Assessing Technology-based Spin-offs from University Support Units

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Abstract

This paper takes a regional studies approach to assess the efficiency of technology-based spin-offs that benefited from financial and infrastructure aid. It does so by following the objectives of institutions for regional support and provides evidence on spin-offs created within the special case of a technology transfer network placed at Catalan universities. We contribute to the literature in at least two ways. First, we detect and conceptualise the specific regional objectives and the associated inputs and outputs needed to assess firms created at university-based support units. Second, an application provides empirical insights into regional mechanisms for firm creation. Results indicate that many efficient spin-offs have formal technology transfer agreements and emerge from universities with more technological background. Second stage analyses show that higher levels of innovation and specific academic knowledge or experience related with the university of origin are associated with higher efficiency. Concluding remarks focus on regional policy making and future research directions.

Keywords: university spin-off; regional development; efficiency; entrepreneurship; technology transfer; innovation

JEL codes: M1, R1

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1. Introduction

This paper assesses the efficiency of technology-based spin-offs from a regional support programme. It adopts a regional studies approach to define the institutional objectives and provides evidence on spin-offs created within a technology transfer network placed at Catalan universities (a Spanish region). This research is thus embedded in the economics and management literature on generating innovation technology for regional development and, more generally, on the importance of SMEs, many times at the centre of regional support programmes. Early studies scrutinised the increasing number and many times improved survival rate of SMEs (*e.g.* Cromie 1991; Hawkins 1993; White and Reynolds 1996). Also, seminal research systematically investigated how assistance policies to business start-ups impact positively on job creation (Birley 1987; Kirchhoff and Phillips 1988; Storey 1994), economic growth (Sexton 1986; Dubini 1989; Wennekers and Thurik 1999), or innovation (Drucker 1985; Pavitt *et al*. 1987; Acs and Audretsch 1988).

More recent studies indicated that SMEs increasingly originate from commercialised research attained via university-based innovations (Carayannis 1998; Siegel *et al*. 2003; Vohora *et al*. 2004; Clarysse *et al*. 2005; Lockett *et al*. 2005). Accordingly, and considering that the correct incentives are in place, local institutions (or governments) and universities instituted related support systems. The implied underlying efforts of public research institutions and the business sector to collaborate towards firm creation have been understood, following the influential contribution of Etzkowitz (1998, 2003, 2004), as the university's "third mission". This mission is nowadays predominantly present in European universities, which traditionally focused on teaching and academic research, while technology or knowledge transfer remained neglected. To further link theory to practice, Etzkowitz designed the Triple Helix model to highlight that university, industry and government must coordinate and cooperate towards achieving the common goal of knowledge-based economic development. This objective is mostly pursued via spin-off firms that employ university knowledge or—more generally—via firms created at university-based support programmes.

These university-based new ventures were examined by a newer array of research jointly with arguments for regional development or wealth creation (Harmon *et al*. 1997; Hindle and Yencken 2004; Ma and Tan 2006). To name just a few findings, university spin-offs are sources of new jobs, intermediaries between basic and applied research, or drivers of economic change towards a knowledge-based economy (Wright *et al*. 2004). Still, there is scarce evidence from quantitative analyses of spin-offs' performance and its associated factors seen through regional studies lenses. Even if there are quite a few single case papers qualitatively describing the university spin-off phenomena (*e.g.* Jacob *et al*. 2003; Carayol and Matt 2004; Debackere and Veugelers 2005; Acworth 2008), this line of research did not measure the efficiency of such firms or the relation between the characteristics of the support mechanisms and efficiency. However, organisation studies usually

assume that assessing efficiency represents a crucial aspect as it is closely linked to meeting financial targets and achieving regional sustainability and competitiveness.

Building on this organisational performance justification, a growing literature links efficiency with technology transfer, although mostly missing the regional focus. Many of the existing efforts turned to frontier analysis. For instance, Chapple *et al*. (2005) used non-parametric Data Envelopment Analysis ((DEA), see, *e.g*., Ray (2004) for details on this technique) to study the efficiency of UK university technology transfer offices (TTOs). They concluded that managers' business skills should be upgraded and found decreasing returns to scale indicating that TTOs should be smaller. Contrasting results are reported by Siegel *el al*. (2003) who employed parametric frontier methods and revealed that TTOs experienced constant returns to scale. A more comprehensive study of the efficiency of university technology transfer is included in Anderson *et al*. (2007). These authors employed DEA and found significantly higher technology transfer efficiency in leading universities and scrutinised differences between public versus private universities. On a related note, DEA was also used to estimate the efficiency of small manufacturing firms (Alvarez and Crespi 2003) or of science parks (Thursby and Kemp 2002), and more recently was indicated as an appropriate way to operationalize innovative entrepreneurial opportunities (Anokhin *et al*. 2011).

We build on this latter research current and tackle various challenges that emerge from existing studies. More importantly, we do so with a regional studies focus. A first task at hand is to properly identify which resources (inputs) are used to produce regional value (outputs). Managerial economics literature many times conjectured that superior performance and competitive advantages emerge from resource configurations and firm practices (or routines). This framework is better known under the label of the resource-based view (Penrose 1959; Wernerfeldt 1984; Barney 1991; Peteraf 1993) or the more recent routines and capabilities approach (Teece *et al*. 1997; Teece 2007; Grant 2008). These theories start from identifying the available resources and related production possibilities, which—as in our case—becomes crucial when the analysed sample comes from a specific regional context in terms of geographical and infrastructure characteristics. Also, under these frameworks, the outputs and the underlying input-output relation (*i.e.* the result of existing routines) are strictly linked to the pursued objectives and organisational features. For instance, the outputs that are important from a regional viewpoint need to be measured according to technology transfer objectives. Failure to do so could lead to inconclusive results, as in the absence of support or correct incentives for technology transfer universities may simply pursue other goals.

On this note, a suitable efficiency indicator should properly assess the objectives of regional policy making institutions, while integrating the fundamental firm value producing activities. In the short run, the main firm objective is aligned with the regional goals, that is, the entrepreneur's target is to increase the probability to survive by maximising revenues. Additionally, regional support institutions desire to create patents—that are usually believed to have a positive impact on long run development—and generate jobs with as low budgets as possible. This latter constraint on regional

policy making is of current interest, as the financial crisis required many local administrations to cut budget spending. Indeed, the Spanish press consistently indicated during 2010-2012 that cutting R&D funds was a priority within the deficit control measures. Given this multidimensionality, the usual methods (*i.e.* profitability, partial indicators or even traditional DEA measures) are not applicable. To account for the various regional goals, this paper uses a particular case of nonparametric frontier-based distance functions. These simultaneously expand multiple outputs and contract multiple inputs, and thus can unite the regional institutions objectives (*e.g.* revenue, patents and jobs maximisation *versus* cost minimisation) in a unique indicator. Moreover, the estimation method provides benchmarking information through efficiency estimations computed with respect to best practice frontiers. Benchmarking-type feedback is appealing to policy makers, who can observe which types of spin-offs are more efficient jointly with their university of origin and characteristics. Second stage analyses enhance the interpretations that emerge from the efficiency measure. Specifically, regressions are estimated to reveal how key variables such as generated patents or different types of employed personnel are related to efficiency.

This paper contributes to the regional studies literature in at least two ways. First, it detects and conceptualises the specific regional objectives and the associated inputs and outputs needed to assess—from the supporting institutions' perspective—firms created at university-based support units. Second, an application provides empirical insights into regional mechanisms for firm creation. To reach these goals, a particular sample of spin-offs created within the so-called Technological Trampolines' (TTs) placed at Catalan universities is evaluated.[1] This Spanish region is known for its propensity to invest in R&D and the regional TT network offers an ideal setting since the firms created within this programme have benefited from various types of regional institutional support, in infrastructure and monetary terms.

The remainder of the paper is ordered as follows. The technology transfer context and data are described in Section 3. Next, Section 4 presents the efficiency measure and employed variables jointly with the main analysis stages. The discussion of the empirical results and the derived conclusions and implications are developed in Sections 5 and 6, respectively. To set the ground for the remainder of the paper, Section 2 presents some theoretical underpinnings.

