INNOVATION PROCESSES IN TECHNICAL UNIVERSITIES - A NEW PERSPECTIVE

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The paper explores new possibilities of developing innovation processes in technical universities by using technology adoption and diffusion studies and the concept of technical level of the product. The process implies the employment of the engineering talent of young students. As a result it is proposed a new approach to the process of university technology development that could lead to an increase in the number of spinoff companies' creation. The approach consists of a new possible path in the process, which is based on further development of technology obtained by involving students in the process, as potential users.

Keywords: innovation, academic entrepreneurship, technology development, technology adoption and diffusion, socio-technical systems, user input.

1. Introduction

Innovation processes have become part of many technical university's every day activity. Although there is still much debate in the academic community regarding the universities' traditional missions of teaching and research versus the entrepreneurial component, the latter has constantly increased in importance over the last decades. Some authors even discuss about the "second academic revolution", which "transformed the university into a teaching, research and economic development enterprise" [1]. Technical universities, in particular, are favorably placed to engage in innovation processes.

The specialty literature distinguishes between different categories of academic entrepreneurship taking into account their degree of compatibility with the traditional view regarding the role of the university and of the university people in society. For example, in [2] the authors distinguish between five basic forms of academic entrepreneurship: (1) large-scale science (obtaining large, externally funded research projects), (2) earning supplemental income outside the university, mainly through consulting (knowledge transfer for personal gain), (3) soliciting funds from industry (capitalizing on university-industry relationships to

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provide new sources of funding for research), (4) patenting the results of research, and (5) forming companies based on the results of research.

Out of this array of possible entrepreneurial activities to be carried out within universities, this paper focuses on the processes of technology development in which the academics take direct involvement by forming companies. In what follows the terms “innovation processes”, “technology development processes” are used interchangeably. As Feldman [3] shows, the development of these processes, with universities at their core, can be the solution for technical institutions that are placed in declining industrial areas. Technical universities in Romania experienced a similar decline in the industrial activity, as their Swedish counterparts in Feldman’s example. They should also be active in developing such processes, but taking into account the specific conditions existing in Romania.

In particular, in looking at the process of academic entrepreneurship, this paper explores the possibility of technology development within technical universities using the engineering talent of young students. The literature on innovation emphasizes the role of the so-called lead user processes. These are designed to collect from lead users’ “information about both needs and solutions” starting from the assumption that “users outside the company have already generated innovations”. The hardest part of the process is to identify those users and be able to adapt their ideas to the business’s necessities [4].

The paper is looking to integrate lessons learned from the literature on technology adoption and socio-technical systems for the further development of technologies in order to create more spinoffs. The innovation process is approached from two directions: the technology adoption and socio-technical systems literature, which emphasizes the role of human beings, and, secondly, a primarily technical process that leads to the development of the product, by using the concept of technical level of the product [5,6]. Thus, it is considered that the innovation processes have a prominent technical side, but also a social one.

The research questions refer to the possibility of extending the processes of university technology development so that the number of university research inventions that are marketed increases. Is it possible to employ the input coming from engineering students regarded as users for the technology development? Which products could be selected for such processes?

Chapter two of this paper presents the processes of university technology development. Chapter three is dedicated to a brief presentation of the academic study regarding technology adoption and socio-technical systems. Chapter four is exploring how these theories can be extended to the university technology development by involving young talent of students as potential users of such technologies and the concept of technical level of the product.

2. The processes of university technology development

In [7], Shane describes the stages in the processes of university technology development: use of funded research, creation and disclosure of invention, decision to seek Intellectual Property protection, marketing the technology, licensing decision.

Only the first of these stages is related to the traditional research function of the university that of developing new knowledge, which is peer reviewed and recognized and, ultimately, published. In fact, this is an important aspect that distinguishes an industrial researcher from an academic scientist [8].

