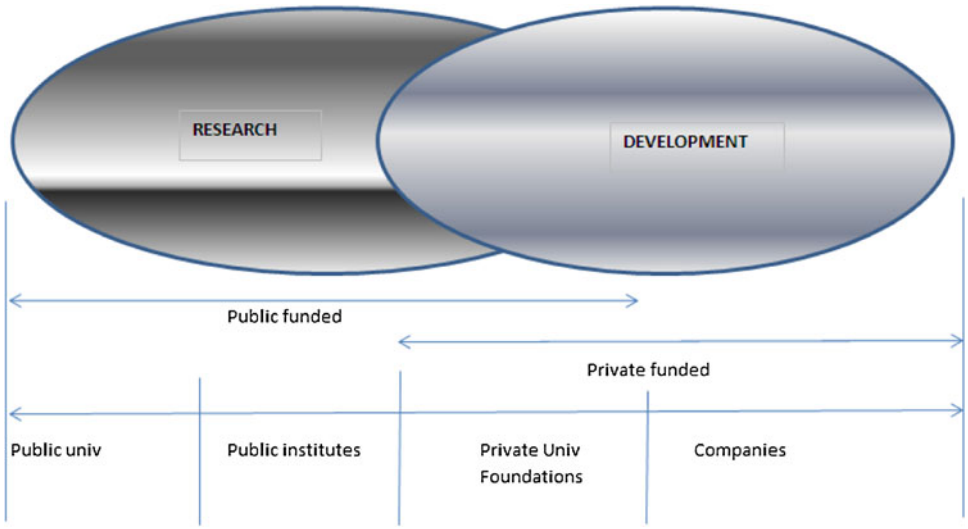

Chart 7 Simplified scheme of the R&D activity main actors and their funding sources. (*Source* Authors' compilation)

schematically the activity of R&D between the public and private sectors, the first one mainly applied to scientific research and the second one to development of products and technologies.

Although this collaboration exists, in Spain there seems to be a disconnection between private companies and public universities, "in a war where everyone fights its battle on its own". In the general case private companies own the market knowledge and are aware of the new products and services trends, whereas universities own the scientific knowledge and methodology (Autio et al. 2008). In order to develop in the right time those new eco-innovative products and services demanded by society they can use their own R&D resources and they can subcontract, totally or partially, this work to universities and institutes. If we all agree that unifying efforts and team working leads to better results, why this collaboration is not taking place at the maximum extent?

Several factors may contribute to keep the barriers between these two worlds.

- *Very complex organization structures at universities* There are many university departments that change their structure and designation almost yearly to respond to changes in the educational plans, or at the university governing body. In other words, knowledge is very compartmentalized. There is, at least, one expert for every subject but it is difficult for a company to find that person to tackle a specific problem. Company managers feel unable to find the right person to talk to, within such a complex organization.
- *University service fees* Spanish universities count, in a number of cases, with a third party body or organization that handles relationships between the university and private legal entities. In case an agreement on an R&D project is reached this organization charges the total cost of the project. Although these organizations help with all the paperwork and legal requirements, this overhead is between 10 and 20 % of the project income.
- *Disconnection between university and company professionals* Most often, these people have followed the same education and academic paths, but once they leave universities and get into the labor market there is little contact between the two worlds. A university professor has seldom worked in a private company. A company employee has seldom taken any specialization training program at the University. This fact may seem banal, but it is a source of mistrust of company managers when facing the decision of subcontracting a research study to a university, and it is also important for university departments to attract a loyal customer portfolio.
- *No effort from universities to advertise their research capabilities* Since their main source of incomes come directly from public funds and their survival is not in danger. This point also tends to make university tenders not competitive since R&D usually is an additional income source which is not strictly necessary for the proper functioning of the entity.
- *No competence among universities* In Spain there is not a culture on ranking universities depending on their prestige and popularity, like there is at the Anglo-Saxon culture. Students usually attend courses at the nearest university to their home place. This is the reason why there is not much competence among Spanish universities. According to the 2009 Shanghai Jiao Tong University Ranking (2009), Table 4 shows the list of the ten best Spanish universities among the top worldwide 500. It can be observed that the number one Spanish university is in the 60–80 ranking for Europe and 150–200 in the international scale.