2. Theoretical underpinnings

This section takes a managerial economics approach to set the theoretical foundations for operationalizing the regional objectives and the variables required for assessing firms that benefit from technological support programmes. We start by assuming that firm performance—in our case efficiency from a regional perspective—is a function of, or can be partially explained using, differences in resources (*i.e.* the available inputs). Probably the most extensively used framework that

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[1] TTs are support units integrated—in the Catalan case—in TTOs. Section 3 describes them in more detail.

proposes and sustains this assumption is the resource-based view (Penrose 1959; Wernerfeldt 1984; Barney 1991; Peteraf 1993). Managerial economics literature further developed this approach to suit in-depth analyses that integrate not only the concept of unique resource bundles, but also organisational practices or routines used for transforming inputs into outputs. Competitive advantages and differences in efficiency are thus expected to spur from core operational processes under what is best known as the routines and capabilities framework (Teece *et al.* 1997; Teece 2007; Grant 2008). This study scrutinises the process of combining new resources in novel ways, as called for by recent conceptual contributions (see, *e.g.*, Denrell *et al.* 2003; Foss and Ishikawa 2007). The many times ignored component is that resources and routines evaluations are given by input-output relations jointly with the capacity to analyse the performance of competitors in a given environment, which may well be regional (Denrell *et al.* 2003). These missing elements can be addressed using distance functions, and—in our case—a regional focus for defining objectives and related inputs and outputs.

While in essence these views are compatible with many managerial economics approaches, the regional context requires a few applied considerations. Foremost, we are dealing with a particular sample which is difficult to benchmark against firms from other regions or even firms from the same region that did not benefit from the university-based support programme. The analysed spin-offs use region- (or institutional-) and unit-specific resources, directly implying that their inputs define a homogenous technology and must be specified as given by the regional and TTs settings.[2] Using resource-based view conceptual lenses, we identify these inputs in the related literature, and match them with regional objectives (*i.e.* the outputs). Furthermore, once the variables are operationalized, the input-output relationship represents—according to the resources and routines framework—the net effect of organisational practices. These resources and input-output routines are firm-specific, but largely determined by the regional context. This view stems from perceiving spin-offs as a manner to exploit intellectual property emerged from science and embedded in parent organisations (see Mustar *et al.* (2006) for more details). In addition, our regional emphasis is even stronger, since the analysed organisations are in their turn rooted in the Catalan environment that is believed to positively influence industrial growth and innovation capabilities (see Ahedo (2006) or Buesa *et al.* (2006)).[3]

Business start-ups in university contexts are conditioned by several factors (see Di Gregorio and Shane 2003; Nicolaou and Birley 2003; Siegel *et al.* 2003; Clarysse *et al.* 2005; Debackere and Veugelers 2005). Key regional and institutional factors, or simply drivers of spin-offs' promotion, include the availability of venture capital in the university area (Di Gregorio and Shane 2003), the university reward system (Nicolaou and Birley 2003), the bureaucracy and inflexibility of university administrators (Siegel *et al.* 2003) or the resources of the TTOs (Clarysse *et al.* 2005). It is worth

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[2] See sections 3.2 (Sample) and 4.2 (Inputs, outputs and final sample) for more details on this statement. Obviously, this study can be replicated for other regions. However, in those cases the variables' operationalization should be transposed to the new context and more primary data would be required.

[3] Yet another review for the Catalan context—but of a qualitative nature and therefore not aiming at assessing efficiency—can be found in Serarols *et al.* (2009).

stressing that these studies did not specifically attempt to evaluate the performance of spin-offs from support institutions similar to the Catalan TTs and therefore do not offer us a set of operationalized variables. We thus propose that in-depth analyses of firms created via support programmes should account for regional development inputs, such as economic aid or infrastructure use.

Note that even in the presence of positive market conditions for firm creation, there have long been various reasons that attempt to justify why universities and regional institutions should invest in generating spin-offs. Matkin (1990) stated three core ones: reasons related to the academic staff, economic reasons and technology transfer. The first type of reasons, many times overlooked in the literature, indicate that creating a new venture could retain a scholar with commercial interests, whom otherwise would probably leave the institution. In line with this assumption, we propose to evaluate the relation between using university personnel and firm regional efficiency. Moreover, evidence indicates that creating spin-offs is more profitable for inventors than external licensing to established companies (Wright *et al*. 2004). This integrates well jointly with the economic reasons, as profits obtained by universities through equity ownership are expected to be greater than royalties from sales.

The reasons related to the impact of technology transfer are more straightforward. Spin-offs usually increase the number and amount of research contracts with universities, particularly in their initial phases of development, because they often externalise their R&D activities (Pérez and Martínez 2003). As a natural result, technology transfer is expected to positively influence teaching and research by creating opportunities for doctoral theses or master's degree projects. However, and on the one hand, there is literature that empirically demonstrates a non-significant or even negative relationship between technology transfer and regional contribution. For example, Harmon *et al*. (1997) showed that technology transfer processes were successful, but without any substantial evidence that they significantly contributed to both new business and job creation. Additionally, they warned scholars and policy makers to be cautions with the notion that new or high technology firms will have any direct economic impact (Harmon *et al*. 1997).

On the other hand, as aforementioned, entrepreneurship research most often assumes—or does not question—the importance of university spin-offs. Nor does it investigate in detail the potential dissimilarities that may exist between spin-offs from the same or different support institutions. One can find in the entrepreneurship literature sentences such as "spin-offs create wealth" (Hindle and Jencken 2004; Wright *et al*. 2004; Mustar *et al*. 2006), "spin-offs create jobs" (Steffensen *et al*. 2000; Clarysse *et al*. 2005) or other similar statements on the general idea that spin-offs provide many benefits to universities and the region, statements typically complemented with some absolute figures. In this array of literature spin-offs are always seen as valuable entities that play a key role in enhancing local economic growth and foster job and wealth creation, all of which are closely related, or emerge from, innovation and management practices (Ireland *et al*. 2001; Shane 2004). Yet again, the role of university personnel seems crucial given its direct relation to innovation and, on most

occasions, to the spin-offs' administrative tasks. We thus propose that a positive relation exists between employing university personnel and firm efficiency.

The caveat of most reviewed studies is that they fail to give a definitive answer to how to empirically assess spin-offs' efficiency. Problems with evaluating spin-offs from both the firms' and the regional institutions' standpoints may well appear when variables are not defined systematically. We propose that one should carefully account not only for the usual firm inputs and outputs but—and maybe more important for the objectives at hand—for regional institutional variables that directly support spin-offs, and for variables that foster regional growth. For instance, in the absence of institutional support for technology transfer, universities may simply lack the correct incentives for spin-off creation, and hence direct their efforts only towards teaching and research.

Through our proposals we reach a basic research design based on the appropriate variables for assessing the regional efficiency of firms from university-based support programmes. We first identify the regional objectives of the promoting institutions. These can be broadly expressed as enhancing regional development, with economic growth as a central factor. In addition, regional policies usually adopt a twofold perspective: wealth and job creation. In the specific case of university spin-offs, innovation—measured via patents generated—plays an essential role. While pursuing these objectives, regional institutions offer several types of assistance (resources). These can also be categorised into two blocks, and follow our proposition to account for economic and infrastructure aid. First, the most common resources consumed for incentivising spin-offs' creation are the grants and other financial aids. Institutions employ these channels to increase the firms' capital, a main contributor to the productivity growth of (Spanish) regions (Badunenko and Romero-Ávila 2012). Second, various services can be offered to spin-off companies (*e.g.* free use of infrastructure or needed technology) to ease the early development processes.

We can now propose the variables' categories that that are operationalized and defined in detail in Section 4.2. We isolate inputs (resources) such as grants or economic aid and external services (from the regional institutions), and funds received from contracts and expenditures (traditional economic and accounting variables). As a natural output for firm and growth we can consider the firms' generated revenues. Regional and institutional-specific outputs are the number of patents generated and the number of jobs created. In-depth assessments should include all these dimensions and be flexible enough to allow for productive specialization, which was previously found to have a close relationship with the efficiency of Spanish regions (Maudos *et al.* 2000). Finally, according to most related literature and our propositions above the level of innovation and the type of employed personnel potentially affect spin-off efficiency and hence this relation should be scrutinised (Ireland *et al.* 2001; Shane 2004).