The other stages in the process imply the involvement of the Technology Transfer Offices' (TTO) experts, an entity directly connected to the entrepreneurial processes within universities. It is, in essence, a selection process. Thus, from a number of inventions that are disclosed by the faculty and students to the TTO, the experts there select the ones that are appropriate for investment in order to seek intellectual property protection. This represents the first stage of selection. Then, the TTOs and the inventors themselves are trying to find a licensee for these inventions. This stage has a rather low success rate due to the fact that the inventions are not very well-defined; they are "'embryonic'… most have not even reached the prototype state" [9].

The data shows that for universities with extended experience in this activity the success rate rarely exceeds 50% [10, 11]. This represents the second stage of selection.

It is important to state that this selection process is not one based on clear, well-defined criteria, but it also involves the prior experience, social ties and expertise of both the TTO experts and inventors.

For the majority of the inventions the licensee is an established company. In fact, in [7], Shane cites the report on the Association of University Technology Managers Licensing Survey from 2001, which states that approximately 86 percent of all licenses go to companies already in existence. For the other 14 percent a new company is created, a university spinoff as the specialty literature makes reference to this construct.

By licensing to an established company, the involvement of the academic scientists in the product development process is rather limited. In [7], Shane shows that "spinoffs are an effective vehicle for encouraging inventor involvement". There are three types of arguments that support this assertion. Firstly, the new companies provide an exciting working environment through "more interesting and more challenging projects" and by having "smarter employees". Secondly, start-up firms "focus more of their attention on technology development as opposed to other aspects of business". And last, but not least, there exist issues regarding financial compensation that can come in the form of equity in a new company, but only in the form of fees or royalties into an established company.

Other authors [12, 13, 14] show that some university people have taken another path for technology development processes that did not involve TTOs, i.e. another commercialization route. They also have another commercialization mode, they tend to establish a new company rather than license their invention to an existing one.

In fact, other researchers [2] used the criterion of equity held in companies with “products and services based on university research” to define this form of academic entrepreneurship as “direct commercial involvement”. In their research they found that this was the least common form of academic entrepreneurship with only about 7 percent of respondents holding equity in such companies, and only “a handful holding equity in more than one”.

So, for the remainder of this paper, the accent is put on spinoff companies, where the inventors from the academia can get involved more in order to see their invention developed in a product or service sell on the market.

The level of the inventor’s involvement can be further characterized if one analyzes who leads the effort to found the new company. Practice has shown that the entrepreneurs who lead the efforts to found university spinoffs are: the inventors themselves (inventor-led spinoffs), external entrepreneurs who license university inventions (external entrepreneur-led spinoffs) and investors who bring together inventors and entrepreneurs to create new companies (investor-led spinoffs).

University spinoffs are different from other new companies in two respects: their products need to be further developed both from technological point of view and from marketing point of view. Because of this, the specialists in technology transfer call them “minus two stage” companies. Thus, the entrepreneurs need “to establish proof of principle and then prototypes for their technologies” and also „to gather information about customer needs… as well as to obtain and incorporate customer feedback about the products and services that make use of their technologies” [7].

In [3], Feldman discusses the specific problems of engineers, which are the results of the industrial decline. He analyzes the processes of institutional transformation through entrepreneurial initiatives and by introducing IT technologies. Universities can become “creative spaces”, where young engineers can be attracted and, thus, the unemployment issues are resolved. Sometimes favored by government funding, universities can form “alliances” with other types of organizations: small or large companies, research institutes, technology transfer centers. One important stakeholder in the innovation processes is the “costumer”, the user of a new technology. Potential users can bring an important contribution to the design of a new product, both in term of utility, its practical character, its use in working environment, and also in terms of profitability.