Table 4 The top 10 Spanish universities

National ranking	European ranking	International ranking	University
1	59–79	152–200	Universidad de Barcelona
2–4	80–125	201–302	Universidad Autónoma de Madrid
2–4	80–125	201–302	Universidad Complutense de Madrid
2–4	80–125	201–302	Universidad de Valladolid
5–6	126–170	303–401	Universidad Autónoma de Barcelona
5–6	126–170	303–401	Universidad Politécnica de Valencia
7–11	171–208	402–501	Universidad de Granada
7–11	171–208	402–501	Universidad Pompeu Fabra
7–11	171–208	402–501	Universidad de Santiago de Compostela
7–11	171–208	402–501	Universidad de Sevilla
7–11	171–208	402–501	Universidad de Zaragoza

Source the Shanghai Jiao Tong University Ranking (2009)

There are already measures in place to try to break some of the above barriers, via subsidies for R&D projects, roadmaps of knowledge and figures like the "associate professor", non-tenured part time teacher (called in Spanish "profesor asociado"). A certain percentage of the faculty teaching staff is contracted as this category. Actually, the applicant must hold a labor contract in force from a private company.

So far the idea is good as it enables a mix in the university teaching staff having the best of the two worlds, academic and corporate. The problem is that, in practice, the staff mainly involved with R&D projects are professors and PhD, which sum up 77 % of the total teaching staff. The amount of staff actually doing R&D or innovation activities exclusively on a continuous basis is low in Spanish universities, depending on the faculties and universities according to the Prendes (2009).

All the above mentioned points are handicaps for the private companies to request collaboration to the Spanish public universities for R&D initiatives. In addition, as noted by Cummings and Teng (2003), much research is lost in a bad or inefficient knowledge transfer to the practical case of a company. None of these issues seem extremely difficult to solve. Then, we move on to the next question: why then is there little interest in pulling down the barriers to get universities and companies closer to each other?

The answer to that question is the root cause of the problem and it is a difficult one to solve. We could think that universities and companies both work to satisfy Society's demands and build a better place to live in, delivering services and products for the sake of the people who work in them. However, the interests pursued by universities and companies are totally different. Companies' ultimate goal is to make money (in a sustainable manner), while public universities work for the individual prestige of the professionals that make part of them. This is reflected in the metrics that they are using to measure their performance against the established goals. While most companies measure their outputs in terms of the economic value created (volume of sales, volume of profit, market share, profitability, return on assets), universities measure their performance by academic metrics (number of students, number of degrees offered, students demand,…) and by research performance metrics (projects, number of impact factor papers,…). Let's focus on the latest for both companies and universities.

Hereby is a list of commonly used metrics to measure the success of the R&D activities in each case:

1. *Companies* Return on investments, return on assets, project profitability and payoff, opportunity cost, increase on sales, increase on margins,… Most of the metrics used are measured in monetary units and have a straight economic impact. These metrics are good to prioritize the best projects for a company profitability point of view, but research projects may also have environmental and social benefits that, in most cases, are dismissed unless they can be converted into economic values for the company.
2. *Universities* Number of projects, number of scientific publications, number of impact factor papers, number of downloads, or hits on self-produced documents and papers, notoriety scales, prestige, and recognition scales… Economic metrics are also considered but they are secondary, according to Fang-Ming and Chao-Chih (2009). The positive aspect is that social and environmental benefits are highly considered. The negative is that, since the economic point of view is not so relevant, very often the topics and contents of the R&D projects are of little practical application to solve real, everyday problems, and the outcomes of these projects are seldom implementable. This point also explains why universities seldom make efforts to capture a customer portfolio or advertise their technical knowledge and capabilities to offer services and products to companies and the general public, and when they do so, they may not always be competitive.

Hence, we see that not only the funds and the project terms are different. In addition, the motivations behind the R&D efforts are, and it is difficult to blend them, particularly for eco-innovation.

Getting public and private sectors research together: the role of the technology centers (TCs) in the innovation process

It is difficult to overcome the above mentioned barriers, mainly because those ultimate goals and metrics are intrinsic to the nature of either entity and it is not the purpose of the paper to call for a revolution to change everything dramatically. Nevertheless a solution has to be found. A solution that leaves universities and companies the way they are, respecting their goals and purpose, but at the same time helps boosting the R&D collaboration and increase the eco-innovation efforts in the wake of a more competitive economy. This solution is neither in the university side nor in the private company side but in both, combining the best of the two worlds into a new kind of entity which is made up of a mixture of the two. This solution already exists and is called TC.

These mixed, private or public TCs, are considered a specific agent in the scientific, technological and social system. These institutes are, at present, regulated by Royal Decree (2093/2008) and are partially modified by Royal Decree (652/2011). Spanish regulation defines the principal conditions required for institutes into be recognized as TC and to be registered into the official register of the Spanish Ministry of Economy and Competitiveness: "entities with legal personality created for the purpose (declared in its statutes) to contribute to overall social benefit and to improve business competitiveness through the provision of R&D and innovation". At the beginning of 2009, 98 Spanish centers were registered, and they were the subject of a deep analysis with respect to the framework of a research project carried out by the authors of this paper.