3. Regional context and data

3.1. Regional environment and the Technological Trampolines

The R&D system of Catalonia is generally known for the resources it employs. This region includes one sixth of the Spanish population (about seven million inhabitants in an area of 32,000 square kilometres), and—before the financial crisis—it generated around 35% of high-technology exports, 22.50% of the R&D expenses and approximately a quarter of the industrial GDP (CIDEM 2006). Even in 2009 Catalonia's R&D spending was of 1.68% of GDP, and the region employed about 46,000 researchers (ACC1Ó 2011). Additionally, its innovation expenses are extensively sustained through the business sector.[4] Note at this point that we do stress that this study can be transposed to other regions or support programmes, situation in which one should identify the corresponding institutions and apply our research design to their characteristics.

In Catalonia—similarly to most other regions—the "third mission" is principally based on commercialising research. The academia-business interaction is mediated at regional level by the Centre for Innovation and Business Development (CIDEM, now named ACC1Ó), the initiator of the Technological Trampolines (TTs) project. The CIDEM was created in 1999 by the regional government to enhance the competitiveness of Catalan SMEs, mostly through innovation policies. Our interest is in one of its programmes: the university-level support for venture creation (CIDEM 2006). Within this mechanism, the CIDEM founded the so-called TTs to encourage and sustain business creation. These promote technology- and knowledge-based spin-offs from the academia, having as main objectives to detect, select, evaluate and offer advice to new projects. TTs usually provide services as: seminars or workshops to explain entrepreneurial activity, office spaces and related infrastructure, feed-back on business projects, assistance and management of intellectual property rights, and information and support for applying for public funding.

TTs were developed during the 2000s and are independent entities integrated in public universities. TTs have separate budgets from universities and the CIDEM funds all their activities apart from the necessary physical assets, provided by the university at no charge. Moreover, TTs have certain technological orientations and must follow the directions given by the CIDEM when choosing which spin-offs to support. In general, selected projects incorporate differentiating or unique technologies and are oriented towards global markets. The TT network has ten units located at different universities, all coordinated by the CIDEM.[5] Between 2001 and 2007 the CIDEM spent around 6,656,000 Euros (mostly as personnel expenses) for funding the TT network. Somewhat in

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[4] One can refer to ACC1Ó (2011), Serarols *et al*. (2009) or Criaco *et al.* (2013) for more detailed information on these issues as well as the TTs. We present here only the main characteristics and support programme mechanics of specific interest for our study.

[5] The ten universities that participate in the TT project are: IESE, Universitat Autònoma de Barcelona (UAB), Universitat de Barcelona (UB), Universitat de Girona (UdG), Universitat de Lleida (UdL), Universitat Oberta de Catalunya (UOC), Universitat Politècnica de Catalunya (UPC), Universitat Pompeu Fabra (UPF), Universitat Ramon Llull (ESADE and La Salle) and Universitat Rovira i Virgili (URV).

parallel, the CIDEM granted 10,180,000 Euros in participative loans, 2,396,000 Euros in other grants, and participated in a venture capital projects that invested 2,199,000 Euros in spin-offs.

Whereas, the CIDEM forms part of the public system, spin-offs sometimes receive support from other actors. These may be venture capitalists in search of profitable projects or foundations that promote entrepreneurship. It is thus important to also account for funding received from sources external to the regional support programmes, but embedded in the regional business environment. Jointly with the support of public and private institutions, this process of spin-off creation is grounded in the regional culture and attitude towards entrepreneurship. This further backs the proposition that the CIDEM and the TT programme cope better with the context and encompass the regional values.

3.2. Sample

The database is drawn from a specific project developed for the innovation support structures of the Catalan region.[6] A two-step methodology was used to build the sample. First, a qualitative stage validated the underlying research design and the questionnaire for the data gathering. For the second stage, all spin-offs created within the TT network placed at Catalan universities were considered. These were a total of 335 firms, out of which the valid registers, after excluding deceased and unreachable firms, were of 262. Primary data were gathered during 2007-2008 through structured telephone and self-administrated Internet surveys. For the core part of the questionnaire, respondents had to indicate the services used from the TTs, jointly with key financial and other types of data on founding team, employees and all types of economic aid obtained. This process yielded 94 valid questionnaires (*i.e.* with complete answers to all questions necessary for this study). The financial information provided by the participants was validated and complemented using the SABI database.[7]

The survival rate of these analysed firms at the end of the year 2011 was of approximately 73%, a very promising figure for the support programme considering the well-known financial distress endured during 2008-2011. The oldest firms in the sample were created in 1998 and the youngest in 2007. Nevertheless, more than 86% of these spin-offs were created after 2002. They have on average between 6 and 7 employees (2 to 3 of which represented personnel from the parent university). Therefore, the sample comprises very young and small technology-based spin-off firms. In addition, it includes three activity areas: (a) technological sciences (*i.e.* computer science and engineering, 73 firms), (b) bio-chemical industries (*i.e.* pharmaceutical, biological or chemical industries, 16 firms), and (c) firms dedicated to employing technology in the social sciences area (5 firms).

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[6] Another paper that uses TT data is Criaco *et al.* (2013), which does not adopt neither a regional studies nor an efficiency analysis orientation and has fundamentally different methodology and objectives from ours. Also, their use of the data is cursory with respect to the variables of interest for efficiency measurement.

[7] The SABI (*Sistema de Análisis de Balances Ibéricos*) database is provided by Bureau van Dijk and includes detailed financial statements, as well as other variables for Spanish enterprises.

When collecting data, the researchers noticed that some of the spin-offs in the sample did not completely fulfil Pirnay *et al.*'s (2003: 356) definition, according to which university spin-offs are "new firms created to exploit commercially some knowledge, technology or research results developed within a university". That is, various entrepreneurs stated that, even if they had received support from the TTs placed at Catalan universities, they did not have a clear relationship with the parent university; they just wanted assistance in applying for public funds. Others suggested that they were not exploiting technology developed within the university. However, cross-checking across the available data clearly indicated that for all cases there was an obvious practical (and not only theoretical) link between each firm and a certain university belonging to the TT network. Having this in mind, the traditional definition was revised to include three different groups of spin-offs:

- Group 1: Spin-offs with formal technology transfer agreements (STTU).[8] These spin-offs have a formal technology transfer agreement with the parent university (*e.g.* patents, know-how contracts, equity, or contract research). Thus, this group fulfils to a complete degree most definitions that can be found in the literature.

- Group 2: Spin-offs that incorporate personnel from the parent university (SPU).[9] These spin-offs integrate at least one member from the parent university within their current staff or founding team. This group does not include firms that have formal technology transfer agreements with the parent university. However, these firms do employ technology that was developed within a certain university placed within the TT network and their activity is run at least partly by university members. Hence, SPUs fulfil to a medium degree most definitions in the literature.

- Group 3: Other spin-offs (OSU). According to the responses received during the primary data gathering, this group does not incorporate members from the parent university, nor does it have any formal agreement with the parent university. In this sense, firms in this category are not the usual spin-off firms and therefore we call them other spin-offs since they do appear in the TT network database. We do consider them spin-offs—even if they are less so than STTUs and SPUs—given that these are start-ups were placed and developed at a certain university of the TT network where they received infrastructure support and funding from the programme. Additionally, the researchers who compiled the database have had, jointly with the official information from the TTs, indications that these firms indeed benefited from support from the universities of origin within which they continued to be embedded.

[Figure 1 about here]

Once set the theoretical classification of the spin-offs, it is of pivotal importance to understand how all firms fit into the analysed sample, jointly with their interpretation according to the theoretical underpinnings. Figure 1 illustrates how the three types of spin-offs are embedded in universities and TTs. The first rationale is that all firms benefited from TT support and are specifically linked to a

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[8] This is equivalent to the "direct research spin-offs" identified by Hindle and Yencken (2004).
[9] This is equivalent to the "indirect spin-off" identified by Nicolau and Birley (2003).

university of origin from the TT network. This defines their specific (and homogenous) technology in terms of available resources (*i.e.* inputs and know-how) and outputs desired by regional support institutions.[10] Thus, they are comparable among each other, but not suitable for benchmarking against other types of firms that did not receive TT support.

The second rationale makes a similar point but is further integrated in our theoretical underpinnings. Figure 1 shows how each type of firm makes use of resources and capabilities (*i.e.* know-how) available from the universities and TTs. Foremost, all firms have access to the same type of funding and infrastructure support, and differ only in terms of their embeddedness into the university-TT mechanism. In inverse order with respect to our above classification, OSUs are the less embedded firms, as they make use of the general infrastructure, funding and know-how. SPUs, add to these general resources and capabilities, the specificity of the university human capital that is integrated and then maintained within the firm. Finally, STTUs not only use the general and human specific resources and capabilities, but also include a contractual perspective to knowledge specificity through the formal technology transfer agreements they have stipulated with the parent university.