3. Academic study of technology adoption and socio-technical systems

The study of technology adoption/use by human users has increasingly become over the past three-four decades an area of intense interdisciplinary academic study and practitioner interest. With the advent, since the 1960s and 70s, of more complex technological systems, often Information Technology (IT) based, or integrating IT together with other technologies, academics and practitioners (engineers, managers, etc.) have increasingly realized the importance of users' views, attitudes and behaviors regarding technology projects. Indeed, they were realizing that technology projects' success or failure (both in terms of development and implementation) depends to a great extent not only, strictly speaking, on the "technical" characteristics of the system but on the ways in which the system interacts with human users and with the social/work system and processes [15]. For this reason several authors proposed a re-conceptualization of technological systems as "socio-technical systems" and calling for increased attention on the social side of these systems and their design process [16, 17].

While initial contributions have triggered alarm signals on the importance of human and social factors, proposed broad conceptual and methodological frameworks for addressing these issues [15, 16, 17], since the 1980s there has been a systematic concern with the empirical (usually statistical) study of determinant factors of adoption of technology.

A pioneering and systematic theory on technology adoption and diffusion was the *Innovation Diffusion Theory* (IDT), introduced by Everett M. Rogers in 1962. IDT asserted that the process of adoption (at individual level) and diffusion (at societal level) of technologies follows an S-shaped curve, where a few *innovators* and *early adopters* open up the diffusion process, followed by an *early majority*, then a *late majority*, to then end the process in a plateau where relatively few *laggards* finally and slowly convert to the new technology as well.

IDT proposed also a set of determinant variables of the adoption of innovations. First there were five variables which were characteristics or "attributes of the innovations" themselves or attributes that existed in relation to their users:

1. *Relative advantage* – "the degree to which an innovation is perceived as being better than the idea that it supersedes" [18];
2. *Compatibility* – "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" [18];

3. *Complexity* – “the degree to which an innovation is perceived as relatively difficult to understand and use” [18];
4. *Trialability* – “the degree to which an innovation may be experimented with on a limited basis” [18];
5. *Observability* – “the degree to which the results of an innovation are visible to others” [18].

In addition, Rogers considered that a certain trait of the adopters themselves is determinant of the adoption process or timing. That trait is termed:

6. *Innovativeness* (or, as later termed, *Personal Innovativeness*) – defined as “the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system” [18].

Furthermore, IDT considers the role of social influences:

7. *Opinion leadership and diffusion networks* – Opinion leaders are individuals who lead in influencing others’ opinions about innovations” [18]. Opinion leaders via social networks may be the change agents driving the process of innovation diffusion.

After its introduction IDT remained for a while a theory mainly supported by anecdotal and qualitative evidence. However, since the 1980s and 90s it has found more systematic evidence and support, being increasingly used in statistical studies of (Information) technology adoption. Thus, in [19] Zmud, proceeding from IDT, formulates a proposition about the role of opinion leadership and diffusion networks, investigating the role of various communication channels in driving “modern practices” in software development companies. By correlation, he finds some evidence that certain channels like subscriptions to specialized magazines, access to professional libraries, certain forms of training (especially by outside consultants) tend to perform better in driving innovative practices than other channels, such as: participation in workshops or professional meetings, paying tuition (by company) for participation in formal education, etc. A very similar study in design reports comparable results emphasizing the role of some communication channels within companies as compared to others [20].

In a study of sales-persons adoption of certain specialized software, the authors also found that some IDT variables like *training* and *personal innovativeness* were significant in driving software innovation adoption, but other “leadership” variables like *management support* or *urging* were not [21]. Other variables (not strictly connected with IDT) were found significant, like the *subjective importance of task* (of using the specific innovation) and *sales [person’s] performance*. In another study exploring the role of *compatibility* in driving technology adoption in companies in a cross-economic sector study, the authors found that the more the task/area of activity or a company (in terms of manufacturing methods, marketing strategies, complexity of parts and materials) are compatible with technologies (in their case a material requirements planning technology) the higher the rate of technology adoption [22].

In two more extensive applications of IDT to technology adoption at individual level, Agarwal and Prasad found that variables like *voluntariness* (not defined above, it is a variable related to IDT referring to leadership and social influences; it is defined by them as the "perception of innovation use being voluntary" as opposed to lead/urged/requested by leaders/hierarchical superiors), *visibility*, *compatibility*, *trialability*, *relative advantage* and *result demonstrability* are significant determinants of information technology adoption [23, 24].