TCs, mainly linked to public universities, usually are private associations or foundations participated by several public bodies and private companies whose interest is not economic (non-profit organizations), although they need to keep a minimum profitability to ensure their survival. They work for both public bodies and private companies and their offer ranges from products and services to training, including customized research and eco-innovation. They are committed to respect the founding charter. 70 % are participated by the public administration but companies, either SME or large corporations, are present even at a higher extent as shown in Chart 8. Approximately half of them are partnered by universities and employ both university professors who dedicate a part of their time to the TC, and independent prestigious professionals, coming from private companies who can apply their experience and knowledge to the research activities.

TCs are structured internally as companies. Their product is "applied practical knowledge" and have an average size of 111 employees. They take part in any tender on a competitive basis and, therefore, their bids should be tight but fair to ensure a minimum profitability to cover the foundation indirect costs. Since a good part of the staff are university professors they use scientific approaches to come up with innovative solutions for their customers at a competitive price. Since a part of the staff comes from private companies they understand better the problems these companies face and give more realistic solutions to the problems presented. TCs have both private and public funding, thus achieving a healthy mix that enables them to cover all aspects of the research: economic, social, and environmental. In other words, TCs are a good solution to boost R&D in Spain as agreed by many authors like Revilla et al. (2000).

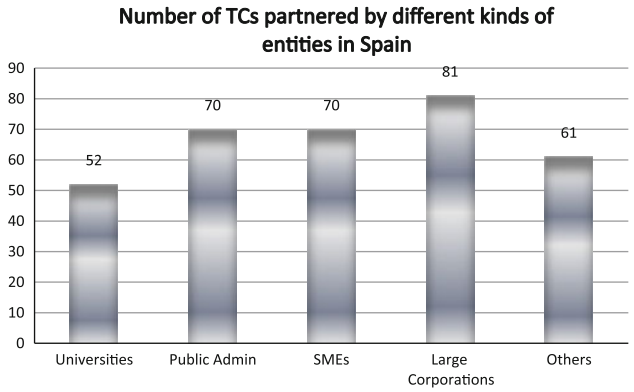

Chart 8 Number of TCs partnered by different kind of entities in Spain. (*Source*: Authors' compilation)

The following chart maps out the location of each TC and other centers registered in the National Innovation and Technology Center Register ("Registro público de Centros Tecnológicos y Centros de Apoyo a la investigación"), classified as TC in 2009, when this inventory was made. Their presence is higher in the Basque Country, followed by Catalonia and Valence. The first two are considered the most innovative regions and concentrate the highest industrial activity in the country (Chart 9).

The number of activities they devote to is broad, R&D being the main one but there are many others as shown in the chart below, made as a result of the Spanish TC characterization study.

As remarked by different publications by Modrego (2004) and Barge (2007) as well as Fernández de Bobadilla (2009), Montejo (Fundación COTEC 2004), Santamaría et al. (2004), and Rico (2007), among those organizations providing know how to companies, TCs play a key role along with universities and suppliers.

As a result of the characterization, TCs can be considered eco-innovation vectors since the real eco-innovation is made by companies, but TCs help speed up the process and reduce the result uncertainty, and hence, the project risk, which is the main aversion companies have to R&D investment. The working scheme is shown in Chart 10.

Chart 9 Classification and location of TCs according to the registration in the TC Register in spring 2009. (*Source* Authors' compilation)

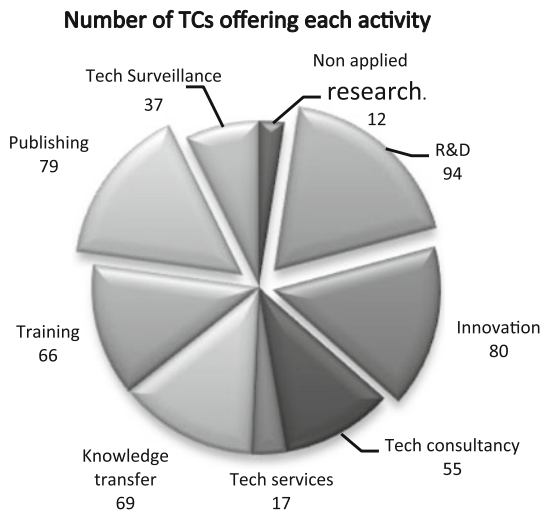

Chart 10 Number of TCs offering each activity in Spain. (*Source* Authors' compilation)

Society continuously demands solutions for the economic and social problems that faces. Public governments' role is to promote eco-innovation by means of R&D aids and program calls, and by setting up the appropriate legislative and regulation framework for companies to find appealing the investments on R&D. This eco-innovation can be made straightforward by companies, or indirectly by means of TCs, who have the means, knowledge and resources to ensure a higher success chance. This way, eco-innovation would be faster and efficient (Chart 11).