4. Efficiency measure, variables and stages of analysis

4.1. Efficiency measure: *The proportional distance function*

TT networks represent complex settings that pursue multiple regional objectives, but act uncertain environments. On the one hand, this implies that various outputs must be expanded simultaneously, while also controlling for input quantities. On the other hand, efficiency levels should be provided accurately even if the real technology distribution is unknown. In these conditions literature usually employs non-parametric efficiency measures based on DEA (see Ray (2004) for detailed descriptions). These methods approximate true but unknown technology frontiers. Also, since they are non-parametric, no a priori technological restrictions are imposed on the sample distribution and no availability of prices is necessary. DEA computes the degree of inefficiency separating a certain firm from the best practice efficiency frontier. In this sense, frontier analysis is a more complex technique for benchmarking the relative performance of firms. Moreover, as opposed to single ratio methods, these technical efficiency estimations permit either to expand various outputs with no more inputs, or to contract various inputs maintaining the output level constant.

However, this last characteristic of traditional efficiency estimators represents a shortcoming for our analysis. That is, from both the TT network's and the spin-offs' perspectives, output expansion is a desired objective. Nevertheless, for the regional institutions, simultaneous input contraction is of equal importance. Efficient input use is a crucial aspect for the support programmes that aim to obtain the maximum amount of output with the minimum provided aid. This policy angle is of increased

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[10] The inputs and outputs—generally defined in the section on theoretical underpinnings—are described in detail in Section 4.2.

importance on the background of the recent financial crisis, which forced local administrations to cut budget spending in all areas. Actually, many press articles from leading Spanish newspapers indicated during 2010-2012 that cutting R&D spending was a priority for the deficit control measures.

One solution is to utilise the directional distance functions proposed by Chambers *et al*. (1996). The advantage of these directional functions is that, instead of focusing only on input or output orientation (as traditional DEA measures do), they account for output expansions and input contractions simultaneously. Within this family of distance functions a special case is represented by the proportional distance function defined by Briec (1997). This function is especially useful for analyses that account for firm-specific characteristics, since each unit chooses its specific direction when measuring its performance against the best practice frontier.

Let $\mathbf{x} = (x_1,\ldots,x_N) \in R_+^N$ and $\mathbf{y} = (y_1,\ldots,y_M) \in R_+^M$ be the vectors of inputs and outputs, respectively, which form the technology T, representing the set of all output vectors ($\mathbf{y}$) that can be produced using the input vector ($\mathbf{x}$):

$$T = \{(\mathbf{x}, \mathbf{y}) : \mathbf{x} \text{ can produce } \mathbf{y}\}. \tag{1}$$

Following Briec (1997: 105), the proportional distance function to estimate the efficiency of firm k' is defined as:

$$D(x^{k'}, y^{k'}) = \max_{\delta} \{\delta : ((1-\delta)x^{k'}, (1+\delta)y^{k'}) \in T(\mathbf{x}, \mathbf{y})\} \tag{2}$$

or as the solution to the following linear programming problem:

$$D(x^{k'}, y^{k'}) = \max \delta$$

$$\text{s.t. } \sum_{k=1}^{K} \lambda^k y_m^k \geq y_m^{k'} + \delta y_m^{k'}, \ m = 1, 2, \ldots, M;$$

$$\sum_{k=1}^{K} \lambda^k x_n^k \leq x_n^{k'} - \delta x_n^{k'}, \ n = 1, 2, \ldots, N; \tag{3}$$

$$\sum_{k=1}^{K} \lambda^k = 1;$$

$$\lambda^k \geq 0 \ (k = 1, 2, \ldots, K).$$

Note that this specification assumes variable returns to scale, an important issue when dealing with firms of different sizes that develop their activity in dynamic sectors. Efficient firms are indicated by a score of 0 (*i.e.* $D(x^{k'}, y^{k'}) = 0$), while the inefficiency degree of units below the best practice frontier is shown by positive values of $D(x^{k'}, y^{k'})$. Figure 2 illustrates the proportional distance function assuming a simple technology of one input and one output.

[Figure 2 about here]

Observe that points A, B and C form the best practice convex efficiency frontier, whereas the rest of the (inefficient) units are enveloped below this frontier. For instance, to reach the frontier, points D and E must expand outputs and contract inputs as shown by the positive results (*i.e.* the inefficiency degrees) of $D(x^D, y^D)$ and $D(x^E, y^E)$, respectively. The directions of these two functions

are given by the proportional expansion (contraction) of the employed outputs (inputs). Moreover, the efficiency results consider convex combinations on the best practice frontier as benchmark points.

4.2. Inputs, outputs and final sample

Inputs and outputs are specified according to the theoretical underpinnings in Section 2 and our specific dataset. We evaluate performance from two regional standpoints: scrutinising firms as fund receivers and as creators of regional value. Figure 3 illustrates the variables that can be classified into three categories and shows how these enter the efficiency measure as inputs or outputs: (a) inputs from regional support institutions and other production inputs for economic growth, (b) commercial outputs that are main firm-level economic growth objectives but also produce regional development, and (c) desirable outcomes from the public policy perspective (*i.e.* job generation for regional development). Considering the regional goals, category (a) is used as inputs, while categories (b) and (c) are outputs for the efficiency analysis. Descriptive statistics corresponding to inputs and outputs are shown in Table 1.

[Figure 3 and Table 1 about here]

In Figure 3—similarly to the equations in Section 4.1—x_1 to x_4 represent the inputs, whereas y_1 to y_3 denominate the outputs. Let us sequentially explain the source and content of each of the seven variables. The first two inputs, grants (or similar economic aid) (x_1) and services used (*i.e.* university and TT network infrastructure) (x_2) are provided by the regional support institutions. x_1 is the absolute monetary value of the funds received directly via the TT programme. For the services used (x_2) data included only aggregated monetary values jointly with the types and numbers of times infrastructure support was used by each firm. We thus computed the weights corresponding to each firm's use of TT services, and employed these weights to allocate the monetary values that proxy to the best possible extent how much each firm benefited from the available infrastructure. Note that these two variables have been created using primary data and are specific to the firms in our sample. The next two inputs capture aspects of typical economic activity. Firms were asked to state the monetary amount of R&D contracts (x_3, excluding any funding from the TT), and the value of operating expenses ((x_4, excluding wages—a component of the job creation variable (y_3)—and any expenses covered by the TT).

On the outputs side, we define revenues (y_1) as the total income received, which represents the primary source of earnings and cash flows associated with operating activities. Moreover, most accounting definitions converge on the fact that generating revenues is the ultimate (short- or long-run) goal of the firm. To reach the complete regional perspective described in the theoretical underpinnings we then introduce the number of patents (y_2), and the number of jobs created (y_3) (computed as the sum of full time employees and half of the part time ones, the result of which is read as total full time employees). Both (y_2) and (y_3) are included as two separate outputs that represent—according to the conceptual framework—two key objectives to pursue when instituting regional

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support programmes. All inputs and outputs are at their 2007 levels. Provided that the sample comprises young firms with significant activity fluctuations during their initial market phases, we assume that growth levels may be approximated by the 2007 absolute value. This decision is also recommended by the high amount of zero values encountered for the first years of activity, and constrained by the availability of the primary data essential for this study.

Next, as indicated by previous literature, tests were run for identifying potential outliers. It is well established that extreme points may influence the shape of the estimated efficiency frontier and produce bias in the obtained scores. The seminal contributions of Andersen and Petersen (1993) and Wilson (1993) are generally employed for outlier detection. Potential outliers are identified through super-efficiency scores, and are sequentially removed from the sample and each time the efficiency is re-estimated. Additionally, as proposed by Prior and Surroca (2010), this process is repeated until the null hypotheses of equality between successive efficiency scores cannot be rejected. After eliminating outliers the final sample is composed of 81 spin-offs.