A different theory of technology adoption, introduced by Davis and colleagues in mid 1980s, was the Technology Acceptance Model (TAM) [25, 26, 27]. Proceeding from the Theory of Reasoned Action (TRA) in social and behavioral psychology [28], Davis adopts a model where human behavior is seen as determined by the intention to perform that behavior, and intention is determined by attitudes toward that behavior. To decide which attitudes are relevant in the context of technology adoption, Davis makes use and proposes a certain refinement of prior theories and research, including IDT. In the end he proposes (only) two attitudinal variables as antecedents of the intention of technology use:

1. *Perceived Usefulness* – "the degree to which a person believes that using a particular system would enhance his or her job performance"
2. *Perceived Ease of Use* - "the degree to which a person believes that using a particular system would be free of effort" [27].

The two independent variables proposed by TAM are clearly semantically very closely related to the variables *relative advantage* and respectively *complexity* as proposed by IDT (as mentioned, IDT was one of the sources of inspiration of TAM). Later psychometric investigations have actually shown the two conceptualizations and their measurement instruments to be closely statistically related as well [29, 30].

The contribution of TAM was to propose a much simpler theory in terms of the number of independent variables (although it also proposed a horizontal complication by adding various interrelationships between variables linked in a chain like structure). Since its introduction TAM has become a very popular model among technology adoption researchers. It was applied (although not without modifications, simplifications or additions) by researchers with regard to various technologies: for example text processors [31], spreadsheet programs [32], email [33], internet [23, 34] etc. It was used in various cultural contexts [35, 36] and with regard to various technology use contexts whether business, education, leisure, online services (banking, e-commerce, etc.). Overall the evidence for the main variables of TAM, *perceived usefulness* and *perceived ease of use*, and their effect on intentions of technology use and technology use behavior itself, has been strong (more so for the former than the later) even if not without some exceptions.

4. User involvement in innovation processes and the technical level of the product

As shown above, the process of developing a company based on a new technology is filled with risks that can lead to failure. One of the main problems that lead to failure is that the potential products based on the new technology are not sufficiently well-defined. In [3], Feldman emphasizes the role of users in developing a product by supporting the engineers' design. In what follows it is explored the potential of involving engineering students in further developing a technology that cannot be successfully marketed. Engineering students are seen as qualified users or, using the IDT terminology, they have good potential for *Personal Innovativeness*; they are more likely than other categories of persons to be innovators or early adopters. This assertion is also supported by the find that *training* is also significant in driving software innovation adoption [21].

It is proposed an extension of the model described by Shane [7] that implies a new approach to the process of university technology development:

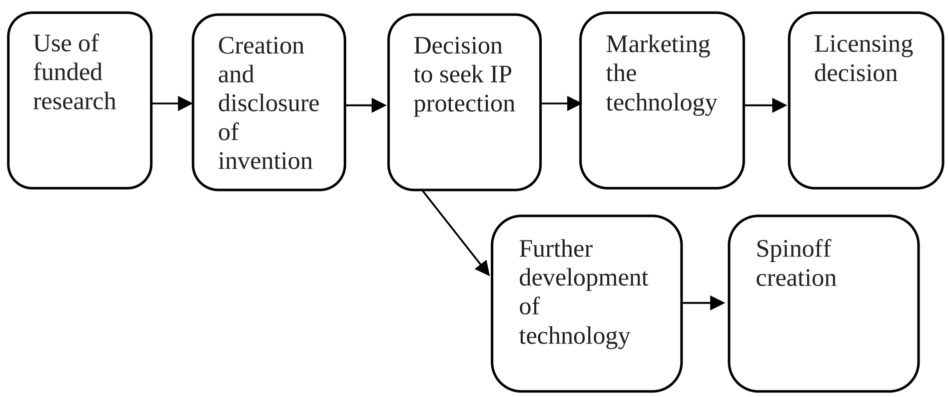

Fig. 1 The process of university technology development – a new approach

The new approach means that the inventor (the university scientist) could embark on another path, different from that described by Shane, which most often leads to licensing to an established company. The inventor could try to further develop the technology using the technical talent of his/her students as potential users of the invention and, at some moment, be able to create a new company based on narrower defined product. While, traditionally, the role of university inventions and academic entrepreneurship was seen mainly in relation to developing the main basic technologies, this new approach proposes that universities could acquire a further role in bringing products close to users.