Some authors have already studied the systemic value that innovation intermediaries play in policy terms in an innovation system (Howells 2006). In the case of Spain, the importance of TCs as catalysers of innovation in the industrial world is reflected in the Spanish economy (Gracia and Segura 2003, González de la Rivera 2008; Guijarro et al. 2005) and in the R&D results by activity sector, reported in the evaluation and impact of Spanish TCs in the competitiveness of Spanish companies (FEDIT 2008[4]), where a 3.2 % increase in companies R&D is ascribed to the TCs' activities. Barge and Modrego (2009) speak about TCs as "collective effort catalysts" from the perspective that most TCs' establishments are the result of a collective effort by different public and private agents. Thus, TCs are the meeting point of those agents to enable a coordinated effort towards common interests.

In previous chapters, we have concluded that private sector does not invest enough on R&D because they do not find enough profitability out of that investment. Causes may lay on a low R&D productivity rate, due to low value added of the R&D outcomes. To improve this productivity,

[4] Full report available at: http://fedit.com/Spanish//DocumentosInformes/Portal/Publico/DocumentosEInformes/MemoriasAnuales/Informe%20anual%202008.pdf.

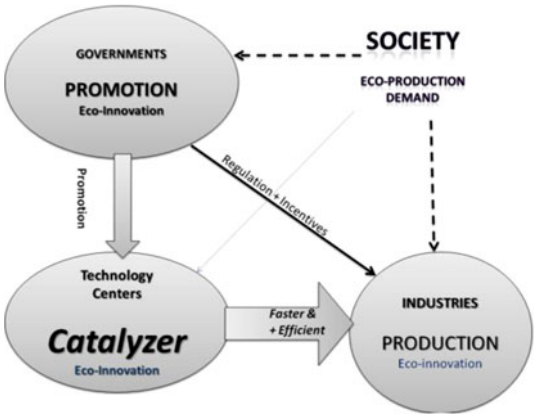

Chart 11 Vector role of the TCs in the innovation process. (*Source* Authors' compilation from)

TCs can play an important role due to their experience and know how, since research is their core business, while it is not most of the companies' core business (Katzy 1996).

Approximately 59 % of private foundation TCs' incomes come from R&D and services demanded and financed by private investment, as shown in Table 5 (2009 data). The rest come from public funds at local, regional, national, and European level. It is relevant to note that

Table 5 TC incomes by activity and source in 2008

	%
Commercial Contracts	59
Training	2
R&D	37
Consultancy	8
Others	12
Public funds	41
Non competitive	12
R&D	23
Training	1
Others	5

Source Authors' compilation

60 % of incomes come from R&D activities, which respond to the vocation of these centers for the research. The ratio of private/public income source is shifting from private to public source since 2008 due to the overall economy downturn and the postponement of long payback investments by the private sector.

According to the COTEC Foundation, based in the Oslo Manual (OECD 2005), the innovation process has four main phases:

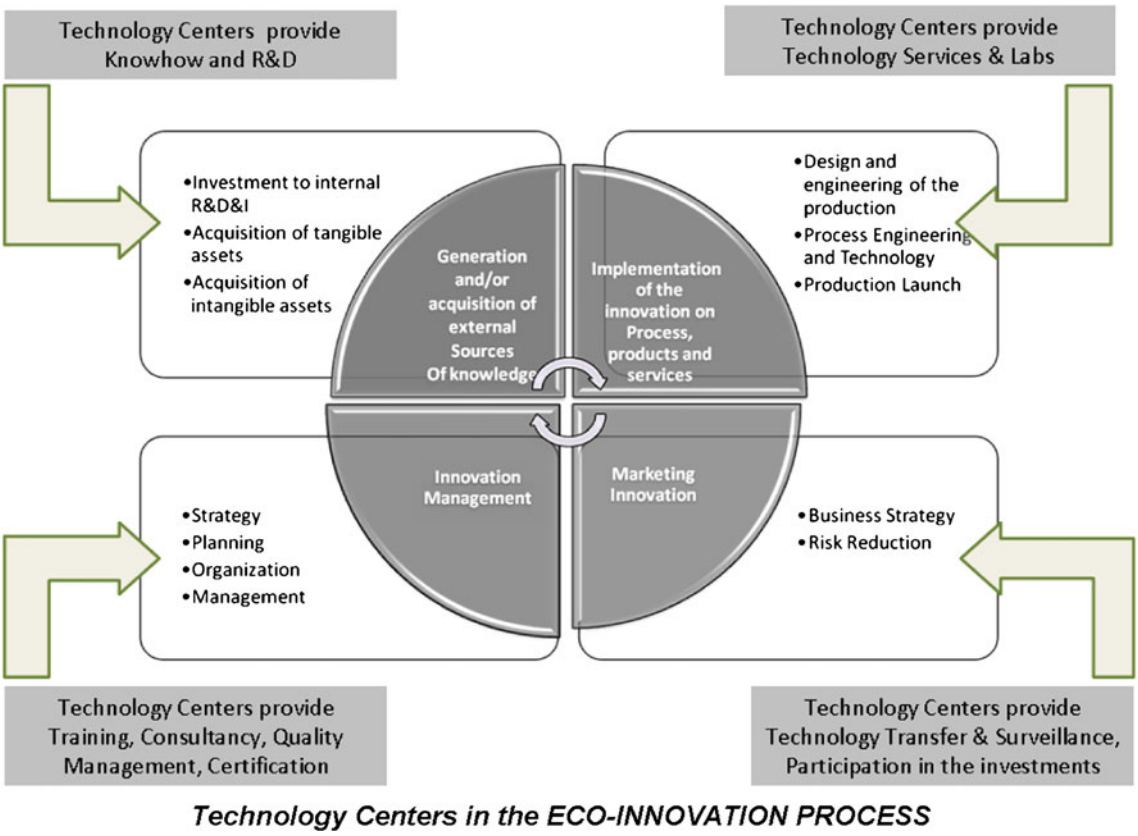

Chart 12 Participation of TCs in the main phases of the innovation process (*Source* Authors' compilation from COTEC 2001 data and Oslo Manual, OECD 2005)

- External knowledge source gathering.
- Innovation deployment in services, products and processes.
- Innovation selling.
- Innovation management.

In Chart 12, it is clearly stated the way TCs can contribute to each of the innovation phases, most intensively in the two first, but to a certain extent, they are active in all the four phases. Information and Communication Technologies (ICT) implementation and use are also areas where TCs contribute, given the importance they have for the eco-innovation process (Buttol et al. 2011).

Conclusions

Eco-innovation, as a long-term objective that seeks eco-efficiency in an innovative way, should be pursued by the main players involved in innovation investments, and the participation of TCs can foster eco-innovative procedures.

The relevance of the R&D efforts in times of downturn is of paramount importance for a country's economy. The situation of the R&D in Spain has large potential for improvement as it lags behind that of the European leading countries, mainly due to a shortage of investments from the private sector. Although many reasons have been pointed out to cause this shortage, one of them is the low profitability of these investments in many company owners' or managers' opinion.

For this purpose, companies should seek more profitability out of their R&D projects, and invest more. One way to achieve this is through a closer work and collaboration with the universities. This collaboration is necessary but it is not taking place nowadays to its fullest potential. The reason is because both companies and universities have different goals in the R&D sector.

Once analyzed the main characteristics of universities and TCs in a country like Spain, it is clear the complementary role that both play encouraging the search of synergies by means of collaboration between them. This is supported by the fact that university-related TCs obtain interesting results in the innovation process.

Due to the difficulty of changing the status quo to boost R&D investment, TCs play a key role on mixing the advantages of both private companies and universities. These research centers are structured and work as a private company but employing university professors and private company professionals who provide the right mix to apply scientific methodology without losing sight of the company's profitability goals. They can be the right partner to work on R&D by subcontracting many research projects to enable companies focus on their core competence activities.

As the study suggests, the direct participation of TCs in eco-innovation initiative, as a catalyst for the process, is a contributory action that complements the promotion work carried out by the public administration, and it could result in the faster implementation of some projects, particularly where motivational and economical barriers are detected in the private sector, commonly in SMEs, as in Spain.

The main challenge is to innovate and for it, companies have to be involved. TCs may become the eco-innovation vector that companies need to facilitate, speed up and reduce risks in the research activities, thus boosting the R&D and innovation efforts and improving the outcomes in terms of innovation, value added and productivity.

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