Finally, let us provide a simple numerical example to enhance the efficiency interpretation introduced in Section 4.1 and explained with the help of Figure 2. For illustrative purposes, suppose that a fictitious firm has the following input and output vectors: $(x_1, x_2, x_3, x_4, y_1, y_2, y_3) = (200, 700, 100, 900, 2500, 2, 8)$, and a corresponding distance function estimation $\delta = 0.3$. This result indicates the inefficiency degree of the analysed unit, which is also the distance to the benchmark frontier formed by the best performers (see Figure 2 and its explanation). To be efficient (*i.e.* on the best practice frontier), this firm should expand revenues (y_1) by $2500 \times 0.3 = 750$, patents (y_2) by $2 \times 0.3 = 0.6$ (in practice, one more patent), and jobs (y_3) by $8 \times 0.3 = 2.4$ (in practice, three more employees). It should have simultaneously used less grants (x_1) by $200 \times 0.3 = 60$, and fewer support services (x_2) by the value of $700 \times 0.3 = 210$. Also, it should contract R&D contracts (x_3) by $100 \times 0.3 = 30$, and operating expenses (x_4) by $900 \times 0.3 = 270$.

4.3. Stages of analysis

The remainder of this paper presents the empirical results and their subsequent discussion and implications. This is done according to the following stages of analysis. First, the efficiency results as defined by expressions (1) to (3) are presented. Second, the descriptive efficiency interpretations are further complemented with a second stage regression analysis to study the relationship between efficiency and key explanatory factors that capture the level of innovation and the different types of employed personnel, while controlling for types of spin-offs and universities of origin. One can assume the following specification:

$$D(x^k, y^k) = \alpha + \beta \mathbf{Z'^k} + \varepsilon^k, \quad k = 1, 2, \ldots, K, \tag{4}$$

which is the approximation of a true but unknown relationship. In (4) α is the constant term, ε^k a random error term (*i.e.* statistical noise), and $\mathbf{Z^k}$ is a vector of variables thought to explain efficiency ($D(x^k, y^k)$) through the parameters $\boldsymbol{\beta}$ (common for all k) that are estimated.

Literature indicates that the appropriate estimation model is a truncated regression, since the estimated efficiency results are constrained by definition to be equal to or greater than 0 (*i.e.* $\delta^k \in [0, \infty)$).[11] For our model we substitute the true but observed regressand in equation (4), $D(x^k, y^k)$, by the estimate of the linear programming problem in (3), δ^k. Thus, the model is now:

$$\delta^k \approx \alpha + \boldsymbol{\beta} \mathbf{Z'^k} + \varepsilon^k, \quad k = 1, 2, \ldots, K, \tag{5}$$

which is estimated by maximizing its corresponding likelihood function with respect to $(\beta, \sigma_\varepsilon^2)$ and given the data.

For the firm-specific characteristics and controls, the following variables are used: number of employees from the university of origin, number of employees holding a PhD, number of employees holding an engineering degree, number of patents divided by number of total employees, firm age and dummy variables for the university of origin and for the type of spin-off (*i.e.* STTU, SPU or OSU).

Next, a supplementary second stage analysis is run with a more entrepreneurial rather than regional focus. To observe the relation between future fundamental firm profitability and efficiency, we estimate the following OLS regression:

$$(EBITDA / employee)_t = \alpha + \theta \delta_{t-1}^k + \boldsymbol{\beta} \text{Controls}_{t-1}'^{\mathbf{k}} + \varepsilon^k, \quad k = 1, 2, \ldots, K. \tag{6}$$

Note that the ratio of EBITDA (earnings before interests, taxes, depreciation and amortization) to total employees is an accounting measure appealing to economists who advocate for the use of fundamental profitability measures, which are difficult to manipulate by the selection of different sources of financing and accounting decisions. Therefore, firms with problems in this ratio have fundamental issues with their operating activity, and consequently with their profitability.

5. Empirical results

Efficiency results indicate that 15 of the analysed spin-offs (approximately 18.5% of the sample) form the best practice frontier. These have a score of 0, while higher values indicate the degree of inefficiency. Table 2 reports the efficiency for the total sample as well as by spin-off type. Their associated distributions can be observed in the different panels of Figure 4, for each of the three spin-off types and for the total sample. One can notice that mean sample inefficiency is of 0.37, a value consistent with the 0.35 median inefficiency level. Furthermore, percentiles illustrate the distribution of these total sample scores, with units below or at p25 experiencing rather low inefficiencies (less or equal to 0.08), and units at p75 or above showing high inefficiencies (greater

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[11] We are using a truncated regression since, if applied under our sample's conditions, standard linear techniques would be conceptually wrong and parameter estimates would be inconsistent (Greene 2003).

than 0.59). In Figure 4 the scores' distribution for the total sample becomes more obvious as, for instance, one can note that many of the analysed units fall below the 0.2 inefficiency level.

[Figure 4 and Table 2 about here]

More insights into the scores' distribution are attained at spin-off type level. Propositions developed in our theoretical underpinnings suggested that the first group (*i.e.* STTU—spin-offs with formal technology transfer agreements) should be the most efficient ones, due to their superior level of embeddedness in the support mechanism (see also Figure 1). This is partly true. Although at mean level the inefficiency of this group is slightly higher than for the other two groups (*i.e.* 0.38 as compared to 0.37 and 0.35 for SPU—spin-offs that incorporate personnel from the parent university—and OSU—other spin-offs—, respectively), this is the group with the highest percentage and absolute number of efficient firms. This can be easily observed in Table 2 through the 0 value (which designates efficient units) reported at p25. Also, the same conclusion can be drawn by scrutinising Figure 4, which shows that many of the efficient firms are STTUs. However, the lower median and p75 levels of the STTUs reveal that this group also comprises many spin-offs with quite high inefficiency. Since these spin-offs are embedded to a higher degree in the university, one policy implication could be that more accurate monitoring systems from regional support institutions may be needed to check for extreme cases *ex ante* and *ex post* transfer agreements. In contrast, the other two groups have similar mean inefficiencies and, even if at p25 the OSUs are more efficient, at p75 inefficiency is roughly the same. Moreover, the second and third panels of Figure 4 illustrate that, while the OSUs have a higher relative number of efficient firms, in absolute terms the SPUs include more efficient firms (as well as more firms with higher inefficiency).

[Table 3 about here]

Results by university of origin are presented in Table 3. Rankings can be devised to include all universities, however, considering that many of these comprise very low numbers of observations one should focus on the first four institutions. Scores at all levels indicate that most of the efficient spin-offs or spin-offs showing lower inefficiencies originated from UPC and La Salle. Both include firms with the lowest mean, median and p75 inefficiency levels, and furthermore put forth efficient spin-offs at their associated p25 levels. These results are in line with our theoretical propositions, as UPC and La Salle are universities with more technological background than their counterparts and are thus expected to be better at selecting and supporting successful projects. Methods used at these universities' TT offices could be carefully reviewed for potentially generalised use that may reduce the heterogeneity observed, for instance, among STTUs. At the opposite extreme, spin-offs from UAB show the highest inefficiencies both at mean and at percentile levels, and are followed by firms from UB that have slightly (but not significantly) higher efficiency levels. Among the rest of the analysed universities, URV and IESE have the best results. Nevertheless, a maximum of two spin-offs originated from these last five universities, making it is rather difficult to interpret efficiency.

[Table 4 about here]

Next, regression analyses use efficiency estimates as dependent variables to reveal the relationships between this assessment of regional objectives and various firm characteristics. The explanatory variables and controls are introduced as described in Section 4.3.[12] Our key independent variables are employees from the university of origin, the different types of personnel and patents divided by total number of employees.[13]

Main findings from Table 4 indicate that having more employees from the university of origin is related to less inefficiency (see the negative sign in the parameter estimate). This is yet another result in line with our propositions derived from the theoretical background of the study (see also Figure 1), and appears consistently so in models 1 and 2, which also reveal that the % of PhDs or engineers has no significant relation with efficiency. However, in model 3 one observes that what seems to matter more is having PhDs from the university of origin (see the significant and negative coefficient of the interaction term "workers from university $\times$ % of PhDs").[14] These findings initially suggested that academic knowledge is not necessarily useful in the market (PhD and engineer degrees not significant), which is consistent with existing literature that indicated a need of upgrading management skills (see, *e.g.*, Chapple *et al.* (2005)). Still, specific academic knowledge or experience related with the university of origin seems to make a difference when employees hold PhD degrees and also are from the university of origin. This type of employees could have a competitive edge when gaining market experience, which is known to positively affect efficiency (see, *e.g.*, Alvarez and Crespi (2003)). Indeed—in both theoretical and practical terms—it seems that retaining a PhD from the university of origin to continue working in the firm could create an interaction between embedded resources and specific capabilities that is positively related to efficiency (see Figure 1). On a related note, Criaco *et al.* (2013) analyse Catalan TT firms and find that using university human capital enhances spin-offs survival. However, their approach is fundamentally different from ours, since they focus only on founders' human capital and exclusively on firm survival, without linking it to regional objectives or efficiency.