The literature describes the inventors' involvement in the process of university technology development within spinoff companies that are developed outside the university. One of the features described in these companies is "smarter employees" than established companies. On the other hand, one of the main tasks to be accomplished in new companies is to gather information about customer needs. The inventors could involve engineering students in this task.

It is also well documented the way companies make products available to users that enable them to further develop other ideas in their portfolio [37].

The inventors could work with students regarding:

- The *relative advantage* of the potential product (how could the new technology be developed so that it is better perceived by the customers?)
- The *compatibility* of the potential product (how could the new technology fulfill the needs of the customers?);
- The *complexity* of the potential product (how could the new technology be less difficult to understand and use?);
- The *trialability* of the potential product (how could the new technology be prepared for experimentation?);
- The *observability* of the potential product (how could the new technology be made visible to others?)

This could be termed as the "social" part of the innovation process. The technical part is based on the concept of technical level of the product. Thus, in order to select products that would enter in a development process one could perform a study of technical level of the product so that to determine directions for perfecting the quality of the product. The technical level of the product is an indicator that shows as a global mathematical expression the characteristics of a product seen in comparison with those of other products. By performing such a study one could trace the effect of modifying one or more characteristics of the product. The study can be carried out regarding:

- *the dynamics* given by the evolution of other products or of the needs of the market;
- *the composition of the product* given by subassemblies, components, raw materials having different characteristics.

There are three indicators that can be applied:

The absolut technical level of a product j (N_{taj}) is calculated through a formula as:

$$N_{taj} = a \prod_{i \in S_1} \left(\frac{k_{ij}}{k_{il}} \right)^{\gamma_{ij}} \prod_{I \in S_2} \left(\frac{k_{il}}{k_{ij}} \right)^{\gamma_{ij}} , \qquad (1)$$

where:

a is a constant of differentiation *(a=1.000);*

k_{ij} - the values of the characteristic *i* of the product *j*;
k_{il} - the values of the characteristic *i* of the reference product *l*;
S_1 - the subset of characteristics of which values is indicated to be as large as possible, for a favourable appreciation of the product;
S_2 - the subset of characteristics of which values is indicated to be as small as possible, for a favourable appreciation of the product;
γ_{ij} - the weight of influence of the characteristic *i* of the product *j* on the technical level.

The relative technical level is calculated through the formula:

$$N_{tr} = \frac{N_{taj}}{\max N_{taj}} \cdot 100 \qquad (2)$$

The real technical level is defined similarly, but the values k_{ij} are those real, at a certain moment or operating system [5, 6].

Of course, for such a process to be successful the inventor should have something that the literature calls “the entrepreneurial inclination” or, to put it differently, he/she should be the “entrepreneurial type” inventor [38]. Having some prior experience in developing technologies is clearly an advantage. On the other hand, involving in such an activity with students could be very rewarding from educational point of view, as Shane [7] reports from an interview with a MIT professor, actively involved in the commercial activity: “I became a better professor because I had a much better idea than many people about what’s going on in the world”

5. Conclusions

The studies carried out until now show that there exists an important potential for improvement in technology development processes. This paper explores a possibility of completing successfully a greater number of such processes within technical universities and proposes in this sense a new approach that involves the young technical talent of students. These authors assert there will be a greater number of spinoff creations originating from technical universities as a result of further developing of technologies through the student involvement as potential users of innovations.

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