Another result consistent with the conceptual framework is the negative relationship between patents/employees and inefficiency. That is, a higher ratio of number of patents per employees leads to lower inefficiency. Moreover, the parameter estimate of this variable is rather high in all three models. To corroborate these results, observe in Figure 5 how—for each spin-offs' category and for the total sample—higher efficiency is associated with higher number of patents. Also, extreme results such as very high inefficiency levels are related with very low number of patents. All these outcomes

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[12] For robustness, we have also run truncated regressions with bootstrap (2,000 replications) and results did not change their tenor.

[13] Note that patents/employees is a variable that is not present in the efficiency analysis. Both patents and number of employees appear as outputs in equations (1) to (3) and therefore their ratio is not computed. Furthermore, keep in mind that for the model in equation (3) more output (*e.g.* more patents or a higher number of employees) does not imply higher efficiency.

[14] The correlation between these two variables is 0.054 and it is not statistically significant.

involving the role of innovation are in line with our theoretical foundations (to name just a two of the many studies, see Ireland *et al.* (2001) or Shane (2004)).

[Figure 5 about here]

Observe next that dummy variables for the university of origin show that spin-offs for UPC and La Salle have lower inefficiencies. This confirms the descriptive statistics and upholds the proposition that universities with more technological background produce more efficient spin-offs. An interesting result is that spin-offs with formal technology transfer agreements (STTU) are associated with a positive and significant coefficient, meaning that less efficient firms belong to this group. This upholds the mean or median results in the descriptive statistics in Table 2. Nevertheless, keep in mind that the STTU group also contains most efficient units, which are now truncated from the distribution. This result is a clear illustration of how the two stages of the analysis complement each other. Controls for firm age and activity area are not significant.[15] Failing to find significant parameter estimates linked to the controls for activity area supports the assumption of a homogenous technology defined through the specific variables for this sample of spin-offs.

[Table 5 about here]

A last set of empirical results takes a more entrepreneurial (*i.e.* individual firm) rather than regional development (*i.e.* local institutions) perspective. Table 5 presents the relation between future fundamental profitability and its relation to efficiency. Expectations are met as we find a negative relationship between inefficiency from a regional development perspective and EBITDA/employee. Results become significant when two lags are used (*i.e.* efficiency in 2007 and profitability in 2009, specification (2 or 4)). Accordingly, firms require about two years for generating profits from improvements in efficiency. This result is relevant for the entrepreneur, as it reveals that higher efficiency from a regional perspective is positively associated with higher medium-term fundamental profitability, which on most occasions indicates that no crucial problems exist with respect to core operating activities. Note also that results are robust to controlling for firm age and size (number of employees), as well as, alternatively, for type of spin-offs and university of origin.

6. Concluding remarks and policy implications

Recent literature highlights the importance of support for venture creation, and the particular value added of regional assistance mechanisms for university spin-offs. However, there is still little evidence on regional programmes' objectives and their operationalization into resources (inputs) used to produce regional value (outputs). Managerial economics frameworks assume that specific resource configurations—given here by the regional support and other usual inputs—determine regional value added—outputs—as required by regional institutions' objectives. We contribute to the regional studies literature in at least two ways: (1) we detect and conceptualise the specific regional objectives

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[15] Models including controls for activity area are not presented in Table 5 for the sake of brevity.

and the associated inputs and outputs needed to assess the regional efficiency of firms created at university-based support units, and (2) we provide empirical insights into these regional programmes.

The first contribution is methodologically achieved by means of directional distance functions that yield a global efficiency indicator matching the multiple regional goals.[16] Theoretical underpinnings show that firms need not only to maximise revenues—a general firm objective for survival and growth—but also to generate more patents and jobs, which are some of the main long term goals of regional institutions. Simultaneously, policy makers face budget constraints and must identify efficient input use. Thus, we account for contraction in employed resources as well (*e.g.* minimising financial aid and/or using less support infrastructure). This latter point is of increased importance on the background of the financial crisis, as, for instance, the Spanish deficit control measures instituted during the economic downturn specifically aimed at minimising R&D spending.

The second contribution is to assess spin-offs created within the so-called Technological Trampolines' (TTs) placed at Catalan universities. This regional setting is ideal given the pre-crisis R&D investment propensity of the region. Additionally, we benefit from a sample of firms with homogenous technology in terms of available support resources and regional objectives, but with different levels of embeddedness into TTs and universities (see Section 3.2 and Figure 1 for details). This offers the possibility of assessing their efficiency from a regional perspective. Additionally, all results have a benchmarking nature which makes them appealing to policy makers who can pinpoint which types of spin-offs are best practices and which characteristics or TT locations are associated with different levels of efficiency. After a cursory overlook, the support programme seems to have been successful, as the survival rate of the analysed firms at the end of the year 2011 was of roughly 73% (rather high considering the well-known financial distress endured during 2008-2011).

Main descriptive results show that the best practice frontier is mostly shaped by spin-offs with formal technology transfer agreements, an encouraging result for the supporting institutions. Additionally, many of the efficient spin-offs originated from universities with more technological background, thus indicating that institutional experience in innovation is positively associated with achieving regional goals. Since in these two exemplified cases spin-offs are embedded to a higher degree at the TT and university levels, one regional policy implication is that monitoring systems from support institutions may check more thoroughly for extreme cases *ex ante* and *ex post* transfer agreements. Methods used at thriving universities' TTs could be carefully reviewed for potentially generalised use that may reduce the heterogeneity among the firms that receive support.

These results are corroborated by the second stage analysis. Regression results show that employing university workers is associated with higher efficiency. Furthermore, while workers with PhDs do not seem to make a difference, having PhD holders from the university of origin is related with higher efficiency. In this sense, retaining a PhD from the university of origin generates a positive

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[16] Our specification is also less restrictive and assumes variable returns to scale, given that previous literature found or directly assumed decreasing (Chapple *et al.* 2005) or constant returns to scale (Siegel *et al.* 2003).

interaction between embedded resources and specific capabilities (see Figure 1). These findings may indicate that academic knowledge is not always useful in the market (a result consistent with previous literature, see *e.g.*, Chapple *et al.* (2005)), however academic knowledge jointly with experience related with the university of origin seems to make a difference for attaining regional objectives. This result is in line with the more narrow approach of Criaco *et al.* (2013) who find that for Catalan TT firms survival—with no specific link to regional objectives or efficiency of these—is enhanced if founders are university members. On a general note, one may say that management skills need upgrading (Chapple *et al.* 2005) but PhDs could have a local competitive edge when gaining experience, which is known to positively affect efficiency (see, *e.g.*, Alvarez and Crespi (2003)).

Yet another policy implication builds on the positive relation between patents (both in absolute and relative—size controlled—terms) and efficiency. It could therefore be useful for local administrations to provide incentives for patent development when aiming at efficiency productivity growth.[17] Moreover, patents could be used as a difficult to imitate signalling technique for efficient firms. Indeed, this could serve as another component of the aforementioned monitoring policy proposal for regional development. In fact, we show that when taking longer term view—at least from an entrepreneurial standpoint—results demonstrate a positive relation between efficiency according to regional objectives and fundamental profitability in subsequent time periods.

Note that our selection and monitoring arguments could be scrutinised in future research that adopts an evolutionary economics perspective. Policy making for investments in regional support programmes obviously benefits from the evolution of knowledge on firm and region mechanics. These rational evolutionary processes are crucial for designing institutions and enhancing productivity (see, *e.g.*, the seminar work on Nelson and Winter (1982) or the more recent efforts of Winter (2002) for a comprehensive view on evolutionary processes and production theory). These views may be integrated in research on regional clusters and worker mobility. For instance, existing literature has presented models of cumulative innovation with endogenous technology spillovers that are generated via worker turnover (see, *e.g.*, Fosfuri and Rønde (2004)). Another connected evolutionary perspective is whether institutions aim at getting better at generating more surviving new technology firms—as the CIDEM has tried via the TTs—or at finding star firms, as it many times happens at US universities that also benefit from more extensive venture capital support.

A strong policy implication for the potential realisation of these research suggestions and the corroboration of our results is the need of regional investments in creating databases that provide detailed longitudinal data for scrutinising the impact of support programmes. Among other things, one could look at the long run impact of retaining workers with PhD degrees, which we are unable to assess with the available data. Ideally, these databases could be matched across regions to determine

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[17] These incentives may well arrive in the form of additional capital provided by regional institutions. Such policies might generate productive specialization and their impact could be compared with the results obtained for Spanish regions by Maudos *et al.* (2000) or Badunenko and Romero-Ávila (2012).

whether it is correctly assumed that supportive regional environments are catalysts for the efficiency of regional programmes. Indeed, proper resource allocation (*e.g.* devote more resources to intellectual property than to assistance in writing the business plan) and selection criteria (*e.g.* focussing more on supporting spin-offs with formal transfer agreements) could lead to regional projects with positive effects on long-run performance and the technological level of the region. While all our policy recommendations aim at desirable outcomes, research also indicates that regional support for higher technology brings about greater coordination costs (Zabala-Iturriagagoitia *et al.* 2007).

Acknowledgements

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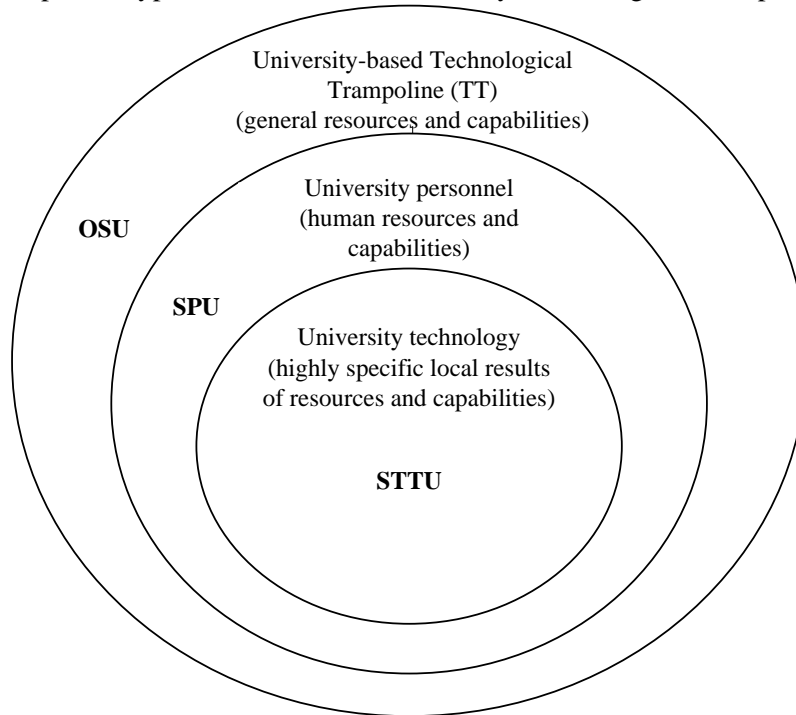Drucker, P.F., 1985. *Innovation and Entrepreneurship*. Harper and Row: New York.

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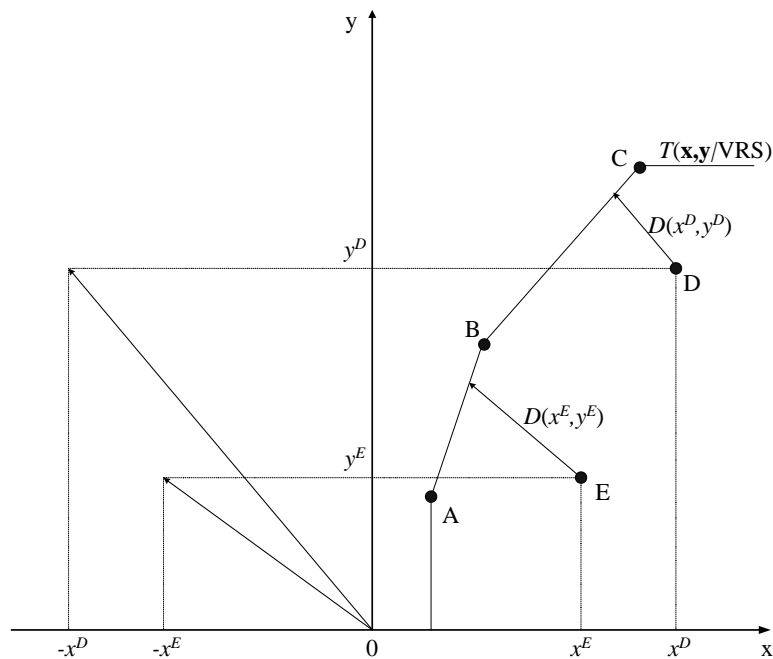
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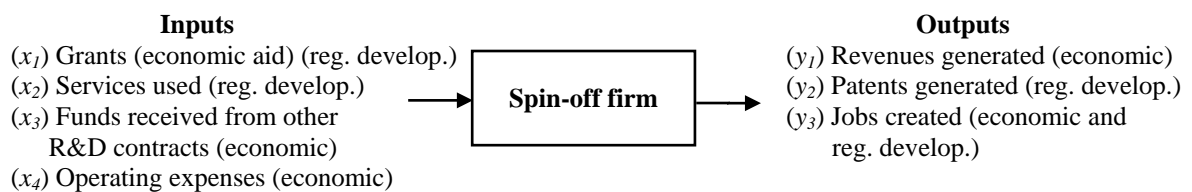
Figure 1: Spin-off type embeddedness at university Technological Trampolines (TTs)

University-based Technological
Trampoline (TT)
(general resources and capabilities)

OSU

University personnel
(human resources and
capabilities)

SPU

University technology
(highly specific local results
of resources and capabilities)

STTU

Figure 2: Efficiency measure: The proportional distance function

Figure 3: Inputs and outputs: A regional studies perspective

Inputs

(x_1) Grants (economic aid) (reg. develop.)
(x_2) Services used (reg. develop.)
(x_3) Funds received from other
R&D contracts (economic)
(x_4) Operating expenses (economic)

Spin-off firm

Outputs

(y_1) Revenues generated (economic)
(y_2) Patents generated (reg. develop.)
(y_3) Jobs created (economic and
reg. develop.)

Figure 4: Distribution of efficiency levels (by total sample and spin-off types)
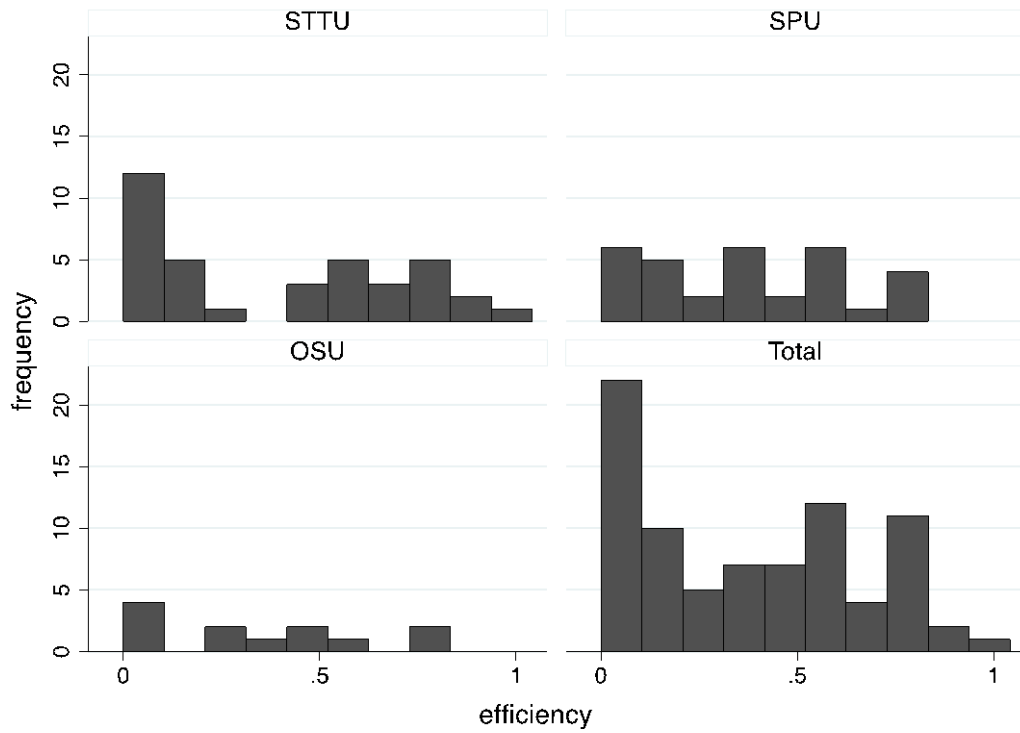
Figure 5: Efficiency and number of patents (by total sample and spin-off types)
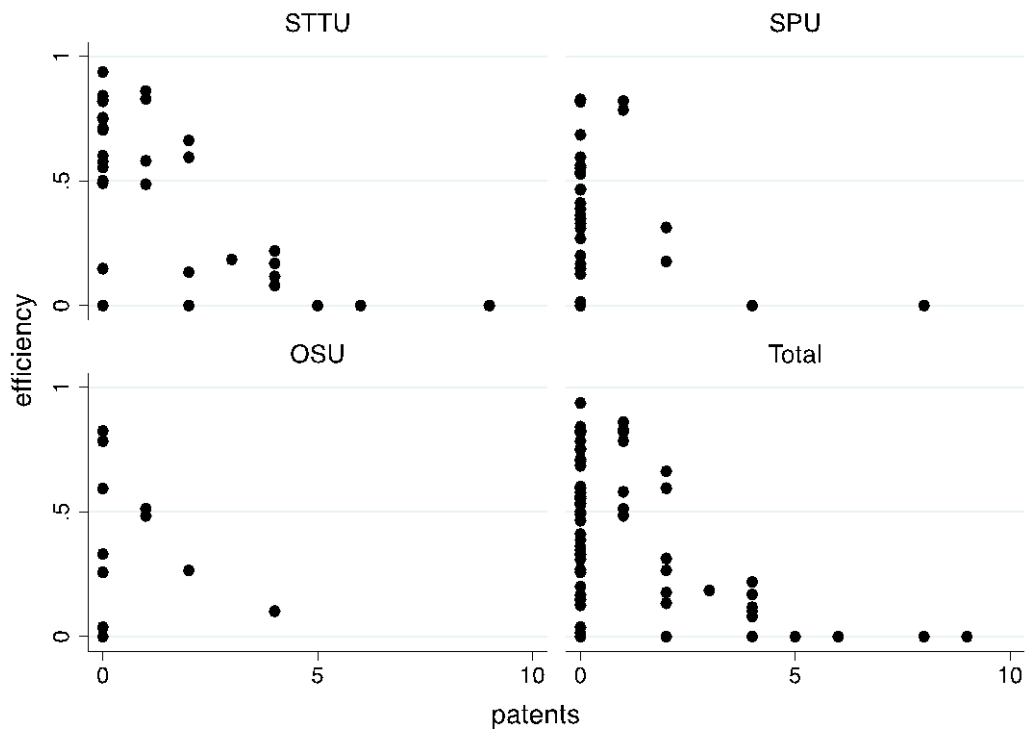
Table 1: Inputs and outputs: descriptive statistics

Inputs and Outputs	Mean	5% Trimmed Mean	Std. Dev.
(x_1) Grants (economic aid) (€)	27321.21	14527.00	76446.08
(x_2) Services used (€)	70625.68	67910.45	53228.31
(x_3) R&D contracts (€)	23862.96	11325.79	64301.90
(x_4) Operating expenses (€)	222246.20	143742.19	438045.20
(y_1) Revenues generated (€)	394853.40	270030.96	727482.60
(y_2) Patents generated (no.)	1.02	0.75	1.85
(y_3) Jobs created (no.)	8.23	7.07	8.12

Table 2: Efficiency by spin-off type and total sample

Spin-off type	Obs.	Mean	Std. Dev.	p25	Median	p75
STTU	37	0.3822	0.3389	0.0000	0.4869	0.7048
SPU	32	0.3669	0.2634	0.1582	0.3548	0.5439
OSU	12	0.3495	0.2921	0.0697	0.2982	0.5534
Total	81	0.3713	0.3007	0.0802	0.3475	0.5951

Table 3: Efficiency by university of origin and total sample

University of origin	Obs.	Mean	Std. Dev.	p25	Median	p75
Univ. Autònoma Barcelona (UAB)	13	0.5132	0.2704	0.3621	0.5525	0.7048
Univ. Politècnica Catalunya (UPC)	21	0.3058	0.2762	0.0000	0.3099	0.4909
Univ. de Barcelona (UB)	8	0.4623	0.3277	0.1517	0.5566	0.6723
La Salle	31	0.3152	0.2908	0.0000	0.2653	0.5809
Univ. de Girona (UdG)	2	0.5059	0.4539	0.1850	0.5059	0.8269
ESADE	2	0.7352	0.0704	0.6855	0.7352	0.7850
Univ. Pompeu Fabra (UPF)	2	0.5150	0.4448	0.2005	0.5150	0.8295
Univ. Rovira i Virgili (URV)	1	0.0000	.	.	.	.
IESE	1	0.0000	.	.	.	.
Total	81	0.3713	0.3007	0.0802	0.3475	0.5951

Table 4: Efficiency and its relation to spin-offs' characteristics

Variable	(1) Coef.	(1) Std. error	(2) Coef.	(2) Std. error	(3) Coef.	(3) Std. error
univ. empl.	-0.029*	0.015	-0.026*	0.015	-0.016	0.014
% of phd			-0.002	0.002		
% of bsc in engineering			0.001	0.001		
univ. empl. × % of phds					-0.001***	0.000
patents / empl.	-0.860***	0.210	-0.809***	0.203	-0.777***	0.196
uab			-0.153	0.141	-0.127	0.139
upc			-0.262**	0.133	-0.282**	0.131
la salle			-0.265*	0.137	-0.294**	0.129
ub			-0.180	0.156	-0.206	0.150
firm age	-0.008	0.019	-0.020	0.019	-0.018	0.018
sttu	0.250**	0.121	0.235*	0.130	0.210*	0.124
spu	-0.022	0.116	-0.059	0.118	-0.107	0.114
_cons	0.522***	0.101	0.773***	0.203	0.831***	0.160
obs.	66		66		66	
log likelihood	10.10		13.53		14.13	
Wald chi2	21.08		28.36		30.04	
prob > chi2	0.001		0.003		0.001	

Truncated regressions; truncated at lower limit (0); 15 efficient units truncated Dependent variable: efficiency; efficient units have scores of 0, values > 0 report the inefficiency degree. All variables are at their 2007 levels. *, ** and *** stand for significant statistical differences at 90%, 95% and 99% confidence levels, respectively.

Table 5: Fundamental profitability and its relation to efficiency

Variable	(1) Dep. var.: EBITDA/empl. 2008 Coef.	Std. error	(2) Dep. var.: EBITDA/empl. 2009 Coef.	Std. error	(3) Dep. var.: EBITDA/empl. 2008 Coef.	Std. error	(4) Dep. var.: EBITDA/empl. 2009 Coef.	Std. error
efficiency	-12524.8	8753.1	-27934***	10336.8	-10877	8670.4	-27475.4**	10255.6
firm age	1657.1	1383.1	-428.16	1565.9	1233.5	1413.9	-1019.4	1590.9
no. empl.	297.5	358.5	-95.8	406.4	446.2	364.8	91.8	413.6
sttu					785.7	8056.5	7002.7	9507.3
spu					11148.3	8456.8	16624.3	9996.6
_cons	2024.8	6150.3	20295.7***	7261.5	-3320.7	8847.6	10390.9	10406.8
obs.	69		65		69		65	
F	2.71		2.61		2.46		2.33	
Prob > F	0.052		0.060		0.042		0.053	
R-squared	0.111		0.114		0.163		0.165	

OLS regressions. Dependent variables for each model are indicated in the first row. Independent variables are at their 2007 levels. *, ** and *** stand for significant statistical differences at 90%, 95% and 99% confidence levels, respectively. Specifications controlling for university of origin have also been run and results do not change significantly.